City of Boulder

Water Conservation Futures Study

July 5, 2000

Prepared by

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DATE: August 11, 2000

RE: Boulder Water Conservation Futures Study

FROM: Paul Lander, WCO x7407

Due to a printer error, some of the tables in the July 5, 2000 report had irregular spacing making them hard/impossible to read. The numbers were right: no data has been changed. Enclosed are new tables for those few pages that you can put into your copy of the report for easier reading.

- Table 10-3 Page 75
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Table 10-3: Unit Costs of Conservation Measures

#	Conservation Scenario	LF Showerhead Program[1] $/Showerhead	LF Faucet Program[2] $/Account	H-Axis Clothes washer rebate[3] $/Washer	Xeriscape Landscape Rebate[4] Avg. $/landscape	Leak Detection[5] $ per year	Increased Irrigation Efficiency[6] $ per year
0	No Conservation	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
1	Codes	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0
2	Current Program	$ 0	$ 0	$ 100	$ 0	$ 0	$ 0
3	Active Indoor	$ 5.75	$ 2.90	$ 150	$ 0	$ 0	$ 0
4	Active Outdoor	$ 0	$ 0	$ 0	$ 350	$110,000	$200,000
5	Comprehensive	$ 5.75	$ 2.90	$ 150	$ 350	$110,000	$200,000
6	Aggressive Peak Reduction	$ 5.75	$ 2.90	$ 150	$ 350	$110,000	$750,000

[1]Cost per showerhead is $5. The additional $0.75 covers the costs of administering the program.
[2]Cost per household is $2.50. The additional $0.40 covers the costs of administering the program.
[3]Actual rebate is $100. Administration costs are part of current O & M costs.
[4]Includes costs of administering program. Rebate based on landscape area converted to Xeriscape.
[5]Covers costs of hiring a leak detection contractor and supplying a vehicle (1999 dollars).
[6]Includes costs for implementing a landscape efficiency conservation program – labor, hardware, materials, etc.

Table 10-5: Utility Water Savings, Costs, and Benefits from Conservation Scenarios

Conservation Scenario		Demand at build-out	Savings at build-out	Peak Demand at build-out	Net present system costs	Net present value of conservation savings	Benefits / Costs Ratio
		acre-feet	acre-feet	MGD	$	$	
0	No Conservation	27785	-3626	64.5	$20,635,425	$ -	NA
1	Codes	24667	-508	57.3	$ 1,175,989	$1,513,351	1.29
2	Current Program	24159	0	56.1	$ -	$ -	NA
3	Active Indoor	23588	571	54.8	$ 1,320,174	$ 1,321,831	1.00
4	Active Outdoor	22483	1676	52.2	$ 2,181,794	$ 3,350,196	1.54
5	Comprehensive	21690	2469	50.4	$ 5,832,812	$ 6,881,313	1.18
6	Aggressive Peak Reduction	20801	3358	48.3	$ 14,560,443	$ 8,576,418	0.59

Benefits / Costs analysis assumptions:

Savings are calculated from the baseline current program
Costs and benefits are calculated over a 40-year period. Build-out is achieved in year 25. No value was assigned to the saved water.
City can lease conserved water at a rate of $20 per acre-foot and this amount will increase at 2% above inflation.
Marginal cost of treating water at Boulder Reservoir Water Treatment Plant (from City rates analyst) - $0.21 per Kgal.
Marginal cost of reducing hydraulic loading at the 75th St. wastewater treatment plant (from City rates analyst) - $0.05 per Kgal.
City of Boulder discount rate – 4.5%.
Cost to expand capacity ≅ $250,000 & $350,000/MGD up to 57.8 MGD & $1,000,000/MGD beyond.
Interest rate for borrowing – 6%. Amortization period of bonds – 20 years. Discount rate for net present worth analysis – 4%.
Conservation programs are revenue neutral for the City. Any shortfall is made up by a rate increase.

Table 10-6: Customer Level Impacts from Conservation Scenarios

Conservation Scenario	Combined Water and Sewer Rate at Build-out	Change in Water and Sewer Rates	Annual Water & Sewer Cost for Single-Family Participant	Annual Water & Sewer Cost for Single-Family Non-Participant	Change in Costs for Participant	Change in Costs for Non-Participant
	$/Kgal	%	$	$	%	%
0 No Conservation	$ 3.02	-3.7%	($360)	($360)	-3.7%	-3.7%
1 Codes	$ 3.09	-1.5%	($337)	($368)	-9.9%	-1.6%
2 Current Program	$ 3.14	0.0%	($271)	($374)*	-27.6%	0.0%
3 Active Indoor	$ 3.18	1.3%	($268)	($379)	-28.3%	1.3%
4 Active Outdoor	$ 3.26	3.8%	($294)	($388)	-21.4%	3.7%
5 Comprehensive	$ 3.37	7.3%	($207)	($401)	-44.7%	7.2%
6 Aggressive Peak Reduction	$ 3.50	11.3%	($203)	($416)	-45.7%	11.2%

*Baseline annual rate

Customer Level Assumptions:

This is *not* a full water rates analysis. This analysis is for single-family customers only.
Combined water and sewer rate is based on rate paid for 1000 gallons by the average SF customer, apportioned proportionally from all three blocks.
Changes in water rates take into consideration lost utility revenues from reduced sales and the costs and benefits to the customer for each conservation program.
Rates were set based on a condition of revenue neutrality for the utility. Rate changes due to inflation are not considered here.
Participation in the conservation program begins in the first year.
Non-participant costs are based on baseline consumption multiplied by the new water rate.

Table 11-1: Conservation Scenario Decision Matrix[1]

Conservation Scenario	Impact for Participants	Impact for Non-Participants	Benefits to the Environment	Impact to the Water System	Overall Score
0 No Conservation	1	6	1	2	10
1 Plumbing Codes	3	5	3	3	14
2 Current Program	6	4	5	5	19
3 Active Indoor	6	4	6	6	22
4 Active Outdoor	6	4	7	7	23
5 Comprehensive	7	3	9	9	28
6 Aggressive Peak Reduction	8	2	10	10	30

[1]Each scenario was given a score from 1 - 10. The highest (best) possible score is 40.

1 Executive Summary

1.1 Findings

Boulder's existing treated water demands average about 22,400 acre-feet (AF) per year (7.3 billion gallons). With an existing service area population of 107,654, this equates to an average daily demand of 186 gallons per capita per day (gpcpd) for all municipal uses.

About 66% of treated water is used indoors, with 34% going to outdoor uses. Indoor use exceeds outdoor use in all customer classes except use by municipal departments.

By current estimates, about 8.4% of treated water production is unaccounted for, mostly due to physical distribution losses.

Winter season use currently averages about 13 million gallons per day (MGD). Peak day summer use currently reaches about 44 MGD. Historically, the ratio of peak day use to average day use (peak ratio) has rarely exceeded 2.6. There is a steady downward trend in peak ratio that has occurred over the last thirty years. This trend is attributable to urban in-fill and the existing water conservation program.

Single family homes account for the greatest fraction of total water use (37%), followed by multi-family homes (30%), commercial/industrial/institutional (29%) and municipal government use (4%).

While Boulder's service area population is projected to grow to a maximum of 126,230 residents, Boulder's treated water use at build-out is projected to grow only very slightly, to about 24,200 AF per year, or about 171 gpcpd, assuming average summer climate. This is due to the demand-reducing effect of replacement of existing water using fixtures and appliances with more water-efficient models over the next twenty to thirty years. However, the demand-increasing aspects of population and employment growth could temporarily exceed the dampening effects of fixture and appliance replacement in the near-term. Therefore, Boulder's treated water demands may temporarily grow beyond 24,200 AF.

During an extreme dry year, Boulder's treated water use at build-out is projected to reach about 26,800 AF.

The firm yield of Boulder's existing raw water supply system (assuming replacement of the Lakewood Pipeline at 20 MGD capacity) is about 33,000 AF per year. This yield does not include water available from Boulder's drought reservation in the Boulder Creek instream flow program, full replacement of Boulder's Windy Gap water, or Boulder's borrowing arrangement with Public Service Company.

In spite of Boulder's abundant water supply, water conservation programs can offer significant benefits to the City and its citizens in terms of cost savings, alternate uses for saved water, addressing public values and planning for uncertainties.

1.2 Recommendations

Based on the analyses conducted in this study the authors recommend that Boulder:

1. **Adopt the Comprehensive conservation scenario.** The Comprehensive scenario promotes the indoor and outdoor conservation measures most likely to have a lasting impact on peak and annual demand in the City – landscape irrigation demand management, horizontal axis clothes washers, LF faucets and showerheads, and ULF toilets. This program increases the current water conservation budget substantially, but it reduces future peak demand to a level that can be handled by current facilities upgraded to their rated capacities.

   a) **Move into design phase**. The first step in implementing this program should be a design phase, which will flesh out the specific elements of the Comprehensive conservation program and will solicit community input.

   b) **Develop environmental and community-based conservation targets and rewards.** Citizens have expressed a strong desire to conserve water because "it is the right thing to do" for the environment and Boulder's watershed. The City should develop a program of annual conservation goals and rewards that include annual and peak water demands and specific program level of effort goals such as the installation of ULF toilets, or distribution of clothes washer and Xeriscape rebates. In addition, the City should develop community goals for other water uses, including instream flow, community gardens, agricultural leasing, etc.

   c) **Develop a program of monitoring, evaluation, and reporting.** To ensure that the conservation program is accomplishing the goals established, an independent comprehensive monitoring, evaluation, and reporting program should be established. Linking of the Comprehensive plan to an allocation billing system would also aid in the monitoring effort and should be considered.

2. **Adopt a peak ratio of 2.6 for water treatment plant capacity planning purposes.** Peak ratio (defined as peak day treated water delivery volume divided by average day volume for a given year) is an important consideration for the City when planning for future water treatment plant capacity. Based upon the analyses described in Chapter 6, we believe the City should adopt a "baseline" peak ratio of 2.6 for its future planning purposes. Assuming that additional conservation measures aimed at peak demand reduction are pursued, this peak ratio could be further reduced.

3. **Study the allocation billing system option for Boulder.** Each customer would be given a base use allocation large enough to handle all reasonable indoor uses depending on the category of customer. Outdoor allocations would be based on the size of the landscaping and a reference crop. Allocations would be flexible according to the size and type of use at the site. Allocations are further adjusted to reflect prevailing weather conditions during a billing period. Actual water charges are

assessed by comparing consumption to the defined allocation. The key to success for the program lies in the fact that those customers who exceed their allocation are faced with such high water charges for their excessive use that they will almost without fail remedy whatever is causing the high use, and bring their consumption down. Customers who stay within their allocation pay customary rates and hence notice little or no difference in the system.

An allocation water billing system could be an effective conservation tool, on its own, or in support of any non-price system. As alluded to above, it would also constitute an extremely fair method for apportioning costs by charging users according to the burden they place upon the system.

treated water production and changes in treated water storage, and therefore represent deliveries into the system inclusive of treated water reservoir regulation.

3.2.1 Total Deliveries

Total treated water deliveries for the 1994 through 1996 baseline condition are presented in Figure 3-1. As shown in the figure, deliveries were highest in 1994 and lowest in 1995, due to variations in irrigation season climate. Baseline deliveries are compared to deliveries over the last twenty-seven years in Figure 3-2. As shown in this figure, treated water use in Boulder grew fairly steadily during the 1970's and early 1980's but fluctuated between 20,000 AF and 24,000 AF during the last 10 years. Treated water use on a daily per capita basis is also shown in this figure.

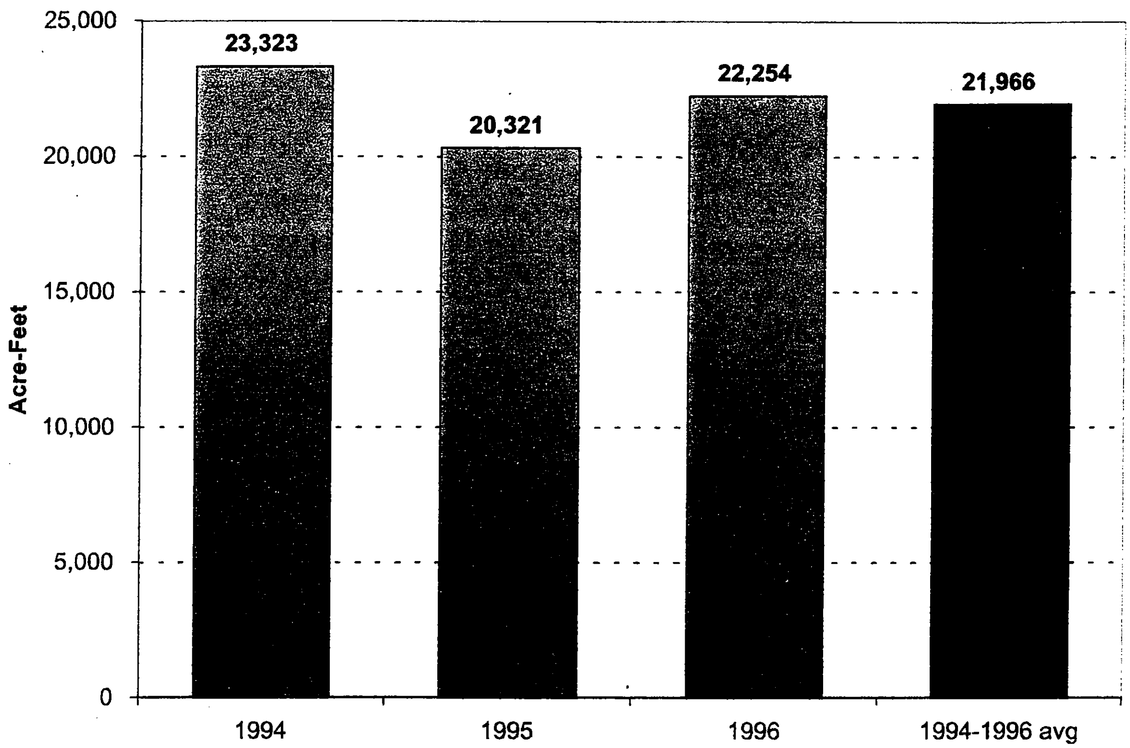


Figure 3.1: Treated Water Deliveries, 1994-1996

3 Characterization of Existing Water Uses

The City of Boulder's municipal water supply system serves a variety of end uses within its service area. A thorough understanding of these end uses and the underlying factors that influence them is essential to water conservation planning. In this memorandum, existing water uses within the City's service area are characterized and evaluated, and the underlying influencing factors are presented and discussed.

3.1 Definition of Baseline Condition

For the purpose of quantifying the City's existing water uses, historical use data for the period of 1994 through 1996 were averaged to arrive at a nominal 1995 baseline condition. This approach was chosen for the following reasons.

During the intensive phase of the study (which involved detailed analysis of the City's utility billing records), the years 1994 through 1996 comprised the most recent three years for which complete data on treated water use deliveries, metered water use, climate, demographics and land use were available. (Treated water delivery data and climate data for 1997 and 1998 have subsequently been included in some of the charts for informational purposes.)

Averaging several years of data minimizes the potential effects of any unusual patterns of use that may have occurred.

This period represents recent data that are reflective of Boulder's current water use, demographic and land use patterns.

It was recognized that this three-year period might not reflect a typical climate regime and associated outdoor water use. This issue was addressed in a following section.

3.2 Treated Water Deliveries

The City keeps daily treated water delivery records for its Betasso and Boulder Reservoir water treatment plants. These records are available for the period of April 1, 1971 through the present. These records were examined to determine total deliveries, relative amounts of indoor vs. outdoor uses and peak uses. Daily treated water delivery records are the most complete source of total water use data because they include both metered and unmetered end uses. However, they also include distribution losses and therefore overestimate actual end uses. These records should therefore be considered in conjunction with other sources of data to arrive at a true picture of end uses.

The City's treated water delivery data include both treated water production and treated water storage. Daily treated water deliveries used in this report were calculated based on indoor use variation caused by weekends and holiday periods, or simply random variation. It was thought that irrigation use would most likely occur during relatively warm dry periods of the winter. This hypothesis was examined via correlation studies between daily deliveries and temperature and precipitation patterns. However, no correlation was found between daily deliveries and temperature or precipitation: high deliveries are just as likely to occur during extremely cold and snowy periods as during warm dry periods. Therefore winter season irrigation use is either: 1) unrelated to climate, or 2) an extremely small component of winter use. An examination of sprinkler account meter data reinforced this second interpretation: winter season sprinkler account use comprises approximately 1% of annual sprinkler account use. It is estimated that outdoor use comprises less than 1% of winter season use.

Daily delivery records for 1994-1996 were used to estimate total indoor and outdoor deliveries using the general methodology described above. Indoor use was assumed to be equal to total deliveries for the period December 1 through February 28. For the remainder of each year, indoor use was assumed to be equal to deliveries minus average daily winter use. However, in Boulder's case it was determined that using the entire December through February period to calculate average daily winter use would underestimate true indoor use by approximately 2 percent. This is because a relatively large number of University of Colorado students and staff leave the City between December 15th and January 15th of each year for semester break, thereby reducing deliveries during this period. Average daily winter use was therefore estimated using treated water deliveries for the periods December 1st through 15th and January 16th through February 28th.

Estimated indoor and outdoor uses for 1994 through 1996 are shown on a daily and annual basis in Figures 3-3 and 3-4. An analysis of the 1972 through 1998 period shows that indoor use as a percent of total use has increased from 62% to 66% since 1972. This trend probably reflects the effects of in-fill in the City's service area over this period, which has reduced irrigation demands relative to indoor uses.

The acre-foot values shown in Figure 3-4 were calculated using treated water delivery records and include distribution system losses; actual indoor and outdoor end uses are therefore smaller. However the percentage estimates for indoor and outdoor use are valid and were used as an overall check during the analysis of uses by customer sector over the baseline period using City billing records.

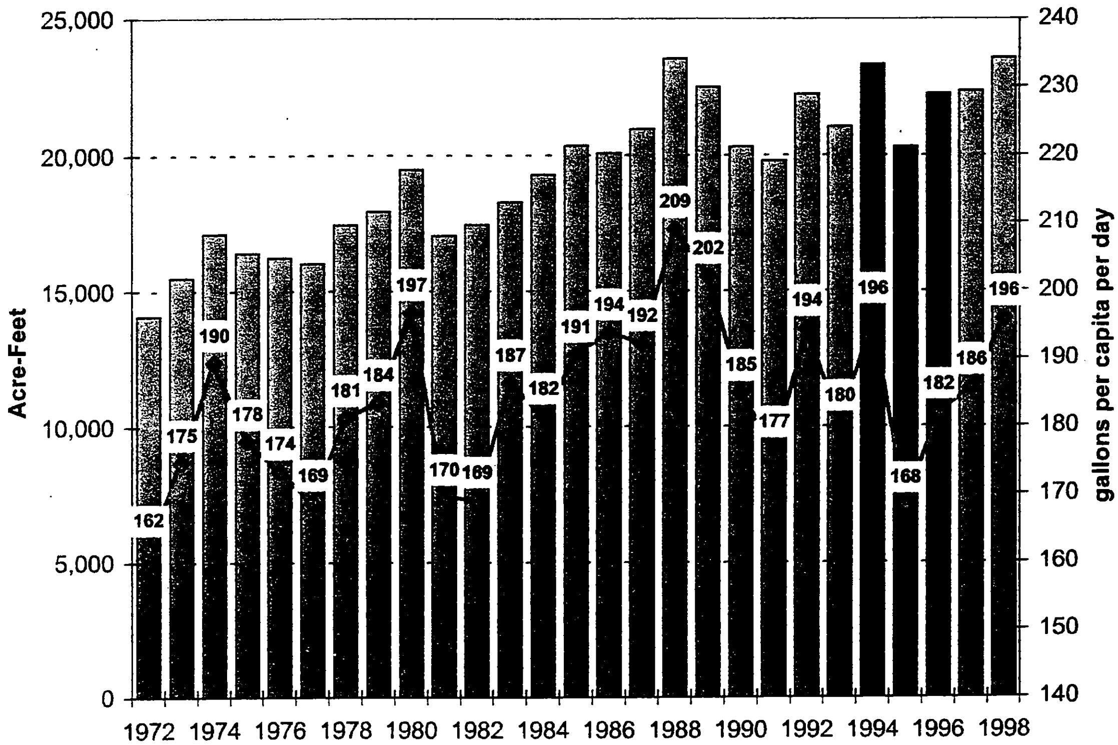


Figure 3-2: Boulder's Annual Treated Water Deliveries, 1972-1998

3.2.2 Total Indoor vs. Outdoor Use

Treated water delivery records are useful for estimating indoor vs. outdoor use on an aggregated basis. Because direct measurements of indoor and outdoor uses are unavailable, such uses must be estimated indirectly. The usual approach is to assume that all use during a selected winter period is exclusively for indoor purposes. For other periods of the year, indoor use is assumed to be equal to the average daily winter use for that selected period, and outdoor use is assumed to be the difference between total use and average daily winter use. Inherent in this methodology are two basic assumptions: 1) no outdoor use occurs during the selected winter period, and 2) indoor use during the winter is representative of indoor use throughout the year. While there are probably minor exceptions to both of these assumptions, this methodology is extensively used and appears reasonable.

Regarding the first assumption, it is known that some irrigation use occurs in Boulder during the winter. This issue was examined using treated water delivery records, climate data and meter records for "sprinkler only' accounts. Daily deliveries during the winter season vary considerably; during the 1995-1996 winter season they ranged from 9 MGD to 17 MGD. Possible explanations for this variation include winter season irrigation, adopt a "baseline" peak ratio of 2.6 for its future planning purposes. Assuming that additional conservation measures aimed at peak demand reduction are pursued, this peak ratio could be further reduced.

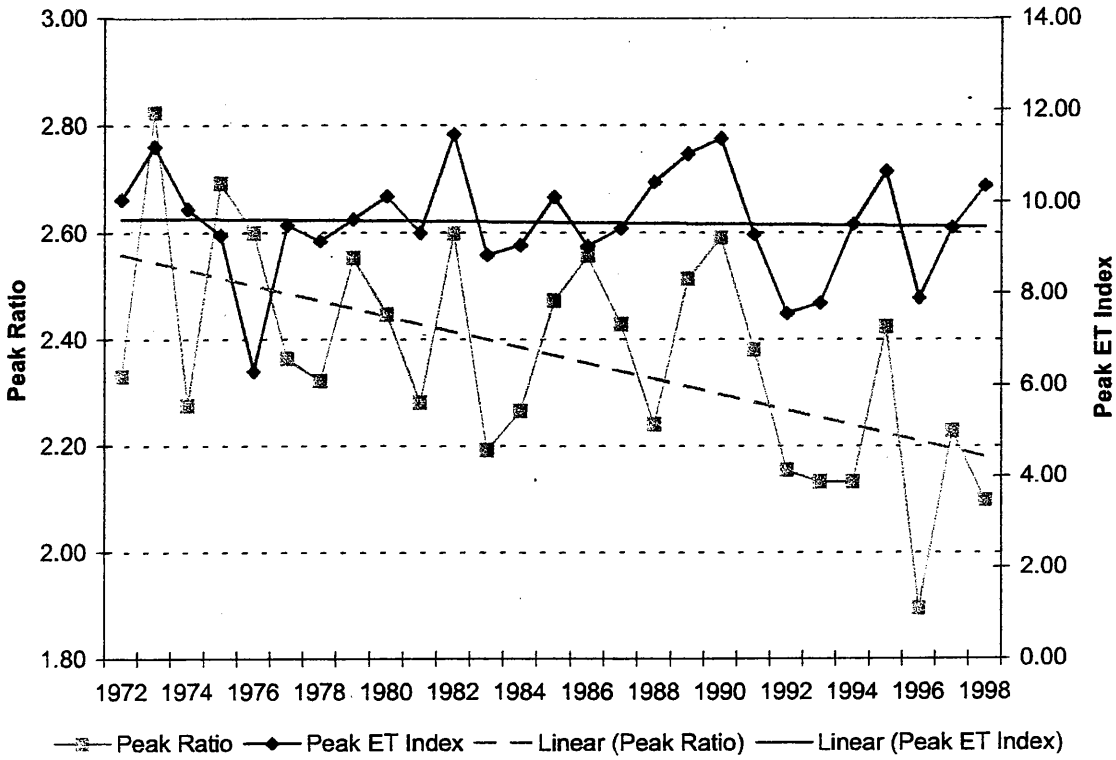


Figure 3-7: Peak Use Analysis, 1972-1998

3.2.4 Adjusted Baseline Use Data

It was recognized that the 1994-1996 baseline period may not reflect a typical climate regime and associated outdoor water use. This issue was addressed by calculating the seasonal net ET requirements for lawn grass in the Boulder area for the period 1949 through 1998 and comparing the 1994-1996 ET requirements to the long term average ET requirements. Figure 3-8 shows the net ET requirements for the years 1949 through 1998. Figure 3-8 shows that the average net ET for the 1994-1996 period was about 8% lower than the average net ET for 1949 through 1998.

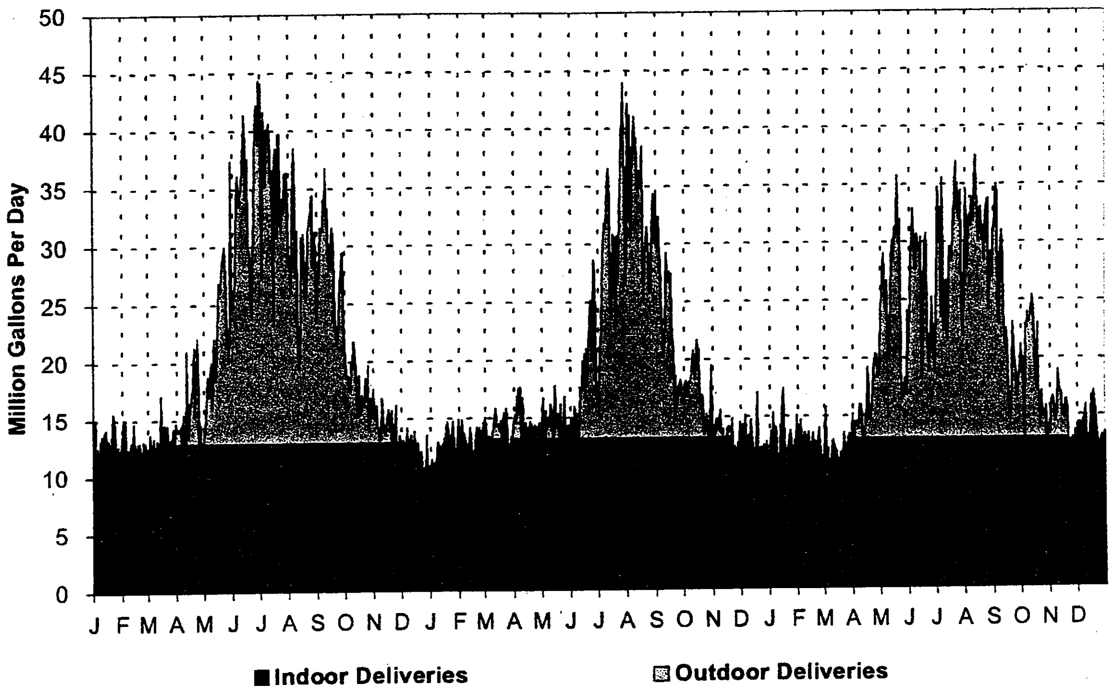
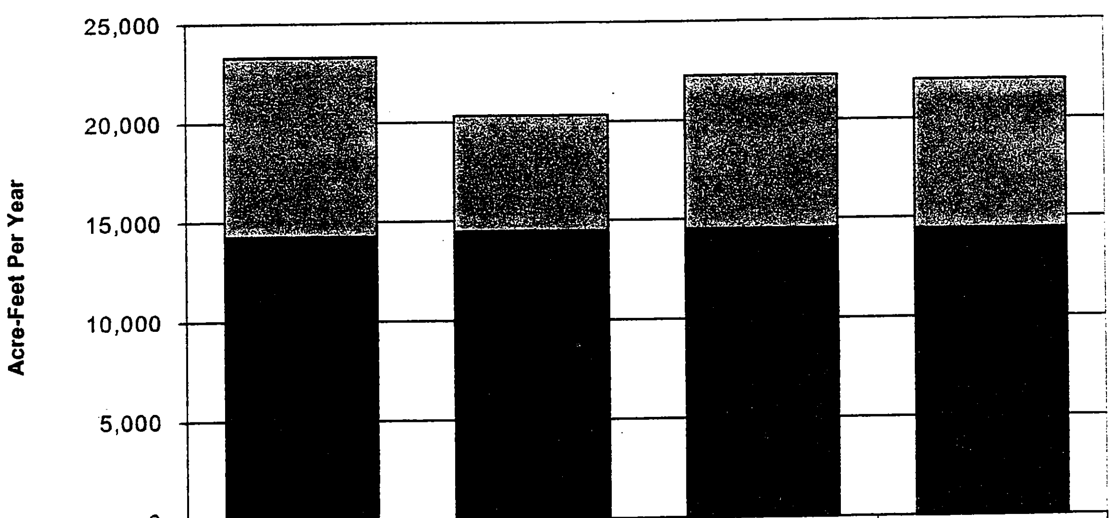


Figure 3-3: Estimated Daily Indoor and Outdoor Deliveries, 1994-1996



	1994	1995	1996	1994-1996 Average
□ % outdoor use	39%	29%	35%	34%
■ % indoor use	61%	71%	65%	66%
□ outdoor use, AF	9,035	5,813	7,724	7,524
■ indoor use, AF	14,288	14,507	14,531	14,442

Figure 3-4: Estimated Annual Indoor and Outdoor Deliveries, 1994-1996

3.2.3 Peak Day Use

The City's total water demand varies considerably from day to day due to customer behavior patterns and variations in climate during the irrigation season. The peak day demand in a given year comprises a basic design and operational challenge to the City's water supply system, which must be capable of meeting this peak day demand consistent with the City's reliability criteria. To accomplish this, the City's system relies upon having an adequate combination of water treatment plant capacity and treated water storage capacity.

Historical peak day uses were quantified for the period of 1971 through 1998 (including the baseline period) using daily treated water delivery records. As shown in Figure 3-5, Boulder's peak day use grew steadily during the 1970's and mid-1980's, but has declined since 1989. Peak ratios (peak day volume divided by average day volume for a given year) have declined fairly steadily over the past 28 years. Peak day uses and peak ratios for the baseline period were relatively low compared to the past 28 years.

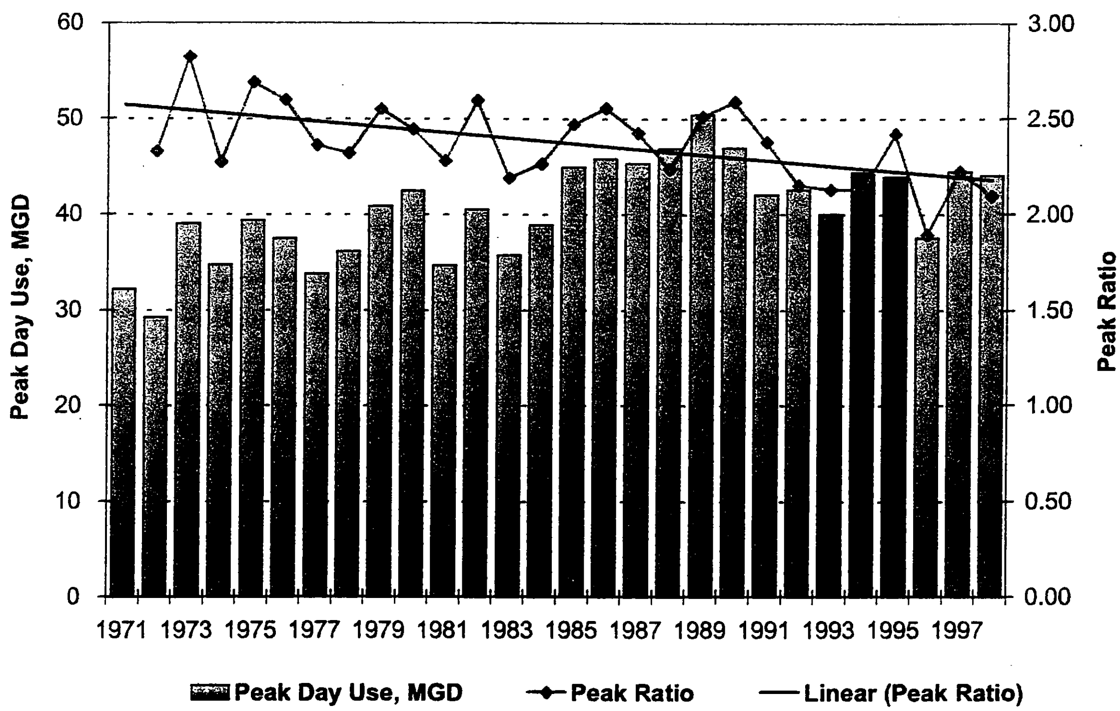


Figure 3-5: Boulder's Historical Peak Day Use and Peak Ratio, 1971-1998

Boulder's peak day use is strongly associated with periods of high temperature and low precipitation. Peak days occurred during extended periods of temperatures over 90 degrees F and little or no rain for 24 of the 28 years from 1971 through 1998. As shown

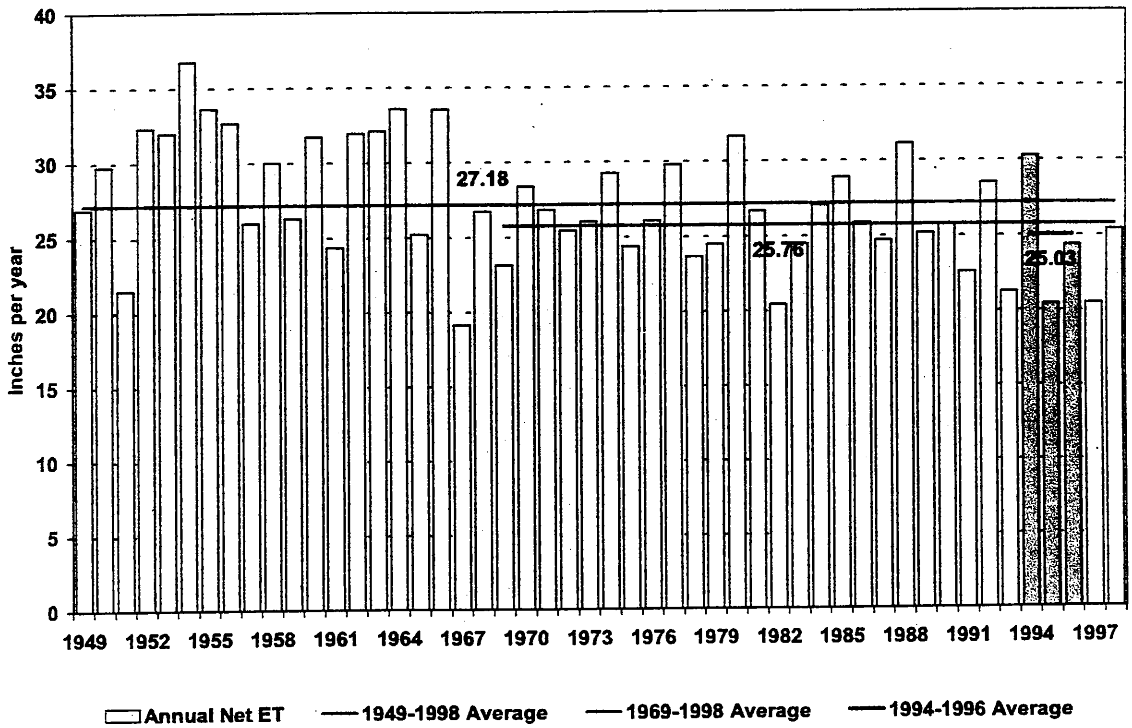


Figure 3-8: Net ET Requirements for Lawn Grass, Boulder, Colorado, 1949-1998

This raised the concern that actual 1994-1996 water uses may not be representative of existing water demands under average climate conditions. Before considering whether any adjustments should be made to the baseline data to address this concern, it was necessary to first address two questions:

1. Has there been a shift in climate in the Boulder area such that the 1949-1996 average is no longer representative?
2. Do net ET requirements have any significant effect on treated water use during the irrigation season?

Figure 3-9 depicts total precipitation and mean temperature patterns for the irrigation over the 1949-1998 period. Linear trend lines for these data suggest that irrigation season precipitation has increased by about 2 inches per year and that irrigation season mean temperature has decreased by about 3 degrees F over this period. While no scientific consensus yet exists regarding climate change worldwide let alone in Boulder, Colorado, these data do show that since the late 1960's Boulder's ET requirements have consistently been lower than during the previous twenty years.

Betasso outflows are measured with the following devices:

To Sunshine Canyon – Venturi Meter on 30" effluent line.

To 6th and Canyon Blvd. – Venturi Meter and flow transmitter

Based on a cursory inspection of the flow meters at Betasso we can conclude that there is no reason why flow measurements could not be obtained with a good degree of accuracy. Based on the data we have obtained so far, however, we can not determine how accurate the metering may be. It is possible that measurements are all good within a few percent, but there are a number of potential problems which could lead to much higher errors which could under report flows in and out of Betasso.

In order to obtain a better estimate of the accuracy of the flow measurement at Betasso it is advisable to hire a consultant who specializes in this type of flow measurement to perform a thorough review of all of the measurement devices, their installation and signal conversion from the meters to the read-out on the control panel. This study would confirm if the proper coefficients are being used for each meter and if any modifications should be made in the placement of the transmitters and pressure lines. Installation of air relieve valves or other protective measures may also be advisable.

The biggest challenge will come in determining the accuracy of the Venturi meters themselves. These tend to change over time so that the original coefficient factors may under-estimate flow through the meters. The best course of action may be to simply replace the old meters with new ones and start with accurately calibrated units.

3.3 Metered Water Use By Customer Sector

Existing water use was also characterized by analyzing the City's water meter records. The City reads meters for residential, commercial and industrial customers on a monthly basis. Meters for municipal departments are read on an annual basis.

3.3.1 Data Collection

Data pertaining to metered water use were pursued and collected from a number of sources, including the following:

Customer Billing Records. The City of Boulder maintains Oracle databases containing historical water utility billing data. City personnel exported the Oracle database tables to Microsoft Access database tables, and then transferred these files to a CD-R disk for Hydrosphere.

Municipal Department Water Use Records. City Utility department personnel provided Hydrosphere with an Excel workbook containing historical indoor and outdoor water use data for municipal department (unbilled) meters that are not included in the City's water utility billing database.

Billing Address Database. City Utility department also provided a Water Utility Billing Address database to Hydrosphere. This database was critical in estimating the percentage of occupant-owned vs. rented residences.

3.3.2 Data Processing

3.3.2.1 Monthly Water Delivery Data From City Utility Billing Department Records

The raw exported Oracle water utility billing data needed significant processing and interpretation before the database was complete. City personnel aided Hydrosphere greatly in understanding the fields and tables in the exported database.

Billing data are based on monthly meter readings for each individual water meter in the City water system. The monthly reading records in the database include meter number, meter address, account type, 3 consumption fields (one for each block rate) in 1000's of gallons, and several other useful fields. Each year's data, therefore, contain two to three hundred thousand records. Because a meter reading contains the cumulative water use for the previous month, January 1997 also had to be processed. Hydrosphere wrote Access queries to filter out records with obviously invalid data such as invalid reading dates, invalid meter numbers, and negative water consumption.

3.3.2.2 Seasonal Municipal Water Use Records From Utility Department Records

The City has meters to record municipal indoor and outdoor water use in the City's parks and buildings. These data are not recorded in the utility billing database, since they are not billed. They also are not recorded on a regular monthly basis. However, the meters are read on a seasonal basis, and are recorded in a spreadsheet database maintained by the City Utility department. These data were provided to Hydrosphere. Municipal water use data from this database were separated into indoor use and outdoor use components based on the account type designation and account ID number. Indoor and outdoor municipal uses were combined with the other metered data from the billing database.

3.3.2.3 COB Water Utility Billing Address Database

It is known that water use patterns in single family rental properties differ significantly from water use patterns in single family homes owned by the occupants. The responses of these two groups to water conservation measures will also differ. Accordingly, quantifying the water use in rental vs. occupant-owned single family homes was an important task in this analysis. The method used to classify SFR meters into rental vs. occupant-owned was to compare the service address to the billing address. The billing address database was also exported by the City from the main Oracle database to a table in a format compatible with Microsoft Access. Hydrosphere used these data to populate an Access database, and the fields were processed so that the meter ID's were compatible with the billing database meter ID's.

3.3.3 Data Analysis

3.3.3.1 Comparison Of Treated Water Daily Production Data To Metered Water Monthly Delivery Data

Hydrosphere compiled databases of treated water production and metered water delivery for the period 1994 to 1996. One of the first tasks was to compare these two independent sources of the City's water use as a QA/QC exercise. While differences between the two data sources are most likely attributable to distribution system losses and nonmetered uses, they could also indicate problems with one of the databases or errors due inaccuracy of the flow measurement devices.

A large amount of data analysis and processing was required to convert the metered water monthly delivery data into daily data so that the two databases could be compared. Individual meter readings occur at any time during the month, and represented total water use since the last meter reading. Hydrosphere developed a method to use the daily distribution pattern from the treated water production data to distribute the total metered consumption measured on any particular day to the previous 30 days. This process was straightforward in design, but required significant processing time due to the literally millions of records that needed to be processed from the monthly billing and treated water production databases.

After the processing, the data were exported to Excel worksheets for charting and statistical analysis. The comparison demonstrates that production data are uniformly higher than the delivery data, which was expected due to losses in the system and nonmetered uses. Also, the monthly distributions are similar, which lends some credibility to both databases. The following charts display the comparison on a daily and monthly basis.

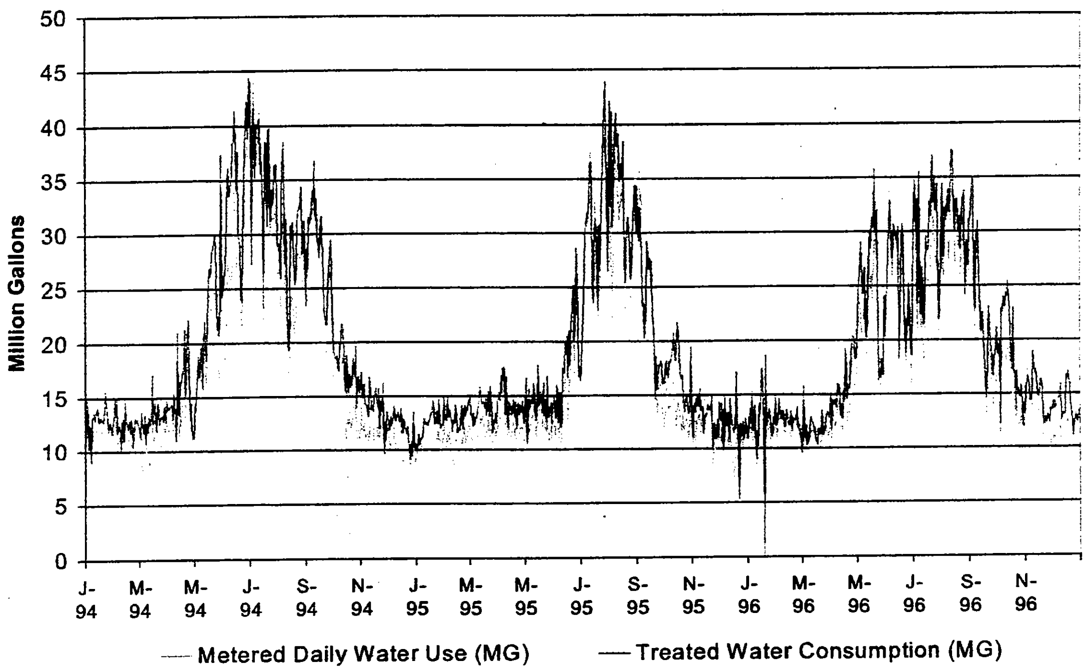


Figure 3-11: 1994 - 1996 Daily Comparison

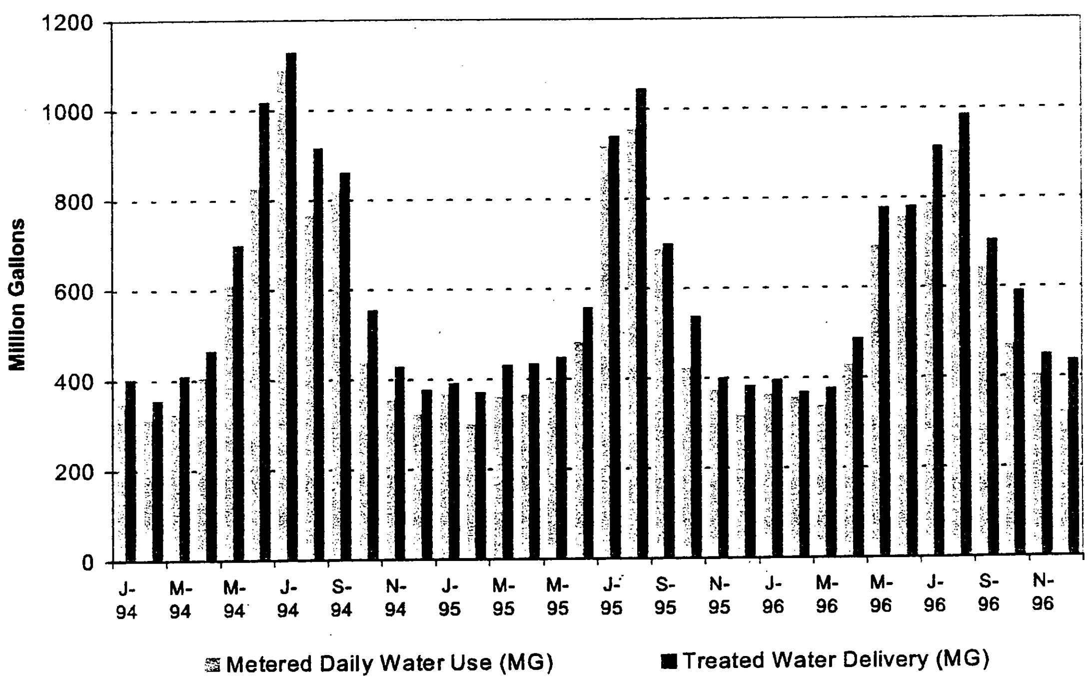
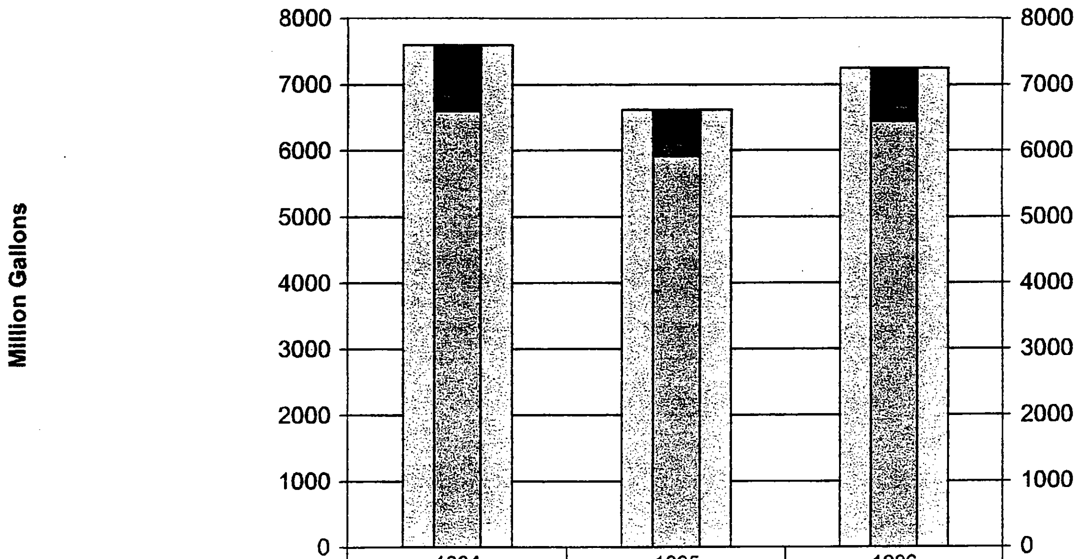


Figure 3-12: 1994 - 1996 Monthly Comparisons

3.3.3.2 Combine Municipal Water Use with Billed Water Use

Because the City Utility Billing database did not contain City municipal water use, the City's metered municipal water use was added to metered and billed uses. Addition of municipal water use helped to explain the difference between the treated water production and the billed metered water deliveries. Other causes for the differences are water line flushing, fire fighting, and water line leakage. The following chart demonstrates how the municipal water use fits into the total water use picture.



	1994	1995	1996
□ Treated Water Delivery (MG)	7600	6622	7252
■ Unaccounted For Water (MG)	733	506	572
▩ Metered Muni Water Use (MG)	268	192	233
□ Metered Billed Water Use (MG)	6599	5923	6447

Figure 3-13: 1994 - 1996 Annual Comparisons

3.3.3.3 Metered Water Account Types

The COB Utility Billing metered water database classified account types as either: Commercial, Industrial, Multi-Family Attached, Single Family, Sprinkler, or Trailer Park /Special District. Hydrosphere combined these classifications into three basic categories (Commercial/Industrial, Residential Multi-Family, and Residential Single Family) and then added municipal water use as a fourth category. As part of this exercise, each sprinkler account had to be assigned to one of the other billed water use categories. This was accomplished matching the paying entity/billing address for each sprinkler account to a paying entity/billing address in one of the other water use categories. The following charts summarize these data.

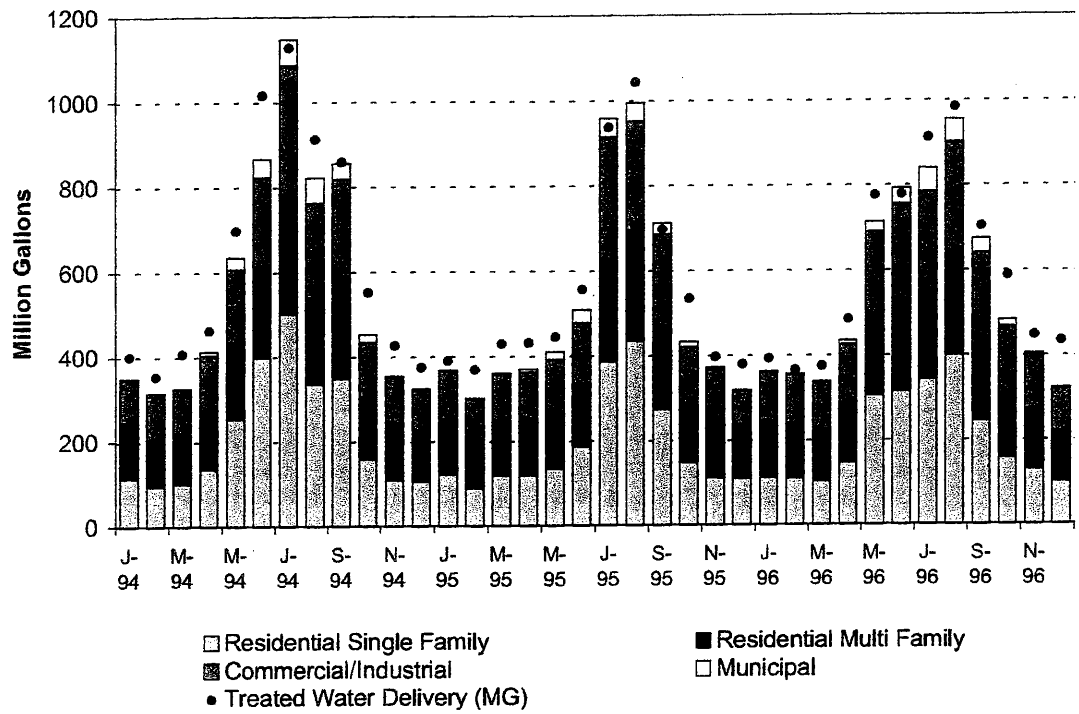
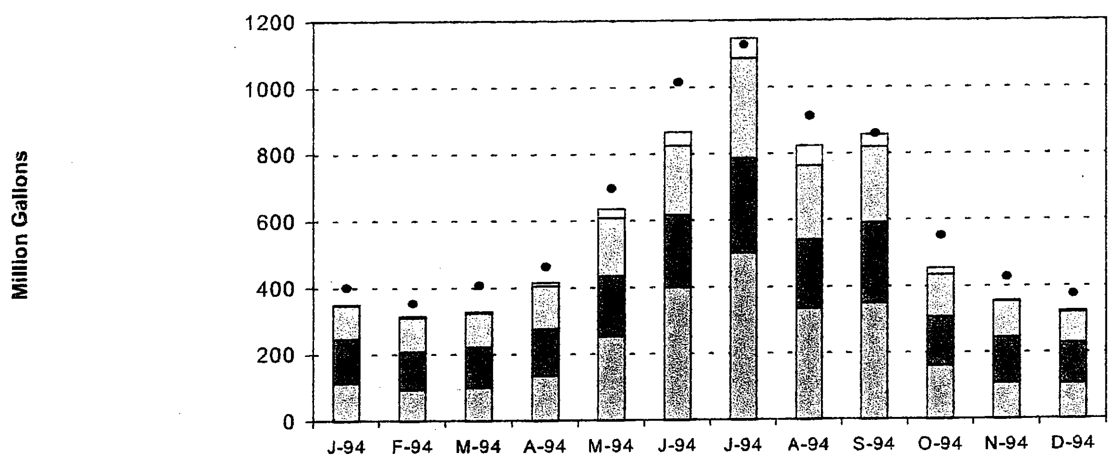
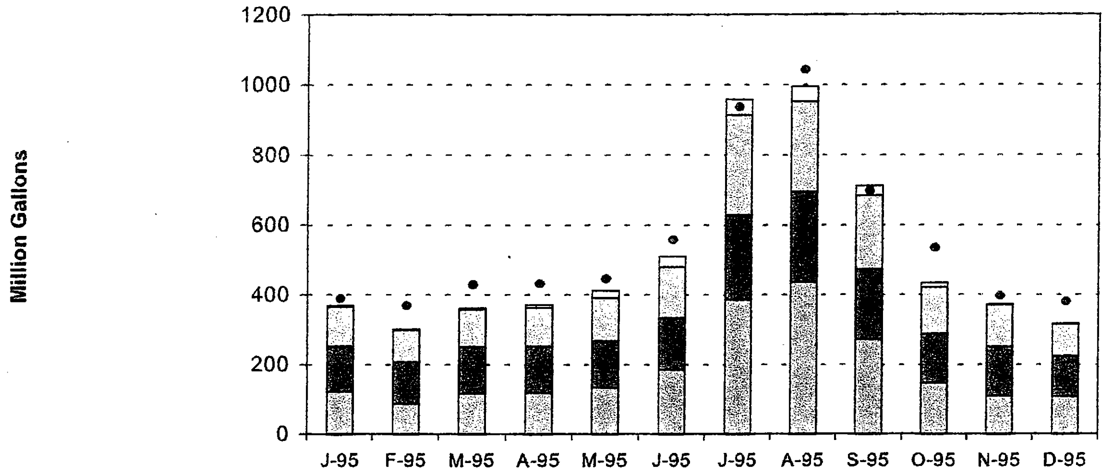


Figure 3-14: 1994-1996 Metered Water Consumption by Account Type



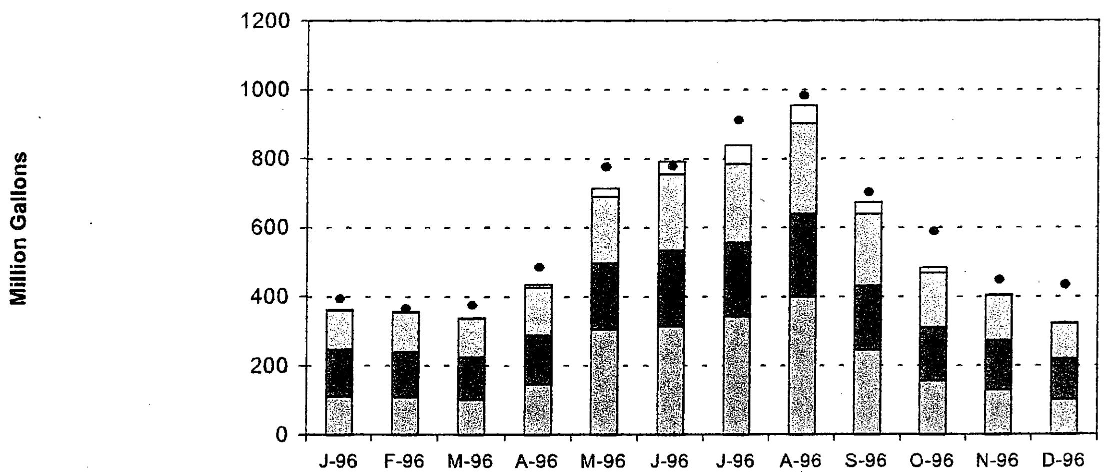
	Jan-94	Feb-94	Mar-94	Apr-94	May-94	Jun-94	Jul-94	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94
□ Municipal	3.1	3.1	3.1	9.2	26.7	41.4	60.6	59.4	37.1	18.0	3.1	3.1
□ Commercial/Industrial	99.7	102.7	102.2	129.4	172.2	208.8	301.6	221.7	227.8	127.7	107.8	93.4
▩ Residential Multi Family	133.6	113.8	121.2	140.4	182.2	216.4	283.2	206.7	242.3	148.1	136.5	121.8
□ Residential Single Family	114.1	95.1	100.6	135.1	253.3	398.6	501.9	334.9	348.7	159.1	108.0	106.2
• Treated Water Delivery (MG)	402	355	408	464	698	1017	1128	913	859	552	428	376

Figure 3-15: 1994 Metered Water Consumption by Account Type



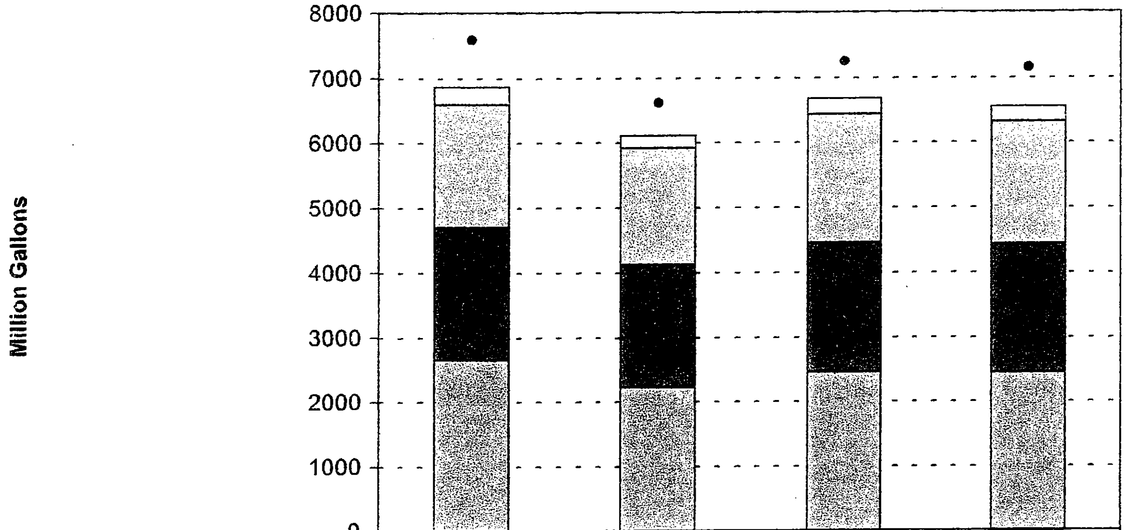
	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95
□ Municipal	2.3	2.3	2.3	6.6	19.1	29.6	43.2	42.4	26.5	12.9	2.3	2.3
□ Commercial/Industrial	112.4	92.0	107.7	110.5	123.4	143.9	286.1	257.5	213.1	132.2	119.5	90.5
▩ Residential Multi Family	131.4	118.7	133.0	134.2	134.9	150.3	242.5	259.9	199.6	141.3	140.5	116.1
□ Residential Single Family	122.6	88.6	118.4	119.4	134.2	185.3	386.6	435.0	272.9	147.8	110.8	109.3
• Treated Water Delivery (MG)	391	370	430	432	447	557	938	1044	698	535	398	381

Figure 3-16: 1995 Metered Water Consumption by Account Type



	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96
□ Municipal	2.1	2.1	2.1	7.5	23.3	36.4	54.0	52.9	32.9	15.7	2.1	2.1
□ Commercial/Industrial	114.5	115.6	112.1	138.3	193.5	221.7	229.7	261.2	208.6	157.9	129.7	101.3
▩ Residential Multi Family	135.5	129.4	122.8	142.1	192.6	219.6	213.5	240.1	187.0	153.9	143.6	118.9
□ Residential Single Family	111.2	109.9	102.0	146.4	304.2	314.1	342.0	400.0	244.7	156.3	130.1	101.1
• Treated Water Delivery (MG)	394	367	376	486	777	779	912	984	704	589	449	435

Figure 3-17: 1996 Metered Water Consumption by Account Type

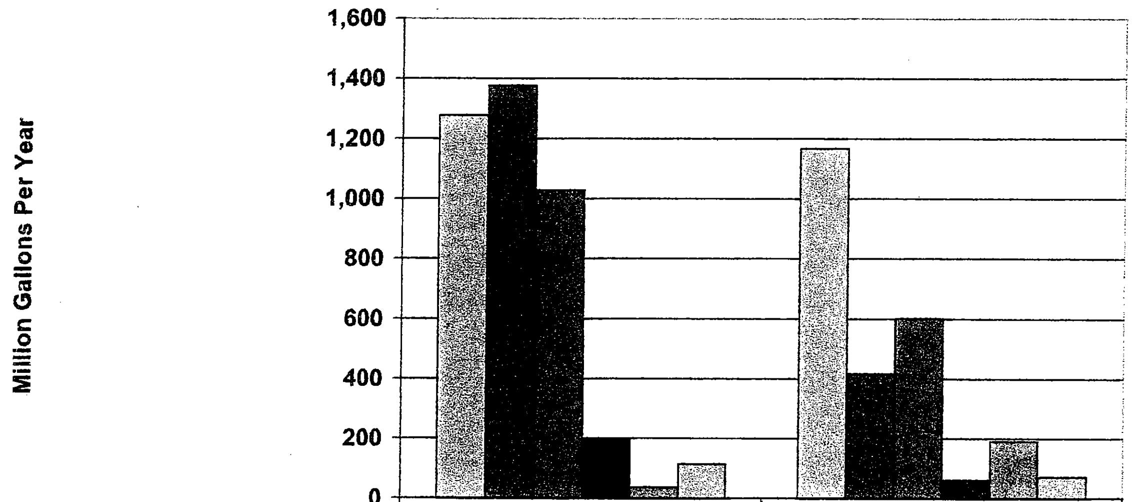


	1994	1995	1996	Average
Municipal Metered	268.0	192.0	233.0	231.0
Commercial/Industrial Metered	1895.1	1788.6	1984.1	1889.3
Residential Multi Family Metered	2046.4	1902.5	1999.0	1982.6
Residential Single Family Metered	2655.6	2230.9	2462.0	2449.5
• Treated Water Delivery (MG)	7600	6622	7252	7158

Figure 3-18: Metered Water Consumption by Account Type

3.3.3.4 Indoor vs. Outdoor

Hydrosphere also calculated indoor vs. outdoor water use for each account type for the study period using meter data. The average water use during the winter months of December through February was used to approximate the indoor component of water use throughout the year. The following chart displays the indoor vs. outdoor comparison. As shown in the chart, most water is used for indoor purposes in all customer sectors, including single family residential users.



	Indoor Use	Outdoor Use
Single Family	1,277	1,169
Multi Family	1,377	418
Commercial	1,030	603
Industrial	199	61
Municipal	39	192
Trailer Park / Special District	116	73

Figure 3-19: Indoor/Outdoor Use By Customer Sector (1994-1996 Average)

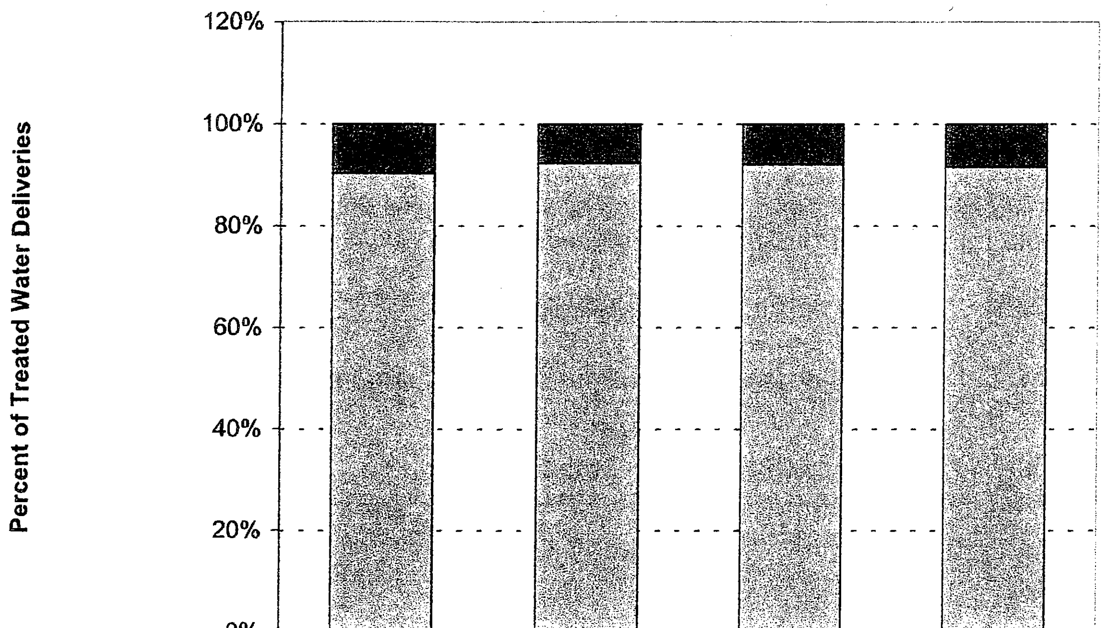
3.3.3.5 Rent vs. Own

Hydrosphere estimated the proportion of single family residential meters that are either occupant owned or rented by comparing a recent (1996) City Water Utility Billing Address database to the meter addresses during 1994 through 1996. If the water bill is sent to a different address it is assumed the occupant was renting. This was an inherently conservative assumption because some single-family renters probably receive their own water bill. Even though historical copies (1994-1996) of the Billing Address database were not available, the comparison should yield good approximations since the ratio (own vs. rent) has likely not changed significantly since 1996.

The results of this analysis showed that approximately 31% of the single-family accounts were rentals. This is consistent with federal census data and City Planning data, which show that, overall, approximately 54% of Boulder's total housing units are renter occupied. This higher number includes multi-family dwellings.

3.3.3.6 Unaccounted For Water

By comparing the results of the treated water delivery data and the metered water records, we were able to develop estimates of unaccounted for water. These represent physical losses of treated water in the City's distribution system as well as meter inaccuracies. Unaccounted for water averages 8.5% of deliveries over the three years of the baseline period as shown in Figure 3-20. In comparison, previous City estimates of unaccounted for water ranged from 1.3 % to 9.2%; however, the methodology used to develop these previous estimates is not known. We believe that the estimates in this study are more reliable and should be used for future planning purposes.



	1994	1995	1996	Average
Unaccounted for Water	9.7%	7.7%	7.9%	8.5%
Metered Uses	90.3%	92.3%	92.1%	91.5%

Figure 3-20: Unaccounted For Water

3.4 Direct Measurement of Single Family Water Use

In 1996 the City of Boulder participated in the AWWARF Residential End Uses of Water Study (REUS) which precisely quantified domestic water use in a representative sample of 100 single family homes in Boulder and 11 other cities across North America. Aquacraft, Inc. was the prime contractor on this study and the data about single family water use in Boulder were easily obtained.

Precise end use data for this study were collected using Aquacraft's flow trace analysis technique which uses data logger technology and signal processing software to disaggregate water use into end use components like toilets, showers, clothes washers, etc. In addition to the specific end use data collection effort, a detailed water use survey was sent to a systematic random sample of 1,000 homes in the City of Boulder service area. Of these 1,000 surveys, 459 were returned and entered into a database. This survey includes data on conservation measures present in homes in Boulder and will be valuable for this conservation futures study.

3.4.1 Sample Selection Procedures

For a detailed description of the sampling procedures, see Appendix A.

3.4.2 Survey Responses

The 46% survey response rate was quite good considering the low level of follow-up employed by the research team. For the purposes of this conservation futures study, we have summarized results of a number of the questions that have bearing upon the current effort. A complete analysis of the survey is also provided at the end of this document.

3.4.2.1 Single Family Households

Table 3-1 shows demographic data from logging sample based on the REUS survey.

Table 3-1: Number of People per Household

	MEAN	MODE	MEDIAN
Adults	1.96	2	2
Teens (13-17)	0.14	0	0
Children (<13)	0.35	0	0
TOTAL	2.40	2	2

Survey results also showed that 89.2% of the successfully logged houses were owner occupied and 10.8% were rentals. In this regard, the sampled houses were not representative of single family homes in Boulder. As discussed above, data from the utility billing database showed that 31% of single family homes were rentals.

3.4.3 Daily Water Use

Data for the REUS study were collected in Boulder during two separate two-week logging sessions. The first session was May 21 – June 6, 1996 and the second was from September 1 – 19, 1996. The data from the REUS study were summarized such that the average daily use per account and per capita per day could be easily calculated. These results are presented in Table 3-2.

Table 3-2: Single Family Residential Daily Water Use (Four Week Sample)

SINGLE FAMILY RESIDENTIAL DAILY WATER USE Boulder, Colorado						
	DAILY USE (gallons)			PER CAPITA DAILY USE* (gallons)		
	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median
Baths	3.9	11.6	0.0	1.4	4.5	0.0
Clothes Washers	32.9	56.2	0.0	14.1	26.3	0.0
Dishwashers	3.3	6.1	0.0	1.3	2.6	0.0
Faucets	26.1	20.9	21.0	11.9	9.9	9.4
Outdoor**	197.4	na	na	82.3	na	na
Leaks	8.3	20.8	1.7	3.7	9.4	0.9
Showers	31.9	31.0	25.1	13.4	12.5	11.1
Toilets	44.6	30.9	40.6	20.0	13.9	16.9
Other Domestic	0.5	3.0	0.0	0.2	1.3	0.0
Unknowns	1.5	6.1	0.0	0.7	2.7	0.0
INDOOR	151.4	107.9	126.5	66.0	44.9	57.3
TOTAL	350.3	na	na	136.0	na	na

*Based on the *actual* number of residents per house and number of day of logged data (weighted average)
**Outdoor use is based on historic billing records average winter consumption method

The daily water use results shown in Table 3-2 corresponds to an average annual indoor water use for the study group of 55,261 gallons per year or 4,600 gallons per month. Because of the limited logging periods it was not possible to extrapolate to the total outdoor water use. However, from the historic billing data that were obtained during the study group selection process we know that this group of 100 homes used an average of 127,310 gallons per year, implying that their outdoor use averages 74,049 gallons per year.

Figure 3-21 shows the frequency distribution of daily water use in Boulder during the two data collection periods. As might be expected, outdoor use is the primary component on high use days, but there are also a large number of zero outdoor use days. Indoor use was predominantly between 50 and 450 gallons per day. Figure 3-21 is based on 2201 logged days or 22.01 days per household.

Figure 3-22 shows the percent breakdown of average daily water use in Boulder. Using historic billing data to calculate outdoor use, and the logging data for indoor use, outdoor use accounted for 56.3% of daily water use. Toilets, clothes washers, showers, and faucets round out the top five water use categories in Boulder. Dishwashers accounted for 1% of total daily use.

It should be once again noted the sampled houses were not representative of single-family homes in Boulder regarding indoor/outdoor use ratio. As previously discussed, analysis of Boulder's utility billing database showed that 52% of single family water use is indoor and 48% is outdoor as shown in Figure 3-19 above.

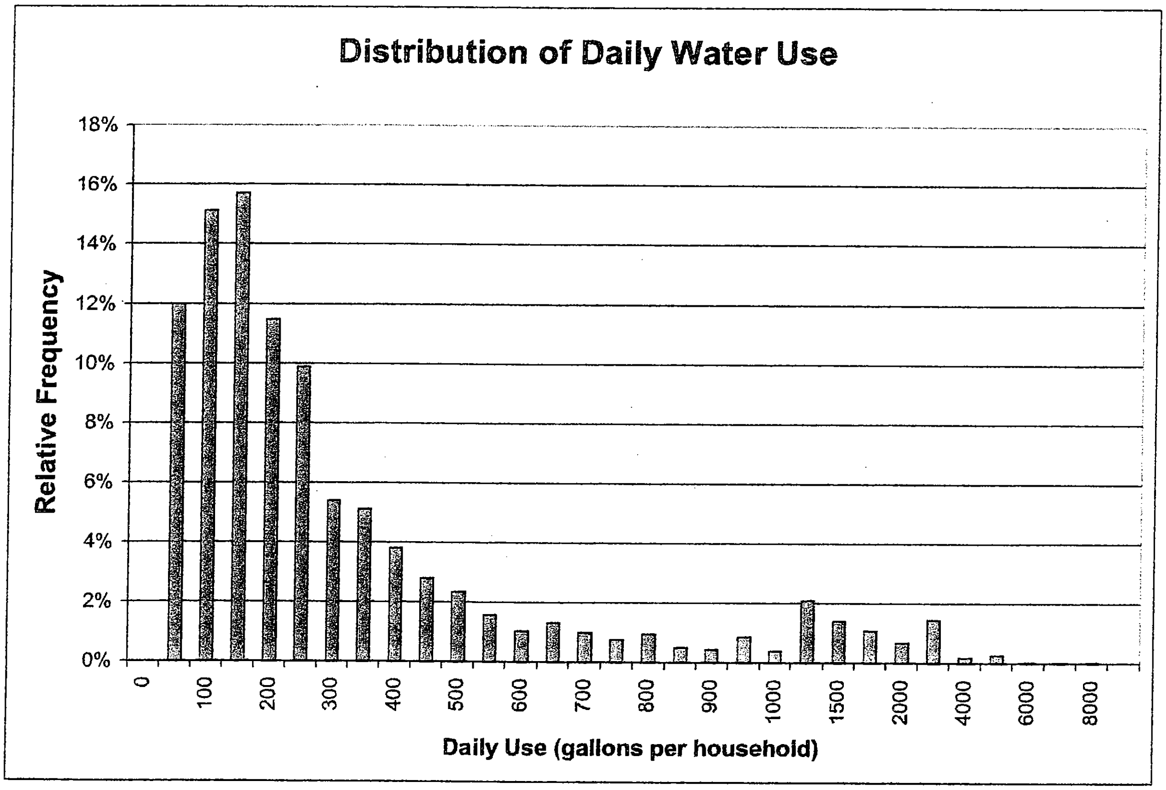


Figure 3-21: Distribution of Daily Water Use, 1996 Residential End Use Study

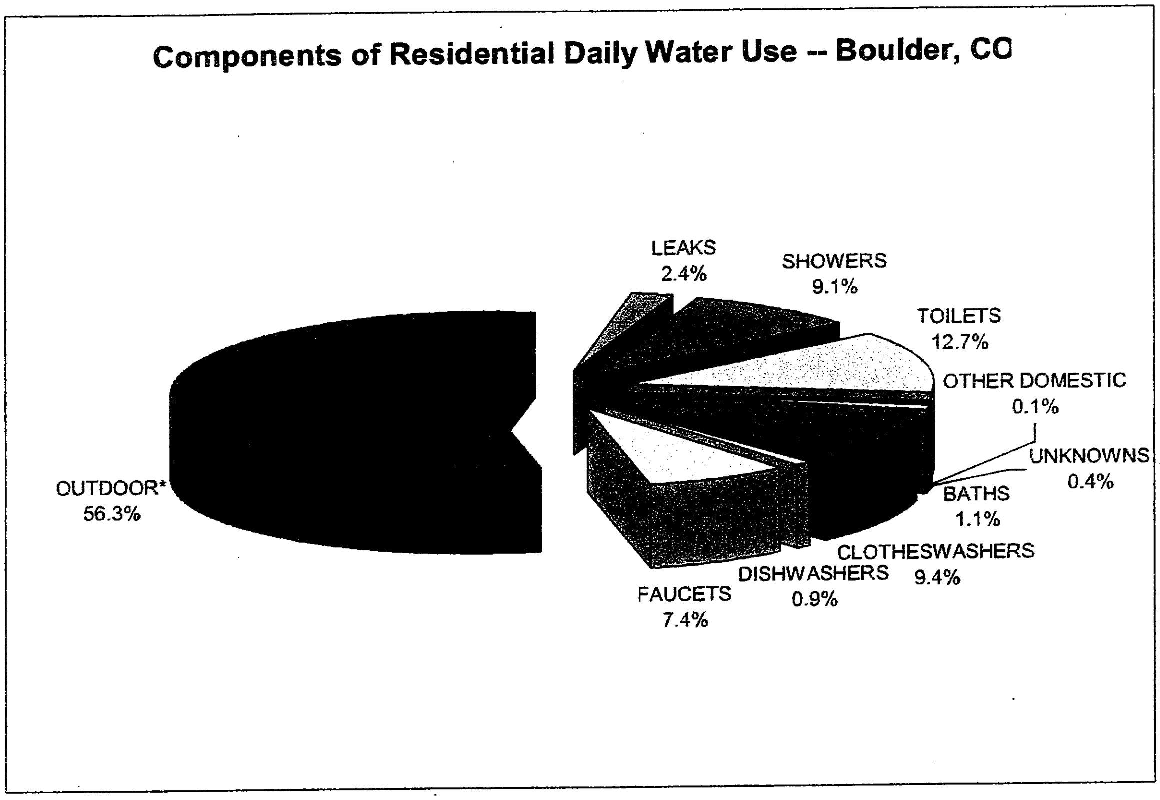


Figure 3-22: Components of Average Daily Use, 1996 Residential End Use Study

3.4.4 Daily Use and Precipitation

The two logging periods in Boulder were both unusually wet and cold. The average minimum temperature during the May and June logging period was 44 degrees and the average maximum temperature was 69 degrees. During the September logging period the average minimum temperature was 49 degrees and the average maximum was 78 degrees. Furthermore 6.64 inches of rain fell during the 30 days when data loggers were in the field. In spite of this relatively high amount of precipitation in Boulder, during the logging period the study group still used 56% of their total volume of water outdoors. This actually corresponds remarkably closely with their average annual outdoor use percentage as calculated from the periodic billing data.

Figures 3-23 and 3-24 show the average daily water use for the study group for each of the days when loggers were in the field and the precipitation on each of those days. This demonstrates the participants' response to rain events.

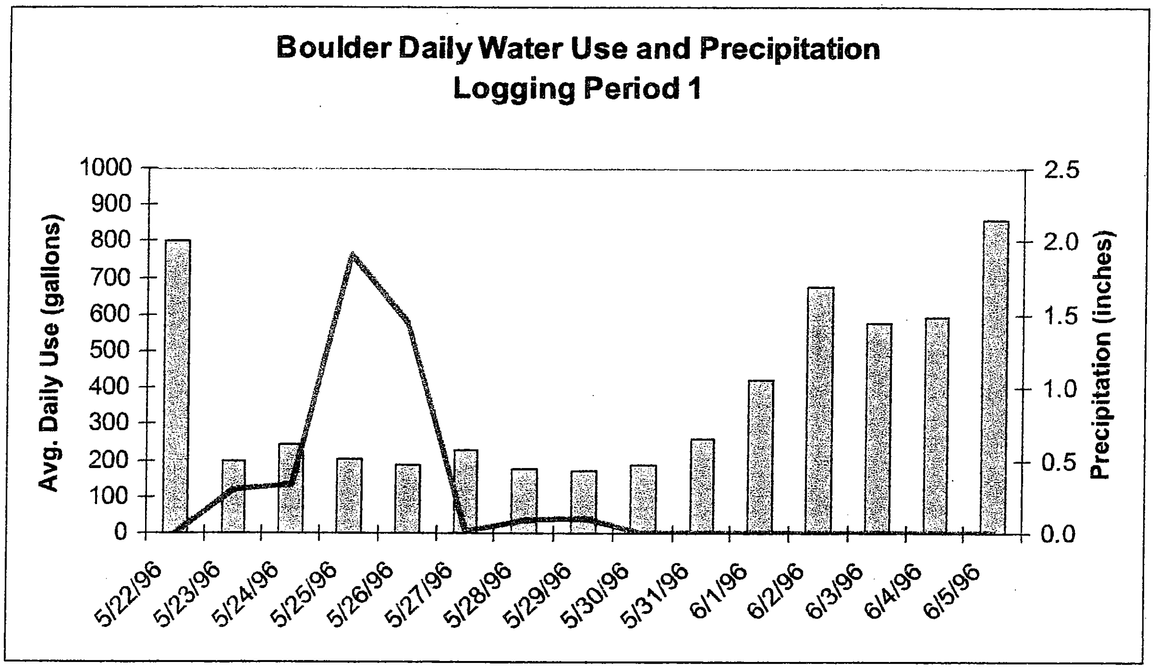


Figure 3-23: Daily Water Use and Precipitation, Log 1

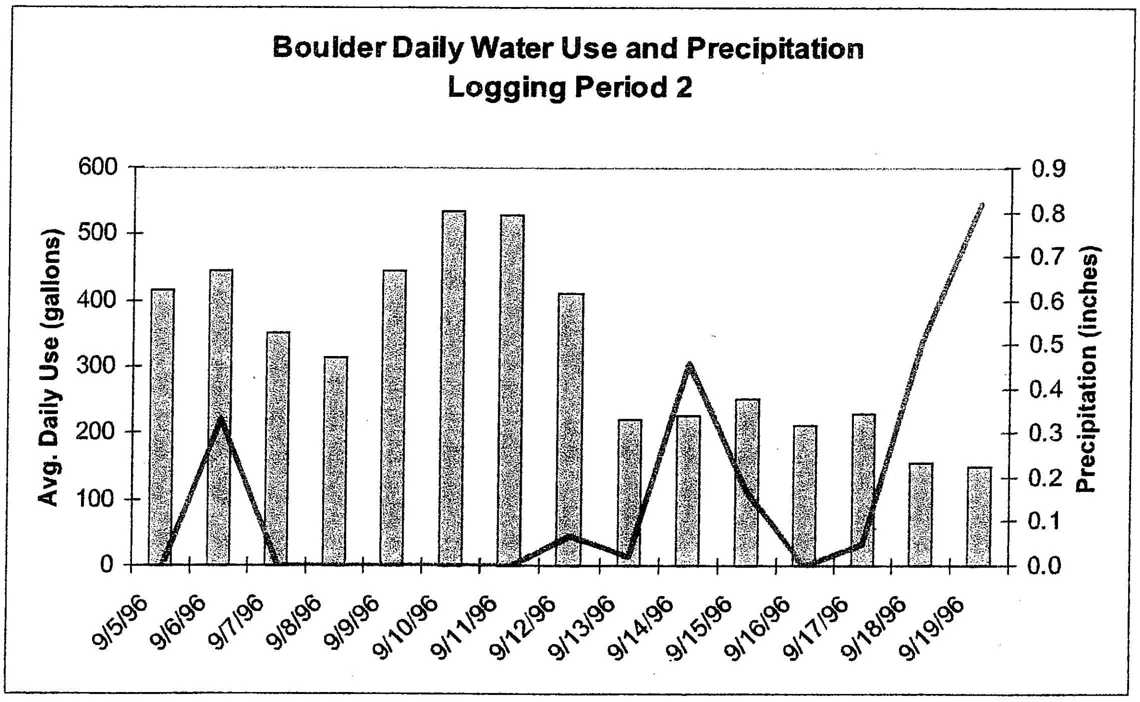


Figure 3-24: Daily Water Use and Precipitation, Log 2

Figure 3-25 is a plot of temperature vs. consumption during the logging period fit with a regression line. As can be seen from this figure, with an r^2 value of 0.38, temperature explains 38% of the variability in total water use.

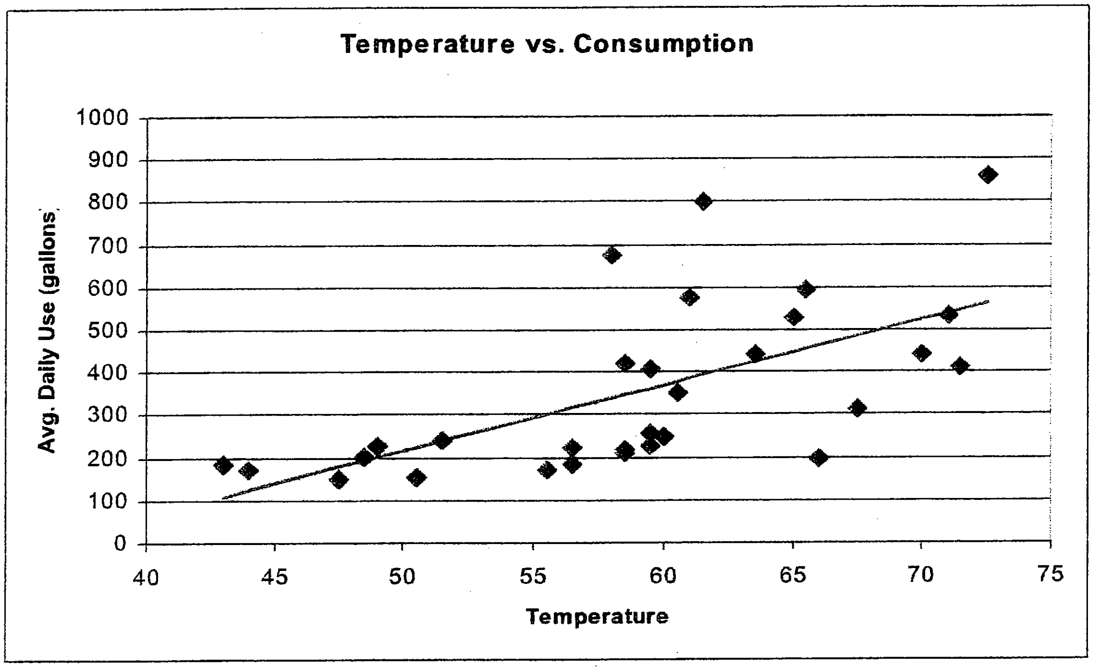


Figure 3-25: Temperature vs. Consumption, $r^2 = 0.38$

3.4.4.1 Rental vs. Owner Occupied

Statistics from the City Planning Department show that approximately 55% of residential units in Boulder are rentals. However, survey results from the REUS show that 10.8% of the logged single family houses were rentals and 89.2% of the houses were owner occupied – indicating that owners were much more likely to return the survey. Perhaps more significant is the fact that 96.6% of the logged households were responsible for paying their own water bill. In only 3.4% of the households did the landlord pay the bill. Table 3-3 shows a comparison of the average daily indoor and total water use for rented and owner occupied houses in the Boulder study group. Average daily use for the two different bill payment groups is also shown.

Table 3-3: Avg. Daily Use -- Rent vs. Own (From AWWARF REUS)

AVG. DAILY USE -- RENT VS. OWN						
	# OF HOUSES	AVG. # OF RESIDENTS	AVG. GPD		AVG. GPCD	
			INDOOR	TOTAL	INDOOR	TOTAL
Who Pays the Bill?						
Landlord	3	2.67	181.53	380.10	68.50	143.43
Household	85	2.41	150.24	340.13	62.34	141.13
Rent or Own?						
Rent	10	2.63	164.38	251.39	62.50	95.59
Own	78	2.39	149.89	352.59	62.72	147.53

Keep in mind that the sample of rental households in very small and the sample of households where the landlord pays the water bill is even smaller. This sample is not representative of rental housing in Boulder. Owner occupied houses and households responsible for their own water bills had very similar average daily water use patterns. Obviously there is a lot of overlap among these two groups. In the small number of rental households where the landlord pays the water bill, the average daily indoor and total water use was somewhat higher than in households that pay their own water bill. Most of the difference is observed in indoor rather than outdoor use.

4 Projections of Factors Affecting Water Demands

4.1 City Planning Data

4.1.1 Demographic Data and Projections

Part of the study effort to define the baseline condition of water consumption in the Boulder Service area included obtaining population, employment, land use and density data. These data were obtained from a variety of sources including the 1996 Boulder Valley Comprehensive Plan, City of Boulder Planning Department data, the 1990 Census Data (and the 1993 update), and the 1999 Boulder Summary of Information (prepared by the City of Boulder Center for Policy and Program Analysis). In addition, projections for growth in population, employment, housing, and density from the present through build-out were also obtained from the same sources. These projections will be used to help develop water use and conservation scenarios for the Boulder Service Area at build-out.

The City of Boulder Planning Department has divided Boulder Valley into three major planning areas: Area I, II, and III. The definition of these areas is detailed in the Comprehensive Plan.

> **Area I** – is that area within the City of Boulder which has adequate urban facilities and services to continue to accommodate urban development.
>
> **Area II** – is the area now under County jurisdiction, where annexation to the City can be considered consistent with current policies. New urban development may only occur coincident with the availability of adequate facilities and services and not otherwise. Departmental master plans project the provision of services to this area within the planning period. Area IIA is the area of immediate focus within the first three years, and Area IIB is available to accommodate development within the balance of the planning period.
>
> **Area III** – is the remaining area in the Boulder Valley, generally under County jurisdiction. Area III is divided into the Area III-Rural Preservation Area, where the City and County intend to preserve existing rural land uses and character, and the Area III-Planning Reserve Area, where the City and the County intend to maintain the option of expanded urban development in the City beyond the time frame of the 15-year planning period.[1]

Based on a conversation with City of Boulder Planner Susan Osborne, only a small portion of Area III is suitable for development and growth. The size of the Area III

[1] The Boulder Valley Comprehensive Plan, November 1996

planning reserve is 648 acres, and 200 acres of this planning reserve has been purchased by the City for a future regional park site. Furthermore, political realities in the City of Boulder make it extremely unlikely that anything beyond the designated suitable areas will ever be developed.

Currently all of the Area I and the vast majority of Area II population are supplied with water by the City of Boulder.

4.1.2 Population

The City's population grew rapidly in the 1950s and1960s, and then slowed in the 1970s. In 1977, the City instituted a residential growth management system, which limited housing construction to no more than a 2 percent increase per year. In the 1980s and 1990s, the City's population increased by an average of 1.1 percent per year.

Population data for the City were available from a variety of sources including: the 1990 census, the 1995 Source Book, the 1996 Boulder Valley Comprehensive Plan, City of Boulder Planning Department, and the City of Boulder Center for Program and Policy Analysis. Project team members Lee Rozaklis and Peter Mayer met with City of Boulder Planner Susan Osborne to discuss available data and appropriate projections.

For this study, population estimates are needed for the City of Boulder water service area, which corresponds to the City planning areas I and II, for both baseline conditions and for build-out. After reviewing data from a variety of sources, it was decided to settle on the numbers presented in Table 4-1. These come from the 1996 Boulder Valley Comprehensive Plan and the 1999 Boulder Summary of Information. For water planning purposes, a reasonable worst case should be assumed. Therefore, the maximum population at build-out, estimated to be 126,230, will be used to develop future water demand projections. This population figure would be associated with development of the remaining available acres in the 648-acre planning reserve in Area III. This represents a growth in total service area population of 17.3% between baseline and build-out.

Table 4-1: Boulder Water Supply Service Area Population: Baseline and Build-out

Boulder Service Area Population		
Area	Population - Baseline*	Population - Build-out
Area I	94,142	104,010 - 108,200
Area II	13,512	16,830 - 18,030
Area I & II	107,654	120,840 - 126,230

* Average of 1994 through 1996 data
Sources: 1999 Boulder Summary of Information, City of Boulder Center for Policy and Program Analysis; 1996 Boulder Valley Comprehensive Plan

4.1.3 Employment

The number of jobs in Boulder under baseline conditions and at build-out will also be needed to develop models of water use and conservation potential. In particular we plan to project commercial and industrial water use in units of gallons per job. Table 4-2 shows the employment assumptions used in this study. According to these projections, at build-out Area I and II will support 115,193 jobs. This represents a total growth in employment of 34.9% between baseline and build-out. Figure 4-1 shows a comparison of population and employment in the Boulder service area for baseline and build-out conditions.

Table 4-2: Boulder Water Supply Service Area Employment: Baseline and Build-Out

Boulder Service Area Employment		
Area	Employment - Baseline*	Employment - Build-out
Area I	84,062	112,799
Area II	1,339	2,394
Area I & II	85,401	115,193

* Average of 1994 through 1996 data
Sources: 1999 Boulder Summary of Information, City of Boulder
Center for Policy and Program Analysis; City of Boulder Planning Department Data

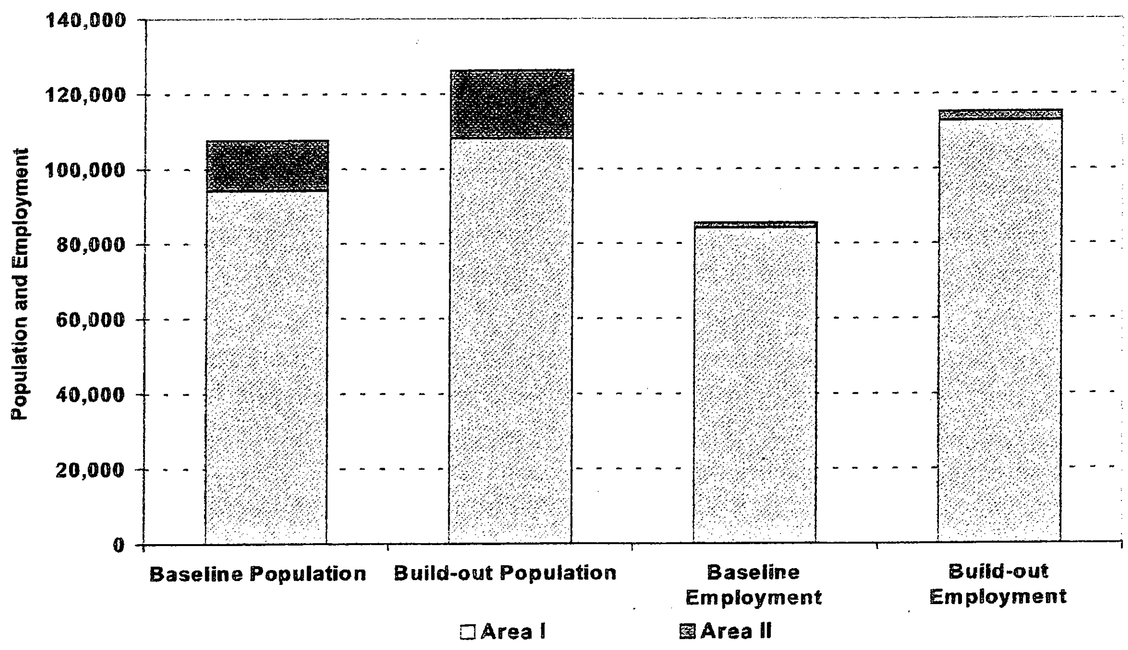


Figure 4-1: Population and Employment in Boulder (1996 Boulder Valley Comprehensive Plan, and Planning Department Data)

4.1.4 Housing

The current and future number dwelling units is another important piece of data for the conservation futures study. For water planning purposes housing is divided into two categories: single family residential (SF) and multi family residential (MF). The Boulder Planning Department divides housing similarly into attached and detached units. The basic definition of a detached unit is a structure that has open space on all four sides and is detached from any other house (SF and mobile homes fall into this category). An attached unit is a structure that has two or more units (e.g. MF, apartment or condominium complexes). The relative frequency of the type of dwelling unit (attached or detached) found in each subcommunity in 1990 is shown in Table 4-3. The Planning Department provided these data. In 1990 57% of the housing units were multi family attached and 43% were single family detached.

Table 4-3: City Dwelling Units 1990 (Planning Dept. Data)

City of Boulder Dwelling Units: 1990						
	Attached		Detached		Total	
Subcommunity	Number	Percent	Number	Percent	Number	Pecent
Central Boulder	7225	57%	5455	43%	12680	30%
Crossroads	3066	97%	86	3%	3152	7%
East Boulder	754	89%	96	11%	850	2%
Gunbarrel	2110	53%	1896	47%	4006	9%
North Boulder	1834	46%	2133	54%	3967	9%
Palo Park	336	37%	571	63%	907	2%
South Boulder	2299	32%	4825	68%	7124	17%
Southeast Boulder	4754	60%	3206	40%	7960	19%
University	1732	94%	110	6%	1842	4%
TOTAL	24110	57%	18378	43%	42488	100%

The Planning Department also provided a spreadsheet of their best estimate of housing units in each subcommunity in Boulder in Area I and II from 1990 to build-out. These data are shown in Table 4-4. The number of housing units in Boulder during the 1994-96 baseline years ranged from 44,420 to 45,013 and averages to 44,765. This average, 44,765, was used in this study as the number of housing units under baseline conditions.

The Planning Department has projected the division of single family and multi family housing at build-out. They anticipate that 56% of the housing units in Boulder will be single family and 44% will be multi family. This suggests only a 1% increase in the relative percentage of multi family housing from 1990 levels. These data are shown in Table 4-5. According to the Planning Department, the subcommunities of North Boulder, Central Boulder, and South Boulder will experience the most growth in housing as the City approaches build-out.

Table 4-4: Dwelling Units 1990 - Build-out (Planning Department)

Housing in Boulder: 1990 - Buildout									
SUBCOMMUNITY	1990	1994	1995	1996	1997	1998	1994-96 Mean	Buildout Projection	Growth to Buildout
CENTRAL BOULDER	**12680**	**12793**	**12815**	**12826**	**12846**	**12867**	**12811**	**13631**	**764**
Area I	12653	12766	12788	12799	12819	12840	12784	13604	764
Area II	27	27	27	27	27	27	27	27	0
CROSSROADS	**3152**	**3277**	**3277**	**3282**	**3283**	**3282**	**3279**	**3817**	**535**
Area I	3150	3275	3275	3280	3281	3280	3277	3796	516
Area II	2	2	2	2	2	2	2	21	19
UNIV. OF COLORADO	**1842**	**1842**	**1842**	**1842**	**1846**	**1846**	**1842**	**1888**	**42**
Area I	1842	1842	1842	1842	1846	1846	1842	1888	42
Area II	0	0	0	0	0	0	0	0	0
EAST BOULDER	**850**	**1073**	**1108**	**1124**	**1132**	**1151**	**1102**	**1234**	**83**
Area I	670	893	928	944	952	971	922	1054	83
Area II	180	180	180	180	180	180	180	180	0
GUNBARREL	**4006**	**4660**	**4728**	**4736**	**4768**	**4779**	**4708**	**5212**	**433**
Area I	274	702	770	778	804	815	750	1052	237
Area II	3732	3958	3958	3958	3964	3964	3958	4160	196
NORTH BOULDER	**3967**	**4194**	**4287**	**4354**	**4378**	**4394**	**4278**	**6230**	**1836**
Area I	2991	3962	4055	4122	4145	4216	4046	5848	1632
Area II	976	232	232	232	233	178	232	382	204
PALO PARK	**907**	**919**	**980**	**1022**	**1071**	**1116**	**974**	**1444**	**328**
Area I	374	386	447	489	538	583	441	623	40
Area II	533	533	533	533	533	533	533	821	288
SOUTH BOULDER	**7124**	**7253**	**7256**	**7257**	**7259**	**7259**	**7255**	**7958**	**699**
Area I	7105	7234	7237	7238	7240	7240	7236	7290	50
Area II	19	19	19	19	19	19	19	668	649
SOUTHEAST BOULDER	**7960**	**8409**	**8568**	**8570**	**8643**	**8722**	**8516**	**9231**	**509**
Area I	7232	7655	7814	7816	7889	7968	7762	8222	254
Area II	728	754	754	754	754	754	754	1009	255
SUBCOMMUNITIES TOTAL	**42488**	**44420**	**44861**	**45013**	**45226**	**45416**	**44765**	**50645**	**5229**
Area I	36291	38715	39156	39308	39514	39759	39060	43377	3618
Area II	6197	5705	5705	5705	5712	5657	5705	7268	1611

Table 4-5: Boulder Dwelling Units: Build-out

City of Boulder Dwelling Units: Buildout*						
	Attached		Detached		Total	
Subcommunity	**number**	**percent**	**Number**	**Percent**	**Number**	**Percent**
CENTRAL BOULDER	7946	58%	5685	42%	13631	27%
CROSSROADS	3711	97%	106	3%	3817	8%
UNIV. OF COLORADO	1775	94%	113	6%	1888	4%
EAST BOULDER	1096	89%	138	11%	1234	2%
GUNBARREL	2749	53%	2463	47%	5212	10%
NORTH BOULDER	2430	39%	3800	61%	6230	12%
PALO PARK	535	37%	909	63%	-1444	3%
SOUTH BOULDER	2566	32%	5392	68%	7958	16%
SOUTHEAST BOULDER	5517	60%	3714	40%	9231	18%
TOTAL	28325	56%	22320	44%	50645	100%

*City of Boulder Planning Department projections

The Planning Department's build-out housing projection of 50,645 housing units is based upon a total build-out population of 120,840 persons, which includes 8,000 persons assumed to be living in group quarters. This housing projection was therefore adjusted upward to reflect the 'worst-case' build-out population projection of 126,230 persons that is used in this study. This was done by dividing the 'worst-case' build-out population of 126,230 persons (minus 8,000 persons in group quarters) by the City's projected average projected household size of 2.3 persons per household, and then factoring in an average vacancy rate for the Boulder area. This resulted in a build-out housing projection of 53,109 units. This was split into single family and multi-family units based upon the 56%/44% ratio projected by the Planning Department. Table 4-6 shows the housing assumptions used in this study.

Table 4-6: Boulder Water Supply Service Area Housing: Baseline and Build-out

Boulder Service Area Housing		
Area	Housing - Baseline*	Housing - Build-out
Area I	39,060	43,377
Area II	5,705	9,732
Area I & II	44,765	53,109

* Average of 1994 through 1996 data
Sources: 1999 Boulder Summary of Information, City of Boulder
Center for Policy and Program Analysis; City of Boulder Planning Department Data

4.2 Water Rates

Increases in water rates impact customer water consumption as well as utility revenues. According to City of Boulder Coordinator of Utilities Project Management, Bob Harberg, the City plans in increase water rates every year for the next five years according to the schedule presented in Table 4-6. These increases apply to water rates only and do not impact sewer rates or PIF charges.

These increases will be applied uniformly across all user categories in the City's system.

Table 4-6: Proposed Water Rate Increases

YEAR	PROPOSED WATER RATE INCREASE
1998	8% (in effect as of 1/1/98)
1999	5% (in effect as of 1/1/99)
2000	3%
2001	3%
2002	3%
2003	3%
2004	3%
Beyond	Unknown

Source: Current utility planning documents conveyed by Bob Harberg

4.2.1 1998 Utility User Charges, Effective 1/1/99

Tables 4-7, 4-8 and 4-9 show all of the water and sewer charges for the City of Boulder, effective January 1, 1999.

planning reserve is 648 acres, and 200 acres of this planning reserve has been purchased by the City for a future regional park site. Furthermore, political realities in the City of Boulder make it extremely unlikely that anything beyond the designated suitable areas will ever be developed.

Currently all of the Area I and the vast majority of Area II population are supplied with water by the City of Boulder.

4.1.2 Population

The City's population grew rapidly in the 1950s and1960s, and then slowed in the 1970s. In 1977, the City instituted a residential growth management system, which limited housing construction to no more than a 2 percent increase per year. In the 1980s and 1990s, the City's population increased by an average of 1.1 percent per year.

Population data for the City were available from a variety of sources including: the 1990 census, the 1995 Source Book, the 1996 Boulder Valley Comprehensive Plan, City of Boulder Planning Department, and the City of Boulder Center for Program and Policy Analysis. Project team members Lee Rozaklis and Peter Mayer met with City of Boulder Planner Susan Osborne to discuss available data and appropriate projections.

For this study, population estimates are needed for the City of Boulder water service area, which corresponds to the City planning areas I and II, for both baseline conditions and for build-out. After reviewing data from a variety of sources, it was decided to settle on the numbers presented in Table 4-1. These come from the 1996 Boulder Valley Comprehensive Plan and the 1999 Boulder Summary of Information. For water planning purposes, a reasonable worst case should be assumed. Therefore, the maximum population at build-out, estimated to be 126,230, will be used to develop future water demand projections. This population figure would be associated with development of the remaining available acres in the 648-acre planning reserve in Area III. This represents a growth in total service area population of 17.3% between baseline and build-out.

Table 4-1: Boulder Water Supply Service Area Population: Baseline and Build-out

Boulder Service Area Population		
Area	**Population - Baseline***	**Population - Build-out**
Area I	94,142	104,010 - 108,200
Area II	13,512	16,830 - 18,030
Area I & II	107,654	120,840 - 126,230

* Average of 1994 through 1996 data
Sources: 1999 Boulder Summary of Information, City of Boulder Center for Policy and Program Analysis; 1996 Boulder Valley Comprehensive Plan

5 Projected Water Demands

5.1 Baseline Demands

Baseline demands for the City of Boulder system were based on monthly metered end use data provided by the City. An average of the deliveries from 1994 – 1996 was calculated and then adjusted to compensate for climate differences during those three years. The project team calculated monthly demand in four sectors: Single-Family, Multi-Family, Commercial, and Municipal. ET compensation was accomplished by proportionally adding 448 acre-feet (which is 479 acre-feet x 0.915 to address system loses) to the April – October deliveries for all four categories.

The baseline end use demand for the City of Boulder service area was determined to be 20,547 AF. Table 5-1 shows the monthly breakdown of the baseline end use demand by user category. Single-family residential used 37% of the total. The residential sector as a whole (single-family plus multi-family) used 67% of the total.

Table 5-1: Baseline End Use Demand, City of Boulder (Average 1994-1996)

	Single Family (AF)	Multi Family (AF)	Commercial /Industrial (AF)	Municipal (AF)	Total (AF)
Jan	356	410	334	8	1,107
Feb	300	370	317	8	996
Mar	328	386	329	8	1,051
Apr	418	433	393	25	1,269
May	726	536	514	72	1,848
Jun	944	620	607	112	2,283
Jul	1,298	788	866	165	3,117
Aug	1,234	753	786	162	2,935
Sep	911	664	684	101	2,360
Oct	485	462	436	49	1,432
Nov	357	430	365	8	1,160
Dec	324	365	292	8	988
Total	7,681	6,217	5,924	724	20,547
Percent	37%	30%	29%	4%	100%

(Based on averaged deliveries 1994 – 1996 adjusted up for ET.)

38,651 people 116 44,213 people 125

Table 4-7: City of Boulder Water Charges

Monthly Service Charges

Meter Size	Inside City	Outside City
3/4"	$6.18	$9.41
1"	$10.80	$17.61
1 1/4"	$16.55	$28.04
1 1/2"	$23.58	$40.98
2"	$41.51	$75.10
3"	$92.68	$160.42
4"	$164.31	$291.87
6"	$369.06	$666.86
8"	$655.70	$1,202.02

Quantity Chgs./1000 Gal.

	Inside City	Outside City
Block 1	$1.45	$1.45
Block 2	$2.05	$2.05
Block 3	$3.20	$3.20

Monthly Raw Water Costs

	Service Charge	Charge/ 1000 Gal.
3/4"	$3.94	$1.30
1"	$5.24	$1.30

Miscellaneous Charges

To terminate water service	$14.00
To mail water service termination notice	$9.00
To remove water meter	$34.00
To reset water meter	$16.00
To resume water service	$16.00
To perform special water meter read/ownership transfer	$13.00

Bulk and Metered Hydrant Rate
$4.00 per 1000 gallons

Table 4-8: City of Boulder Wastewater Charges

Monthly Service Charges

Meter Size	Inside City	Outside City
3/4"	$0.64	$4.97
1"	$0.96	$8.57
1 1/4"	$1.39	$13.21
1 1/2"	$1.90	$18.86
2"	$3.09	$33.21
3"	$8.31	$74.87
4"	$13.60	$132.49
6"	$29.15	$297.37
8"	$49.64	$527.77

Quantity Chgs./1000 Gal.

Inside City	Outside City
$1.50	$2.23

Table 4-9: Flood Management Fees, Single family dwellings

Monthly Stormwater and Flood Management Fees

Size of Parcel	Cost
up to 15,000 sq. ft.	$5.10
15,000 to 30,000 sq. ft.	$6.36
30,000 sq. ft. and up	$7.68

The stormwater and flood management fees for all non-single family dwellings is individually calculated by the City.

5.3 Demand Projections

Using the projected increases in population, employment, and housing from baseline to build-out combined with the anticipated effects of the current conservation program, natural replacement of worn fixtures, and the current federal plumbing codes, the water demand for each category was calculated at build-out. Although the Planning Department projects the single family sector will grow by 16.6% to build-out, this study projects that water demand for that sector will increase by only 1.8%. The multi-family sector is expected to grow by 21.4%, but the water demand for that sector is projected to decrease by 2.6% by build-out. These results are due to the anticipated effect of federal plumbing codes and Boulder's existing conservation program. Over the next 25 years it is anticipated that, through natural retrofit and conservation efforts, most homes, apartments, and condos in Boulder will replace their old plumbing fixtures with the more efficient low-flow fixtures currently mandated. If federal plumbing codes are repealed, these projections may change. Chapter 7 presents an example of projected demand in Boulder without the current conservation program and federal plumbing codes.

For the commercial/industrial sector the rate of increase in water demand is projected to be 25.0%. The demand reducing effects of federal plumbing codes and the City's current conservation program on projected water demand for this sector are outweighed by the proportionately greater amount of projected job growth.

Because of significant planned increases in irrigated parkland in Boulder, water demand by municipal government is projected increase by approximately 18.0% at build-out. Federal plumbing codes will have little effect upon demand growth in this sector, which is driven by increased outdoor use.

Overall demand in the City is expected to increase by 7.7% if current conditions (conservation program and plumbing codes) continue to build-out. The model input baseline demand for the City was 22,499 AF (including unaccounted water) and at build-out this study projects a total demand of 24,159AF (including unaccounted water). Demand projections for each City sector are shown in Table 5-3. The three-year average for unaccounted water of 8.43% was used to calculate total demand at build-out.

Figure 5-1 shows the growth in annual demands from baseline to build-out over a 25-year modeling period. An assumption of linear growth from baseline to build-out has been made in preparing this figure. However, the demand-increasing aspects of population and employment growth may temporarily exceed the dampening effects of fixture and appliance replacement in the near-term. Therefore Boulder's treated water demands may temporarily grow beyond 24,159 AF.

The total water delivered shown in Table 5-1, 20,547 AF, does not include unaccounted water. The 1994 – 1996 average for unaccounted water was 8.43% and the total treated water that was put into the system was measured at 21,966 AF by the Betasso meters.

5.2 Population, Employment, and Housing at Build-out

In order to calculate the unrestrained demands the City might expect during an average year at build-out, the population, employment, and housing projections provided by the City Planning Department were used to determine the growth in each of the four use sectors. Planning Department data from 1994-1996 were averaged so that the demographic data at baseline corresponds to the baseline water demand. Table 5-2 shows the population, employment and housing levels at baseline (1994-96) and at build-out. The service area population is expected to increase by 17.3%, housing by 18.6%, and employment is expected to increase by 34.9%. This indicates that water use in the commercial sector is projected to increase more significantly than in the residential sector. Another important factor is the increase in multi-family housing which is expected to exceed the growth rate of single-family housing.

In the baseline year the average number of people per dwelling in Boulder was 2.30. The Planning Department numbers suggest that this number will remain constant through build-out.

Table 5-2: Population, Employment, and Housing – Baseline and Build-out[1]

	BASELINE	BUILDOUT	%INCREASE
POPULATION (people)	107,655	126,230	17.3%
Persons in households	99,655	118,230	18.6%
Persons in group quarters[2]	8,000	8,000	0.0%
EMPLOYMENT (jobs)	85,401	115,193	34.9%
HOUSING (units)	44,765	53,109	18.6%
Single-Family	25,516	29,241	16.6%
Multi-Family	19,249	23,368	21.4%[3]
Average Household Size	2.3	2.3	0.0%

1 Based on data and population projections from the Planning Department.

2 Includes residents of CU dorms, fraternities, and sororities, as well as group homes, retirement communities, etc.

3 For modeling purposes a multi-family growth rate of 19.9% was assumed. Because the demand of persons in group quarters accounted for approximately 7.2% of the multi-family demand, and the population in group quarters is not projected to grow, the rate of growth for multi-family demand was reduced by 7.2% - calculated as (21.4% * 0.928) = 19.9%.

5.3.1.1 Dry Year

Since 1949 when climate records were first kept, the driest year on record was 1954. Known as the worst year of the 1950's drought, 1954 has an estimated recurrence interval of at least a once in fifty years. The actual recurrence interval is not known because only 50 years of data are available.

Using the correlation analyses described in Section 3.2.4, we were able to estimate the City's projected build-out demand under 1954 conditions. Based on this analysis it can be shown that 1954 dry year conditions would increase Boulder's build-out water demand by approximately 11% over average year conditions.

Applying this "dry year factor" to the projected average year build-out demand developed for this study results in a dry year build-out demand of 26,816 AF.

5.3.1.2 Wet Year

A similar analysis was completed for the wettest year in Boulder during the past 50 years. Based on the available climate data, 1967 was the wettest year on record. The increased precipitation in 1967 resulted in a 10% decrease in total system demand over an average year.

By applying this "wet year factor" to the projected average year build-out demand developed for this study results in a wet year build-out demand of 21,743 AF.

The results of the extreme year analysis are shown in Table 5-4.

Table 5-4: Projected Extreme Year Demands at Build-out

Type of Year	Extreme Year Adjustment Factor	Projected Build-out Demand (AF)
Average	0%	24,159
Dry (1954 level)	11%	26,816
Wet (1967 level)	-10%	21,743

5.4 Peak Demand Projection

Based on the analysis in Chapter 3 of this report, it was recommended that the city consider adopting a "baseline" peak ratio of 2.6 for its future planning purposes. Using this factor the projected peak day demand for build-out conditions was calculated. The

Table 5-3: Projected Growth from Baseline to Build-out

	Baseline Demand (AF)	Water Demand Growth Rate	Build-out Demand (AF)
Single-Family	8,390	1.7%	8,533
Multi-Family	6,791	-2.7%	6,608
CI	6,471	25.0%	8,085
Municipal	793	17.7%	933
TOTAL	22,445	7.6%	24,159

Includes unaccounted water

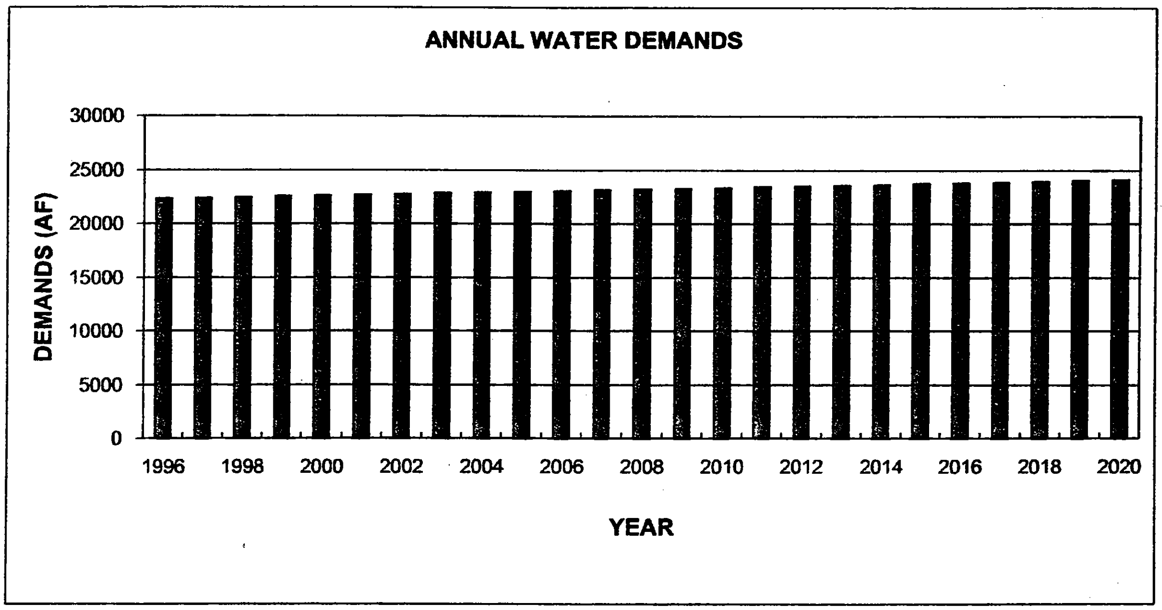


Figure 5-1: Projected annual demands to build-out (25 year time window) assuming continuation of current conservation program and Federal plumbing codes

5.3.1 Extreme Year Projections

The projected system wide build-out demand of 24,159 AF was developed as a "typical" or average year demand projection. What might the build-out demand be in a dry year or a wet year?

Residential Sector Demand: Outdoor Use Factors – Our residential water demand projections with existing conservation programs in place assume a constant per-household outdoor water use factor. In reality, a major portion of Boulder's residential growth will involve significant infill and densification. This will probably result in reduced per-household outdoor use factors.

Municipal Sector Demand – We have estimated that municipal sector demands will increase by 17.7% percent due to the additional acres of irrigated parkland the City plans to add in the next 25 years. Based on conversations with the Parks and Recreation Department there appears to be little opportunity for raw water irrigation at most of these new parks.

Commercial/Industrial Demand – The increase in commercial and industrial demand is based on the projected 34.9% increase in the number of jobs in planning areas I and II. However, it is unlikely that irrigated landscapes associated with projected development in this sector will increase by the same 34.9%. Instead, future development in this sector will probably involve a significant amount of in-fill and densification. This would reduce the outdoor component of commercial/industrial demand. In our projections, a constant per-job water use factor was assumed.

Plumbing Codes – Indoor water use factors for all sectors are projected to decrease in a unit basis primarily due to the impact of the natural replacement of plumbing fixtures and appliances with newer water conserving models. In 25 years, it is expected that most homes, apartments, and condos will have replaced their toilets, showerheads, and faucets with conserving fixtures. If Congress repeals the 1993 plumbing codes, and non-conserving fixtures return to the market, these projections could change significantly.

Water Use Habits and Patterns– A key assumption in this model is that future houses and commercial establishments will have similar water use habits and patterns to the existing population. Advancements or setbacks in conservation technology, changes in personal habits, and policy revisions could result in changes in the demand at build-out.

Fluctuations in Demand Projections - A linear rate of growth during the 25 year modeling windows was assumed. This includes growth in population, construction, and natural retrofit of fixtures and appliances. It is likely that growth in one of these areas will outpace the others at various points, which would cause fluctuations in annual demands. However these fluctuations would not affect the ultimate build-out demand projections.

projected build-out peak day demand is 56.1 MGD and in a dry year the peak demand is projected to be 62.2 MGD. These results are shown in Table 5-5.

Table 5-5: Projected Extreme Year Peak Day Demands at Build-out

Type of Year	Extreme Year Adjustment Factor	Projected Build-out Demand (MGD)
Average	0%	56.1
Dry (1954 level)	11%	62.2
Wet (1967 level)	-10%	50.5

Calculated using the recommended peaking factor of 2.60.

5.5 Uncertainty Factors

Any projection of future demand will contain a number of uncertainties that must be understood. We have attempted to identify some of the key assumptions and uncertainties that are inherent in the demand projection presented in this report. Although projected demand stays essentially constant, we believe this projection is reasonably conservative. In this study we have actually opted to make demand projections *larger* by assuming the high end of the City's projected rates of growth in residential, commercial and municipal demand, which may not occur. In spite of these uncertainties, this projection represents our best estimate of average annual system demand at build-out assuming continuation of the current Federal plumbing codes and the City's existing water conservation program.

Planning Numbers – Our projection is based population, housing, and employment data provided by the City's Planning Department and Center for Program and Policy Analysis. While these numbers are the best available, any inaccuracies in either the current data or build-out projections will affect our demand projections.

Climate Change – Long-term changes in the Boulder area climate could increase or decrease this demand projection.

Residential Sector Demand: Area III Planning Reserve – Our projections for growth in residential demand are based on the assumption that full residential development of the remaining available acres in the Area III Planning Reserve will occur. This is a worst case assumption, given the political realities of further development in that area.

City system facility capacities:

Barker storage: 8,000 AF
Watershed storage: 6,987 AF
Boulder's Boulder Reservoir account: 3,143 AF winter/5,257 AF summer
Barker Gravity Line: 43 cfs
Lakewood Pipeline: 30 cfs (Lakewood Pipeline replacement assumed in place)
Betasso WTP: 50 MGD (existing hydraulic capacity)
Boulder Reservoir WTP: 10 MGD (existing hydraulic capacity)

Water Rights/Contracts:

No drought reservation assumed for the CWCB Conveyed rights
PSCO "borrowing" arrangement is not reflected
Recent acquisitions (N. Boulder Farmers, Lower Boulder) are not reflected
Windy Gap: 3,700 AF (out of 8,000 AF original interest)
CBT: 21,015 Units

Based on the model analysis, the firm yield of the City's existing system is estimated to be approximately 33,000 acre-feet per year. Assuming that the City would exercise its drought reserve rights in the instream flow program and its borrowing arrangement with PSCO, the City's firm yield would increase to approximately 37,000 acre-feet per year. Both of these yield figures are significantly greater than the projected build-out demands for the City. It should be noted that, because the model does not operate on a daily time step, the peak day implications of these results have not been explored.

6.3 Treatment Capacity

Several meetings were held with the City's water treatment plant operators and design consultants to estimate the current treatment capacity at the Betasso and Boulder Reservoir treatment plants. Based upon currently available information, the existing capacity of the Betasso and Boulder Reservoir plants during the peak use season is assumed to be 50 MGD, plus or minus a 3 MGD operating uncertainty range. The 50 MGD capacity assumes that Boulder is treating its raw water to meet a turbidity standard of 0.3 NTU. The 3 MGD uncertainty range reflects short-term fluctuations in influent raw water quality. It should be noted that the City's treatment plant staff are exploring several plant optimization processes that should increase the 50 MGD capacity and/or reduce the 3 MGD uncertainty range in the near future.

It is also the City's policy to maintain a 10% safety factor in its treatment capacity to address unknown situations. Given this safety factor and the 3 MGD operating uncertainty range, the City's existing reliable peak season treatment capacity is 42 MGD. However, the City's peak day use has consistently reached 44 MGD over the past several years, suggesting that either the 10% safety factor is not being maintained, or that the 3 MGD operating uncertainty range is overstated.

6 Assess Water Supply Yield and Treatment Capacity

6.1 Introduction

The yield of the City's water supply system was evaluated in order to assess the City's ability to meet its projected future water needs. The system was modeled under existing and future facilities capacity assumptions.

The current treatment capacity at Betasso and Boulder Reservoirs was determined in order to assess the City's ability to meet future treatment demands.

6.2 Water Supply Yield

This assessment was done using Hydrosphere's Boulder Creek model, which was previously developed as part of other water supply planning studies for the City. The current version of the model operates on a quarter-monthly time step over a 1950-1994 period of hydrologic record. The major assumptions of the model are as follows:

The City's demands were portrayed as a constant annual amount over the 45-year period of record, with a seasonal pattern reflective of demand patterns over the 1994 through 1996 baseline period.

Model inflows consist of natural flow hydrology for North, Middle and South Boulder Creeks, natural stream gains along stream reaches, estimated historical irrigation return flows along lower Boulder Creek and projected future wastewater discharge levels from in-basin municipalities.

Agricultural demands are modeled based on estimates of consumptive use requirements, overall ditch efficiencies, and current estimates of irrigated acreage.

Other municipal demands (Denver, Lafayette, Louisville) are modeled at projected build-out levels.

The Boulder Creek instream flow program is assumed to be in effect and the City is assumed to not exercise its drought reservation during the modeled period.

South Platte call conditions are modeled at historical levels.

7 Potential Water Conservation Benefits

A series of focus groups were held with interested citizens and utility staff to review the information developed on Boulder's existing water uses, projected future water demands and raw water supply yield. At these meetings the potential benefits and rationales for various water conservation programs were discussed, as summarized below.

7.1 Capital Cost Benefits

7.1.1 Reduce, Defer or Eliminate Boulder Reservoir Treatment Plant Expansion Costs (Peak Programs)

Summer peak demands and future water quality standards are likely to be the driving factors for possible future expansions of the Betasso and Boulder Reservoir Treatment Plants. Water conservation programs aimed at reducing peak demands could be particularly effective in this regard.

However, the City also has adopted water supply system reliability criteria that recommend the capability of meeting 100% of the City's indoor demands from either treatment plant. This aspect of the City's reliability criteria is not currently being met; there are several treatment and distribution "bottlenecks that prevent the Boulder Reservoir plant from being able to supply the City's entire service area at any capacity. If this aspect of the City's reliability criteria were seriously pursued, an expansion of the Boulder Reservoir plant (plus additional pumping capacity) would be required irrespective of water conservation programs.

7.1.2 Reduce Wastewater Treatment Plant Expansion Costs (Indoor Volumetric Programs)

Reduction of sanitary flows could potentially reduce average and maximum month design flows into Boulder's wastewater treatment plant. This could in turn reduce the costs of future facility expansions needed to meet NPDES permitting. Additional savings from water conservation programs could provide for higher instream flows via the Boulder Creek Instream Flow program, with associated potential NPDES permitting benefits. Water conservation programs aimed at achieving volumetric savings in indoor use would be particularly effective in these areas.

However, recent analyses of the City's wastewater treatment plant expansion options suggest that the reductions in sanitary flows achievable via conservation would not significantly reduce the City's expected wastewater treatment upgrade costs.

Based on information obtained from the City's treatment plant design consultant, treatment plant capacity expansion costs would be approximately $250,000 per MGD at Boulder Reservoir and $350,000 per MGD at Betasso, up to a combined capacity of 57.8 MGD. This combined capacity level reflects the flow limitations associated with the Barker gravity line into Betasso and certain hydraulic limitations at the Boulder Reservoir Treatment Plant. Beyond this 57.8 MGD level, expansion costs would be approximately $1,000,000 per MGD.

7.6 Non-Cost & Public Values Benefits

Water conservation programs increase operational flexibility. By reducing indoor and outdoor demand, it will be easier for the City to move water within its system to meet demands in different areas or pressure zones. Reducing indoor demand could increase the City's ability to serve the entire system's indoor demand from either treatment plant – an important consideration in system reliability. Conservation will also increase system flexibility to used saved water for other desirable purposes such as park/open space irrigation, water-related recreation, support of irrigated agriculture and instream flow.

Conservation can improve water quality in Boulder's system. It can reduce the frequency of peak treatment operations and reduce the degree of reliance on relatively lower quality sources from Boulder Reservoir. Conservation can also improve water quality in Boulder Creek and its tributaries. Outdoor conservation efforts would reduce lawn irrigation return flows and associated nonpoint source pollution.

Indoor conservation reduces wintertime demand, which results in consistently fuller reservoirs in the Watershed and at Barker, with associated environmental, recreational and system reliability benefits.

Results from several Boulder water user surveys over the past 15 years have consistently revealed a high degree of interest and awareness of water conservation among Boulder's citizens. The people of Boulder expect responsible stewardship of our community's water resources. Conserving water makes sense and people view it as "the right thing to do".

Conservation programs are also an effective way for the utility to provide a community service since they involve direct contact between the utility and its customers, local schools and a variety of interest groups. Dollars spent on conservation programs are more likely to remain in the community than those spent on large capital projects.

Finally, no one knows precisely what the future may bring. Unforeseen events could dramatically impact Boulder's water supply. Conservation can greatly reduce the severity of droughts, pipeline breaks, adverse legal decisions, permitting requirements, and other hazards.

7.2 O&M Cost Benefits

Reduced demands from water conservation programs result in reduced chemical and energy costs for water and wastewater treatment. Volumetric programs would reduce both chemical and energy costs while peak programs would reduce only energy costs. Volumetric savings would also increase the City's leasable water supplies to agricultural users, thereby increasing revenues from that program.

7.3 Cost Benefits to Customers

Water conservation programs typically result in reduced water bills and energy bills for participating customers, compared to nonparticipants. Xeriscape landscaping programs, included in outdoor water conservation programs, can also result in lower landscaping maintenance costs.

7.4 Windy Gap Replacement (Volumetric Programs)

Boulder's utilities staff has a general directive to replace 4,300 AF of Windy Gap water that Boulder sold to Broomfield with other water sources which would maintain the reliability of the City's water supply system in a manner that would better address City goals. Water conservation programs aimed at volumetric savings could be considered as a demand-side replacement "source".

7.5 Alternate Uses for Water Saved

Additional demand reduction would increase the City's potential water supplies and operational "comfort level" for meeting its instream flow targets on various Boulder Creek tributaries.

Volumetric water conservation savings could also increase the size and reliability of Boulder's agricultural leasing program, enhancing the viability of local agriculture.

While Boulder is not contemplating selling any of its water rights, it should still place a fair market value on its water when analyzing the impacts and benefits of water conservation. Valuation should also take into account anticipated future use of water as the Front Range continues to grow. By reducing demand, conservation increases the value of Boulder's water.

A surplus of water may provide as yet unknown opportunities for Boulder to participate in regional cooperation in which water may provide a lever for attaining goals in other areas including growth management, open space and other Comprehensive Plan goals.

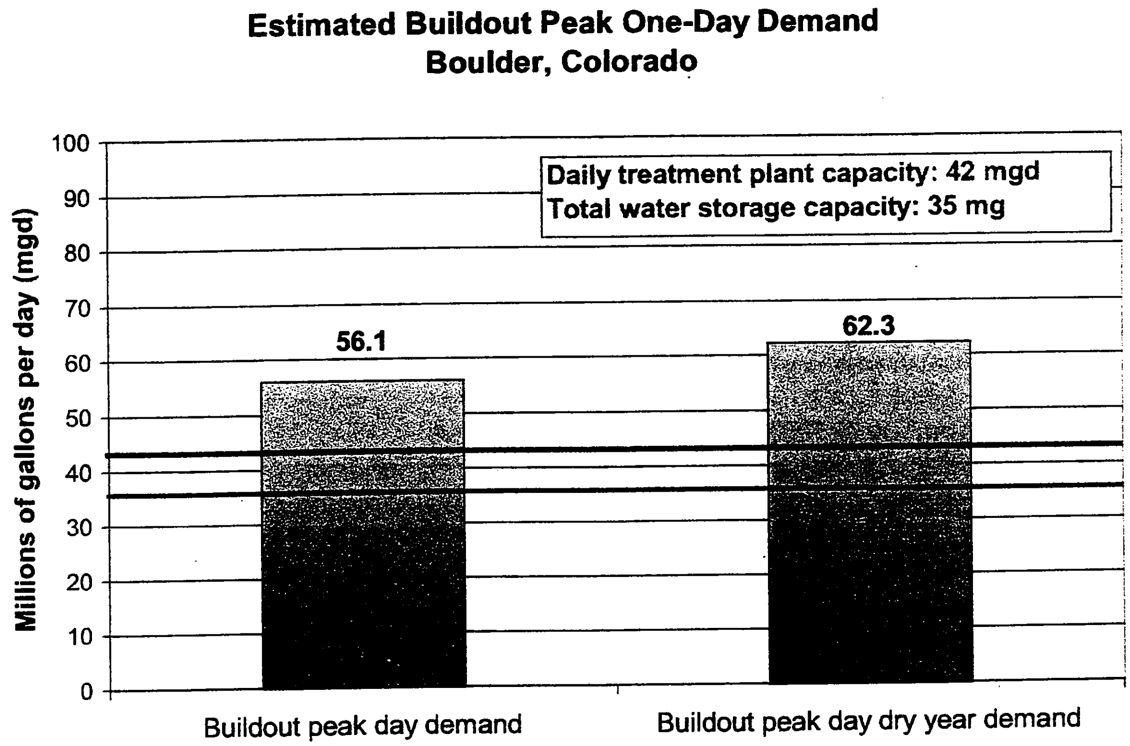


Figure 8.1: Projected build-out peak day demands assuming continuation of the current program and federal plumbing codes

While the likelihood of eliminating the need to expand the treatment capacity is a compelling and fiscally responsible reason for conservation in Boulder, focus group participants made it clear that they would support conservation for a wide variety of reasons. One of the most frequently cited reasons for water conservation was the pragmatic value of preserving Boulder's natural environment and watershed for future generations. These sentiments echoed the response to a survey the Department of Public Works and Department of Community Planning and Developed conducted which found a greater inclination to save water for the purpose of protecting the environment than for monetary rewards.[4]

Another important reason for conservation is improved water quality. Water treated at the Betasso water treatment facility is of perceptibly higher quality than the water treated at Boulder Reservoir. Currently 80 percent of Boulder's water is treated at Betasso and 20 percent at Boulder Reservoir. While the treatment capacity at Betasso cannot be easily increased, the Boulder Reservoir plant can be readily expanded. As Boulder grows to build-out, increases in water demand will be met exclusively with lower quality water treated at Boulder Reservoir.

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[4] Brown and Caldwell. 1990. *City of Boulder Treated Water Master Plan Phase 1 - Final Report*. Boulder, CO.

8 Alternative Water Conservation Futures

The previous tasks have laid the groundwork for the evaluation of various conservation program options available to the City. Through these efforts we have a solid grasp of water demand in Boulder's system. From the City Planning Department projections we have a good estimate of the growth Boulder is likely to experience from now until build-out. Hydrosphere's evaluation of the yield of Boulder's water rights and the maximum daily water treatment capacity provided the constraints or limits in demand and treatment for the system. Finally, two focus group meetings and discussions with City staff gave initial direction and rationale for developing conservation scenarios.

Boulder is in an enviable position among Front Range communities. Results of Hydrosphere's evaluation of the City's water rights indicate that a shortage of raw water in Boulder is extremely unlikely, even at build-out. There is little rationale for conservation in Boulder strictly from the perspective of raw water supply. Demand projections have demonstrated that if Boulder continues with its current conservation program coupled with a continuation of federal plumbing codes[2], some additional water treatment capacity will be required at either of the city's facilities.

Figure 8.1 shows projections for peak day demand at build-out assuming the continuation of the current conservation program and the 1993 National Energy Policy Act plumbing standards. Estimated peak demand is shown for a typical build-out year and for an "extreme" (dry) build-out year. An extreme year would be similar to the hot and dry weather conditions experienced in 1954 in Boulder. Peak daily demand even in a typical year is above Boulder's current water treatment capacity of 42 MGD[3]. Boulder also has a treated water storage capacity of approximately 35 million gallons (mg) which could be available to meet peak day demands given proper preparation and planning. Because peak days often come in groups of 2 or more it is inadvisable to permit peak day demand to exceed water treatment capacity even when sufficient storage capacity exists.

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[2] Currently the US Congress is considering legislation put forward by Rep. Joseph Knollenberg (R-Michigan) which would do away with the 1993 water efficient plumbing codes. If this bill passes (it failed last year) the conservation landscape could change dramatically and assumptions in this study should be reviewed. Boulder City Council forwarded a letter to Rep. David Skaggs last year urging the defeat of this legislation.

[3] Treatment capacity=50 MGD ± 3 MGD - 5 MGD safety factor (Source: Kipp Scott and Bob Harberg)

Many studies nationwide have documented the effectiveness of these toilets in conserving water. In 1996 Aquacraft conducted a retrofit study for the Boulder Office of Water Conservation which included the installation of 21 ULF toilets in 14 homes in the Heatherwood neighborhood[6]. These toilets caused a 30 percent reduction in the amount of water used for toilet flushing and the study participants reported satisfaction with the performance of these fixtures. Since the FEPA passed, ULF toilets have undergone extensive re-design and re-engineering which has improved their effectiveness and acceptability with customers. A 1996 study in New York City found general satisfaction with a wide variety of ULF toilet makes and models[7]. The nationwide end use study found that homes equipped with ULF toilets do not flush more often on a per capita basis that homes equipped with standard toilet fixtures[8].

It is also anticipated that replacing older toilets will reduce leakage (a significant loss of water in the residential sector) which is often caused by faulty flapper valves. The City offered trial rebates in 1994 and 1995 to encourage people to retrofit their older toilets with these more efficient models, but no rebate for toilets is currently offered.

Conservation potential: ULF toilets offer significant, reliable water savings. It is estimated that ULF toilets will reduce indoor water use from 8 to 17 percent in typical Boulder homes.

8.1.1.2 Horizontal Axis Clothes Washers

Recent research has shown that after toilets, the clothes washer is the largest indoor water-using fixture in the residential setting. A typical top-loading clothes washer uses between 35 and 55 gallons per load of clothes.

In the past two years all major US manufacturers have introduced new horizontal axis clothes washers which are considerably more water efficient and energy efficient than the standard top-loading models.[9] These clothes washers look similar to Laundromat machines and the door is on the front instead of on the top. These machines use from 15 to 25 gallons of water per load, depending on the setting, and they render the clean clothes with less moisture content (they spin much faster than conventional machines) and thus require less drying time (a significant energy savings).

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[6] DeOreo, W. B. and P. Mayer. 1996. *Measuring Actual Retrofit Savings and Conservation Effectiveness Using Flow Trace Analysis.* Aquacraft, Inc., Boulder, Colorado.

[7] Westat, Inc., 1996. *Evaluation of New York City's Toilet Rebate Program.* NYC Department of Environmental Protection. New York, New York.

[8] Mayer P. and W.B. DeOreo, et. al. 1999.

[9] Efficient top-loading models are expected to arrive on the market sometime in 1999.

Conservation in Boulder means that less water from Boulder Reservoir will be put into the system thus increasing the overall quality of the water delivered.

The purpose of this chapter of the study is to present the range of conservation programs and options available to the city. Individual measures are described and discussed below and the most promising and feasible measures have been combined to form a series of conservation scenarios or alternative futures. These scenarios were developed and evaluated based on Aquacraft's understanding of the City's needs and conservation goals, discussions with City staff, and two focus group meetings with concerned citizens. The impacts of these measures were evaluated using Aquacraft's Integrated Conservation Model (ICM) which is described in detail later in this chapter.

8.1 Conservation Measures

8.1.1 Recommended Indoor Conservation Measures

A variety of indoor conservation measures are available to the City. The Boulder Office of Water Conservation has used some of the measures recommended here in the past. Many have been subject to rigorous scientific research to determine effectiveness conducted here in Boulder and sponsored by the City Office of Water Conservation and conducted through the University of Colorado and Aquacraft, Inc.

8.1.1.1 Ultra-Low-Flush (ULF) Toilets

An Ultra-Low-Flush Toilet (ULF) is any toilet that uses 1.6 gallons or less per single flush. Under the Federal Energy Policy Act (FEPA) of 1993, ULF toilets are the *only* style of toilets permitted to be manufactured in the United States. These toilets are made by all the major manufacturers in the US and come in a wide variety of models and styles. Because the average "life span" of a toilet fixture is between 18 and 20 years it is anticipated that most toilet fixtures in Boulder will be replaced with ULFs by 2025, provided that Federal plumbing codes are kept in place. This switch to ULF toilet fixtures is expected to significantly reduce demand in Boulder's residential sector.

The City of Boulder participated in a nationwide study of residential water use conducted over the past three years which measured the amount of water used for toilets in a random sample of 100 homes in Boulder[5]. The average flush volume for a toilet in the study homes in Boulder was 3.9 gallons per flush – more than double the ULF rating. This indicates that significant conservation potential exists through the natural retrofit of ULF fixtures.

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[5] Mayer P. and W.B. DeOreo, et. al., 1999. *Residential End Uses of Water Study.* American Water Works Association Research Foundation, Denver, Colorado.

8.1.1.4 Low-Flow Faucets

Similar to showerheads, federal law mandates that all faucet fixtures manufactured in the US not exceed 2.2 gpm. This includes faucet aerators and entire fixture systems.

The 1996 Heatherwood retrofit study found that the installation of 2.2 gpm faucet aerators reduced faucet usage by 28.7 percent at a cost of less than $5 per household.

Conservation potential: Dollar for dollar, faucet aerators may be the most effective conservation devices on the market. They are simple and effective and should be included in any indoor conservation program.

8.1.2 Indoor Conservation Measures Not Recommended at This Time

8.1.2.1 Hot Water Re-Circulating Systems

Several manufacturers are offering hot water re-circulation systems as conservation devices. These systems re-circulate hot water to the most distant hot water fixtures in the house so that when a shower or a faucet is turned on, hot water is immediately available thus eliminating the need to run water through the tap until hot water arrives.

These re-circulating systems cost somewhere between $300 and $500 each and while the manufacturers claim significant savings are available from these devices there have been no independent field tests that confirm these savings. It is anticipated that in the next few years research will be conducted to test the efficacy of these devices at saving water.

Conservation potential: Unknown at this time. Use of these devices is not recommended until their efficacy has been confirmed.

8.1.2.2 Pressure Activated Faucet Controllers

One of the few new conservation products to appear at the national water conservation conference, Conserv99, was a pressure activated faucet controller called the AquaLean™. This device consists of a bar that is mounted on the fact of the sink front. When the occupant needs water through the faucet she leans on the bar, which activates a diaphragm valve. This device, which costs approximately $35, could reduce faucet use in bathrooms and kitchen sinks considerably, and appears worth investigating.

Conservation Potential: Faucet use accounts for 17 percent of indoor residential water use in Boulder. We know that simple aerators can effectively reduce this use, and any product that is not expensive and simple to install has the potential to save water, but until tested its actual potential is unknown.

8.1.2.3 Gray Water and Re-Use

The re-use of water, often called "gray water" has often been put forward as a conservation technique. Modern gray water systems collect almost all water (except for toilet flushes) and filter it so that it can be re-used for non-potable purposes such as irrigation. A number of cities have embarked on ambitious gray water re-use programs particularly for the industrial and commercial sectors. The cost and feasibility of these gray water systems for Boulder was not investigated in this study.

Conservation potential: These systems may offer tremendous savings. However, they are expensive to install and maintain (especially in existing homes). Because Boulder is fortunate to have an ample supply of raw water it is more cost effective to utilize raw water resources rather than gray water at this time.

8.1.2.4 Water Use Feedback System

It has been suggested that a water use feedback system that provides users with a simple way to regularly monitor and evaluate their water use would be an effective conservation device. This system could be a simple as a remote water meter reading device inside the home or as complex as a computer controlled utility monitoring system. Such systems are not currently offered for sale to the mass market (to our knowledge) and have never been independently tested for their conservation potential.

Conservation potential: Unknown.

8.1.3 Recommended Outdoor Conservation Measures

Outdoor water conservation offers the greatest potential water savings for the City. At the same time, it is often more difficult to achieve and maintain deep reductions in outdoor use because behavioral changes, rather than hardware, are often required. A variety of outdoor conservation measures are available to the City. The Boulder Office of Water Conservation has implemented many of the measures recommended here in the past and some have been subject of rigorous scientific research to determine effectiveness.

8.1.3.1 Xeriscape Landscaping

Xeriscape is a systematic concept for saving water in landscaped areas and refers to an entire system of landscaping which seeks to maximize both the beauty and water efficiency of urban landscaping through application of a set of design principles. The term Xeriscape comes from a combination of the Greek word "xeros" meaning dry and the English word landscape. Ideally, Xeriscape minimizes the planting of high water use materials such as turf grass, and instead substitutes native plants, grasses, mulches, etc. that take advantage of the local climate conditions and require less irrigation watering.

A recent study in Las Vegas conducted by Aquacraft found that the installation of Xeriscape in existing single family homes reduced outdoor water use by 41 percent[12]. The Bureau of Reclamation is currently studying the conserving potential of Xeriscape in the Rocky Mountain region.

Replacing a turf landscape with a Xeriscape landscape of the quality required to satisfy many customers in Boulder can be expensive. Landscaper estimates for replacing 3,000 square feet of turf with Xeriscape range from $6,000 to $12,000. Someone willing to do the work themselves could probably cut this cost considerably, but the cost of Xeriscape is prohibitive for many people. One solution to this problem would be for the City to establish a revolving loan fund for the purpose of helping water customers to Xeriscape. Once established the program would be self-sustaining and loan payments from participants in one year could fund participants in the next year. Such a program would require careful management, but might be an excellent way to encourage Xeriscaping in the City.

Conservation potential: Xeriscape is one of best tools for reducing outdoor water demand, but it can be an expensive proposition. Converting existing landscapes is especially costly to implement, but the savings are likely to be permanent and reliable and many additional benefits ensue including reduced pesticide use, reduced mowing, etc. Xeriscape should be considered for any outdoor conservation program.

8.1.3.2 Centralized Irrigation Control

A centralized irrigation control system typically consists of a computer that is linked to a number of sprinkler clocks in the field either by radio or phone lines. Using this system it is possible to program and control the client sprinkler clocks from the central computer and to monitor the operation of each individual clock system. These systems can conserve water in a number of ways including: 1) improved scheduling; 2) ability to shut off sprinkler systems promptly when malfunctions occur; 3) ability to shut off sprinkler systems in event of a peaking emergency; 4) micro management of each individual sprinkler system to match prevailing climate conditions.

A number of centralized control systems are currently in use in Boulder including large systems at CU and at the City Parks and Recreation Department. The Parks and Recreation system (commonly known as the "master valve system") currently controls approximately 25 parks in the City system. However, Parks and Recreation management concede that the system is presently under-utilized and the department doesn't have a staff member who can adequately operate the system to take advantage of its many capabilities.

Upgrading the operational capability of the Parks and Recreation centralized control system offers an excellent opportunity for the City to save water and improve the management of irrigation in public parks. Over the next 8 to 10 years the Parks and Recreation Department

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12 DeOreo, W.B. and Peter Mayer. 1999. *Analysis of Southern Nevada Xeriscape Project.* Aquacraft, Inc. Boulder, Colorado.

expects to increase the overall irrigated acreage in the parks system by 20 percent through a series of new parks. Almost all Boulder City parks irrigate with treated water – the same water we drink and bathe in. The centralized control system, when operated properly, provides a simple way for the City to quickly shut down all Park sprinkler systems when it rains, and could dramatically reduce peak day demand through coordination and planning during summer peak demand periods. The careful management of irrigation on Park property is a way for Boulder to lead by example in the area of water conservation. One possibility for improving the operation of the Parks and Recreation system would be to contract the operation of the system with a private consultant.

Conservation potential: Parks and Recreation staff agree that improving their centralized irrigation system would be one of the best ways to conserve water in the City's park system. The master valve system is currently under-utilized. The City should consider a three tiered approach to improving this system as part of its conservation program: 1) Old irrigation systems at city parks should be upgraded and rebuilt; 2) someone should learn how to use the City's centralized control system so that it can be used to it's full potential; 3) a program should be established to incorporate all City parks into the centralized control system.

8.1.3.3 Irrigation Efficiency Improvement Program

Improving the efficiency of public and private irrigation can be accomplished through a variety of means including: Education, water budget/allocation, soil preparation, updated irrigation technology, water efficient plant materials, better irrigation management, etc.

The task of improving efficiency across all irrigated landscapes within Boulder's system would require a concerted effort on behalf of the utility backed with considerable institutional support and financial backing. Ideally an irrigation efficiency staff would work out of the water conservation office. Their mission would be to identify landscapes that appear to be irrigating inefficiently and then work with the owners to improve the situation.

Inefficient landscapes could be identified using a integrated water billings/GIS. With such a tool it should be possible to calculate (roughly) the amount of water being applied to different landscapes across the City. Once identified, the irrigation efficiency staff could work with the property owner employing a variety of techniques ranging from education to replacing portions of the irrigation system to developing improved water use feedback tools.

Conservation Potential: The potential of improved irrigation efficiency depends greatly upon how many properties are currently irrigating inefficiently. There is a lot of anecdotal evidence about poor irrigation practices, but little hard data. Integrating the City's water billing database with the current GIS coverages could go a long way towards identifying the extent of inefficient irrigation in Boulder. If there is room for improvement in this area, then a targeted program to improve irrigation efficiency could be effective.

8.1.4 Outdoor Conservation Measures Not Recommended At This Time

8.1.4.1 Rain Shutoff Devices and Soil Moisture Sensors

Rain shutoff devices such and the "Mini-Click" and soil moisture sensors such as the Watermark™ are inexpensive devices that can be added to existing automatic irrigation systems to halt watering when it is not required. The mini-click is a rain sensor that will shut off the sprinkling system if sufficient precipitation falls prior to a scheduled sprinkling session. Soil moisture sensor systems halt irrigation based on a measurement of the actual moisture present in the soil at the plant root level.

A few studies have been conducted on the mini-click device and the general consensus is that they are more effective in wet and humid climates. The Boulder Office of Water Conservation has sponsored a number of studies testing the effectiveness of soil moisture sensors. Although the results have consistently shown these devices do work and are a cost-effective way to save water in Boulder, soil sensors have not gained acceptance among landscape maintenance personnel or homeowners. It is our belief that the soil moisture sensor product needs several engineering improvements before it will be accepted and used on a widespread basis.

Conservation potential: Soil moisture sensors are a technology that may improve irrigation efficiency in Boulder. However, further pilot testing, demonstration projects, and engineering improvements are needed (and warranted) before they will be accepted as part of any large-scale conservation program. Rain shutoff devices such as the mini-click are currently not suitable for Boulder's dry climate.

8.1.4.2 Raw Water Conversion

Watering landscapes with treated drinking water is the norm in Boulder. If some of this treated water irrigation could be replaced with plentiful raw water supplies, then more treated water would be available to meet demand and the need for a larger treatment facility reduced.

The technology exists for using raw water to irrigate parks and other urban landscapes, but it is currently not feasible option. A systematic raw water conversion program would require significant coordinated effort on behalf of the City and ditch operators. While many irrigation ditches and other raw water conveyances such as streams and creeks exist in Boulder, these conveyances are not operated in a manner conducive to raw water conversion for irrigation. For example, when the Parks and Recreation Department wants to use water at a City park they almost always install duplicate irrigation systems, one for raw water and one for treated water, because raw water is not readily available at all times of the year when irrigation is required.

To make the raw water supply more reliable it might be necessary for the City to develop a raw water utility – analogous to the treated water utility it currently operates. The raw water utility would be in charge of providing raw water to designated customers, managing Boulder's raw water portfolio, and maintaining and expanding the raw water conveyances needed for delivering the water. Obviously this is a major undertaking, and developing specific recommendations for a raw water utility is beyond the scope of this conservation plan, but it may be something the City wishes to consider in the future.

Conservation Potential: If irrigation with treated water can be replaced with raw water, tremendous savings are available and these savings could have a profound impact on peak demand. At this time it is not possible to recommend a systematic raw water conversion program, but this is an important conservation tool which should be considered in years to come.

8.2 Recommend System-Wide Conservation Measures

8.2.1 Allocation Billing System

An allocation water billing system is designed to benefit accounts that practice conservation with lower water bills and send a strong message to accounts, which waste water through high bills. An allocation billing system accomplishes this by adding intelligence about the characteristics of each account into the calculation of each monthly water bill. Boulder's current three-tiered block system attempts to accomplish some of the goals of an allocation billing approach, but is not as robust or detailed.

An allocation billing system would develop a specific water allocation for each account in the City's system based on several key factors:

- Number of residents (or employees)
- Landscape square footage
- Evapotranspiration (ET) rate for turf grass

Accounts with more people are given a larger allocation, as are accounts with large lots. For example, a single-family account with a 1/2 acre lot would receive a larger outdoor use allocation than a patio home which has no irrigatible area to speak of. On the other hand, if only one person lives in the home with the 1/2 acre lot and a family of five live in the patio home, the patio home would receive a larger indoor use allocation. Allocations are further adjusted to reflect prevailing weather conditions during a billing period. Actual water charges are assessed by comparing the metered consumption at each account to the defined allocation. Variances are available for larger than normal landscaped areas, more people living in a home, or special medical needs.

Clearly such a billing system would take considerable effort to implement. But once in place this system gives a tremendous boost to all conservation efforts by placing clear financial incentives on end users to conserve water.

The Irvine Ranch Water District (IRWD) in Orange County, California has implemented one of the most successful allocation billing systems in the country. Their system sets allocations on the three factors listed above and then charges for water using a five tiered billing system shown in Table 8.1. The key to the success of such a system is to develop an allocation that provides sufficient water for each account for indoor purposes and for reasonable irrigation of the existing landscape. Account holders who keep within their allocation amount pay the same or less for water than under a traditional system. Those who exceed their allocation a little bit pay a little bit more. Those who use more than twice their allocation pay dearly.

Since implementing their allocation billing system, the IRWD has documented water savings across their entire system. Furthermore, customers have expressed more satisfaction with the allocation system than with the previous water billing system. The IRWD system is easy for consumers to understand and assigns responsibility for water usage and for conservation to the customer. Coupled with an active conservation program, the IRWD has shown that an allocation billing system can be one of the most effective conservation tools.

Table 8.1: Adapted IRWD allocation billing rates for Boulder

Tier/Block	Rate (per Kgal)*	Use (percent of allocation)
Low Volume Discount	$1.09[1]	0 – 40%
Conservation Base Rate	$1.45[2]	41 – 100%
Inefficient	$2.05[3]	101 – 150%
Excessive	$3.20[4]	151 – 200%
Wasteful	$6.40[5]	201% +

*These are hypothetical rates for Boulder based on current block rates, and the IRWD increasing structure. Actual rate setting in such a system would require detailed analysis.
[1]75% of current Block 1 rate (as of 1/1/99)
[2]Current Block 1 rate
[3]Current Block 2 rate
[4]Current Block 3 rate
[5]200% of current Block 3 rate

We had hoped to develop a model allocation billing system for the City of Boulder as part of this futures study, but currently the City does not have computerized links between historic water billing data and lot size information. It is anticipated that these data will be linked and available in the coming months at which time a model allocation billing system which evaluates impacts to the customer and the utility can be developed.

Conservation potential: There appears to be tremendous potential for water savings using an allocation billing system that provides significant incentive to conserve. With the price of water forecasted to be less than 1 percent of disposable income for the foreseeable future, the only way to effectively tie price to usage is through an allocation system that provides customers both a context and a guideline for appropriate water use.

While not considered in the scenarios presented below, an allocation billing system could drive the success of all conservation programs in Boulder by providing strong financial incentive for participation. Installing individual water meters was the single most effect water conservation program the City has ever undertaken. Implementation of an allocation billing system would require considerable time, effort, and financial commitment on behalf of the City. The system must be carefully designed to ensure equity for customers and fiscal stability for the utility. If the City desires to implement such a system, resources should be devoted to developing and modeling a tailored system for Boulder.

8.2.2 Industrial, Commercial, and Institutional Conservation

While not specifically addressed in this study, the industrial, commercial, and institutional (ICI) sector in Boulder is a relatively unexplored area for water conservation. All of the outdoor measures discussed in this report apply equally well to irrigation in the ICI sector, but only a few of the indoor measures (ULF toilets and faucet aerators) are likely to have any impact in this area. The ICI sector also features water using devices such as cooling towers and manufacturing processes, which may have significant potential for improved efficiency.

Planning department projections suggest that the industrial and commercial sectors are going to grow more rapidly than the residential sector in Boulder. A study of water use and conservation potential in this sector makes sense as a way to develop targeted conservation programs for this sector.

9 Integrated Conservation Model

The conservation measures and scenarios described in this report were evaluated for the City of Boulder using Aquacraft's Integrated Conservation Model (ICM). The ICM is a detailed computer model that evaluates the impacts of conservation on each sector in a water system. Originally called the CIRCE Model (Colorado Integrated Resource Conservation and Economics Model), this model was developed for the Colorado Water Conservation Board and the Cherry Creek Valley Water and Sanitation District in 1994 by Aquacraft and Aquasan.

The ICM integrates water conservation, structural alternatives, system operation, costs, revenues, and water development into a holistic and comprehensive plan. As implemented for the Boulder Water Conservation Futures Study, information about the existing use patterns in the four major sectors in Boulder's system (single-family, multi-family, ICI, and municipal/irrigation) from billing data and from detailed end use studies were input along with growth projections from the City Planning Department. The model then generated separate monthly demand projections for each sector over a 25-year modeling period. The model was set up so that at the end of 25 years Boulder has achieved build-out. This first set of projected demands, based on extrapolations of historic usage patterns, represents the baseline demand and is called Scenario 0.

Next a set of six conservation scenarios, described below, were input into the model and the baseline monthly demands were updated for each sector under each modeling scenario. The modified demand pattern over 25 years was developed for each conservation scenario based on the anticipated savings from each implemented conservation measure. These anticipated savings values are based on empirical studies whenever possible and engineering estimates when appropriate measurements were not available.

The modified water demand scenarios were then passed to the financial portion of the model, which determined the annual costs and benefits of each conservation scenario. The costs figured into the model included O&M costs for the conservation program, the individual cost of each conservation measure such as a rebate or fixture replacement, and the costs of irrigation efficiency and leak detection efforts. The ICM calculated the benefits of each scenario based on: The value of the water saved each year, savings in water and wastewater treatment based on the marginal costs of treating water and wastewater in Boulder, and money saved by forestalling or eliminating capital projects - in this case the expansion of the Boulder Reservoir Water Treatment Plant.

The output from the ICM was used to develop benefit/cost factors for each of the conservation scenarios. Details of the model inputs, water saved, peak reductions, and the benefit/cost results are presented in Tables 10-1 through 10-5 and Figures 10-1 and 1-10-2.

10 Conservation Scenarios

This section describes each conservation scenario evaluated as part of this study. Using Aquacraft's Integrated Conservation Model (ICM) described above; seven different conservation scenarios were examined and tested taking into consideration feasibility, reliability, cost effectiveness, and community acceptance. These scenarios are detailed in Tables 10.1 and 10.2. The unit costs of each recommended conservation measure are shown in Table 10.3. Projected water savings and peak demand reduction are shown in Table 10.5. Program cost and benefit analysis for the utility are shown in Table 10.6 while a cost and benefit analysis for the customers are is shown in Table 10.8. Projected peak demands under different conservation scenarios are shown in Figure 10.3.

10.1 Scenario 0 - No Conservation Program

Under this scenario, Boulder abandons its current conservation program and continues to grow towards build-out with the same mix of indoor and outdoor demand in all sectors as the City currently experiences. This scenario also assumes a repeal of the federal plumbing codes which mandate efficiency standards for toilets, faucets, and shower heads so it is assumed that water use patterns in new buildings will be comparable to patterns in similar existing buildings. Water savings for all other scenarios are based upon reductions over and above this non-program.

It should be noted that the federal plumbing codes which mandated exclusive manufacture of conserving fixtures were under attack in the last congressional session with a number of representatives calling for repeal of the standards. Legislation to repeal these standards has been reintroduced in the current congressional session. While both of these efforts have failed to gain significant Congressional support, the future of these standards is uncertain and there is no guarantee that these federal codes will be in place in perpetuity. The results of this study show that the repeal of these codes could have significant repercussions for water planning in the City of Boulder.

10.2 Scenario 1 – No Conservation Program - NEPA Plumbing Codes Only

Under Scenario 1, Boulder abandons its current water conservation program while current plumbing codes remain in effect. Without an active conservation program the only anticipated impact on water use would be a result of the 1993 National Energy Policy Act (NEPA) federal plumbing codes which mandate the manufacture of 1.6 gallon per flush (gpf) toilets, 2.5 gpm shower heads and 2.2 gpm faucet aerators. As fixtures in Boulder age, there will be substantial natural replacement with conserving fixtures due to these codes. In addition, new construction would install these conserving fixtures by default because no other products are available for sale within the U.S.

10.3 Scenario 2 – Current Water Conservation Program (Baseline)

Under Scenario 2, Boulder continues its current conservation program at the current level of funding and support. This program assumes a continuation of federal plumbing codes. The Boulder Office of Water Conservation was created with the charge of reducing peak demand over a 15-year period. In 1998 the Office of Water Conservation had an operating budget of $204,000. For modeling purposes the current program has been considered the baseline approach against which all other scenarios are compared.

In this scenario the Boulder Office of Water Conservation will continue current conservation efforts and will take advantage of anticipated natural replacement of toilets, clothes washers, and other fixtures. Under this regime, over the next 25 years it is projected that 90 percent of existing customers in all sectors will replace their toilets with ULF models. Ninety percent will replace their showerheads with LF models, and 90 percent will replace their faucets with LF aerators. No rebates will be offered for replacement of toilets, showers, and faucets. Rather, education combined with information encouraging natural replacement will drive the changes.

Under Scenario 2 it is assumed that Boulder's successful conserving clothes washer rebate program will continue. These clothes washers use about 25 gallons per load of laundry as opposed to 40 – 45 gallons per load used by a traditional full sized washing machine. These conserving washers also use significantly less electricity. In 1998 more than 300 rebates of $100 were given out to residents who purchased a horizontal axis conserving clothes washers which uses significantly less water and electricity than current models. Assuming this replacement rate continues, at build-out 37 percent of current customers will have installed conserving washing machines. In addition it is assumed that 40 percent of new housing will automatically install and retain these conserving machines.

This program also assumes continuation of existing levels of conservation education and research programs which serve the purpose of maintaining awareness of water conservation and providing ongoing monitoring of the effectiveness of various programs and measures.

10.4 Scenario 3 – Active Indoor Conservation

This scenario is based on a modest expansion of current conservation programs in Boulder's service area and a full continuation of federal plumbing codes. This program makes the same assumptions and includes the same programs as Scenario 2. Furthermore Scenario 3 includes a LF showerhead and LF faucet replacement program in which conservation kits containing showerheads and faucets will be distributed across the City.

It is projected that these efforts will succeed in ensuring 100 percent of faucets and showerheads in Boulder are low flow devices. The budget for the conservation program under this scenario is approximately 25 percent higher than the annual budget for Boulder's current program.

10.5 Scenario 4 – Active Outdoor Conservation

The active outdoor conservation scenario includes all elements of Scenario 2 – Current Program Level and adds programs to encourage installation of low-water-use landscape or Xeriscape, increase irrigation efficiency, and find and repair system leaks.

New and existing accounts will be offered a rebate as an incentive for employing Xeriscaping techniques. The amount of the rebate will be based upon the square footage of landscape that is Xeriscaped, but the average rebate will be $350. It is assumed that the average Xeriscape landscape will use 25% less water annually than a typical turf landscape. Because of the expense involved in creating a high quality Xeriscape, it is projected that only 0.4% of accounts in the City will participate in the Xeriscape retrofit program each year. A local landscape architect estimated that it would cost approximately $3.00 per square foot to install a Xeriscape of the quality demanded by most Boulder residents.

Scenario 4 includes $110,000 per year for system-wide leak detection measures so that unaccounted water in Boulder can be reduced from 9% to 6% by 2020. This money would be allocated to the Maintenance Division budget and would be used to contract with a full time leak detection specialist and to purchase equipment for finding leaks. Actual repair of leaks in the City's water system would be performed and would come out of the regular maintenance budget.

A significant portion of this conservation scenario is $200,000 a year for improving irrigation efficiency across the city in single-family, multi-family, commercial, and institutional sites. Special attention will be given to improving irrigation efficiency in City parks and other municipal properties. This money will be used to provide education, replace and upgrade current irrigation systems, and to increase participation in and improve the operation of the City's system wide computer controlled irrigation system. This computer system enables centralized shutoff of irrigation of a wide number of sprinkler clocks when conditions (such as rain or peaking emergency) dictate. Under this future, by 2020, a 10% savings will be achieved in Boulder's municipal demand through increased efficiency. Funds will also be used for training irrigation technicians in providing support for single-family customers to improve irrigation efficiency. At build-out a 10% reduction in irrigation will be achieved in all other city sectors.

10.6 Scenario 5 – Comprehensive Indoor and Outdoor Conservation Program

This program combines scenarios 3 and 4 to create a Comprehensive conservation program targeting indoor and outdoor water use.

10.7 Scenario 6 – Aggressive Peak Demand Reduction Program

One of the stated goals for Boulder's Office of Water Conservation when it was founded was to reduce peak day demand. This scenario reduces dry year peak day demand to an estimated 45.0 MGD. To accomplish this goal, all of the conservation programs from Scenario 5 are included and considerable additional funds are added to the irrigation efficiency program to reduce summertime peak demand. Outdoor use in the single-family and multi-family residential sectors and the industrial and institutional sectors will be reduced by 20%. Outdoor use in the municipal sector will be reduced by 22% to achieve this peak reduction.

It is difficult to develop cost estimates for programs that would achieve savings of these proportions (20% outdoor reduction). It is suspected that the first 10% reduction in outdoor demand might be easier (and less expensive) to achieve than the second 10%. In this scenario we have allocated $750,000 per year for the purpose of reducing outdoor demand. This money could be used in a variety of ways ranging from increasing Xeriscape coverage, providing rebates for lawn area reduction, installing centralized irrigation control on more sprinkler systems, and expanded education programs.

10.8 Conservation Scenario Tables and Figures

Details about each conservation scenario and their impact on annual and peak day demands are presented in the tables on the following pages. Table 10-1 details the indoor conservation measures and installation rates. Table 10-2 details the outdoor conservation measure and installation rates. The unit costs of each conservation measure are shown in Table 10-3. The projected water savings and peak demands under each scenario are shown in Table 10-4. Total program costs and benefits/costs analyses are shown in Table 10-5. Footnotes to Table 10-5 describe the assumptions which were made for the benefits/cost analysis including the market value of an acre-foot of water, the marginal cost of treating water and wastewater, the cost to expand the treatment capacity, the interest rate for borrowing, and the amortization period. Projected annual demands under each conservation scenario are shown in Figure 10-1 and projected peak demands under different conservation scenarios are shown in Figure 10-2.

It is assumed that all conservation scenarios will be revenue neutral to the utility. This means that under certain scenarios customers may experience a rate increase (or decrease) to ensure the assumption of revenue neutrality. These rate increases are caused by the following factors:

- Reductions (or increases) in the amount of water sold
- The cost of the conservation program
- Utility savings from reduced treatment costs
- Utility revenues from agricultural leasing
- The cost of expanding the Boulder Reservoir Water Treatment Plant

Under a conservation program, any change in rates is likely to impact those customers who participate in the program differently from those who do not participate. Accordingly it is important to consider the impacts of conservation on both participants and non-participants through a rate analysis and an evaluation of the impacts of any rate changes on each set of customers. This analysis is presented in Table 10-6.

The impact of rate changes required to maintain revenue neutrality are evaluated by comparing the anticipated annual water bill for an average single-family customer under each scenario against a "baseline" customer. The "baseline" is an average customer who uses 119,000 gallons per year under the current program and who does not participate in conservation, i.e. does not replace any old toilets or fixtures, does not install a horizontal axis clothes washer, and does not attempt to improve irrigation efficiency.

Table 10-1: Indoor Conservation Scenarios

#	Scenario	ULF Toilets		LF Showerheads		LF Faucets		Conserving Clothes Washers	
		Installation Rates		Installation Rates		Installation Rates		Installation Rates	
		New Customers	Existing Customers	New Customers	Existing Customers	New Customers	Existing Customers	New Customers	Existing Customers
0	No Conservation	0%	0%	0%	0%	0%	0%	0%	0%
1	Codes	100%	3%/year	100%	3%/year	100%	3%/year	10%	0.5%/year
2	Current Program	100%	3.5%/yr. to 90%	100%	3.5%/yr. to 90%	100%	3.5%/yr. to 90%	40%	1.5%/yr. to 37.5%
3	Active Indoor	100%	3.5%/yr. to 90%	100%	4%/yr. to 100%	100%	4%/yr. to 100%	75%	3%/yr. to 75%
4	Active Outdoor	100%	3.5%/yr. to 90%	100%	3.5%/yr. to 90%	100%	3.5%/yr. to 90%	10%	0.5%/year
5	Comprehensive	100%	3.5%/yr. to 90%	100%	4%/yr. to 100%	100%	4%/yr. to 100%	75%	3%/yr. to 75%
6	Aggressive Peak Reduction	100%	3.5%/yr. to 90%	100%	4%/yr. to 100%	100%	4%/yr. to 100%	75%	3%/yr. to 75%

Assumptions

Toilets – Current avg. flush volume in Boulder = 3.9 gpf. ULF flush volume = 1.6 gpf.
Showers – Current avg. shower flow rate in Boulder = 3.4 gpm. LF shower flow rate = 2.5 gpm.
Faucets – Current avg. faucet flow rate = 2.5 gpm. LF faucet flow rate = 2.25 gpm.
Clothes washers – Current avg. clothes washer load volume = 48.8 gallons. Conserving clothes washer load volume = 25 gallons.

Table 10-2: Outdoor and System Wide Conservation Scenarios

#	Conservation Scenario	Xeriscape Landscaping Installation Rates		Unaccounted Water Leak Detection		Increased Irrigation Efficiency In Automatic Irrigation		
		New Customers	Existing Customers	Current Rate	Build-out Rate	Residential Sector	ICI Sector	Municipal Sector
0	No Conservation	0%	0%	8.43%	8.43%	0%	0%	0%
1	Codes	0%	0%	8.43%	8.43%	0%	0%	0%
2	Current Program	0%	0%	8.43%	8.43%	0%	0%	0%
3	Active Indoor	0%	0%	8.43%	8.43%	0%	0%	0%
4	Active Outdoor	10%	<0.4%/yr. to 10%	8.43%	6%	5%	10%	10%
5	Compre-hensive	10%	<0.4%/yr. to 10%	8.43%	6%	5%	10%	10%
6	Aggressive Peak Reduction	10%	<0.4%/yr. to 10%	8.43%	6%	20%	20%	22%

Assumptions

Xeriscape –	Xeriscape landscaping reduces outdoor demand by 25% per installed property.
Leak Detection –	Targets leaks/unaccounted water in the distribution system.
Irrigation efficiency-	Broad-based effort including education, hardware, landscape design, etc.

Table 10-3: Unit Costs of Conservation Measures

#	Conservation Scenario	LF Showerhead Program[1]	LF Faucet Program[2]	H-Axis Clothes washer rebate[3]	Xeriscape Landscape Rebate[4]	Leak Detection[5]	Increased Irrigation Efficiency[6]
		$/Showerhead	$/Account	$/Washer	Avg. $/landscape	$ per year	$ per year
0	No Conservation						
1	Codes						
2	Current Program	$ 0	$ 0	$ 100	$ 0	$ 0	$ 0
3	Active Indoor	$ 5.75	$ 2.90	$ 150	$ 0	$ 0	$ 0
4	Active Outdoor	$ 0	$ 0	$ 0	$ 350	$110,000	$200,000
5	Comprehensive	$ 5.75	$ 2.90	$ 150	$ 350	$110,000	$200,000
6	Aggressive Peak Reduction	$ 5.75	$ 2.90	$ 150	$ 350	$110,000	$750,000

[1]Cost per showerhead is $5. The additional $0.75 covers the costs of administering the program.
[2]Cost per household is $2.50. The additional $0.40 covers the costs of administering the program.
[3]Actual rebate is $100. Administration costs are part of current O & M costs.
[4]Includes costs of administering program. Rebate based on landscape area converted to Xeriscape.
[5]Covers costs of hiring a leak detection contractor and supplying a vehicle (1999 dollars).
[6]Includes costs for implementing a landscape efficiency conservation program – labor, hardware, materials, etc.

Table 10-4: Impacts of Conservation Scenarios

#	Conservation Scenario	Estimated Demands at Build-out: System Demands (AF)	Typical Peak Day Demand (MGD)	Extreme Year[1] Peak Day Demand (MGD)
0	No Conservation	27785	64.5	71.6
1	Codes	24667	57.3	63.6
2	Current Program	24159	56.1	62.3
3	Active Indoor	23588	54.8	60.8
4	Active Outdoor	22483	52.2	58.0
5	Compre-hensive	21690	50.4	55.9
6	Aggressive Peak Reduction	20801	48.3	53.6

[1]Drought year at a level similar to 1954

Baseline demands (all scenarios) = 22,212 AF

Water rights yield assuming full availability of water and full allocation = 38,000 AF

Daily treatment plant capacity (assuming completion of Lakewood pipeline project) = 42 MGD

Storage capacity in Boulder = 35 MG

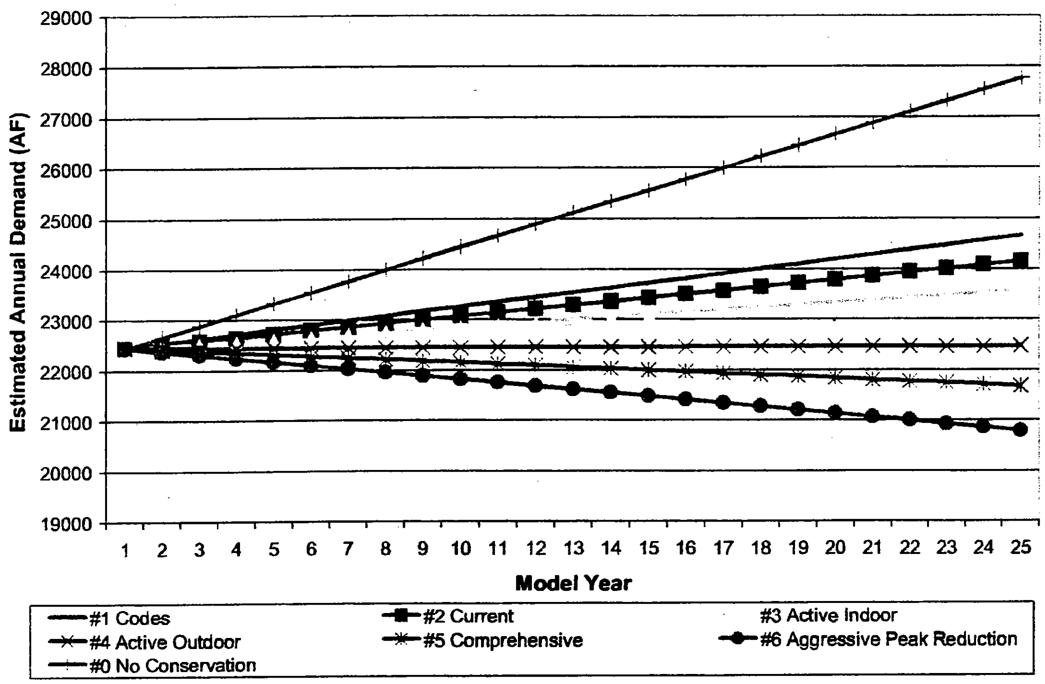

Figure 10-1: Estimated annual demands under different conservation scenarios

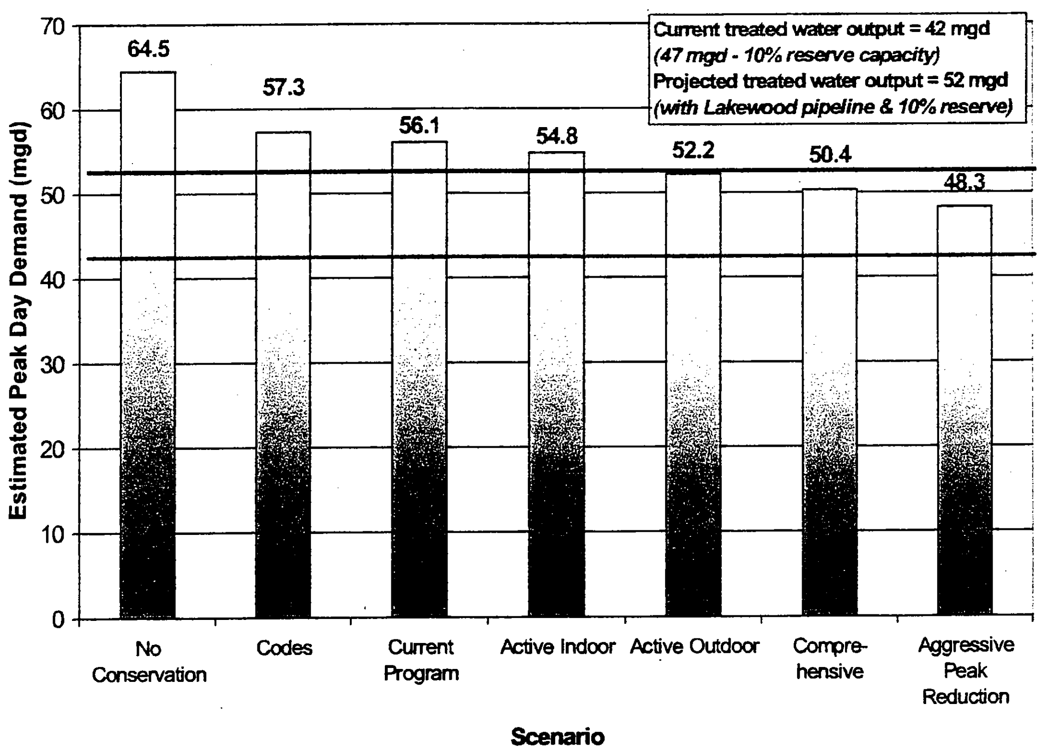

Figure 10-2: Estimated peak day demands under different conservation scenarios

Table 10-5: Utility Water Savings, Costs, and Benefits from Conservation Scenarios

	Conservation Scenario	Demand at build-out	Savings at build-out	Peak Demand at build-out	Net present system costs	Net present value of conservation savings	Benefits / Costs Ratio
		acre-feet	acre-feet	MGD	$	$	
0	No Conservation	27785	-3626	64.5	$20,635,425	$ -	NA
1	Codes	24667	-508	57.3$ 1	,175,989	$1,513,351	1.29
2	Current Program	24159	0	56.1	$ -	$ -	NA
3	Active Indoor	23588	571	54.8	$ 1,320,174$ 1	,321,831	1.00
4	Active Outdoor	22483	1676	52.2	$ 2,181,794$ 3	,350,196	1.54
5	Comprehensive	21690	2469	50.4	$ 5,832,812$ 6	,881,313	1.18
6	Aggressive Peak Reduction	20801	3358	48.3	$ 14,560,443$ 8	,576,418	0.59

Benefits / Costs analysis assumptions:

Savings are calculated from the baseline current program
Costs and benefits are calculated over a 40-year period. Build-out is achieved in year 25. No value was assigned to the saved water.
City can lease conserved water at a rate of $20 per acre-foot and this amount will increase at 2% above inflation.
Marginal cost of treating water at Boulder Reservoir Water Treatment Plant (from City rates analyst) - $0.21 per Kgal.
Marginal cost of reducing hydraulic loading at the 75th St. wastewater treatment plant (from City rates analyst) - $0.05 per Kgal.
City of Boulder discount rate – 4.5%.
Cost to expand capacity ≅ $250,000 & $350,000/MGD up to 57.8 MGD & $1,000,000/MGD beyond.
Interest rate for borrowing – 6%. Amortization period of bonds – 20 years. Discount rate for net present worth analysis – 4%.
Conservation programs are revenue neutral for the City. Any shortfall is made up by a rate increase.

Table 10-6: Customer Level Impacts from Conservation Scenarios

Conservation Scenario	Combined Water and Sewer Rate at Build-out	Change in Water and Sewer Rates	Annual Water & Sewer Cost for Single-Family Participant	Annual Water & Sewer Cost for Single-Family Non-Participant	Change in Costs for Participant	Change in Costs for Non-Participant
	$/Kgal	%	$	$	%	%
0 No Conservation	$ 3.02	-3.7%	($360)	($360)	-3.7%	-3.7%
1 Codes	$ 3.09	-1.5%	($337)	($368)	-9.9%	-1.6%
2 Current Program	$ 3.14	0.0%	($271)	($374)*	-27.6%	0.0%
3 Active Indoor	$ 3.18	1.3%	($268)	($379)	-28.3%	1.3%
4 Active Outdoor	$ 3.26	3.8%	($294)	($388)	-21.4%	3.7%
5 Comprehensive	$ 3.37	7.3%	($207)	($401)	-44.7%	7.2%
6 Aggressive Peak Reduction	$ 3.50	11.3%	($203)	($416)	-45.7%	11.2%

*Baseline annual rate

Customer Level Assumptions:

This is *not* a full water rates analysis. This analysis is for single-family customers only.

Combined water and sewer rate is based on rate paid for 1000 gallons by the average SF customer, apportioned proportionally from all three blocks.

Changes in water rates take into consideration lost utility revenues from reduced sales and the costs and benefits to the customer for each conservation program.

Rates were set based on a condition of revenue neutrality for the utility. Rate changes due to inflation are not considered here.

Participation in the conservation program begins in the first year.

Non-participant costs are based on baseline consumption multiplied by the new water rate.

10.9 Reasons and Incentives for Conservation in Boulder

The citizens of Boulder have responded to numerous surveys and participated in a variety of focus groups about water conservation over the past 15 years. The people of Boulder have consistently expressed support for water conservation efforts not as a means to save money or to forestall treatment plant expansion, but rather because they believe it is the right thing to do for the Boulder environment and watershed we all enjoy. It must also be noted that the single most effective conservation measure ever implemented by the City was the installation of individual water meters on all properties. This program dramatically reduced outdoor demand in the city as has been shown in a number of studies[13].

These two somewhat divergent conservation rationales or behaviors suggest that participation in water conservation could be positively influenced by the adoption of two programs or principles by the City: an environmental and community-based incentive program and an allocation billing system.

1) *Environmental and community-based incentives for conservation.* If citizens wish to conserve so that environmental quality can be improved, the City should investigate creating community environmental goals for water use and for instream flow and agricultural leasing. The City could provide information on such a targeted program on water bills along with information about City conservation programs that help achieve targets.

2) *Allocation billing system.* The allocation billing system described earlier in this section is the progressive "next step" to the metering program the City implemented in 1960 and the block rate billing system in that it provides customers both a context and a guideline for appropriate water use. An allocation billing system could refocus water customers on how much water they use, how much water use is appropriate for their landscape, and provides strong financial incentives for conservation. This system is the latest in conservation oriented water rates and has numerous advantages over the current block rate system. An allocation system is easier to understand because water allocations are based on the physical characteristics of each account. This system has been extremely successful in Irvine California, which pioneered this billing approach. In a survey conducted for the 1990 treated water master plan, only 23 percent of Boulder's residents were even aware of the current block rate billing system. An allocation system provides strong incentives to conserve including financial savings for low water use and financial penalties for wasting water.

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13 Steve Hanke, Johns Hopkins University, 1970.

11 Discussion

Boulder is blessed with ample renewable raw water resources to meet the needs of the population at build-out. Because of this fortunate circumstance, the rationale for water conservation in Boulder does not come from a projected shortfall or the need to develop new water projects. Instead the rationale for the efficient use of water in Boulder comes from a desire to forestall or eliminate the need to expand current infrastructure and to improve and enhance water quality and the environment.

Conservation in Boulder means higher water quality throughout the system because of a reduced reliability on the Boulder Reservoir treatment plant. Conservation is an investment in existing customers. Conservation provides considerable benefits to customers in Boulder including free fixtures, rebates for new fixtures, innovative education programs in the public schools, watershed protection, and increased environmental and water quality. However, any expansion of Boulder's successful water conservation program will likely result in a small increase in water rates which may differentially impact those customers who do not participate in the conservation program. Customers who employ conservation will have a reduced water bill (because of demand reduction) in spite of any rate increase, while customers who opt not to participate will pay more for using the same amount. Any decision on future of water conservation in Boulder should be based on a combination of the benefits and costs which accompany each program envisioned here.

In this study, the consultants have endeavored to present pragmatic, realistic conservation program options for the City of Boulder. Each of the conservation scenarios presented in this study includes reasonable and feasible options for the City to consider. None of these scenarios contains conservation measures which are unproven or which cannot be implemented, nor do any of these programs require significant increases in the conservation department staff. Each scenario has strengths and weaknesses, which are discussed here and are summarized in the conservation scenario decision matrix presented in Table 11-1.

The decision points for the conservation matrix include the following categories: Impact to program participants, impact to program non-participants, impact to the environment, impact to the water system.

11.1 Impact to Program Participants

This decision point evaluates the costs and benefits of each conservation scenario to the customers who opt to participate in the program; i.e. install a ULF toilet or horizontal axis clothes washer, convert to Xeriscape, or have an irrigation efficiency audit. Included in this evaluation are the required water rates under each scenario, voluntary costs incurred by the participants (such as the cost of Xeriscaping), finished water quality, enhanced recreation opportunities, and the cash and non-cash benefits of participation.

11.2 Impact to Program Non-Participants

Conservation programs tend to negatively impact customers who opt not to participate because conservation often means that water rates must be increased to maintain the utility revenue stream. On the other hand, non-participants benefit from improved water quality and positive impacts to the environment brought about by conservation. Included in this evaluation are the required water rates under each scenario, anticipated changes in water costs for non-participants, finished water quality, enhanced recreation opportunities, and the non-cash benefits of non-participation.

11.3 Impact to the Environment

Water conservation can have important benefits to environment provided that saved water can be put to beneficial use. Potential environmental benefits from conservation include increasing management flexibility in addressing the varied goals of instream flow programs, water for agricultural leasing, enhanced environmental benefits for fish, waterfowl, and other animals that use the creeks and streams of Boulder.

11.4 Impact to the Water System

Reducing water demands can provide benefits to the utility which were unanticipated when the conservation program was put in place. Benefits to the system include increased flexibility in operation of the water system and improved residual reliability. These benefits accrue from an increase in system capacity brought about through demand management.

11.5 Evaluation of Conservation Scenarios

11.5.1 Scenario 0 - No Conservation Program

11.5.1.1 Impact to Program Participants and Non-Participants

This scenario provides no specific benefits to the water customers in Boulder. Water rates may decrease slightly because of increased water sales. It is estimated that customers will pay 3.7% less on average than a "baseline" customer who, under current conditions, does not participate in the conservation program.[14]

[14] The impact of rate changes required to maintain revenue neutrality are evaluated by comparing the anticipated annual water bill for an average single-family customer under each scenario against a "baseline" customer. The "baseline" is an average customer who uses 119,000 gallons per year under the current program and who does not participate in conservation, i.e. does not replace any old toilets or fixtures, does not install a horizontal axis clothes washer, and does not attempt to improve irrigation efficiency.

11.5.1.2 Impact to the Environment

This scenario provides no benefit to the environment because it consumes the maximum amount of water from Boulder's portfolio. This means increased difficulty in meeting other community water goals: instream flow, agricultural leasing, and other beneficial environmental programs.

11.5.1.3 Impact to the Water System

This scenario has mixed impacts on the water system. In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded to their rated capacities (57.8 MGD combined) and approximately 13 MGD of capacity must be added to the system. Because of the required expansion to treatment capacity the system may make some gains in reliability and flexibility. However the scenario reduces flexibility to use the City's water portfolio in other beneficial ways.

11.5.2 Scenario 1 - No Conservation Program - NEPA Plumbing Codes Only

11.5.2.1 Impact to Program Participants and Non-Participants

This scenario provides important benefits to the water customers in Boulder. New development will by law be equipped with conserving fixtures and existing customers will save water due to natural replacement of toilets, showerheads, faucets, and clothes washers. Customers who install conserving fixtures will see a 9.7% reduction in their annual water bill when compared with "baseline" non-participants in the current program. Customers who maintain older fixtures or don't improve their irrigation efficiency will see a 1.5% decrease in their annual bill vs. the baseline.

11.5.2.2 Benefits to the Environment

This scenario provides benefits to the environment because the plumbing codes will hold down demand in the City to an estimated 24,667 AF per year at build-out. However this is about 500 AF more demand than is estimated under a continuation of the current conservation program which means that there is less management flexibility in meeting the goals of instream flow programs and for agricultural leasing.

11.5.2.3 Impact to the Water System

All scenarios require some level of treatment plant expansion in order to meet future peak demands. In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded to their rated capacities (57.8 MGD combined) and approximately 5 MGD of capacity must be added to the system.

11.5.3 Scenario 2 - Current Conservation Program

11.5.3.1 Impact to Program Participants and Non-Participants

This scenario provides a number of benefits to the water customers in Boulder. A substantial cash rebate is available for the purchase of a new horizontal axis clothes washer. Conservation materials are distributed through the schools, the media, and through bill stuffers. Boulder customers are regularly encouraged to conserve water in Boulder and are informed about new conservation technology as it comes on the market. Customers are also provided the benefit of the conservation research sponsored by the City Office of Water Conservation. New development will by law be equipped with conserving fixtures and existing customers will save some water due to natural replacement of toilets, showerheads, faucets, and clothes washers.

Participants the water conservation program will experience a 27.6 percent reduction in their annual water bill compared with non-participants. A non-participant is classified as a household which maintains its old 3.5 or 5 gallon per flush toilets, high flow plumbing fixtures and top loading clothes washer. The non-participants in the current program are also the "baseline" against which impacts from other programs are measured.

11.5.3.2 Benefits to the Environment

This scenario saves water and keeps conservation in front of the public. The net impact to the environment from the current program is undoubtedly positive.

11.5.3.3 Impact to the Water System

In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded to their rated capacities (57.8 MGD combined) and approximately 4 MGD of capacity must be added to the system.

11.5.4 Scenario 3 - Active Indoor Program

11.5.4.1 Impact to Program Participants and Non-Participants

This scenario provides mixed benefits to the water customers in Boulder. A increased cash rebate of $150 will be available for the purchase of a new horizontal axis clothes washer to encourage additional participation in that program. Free showerheads and faucet aerators will be distributed across the service area. Conservation materials are distributed through the schools, the media, and through bill stuffers Boulder customers are regularly encouraged to conserve water in Boulder and are informed about new conservation technology as it comes on the market. Customers are also provided the benefit of the conservation research sponsored by the City Office of Water Conservation. New development will by law be equipped with conserving fixtures and existing customers will save some water due to natural replacement of toilets, showerheads, faucets, and clothes washers.

Participants the water conservation program will experience a 28 percent decrease in their annual water bill while non-participants will experience a 1.3 percent increase.

11.5.4.2 Benefits to the Environment

This scenario saves water and keeps conservation in front of the public. At build-out when annual demand is projected to be 23588 AF, the City would have water available to meet other community goals such as increased instream flow or agricultural leasing. The projected annual demand represents a net reduction over the 1998 demand in Boulder. The net impact to the environment from the current program is undoubtedly positive.

11.5.4.3 Impact to the Water System

In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded to their rated capacities (57.8 MGD combined) and approximately 2.5 MGD of capacity must be added to the system.

11.5.5 Scenario 4 - Active Outdoor Program

11.5.5.1 Impact to Program Participants and Non-Participants

Because of the cost of installing an attractive Xeriscape landscape (conservatively estimated at between $6,000 and $12,000 for 3000 square feet of landscape), it is not cost effective for customers to participate in this program simply from the perspective of saving money on water in spite of the anticipated 25 percent reduction in outdoor use. However, it is assumed that customers who undertake Xeriscape conversion projects do so for many reasons beyond simple water savings. Participants in the program will reduce their annual water bill by an estimated 21.4 percent. Because of the required rate increase, non-participants in the program will see a 3.8 percent increase in their annual water bill.

The active outdoor conservation program provides an number of additional benefits to customers in Boulder. A cash rebate ($350) is available for Xeriscaping. A leak detection program will reduce system losses. An irrigation efficiency program will reduce outdoor demand in municipal, ICI, and residential accounts. Conservation materials are distributed through the schools, the media, and through bill stuffers. Boulder customers are regularly encouraged to conserve water in Boulder and are informed about new conservation technology as it comes on the market. Customers are also provided the benefit of the conservation research sponsored by the City Office of Water Conservation. New development will by law be equipped with conserving fixtures and existing customers will save some water due to natural replacement of toilets, showerheads, faucets, and clothes washers.

11.5.5.2 Benefits to the Environment

This scenario saves water and keeps conservation in front of the public.

11.5.5.3 Impact to the Water System

This scenario has positive impacts for the water system. In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded near their rated capacities to 57.4 MGD.

11.5.6 Scenario 5 - Comprehensive Program

11.5.6.1 Impact to Program Participants and Non-Participants

This scenario provides significant benefits to the water customers in Boulder, especially those who participate in the program and reduce their demand. A $150 cash rebate is available for the purchase of a new horizontal axis clothes washer and $350 for Xeriscaping. Free showerheads and faucet aerators will be distributed across the service area. Conservation materials are distributed through the schools, the media, and through bill stuffers. Boulder customers are regularly encouraged to conserve water in Boulder and are informed about new conservation technology as it comes on the market. Customers are also provided the benefit of the conservation research sponsored by the City Office of Water Conservation. New development will by law be equipped with conserving fixtures and existing customers will save some water due to natural replacement of toilets, showerheads, faucets, and clothes washers.

Customers who participate in the indoor and outdoor conservation programs and reduce their demand will experience an estimated 44.6 percent reduction in their annual water bill even though rates will increase. However, participants will not recover their landscaping costs from water savings. Non-participants will annually pay 7.3 percent more for water and sewer under this scenario.

11.5.6.2 Benefits to the Environment

This scenario saves water and keeps conservation in front of the public. At build-out, savings from this program alone would provide nearly 2500 AF for use in meeting other community goals.

11.5.6.3 Impact to the Water System

This scenario has positive impacts for the water system. In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded near their rated capacities to 55.4 MGD.

11.5.7 Scenario 6 - Aggressive Peak Reduction Program

11.5.7.1 Impact to Program Participants and Non-Participants

This scenario provides significant benefits to the water customers in Boulder, especially those who participate in the program and reduce their demand. A substantial cash rebate is available for the purchase of a new horizontal axis clothes washer and for Xeriscaping. Free showerheads and faucet aerators will be distributed across the service area. Conservation materials are distributed through the schools, the media, and through bill stuffers. Boulder customers are regularly encouraged to conserve water in Boulder and are informed about new conservation technology as it comes on the market. Customers are also provided the benefit of the conservation research sponsored by the City Office of Water Conservation. New development will by law be equipped with conserving fixtures and existing customers will save some water due to natural replacement of toilets, showerheads, faucets, and clothes washers.

Customers who participate in the indoor and outdoor conservation programs and reduce their demand will experience an estimated 45.5 percent reduction in their annual water bill even though rates will increase. However, participants will not recover their landscaping costs from water savings. Non-participants will annually pay 11.3 percent more for water and sewer under this scenario.

11.5.7.2 Benefits to the Environment

This scenario saves water and keeps conservation in front of the public. At build-out, savings from this conservation program will be sufficient to provide over 3300 AF for use in meeting other community goals.

11.5.7.3 Impact to the Water System

This scenario has positive impacts for the water system. In order to meet future peak demands with the required 10% factor of safety, the current treatment plants must be upgraded near their rated capacities to 53.1 MGD.

11.6 Conservation Decision Matrix

To help determine the "best" conservation option for the City beyond simply a cost benefit analysis, a decision matrix was developed which ranks the various scenarios on four different criteria:

1. Impact to program participants
2. Impact to program non-participants
3. Environmental benefits
4. Impacts to the water system such as improved reliability and flexibility

Each scenario was given a rating of 1 - 10 for each of the above criteria. The best possible score is 40. This matrix is shown in Table 11-1.

Scenarios 3 through 6 all achieved scores of between 22 and 30 points while scenarios 1 and 2 scored 10 and 14 points respectively. A single "best" does not emerge from this analysis, but rather the relative strengths and weaknesses of each scenario can be seen.

Table 11-1: Conservation Scenario Decision Matrix[1]

Conservation Scenario	Impact for Participants	Impact for Non-Participants	Benefits to the Environment	Impact to the Water System	Overall Score
0 No Conservation	1	6	1	2	10
1 Plumbing Codes	3	5	3	3	14
2 Current Program	6	4	5	5	19
3 Active Indoor	6	4	6	6	22
4 Active Outdoor	6	4	7	7	23
5 Comprehensive	7	3	9	9	28
6 Aggressive Peak Reduction	8	2	10	10	30

[1]Each scenario was given a score from 1 - 10. The highest (best) possible score is 40.

12 Consultant Recommendations

Based upon the analysis of the different conservation scenarios presented in this chapter, the following recommendations are put forward:

1. **Adopt the Comprehensive conservation scenario.** The Comprehensive scenario promotes the indoor and outdoor conservation measures most likely to have a lasting impact on peak and annual demand in the City – landscape irrigation demand management, horizontal axis clothes washers, LF faucets and showerheads, and ULF toilets. This program increases the current water conservation budget substantially, but it also reduces future peak demand to a level that can be handled by current facilities upgraded to their rated capacities. Such upgrades costs between $250,000 and $350,000 per MGD of added capacity compared to an estimated $1,000,000 per MGD required to add new capacity.

   The Comprehensive program encourages water conservation in all customer classes, promotes better irrigation management for City properties, and includes money for system wide leak detection. The rebate and retrofit programs included in the plan provide a direct benefit to the customers from the utility, making this program a highly visible vehicle for providing customer service. Finally, the program provides the City with the opportunity to "lead by example" by taking substantive steps to reduce demand at City parks and municipal properties.

   a) **Move into design phase**. The first step in implementing this program should be a design phase, which will flesh out the specific elements of the Comprehensive conservation program and will solicit community input. If this recommendation is adopted, the Water Conservation staff would develop a specific set of detailed programs with budget requests, for implementation of each element, and include these as parts of future water utility spending plans.

   b) **Develop environmental and community-based conservation targets and rewards.** Citizens have expressed a strong desire to conserve water because "it is the right thing to do" for the environment and Boulder's watershed. The City is in a position to offer citizens an opportunity to put this commitment into action. The City should develop a program of annual conservation goals and rewards for instream flow and other beneficial purposes (community gardens, agricultural leasing, etc.). These goals should include annual and peak water demands and specific program level of effort goals such as the installation of ULF toilets, or distribution of clothes washer and Xeriscape rebates. Citizens could be updated on their conservation performance on their monthly billing statement and the City website. Conservation targets should be adjusted based on climate factors and the fulfillment of community goals must be well publicized.

   c) **Develop a program of monitoring, evaluation, and reporting.** To ensure that the conservation program is accomplishing the goals established, an independent monitoring, evaluation, and reporting program should be established. Results should be presented to the customers regularly so that they can monitor the success of the conservation program. Reports should be submitted to the City Council and other responsible boards annually. These reports should include recommendations for adjusting or changing the conservation program as indicated by documented successes and failures of the programs. There is a natural link between the evaluation program and the allocation billing system discussed below since the information provided by this system would provide the foundation for an active monitoring system.

2. **Evaluate the water treatment plant flow meters as part of the upcoming treated water master plan update and implement system-wide leak detection if necessary.** The City's system currently is reporting about 8.4% unaccounted for water. As a general rule, utilities with an unaccounted for rate of 10% implement a leak detection and repair program. The flow meters at the Betasso and Boulder Reservoir treatment plants are old and may be underreporting. As part of the upcoming Treated Water Master Plan Update, the City should hire an independent expert to examine and evaluate the flow meters at both plants. If deemed necessary these monitoring devices should be replaced so that the true extent of the unaccounted water in Boulder can be determined. If the treatment plant meters have been underreporting, the City should correct its water accounting accordingly, and implement a leak detection and repair program if called for.

3. **Adopt a peak ratio of 2.6 for water treatment plant capacity planning purposes.** Peak ratio (defined as peak day volume divided by average day volume for a given year) is an important consideration for the City in terms of planning for future water treatment plant capacity. Based upon the analyses described in Chapter 6, we believe the City should adopt a "baseline" peak ratio of 2.6 for its future planning purposes. Assuming that additional conservation measures aimed at peak demand reduction are pursued, this peak ratio could be further reduced.

4. **Study the Allocation Billing System Option for Boulder** – An allocation billing system would develop a specific water allocation for each account in the City's system based on several key factors:

   - Number of residents, square feet of business area or other indicator of indoor use
   - Landscape square footage
   - Evapotranspiration (ET) rate for turf grass

   Each customer would be given a base use allocation large enough to handle all reasonable indoor uses depending on the category of customer. Out door allocations would be based on the size of the landscaping and a reference crop. Allocations would be flexible according to the size and type of use at the site. Allocations are further adjusted to reflect prevailing weather conditions during a billing period. Actual water charges are assessed by comparing consumption to the defined allocation. The key to success for the program lies in the fact that those customers who exceed their allocation are faced with such high water charges for their excessive use that they will almost without fail remedy whatever is causing the high use, and bring their consumption down. Customers who stay within their allocation pay customary rates and hence notice little or no difference in the system.

An allocation water billing system could be an effective conservation tool, on its own, or in support of any non-price system. As alluded to above, it would also constitute an extremely fair method for apportioning costs by charging users according to the burden they place upon the system.