CITY OF BOULDER, COLORADO

DROUGHT PLAN

Volume 2

Drought Plan

Technical Information and Analysis

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City of Boulder

Public Works Department

HYDROSPHERE
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WATER ENGINEERING & MANAGEMENT

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Technical Information and Analysis

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INTRODUCTION

This volume of the Drought Plan contains the more detailed background information and analysis behind the development of the drought response actions contained in Volume 1 – Drought Response Plan. The following technical information and analysis will be of interest to those individuals desiring more detailed knowledge of the potential drought situations that might have an effect on their water supply. Although it is not necessary to have a complete understanding of the information contained in this volume of the Drought Plan to successfully respond to a drought affecting Boulder's water supply system, this information will be of use to the city staff and consultants working with drought issues.

The purpose of Volume 2 – Drought Plan Technical Information and Analysis is twofold:

- To re-assess the adequacy of Boulder's water supply system in light of the most recently available information, including information on the 2002 drought; and
- To develop a plan for recognizing and responding appropriately to future droughts that may significantly impact Boulder's water supply system.

This plan is based upon information and analyses from a variety of sources including the Water Conservation Futures Study, Hydrosphere's Boulder Watershed Model, and water supply system operating information from City of Boulder Public Works/Utilities Staff.

BACKGROUND INFORMATION

An understanding of Boulder's drought management challenges and options requires some basic information about Boulder's water supply system, stream flow hydrology and droughts in northeastern Colorado, and the nature of Boulder's water demands and uses. These topics are briefly covered in this section. More detailed information can be found in the appendices to this report and in the referenced documents.

BOULDER'S WATER SUPPLY SYSTEM

Boulder's water supply comes from surface water diverted from several locations in the Boulder Creek basin and from the Colorado-Big Thompson (CBT) and Windy Gap projects, which divert surface water primarily from the headwaters of the Colorado River basin. Boulder's water supply system consists of two separate but interrelated components: its raw water system and its treated water system.

Boulder's raw water system includes all diversion structures, reservoirs, pipelines, pumps and canals that convey and store water prior to its treatment. Boulder's raw water system must operate in a manner consistent with Colorado's prior appropriation doctrine water laws, with policies and rules that govern the operation of the CBT and Windy Gap projects, and with Boulder's internal system operating policies. The primary goal of Boulder's raw water supply system is to economically supply treatable quality water to Boulder's water treatment plants in a manner that meets Boulder's seasonal and daily demand patterns consistent with Boulder's adopted reliability criteria and adopted water conservation plan.

Boulder's raw water system supplies water to Boulder's treated water system, which must deliver high-quality water at appropriate rates and pressures to Boulder's retail and wholesale customers, to public uses, and for firefighting purposes. Boulder has two water treatment plants: the Betasso Water Treatment Plant with a nominal capacity of 45 MGD and the Boulder Reservoir Water Treatment Plant with a nominal capacity of 10 MGD.

Facilities

Boulder diverts its municipal water supply from North Boulder Creek, Middle Boulder Creek and Main Boulder Creek. Boulder also receives water from the Colorado-Big Thompson and Windy Gap projects via the Boulder Feeder Canal and Boulder Reservoir.

Boulder diverts water from North Boulder Creek at three locations: the Silver Lake Pipeline intake, the North Boulder Creek Inlet to Lakewood Reservoir and the Como Creek Inlet to Lakewood Reservoir. These diversions flow into Lakewood Reservoir, a small regulating reservoir that feeds the Lakewood Pipeline. This pipeline then conveys water to the Betasso Water Treatment Plant. Boulder operates seven reservoirs located upstream of the Silver Lake Pipeline intake in the city-owned Silver Lake Watershed. These reservoirs include Silver Lake, Island Lake, Goose Lake, Albion Lake, and Green Lakes Nos. 1, 2 and 3. They have a combined storage capacity of approximately 7,000 acre-feet.

Boulder diverts water from Middle Boulder Creek at Barker Reservoir and the Barker Gravity Pipeline. Barker Reservoir has a storage capacity of about 11,600 acre-feet. The Barker Gravity Pipeline runs from the base of Barker Reservoir to Kossler Reservoir and supplies water to the Boulder Canyon Hydroelectric Plant or to the Betasso Water Treatment Plant. Boulder began using the Barker system as part of its municipal water supply system in the 1950s and acquired the Barker system in its entirety in March of 2001.

Boulder diverts water from main Boulder Creek via the Farmers Ditch to Boulder Reservoir for use at the Boulder Reservoir Water Treatment Plant.

Colorado-Big Thompson and Windy Gap Projects

Boulder obtains a significant part of its water supply from the Colorado-Big Thompson (CBT) and Windy Gap Projects. These projects divert water from the headwaters of the Colorado River basin to the east slope via the Adams Tunnel.

The CBT project was built in the 1940's and 1950's to provide supplemental water to farms, cities and industry along the northern Front Range. The project's water rights are senior enough to allow the project to divert the entire river flow into Granby and Willow Creek Reservoirs, subject to a relatively small bypass requirement. The project includes over 700,000 AF of active storage capacity, including Granby Reservoir (466,000 AF), Horsetooth Reservoir (150,000 AF) and Carter Lake (109,000 AF). Water is delivered to over 100 project participants via an extensive system of canals and pipelines. Units (contract rights for water delivery) in the project are bought, sold and leased among water users located within the project's service area. Annual water deliveries are based upon the number of units owned and an annual 'quota' set by the project's board of directors. The project's normal operating policy has been to deliver a larger supply to project participants in dry years and a smaller supply in wet years, subject to the project's available supply.

The Windy Gap Project was built in the 1980's as an independent municipal water supply project that delivers water through the CBT Project facilities. It diverts water from the Colorado River downstream of its confluence with the Fraser River into Granby Reservoir via a pumping station and pipeline. The Windy Gap Project uses excess capacity in the CBT Project system to deliver its water to municipal and industrial participants on the east slope. Windy Gap diverts under junior water rights that are normally in priority only during May and June of relatively wet years. Consequently, Windy Gap's yield is unreliable, and some project participants are currently contemplating building a new reservoir to firm up the project's yield.

Water Rights

Boulder's water supply system must operate under Colorado's water laws, which reflect the prior appropriation doctrine of "first in time, first in right". While the details of these water laws are complex, their most important practical features can be summarized as follows.

- Water is a public resource. Anyone can establish a property right to use water on the basis of beneficial use without waste.

- The natural flow of the stream is allocated among water rights on the basis of priority. In times of short supply, junior water rights are curtailed in favor of senior water rights.

- The location and type of use of a water right can be changed, subject to a criterion of no injury to any water rights in existence at the time of the change.

- Exchange rights allow for introduction of supplies owned or controlled by an entity at one location in order to allow for diversion by that entity at an upstream location, subject to no injury of existing rights.

- Water rights normally allow only a single use of water without reuse, unless: (1) rights were originally decreed for reuse, (2) a 'foreign' water source is involved (i.e. trans-basin imports or deep groundwater), or (3) rights were changed from their original use on the basis of historical consumptive use.

Operations

While the operation of Boulder's water supply system involves many details and much complexity, it is governed by the following general rules.

- The system is operated to maximize its water supply yield, subject to the ability of its water treatment plants to reliably produce high quality finished water. Hydropower generation from the excess water pressure in the system is a secondary objective.

- As a first priority in meeting its water demands, Boulder maximizes its diversions under its direct flow rights.

- As a second priority, Boulder uses its CBT and Windy Gap supplies as an exchange source for transferring water into its upper Boulder Creek basin reservoirs and pipelines.

- As a third priority, during the irrigation season when the Boulder Feeder Canal is running, Boulder delivers its CBT and Windy Gap supplies directly into the Boulder Reservoir Water Treatment to supplement native basin direct flow yields.

- Boulder takes water from its mountain reservoirs or water stored in Boulder Reservoir into the treatment plants to meet any remaining demand. Boulder attempts to minimize spring and summer releases from its reservoirs in order to preserve this storage water for meeting fall and winter demands and for multi-year drought protection.

- Boulder supplies water to satisfy the commitments made by the city to the Colorado Water Conservation Board for provision of instream flows on North Boulder and main Boulder Creeks.

- Boulder leases any excess CBT and Windy Gap supplies to agricultural users in Boulder Creek on an annual basis.

WATER USE AND WATER DEMANDS

Water use patterns in Boulder have changed over time as the city has grown and water use habits have evolved. This section of the report is primarily based on the analysis of water use patterns completed as part of the City of Boulder Water Conservation Futures Study, which looked at water use records from 1994 to 1998.[1] Although these are not the most recent data available, there is no reason to believe that water use characteristics have changed significantly since that study was completed.

Use Characteristics

Over the course of a normal non-drought year, about two-thirds of the water used in Boulder goes for indoor purposes and about one-third for outdoor irrigation, as shown in Figure 1. In this regard, Boulder is somewhat different than some other Front Range communities, where most of the water use is for outdoor purposes. This difference is attributed to Boulder's more compact urban form, with a predominance of smaller lots and multifamily housing units. Indoor use remains fairly constant over the course of the year with the exception of a slight but perceptible change corresponding with the arrival and departure of students at the University of Colorado at Boulder.

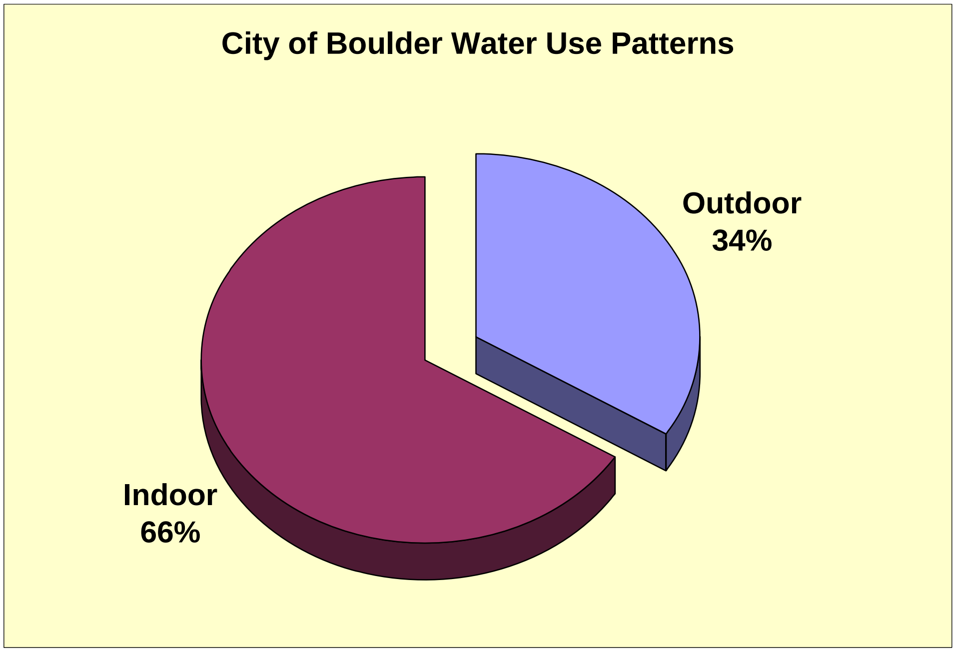


Figure 1: City of Boulder indoor and outdoor water use breakdown

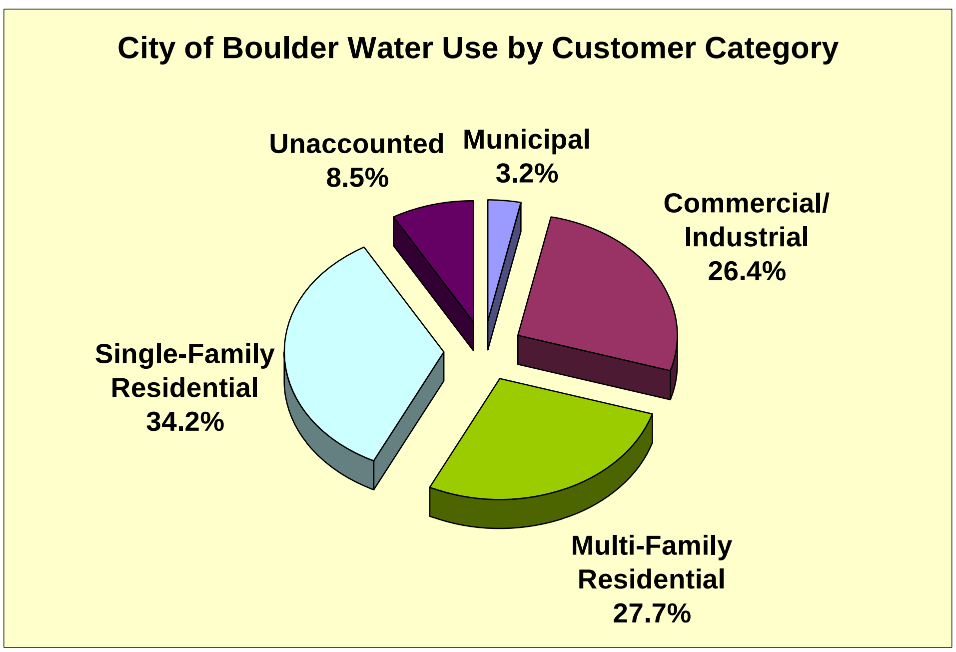


Figure 2: City of Boulder water use by customer category

Figure 2 shows a breakdown of treated water use during a typical non-drought year in the city by customer category. The residential sector (single-family and multi-family combined) consumes the largest amount of water in the city, using nearly 62 percent of the total treated water deliveries. The commercial, industrial, and institutional sector uses about 26 percent of the total. The municipal sector, which includes parks, recreation centers, street medians, and public swimming pools, as well as all city buildings, is the smallest use category, accounting for only about 3 percent of the total treated water demand. Nearly 9 percent of the treated water is unaccounted-for – which is fairly typical for a utility of this size and age.

Among single-family customers (the largest user category), indoor use accounts for 52 percent of their total use and outdoor use accounts for about 48 percent. These results are shown in Figure 3.

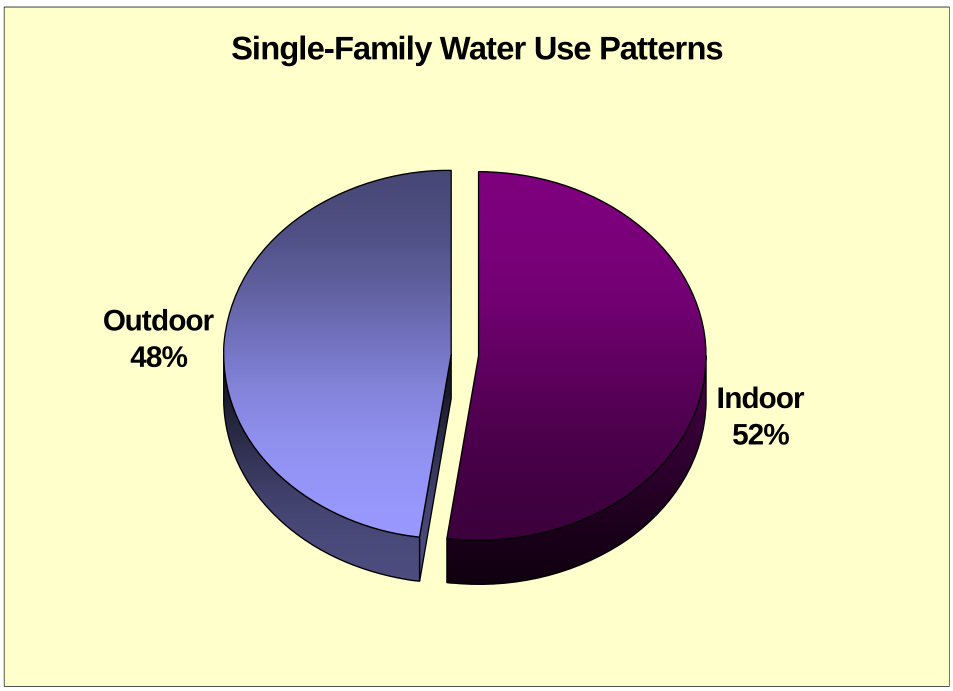


Figure 3: Single-family residential water use patterns

In the commercial, industrial, and institutional (CII) sector, about 63 percent of the water is used indoors and 37 percent outdoors. Some of the largest water customers are in this sector. There are a number of water-intensive industries located in Boulder such as car washes, bio-chemical firms like Roche, and others. In the municipal water use sector, over 85% of water use is for outdoor purposes, such as park and street median irrigation.

Demographics/Projections

Boulder's future water demands are driven by future growth in the city. The Water Conservation Futures Study projected water demands at build-out conditions under various water conservation scenarios using the most recently adopted population and employment projections from the latest Boulder Valley Comprehensive Plan update and from the city planning department. (Those projections have since been updated to reflect the results of a 2000 census challenge, which resulted in an additional 8,000 persons added to Boulder's year 2000 population.)

The recent Jobs and Population Project Study commissioned by the City Council has raised the possibility of dramatically different build-out projections for employment and population. It is important for water planners in the city to include these different scenarios in their projections of future water demand. Once the issues raised through the Jobs and Population Project are resolved, those results can be used to update the analyses completed for the Water Conservation Futures Study.

In the interim, the reliability of Boulder's water supply system has been assessed in this plan using Scenario 1 from the Jobs and Population Project memorandum of 9/18/2002.[2] This scenario represents the highest water demand of the three proposed scenarios. Each of these scenarios would limit the number of jobs below the current zoning capacity. The demographic assumptions and resulting water demand for the maximum water use scenario (Scenario 1) are shown in Table 1 below. The Jobs and Population Project also looked at future conditions should the current trends in Boulder continue unchecked. The Current Trends scenario would increase the city's build-out demand by an additional 11%.

Table 1: Projected build-out water demands

Population	140,500 people
Employment	164,600 jobs
Treated Water Demand	26,000 acre-feet (with adopted water conservation plan) [1]

[1] The comprehensive water conservation plan is projected to reduce the city's projected build-out demand by about 10%, which is reflected in this projection. Without the funding and implementation of this plan the city's projected build-out demand under the Jobs and Population Project Scenario 1of 9/18/2002 would be about 28,800 acre-feet.

BOULDER'S WATER SUPPLY RELIABILITY CRITERIA

In developing drought management strategies, water managers have recognized that it is not feasible to design a system to meet unrestricted demand in the face of any and all droughts. The costs of such a system would be socially unacceptable in terms of water rates and environmental impacts of water development compared to the inconveniences and minor damages that would from occasional demand reductions in response to droughts.

During the development of Boulder's 1988 Raw Water Master Plan[3], Boulder adopted water supply reliability criteria that struck a balance between the costs and environmental impacts of increased reliability and the consequences of temporary water supply restrictions. These criteria were the subject of extensive public meetings and reflected the near-consensus of public opinion.

- For those uses of water deemed essential to the maintenance of basic public health, safety and welfare such as indoor domestic, commercial and industrial uses and fire fighting uses, Boulder shall make every effort to ensure reliability of supply against droughts with recurrence intervals of up to 1,000 years.

- For that increment of water use needed to provide continued viability of outdoor lawns and gardens, Boulder shall make every effort to ensure reliability of supply against droughts with recurrence intervals of up to 100 years. (The phrase 'continued viability of outdoor lawns and gardens' has been defined as provision, at a minimum, of the amount of water necessary to meet the basic survival needs of outdoor landscaping in general, including trees and shrubs.)

- For that increment of water needed to fully satisfy all municipal water needs, Boulder shall make every effort to ensure reliability of supply against droughts with recurrence intervals of up to 20 years.

The criteria suggest that, during droughts with recurrence intervals between 1-in-20 years and 1-in-100 years, watering of lawns may be restricted to the extent that grass goes dormant and other landscape vegetation may become stressed, but that sufficient water would be provided to prevent death of plants, trees, and shrubs. In droughts more severe than a 1-in-100 year recurrence, it can be expected that water availability for landscaping would be reduced to the point of threatening the continued viability of portions of the landscape.

The performance of the city's water supply system during the 2002 drought was consistent with the city's reliability criteria. During 2002, stream flows in Boulder Creek were at the lowest levels in about 300 years. In this 1-in-300 year drought, the system performed better than expected by providing 57% of the normal outdoor use. This drought year was severe enough that, according to the criteria, only a minimum amount of water was expected to be available for landscape irrigation. Instead, the Boulder water system continued to provide enough water for outdoor irrigation such that only minor loss of landscape throughout the city occurred, mostly in turf areas.

DROUGHT INFORMATION AND ANALYSIS

DEFINITIONS

While it is a widely used term, there is no single universally accepted definition of drought. From a meteorological perspective, drought is defined as an extended period of below-average precipitation for a given region. However, most definitions recognize drought as causing ***a water shortage to a particular human activity or environmental function*** (e.g. water supply, agriculture, stream fisheries, forest health). Thus, drought is most commonly thought of as an interplay between climate and water-dependent processes. Often, drought is more defined by its effects than its causes.

There are four perspectives that are evident in how people talk and think about drought:

- Meteorological – From this perspective, drought is usually defined as an extended period of below-normal precipitation. "Extended period" is a relative term. In areas with relatively steady year-round precipitation, such as tropical rainforests and humid mid-latitude climates, significant droughts can occur in as little as a few weeks. In semi-arid areas with seasonal precipitation patterns and where extended periods of no precipitation are a common occurrence (such as northeastern Colorado) droughts tend to be defined in terms of seasons or years.

- Agricultural – Agricultural definitions refer to situations in which soil moisture and irrigation supplies are insufficient to meet the needs of the crops growing in the area. (In semi-arid areas such as northeastern Colorado, this definition does not apply to the normal condition of aridity where farms with no irrigation supply or with junior water rights routinely have insufficient supplies to grow most crops). From an operational perspective, agricultural drought definitions will also account for timing issues related to crop vulnerabilities during different growth stages. The onset and end of agricultural drought tends to lag behind those of meteorological drought because of the buffering effects of soil moisture and irrigation supplies. Thus it can take several months of above-average precipitation to relieve agricultural drought conditions

- Hydrologic – A drought that reduces stream flows, reservoirs, lakes and groundwater to below-normal levels. While hydrologic droughts are caused by extended periods of abnormally low precipitation, they tend to lag behind the onset of low precipitation because of the buffering effects of soil moisture, groundwater, permanent snowfields and glaciers, etc. Hydrological droughts often extend far downstream from the areas experiencing unusually low precipitation. As with agricultural drought, it can take several months of above-average precipitation to relieve hydrologic drought conditions. Typically stream flows and reservoir levels recover first, followed by groundwater conditions.

- Socioeconomic – Droughts are discussed from this perspective when water shortages begin to effect people and their lives in terms of water supply, loss of hydropower production, loss of fisheries, agricultural production losses and food shortages.

While drought is a normal aspect of climate variability that periodically occurs virtually everywhere on earth, it is a particularly complex and insidious form of natural hazard. Because drought is not confined to happening within a single year or season, its onset cannot be easily recognized and its magnitude cannot be determined while it is unfolding. The magnitude of a drought period can only be gauged after it has concluded. The severity of a drought depends on the degree, duration and geographical extent of precipitation deficiency and the sensitivity of affected water uses.

DIRECT HISTORICAL EVIDENCE OF DROUGHTS

Stream gage records provide direct evidence of historical droughts. From the perspective of Boulder's water supply system, the stream gage on Boulder Creek near Orodell is the most suitable gage for this purpose. This gage measures the combined stream flow from North and Middle Boulder Creeks, which provide the majority of Boulder's physical water supply.

Recorded flows at the Orodell gage are not natural or virgin flows. They reflect several upstream diversions including those at Barker Reservoir and Boulder's Silver Lake Watershed. However, records of these diversions are readily available and the virgin flow at Orodell can be easily reconstructed, as shown in Figure 4. This figure illustrates that Boulder Creek streamflow volumes are highly variable and significant droughts occur regularly. The current drought in the Boulder Creek basin began in 2000 and includes the lowest stream flow year (2002) of the last few centuries.

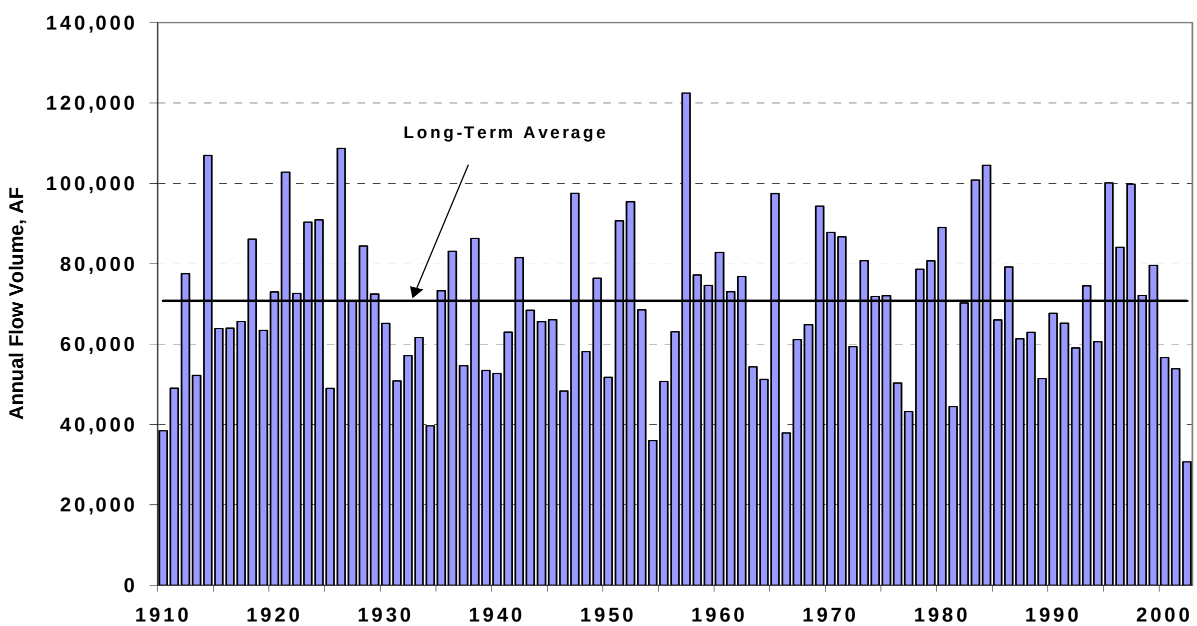


Figure 4: Reconstructed virgin flow, Boulder Creek near Orodell

From the perspective of Boulder's water supply system, the three most important characteristics of a drought are its worst single-year flow deficit, its average flow deficit and its duration. These three aspects of recorded droughts on Boulder Creek at the Orodell gage are illustrated in Figure 5.

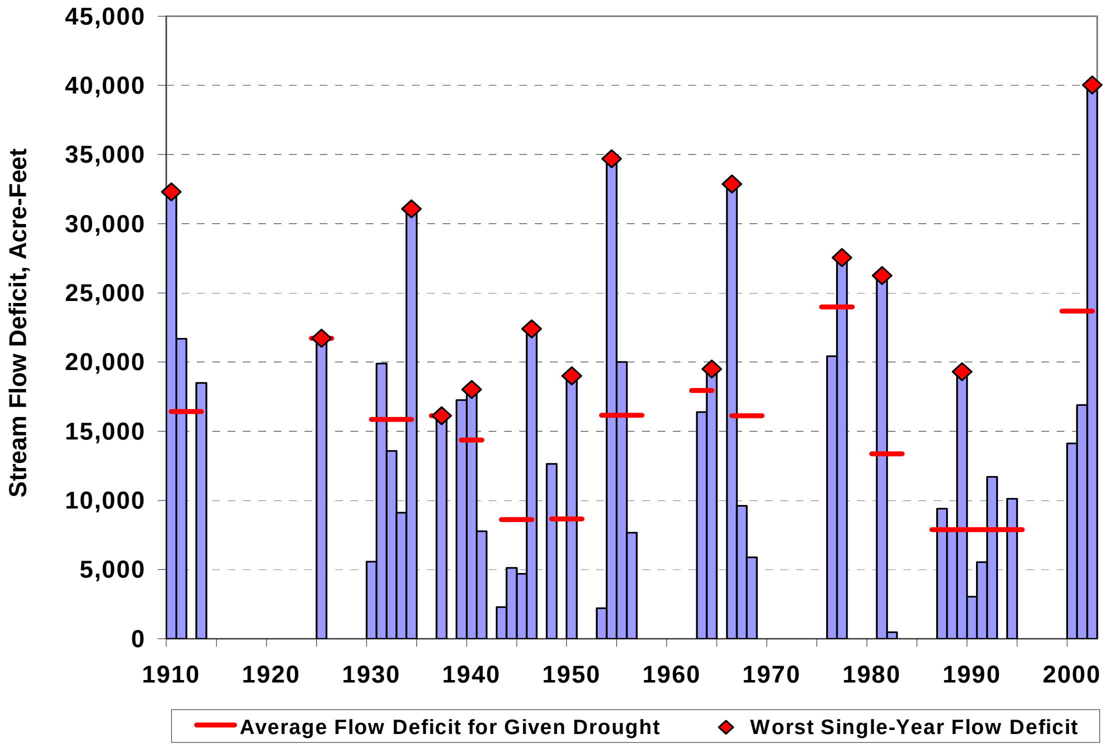


Figure 5: Flow deficits and duration of major droughts for Boulder Creek near Orodell

The worst single year flow deficit of a drought is defined as the volume of flow deficit in lowest flow year of the drought compared to the average annual flow. The average flow deficit drought is defined as the accumulated volume of flow deficit in each year of the drought (again compared to the average annual flow) divided by the number of years in the drought. These two characteristics are synonymous with a drought's intensity. As a drought's intensity increases, the yields of Boulder's water rights are reduced and Boulder's system becomes more dependent on releases from storage to meet water demands.

The duration of a drought is sometimes defined as the number of consecutive years of below average stream flow. As a practical matter, a drought should not be considered over until it is followed by a year with sufficiently high stream flows to assure filling of Boulder's reservoirs. Drought duration is relevant because, as it increases, more releases from storage are needed to reliably meet a given level of water demand. However, droughts with long duration but relatively low intensity do not necessarily stress Boulder's water supply system. This is illustrated by the period of 1987-1994, which was the longest hydrologic drought in the twentieth century, but it had a relatively low intensity.

Table 2 provides numeric data regarding duration, worst single-year deficit and average deficit for the significant hydrologic droughts on Boulder Creek as measured at the Orodell gage. This data shows that the 2002 drought is the worst on record in terms of single year flow deficit and the second worst (so far) in terms of average flow deficit. During 1987-1994, Boulder experienced an eight-year drought with no adverse effects on Boulder's water supply system, because the average deficit of this drought was relatively small.

Table 2: Comparison of significant historical droughts, Boulder Creek near Orodell.

Drought Period	Duration	Worst Single Year Deficit	Average Deficit
1910-1913	4 years	32,300 AF	16,400 AF
1925	1 year	21,700 AF	21,700 AF
1930-1934	5 years	31,100 AF	15,800 AF
1937	1 year	16,100 AF	16,100 AF
1939-1941	3 years	18,000 AF	14,400 AF
1943-1946	4 years	22,400 AF	8,600 AF
1948-1950	3 years	19,000 AF	8,700 AF
1953-1956	4 years	34,700 AF	16,100 AF
1963-1964	2 years	19,500 AF	17,900 AF
1966-1968	3 years	32,900 AF	16,100 AF
1976-1977	2 years	27,500 AF	24,000 AF
1981-1982	2 years	26,200 AF	13,400 AF
1987-1994	8 years	19,300 AF	7,900 AF
2000 - ????	3 years +	41,000 AF	23,700 AF

Boulder's water supply system is dependent on stream flows in both Boulder Creek and the Colorado River because much of Boulder's water supply comes from the Colorado-Big Thompson (CBT) and Windy Gap Projects. These water supply projects divert water from the Colorado River west of Rocky Mountain National Park.

Flows in the Colorado River at Hot Sulphur Springs have been recorded since the early 1900s. Virgin flows at this location are a good index of the divertible supply for the CBT and Windy Gap projects. The reconstructed virgin flows for the Colorado River at Hot Sulphur Springs are shown in Figure 6 below.

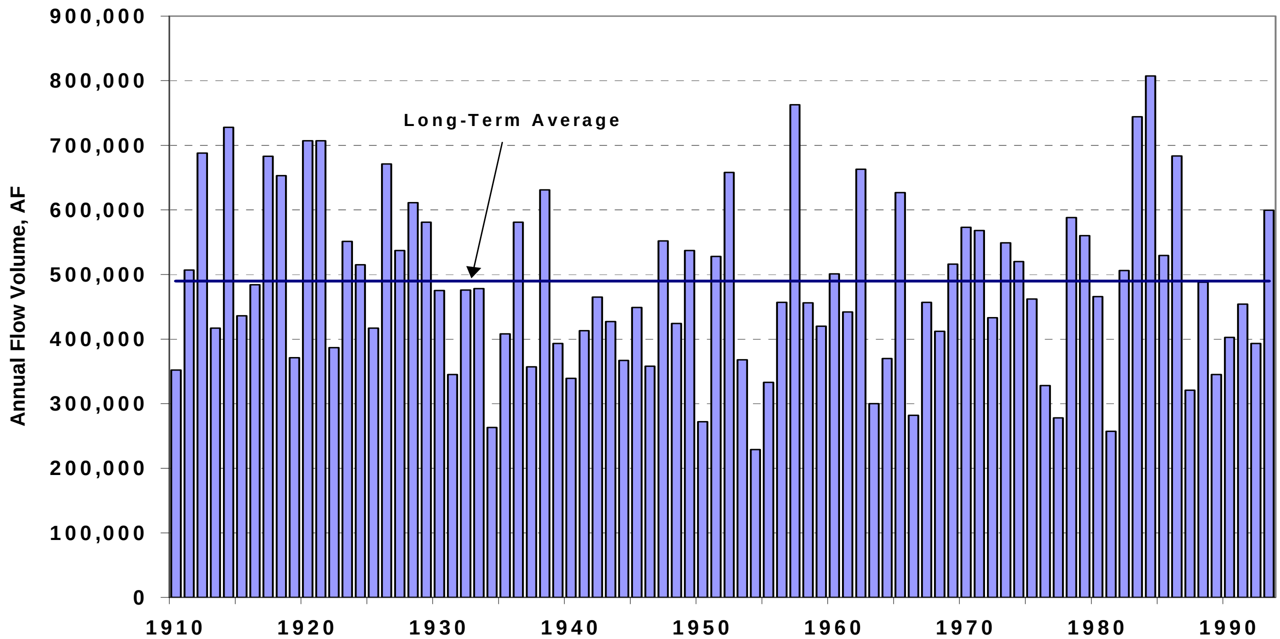


Figure 6: Reconstructed virgin flow, Colorado River at Hot Sulphur Springs

Figure 7 shows that stream flows in the Colorado River exhibit the same high degree of variability as those in Boulder Creek. Furthermore it can be demonstrated that droughts in the Colorado River generally coincide with droughts in Boulder Creek, also as shown in Figure 7. Consequently, the large storage volume (over 720,000 AF) of the CBT project is vitally important in allowing that project to act as a supplemental supply during droughts.

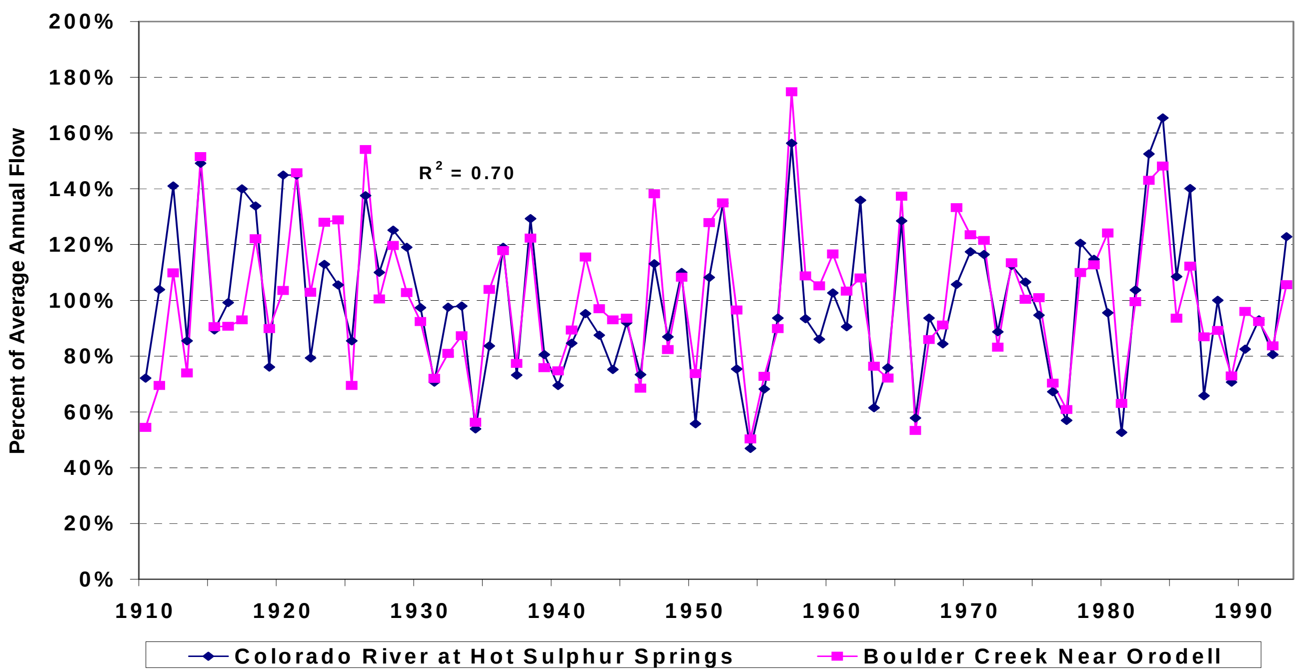


Figure 7: Comparison of virgin flows, Boulder Creek vs. Colorado River

TREE RING EVIDENCE OF HISTORICAL DROUGHTS

While stream flows records are limited to the past century, tree rings provide another source of evidence of historical droughts. Tree rings have proven to be useful in extending our records of stream flows back in time and providing valuable insights on the long-term variability of stream flows. This is possible because the growth rings of properly selected trees adequately reflect the year-to-year variation in flows in nearby streams.

Scientists at NOAA's Paleoclimatology Program and Hydrosphere have recently used tree ring data to reconstruct virgin stream flows in Boulder Creek that extend back as far as the early 1700's.[4] The results of this analysis are shown in Figure 8 below. These data show that Boulder Creek has experienced droughts that were more severe than those of the last 90 years. The current drought, although extreme, appears to be within the range of historical variation.

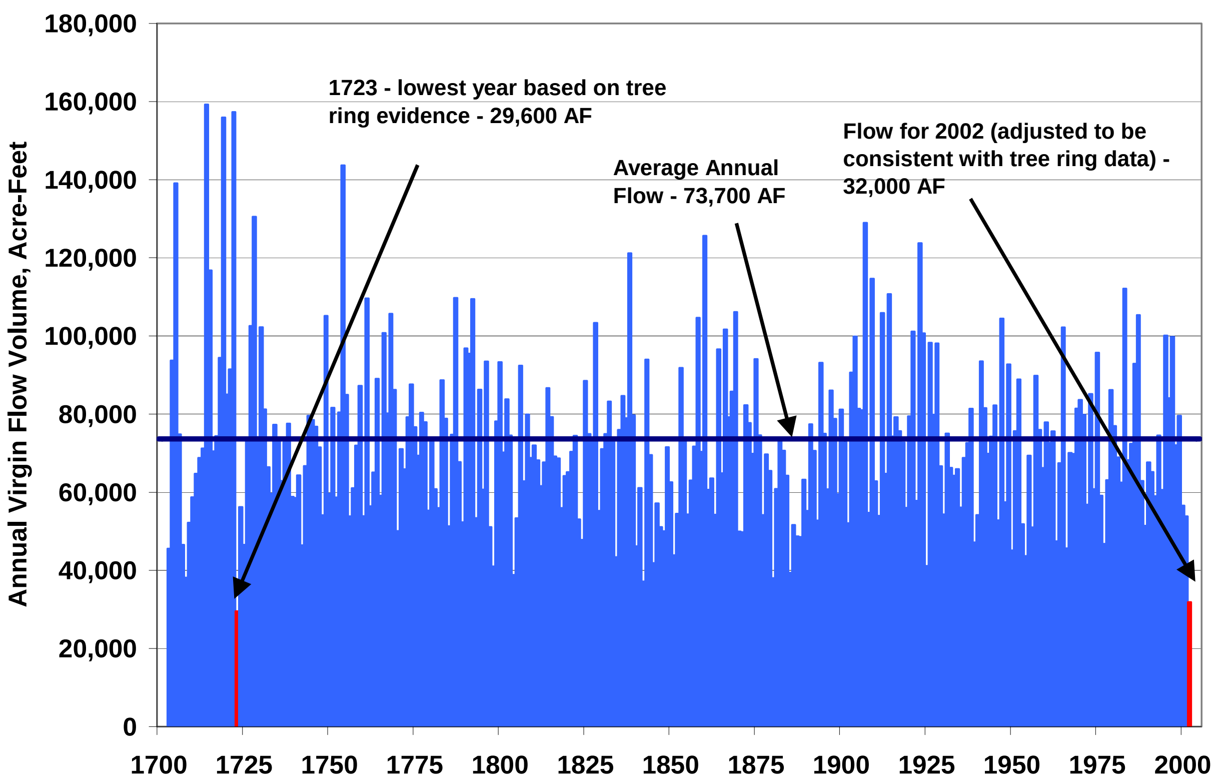


Figure 8: Boulder Creek near Orodell, natural flow based on tree ring evidence

Figure notes:
Flows for 1703-1987 based on tree ring reconstructions
Flows for 1988-2001 reconstructed from gage flows by Hydrosphere.
Flow for 2002 expressed as the mean tree ring-based flow for 1907-1987 minus 2.14 standard deviations, based upon the number of standard deviations between the actual projected 2002 flow and the mean reconstructed gage flow for 1907-1987. The actual projected natural flow for 2002 was less than 32,000 AF.

Tree ring-based hydrology and demand data were incorporated into analyses of Boulder's water supply system conducted as part of the Drought Plan development. By using this information to extend the available hydrologic record, it is possible to formulate drought management strategies that can address the relatively more severe droughts evidenced by the tree ring records. This is described in more detail in a later section of this report.

POTENTIAL EFFECTS OF CLIMATE CHANGE

The likelihood of human-influenced climate change due to increased atmospheric concentrations of CO_2 and other greenhouse gases and its environmental and socioeconomic impacts has been a major focus of scientific research over the past decade. In spite of political controversy surrounding the subject, there is a broad consensus within the scientific community that the earth is warming, primarily due to human activity and that this warming trend will continue.[5]

The potential consequences of climate change on U.S. water resources have been assessed on a national level.[6] This assessment included an evaluation of scenarios from two well respected and widely reviewed General Circulation Models (GCMs), one from the Canadian Center for Climatic Modeling and Analysis (the Canadian model) and the second, the "HadCM2" model from the Hadley Centre for Climatic Prediction and Research of the Meteorological Office of the United Kingdom (the Hadley model). At a national level the assessment concluded that:

- Precipitation has increased an average of 10% across the U.S. over the past century, with much of the increase attributable to heavy precipitation events. This trend towards increased precipitation is very likely to continue.

- Streamflow has increased about three times more than the increase in precipitation, except in the West where snowmelt dominates peak flows.

- In snowpack dominated regions, a shift has been observed in the timing of the peak runoff to earlier in the season. This has been attributed to a greater portion of precipitation falling as rain versus snow. This has led to reductions in the areal extent of snowpack along with a substantial retreat of glaciers. Snowpack is very likely to be reduced even in the context of increased precipitation.

However, at the regional level, particularly at a geographic scale relevant to Boulder's water supply system, there is much uncertainty about the impacts that climate change may have upon water resources. The assessment noted:

- While average precipitation within the U.S. is likely to increase, particularly in the Southwest, there is disagreement between the Canadian Model and the Hadley model as to whether precipitation will increase in the Upper Colorado and Missouri basins. (Boulder's water supply system is located at the headwaters of these two basins.)

- The degree to which increased precipitation would translate into increased stream flow depends on plant responses. Increased CO_2 concentration may result in more biomass production and related water consumption, but increased CO_2 concentration also increases plants' stomatal resistance to water vapor transport, which could decrease plants' water use for a given level of production. Thus, increased precipitation may not necessarily result in proportionately increased stream flow.

- The amount of precipitation that falls as snow versus rain is likely to decrease in the Pacific Northwest, Sierra Nevada and Southern Rocky Mountains, resulting in larger and earlier spring season runoff and lower stream flows in summer. However, there is disagreement between the Canadian Model and the Hadley model as to whether this shift from more snow to more rain will occur in the Central Rocky Mountains. (Northeast Colorado falls within the Central Rocky Mountains as defined in the research.)

- Year-to-year variation in precipitation is expected to increase, particularly with respect to more intense wet periods, but it is less clear if droughts will intensify, particularly with respect to the Central Rocky Mountains.

Most of the research published since the national assessment supports the notions that a greater portion of northeast Colorado's precipitation will fall as rain versus snow, and that the year-to-year variation in precipitation will increase. Whether the trends will be toward an increase or decrease in average precipitation and average stream flow remains unclear. Whether changes in climate will occur gradually or abruptly is also unclear.

While the prospect of climate change significantly affecting water resources is very real, the specific effects upon water resources in northeast Colorado cannot yet be projected with any certainty. In addition, the effects of any changes in stream flow timing and volume upon Boulder's water supply system are complex, due to water right allocation mechanisms, storage, and seasonal demand patterns.

If northeastern Colorado experiences a shift from snow towards rain and increased variation in annual precipitation, the effects upon Boulder's water supply system are likely to be fairly neutral. On the positive side, Boulder's reservoirs may be more likely to fill in the spring under their relatively junior storage rights because more runoff would occur prior to the onset of most downstream irrigation demands. Also, Boulder's major direct flow rights would probably not be significantly impacted by decreased summer stream flows because of their senior priorities. On the negative side, increased variation in year-to-year precipitation could result in longer or more severe drought periods, which could put more stress on reservoirs.

It would not be prudent to base the analyses within this plan upon any specific climate change scenario. The increased level of stream flow variation evidenced by tree ring records provides a sufficient basis for initially formulating a drought plan. For these reasons, this plan does not explicitly address the potential implications of climate change upon Boulder's water supply system. Once the city's drought plan has been initially formulated, we recommend that refinements be made to the city's drought response triggers and the reliability assessment portions of the plan by modeling a range of reasonably bounded climate scenarios designed to illustrate the sensitivity of the city's water supply system toward such changes.

ANALYSIS OF THE 2002 DROUGHT

DEVELOPMENT OF THE 2002 DROUGHT YEAR

From a meteorological perspective, the drought period including 2002 actually began in the spring of 2000. Precipitation records for SNOTEL sites in the headwaters of Boulder Creek and the Colorado River upstream of the CBT project show that precipitation in these areas fell below average beginning in April of 2000 and remained below average in 2001. Precipitation fell drastically below average in 2002 and remained so until snowstorms occurred in October 2002.

Boulder has two snowcourses in the Silver Lake Watershed on North Boulder Creek that are measured at the first of every month throughout the winter. Each of the two snowcourses showed readings as low as or lower than they had ever been. City staff followed the snowcourse readings throughout the winter and realized that they were quite low. Concern was heightened about the upcoming year's municipal water supply, but was not extreme because, in almost all years, snowpack levels increase from April 1 to May 1, often by 20 to 25%. However, the May 1, 2002 readings for the two snowcourses showed that the snowpack had decreased significantly during April. The streamflow levels in Boulder Creek had not risen by the amount expected if the missing snowpack had been melting into the stream. Much of the snow had apparently sublimated or been soaked up by the soil.

On May 1, 2002, no snow could be found at the Boulder Falls snowcourse which had never happened at this site as long as records had been kept. The average snowpack measurement on May 1 at this site over fifty years of record is 13.3 inches of water content. Previously, the lowest May 1 measurements had occurred in 1954, with a reading of 1.6 inches, and in 1981, with a reading of 1.2 inches. Both 1954 and 1981 were considered to be very severe drought years. At the University Camp snowcourse, the May 1, 2002 reading was 4.9 inches compared to an average over 62 years of record of 20.5 inches, so snowpack was at 24% of average at this site. On May 1, 1954, this site had a reading of 15.1 inches. Snowcourse readings and comparisons with previous years are shown in Figure 9 and Figure 10.

Streamflows in Boulder Creek and the CBT collection area fell significantly below average in 2000 and 2001, and dropped to unprecedented low levels in 2002. Streamflow information is shown in Figure 11.

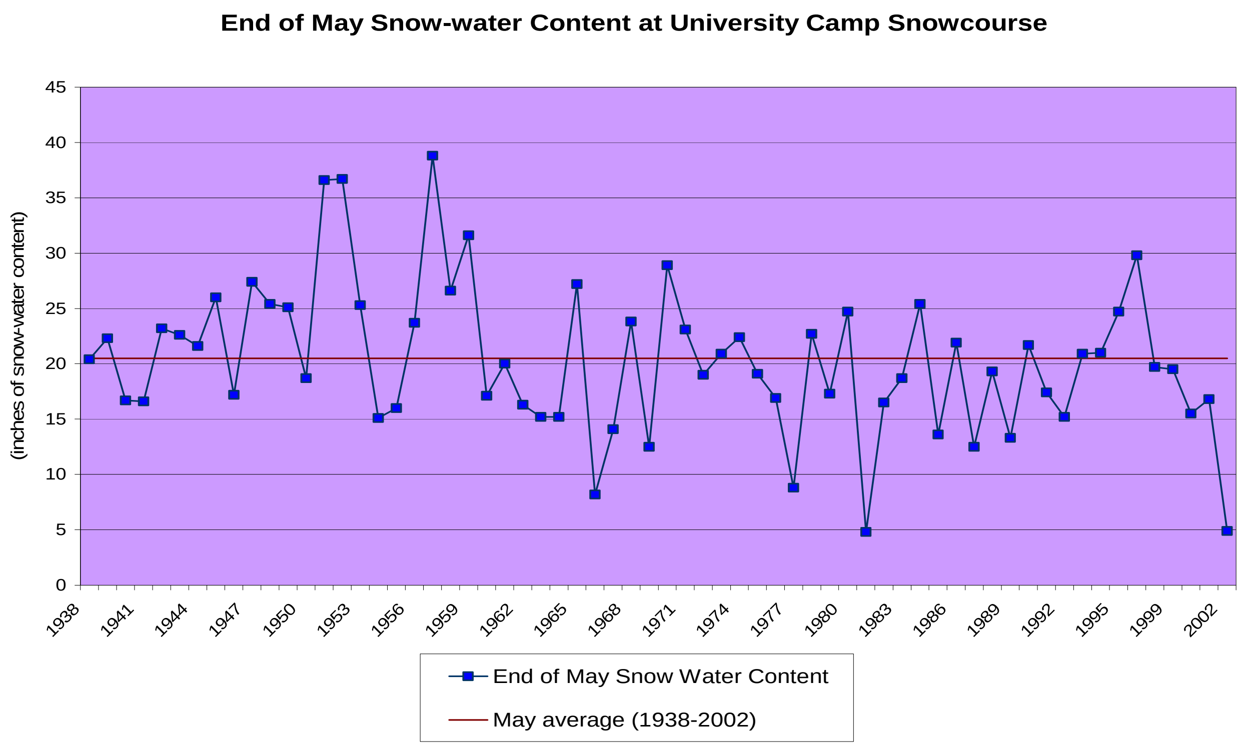


Figure 9: University Camp Snowcourse

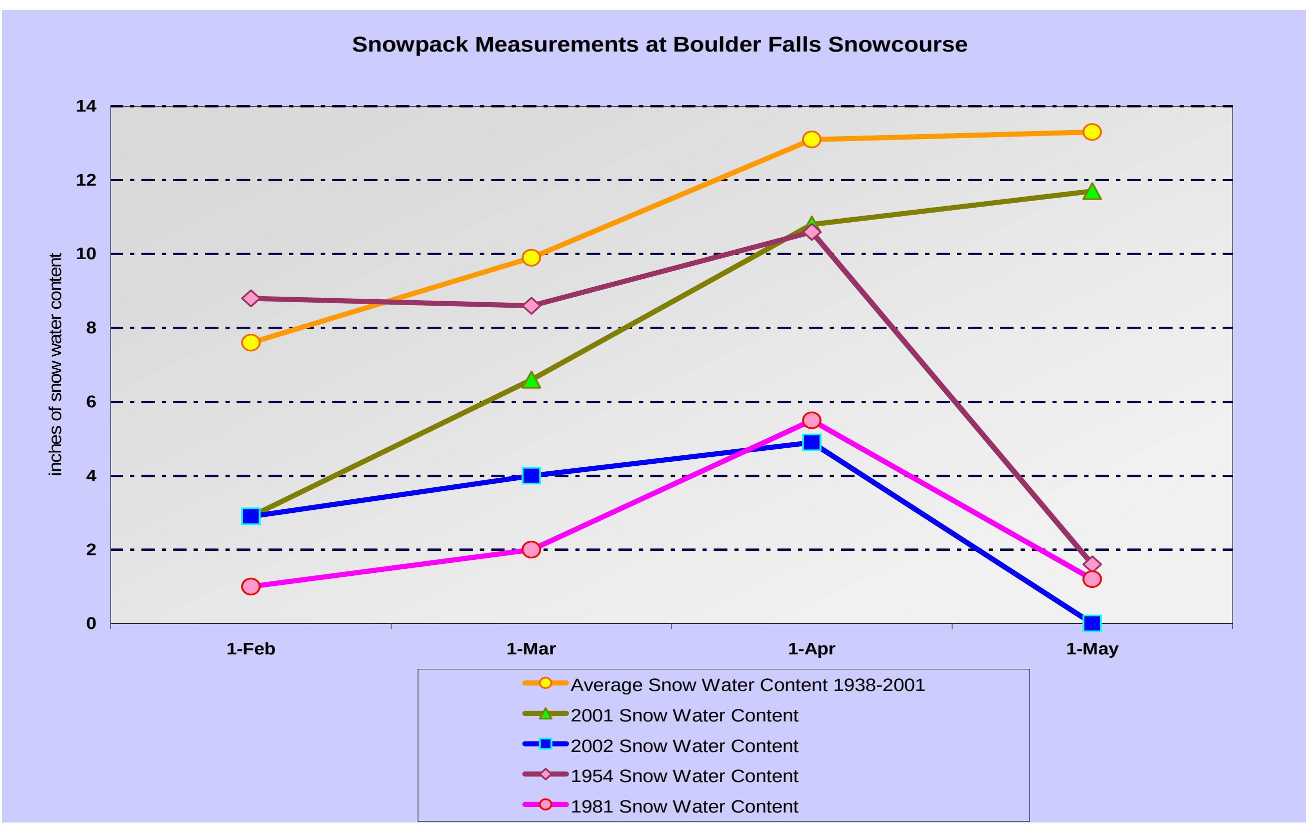


Figure 10: Boulder Falls Snowcourse

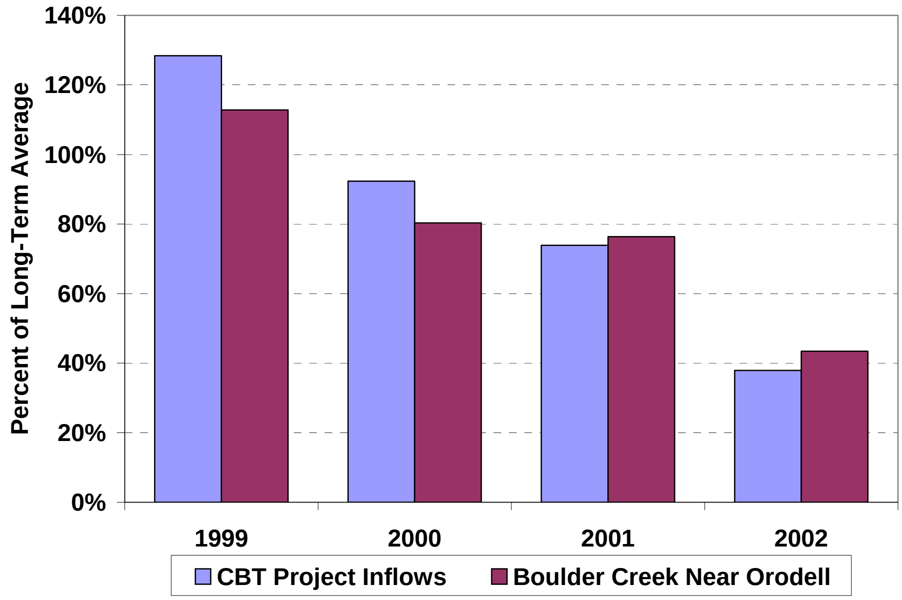


Figure 11: Annual flow volumes for Boulder Creek and inflow to CBT Project

In spite of below average streamflows, Boulder's water supply reservoirs filled in 2000 and 2001. However, the CBT Project's reservoirs did not fill during these two years. When the drought intensified during 2002, Boulder's reservoirs did not fill and CBT Project reservoirs were drawn down to the lowest levels in the project's history, as shown in Figure 12.

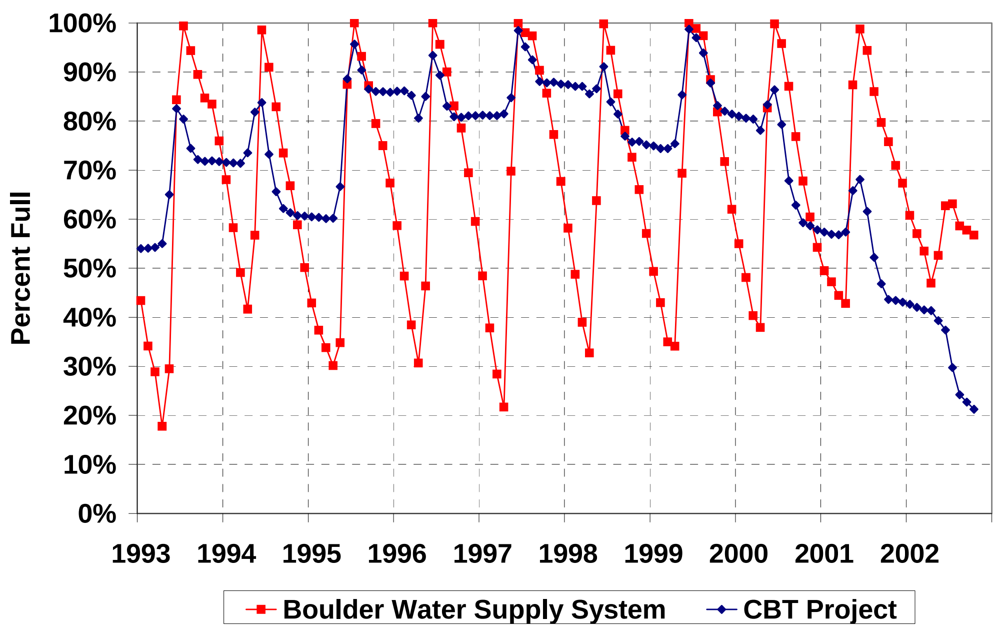


Figure 12: Storage contents: Boulder water supply system and CBT Project

BOULDER'S 2002-2003 WATER USE RESTRICTION PROGRAM

In response to the worsening drought situation, Boulder requested voluntary watering restrictions from its customers in early May of 2002 and imposed mandatory restrictions in early June. The mandatory restrictions applied to all city water users and were primarily targeted at irrigation use, but included restrictions on other outdoor uses. The program also included efforts to reduce indoor water use even though any restriction on indoor uses would be difficult to enforce.

Spray irrigation and hand watering of lawns, gardens, or other landscapes was restricted to twice a week for no more than 15 minutes in any sprinkler zone or area. Irrigation was limited to designated days of the week based on customer address and was further limited to the hours of 6 p.m. through 9 a.m. Drip irrigation systems, bubbler or soaker hoses could be used for up to two hours for each area on the same days and hours designated for sprinkler outdoor watering. The restriction program also prohibited washing of sidewalks, driveways, patios or similar hardscapes, and required that private washing of vehicles be done with a bucket or a hose fitted with an automatic shut-off nozzle. Penalties were established for violations of the restrictions, escalating from $50 for the first violation to $300 for the third violation and eventual shut-off of water service for repeated violations.

Restrictions were modified in August 2002 to allow deep-watering of trees and shrubs on specified days once a month. Boulder's water use restriction program continued through the winter and spring of 2002-2003 with some modifications to accommodate hand watering to reduce the potential for long-term damage to trees and shrubs and to allow lawn watering in accordance with the restrictions except for allowing watering during daylight hours through the winter.

The program was prominently and repeatedly announced through a wide range of media including newspapers, television, water bill inserts and the city's drought web site. Weekly water use target goals were established and published along with the previous week's water use to give feedback to the city's customers on water savings, as shown in Figure 13. Current water use information and tips on saving water were posted on the city's website.

Customer Response

Boulder's water customers responded quickly and substantially to the restriction program. Boulder's total water use dropped by about 30% from June through September 2002 and remained about 18% below normal through March 2003, as shown in Figure 14. Weekly water use goals were met most weeks as shown in Figure 15 and Figure 16. Through the irrigation season of 2002, the restriction program reduced outdoor use by about 50% and indoor use by about 10%. The 10% indoor use reduction level was maintained through the winter of 2002-03. The program was expected to reduce overall demand by about 20% (approximately 4,800 AF) over the 12-month period of May 1, 2002 through April 30, 2003. These savings translated directly into an equal amount of increased storage in Boulder's mountain reservoirs, which were projected to carry over about 6,000 acre-feet of usable water in storage through the end of April 2003, when the next year's runoff was to begin.

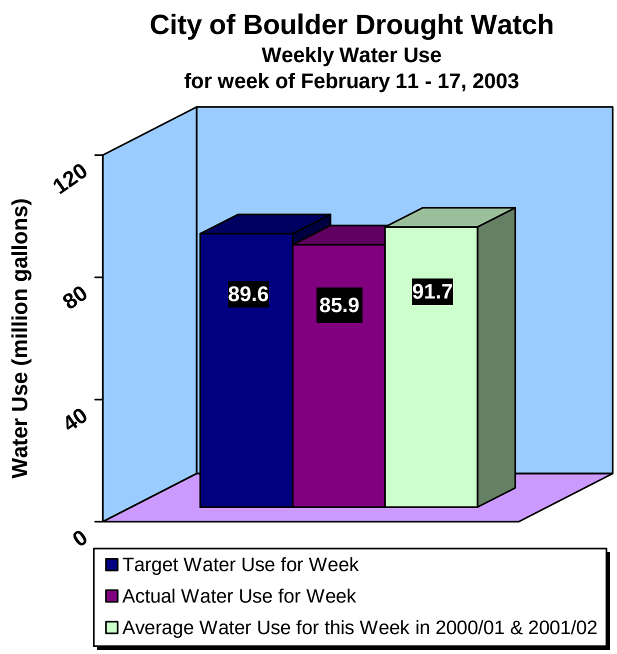


Figure 13: Sample of weekly water use information

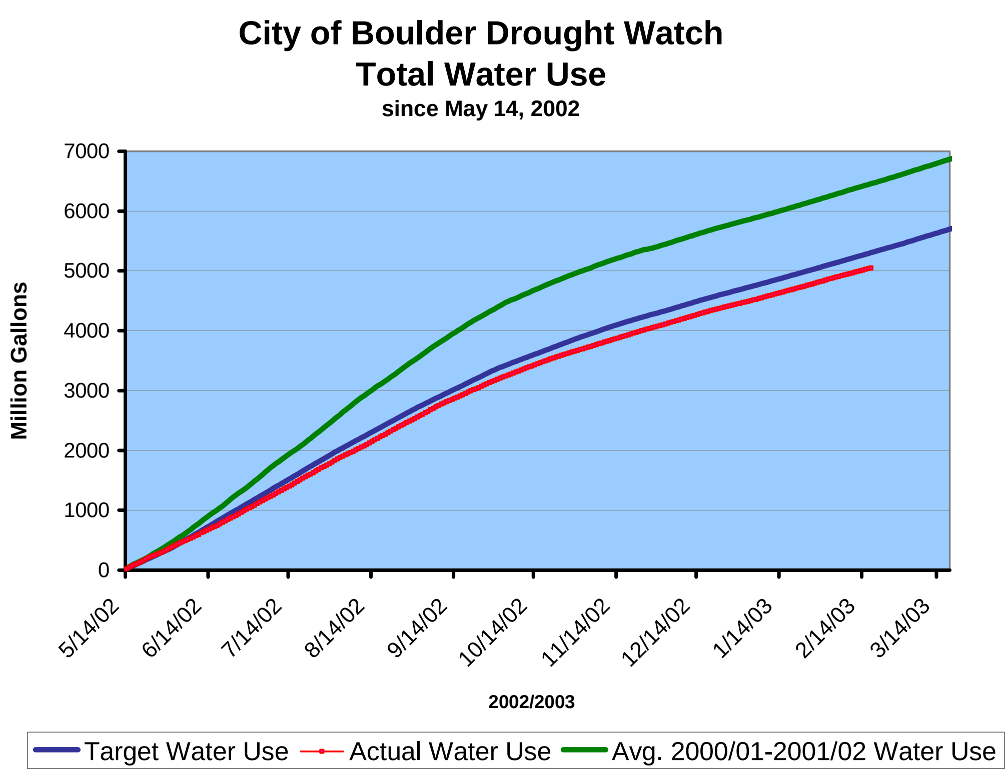


Figure 14: Cumulative 2002/2003 water savings

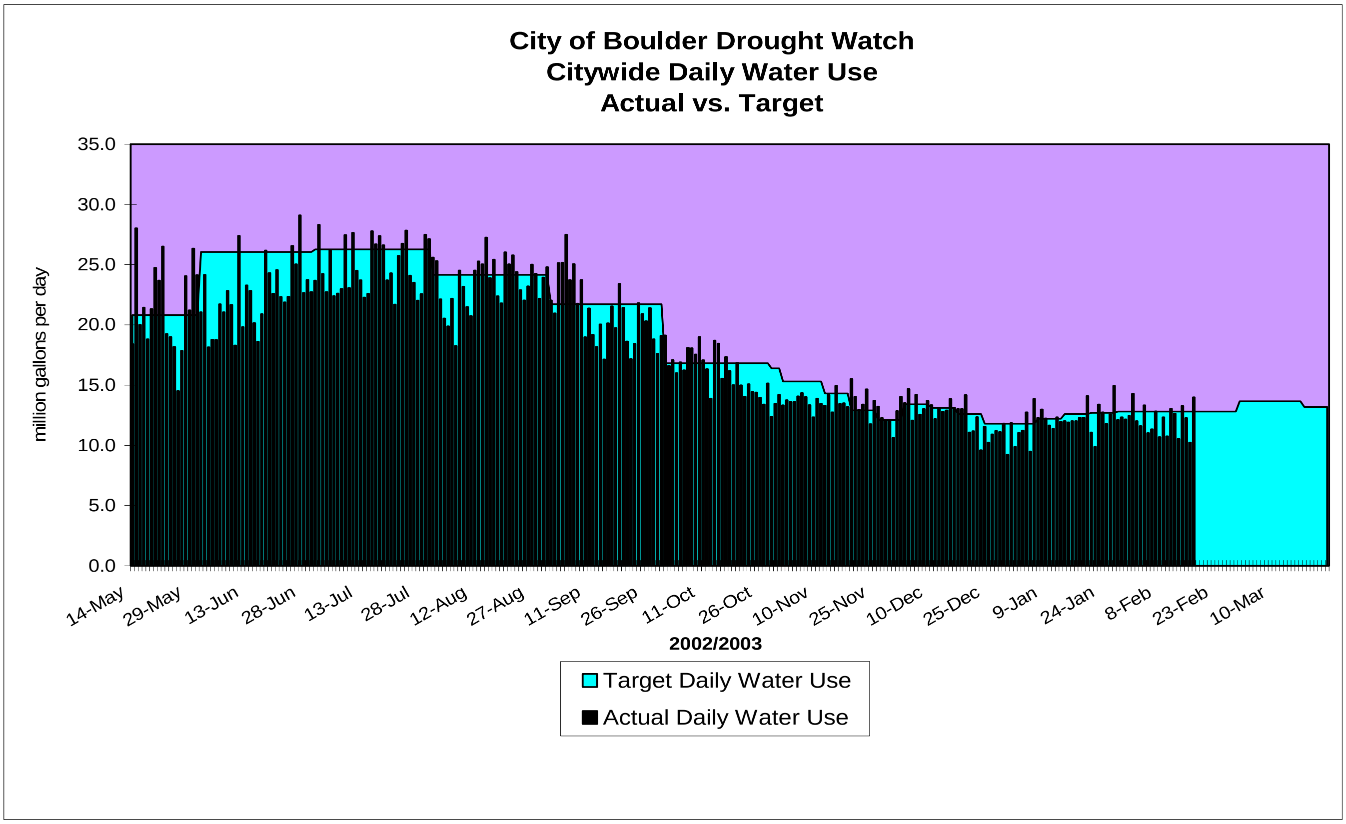


Figure 15: Comparison of actual and target water use

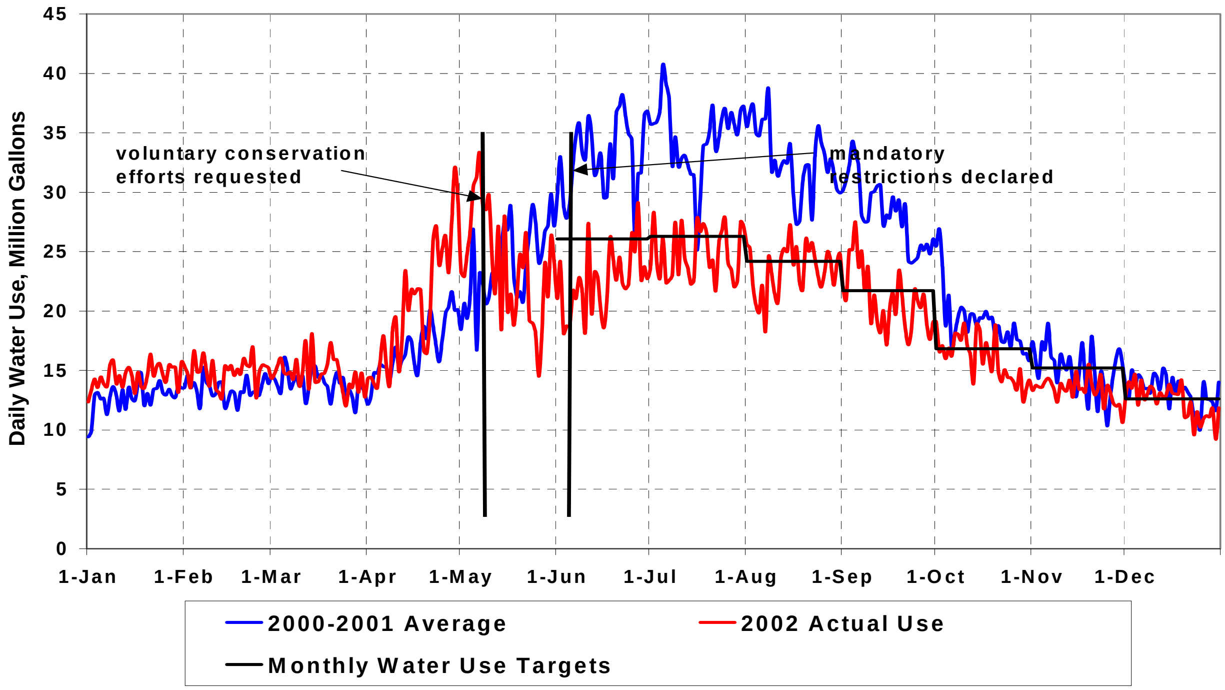


Figure 16: Effects of Boulder's water use restriction program

An analysis of the city's billing data for July and August showed that the compliance rate among Boulder's water customers was quite high. Overall, 75% of Boulder's customers reduced their water usage during the summer of 2002. Compliance levels were slightly higher (78%) for single family users and somewhat lower (58% to 68%) for multifamily, commercial and industrial users. As illustrated in Figure 17, most of the customers that did not reduce their water use were low-volume users to begin with, and their allowable use under the restriction program was probably greater than their use in non-drought years.

A private firm, Pinkerton Security, was hired to assist with compliance efforts. Monitors traversed the city and issued notices of water waste when non-compliance was observed. Official enforcement of the watering restrictions began on June 10, 2002. Of the 523 notices of water waste that were issued in 2002, 53 citizens requested a court hearing to contest the charge. Of the 53, only 40 court hearings occurred since, in some cases, the request for a hearing was made after the 10 day deadline had passed or the water waste charge was dropped and no hearing occurred. Of the 40 hearings that occurred, 6 water waste charges were dropped for various reasons. In a few cases, it became apparent during the hearing

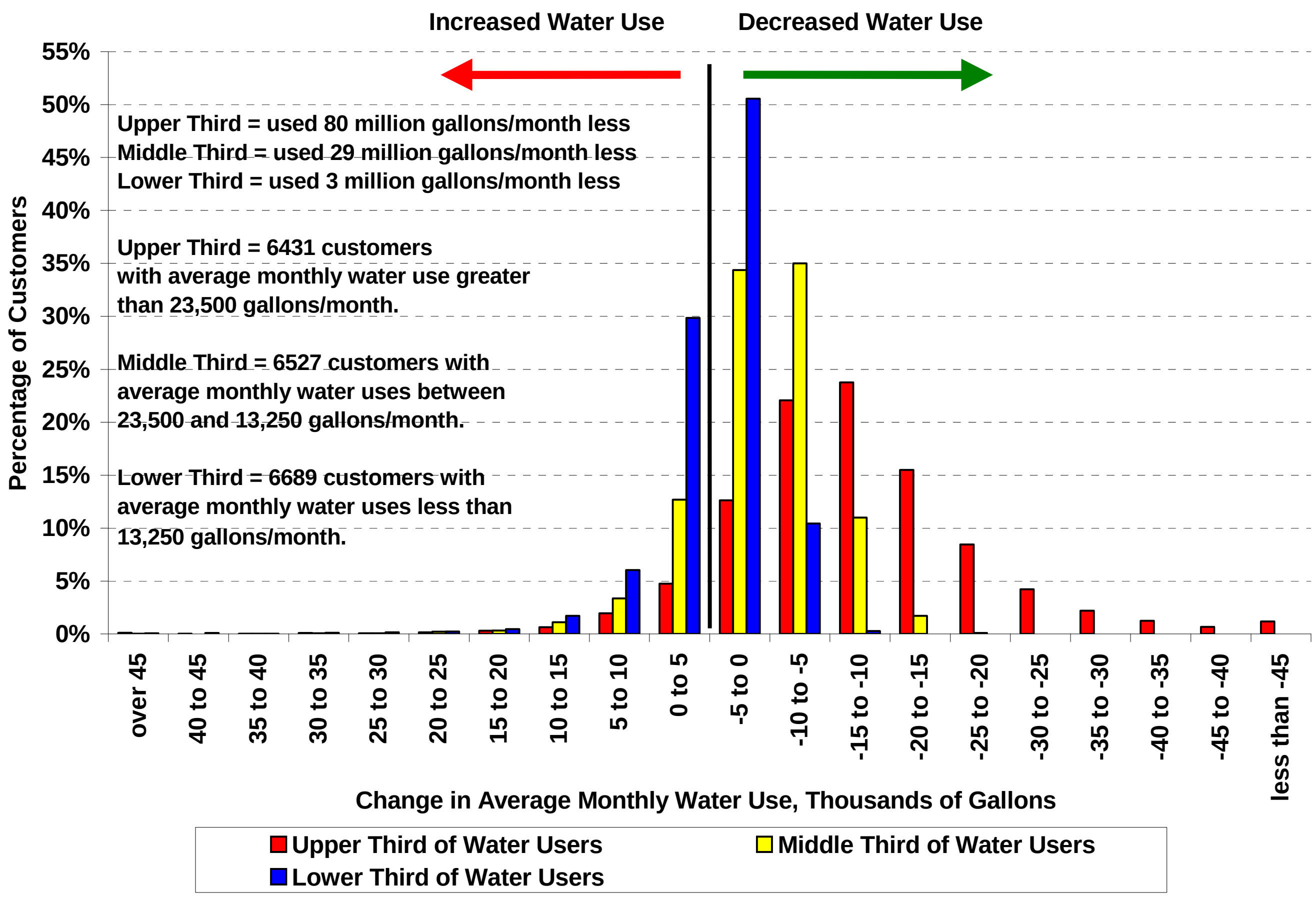


Figure 17: Single family residential response to demand restrictions, July/August use: 2002 vs. Average of 2000 and 2001

that the property did not belong to the citizen who received the water waste charge. The city lost 4 cases. In the remaining 30 cases, the court upheld the water waste charge. The violations can be divided by type of user and by type of violation as shown in Figure 18 and Figure 19. The number of water use violations dropped steadily over the course of the summer as shown in Figure 20. The last water waste violation was observed on October 14, 2002.

As of December 3, 2002, the city had collected a total of $27,615 in water waste charges. Of the $27,615, approximately $8,815 was collected through utility billing (meaning, the citizen did not pay the original notice and therefore, the water waste charge went onto the citizen's water bill along with a $15 administrative charge) and the remainder ($18,800) was collected directly in response to the original notice of water waste charge. The cost of staff time for Pinkerton Security for the summer cost approximately $39,280. Costs for city staff time and other costs incurred over the summer in response to the drought were substantial.

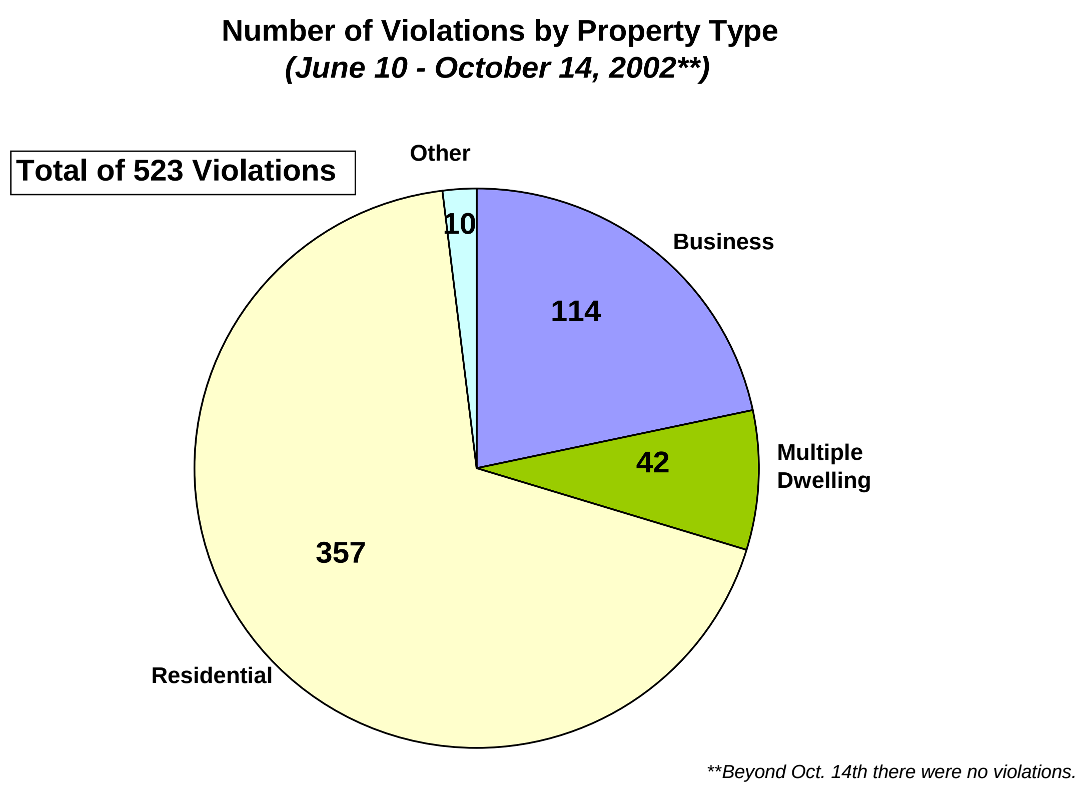


Figure 18: Water use violations by property type

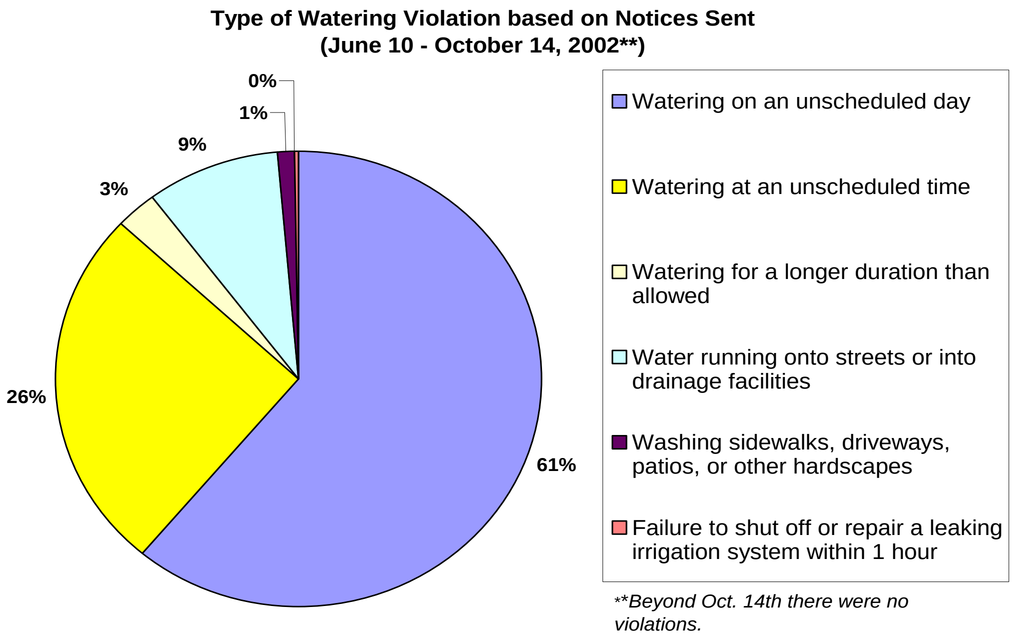


Figure 19: Types of water use violations

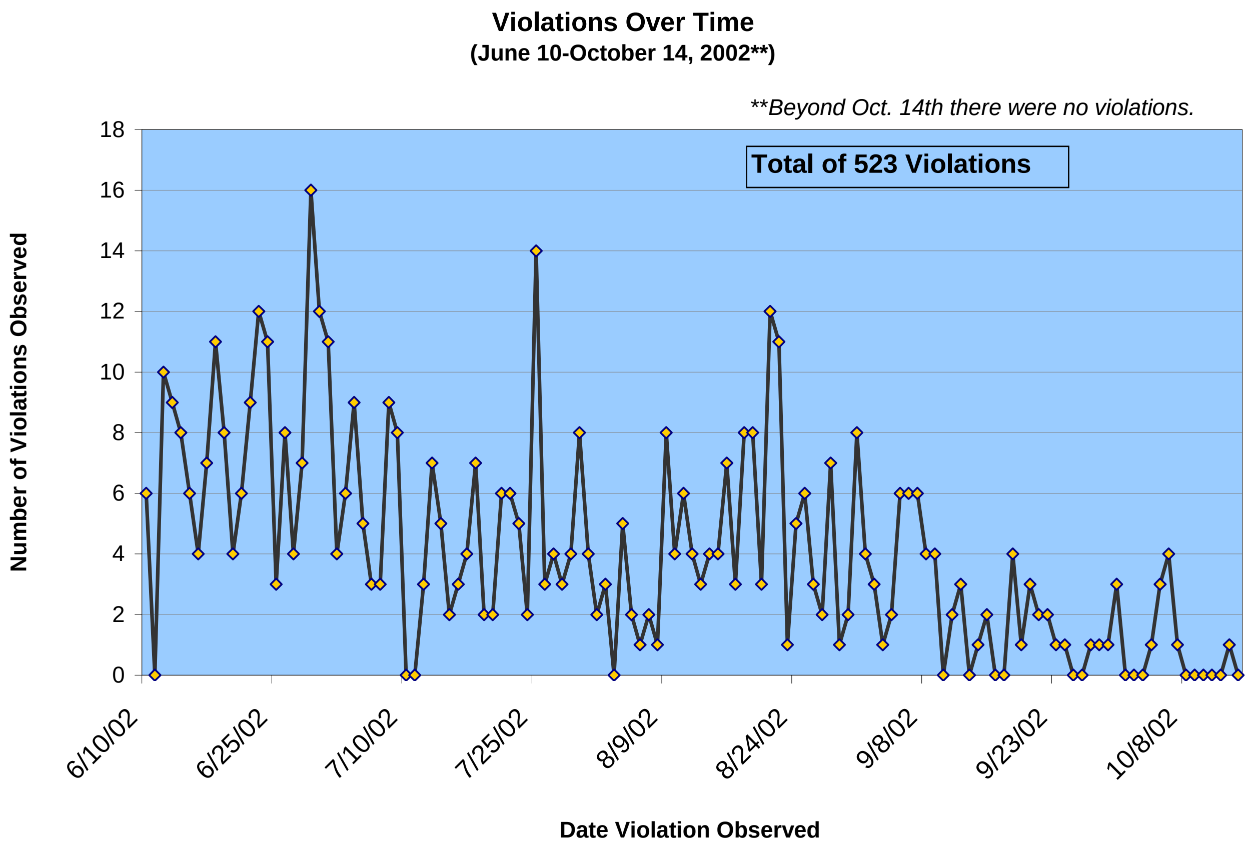


Figure 20: Number of water use violations during 2002

EFFECTS OF DROUGHT ON AGRICULTURAL LEASING

During years in which the city has CBT or other water available that is in excess of Boulder's municipal needs, the city will lease this water, on an annual basis, to agricultural users in Boulder and Weld Counties. The determination of whether there is any water available for leasing is made after the CBT quota is set in April and after the normal exchange season for Boulder's water exchange of CBT to the city's upper reservoirs is over in June. The city typically leases CBT water to agricultural users for about $22 per acre-foot under the annual leases.

In 2002, the CBT quota was set at 70% even though water supplies in northeastern Colorado were so low that a 100% quota would have been expected under more normal circumstances. However, storage levels within the CBT Project were at such a low level that the NCWCD board did not believe that a full quota could be supported without running the project dangerously low of water. Based on the limits set on CBT water supplies and the low levels within the city's reservoirs, the decision was made that the city would not be leasing any water to agricultural users in 2002 that could be used within the city's municipal water system.

The city's decision did not seem to have a significant effect on agricultural producers. Many farmers had already decided to fallow fields or grow less water-intensive crops in the early part of 2002 when it began to be apparent that the snowpack was below average. More followed suit in May when the final snowpack readings came in and the severity of the drought became known. Many agricultural producers determined that they could make more money in 2002 by leasing what water they did have to municipalities and rural domestic water providers. The water lease market from agricultural users to domestic water suppliers heated up to the point that some sales were made of CBT water at a rate of $500 per acre-foot. It can reasonably be concluded that the city does not harm agricultural users by suspending the annual water leasing program during drought periods.

DETERMINING FUTURE HYDROLOGIC PROSPECTS

While no one can successfully predict the weather in Colorado for more than a few days into the future, there are three factors that provide some insight into the future of drought in northeast Colorado: historical stream flow statistics, current regional climate trends and global climate patterns.

Historical Stream Flow Statistics

Natural stream flows reconstructed from gage data and tree rings can be used to examine the tendencies of drought persistence in the region. An analysis was performed that examined 300 years of reconstructed natural flows for Boulder Creek near Orodell to determine what happened during the years immediately following significantly dry years. For this analysis, a significantly dry year was defined as one in which the annual stream flow volume is 65% of average or less. There were 21 such years during the reconstructed period of 1703-2001. An inspection of the years immediately following the 21 significantly dry years revealed the following:

- Stream flows in 'following years" are twice as likely to be below average than above.
- 9 of the 21 "following years" had stream flows of 90% of average or greater.
- 15 of the 21 "following years" had stream flows of 75% of average or greater.
- 20 of the 21 "following years" had stream flows of 60% of average or greater.
- None of the "following years" had stream flows less than 50% of average. (By comparison, stream flows in 2002 were about 40% of average.)

While historical data do not take in account current conditions or the potential of climate change, they do reflect the persistence patterns of numerous historical droughts over the long-term. These data suggest that streamflows in 2003 are likely to be below average, but they probably won't be anywhere near as low as those of 2002.

Current Regional Climate Trends

Precipitation data from SNOTEL sites in the headwaters of Boulder Creek and the CBT project showed a worsening trend from April 2000 through April 2002, an improving trend from May through November 2002, and a worsening trend from December 2002 through mid-February 2003, as shown in Figure 21. While precipitation during the summer of 2002

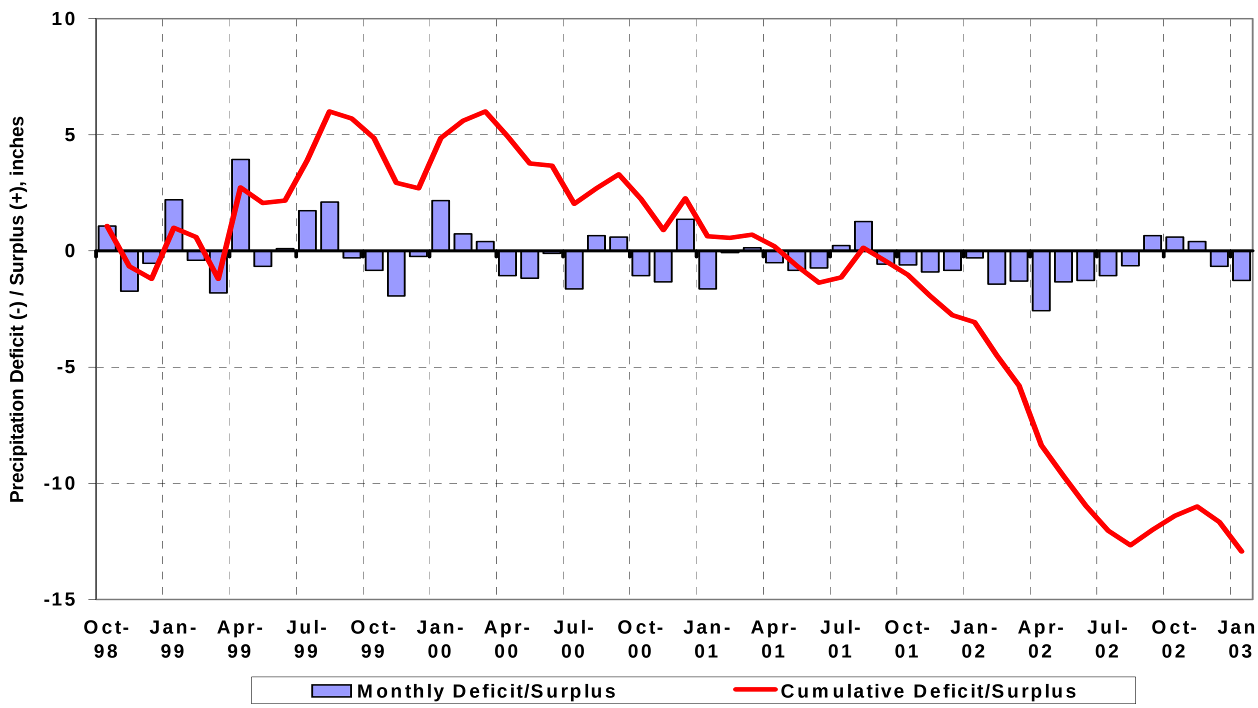


Figure 21: Recent precipitation trends, Boulder Creek and CBT Project

remained below average, monthly deficits were progressively smaller and shifted to surpluses in September, October and November of 2002. The trend suggested that precipitation patterns were gradually improving. While the precipitation trend worsened again in December 2002 and January 2003, recent storms have reduced the precipitation deficit. The outlook for March through May of 2003 is for slightly increased chances of above-normal precipitation. This is consistent with the projected effects of the current El Nino, as discussed below.

Global Climate Patterns

An addition to historical statistics and current regional trends, the current status of global climate patterns should be considered. The El Nino Southern Oscillation (ENSO) is the global climate pattern that is generally considered to have the greatest influence on North American climate. ENSO is a naturally occurring oscillation of atmospheric pressure and surface sea temperature in the tropical Pacific Ocean. The extreme phases of this oscillation are known as El Nino and La Nina. During an El Nino phase, surface sea temperatures in the eastern Pacific off the west coast of South America are unusually warm and the normal easterly trade winds in that area slacken or reverse. During a La Nina phase these conditions are reversed.

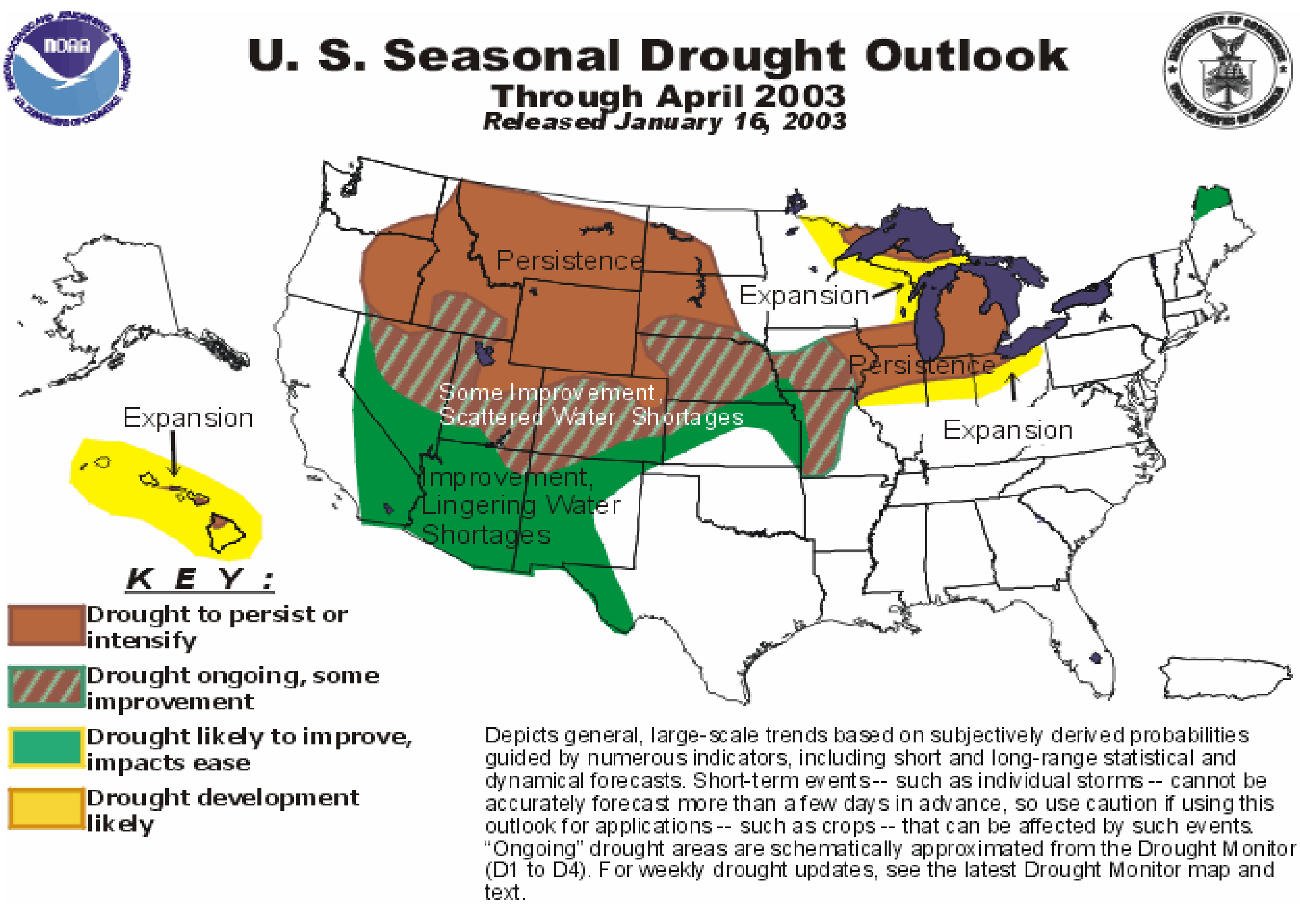


Figure 22: U.S. seasonal drought outlook

Numerous studies have shown that El Nino phases are correlated with increased precipitation in southern California, Arizona, New Mexico and most of Colorado. NOAA scientists have confirmed that a mature El Nino phase has developed and is persisting. Last September, on the basis of the current El Nino, NOAA projected that there was an increased chance for a relatively wet fall, a dry winter and a wet spring. These projections have generally held true for the fall and winter, and NOAA continues to project an increased chance for a relatively wet spring. However, El Nino's influence is generally not as great in northeast Colorado. If anything, the current El Nino phase, coupled with the promising early season snowfall tilt the odds slightly toward a wetter outcome for the upcoming spring snow accumulation season that what is suggested by historical statistics alone. This notion is supported by the latest U.S. Seasonal Drought Outlook issued by NOAA's Climate Prediction Center, as shown in Figure 22 above.

Analysis of 2003 Scenarios

The Boulder Watershed Model was used to evaluate the likelihood that Boulder would need to impose demand restrictions in 2003. The model was used to simulate the operation of Boulder's water supply system over the period of October 2002 through April 2004 under four alternative hydrologic scenarios designed to portray the range of likely stream flow conditions during that period. The scenarios portrayed stream flow volumes from May 1, 2003 through April 2004 equal to 100%, 90%, 75% and 50% of average, respectively. Each scenario was run twice: once with Boulder supplying unrestricted demands and once with demands reduced by 20% (the level of reduction expected to be achieved by the city's current restriction program through April 30, 2003). All four model runs had the following common assumptions:

- Starting conditions for reservoirs in the Boulder Creek basin and the CBT project were set equal to actual conditions on September 30, 2002.
- Stream flows for October 2002 through April 2003 were assumed to be equal to historical stream flows during October 1954 through April 1955 (the driest fall/ winter/spring season on record).
- The Boulder Reservoir Treatment Plant was assumed to have a 10 MGD capacity from April through October (when the plant can draw water directly from the Boulder Feeder Canal) and a 5 MGD capacity from November through March (when the plant must draw water directly from Boulder Reservoir).
- Downstream South Platte water rights were assumed to be continuously calling for water through the October 2002 through April 2004 period, regardless of stream flow assumptions.

For each scenario, Boulder's supply of CBT water was estimated based upon the range of likely quotas for 2003 plus Boulder's supply of CBT water being carried over in the CBT project. The Colorado-Big Thompson project is expected to have about 95,000 acre-feet of 'unreserved' water in storage by the beginning of April 2003. This equates to a 30% quota, which is what the Northern Board has set as a preliminary quota for 2003. Based upon recent discussions with NCWCD staff, the Board is likely to increase the quota to 40% if runoff into the CBT system is 75% of average or greater next spring and to 50% if runoff into the CBT system is 100% of average or greater.

The results of this analysis are shown in Figure 23, expressed in terms of Boulder's mountain reservoir storage contents. In the 100% and 90% flow scenarios, Boulder's system was able to meet unrestrained demands through April 2004 while maintaining at least 8,000 acre-feet of usable mountain storage, which is Boulder's normal end-of-April storage volume. In the 75% flow scenario with unrestrained demands, Boulder's system fell short of this target by about 1,700 acre-feet, but was able to maintain more water in storage than what is currently projected to occur through the end of April 2003.

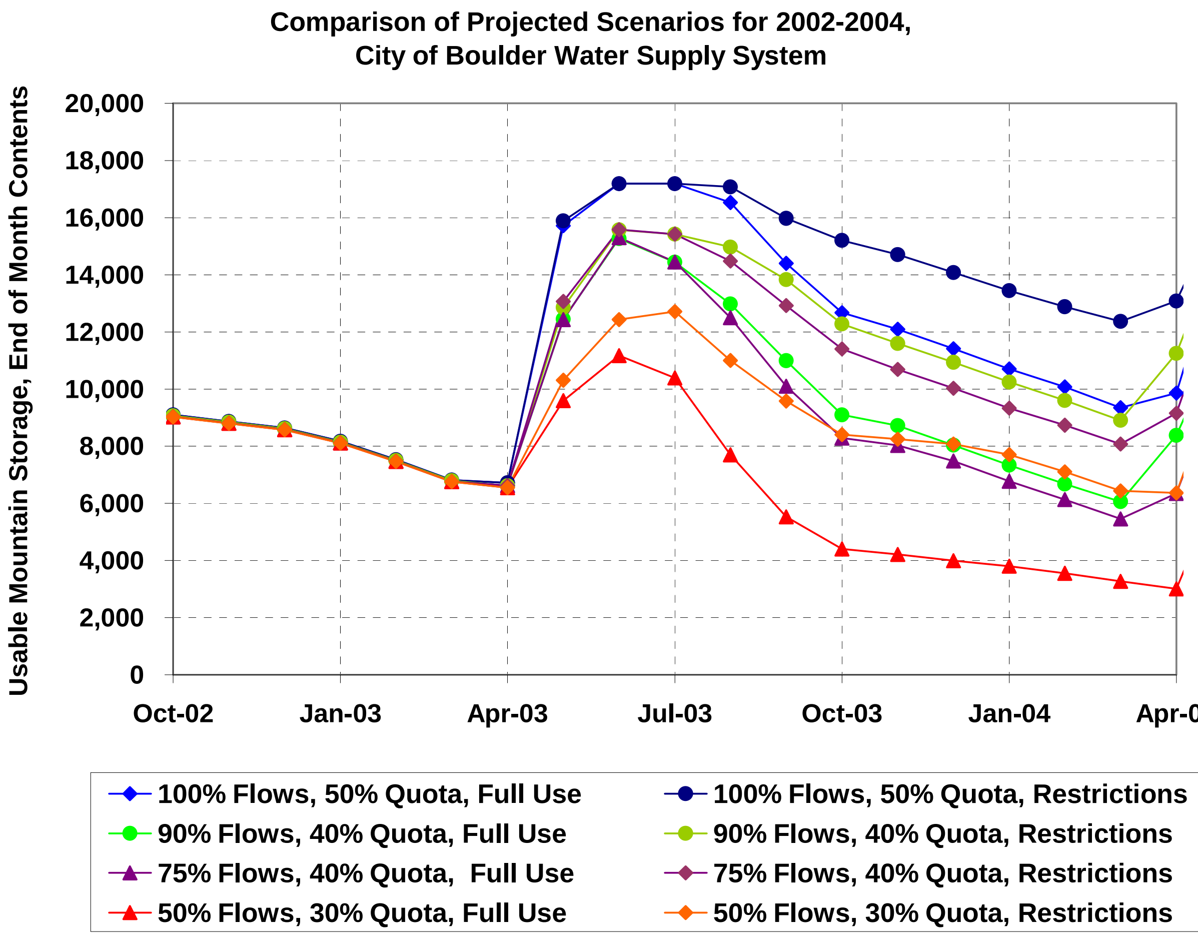


Figure 23: Comparison of selected water supply scenarios for 2002-2004

These results suggest that Boulder might not need to impose demand restrictions for 2003 unless runoff conditions are projected to be less than 75% of average or unless the CBT quota remains at 30%. Of course, these modeling results are only as a guideline. Actual decisions on demand reduction programs for 2003 would be based upon precipitation patterns, snowpack accumulation and reservoir levels through the prior winter and spring.

DROUGHT RECOGNITION AND RESPONSE

DROUGHT ALERT STAGES AND WATER USE REDUCTION GOALS

Droughts vary considerably and Boulder's response must be suited to the severity of a given drought. In developing a drought response plan it is useful to categorize Boulder's demand reduction responses into specific stages that are associated with various levels of drought. The range of droughts that Boulder might have to respond to, along with Boulder's demand reduction goals, can be categorized into drought alert stages as shown in Table 3.

The range of drought associated with each alert stage was developed by modeling the operation of Boulder's water supply system through a wide range of wet and dry periods, as described in the following section. The details of Boulder's water use reduction goals for each of the alert stages are presented in Volume 1 of this Drought Plan.

Table 3: Drought alert stages

Drought Alert Stage	Drought Description
I	Moderate
II	Serious
III	Severe
IV	Extreme

DROUGHT RECOGNITION CONSIDERATIONS

While water supply conditions and the potential for drought are both continuously monitored by Boulder's water managers and consultants, there are several factors that can be used to influence how and when Boulder recognizes and reacts to droughts. Other climate indicators that are relevant in other parts of the country have little predictive value in Colorado. The Colorado Front Range is a location where four different major climate systems converge. This makes weather prediction for the area notoriously difficult. The following factors are known about the Boulder area.

- Snowpack accumulation becomes a relatively reliable indicator of runoff by May 1 of each year (see Figure 21 below.)

- To date, global factors (El Nino Southern Oscillation, Pacific Decadal Oscillation, etc.) basically have no predictive skill with respect to droughts in Boulder Creek or the Upper Colorado/CBT drainage area.

- Multi-year persistence of droughts is evident only in the years following extremely low flow (<65% of average) years.

- Modeling studies suggest that, under historical and tree ring-based climate regime, Boulder's water supply would be very infrequently impacted by droughts, only 1-in-50 year droughts or worse.

- May 1 is the time when Boulder has the most foreknowledge about its water supply system because virtually all of the snowpack has usually developed by this time and Boulder's final CBT quota for the year is known. May 1st is also early enough for Boulder to influence almost all outdoor uses for the ensuing irrigation season.

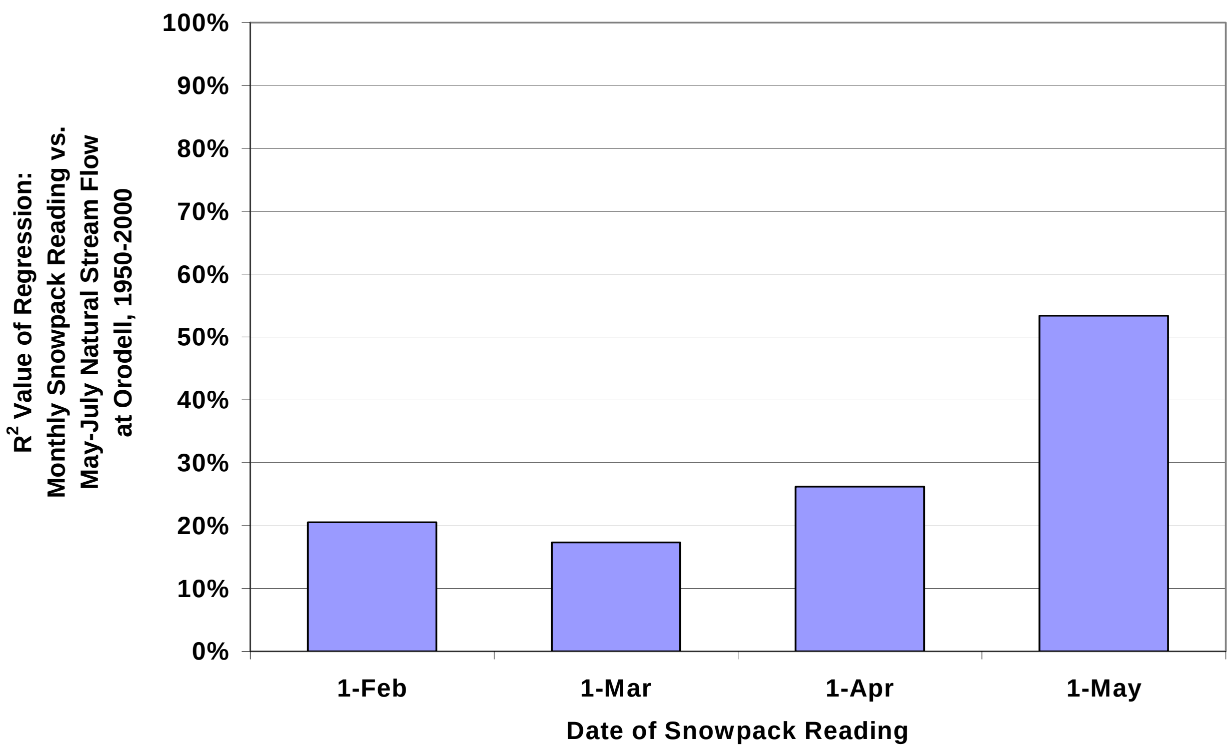


Figure 24: Seasonal value of Boulder Creek snowpack in predicting Boulder Creek runoff volume

DROUGHT RESPONSE TRIGGERS

Based on the factors listed above, drought response triggers were developed for use on May 1 of each year. The triggers incorporated three quantitative factors:

- Boulder's projected mountain storage during the ensuing May-June period based on snowpack measurements and the projected resulting streamflows during the spring runoff period.

- Boulder's portion of water projected to be available in CBT reservoirs during the ensuing May-June period.

- Boulder's unrestrained water demand.

Perhaps the most important factor in evaluating the drought stage is how full the city's Boulder Creek basin reservoirs are likely to get during the following runoff, because mountain storage water is likely to be Boulder's main supply in meeting its demands in a severe drought year. The interpretation of the factors listed above should be modified as necessary based on other appropriate data and operating experience.

The next most important factor is Boulder's portion of the total amount of water that is likely to be in storage in the CBT project during the following runoff. Boulder owns a 7% share of the contract delivery rights for the CBT project, which corresponds to about 50,000 acre-feet of the usable storage capacity in the project. Boulder does not own this storage space directly and cannot draw this entire volume of water from the project in a single year due to CBT quota policies and capacity limits at the Boulder Reservoir treatment plant. However, Boulder does have the right to expect water delivery in accordance with the operating policies of the project and this represents Boulder's main 'bank account' during severe, multiple-year droughts.

The two factors relating to storage levels in the upper and the lower part of Boulder's municipal water supply system are equivalent in value as components of an overall drought response trigger. If the portion of CBT storage associated with Boulder's CBT units is at or near its maximum value, this could somewhat compensate for Boulder's mountain reservoirs being abnormally low.

Finally, the size of Boulder's unrestrained annual water demand should also be factored into Boulder's drought response triggers. As Boulder's water demand increases, more storage would be needed if unrestrained demands were to be met during a given drought. Given the potential environmental and economic effects of providing more storage, it is more cost-effective to plan for restraints on demand during significant drought periods.

Based on detailed modeling of the operation of Boulder's water supply system and the CBT and Windy Gap projects over 300 years of stream flows evidenced by tree rings, the drought response triggers in Table 4 appear to be the most appropriate. These triggers mathematically incorporate all three of the factors listed above. However, Boulder's portion of CBT storage is discounted by 40% because of the multi-year carryover function of this supply.

Table 4: Suggested drought response triggers for May 1

Projected Storage Index (1)	Drought Alert Stage
Greater than 0.85	None
Between 0.85 and 0.7	I
Between 0.7 and 0.55	II
Between 0.55 and 0.4	III
Less than 0.4	IV

(1) **Projected storage index = (projected usable Boulder mountain storage + 40% of Boulder's portion of projected CBT storage) / Boulder's unrestrained water demand in non-drought years.**

Projected usable Boulder mountain storage is the maximum amount of projected storage in Barker Reservoir plus the Silver Lake Watershed following the peak of the spring runoff during the ensuing May-June period, minus 1,000 acre-feet for dead storage allowance. This value will be based on estimates of final snowpack levels and resulting streamflows to occur following May 1. Presently, the maximum potential projected usable mountain storage, if all reservoirs were full, less 1000 acre-feet of dead storage is 18,500 acre-feet.

Boulder's portion of projected CBT storage is the maximum amount of projected available water stored in Granby, Carter and Horsetooth Reservoirs during the ensuing May-June period, times the ratio of (Boulder's CBT units divided by the total number of CBT units in the CBT Project), plus the net amount of any CBT water that Boulder is carrying over in the CBT system. Presently, Boulder Utilities owns 21,015 units of CBT and there are 310,000 units, so the ratio would be 6.78%.

Boulder's unrestrained demand is the average of Boulder's annual treated water demand (May 1 to April 30) for the last two years in which there were no drought response-related demand reduction programs in place. For example, in the drought year of 2002, the average demand for the period of May 1, 2000 to April 30, 2002 was used for the calculation. If a drought continues for an extended period, it may be desirable to adjust the information for unrestrained year demand to account for increases in population.

It should be noted that these drought response triggers are intended to be used only as a guideline and in conjunction with other appropriate data and operating experience. The response triggers should be modified as necessary to account for the unique characteristics of the drought period in progress. Modifications should be made as necessary based on actual measurements of snowpack and streamflow, observations of the operational response of Boulder's municipal water supply system to the drought, and the recommendations of Boulder's water system managers. While Boulder's drought response can be decided upon and communicated to the public in early May, Boulder should continue to monitor trends in snowpack, runoff and reservoir filling through May and June, and should be ready to modify its drought response plan accordingly, if needed.

WATER SUPPLY RELIABILITY ASSESSMENT

SUMMARY OF APPROACH

Hydrosphere used the Boulder Watershed Model to assess the ability of Boulder's water supply system to meet its projected build-out demands in accordance with Boulder's water supply reliability criteria. The model was originally developed to simulate all significant aspects of hydrology, water rights, water storage and diversion facilities and water uses in the Boulder Creek basin. The model utilized a 1950-1994 period of hydrologic record under the assumption that the historical drought of 1953-1956 was a sufficiently severe drought event against which to test the city's water supply system.

In developing this plan, the model was expanded to include a simplified sub-model of the CBT Project and Windy Gap projects. This allowed for simulating operation of the two projects during periods prior to their construction.

The model was modified to run against a 300-year period of record that reflects the results of tree ring-based reconstructions of natural flows for Boulder Creek and the Colorado River for the years 1703-1987 (actual historical data were used for 1988-2002). This expanded data set allowed for a more robust assessment of the reliability of the city's water supply system, including the performance of the CBT and Windy Gap projects.

The model was also refined to include the drought response triggers and associated demand reductions shown in Table 4 above. The response triggers were evaluated on May 1 of each year in the model. The response triggers were a function of the forecasted degree of fill of Boulder's upper Boulder Creek water system storage and CBT system storage over the following two-month period. The demand reductions were applied to the subsequent 12-month period. The model also simulated Boulder's invoking of drought reservations associated with its instream flow program and its raw water delivery obligations.

KEY ASSUMPTIONS

In the modeling analyses done in this reliability assessment, several key assumptions were made. Each assumption is treated as a 'given', including two capital expenditure items that have been previously identified as top priorities for maintaining the reliability of the city's water supply system.

- All of Boulder's existing raw water storage, diversion and conveyance facilities are in good working order and capable of operating up to their full capacities. The adequacy of the Farmers Ditch in allowing the city to divert its full portion (12.17 cfs) of Farmers Ditch water rights to Boulder Reservoir should be particularly noted in this regard.

- Boulder is able to use all of its water rights according to their decrees.

- The reliable capacities of the Barker Gravity Line and the Lakewood Pipeline were assumed to be 26 MGD and 20 MGD, respectively, and the Betasso plant was assumed to be capable of simultaneously treating the combined maximum inflows of these pipelines up to 46 MGD.

- The reliable treatment capacity of the Boulder Reservoir plant was assumed to be 15 MGD year-round, including during the winter season when the Boulder Feeder Canal is not operating.

- Boulder's raw water delivery obligations to the Silver Lake Ditch, Caribou Ranch and Valmont Reservoir operate according to their respective contractual agreements with respect to droughts and drought reservations.

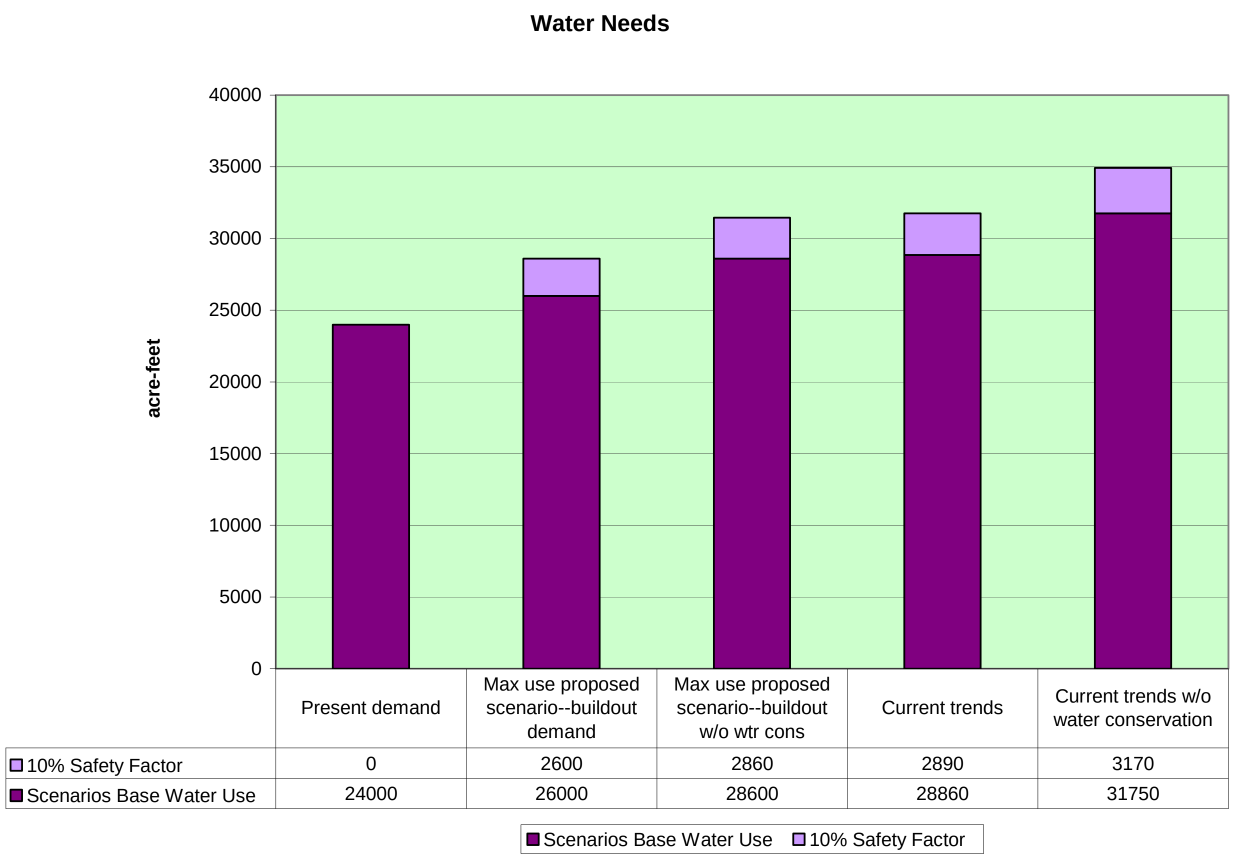
- Annual leases of municipally-decreed water to agricultural users are discontinued during drought years so that the water is available for delivery into the municipal system.

- The drought interruption clause within the donation agreements to the Colorado Water Conservation Board is invoked during severe drought periods and use of the donated water for instream flow purposes is temporarily suspended.

- Boulder's build-out water demand was projected to be 28,600 acre-feet. This is based on population and employment assumptions presented in Table 1 (which reflect the proposed scenario with the highest water use developed through the Jobs and Population project) increased by a 10% safety factor. This safety factor addresses uncertainties related to potential increases in water-intensive industries and 'real world vs. modeled' operational factors of the water supply system.

- This modeled demand assumes that the water savings associated with Boulder's recently adopted Comprehensive Water Conservation program will have been achieved. If this program is not implemented or does not result in the projected level of water savings, then the 10% safety factor assumed in the water demand projections above will not exist.

The Jobs and Population Project has proposed several different scenarios for Boulder's future housing/worker balance. Each scenario would result in its own water demand pattern at buildout. However, use of the proposed scenario with the highest water demand will accommodate the needs of the other, less water-intensive, scenarios should they come about. The Jobs and Population Project also projected the number of workers and population in Boulder if the current trends continue into the future. The water use associated with the current trends scenario is 11% higher than the proposed scenario with the highest water use. Boulder's present water demand and water needs under the current trends scenario and the proposed scenario with the maximum water use are shown in Figure 25.



	Present demand	Max use proposed scenario--buildout demand	Max use proposed scenario--buildout w/o wtr cons	Current trends	Current trends w/o water conservation
10% Safety Factor	0	2600	2860	2890	3170
Scenarios Base Water Use	24000	26000	28600	28860	31750

Figure 25: Boulder's water use under several future scenarios

RESULTS OF ASSESSMENT

The modeling results show that, given implementation of the demand management and capacity expansions listed in the assumptions above, Boulder's water supply system would be capable of meeting its projected buildout demands, plus a 10% safety factor, in a manner consistent with Boulder's adopted reliability criteria. Over the 300-year modeled period, Boulder's projected buildout demand was fully satisfied in all but 10 years, as summarized in

Table 5. This equates to some level of demand reduction once every 30 years on average and no demand reduction great enough to cause significant permanent damage to landscaping.

Table 5: Results of reliability assessment

Drought Alert Stage	Number of Occurrences	Years of Occurrence
Full demand satisfied	290	All years but those listed below
Level I	5	1842, 1848, 1852, 1885, 1890
Level II	3	1851, 1887, 1889
Level III	2	1888, 2002
Level IV	0	None

CAVEATS AND AREAS OF UNCERTAINTY

It should be noted that this finding of adequacy is contingent upon the assumptions listed above. Several of these assume significant capital expenditures by the city.

Sensitivity analyses show that if Boulder's modeled build-out demand is increased by an additional 10% to 31,500 acre-feet (while still maintaining a 10% safety factor), the number of years with required demand reductions would rise from 10 to 25 years out of 300, equivalent to demand reductions once every 12 years on average. The 25 reductions would include seven years with Level 2 reductions, five years with a Level 3 reduction, and one year with a Level 4 reduction as shown in Figure 26. This level of performance would not meet the city's reliability criteria and still maintain a 10% safety factor. The 10% safety factor should not be considered discretionary as this safety factor addresses uncertainties related to potential increases in water-intensive industries and 'real world vs. modeled' operational factors of the water supply system.

A 10% increase in the city's build-out demand could result from failure to implement the Comprehensive Water Conservation Program included in the Water Conservation Futures Study. An 11% increase could result from allowing the Jobs and Population Project's 'Current Trends' scenario to materialize. Failure to implement the Comprehensive Water Conservation Program or allowing the Current Trends scenario to materialize would place water demand levels beyond the margin of error for assurance of a reliable water supply. A comparison of supply and demand under various scenarios is shown in Figure 27.

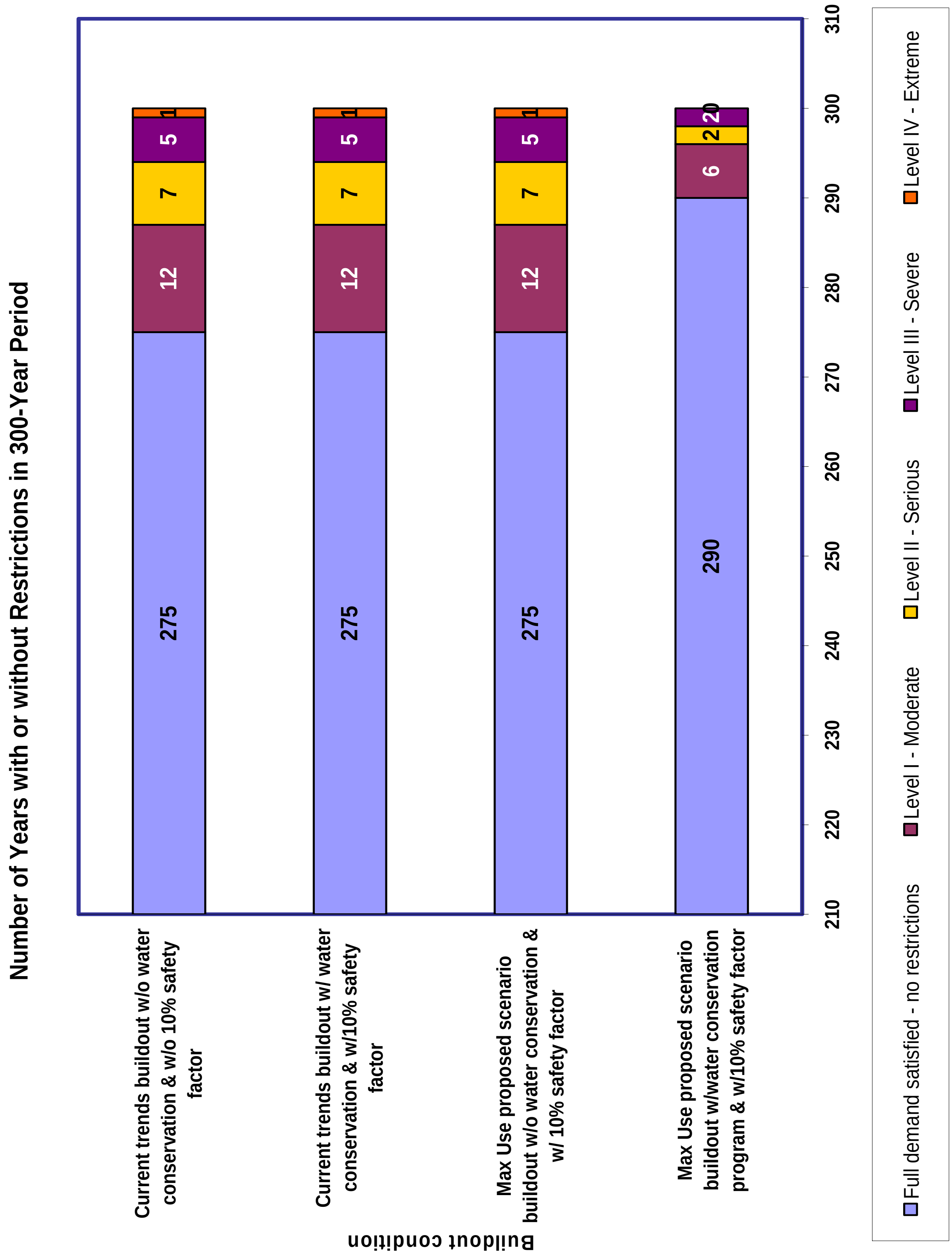
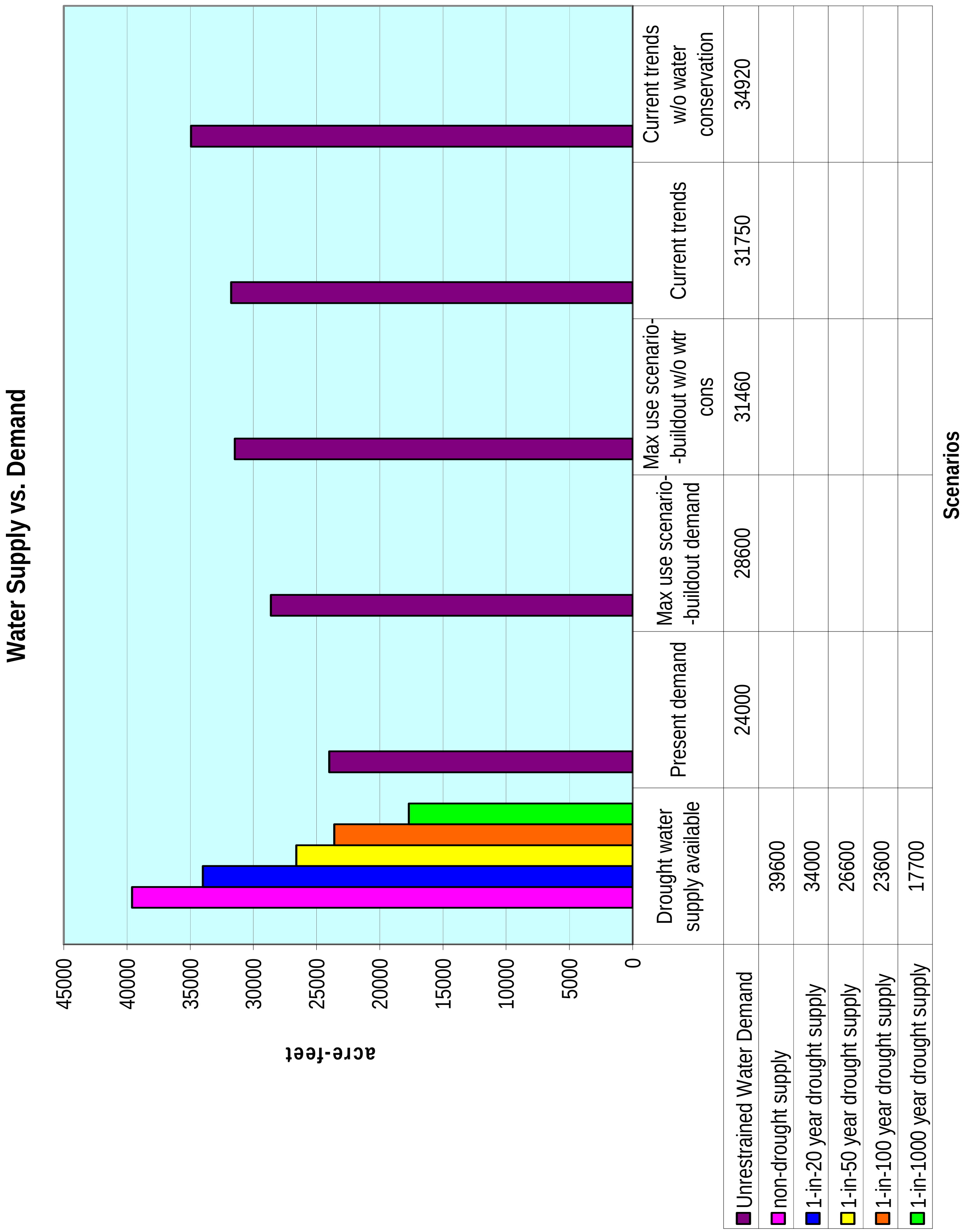


Figure 26: Number of years with restrictions under buildout water use scenarios



	Drought water supply available	Present demand	Max use scenario--buildout demand	Max use scenario--buildout w/o wtr cons	Current trends	Current trends w/o water conservation
Unrestrained Water Demand		24000	28600	31460	31750	34920
non-drought supply	39600					
1-in-20 year drought supply	34000					
1-in-50 year drought supply	26600					
1-in-100 year drought supply	23600					
1-in-1000 year drought supply	17700					

Figure 27: Water supply and demand under water use scenarios

Each scenario would result in its own pattern of occurrences of the various drought alert levels as previously described. This pattern is shown in Figure 28.

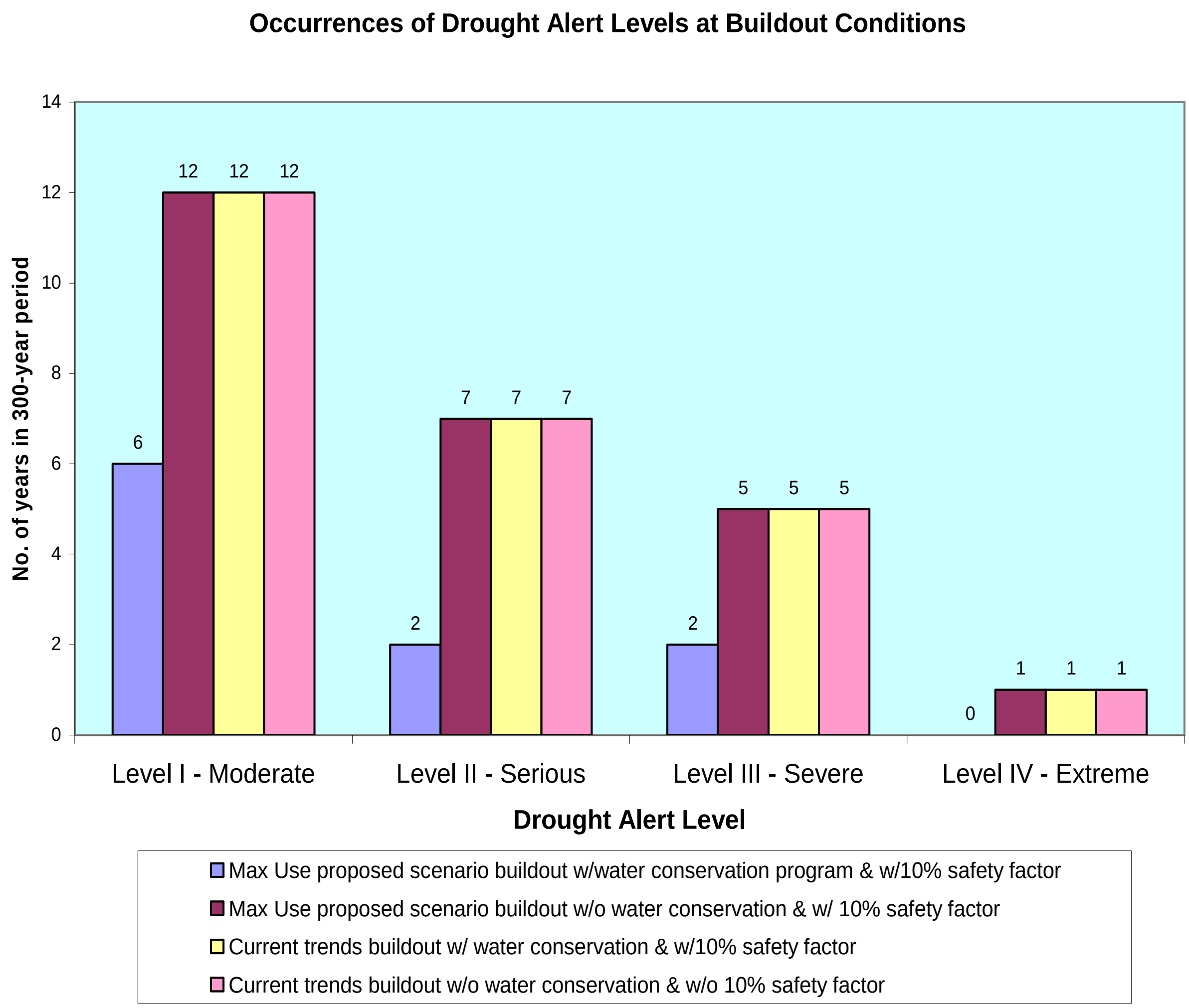


Figure 28: Occurrences of drought alert levels

The water yield analysis is based on evaluation of historic climate data. There are several plausible climate change scenarios that could significantly improve or degrade the city's ability to reliably meet its currently projected build-out demands. As discussed previously, the current state of climate modeling at a regional level is not sufficiently developed to fully evaluate the extent, if any, of the effect of future climate changes on Boulder's water yields.

While many areas of uncertainty are out of Boulder's control, the city can manage its growth and its related water demands and can pursue additional water supply development options. Strategies for drought demand management and supply development are discussed in the following sections. Long-term strategies for water conservation have been developed through the Water Conservation Futures Study.

EVALUATION OF DROUGHT DEMAND MANAGEMENT STRATEGIES

EFFECTIVENESS OF VARIOUS DROUGHT DEMAND MANAGEMENT STRATEGIES

On-going water conservation efforts and drought demand management strategies are related, but are two separate areas for discussion. An on-going water conservation program is aimed at establishing wise water use practices everyday and should include long-term goals for water use reduction. A successful on-going water conservation program can improve a city's ability to weather drought periods by lessening overall water demand. However, for a water system that has established reliability criteria, such as Boulder's, it is expected that temporary, more stringent water use reductions will be made during drought periods. This protects the city from the need to make excessive capital investments in water facility capacities and water rights that may be used only every twenty years or less often.

Drought demand management strategies temporarily reduce water usage without necessarily affecting the long-term demand. These strategies may include use of restrictions, rationing, price increases, public education programs, and distribution of water-saving devices. Some methods will continue to reduce use after the end of the drought since they change water-use habits or improve system efficiency.

Demand management methods, whether for on-going efforts or for temporary drought-related use reductions, can be divided into four general categories.[7] Structural means modify the water system by metering, pressure reduction, flow controllers, or recycling. Economic measures include rate structures, pricing, penalties, and incentives. Operational changes include leak repairs or water use restriction programs. Finally, social methods consist of public education, building code modifications, and landscaping changes.

Some of these methods are more suited for including in an on-going water conservation program rather than in a drought response plan due to the length of time necessary to see any reduction in water use from the method. These measures include items such as landscaping changes and altering the rate structure. However, making changes in these areas during non-drought periods can pay off during a drought by, for example, having established xeriscape landscaping in place that can tolerate reductions in water application or having a rate structure that can easily be modified to accept a drought surcharge. Although this drought plan includes some discussion of these longer-term measures for purposes of creating a more-rounded discussion and acknowledging the benefits of these methods, they are not included in the drought response plan as measures to put in place in the event of a drought. The implementation of these longer-term measures is best completed through the city's on-going water conservation program or through other efforts.

This drought plan focuses on measures that can be implemented relatively quickly and that will result in the rapid water use reductions that are anticipated for each of the drought alert stages discussed in previous sections of the plan. Achieving these rapid, but temporary, water use reductions will assure that the reliability criteria for the water system are met. It is worth noting, however, that adoption of the water conservation program proposed within the Water Conservation Futures Study will improve the city's ability to meet or exceed the reliability criteria during drought periods as water demands increase in the future to projected build-out levels.

There are a considerable number of studies available within the water industry literature that examine the amount of reduction that can be achieved by a municipality from various water conservation and drought management efforts. Some of the same methods employed during drought and non-drought periods show a much higher water savings during the drought period. This indicates that the perception of a crisis during a drought influences behavior and indicates that a conservation method may not achieve as great a savings without the perceived threat of water shortages.[8]

Several communities have had success in producing large reductions in water use through a well-developed contingency plan. In July 1977, the Washington Suburban Sanitary Commission's Potomac River Treatment Plant failed. They were able to reduce water use by 40% within 2 days with a program of increasingly stringent restrictions.[9] A study in Rhode Island found that municipal water use can be temporarily reduced during shortages by 35% without extraordinary inconvenience to customers.[10] During the 1976-1977 drought in Marin County, California, a ban on outdoor water use was instituted in 1976. Even though it produced a 25% reduction in water use, this was insufficient to deal with the severe water shortages. In 1977, a rationing plan was instituted that limited use to 46 gallons per person per day and was enforced by fines. It produced a 63% drop in use.[11]

Based on information about successful strategies in other communities and on information regarding the response of Boulder's citizens during shortages caused by breaks in the Barker Gravity Pipeline in 1996 and 1997 and during the drought year of 2002, it is possible to establish a program of measures that can produce varying levels of water use reduction for Boulder for each drought alert level.

Demand curtailment strategies to be employed during a particular drought period will vary depending on the size of reduction required. They will also vary based on the season because the majority of outdoor use occurs during the irrigation season from May 15 to October 15 and outdoor use will be targeted for a larger percentage reduction than indoor use. During drought periods, the restriction strategies are designed to result in total city-wide reductions in water demand during the irrigation season (May 15 to October 15) ranging from 10 to 55%. Indoor use reduction targets to be achieved throughout all seasons of drought years range from 5 to 15%.

The indoor reduction strategies implemented through the drought plan are intended to be in addition to indoor use reduction measures implemented through an on-going water conservation program. The drought-focused measures will mostly involve behavioral changes that are possibly temporary in effect. The 5 to 15% reduction in use from these measures in drought years will be in addition to any reductions achieved through the more permanent indoor use reduction measures pursued through other city programs.

These strategies can employ both voluntary and mandatory measures depending on the severity of the drought. These programs and measures can be used individually or as part of a package to achieve the water usage reduction required by the specific drought. Each drought period will have its own characteristics and will require tailoring the measures suggested for each drought alert stage to the particular situation.

The total annual reductions in water use that are set as a goal for each drought alert stage are composed of reductions in both indoor and outdoor use. Outdoor irrigation use is the most discretionary water use and will be the area comprising the bulk of the reductions achieved. Therefore, the proportion of the annual water use that is derived from changes in irrigation season use will be higher than that obtained in the winter when water use is almost all indoors.

The percentage reductions desired for the irrigation season (May 15 to October 15) at each drought alert stage is expressed in simple rounded numbers as shown in Table 6 for purposes of easily conveying to the public what response is expected of them. The corresponding demand reductions for year-round indoor use, irrigation season outdoor use and for the total annual reduction are also shown in the table. The percent of reductions are based on the current split of 34% outdoor use and 66% indoor use for Boulder's water customers. Given that each drought is different and that the characteristics of Boulder's population and drought response may change slightly over time, the percentages given are intended to define the mid-point of a range of expected use reduction for each stage and should be modified if the ratio of indoor to outdoor use changes significantly.

Table 6: Percentage reduction goals for types of water usage

	Drought Alert Stage			
Water Use Reduction %	**I**	**II**	**III**	**IV**
Total City-wide Annual	**8**	**14**	**22**	**40**
City-wide May 15 – Oct 15	10	20	30	55
City-wide Oct 16 – May 14	5	5	10	15
Commercial / Industrial / Institutional Average Annual	8	14	22	40
City-wide Indoor Year-round	5	5	10	15
Outdoor (mostly May 15 – Oct 15)	16	32	46	87

In 2002, Boulder's irrigation season use was reduced by 28%. This was made up of a 10% reduction in indoor use and a 50% reduction in outdoor use. The outdoor use reduction was achieved through irrigation restrictions that limited lawn irrigation to two times per week and 15 minutes of irrigation for any zone. The 10% reduction in indoor use was achieved mostly through education and providing information regarding the severity of the drought. The indoor use reduction level continued through the winter months of 2002-03, putting the city on target for reaching a total annual reduction in water use from May 15, 2002 to May 14, 2003 of 20%. Therefore, the city achieved water use reductions in line with the goals for a Level III drought alert stage through use of the mechanisms recommended at this stage.

VOLUNTARY REDUCTIONS

Voluntary approaches can be employed when the water use reductions required are small and can be successful when the drought is not severe. Voluntary water use reduction programs, including an aggressive public information campaign, could achieve reductions in use of 7 to 10%. The higher end of this range could more readily be achieved if requests for voluntary reductions are coupled with implementation of economic disincentives against water use such as a water rate drought surcharge. An effective program could be designed around efforts aimed at several different areas.

Education and Information

Provision of information and education on water-saving techniques is an essential basis for any drought response effort. A portion of the information effort can be directed at increasing awareness of the drought situation. The drought response information can be designed to build on the efforts to create a conservation ethic that would be part of an on-going water conservation program. For any of the other drought demand management techniques to be fully effective, education and information must be a central component of any drought response plan. Efforts can be targeted to specific water user groups such as commercial users or single family residents who are responsible for the lawn irrigation.

Studies[12] have shown that effective educational material aimed at reducing water use meets the following criteria:

- The information must be clear.
- The most effective water use reduction measures must be identified.
- The public must view the informational source as credible.
- The provision of information must be reinforced with other methods.
- The medium used to disseminate the information and the type of appeal (economic, moral, etc.) must be carefully considered to speak to the target audience.

Large commercial and industrial customers are among the largest individual users of water in Boulder. The city's on-going water conservation program may include an efficiency mentoring program for these customers that could be intensified and built upon during the drought. It is possible that these large water users may be willing to make temporary water use reductions in their business operations that could result in substantial water savings if they are requested to as a response to a drought. A portion of these more extensive temporary reductions might become permanent after the drought resolves.

Irrigation Use Reduction

Reducing irrigation demand can have a large effect on total water demand and on peak demands since, as previously discussed, irrigation makes up a large percentage of summer-time use. There are two very effective means to reduce irrigation use—changing the plants within the landscape and changing lawn watering methods.

Installation of new landscapes for new construction or remodeling can be addressed through the building code. Since this is considered a longer-term means to address water use, it is not covered in this drought plan. Information on the city's codes relating to landscaping requirements for new construction are included in Appendix G.

The city's on-going water conservation program offers landscape consultations to customers who request the service. A landscape consultation is an opportunity for the city to communicate on an individual basis with the customer and provide guidance on how water can be used more efficiently. This program can be intensified and publicized during droughts. In addition, implementing changes to a homeowner's landscape to incorporate more water-wise and xeriscape landscaping can be encouraged during non-drought years and Stage 1 moderate droughts when water use reductions are voluntary. Implementation of landscaping changes might be discouraged during more serious droughts when irrigation restrictions are in place which may not allow sufficient water to establish a new landscape.

Landscapers estimate that an established xeriscape landscaping will use 1/3 to 1/4 of the water recommended for bluegrass lawns. In addition, it is estimated that the water use for a newly-installed xeriscape will use half the water that an established bluegrass lawn uses.[13] This is based on the following assumptions:

- The bluegrass lawn is receiving 1 ½" of water a week with a 70% efficient sprinkler system.

- For every 5000 square feet of xeriscape, 1000 square feet is bluegrass,1000 square feet is perennial flowers and groundcovers, and 3000 square feet is shrubs.

- The flowers and groundcovers have moderate water requirements (10 gallons/square foot/season), rather than being very xeric. They are watered using an in-line soaker line with 0.6 gallons per hour (gph) emitters every 12 inches, with the soaker lines laid 18 inches apart.

- The shrubs are planted an average of 3.5 feet apart, and each have one 1gph emitter.
- The shrub and flower irrigation zones are run for 1.5 hours twice a week.
- The shrub and flower beds are mulched with wood mulch: 1 inch for flowers and 3 inches for shrubs.
- The soil is clay or clay loam.

Many bluegrass lawns receive more water than this, as discussed below, and many xeriscapes use less water than this. A xeriscape using buffalograss or having no lawn, and having more xeric perennials and groundcovers will use less water. However, inclusion of some bluegrass, even in a xeriscape, is very appropriate in some locations and often helps to make the appearance of xeric landscapes more acceptable to homeowners who desire a more “traditional” landscape. (See Appendix D for information on turfgrasses.)

Some turfgrass specialists state that the drought tolerance of bluegrass is generally underestimated.[14] While bluegrass may require more water than other turfgrass species to look its best, bluegrass may also survive drought better because of its capability of going dormant. When bluegrass is allowed to go dormant, as little as ½ inch of water every 2 to 3 weeks will keep the crowns of the plants alive. After sufficient rain or irrigation is then received, the grass will quickly recover. Bluegrass can potentially survive several months without significant rainfall or irrigation.

The drought tolerance of bluegrass was demonstrated during the drought year of 2002 for many Boulder lawns. The irrigation restrictions caused most bluegrass lawns to go dormant during the summer. The city received many calls from residents who were not willing to readily believe that their lawn was dormant and not dead. However, after some precipitation arrived in the fall, lawns throughout the city quickly turned from brown to green.

Even with landscapes composed almost entirely of bluegrass, much can be done by the city to reduce water use through education on proper irrigation and provision of information on the amount of water required. Bluegrass lawns are often over-watered. In Denver, studies have indicated that 1.5 to 2.0 inches of water have been applied by homeowners to lawns each week when only 0.9 inch is required for an attractive bluegrass lawn.[15]

The amount of water applied to a lawn need not exceed the maximum evapo-transpiration (ET) rate of the lawn less the rainfall, as this is all that the plants can use. However, studies have found that adequately fertilized grass, with sufficient nitrogen, had a minimal reduction in visual quality when irrigation was decreased to 70% of the amount needed to meet the maximum ET rate.[16] Bluegrass can be maintained in a dormant state with little plant die off with as little as 50% of the maximum ET rate.[17] The maximum ET rate for lawngrass and 70% of the maximum ET in average and dry years for the Denver-Boulder area is shown in Table 7.

Table 7: Evapo-transpiration rate for lawngrass in the Denver-Boulder area

ET rate (acre-feet per acre)

Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Annual
Average	0.01	0.17	0.30	0.47	0.49	0.42	0.32	0.19	0.02	2.39
70%Avg		0.12	0.21	0.33	0.35	0.30	0.22	0.13	0.01	1.67
Dry		0.25	0.38	0.54	0.49	0.49	0.36	0.25	0.07	2.83
70% Dry		0.18	0.27	0.39	0.34	0.34	0.25	0.18	0.05	1.99

Indoor Use Reduction

- **Ultra-low flow toilet rebates –** It has been proposed that the city might offer rebates for the installation of ultra-low flow toilets as a part of an on-going water conservation program. However, if a rebate program were not in place at the beginning of a drought, it still might contribute sufficiently to immediate water savings to be considered as a drought response measure. Research has shown that replacing old high-water-use toilets with a standard 1.6 gallons per flush toilet (the only type of new toilet sold in the United States) is one of the most cost-effective water use reduction methods available. Replacing all of the old toilets in a house saves an average of 10.5 gallons per capita per day.[18] For an average household of four people, this equals more than 15,000 gallons of savings over a year. Given the age of much of Boulder's housing, there may be significant water savings potential from replacement of old toilets.

- **Toilet dams –** The city could distribute toilet dams to be placed in the holding tank of old toilets to reduce their water use. While these are not considered to be a long-term solution due to their insubstantial construction, they can reduce water use for the duration of a drought.

- **Faucet Aerators -** Low flow faucet aerators are inexpensive and could be purchased in kits by the city and distributed along with conservation literature to customers. Research has shown that the water savings from faucet aerators can be large when they replace high flow fixtures. A kit with two aerators and installation information would cost about $5. Research indicates that showerhead replacement offers very small water savings and is usually not cost effective.

MANDATORY RESTRICTIONS

Mandatory restrictions are not usually very popular with customers, but are necessary if the amount of water use reduction to be achieved during an irrigation season is greater than 10%. Voluntary restriction programs offer the most flexibility for customers, but their water savings may be relatively small. In 2002, Front Range cities that opted for voluntary programs reduced demand by only 10% compared with the more than 25% reduction in summertime usage achieved in Boulder through mandatory restrictions. Voluntary measures have not been demonstrated to have the ability to produce use reductions much greater than 10% unless coupled with price surcharges. The surcharges would need to be extremely large (in the range of 400% or more of the normal water rates) to produce water use reductions much greater than 12% (see Appendix E.)

Relying on pricing mechanisms or rate structures alone, without mandatory restrictions, may not produce water use reductions fast enough to deal effectively with a serious drought situation. If large, rapid water use reductions are necessary, then a program of mandatory restrictions is likely required. Another consideration is the need to fairly balance the impacts of a serious drought across all segments of the population. Voluntary measures may be ignored by some people. In addition, a significant portion of Boulder's population may choose to just pay the bill for higher water rates aimed at reducing water use or ignore penalty structures for water use above set levels, leaving the city-wide water use reductions to be achieved by less-affluent residents. If a large enough segment of the population were willing to pay the high cost of maintaining a green lawn during a drought, the city utility might be well funded, but would run short of water.

In Boulder, outdoor uses make up 34% of the entire city's water use and 48% of the use of single-family homes, but are usually more discretionary in nature than indoor uses. In addition, mandatory water use restrictions for indoor uses would be difficult, if not impossible, to enforce. Therefore, mandatory restriction programs focus on outdoor uses, particularly on irrigation use. When irrigation restrictions are implemented, it makes sense to bundle them with other measures such as prohibiting washing pavements and sidewalks, limiting or prohibiting home car washing, mandatory leak repair, and limiting swimming pool re-filling. The extent of the restrictions can be adjusted to the varying drought alert levels described in Volume 1 – Drought Response Plan and can be tailored further to correspond to the individual characteristics of the particular drought.

Due to the need to achieve the majority of the annual water use reductions from reducing the more discretionary irrigation use, the reduction goal needs to be higher for the irrigation season than the overall annual reduction goal, as previously demonstrated in Table 6. The overall annual reduction goal can be reached for each drought alert level through use of the irrigation restrictions shown in Table 8 and the indoor use reduction goals.

Table 8: Outdoor restriction programs and estimated water savings

Drought Alert Stage	Restriction Program	Estimated Outdoor Water Use Savings	Estimated Irrigation Season Overall Water Savings	Comments
I Moderate	Voluntary Measures – focuses on education about proper irrigation practices and minimizing waste	16%	10%	Useful when small reduction needed, but not effective when large reductions are required. Requires extensive education and information effort.
II Serious	Restricted Irrigation Time – e.g. limited hours for irrigation on designated days per week	32%	20%	Visual effect on landscaping mostly minor with little long-term impacts. Could adversely affect large area irrigators by fixing total length of watering time. Enforcement required.
III Severe	Very Restricted Irrigation Time –e.g.- limited number of minutes per zone for 2 designated days per week	46%	30%	Effective means of saving large quantities of water, but lawns will go dormant and trees will be stressed. Enforcement of time limit may be difficult.
IV Extreme	Full ban on irrigation and most outdoor uses with possible allowance for tree watering	90%	55%	Without sufficient rain, this program could cause significant loss of landscape plantings across the city.

PROGRAM MODIFICATIONS AND EXEMPTIONS

Exemptions are a controversial component of any mandatory restriction program. Any exceptions or exemptions to a mandatory watering restriction program should reflect the overall values of the community.

Installation of New Xeric Landscaping

As previously discussed, xeriscapes can use significantly less water than a bluegrass lawn even when newly installed and requiring extra water to get established. However, a newly installed xeriscape does require about half of the water normally applied to a bluegrass lawn to become established. During more severe droughts when irrigation restrictions are in place, the amount of water required to establish a new xeriscape may exceed the amount of irrigation allowed under the restrictions.

It may be desirable to encourage installation of new xeriscapes during Stage II droughts when the use reduction goal for outdoor uses is 32% as shown in Table 6. In this situation, the new xeriscape, even while becoming established, would immediately use less water than the bluegrass it replaced, even under water use restrictions. However, during Stage III and IV droughts, the outdoor use reduction goals increase to 46% and 90%, respectively. The city might be increasing water use during a Stage III drought if exceptions to watering restrictions were allowed for installation of new xeriscapes because an existing bluegrass lawn would be limited to half of its non-drought water application under the restrictions. New installations of xeriscaping should not be encouraged in a Stage III drought and customers should be advised that new installations may not survive with the amount of water available under the irrigation restrictions. In a Stage IV drought, any exceptions for irrigation to establish new xeriscapes would most likely increase water use in the short-term and so, the city may wish to prohibit new installations and encourage homeowners and landscape managers to wait until the end of the drought and lifting of watering restrictions before attempting to establish new landscaping.

Vegetable gardens

Many Boulder residents plant vegetable gardens during the spring and summer and take great pride in growing and eating their own food. During Level I and Level II, moderate to serious droughts, it is most likely unnecessary to seek water savings from restricting water use for gardening. In severe droughts, watering restrictions for vegetable gardeners could follow the same use restrictions in place for lawns or the city may choose to grant exemptions for vegetable gardens. Exemptions could be designed in such a way that would encourage the efficient use of water on local gardens, but that would still provide enough flexibility for people to successfully grow and harvest food. During an extreme drought when all outdoor water use is prohibited, water use for gardening should be prohibited as well.

Private swimming pools

Water use restrictions need to address the use of private swimming pools, outdoor hot tubs, and kiddie wading pools. Promoting the use of swimming pool covers for all outdoor swimming pools and hot tubs may reduce evaporation and could prove to be an effective tool for reducing water loss in pools. A limitation on filling wading pools only once per day could also be considered.

Individual Water Management Plans for Large Water Use Irrigation Taps

Individual water management plans could be allowed for customers willing to commit to a specific individual plan and pay a fee to cover the extra administration involved in monitoring compliance with the plan. Approval of a submitted individual water management plan would allow an approved customer to manage their own water applications with respect to irrigation days, run times, and application rates. As part of this they would be required to submit a proposed monthly water use schedule and report that shows their overall annual water use target and the use reductions they are promising. Customers who elect to follow this approach would display a sign stating that they are operating under a water management plan, and would then not be ticketed for violations of the restrictions schedule. On the other hand, these customers would face stiff penalties if they exceed their monthly target allocations. The fee for this special service could be set high enough to fully pay for the additional personnel necessary to accommodate this option.

This system could provide flexibility for customers who have demonstrated an ability to reduce their usage on their own terms. However, managing and monitoring compliance with the individual management plans would be labor intensive and might require hiring additional staff or consultants to manage the program. Manual water bills or monthly use reports would have to be generated for each management plan customer. This option may only be practical for owners of large landscapes (10 acres or more).

COMMERCIAL AND INDUSTRIAL WATER USE

During a drought, water-intensive industries such as car washes and circuit board manufacturers are likely to come under increased scrutiny and possibly restrictions. In most cases, water-intensive industries consider water an essential component of their business practices and could face a reduction in business or closure if strict restrictions are imposed. Restrictions placed on commercial and industrial users can be tailored to the needs of a particular industry. For instance, motels can be restricted in the frequency of changing sheets for guests staying for several nights. Car dealerships can be restricted in the frequency of car washes.

WATER USE FOR CITY PARKS AND STREET LANDSCAPING

Presently, municipal use (including parks irrigation, recreation centers, and street median irrigation) in Boulder accounts for about 3% of the total annual demand of the city water system. As a part of the city's on-going water conservation program, an annual water allotment is set for all irrigated city parks property. The goal of this allocation has been for the Parks Department to use only 75 percent of the theoretical maximum water requirement for bluegrass for these properties. The Transportation Maintenance staff follows the same allocation practice for irrigation of street landscaping. As discussed in the Voluntary Reduction section above, adequately fertilized bluegrass remains attractive and healthy-looking when irrigation is decreased to just 70% of the maximum ET rate.

During the public meetings for the Drought Plan development, strong support was voiced by the majority of citizens for the concept of setting different, more lenient standards for the irrigation of public landscapes than for private users. The community has commented that it highly values the city's many parks and playing fields and desires to have a high level of maintenance for these properties, even during a severe drought. Many citizens attending public hearings and writing to local newspapers expressed that they would be accepting of efforts to keep public landscaped areas green even as private yards are going brown.

There appears to be broad support for a policy decision to allow the city Parks and Recreation Department to operate under an individual irrigation management plan allowing city parks staff to manage an allocated amount of water during drought periods when restrictions limiting irrigation time are in effect for other water users. The Parks Department has demonstrated their ability to keep water use within a fixed allotment requirement. If restrictions are required in the future, the Parks Department could follow its own set of water use reduction targets because of its capability to manage the irrigation systems in the parks system to meet those targets. There is presently in place a monthly reporting system that provides direct feedback on water use to the Parks Department staff every month. Parks staff has the training to read the parks water meters using a remote read tool which can give them daily or weekly water consumption data if needed.

The overwhelming majority of the Parks and Recreation Department water use and the Transportation Maintenance water use is for irrigation and occurs during the summer months. This is the period when, in droughts, the city will be asking its water users to achieve the water use reductions percentages for the irrigation season as previously shown in Table 6. The irrigation season targets for the overall city are higher than the annual targets because only 34% of the city's overall water use is outdoor use, occurring in the irrigation season, and this is the most discretionary type of water use. However, because of the Parks Department's demonstrated ability to carefully manage their water allocation and because of the unique seasonal and outdoor use distribution of their water use, it is appropriate to set indoor and outdoor water use reduction goals specific to the Parks Department, rather than applying the irrigation season goals for the city as a whole. Transportation Maintenance can continue to follow the same allocation percentages as is set for parks in irrigation of street landscaping.

The city's overall annual water use reduction goals can be used to develop goals for reductions in indoor and outdoor use for the Parks Department to achieve in each drought stage. The Parks Department overall annual goals would be the same as the city's overall goals for Drought Stages II, III, and IV. However, the Parks Department goal for Stage I droughts can be set slightly lower (5% instead of 8%) in recognition of the high degree of on-going conservation practiced by the Parks Department in achieving the regular annual water allocation goal. The overall annual goals can be expressed in terms of the reductions in indoor and outdoor water use that will be required of the Parks Department, assuming 85% of Parks Department water use is outdoors and 15% is indoor use. If the ratio of Parks Department indoor to outdoor use changes in the future, it would be appropriate to alter the values shown in Table 9.

The reduction in water usage for irrigation of parks properties at each drought stage can be expressed in terms of the maximum ET rate for bluegrass in the same manner as the allocation is set in non-drought years. In evaluating these numbers and how they translate into visual quality of parks landscaping, it is important to remember that an amount of water that meets 75% of the maximum ET rate is considered a 100% allocation in non-drought years because 70% of the maximum ET rate is sufficient to sustain a healthy bluegrass lawn. Also, as previously discussed, bluegrass can remain in a dormant state for months and recover readily with little long-term damage with as little as 50% of the maximum ET rate applied. Therefore, these water use allocations should provide for parks turf to remain green and healthy in Stage I, remain green though stressed in Stage II, remain alive though dormant in Stage III, and not die off until a Stage IV drought. As previously discussed, these restrictions on irrigation water availability should occur in from 10 to 25 years out of 300 years.

Table 9: Water use allocation levels for Parks Department

Drought Alert Stage	Annual Water Use Reduction Goal %	Parks Indoor Use Reduction %	Parks Irrigation Use Reduction %	Parks Irrigation Allocation %	% of Maximum ET
None	0	0	0	100	75
I	5	5	5	95	71
II	14	5	15	85	64
III	22	5	25	75	56
IV	40	10	45	55	41

WATER RATE ADJUSTMENTS

As discussed in the following section, the use of short term, but large rate increases in Blocks 2 and 3 of the water rate structure could support efforts to achieve short term demand reductions. In order to have any effect by itself, the rate increase would need to be in the order of 250% or more in these blocks to inspire a change in customers' water use behaviors.[19] In moderate droughts, these rate increases could reinforce the voluntary restrictions. Consumers would be free to use water when and how they chose, and the high prices for the water would be relied upon to curtail use. These rate increases would be classified as drought surcharges. They could be lifted once the drought abated. In more severe droughts, drought surcharges or other economic means are not likely to be sufficient to achieve the water use reductions required.

OTHER IDEAS

Additional ideas were offered during public hearings and focus group meetings. Although these ideas are not recommended, they are included here for documentation.

It was suggested that the city repeal the regulation that makes gaining access to water meters illegal. Allowing customers to access the water meter for their property could improve their understanding and awareness of their water use. However, the city has recently installed equipment for an Automated Meter Reading system throughout the city that was both expensive and easily damaged. The equipment is designed to send a signal to data-collection equipment operated by meter-reading personnel, even as they drive by, and has resulted in significant improvements in the efficiency of reading water meters. The meters are not designed to provide on-site readouts for customers.

Modifying the new equipment to provide a customer readout device would be expensive. In addition, allowing customer access to meters could cause increased maintenance problems with the new AMR system and could encourage tampering with the meter. If a customer desires a meter readout, he presently has the option of installing a personal meter on the incoming water line. This solution would not increase the responsibilities, workload or costs to the city utilities and all ratepayers for a special service that may only be desired by a few.

It was also suggested that, in a declared drought emergency, the city should implement a moratorium on new water taps in the city. It was believed that eliminating new demands on the water system would increase the amount of water available for existing city residents. Restriction of growth in the city is the decision-making province of the City Council. Implementation of such a serious action would require a City Council process and may require a very long time to implement during a drought.

EVALUATION OF WATER RATE STRUCTURES

This section is designed to provide basic information about water rates, various rate structures, and pricing impacts on water usage. The American Water Works Association's (AWWA) M1 manual 5th edition, Principals of Water Rates, Fees, and Charges is an excellent reference for more detailed information regarding water rate design. The AWWA is the association of water supply industry professionals that establishes professional standards for the operation of all aspects of municipal water supply systems.

This section also discusses Boulder's current water rate structure, how it compares to surrounding communities, potential billing enhancements to further encourage water conservation, and revenue management during a drought, including implementation of drought surcharges.

RATE DESIGN AND RATE STRUCTURES

In order to meet the fundamental goal of providing safe and reliable water to its customers, all water utilities must collect revenue sufficient to cover their operating and maintenance costs, meet debt service coverage requirements and fund designated reserves. The majority of the City of Boulder's water utility revenues are from water sales to customers.

The City of Boulder employs a cost-of-service methodology in designing water rates. The cost-of-service analysis normally consists of four steps, as adapted from AWWA M1

Manual: 1) definition of revenue requirements, 2) allocation of revenue requirements to functional cost components, 3) distribution of functional costs to customer classes, and 4) rate design.

A water rate structure is primarily a schedule of fees designed to recover costs. A rate structure is likely to support other goals such as yielding revenue in a stable manner, encouraging water conservation, and promoting fairness and equity to customers. There are two fundamental types of rate structures – (1) non-conservation oriented; and (2) conservation oriented.

Non-Conservation Oriented Rate Structures

Non-conservation oriented rate structures include uniform (flat) rates and declining block rates. These rate structures are some of the oldest still in use and are typically employed in areas where the amount of water available to be supplied is not a concern.

Uniform/Flat Rates

A uniform or flat rate is a "constant unit price for all metered volumetric units of water consumed on a year round basis" (AWWA M1, 2000). Under this rate structure each gallon of water costs the same amount to the customer. Uniform rates are simple to implement and understand and can be considered equitable because all customers pay the same price. Uniform rates can send a usage-based price signal because the customer bill does vary with the level of usage.

Declining Block Rates

"A declining or decreasing block rate is a rate structure in which the unit price of each succeeding block of usage is charged at a lower unit rate than the previous block" (AWWA M1, 2000). Declining block rates are sometimes used to encourage equity between customer classes and to provide quantity discounts to large uses. Declining block rates are generally perceived as promoting water consumption rather than conservation. This structure would not be appropriate for a community that hopes to encourage the efficient use of water through price signals.

Conservation Oriented Rate Structures

Conservation oriented rate structures are designed to provide a price signal to the customer that encourages water conservation. Boulder's current rate structure falls into this category. The goal of these structures is to encourage the efficient use of water by sending a clear price signal for high or excessive water use. At the same time many of these structures provide a measure of equity to low-income customers by keeping the cost for basic water service and fundamental indoor use fairly low.

Seasonal Rates

"A seasonal rate is a form of time-differentiated rate, or a rate that varies by time period. It establishes a higher price for water consumed during a utility's peak demand season, usually reflecting the increased costs of providing service" (AWWA M1, 2000). A seasonal rate can encourage outdoor conservation by charging more for water during the summer months than in the winter months. Seasonal rates are more complicated than uniform rates. Seasonal rates can do a good job of encouraging outdoor conservation, but may be less effective at promoting indoor efficiency through price signals.

Increasing Block Rates

Boulder's current rate structure is an increasing block structure. "Increasing block rates (also known as ascending, inclining, or inverted block rates) charge increasing volumetric rates for increasing consumption" (AWWA M1, 2000). Increasing block rates tend to be more complicated than uniform rates and revenues from water consumption in the higher priced blocks may be more volatile due to changes in weather or customer usage patterns. Utilities employing an increasing block structure usually have a healthy financial reserve to be drawn upon during periods of reduced water sales. Increasing block rates, when designed properly, encourage the efficient use of water by sending a strong price signal to high water users. A key decision when designing an increasing block rate structure is the break point between blocks where the price increases.

Water Budget Rates

A water budget rate system is an increasing block rate structure combined with customer-specific water budgets based on available water supplies and the indoor and outdoor requirements of each customer. This is a fairly new type of rate structure which has only been successfully implemented in a few communities, most notably Irvine, California. In a water budget rate system each customer is given an individual annual water budget (divided into monthly increments based on climate patterns). This budget is typically created by establishing an indoor use amount for each customer and then creating an outdoor use budget based on the specific landscape characteristics of the site. Customers pay substantially more for water use in excess of their established budget.

Water budget rate structures are an option for encouraging long-term conservation and enhancing drought management. They are more complex to design and manage than the city's current three tier rate structure based on AWC, but could be used to more equitably distribute water deficits during droughts and provide customers more flexibility in the use of the available water. The AWWA Rates and Charges Subcommittee does not consider this type of rate structure to be a standard industry practice and, therefore, elected not to reference it in the AWWA M1 Manual for standard rate-making practices. This position of the AWWA Subcommittee may be re-evaluated in the future.

Water budget rate structures may be more suited to communities that are under constant pressure to reduce water use (such as California cities that must reduce water use under the Colorado River Compact.) It is necessary to weigh the level of resources and personnel required to support this type of rate structure, the level of need for significant water use reductions in response to infrequent events such as drought. Appendix F provides more detailed information on a water budget rate system as used in the Irvine Ranch Water District in California. Information from other communities using this rate structure is limited.

The use of a water budget system in Boulder that is more complicated than the city's present AWC system would require the development of a new billing system. The current system does not have the configuration or flexibility to implement a water budget rate structure similar to that of Irvine Ranch. The Boulder City Council has approved a study of possible new water rate structures and the feasibility of implementing a new billing system. The study will include an evaluation of the cost-effectiveness of implementing a water budget rate structure, along with evaluation of other rate structures, including the cost of software development and of long-term management and data maintenance. A decision will then be made on the optimum rate structure to implement in conjunction with the installation of a new billing system.

Price Elasticity for Water

In designing water rates and projecting revenues from water sales, it is important to note the impact of price on water usage or demand. Price elasticity measures the responsiveness of demand or use of a commodity to changes in price. Because there is an inverse relationship between price and use, price elasticity coefficients have negative values. For example, an elasticity coefficient of –0.2 would indicate that a 10 percent increase in price would result in a 2 percent decrease in demand.

The precise relationship between water price and demand is difficult to pinpoint because of other factors involved such as temperature, rainfall, household income, inflation adjustments, property value, and value of landscaping. There have been many studies regarding the effects of price on water demand. In general the findings have been:

- Overall water demand is relatively price-inelastic (studies have shown values for residential demand ranging from -0.1 to -0.4).
- Seasonal (outdoor) demand is more price-elastic than nonseasonal (indoor) demand. Price increases are more likely to affect outdoor watering use than indoor use.
- Higher priced water is more elastic than lower priced water.

BOULDER'S CURRENT RATE STRUCTURE

The City's current rate structure for water is a three-block increasing structure and is designed to equitably distribute costs to customer classes and to encourage efficient use of water by charging a higher unit price for using more water. It is a cost-effective means of providing semi-tailored rates based on individual consumption patterns without incurring the increased cost and effort of a fully-individualized water budget rate structure.

Water charges are composed of two parts: a monthly service charge that is based on meter size and a quantity charge. The quantity charge, based on monthly meter readings, consists of three blocks of rates. As the amount of water use increases and moves into the next rate block, the cost per thousand gallons increases.

Average Winter Consumption (AWC)

Block thresholds are determined using the individual account's average winter consumption (AWC). The AWC is calculated using the actual water use reflected on the customer's December through March water bills. The AWC is used to determine the point at which water use moves into the next highest block and to assess wastewater commodity charges.

All consumption up to and including an account's AWC is billed at the Block 1 rate. Consumption greater than an account's AWC, but less than 350% of the account's AWC is billed at the block 2 rate. All consumption greater than 350% of an account's AWC is billed at the block 3 rate.

The only exception is made to protect smaller residential users, whose summer irrigation usage might otherwise be unreasonably constrained or expensive due to having a very low AWC or indoor usage. If a residential account's AWC is lower than the average AWC of all residential customers with the same meter size (also known as the customer class average – CCA), the CCA shall be used to determine the block thresholds for water quantity charges. The current water charges (2003) for an inside-city, single-family residential account are shown in Table 10.

Table 10: Current City of Boulder water rates

Service Charge	$8.12/month
Block 1	$1.65/1000 gallons
Block 2	$3.00/1000 gallons
Block 3	$4.40/1000 gallons

Figure 29 shows the percentage of water consumption for each block. Figure 30 shows the percent of water sales revenues derived from each block. Both Figures represent typical patterns in a non-drought year. Note that Figure 29 includes municipal water consumption that is not billed and therefore not represented in Figure 30.

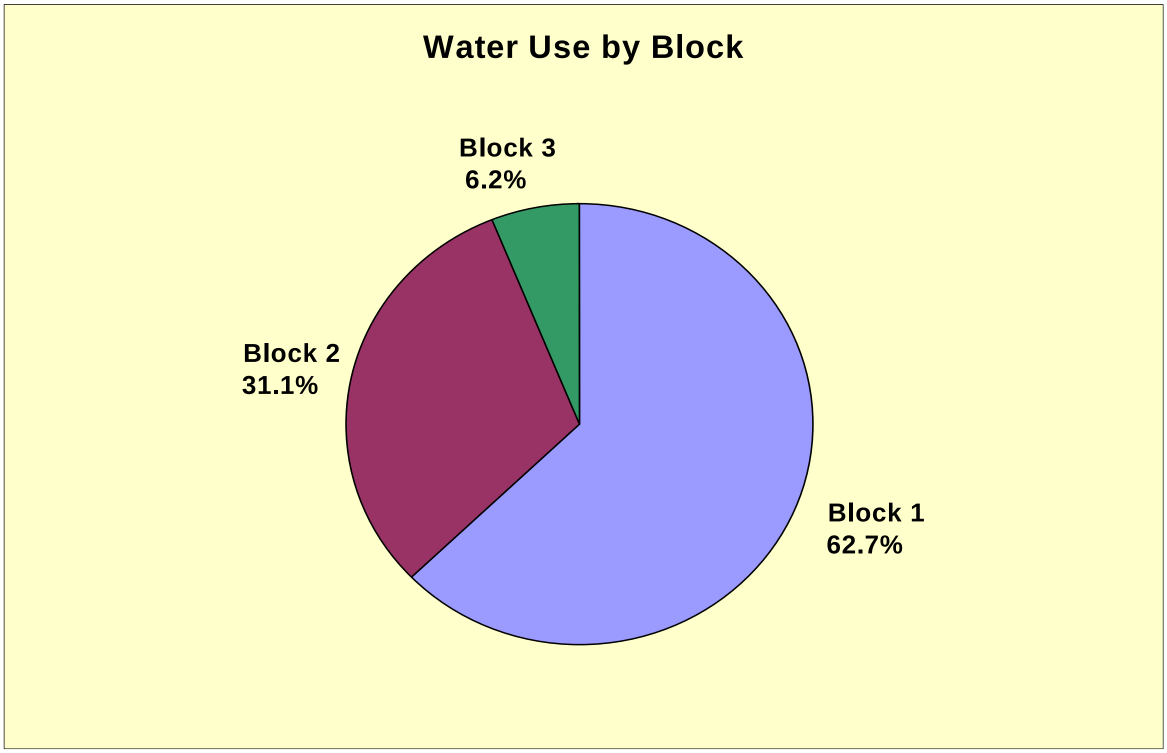


Figure 29: Percent of water use by block

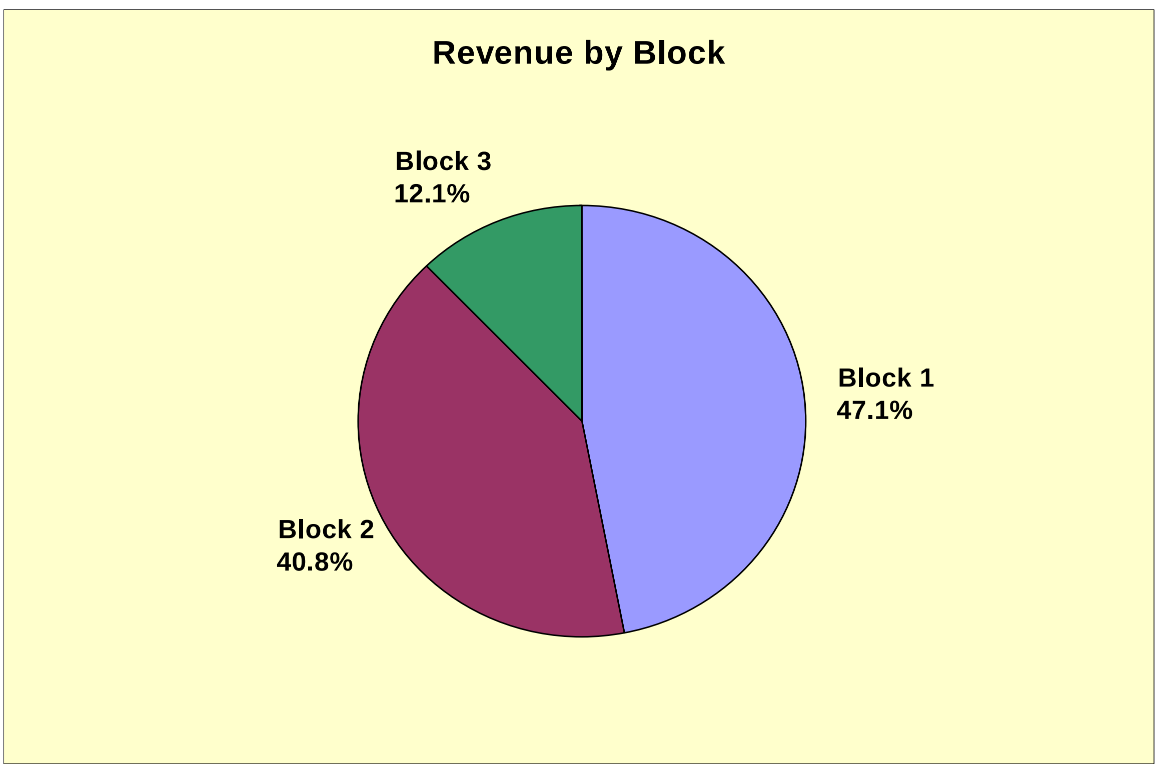


Figure 30: Percent of water sales revenue by block

COMPARISON TO RATE STRUCTURES OF OTHER FRONT-RANGE COMMUNITIES

Since Colorado is a semi-arid region, many communities use an increasing block rate structure to encourage efficient use of water. During 2002, as a response to the drought situation, Aurora and Colorado Springs changed from a flat rate to an increasing block rate and may continue using the block rate structure even after drought conditions subside. Other communities, such as Broomfield, Fort Collins, and Greeley are considering changing to an increasing block rate structure in 2003. Water rate structures for single family residential customers along the Colorado front-range area are summarized in Table 11.

Table 11: Water rate structures of front range communities

Community	Rate Structure	Number of Blocks	Block Threshold (in gallons)
Arvada	Increasing Block	2	0-30,000; > 30,000
Aurora	Increasing Block	3	0-15,000; 15,001-25,000; > 25,000
Boulder	**Increasing Block**	**3**	**Based on AWC**
Broomfield	Flat	n/a	n/a
Colorado Springs	Increasing Block	3	0-7,480; 7,481-22,440; > 22,441
Denver	Increasing Block	3	0-11,000;11,001-30,000; >30,000
Erie	Increasing Block	23	1st 3,000 included in monthly service fee; price change every 1,000 gallons to 26,000 gallons
Fort Collins	Flat	n/a	n/a
Greeley	Flat	n/a	n/a
Lafayette	Increasing Block	4	1st 5,000 included in monthly service fee; price change every 5,000 gallons to 20,000 gallons
Longmont	Increasing Block	3	0-10,000;10,001-20,000; >20,000
Louisville	Increasing Block	11	1st 7,000 included in monthly service fee; 7,001-15,000; 15,001-20,000; price change every 10,000 to 100,000 gallons
Northglenn	Increasing Block	2	0-12,000; >12,000
Superior	Increasing Block	3	0-20,000;20,001-30,000; >30,000
Thornton	Flat	n/a	n/a
Westminster	Increasing Block	3	0-4,000; 4,001-20,000; >20,000

Boulder's inclining block rate structure is unique in that the block thresholds are determined using each account's AWC as opposed to pre-determined thresholds. The first block, corresponding to each account's AWC, represents the amount of water normally used for indoor purposes. Block 2 is the amount of water used that is up to 3.5 times the Block 1 usage and is generally associated with a reasonable amount of water needed for outside purposes. Block 3 is the amount of water that is greater than 3.5 times the Block 1 usage and is generally associated with a large and possibly excessive use of outdoor water.

Enhancements to the Current AWC Rate Structure

There are several enhancements that could be made to the current billing system to further encourage efficient use of water regardless of drought conditions.

Change the Block Threshold

The threshold or break point for Block 2 and Block 3 could be adjusted downward to further encourage outdoor water conservation. Currently this threshold is 350% of each customer account's AWC. For example, this threshold could be reduced to 250% of AWC. That would effectively shrink the size of block 2 for all customers. As a result more water would be charged at the higher Block 3 rate, sending a stronger price signal for outdoor water usage.

"Capping" the AWC

It has been argued that customers can "manipulate the system" by increasing their indoor water use in the winter, thereby increasing the size of their Block 2 allotment for the summer. However, wastewater charges are assessed using the AWC. Therefore, if the customer tries to "manipulate the system" by increasing their AWC, the customer's total bill almost always ends up being higher because of the increase to wastewater fees. To illustrate, the following table shows water and sewer bills for customers with identical consumption patterns in the summer and fall, but different AWCs.

Although this type of manipulation is not in the customer's best interest, changes to the billing program could be made to safeguard against such activity. A condition could be added that "caps" the AWC of an account with an unusually high AWC to a value that is a reasonable percentage above the customer class AWC. This pre-determined number would then be used in calculating block thresholds, not the account's individual AWC. This would be applied to single-family residential, trailer parks, and multi-family single unit residential accounts. Several examples of water bills with varying consumption patterns are shown in Table 12.

Customers with a legitimately high AWC may perceive this "cap" as inequitable. Also, since the number of customers who attempt to manipulate their water bill is unknown, it is not clear whether the reprogramming costs and additional system complexity would be justified.

Table 12: Water bills at varying Average Winter Consumption levels

Consumption Pattern	AWC (in 1000s of gallons)	Water Bill	Sewer Bill	Total Water and Sewer Bill
A	5	$371.44	$119.16	$490.60
A	8	$359.89	$177.13	$537.02
B	3	$335.74	$ 74.28	$410.02
B	5	$348.54	$117.29	$465.83
C	8	$454.64	$186.48	$641.12
C	11	$445.09	$250.06	$695.15
C	14	$445.54	$300.55	$746.09

Pre-determined Block Thresholds

If the City wished to replace the use of AWC in determining water block thresholds, but keep the inclining block rate structure, pre-determined thresholds could be assigned. This initially would be applied to single-family residential and multi-family residential single unit accounts. Consumption data would be analyzed to determine the appropriate breakpoints. This would then fix the Block 1, 2, and 3 break points for all customers, regardless of household size, lot size, or vegetation needs. This system would be simpler to implement, explain and understand by customers than the current system. However, it would eliminate all customization for individual accounts.

REVENUE MANAGEMENT DURING A DROUGHT

During a drought, the major objective is to quickly reduce the water demand and conserve water. This is generally accomplished through voluntary or mandatory watering restrictions, terminating water delivery to secondary customers, increasing water rates or adding surcharges, or some combination of these activities. Customer acceptance and cooperation is essential to the success of any drought response approach.

Revenue Needs

Revenues from monthly water user fees account for approximately 70% of the city water utility's annual revenue. When water sales decline, so do revenues but there is generally not a corresponding drop in expenditures. In fact there may be additional costs associated with drought response such as enforcement and monitoring. Only a minimal amount of the water utility's operating costs are variable. In times of a significant revenue shortfall it may not be possible to reduce expenditures by a corresponding amount. Capital projects may be delayed for a year or two, but generally cannot be eliminated without jeopardizing water quality or reliability of the water delivery system.

A utility may draw upon its financial reserves when revenues are down. Currently the City of Boulder's water utility maintains a 20% operating reserve that is available to offset revenue shortfalls or to fund unanticipated expenditures.

Also, when revenues are down it is important to ensure that bond coverage requirements continue to be met. Through its bond covenants, the City's utilities are required, on an annual basis, to generate net revenues (total revenues minus operating expenditures) before debt service, equal to a minimum of 1.25 times its annual debt service requirements. Therefore, it is important that the water utility's financial position be monitored closely during a drought period and if necessary implement rate changes to generate necessary revenues.

Drought Surcharge

Drought surcharges may be in the form of a separate charge or an increase to existing rates. The surcharge is designed to provide revenues to the utility during a drought period and also convey a price signal or message that can assist in influencing water usage. From an economic standpoint, the exact amount of the surcharge would need to be evaluated closer to the time of implementation in order to take into consideration all aspects of the utility's financial position (e.g. available reserves, overall revenue status).

Public education and information is very important when implementing surcharges. Customers may view the surcharges as punitive. It can be difficult to explain why surcharges are being implemented to customers who are being asked to use less and pay more.

Because of the price elasticity of water, a surcharge implemented to reduce demand significantly would need to be very large. This concept is highlighted in an article written by Charles Howe, emeritus professor of economics at the University of Colorado. His article appeared in the October 2002 edition of the American Water Works Association Journal and discussed Boulder's drought response and water rates. In this article, Howe examined the water savings achieved in Boulder in 2002 through the watering restriction program and using his measurements of price elasticity, estimated the change in price required in Boulder's Block 2 and Block 3 rates to accomplish the same reduction. Howe concludes, "the price increases needed to cause significant reductions already caused by watering restrictions will have to be large (+100% for Boulder's Block 2 and +200% for Block 3) and even with those price increases only part of the households will reduce their demand in response to the price increase." The complete text of Howe's article appears in Appendix E.

Pricing is one tool that may be used to influence water use behavior and in moderate droughts may be an effective water use reduction strategy used only in conjunction with education efforts. However, in more severe droughts, implementing a surcharge alone probably will not influence people's behavior enough to provide the necessary demand reductions, as was experienced by other Denver metro area communities trying this approach to dealing with the 2002 drought. Pricing is one tool to influence behavior, but should be used in conjunction with other programs such as public education, voluntary or mandatory restrictions to achieve its full potential.

POTENTIAL LONG-TERM STRATEGIES FOR INCREASING WATER SUPPLY

The results of Boulder's water supply reliability assessment show that, with investments in water conservation and expansion of the Boulder Reservoir treatment plant's effective capacity, Boulder's water supply system can meet Boulder's projected build-out demands in a manner consistent with the city's reliability criteria, with a margin of safety. However, there are several areas of uncertainty associated with this finding, including potential effects of climate change, unexpected additional growth, unforeseen water-intensive uses, environmental needs, etc. It is therefore worthwhile for Boulder to consider a range of long-term strategies for increasing the city's water supply.

ACQUIRE WATER RIGHTS

Boulder should continue to acquire appropriate Boulder Creek water rights and change them to municipal use on Middle Boulder Creek at Barker Reservoir and the Barker Gravity Line. However, instream flow rights on Boulder Creek somewhat limit the utility of this strategy. Only those water rights that can reliably divert during May through July of average and relatively dry years should be acquired. This strategy has considerable merit because most of Boulder's Middle Boulder Creek water rights are relatively junior and Boulder must divert most of its water from Middle Boulder Creek during average and dry years by exchange using Boulder's CBT supplies. Acquiring more Boulder Creek rights would help Boulder conserve its CBT supplies during extended drought periods, when CBT supplies may be a limiting factor.

Boulder could also acquire more CBT shares in order to increase its overall CBT supplies during extended dry periods. This would serve the same function as acquiring more Boulder Creek rights. Boulder's choice between acquiring more CBT supplies versus Boulder Creek rights should therefore be based upon economic and yield tradeoffs between these two sources.

BUILD/REBUILD STORAGE

Building reservoirs to store water during runoff for use during seasonal low flow periods and for longer-term drought protection has long been the primary strategy of water users throughout the West. This strategy has proven to be effective in increasing the amount of reliable water supply for cities and agriculture. However, the monetary, environmental and social costs of reservoir development have always been high, and even a large amount of storage development is not a panacea for extended and severe droughts.

Potential storage sites in the Boulder Creek basin were extensively inventoried by the U.S. Bureau of Reclamation in the 1940s and 1950's, and few feasible sires were identified at that time, even without today's environmental and land use realities.

As a factual matter, there are no 'easy' storage development sites in the Boulder Creek basin upstream of Boulder's points of diversion, and storage development at the remaining few theoretically feasible sites would be severely constrained by environmental, land use/land ownership and relocation issues.

However, Boulder does have some legitimate storage development options that could be part of long-term supply development strategy.

- Boulder could reconstruct Green Lake No. 2 in the Silver Lake Watershed. Green Lake No. 2 was used by the city for water supply storage until 1986 when it was breached due to dam safety concerns. Boulder already owns storage rights for Green Lake No. 2 in the amount of 333 acre-feet of capacity. Rebuilding Green Lake No. 2 would increase the city's critical stored supply upstream of its diversion points.

- Boulder owns Skyscraper Reservoir, located on Woodland Creek within the Indian Peaks Wilderness area. Skyscraper's current storage capacity is 146 acre-feet. While the reservoir is nominally functional, the city does not actively operate it because of its remote location and small size. Instead, Boulder has informally relied on Skyscraper as a 'reservoir of last resort' for extreme droughts. Boulder should formally incorporate the operation of Skyscraper Reservoir into its water supply system on a normal basis.

- Boulder owns a 3,000 acre-foot conditional storage right for the Park Reservoir site, which is located on Caribou Creek, a tributary of North Boulder Creek upstream of the Lakewood Reservoir inlet. Previous studies indicated that new storage at this location would marginally increase the reliability of the city's water supply system. However, the site is situated within one of the largest willow carr-type wetlands in Boulder County. The site also contains one of the most popular off-road 4-wheeling areas in the county.

- Boulder owns the Wittemeyer Ponds, a series of excavated and unlined gravel pits located adjacent to Boulder Creek just west of the Weld County line. Boulder could line and develop these pits in order to store water that could be exchanged upstream to Boulder's municipal points of diversion.

- Boulder owns 37 units of the Windy Gap project, equivalent to 3,700 acre-feet of average deliveries. However, Windy Gap's water rights are very junior and the project does not provide any reliable yield during droughts. Boulder can firm up about 1/3rd of its Windy Gap water in its long-term storage account in Boulder Reservoir. Several Windy Gap participants are planning to construct a firming reservoir or reservoirs at several potential locations adjacent to existing CBT project reservoirs. It may be worthwhile for Boulder to participate in this project as a means for firming up the remainder of its Windy Gap supplies.

NONPOTABLE WATER USE

In response to this year's drought conditions and Boulder's watering restriction program, there has been much interest voiced in various ways to reduce treated water use within the city. Ideas such as household greywater reuse, rain barrel storage of rooftop runoff, a city-wide reuse system, increased use of ditch water for park irrigation and groundwater use were brought up.

Rainbarrel Storage of Rooftop Runoff

Several concerned citizens thought it would be a good idea for homeowners to capture rooftop runoff in rainbarrels in order to partially meet water needs for landscaping. Unfortunately such practice is probably illegal under Colorado water law. The State Engineer has stated that capturing rain runoff in rain barrels represents an unlawful diversion of water that is a part of the stream system and that should be administered according to the priority system. The city is unable to authorize or promote rain barrels for this reason.

Even if rain barrels were legal in Boulder, the amount and frequency of rain in the summer make them a doubtful proposition at best when a cost benefit analysis is performed. For example, a 55 gallon barrel filled once a week would supply less than 5% of the water needs for an 800 square foot lawn. During a drought period when precipitation is limited, it is unlikely that even this much water could be captured.

Water Reuse

The broad concept of water reuse covers several ideas ranging from household greywater use to a city-wide reuse system supplying large irrigated areas.

There are important legal restrictions common to all reuse options. Under Colorado water law, water rights are created on the basis of an applicant's intended beneficial use. The return flows from that beneficial use are normally considered part of the allocable supply in the stream available to other water rights. Colorado water law therefore prohibits reuse of water, except for the following situations.

- Water diverted under a water right was originally decreed to allow for such reuse.

- Groundwater pumped from nontributary aquifers is generally reusable because this type of groundwater is not part of the natural stream system.

- Water imported from another stream basin is generally reusable because of its 'foreign' nature with respect to the receiving basin. However, CBT project water <u>cannot</u> be reused due to specific project restrictions that assure that farmers on the lower South Platte, who helped pay for the project but are located far from project facilities, would receive the benefit of increased return flows.

- Changed water rights whose diversions are limited to the amount of water that was historically consumed in the original use. In this case, the changed water right is diverting water that was historically lost from the system via beneficial consumptive use. Other water rights are therefore not entitled to the return flows from such a changed water right.

Most of Boulder's water rights are decreed for municipal use on a one-use basis only. The only significant exception is Boulder's Windy Gap rights. Windy Gap water is imported from the Colorado River Basin and its return flows are fully consumable. While Boulder owns an average supply of 3,700 AF of Windy Gap water, this supply is not reliable during droughts due to Windy Gap's junior water rights. Boulder can firm up about one-third of its Windy Gap water in its long-term storage account in Boulder Reservoir and through exchange to Barker Reservoir.

Boulder also owns a several changed irrigation rights associated with the North Boulder Farmers Ditch, the Lower Boulder Ditch and Baseline Reservoir. Boulder changed these rights to allow for reuse of that water to extinction. However, the amount of net reusable water provided by these rights is relatively small.

In order to implement a large scale reuse system, Boulder would have to firm up some or all of its Windy Gap water and develop an augmentation plan based upon its Windy Gap supplies.

Household Greywater Systems

Some citizens have requested information on greywater systems with the belief that reuse of household greywater would be an effective way to conserve water and reduce the impacts of droughts. Household greywater reuse typically involves manually capturing rinse water from sinks, washing machines, tubs and showers and using that water for landscaping irrigation. While a few 'designed' household greywater systems have been built in urban settings, most have fallen into disuse because of maintenance requirements and the relative ease of treated water options.

A brief analysis of household greywater potential shows that very aggressive promotion of this water source (active participation by 20% of Boulder's single family households capturing 20% of their total indoor use) could probably meet up to 70 acre-feet of the city's 24,000 acre-feet of treated water demand per year. Realistically, both of these assumptions are probably extreme upper limits given the labor and time-intensive nature of greywater capture and reuse. More realistically speaking, a minor and informal level of household greywater reuse normally goes on during periods of watering restrictions.

The city cannot formally support or organize household greywater reuse on either level without first developing an augmentation plan and obtaining a Water Court decree allowing the use in order to avoid injury to other water rights. In addition, public health concerns would need to be addressed. While it would be possible for the city to do this, the costs would probably be prohibitive given the insignificant water savings potential.

Water Rights Considerations with Greywater Use

Colorado operates under the Appropriation Doctrine for administration of its water. This means that the right to divert water from the stream for use is determined based on ownership of water rights. Each water right has its own characteristics including its priority date (which determines when water is allowed to be diverted under a water right as compared to other more junior or senior water rights), its flowrate or volume limitations, its possible uses, its diversion point, and whether or not it carries the right to reuse water after the first use under the diversion. If any of these characteristics are changed, other water users on the stream have the right to review the proposed changes before they are approved by the Water Court in order to make sure that they are not injured by the changes. Other water users have this right because the diversions and return flows from one water use directly affect other water rights. The frequently-used saying is that "One person's return flow is another person's water right."

If the amount of water returning to the river from one water user's diversions is reduced from the historic levels, it might cause less water to be available to another water user who has depended on the return flow for a long period of time. This is why water cannot be reused by the original diverter after the water's initial use for its decreed purpose unless the water right specifically states that reuse is allowed. Water not consumed by the first user is not "wasted". It will be used by diverters downstream who have the legal right to expect that the unconsumed portion of the first use will become available to them. In this manner, Colorado's water allocation system has a built-in reuse system that assures no water goes to waste.

Most of the city of Boulder's water rights are decreed for municipal use on a one-use basis only. The return flows from the city's single use are part of the allocable supply available to other water rights once discharged from the wastewater plant or returned to the stream from lawn irrigation. The only exceptions are water owned by Boulder in the Windy Gap Project, and a small amount of Boulder's recently changed North Boulder Farmers and Lower Boulder Ditch water rights. When the city uses water under these rights, the city is entitled to claim ownership of the water remaining after the first use either for crediting against new diversions into the municipal system or for leasing to water users downstream.

Household greywater systems would have the effect of increasing depletions to Boulder Creek below 75th Street by increasing the consumed portion of Boulder's municipal water supply. Consumed water is water that is not sent to the water treatment plant, treated, and then put back into Boulder Creek for others downstream to use. Any change of the historic return flow pattern of Boulder's water system, including extensive use of greywater, has the potential to cause a decrease in the historic return flows to other users. This could trigger a "call" on the river for water by senior water rights owners and force Boulder to pass water that the city could otherwise divert under more junior water rights if the senior users had been satisfied by return flows. In the longer-term, promotion of greywater systems by the city has the potential to trigger a reopening of many of the city's water decrees with imposition of new terms and conditions on Boulder's ability to divert water into the municipal water system. Therefore, if the city were to actively promote use of household greywater systems, it could cause the ironic effect of reducing the total amount of water available to divert into the municipal system.

Water users downstream are entitled to the historic amount of return flow whether it is obtained from return flows from city water customers or from decreases in the city's initial water diversions. In the end, no water is "saved" either for the city or the stream through use of household greywater systems.

Boulder has an extensive reuse system and de facto greywater system already in place in the form of downstream senior water rights that divert Boulder's wastewater and put it to use. In this manner, Boulder's return flows help to meet the needs of downstream water rights, thereby increasing the city's ability to divert in priority upstream. In addition, this existing reuse system is based on discharges of treated wastewater from the treatment plant delivered to downstream users and meets all state permitting requirements. Assuring the quality of wastewater from greywater systems may be difficult and would not provide the same protections to human health as reuse through the city's wastewater plant.

Public Health Considerations with Greywater Use

The State of Colorado has a regulatory framework for regulating individual sewage disposal systems (ISDS) which is how greywater systems would be classified. The state has adopted the Individual Sewage Disposal Systems Act, (the "ISDS Act") that sets the minimum standards for individual sewage disposal systems. See C.R.S. § 25-10-101 et seq. The Colorado Legislature directed the State Department of Public Health and Environment to adopt guidelines that set the minimum standards that County Health Departments are supposed to meet when they develop these standards. See § 24-10-104, C.R.S. The standards of the local health board are required to be no less stringent than the State ISDS guidelines. See § 24-10-104(2), C.R.S. and State ISDS Guidelines, § II.A. and

The State Department of Public Health and Environment has adopted guidelines for regulating the ISDS permitting process. That document is called "Guidelines on Individual Sewage Disposal Systems - Revised 2000" (the "State ISDS Guidelines") This document contains the minimum standards that should be included in local regulations related to ISDS permits. The State ISDS Guidelines require that a greywater system "shall meet at least all minimum design and construction standards for a septic tank system . . ." See State ISDS Guidelines, § VIII.D.1.

Boulder County has adopted ISDS regulations that comply with the State ISDS Guidelines. Therefore, a person that would like to install a graywater system within Boulder County would need an individual sewage disposal system ("ISDS") permit from the County.

Typically, there would be two components with a permit, the design of the system and monitoring of the effluent. The system is required to be designed by a registered professional engineer. §7.01 BCISDS Regulations. The effluent from the system would have to meet a number of minimum performance standards related to the content of the effluent. The items include fecal coliform, biological oxygen demand, and total suspended solids. §7.02 BCISDS Regulations.

The components of a graywater system would include some type of collection area. Treatment of the effluent would typically include a process where by solids would be allowed to settle out; some type of filtration system; and then some type of disinfection or treatment of the effluent.

Finally, there are testing and monitoring requirements. The regulations require weekly monitoring of the effluent. Iris estimated that the cost for such tests are about $75 to $100 per test.

Fecal coliform and virus are often found in graywater systems, even when the toilets are not connected into the system. The level of pathogen concentration in the discharge from a typical graywater system, that may include collection from sinks and bathtubs, washing machines, and dishwashers, can be quite high. The county has found that there is little difference, from a public health perspective between greywater and waste water.

If a system exceeds 3000 gallons per day, or averages over 2000 gallons per day, additional approval is required from the Colorado Department of Public Health and Environment §1.02(F) BCISDS Regulations.

City-wide Reuse System

Developing a city-wide reuse system for irrigating large areas would be theoretically feasible but practically cost-prohibitive. There are relatively few large irrigated areas that receive raw or untreated water from the city and they are dispersed throughout the city.

Raw Water Ditch Supply

A significant amount of urban irrigation use within the City is already being supplied by ditch water: the CU campus, NOAA/NIST, several Boulder Valley School District properties, Long's Gardens and numerous private shareholders along several ditches. Ditch irrigation of the proposed Valmont Park is already being planned for. Farmers Ditch water rights could potentially be acquired and used to irrigate North Boulder Park and Pleasantview Soccer Fields.

MUNICIPAL WELLS

Groundwater resources in the Boulder Valley are relatively limited. Boulder's development of groundwater on a municipal level would require an extensive and costly augmentation plan and would not significantly increase the yield of the city's water supply system. Municipal development of groundwater could also impact individual well users in the Boulder Valley.

APPENDIX A

PARKS AND RECREATION DROUGHT RESPONSE PLAN

APPENDIX B

TRANSPORTATION LANDSCAPE GUIDELINES—SECTION 8

APPENDIX C

"THE WILD CARD IN THE CLIMATE CHANGE DEBATE," ISSUES IN SCIENCE AND TECHNOLOGY, SUMMER 2001

The Wild Card in the Climate Change Debate

ALEXANDER E. MACDONALD

The potential for abrupt, drastic climate changes on a regional scale is being underestimated by policymakers.

The debate on global warming, framed on one side by those who see a long-term gradual warming of global surface temperatures and on the other side by those who see only small and potentially beneficial changes, misses a very important possibility. A real threat is that the greenhouse effect may trigger unexpected climate changes on a regional scale and that such changes may happen fairly quickly, last for a long time, and bring devastating consequences. Yet, U.S. and global programs designed to study human-caused climate change do not adequately address this regional threat. The nation needs to develop a larger, more comprehensive, and better focused set of programs to improve our ability to predict regional climate change.

If emissions of greenhouse gases continue to grow as they have, several regional surprises are possible during this century. Summers may become much drier in the mid-continents of North America and Eurasia, with the potential to devastate some of the earth's most productive agricultural areas. The Arctic ice cap may disappear, a profound blow to a unique and fragile ecosystem. The Atlantic Ocean currents that warm Europe may be disrupted. The West Antarctic Ice Sheet may collapse, leading to a rise in sea level around the world.

Regional changes such as these are seen in studies that examine the long-term climate effects that would accompany the quadrupling of atmospheric carbon dioxide, projected for the middle of the next century if current trends continue. Although each of these climate scenarios is individually unlikely, the chance that one or more major regional changes will occur is probably quite high. Numerous studies of past climate have shown a tendency of regional climate to shift rapidly from one state to a radically different one. This characteristic behavior of geophysical systems--to generate abrupt climate changes rapidly over limited areas--makes the threat of anthropogenic global change much greater and more urgent than it is currently perceived to be.

Proclivity for abrupt change

To understand why large, abrupt climate change over limited areas is more likely than uniform gradual changes over the whole globe, we need to examine the laws that govern the solids and fluids that envelope the earth. First, the earth's geophysical and biological systems operate in a nonlinear fashion, exemplified in the way the wind blows itself: An area of high winds and cold temperature will blow toward an area with calm winds and warm temperatures. The place where the air masses converge is called a front, bringing temperature differences that originally extended over 1,000 miles into a zone just 30 miles across. A second key characteristic of the earth's systems is internal feedback. For example, a large area of snow cover is nature's way of generating very low temperatures. Snow is both an excellent reflector of the sun's rays and an excellent radiator of energy away from its surface. Thus, the effect of snow over a significant area is to generate a large decrease in temperature in as little as a couple of days. When the air and ground are too warm for snow, a response to forcing, such as the seasonal decrease of solar radiation, is gradual. However, a threshold is crossed when the ground and air become cool enough to support snow cover. All at once, much lower temperatures can occur and be sustained over large areas. We see this behavior in weather every fall, when weeks of warm weather are terminated by a cold front that drops temperatures 30 degrees or more.

The proclivity for crossing the threshold from gradual to large change is typical of the climate system as well as the weather system, for the same reasons. The Arctic ice cap is a case in point. When spring arrives, the Arctic Ocean is covered with ice. By early summer, the periphery is open water, with breaks in the ice and pools of water on top of some of the ice. Sea ice rejects up to 80 percent of solar heating by reflection, whereas water absorbs 80 to 90 percent. This is a powerful feedback: The open water captures heat in the continuous summer sunlight that acts to melt more ice and create more open water.

The melting of the Arctic ice may already be well under way. A study by University of Washington researchers found that the cap's average thickness at the end of the summer declined from more than 10 feet in the 1950s to about 6 feet in the late 1990s. If the melting were to continue at this rate, we would expect the Arctic to become open by about 2060. But as noted above, linear extrapolation almost never works in weather and climate prediction. If feedback effects are causing the current thinning, it is conceivable that the ice could be gone in a few decades. More typically, calculations such as those performed with the Geophysical Fluid Dynamics Laboratory (GFDL) climate model, which may underestimate the feedback effect, require a quadrupling of carbon dioxide and several hundred years to eliminate the ice pack.

It would be hard to overstate the many ramifications of an open Arctic Ocean. Certainly, people will see advantages in livability (if warmer weather is regarded as better) and in greater opportunities for shipping, while also wondering about the geopolitical implications of Europe, Russia, Canada, and the United States sharing a new open ocean. One thing is certain: The biological makeup of the high latitudes of the Northern Hemisphere would be profoundly changed. Populations of humans, small and large mammals, fish and other ocean dwellers, and birds would face a rate of environmental change unlike any seen since the end of the last ice age. The potential wholesale disappearance of polar habitat and the associated loss of species that are highly adapted to the cold and ice are probably the most important issues.

Another scenario under which abrupt regional climate change could occur is the possible change in the circulation of the Atlantic Ocean. Currently, warm, salty water flows northward along the coasts of the United States and Europe into the far northern Atlantic on both sides of Greenland. Here, the water is cooled to the point that it becomes convectively unstable--the top water is denser than that below and thus sinks deep into the ocean. This deepwater zone is a key to maintaining the northward flow of warm water; cessation of this process would bring the Atlantic conveyor belt to a halt. Such a halt appears to have occurred suddenly 12,000 years ago, resulting in a 15-degree temperature drop in Europe. Some climate models predict it will happen again as the earth continues to warm. In this scenario, warm water sequestered in the southeast Atlantic would warm the adjacent land (the United States), while a decrease in warm currents would cool the lands downwind of the North Atlantic (Europe). The conveyor belt's halt could occur, for example, with an average global surface temperate increase of 3 degrees F but be consistent with a much greater regional change. As a result, an area of Europe could be 7 degrees colder than today whereas an equal area of the United States could be 13 degrees warmer. This particular lose-lose scenario would be devastating for agriculture on both continents.

Current funding for climate change programs is skewed toward earth-observing satellites.

Some of the regional climate change scenarios could interact with other regional changes. It is valuable to ask why central Australia is dominated by desert, whereas the North America interior is the richest agricultural land in the world. Australia is somewhat closer to the equator, which results in subtropical sinking air causing increased surface heating and evaporation. The temperatures become so high that the moisture is baked out at the beginning of the growing season. In many of the global warming scenarios, this process would operate in the U.S. interior. For the great agricultural zone that extends from the eastern slope of the Rockies to the Atlantic, the GFDL model predicts a 30 percent reduction in soil moisture for a doubling of carbon dioxide (shortly after mid-century) and a 60 percent reduction for a quadrupling (in the next century). Loss of the Arctic ice cap would change the amount of cool air entering North America, whereas a warmer Atlantic ocean would increase summer convection adjacent to the eastern half of the United States. Both of these changes would make North America more like Australia. It should be pointed out, however, that not all the models predict the creation of a permanent dustbowl in the eastern United States. Some predict increased precipitation.

I was once told that the 60 percent reduction in eastern U.S. summer soil moisture seen in the GFDL model was not a serious worry. "If it happens," I was assured, "we'll just have to irrigate the place." Others may not take nature's richest gift to the North American continent so lightly. The prospect of summer dryness, with its associated large impact on U.S. agriculture, should capture the attention of policymakers. And such a change would not be short lived. A reasonable timescale for this new dust bowl would be hundreds to thousands of years.

Currently, there is agreement neither among the models nor the scientific experts about the likelihood of these regional climate changes; they must be regarded as low-probability possibilities. Then again, it is unlikely that there will be a fire in your house in the middle of the night. Yet you protect yourself against this low-probability event by installing smoke detectors. Highly credible climate models could be our global change smoke detectors. The regional changes described above may have a low probability, but we should do everything possible to predict them while we have time to act.

Predicting climate change

Recently the Intergovernmental Panel on Climate Change (IPCC) issued its Third Assessment Report. It projected a global temperature increase of 2.5 to 10.4 degrees F between 1990 and 2100, based on scenarios of greenhouse gas emissions and a number of climate models. My experience as a weather forecaster leads me to believe that human intuition cannot compete with the millions or trillions of calculations that can be applied in a modern climate model. Yet the models produce disparate results, with one group predicting warming of 3 to 4 degrees F and another of 8 degrees. Differences in how the models handle internal feedback, such as the cooling caused by increasing cloudiness, is the reason for the different projections. With current capabilities, we can't know whether those who say that feedbacks such as clouds will keep global change minimal are correct. Weather predictions have improved over the years because of better observations, more realistic descriptions of the physics of clouds and radiation, and faster computers. A similar approach is the only viable route to the answers we need on global change.

It is my belief that reliable prediction of climate change can be achieved in the early decades of the 21st century. Climate, unlike weather, is not inherently unpredictable beyond certain periods. Weather is unpredictable because a very small change in initial conditions can be shown to result in a large change at a later time (a few months). Climate, even with its feedbacks, is a forced system that does reach an equilibrium based on the balance of its forcing factors such as solar radiation. For example, St. Louis has a summer climate that is similar to the year-round climate of Iquitos, Peru, in the Amazon basin. However, it is easy to predict that St. Louis will be much colder than Iquitos in January; the decrease in solar radiation is a highly predictable forcing, augmented by feedback effects such as snow cover. Our regional climate models will be reliable when the estimates of forcing, such as that due to carbon dioxide, and the estimates of feedbacks are properly accommodated. It is both feasible and compelling to design a comprehensive global program to determine the future forcing and feedbacks that will cause regional climate changes.

Fortunately, the science and technology needed to provide answers is rapidly advancing. Progress will require directed and intensive efforts in three main areas: observations, physical understanding (resulting from research), and modeling. In each of these areas, the sum of global efforts is substantial but far below that dictated by the urgency of the threat.

The importance of in situ monitoring

There are both strengths and weaknesses in the current global observational system. After National Aeronautics and Space Administration (NASA) scientist James Hansen's eye-opening congressional testimony about global warming during the hot, dry summer of 1988, the United States and other countries have spent about $3.25 billion per year on research and equipment designed to understand global change. About 60 percent of this has gone into satellite programs. In FY 1999, the United States spent about $1.85 billion on global change, with NASA's earth-observing satellite program funded at $1.1 billion and the National Oceanic and Atmospheric Administration's operational geostationary and polar orbiters funded at $500 million. Satellites have the advantage of perspective: A geostationary satellite continuously scans an entire hemisphere; a polar orbiter looks at the entire earth sequentially. It is eminently reasonable that the response of the political system was to put funds into the earth-observing satellite programs. These investments have provided rich rewards, including the continuous tracking of global sea surface temperatures, the ability of true color satellites to determine ocean and land surface biology over much of the globe, and microwave sensors that can determine average temperature for deep atmospheric layers and distinguish open water from ice.

The great strength of satellites, their overarching view of the planet, is counterbalanced by their great weakness: They are far from the substances (air, land, water) they are trying to measure. Scientifically, the best combination is often to use the satellite and an in situ sensor (one that is in the air or the ocean), with the satellite painting a broad and comprehensive picture and the in situ sensors providing calibration and necessary detail. For example, the top and horizontal size of a cloud of dust is easy to determine from a satellite, but only an in situ sensor such as an aircraft can determine the depth of the cloud and the size and type of dust particles. In trying to determine the fate of the Arctic ice, only in situ sensors are capable of measuring the most important geophysical parameters: the detailed temperature, humidity, and wind in the boundary layer just above the ice, and the temperature and interaction of the water immediately below the ice.

A new global system of in situ sensors is imperative for understanding regional climate change.

In recent years, a variety of in situ sensors have been developed, though the use of these sensors has been stingily funded compared to satellites. In the ocean, in situ sensors such as surface-based buoys with tethers and autonomous vehicles that cruise the subsurface are beginning to be used to measure variables such as temperature, salinity, and current beneath the surface. In the atmosphere, new unmanned aircraft and balloons that can cruise the stratosphere for months and drop instruments in various locations are being deployed to take measurements in the atmosphere and the ocean. If used more extensively, these in situ systems could provide a powerful boost to our understanding of the earth's weather, climate, and chemistry.

Although we do have a global system of balloons that take atmospheric measurements, it was designed for weather forecasting, not climate prediction. Nevertheless, it is the best tool we have for detection of climate trends above the Earth's surface. However, these measurements have been taken mainly in rich countries, leaving the great bulk of the earth's area--the oceans, polar areas, and Africa and South America--essentially unobserved. Trying to discern climate trends with the existing network is like a drunk looking for his lost wallet beneath the only lamppost in the mile between his house and the bar. It is now possible to field a global array of stratospheric aircraft and balloons that drop climate-quality instruments at a few hundred locations equally distributed over the globe. Such a system could be in place by the time of the next polar orbiters, scheduled for late in the decade, although so far it has received minimal support. Development and operation of such a system would costs about $1 billion per year, which could be shared among the leading industrial nations. If we are going to understand regional climate change, this system is imperative. In addition to its value for climate prediction, the in situ system would also significantly improve weather forecasts.

The program discussed above differs greatly from the existing and planned efforts. Currently, many programs to measure regional change are episodic; an expedition is mounted to a geographic area of interest, such as the tropical Pacific or the Antarctic, and the data are collected for a year or so. Although these are certainly worthwhile, they do not capture the key attribute of interest: the change with time of the global state. Nor is it adequate to take measurements only where scientists expect problems; changes may occur where they are least expected. The global system operates as a giant clock, with toothed wheels of many sizes, each physically connected to the others. Thus, prediction of change for the United States will require knowledge of change as it occurs across the globe.

Bolstering research and modeling

Jerry Mahlman, the recently retired director of GFDL, has for years spoken eloquently about the dangers of climate change. One of his most important points bears repeating: The political system seems more willing to invest in hardware than in "brainware." In other words, support for scientists is often crowded out by the investment in big systems. The investment in climate research, now about $800 million per year, could usefully be doubled. If our goal is much faster and better understanding of global change, it is clear that more support for scientists must be forthcoming. The final leg of the three-legged stool needed to support prediction of regional climate change is modeling. The exponential growth of computer power has spurred vast improvements in climate models, but even now the physical effects are incorporated in a simple fashion in climate models compared to the way they are used in weather models. New efforts that focus on modeling regional change, such as the community efforts led by the National Center for Atmospheric Research, would benefit from substantial increases in resources.

Above all, a directed program of research focusing on regional climate change is essential. Although the U. S. Global Change Research Program has coordinated an excellent suite of programs in a variety of federal agencies, the end result has been something akin to a partially painted wall: Many important things are being left undone because of limits in agency mission, funding, or interest. Research whose goal is to achieve understanding is different from a directed program whose goal is to solve a specific problem. The programs that exist aren't wrong, they are simply inadequate for the new phase we are entering. Excellent approaches to improving climate prediction are presented in the National Research Council report *The Science of Regional and Global Change.*

The dangers of climate change--seen as a gradual and mild warming over the coming centuries--fit with the current suite of loosely coordinated, discovery-driven programs. If instead the danger could be closer at hand and more profound than previously appreciated, then new programs should be initiated commensurate with the threat. The obvious solution is to identify within government an organization that would have comprehensive, overall responsibility for long-term climate prediction. Such an entity should be funded to provide a complete and balanced approach: It must ensure that the whole wall is painted. Historically, the route to a capability has been evolutionary. For example, current progress in making seasonal predictions, such as the El Nino forecast of 1998, is the correct approach to learning how to make credible longer-term prognostications. A strong U.S. program to expedite reliable prediction, complementing the international programs coordinated by the World Meteorological Organization and the United Nations Environment Program, is probably the best action the United States could take at the current time.

It will require far more certainty than now exists for democratic societies to make the large investments needed to switch to carbon-free economies. The most important thing to be done in the next 20 years is to develop reliable capability to predict in detail how the earth's atmosphere will respond to various scenarios of greenhouse gas emissions. Our current set of programs will not deliver the climate prediction capabilities we will need. The more directed and intensive program described above, with a program of in situ sensing to complement the global satellite system, more research, and a directed modeling program, can deliver reliable answers needed in time and if necessary to change the outcome of the 21st century.

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APPENDIX D

TURFGRASS INFORMATION

APPENDIX E

EFFECTIVENESS OF WATER RATE INCREASES FOLLOWING WATERING RESTRICTIONS

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(Revised August 15, 2002)

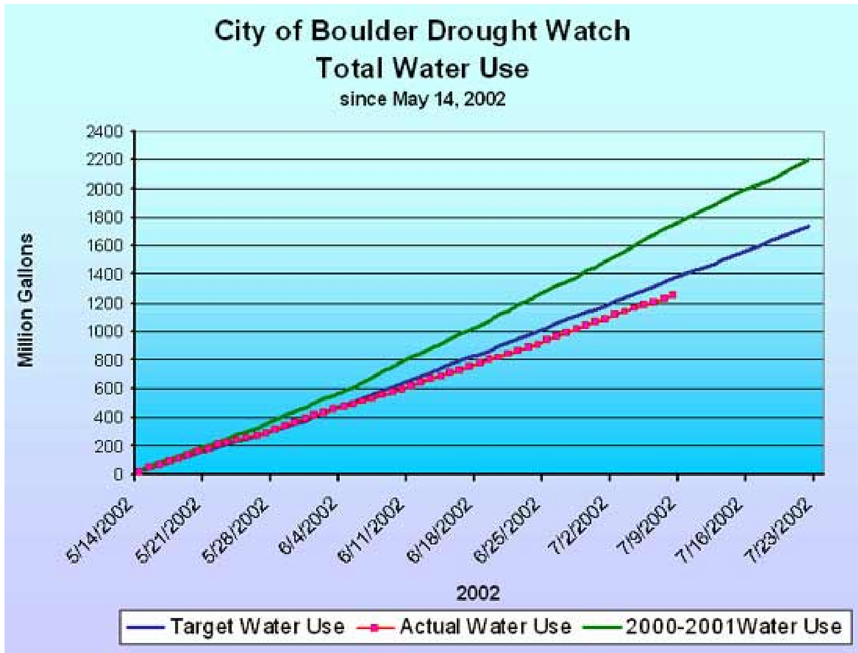
The Drought Situation

Municipalities across the drought-stricken Southwest have begun using various demand-side restrictions to reduce residential water use. The severity of the drought has induced many utilities such as Aurora, Colorado Springs, Boulder and Trinidad, Colorado to impose watering restrictions. The persistence of the drought has led numerous towns to consider rate structure increases in addition to and following the watering restrictions. Colorado Springs and Aurora, Colorado have instituted post restriction rate increases (Denver Post, June 17 and July 1). The issue is "What kind of demand responses to the rate increase can be expected in the face of pre-existing watering restrictions?" For reasons given below, the additional reductions in use may be much less than expected.

Numerous studies have explored the responsiveness of residential water demands to changes in the rate structure (e.g. Hall and Hanemann, 1996; Billings and Agthe, 1980; Howe, 1982), while only a few studies have investigated the effectiveness of non-price restrictions in reducing withdrawals or in knocking off peak demands (e.g.--Michelsen, McGuckin and Strumpf, 1999; Renwick and Green, 2000). No study to date has analyzed the effectiveness of both strategies when used together. One might assume that the use of both measures would result in total reductions equal to the sum of each step's effect, but that will not be the case.

Effective June 5, 2002, Boulder, Colorado initiated twice per week-fifteen minute outdoor watering restrictions with the goal of reducing withdrawals by 25% relative to pre-restriction conditions. While Boulder has been relatively successful in meeting its goals (see figure below), results in other areas have been mixed. Colorado Springs and Aurora experienced initial reductions in use, followed by small increases. Trinidad, Colorado actually experienced an increase in water consumption of 13 % compared with one year ago.

The somewhat ambiguous results of the watering restrictions and the need for further conservation as well as augmenting diminished revenues have motivated utilities managers in Boulder, Aurora, Colorado Springs and elsewhere to explore increases in the rate structure.

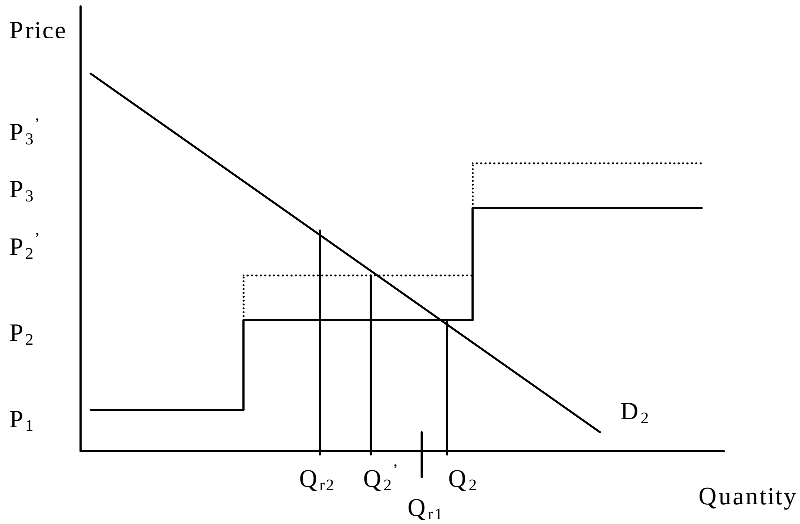


Water savings in 2002

Analysis of the Effects of Price Increases

Consider a typical town with a three step block rate structure, as shown in the figure below. Most towns will leave the first block unchanged for equity reasons, so the second and third blocks are raised as shown by the dotted segments. The demand curve of a typical household falling into the second block is shown as D_2 at the initial price P_2 and resulting quantity Q_2. At the raised price P_2', the household would, in the absence of restrictions, want to withdraw the quantity Q_2'. The critical issue is whether the reduced quantity required by the restriction, Q_r is greater than or less than Q_2'. If Q_r falls between Q_2 and Q_2' (as shown by Qr1), the price boost will result in a further reduction in the quantity withdrawn as shown by Q_{r1}. If Q_r is smaller than Q_2' (as shown by Qr2),then there will be no further reduction in withdrawals due to the price increase.

Of course other situations can occur. The restrictions might "bump" the household down into the next lower block. If that is Block 1, there is no price increase for the household. If the "bump" is from Block 3 to Block 2, the household faces the new price P_2' but would desire more water than the restriction allows, resulting in no further reduction. Thus, for a significant percentage of households, the price increase will result in no further reductions beyond the amount allowed by the restrictions. (The price increase could have a "real income effect" but it would be negligible.)



Elasticity and block rate pricing

Let us illustrate the situation by looking at the rate structure of Boulder, Colorado to ask "How large must the price increases be to effect reductions below the those already imposed by the restrictions?" The city's current water rate structure is given in the following table.

Water Rates in Boulder

Component	Rate	Approximate # of gallons
Service Charge	$ 8.12/month	NA
Block 1	$ 1.60/1,000 gallons	5000
Block 2	$ 2.85/1,000 gallons	5001-17,500
Block 3	$ 4.25/1,000 gallons	17,501-

To answer this question, we must introduce "the price elasticity of the demand for withdrawals"-a measure of the sensitivity of the household to price changes. This well known measure is defined in equation (1).

(1) price elasticity of withdrawal demand = % change in withdrawals**/** % change in price

This elasticity (which has a negative value because of the opposite movements of price and quantity) depends on the income level of the household: the higher the income, the less attention is paid to the price of water. Higher income households find themselves on higher blocks of the rate structure. A survey of the literature (e.g. Renwick and Archibald, 1997; previous references) would show that the price elasticity for Boulder's Block 2 might be approximated by –0.22 and Block 3 by –0.11. Let's assume that the 25% reduction sought by Boulder has been achieved by each household. For Block 2, we insert the –0.22 and the

25% into equation (1) to solve for the % change in price that would be required to make the amount imposed by the restriction just equal to what the household would choose at price P_2' without the restriction, i.e. the % price increase that would result in $Q_2' = Q_r$. The result is that, for Block 2, price would have to be raised by **114%** before it begins to have an effect beyond the already restricted amount. For Block 3, the same calculation (using an elasticity of –0.11) leads to the need for a **227%** increase in price before it begins to reduce demand below the restricted quantity.

Conclusions

The conclusions are fairly straightforward: (1) the price increases needed to cause significant reductions in addition to reductions already caused by watering restrictions will have to be large (100% + for Boulder's Block 2 and 200% + for Block 3) and (2) even with those price increases, only part of the households will reduce their demands in response to the price increase.

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APPENDIX F

WATER BUDGET RATE SYSTEM USED IN THE IRVINE RANCH WATER DISTRICT, CALIFORNIA

Overview and History

The Irvine Ranch Water District (IRWD) is located in Orange County, California, located in southern Los Angeles. In the 1700's and 1800's, the area was predominantly used for agricultural and ranching purposes. In the early 1900's, the area became more populated, orange orchards were introduced, and the need for water dramatically increased. This is the period in which groundwater wells and storage reservoirs were constructed. In 1961, after the pressures of urban development created the need for additional water supplies, the IRWD was created to serve Irvine, the University of California-Irvine campus, and other surrounding districts. It was at this time that the IRWD also began purchasing treated water from the Metropolitan Water District of Southern California (Los Angeles metropolitan area), which derives a large portion of its raw water supplies from the lower Colorado River.

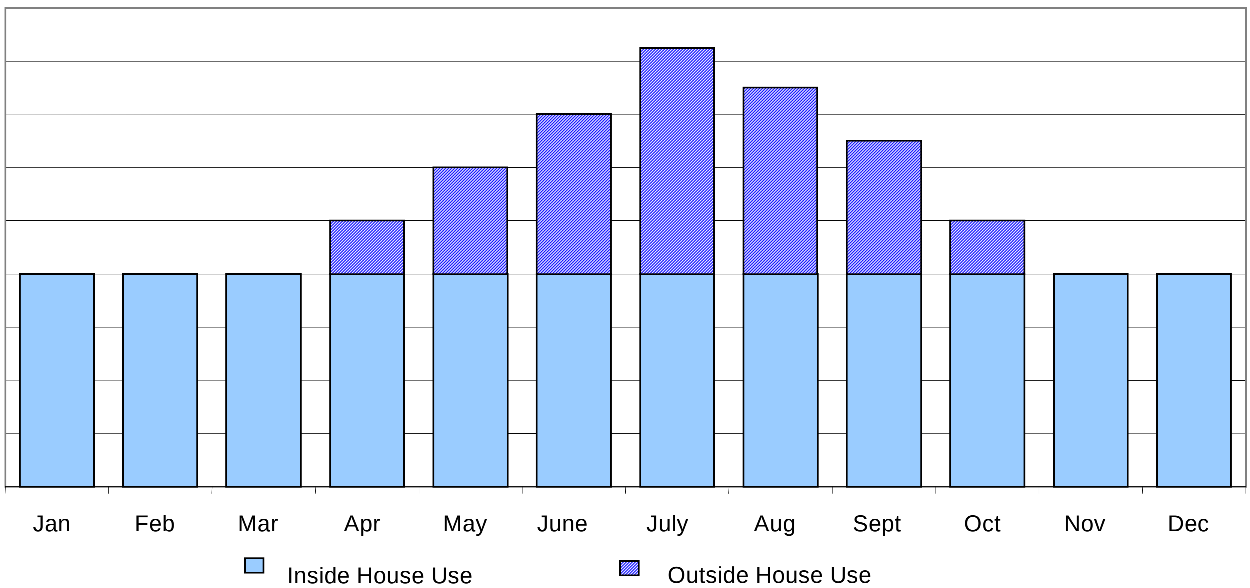
In response to California's prolonged drought of the early 1990's, IRWD conceived a unique water budget based billing approach in order to encourage water conservation and penalize water wasters. The rate structure is based on the assignment of a water allowance, or budget, to each property. The water budget is specifically determined for each property and is dependent upon household size, landscape area, and actual daily weather conditions at the customer's property. The rate structure is a five block, inclining rate structure, as shown in the following table.

IRWD Budget Based Rate Structure, 2002

Tier (Block)	**Rate** (per 100 cubic feet)	**Equivalent Rate** (per 1000 gallons)	**Water Use** (% of water budget)
Low Volume Benefit	$ 0.53	$ 0.71	0 – 40%
Conservation Base Rate	$ 0.69	$ 0.92	41 – 100%
Inefficient	$ 1.38	$ 1.84	101 – 150%
Excessive	$ 2.76	$ 3.68	151 – 200%
Wasteful	$ 5.52	$ 7.36	201% +

The water allocation varies on a monthly basis, depending upon the weather conditions. Assuming that the household size and the amount of landscape area do not change in a year, the water allocation/budget variation is reflected in the following figure.

Water budget monthly adjustment curve



A comparison of the characteristics of the IRWD with Boulder is shown in the following table.

Data Comparison between IRWD and City of Boulder

Characteristic	*IRWD*	*City of Boulder*
Size of Service Area	85,000 acres	17,500 acres
Population Served	266,000	114,000
Total Employees - Water/Sewer	275	130
Water Source	- 50% wells (May-Oct) - 50% MWDSC (Nov-April), treated water	100% surface water
Water Delivered - Treated - Untreated (Raw) - Reclaimed from WWTP - Total	 - 44,348 AF - 14,188 AF - 17,108 AF - 75,644 AF	 - 24,532 - 496 - 0 - 25,028

Customers - Residential - Commercial/Industrial - Irrigation - Total	 - 68,488 - 5,387 - 1,723 - 75,598	 - 24,694 - 2,117 - 1,147 - 27,958
Rate Structure	5-tier, increasing block	3-tier, increasing block
Water Allocation Determined By:	- Number of house occupants - Landscape area - Daily weather and ET data at property	Not required
Variances for Allocations	Considered, if - Additional occupants - Special medical needs - Additional landscape area	Actual Average Winter Consumption for each property
Pumping (energy) Surcharge	Variable, depending upon property location	Flat/Fixed, same for all customers
Treated Water delivered per person	44,348 AF/266,000 people = 0.17 AF/person	24,694 AF/114,000 people = 0.22 AF/person
Total Water delivered per person	75,598 AF/266,000 people = 0.28 AF/person	25,028 AF/114,000 people = 0.22 AF/person
Hydroelectric Facilities	None	7 Facilities

APPENDIX G

CITY COUNCIL WEEKLY INFORMATION PACKET ON LANDSCAPING REQUIREMENTS

APPENDIX H

CITY ORDINANCES OF RELEVANCE TO DROUGHT PLAN

11-1-19 **Water and Ditch Rights**.

(a) Except as provided in paragraphs (a)(1) and (a)(2) of this section, an applicant for a permit under Sections 11-1-14, "Permit to Make Water Main Connections" and 11-1-15, "Out-of-City Water Service," B.R.C. 1981, shall offer for sale to the city all water and ditch rights available for use on the land at the fair market value determined by the city and the applicant at the time of the sale. The provisions of this subsection apply: 1) to all persons who have voluntarily annexed to the city and are applying for water utility service under the requirements of Section 11-1-13, "When Connections with Water Mains are Required," B.R.C. 1981; 2) to applicants choosing to apply for water utility service after having been unilaterally annexed by the city; and 3) to all owners of Silver Lake Reservoir and Ditch Company Shares, but such owners may apply to sell their shares to the city at a date later than that of the application for a permit under Section 11-1-14, "Permit to Make Water Main Connections" or 11-1-15, "Out-of-City Water Service," B.R.C. 1981.

(1)The provisions of this subsection do not apply to persons applying for water utility service when either the initial city zoning of the property is RR-E, ER-E, or agricultural or when the property is used for residential or agricultural use only and is 15,000 square feet or larger in size. In such circumstances the applicant shall offer to the city on a form provided by the city manager the right of first refusal on all water and ditch rights used on or appurtenant to the property and shall file such form in the office of the Boulder County Clerk and Recorder. The right of first refusal shall provide that the applicant shall give the manager at least sixty days' advance written notice that water and ditch rights are for sale and the details of the sale. At such time as the RR-E, ER-E, or agriculturally zoned land is subdivided or redeveloped, the owner thereof shall offer for sale to the city all water and ditch rights used on or appurtenant to the land at the fair market value determined by the city and the applicant at the time of the sale.

(2)The provisions of this subsection do not apply to persons owning property that has been unilaterally annexed to the city who are applying for water utility service under the requirements of Section 11-1-13, "When Connections with Water Mains are Required," B.R.C. 1981, but the applicant shall offer to the city on a form provided by the city manager the right of first refusal on all water and ditch rights used on or appurtenant to the property annexed to the city and shall file such form in the office of the Boulder County Clerk and Recorder. The right of first refusal shall provide that the person shall give the manager at least sixty days' advance written notice that water and ditch rights are for sale and the details of the sale.

(b)If a person purchases or obtains any water or ditch rights after connecting to the city water utility or if a person outside the city and connected to the city water utility who owns water or ditch rights is annexed to the city, the city shall discontinue water utilities services to such person. But the city shall continue water service if such person offers to sell the water or ditch rights to the city at fair market value as determined by the city and the person at the time of sale.

(c)The fair market value of Silver Lake Reservoir and Ditch Company shares is deemed to be $25.00 per share.

11-1-30 **Use of Water from Private Well**.

No person shall have a cross-connection between a private line carrying well water and line carrying water from the water utility.

11-1-48 **Water Conservation Program**.

(a) The purpose of this section is to create incentives for water conservation by users of the water supply of the city, to prevent unnecessary depletion of the raw and treated water supply of the city, to attempt to supply a continuing level of satisfactory service to existing water utility customers, and to insure the city's ability to meet the present and future basic water needs of the city's residents.

(b)The provisions of this section apply to all users of water supplied through the water utility of the city, including, without limitation, customers of any water and sanitation district or any public or private water supply company to which the city provides water.

(c)The city manager may implement the water conservation measures under this section after twenty-four hours' public notice, or upon publication in a newspaper of daily circulation in the city, whichever occurs first, whenever in the manager's reasonable judgment such measures are necessary to maintain, conserve, replenish, or protect the water supply of the city. The manager shall determine the extent and duration of any water conservation measures implemented. Nothing in this section shall be deemed to limit or restrict the emergency powers of the city manager under Section 11-1-27, "Water Restrictions in Case of Emergency," B.R.C. 1981.

Ordinance Nos. 5068 (1987); 5426 (1991); 5526 (1992); 7010 (1999).

11-1-49 **Water Conservation Measures**.

(a) The city manager may prohibit or restrict the use of water from the water utility or from any other source of water owned by the city.

(b) The city manager may impose water conservation measures, including, without limitation, the following:

(1) Restrictions limiting water which may be used for lawn irrigation or other purposes outside a residence, apartment, commercial, or industrial building or any other structure on a schedule established by the manager.

(2) Restrictions on filling swimming pools.

(3) Restrictions on vehicle washing, including, without limitation, the restriction that vehicles may be washed only with a bucket or a hose running with an automatic shut-off nozzle but not with any free-running hose.

(4) Restrictions on the hours during which water may be utilized for outside irrigation of lawns, gardens, or landscaping.

(5) An excess water surcharge of five times the highest inside city quantity charge per one thousand gallons for inside city customers, and five times the highest outside city quantity charge per one thousand gallons for outside city customers, imposed on all water use exceeding the following limits:

User Type[1]	Limits
All non-irrigation accounts	15,000 gallons per billing period per meter, or the sum of the user's average winter consumption plus 60% of the user's seasonal demand, whichever is greater.
Irrigation only accounts	The sum of the user's average winter consumption plus 60% of the user's seasonal demand; and

(6) A moratorium on out-of-city water permits under which no new permits to take or use water from the water utility of the city to serve property located outside the city's corporate limits are issued, notwithstanding the provisions of Section 11-1-15, "Out-of-City Water Service," B.R.C. 1981.

(7) If the city manager imposes an excess water surcharge upon a user, the manager, after recommendation of the director of utilities, may grant an exemption to the surcharge requirements, if the user demonstrates unusual circumstances that will result in substantial inequity. If the manager imposes a moratorium on out-of-city water permits, the manager may, upon recommendation of the director of utilities, permit special requests to the city council and only upon a written finding of extreme hardship resulting in immediate danger to life or property. The manager may impose such reasonable conditions upon the grant of any exception authorized herein as the manager deems advisable.

[1]The city manager shall establish limits based on use of similar accounts for new accounts for which no average winter consumption or seasonal demand figures are available.

Ordinance Nos. 5068 (1987); 5426 (1991); 7010 (1999); 7215 (2002).

11-1-50 **Special Permits**.

(a) If the city manager imposes daily or hourly watering restrictions, the manager may issue special permits, upon recommendation of the director of utilities, as follows:

(1) For watering newly sodded lawns, each day for a period not exceeding fourteen consecutive days;

(2) For watering newly seeded lawns, each day for a period not exceeding twenty-five consecutive days;

(3) For period watering of outside stock at nurseries, greenhouses, and stores;

(4) When there are circumstances that do not permit a water user to deliver three-fourths of an inch of water per week on landscaped grounds of the user's premises, if the water user submits a plan

describing the area to be served and the method to be used to deliver an adequate amount of water; and

(5) For water schedules otherwise prohibited, in cases of a clear and present hardship.

(b) An applicant for a special permit shall pay the special permit fee prescribed by Section 4-20-23, "Water Permit Fees," B.R.C. 1981, and apply in writing on forms provided by the city manager that contain the following information: the reasons for requesting the permit; the period of time for which the permit is requested; the area or address of the premises to which such permit applies; for requests for additional watering times, a plan describing the area for which the permit is requested and a description of the method to be used to deliver an adequate amount of water to the area; and such other applicable information as the manager may reasonably request in order to review the application.

(c) The application shall be submitted to the director of utilities, who shall review all requests for special permits and forward a copy of the application and a recommendation thereon to approve, deny, or approve with conditions to the city manager for final review, approval, denial, or approval with conditions. If the manager denies the application or approves it with conditions, the applicant may, within five days of receiving the decision, request a hearing before the manager under the procedures prescribed by Chapter 1-3, "Quasi-Judicial Hearings," B.R.C. 1981, except that the manager shall hold the hearing within twenty-one days of the date of the applicant’s written request. The hearing officer shall not be the same person who denied the application.

(d) The holder of each special permit shall post the permit in a conspicuous place on the premises to which the permit applies so that it is readily visible from the street in front of or abutting the premises.

(e) No person who holds a special permit shall transfer that permit from the premises for which the permit is issued to any other premises or location. Any attempt to do so voids the permit.

(f) If any person holding a permit under this section violates any condition of the permit, the city manager may revoke the permit, after affording the permittee an opportunity for a hearing under Chapter 1-3, "Quasi-Judicial Hearings," B.R.C. 1981. Before such hearing, the manager may suspend the permit for up to twenty days, if the manager finds that the public health, safety, and welfare requires such suspension.

(g) The city manager may establish such additional procedures as deemed necessary for the review and processing of special permit applications.

(h) The city manager may establish a moratorium on the issuance of some or all of the special permits authorized by this section.

Ordinance Nos. 5425 (1991); 7215 (2002).

11-1-51 **Enforcement of Water Conservation Measures**.

No owner and no occupant of a premises receiving municipal water shall fail to comply with the provisions of Sections 11-1-25, "Duty to Maintain Service Lines and Fixtures," 11-1-48, "Water Conservation Program," 11-1-49, "Water Conservation Measures," and 11-1-50, "Special Permits," B.R.C. 1981. Violations of the provisions of these sections during any time when water conservation measures have been imposed by the city manager pursuant to Section 11-1-49, "Water Conservation Measures," B.R.C. 1981, are subject to imposition of the following penalties:

(a) Administrative Charges:

(1) For a first violation within a twelve-month period, the city manager shall notify the owner in writing of the violation and that a $50.00 water waste charge is due, payable, and collectable pursuant to the provisions of this chapter within ten days of the date of the notice.

(2) For a second violation within a twelve-month period at the same premises, the city manager shall notify the owner in writing of the violation and that a $100.00 water waste charge is due, payable, and collectable pursuant to the provisions of this chapter within ten days of the date of the notice.

(3) For a third or any subsequent violation within a twelve-month period at the same premises, the city manager shall notify the owner in writing of the violation and that a $300.00 water waste charge is due, payable, and collectable pursuant to the provisions of this chapter within ten days of the date of the notice.

(4) The notice of the water waste charge shall be served no later than thirty days after the city manager learns of the violation and the identity of the owner of the property. Service shall be upon the owner of the property in person or by first class or certified mail addressed to the last known owner of the property on the records of the Boulder County Assessor. The manager may send copies of the notice to such occupants of the property or agents of the owner as the manager deems useful. The notice shall advise the owner of the right to a hearing under paragraph (5) of this subsection, and that if payment of the water waste charge is not received by the city or a hearing requested within the ten days, the water waste charge, together with a $15.00 administrative processing fee, will appear on the next regular water bill.

(5) The owner of the property notified of a water waste charge, or any agent of the owner authorized in writing by the owner, may file a written request for a hearing regarding the factual basis for imposing the charge with the municipal court within ten days of the date of the notice. The request must identify the notice being appealed by attaching a copy or otherwise identifying it, and shall contain the name, address, and telephone number of the person to whom notice of the date, time, and place of the hearing should be given. Filing occurs when the municipal court receives the request. The hearing shall be conducted in accordance with Chapter 1-3, "Quasi-Judicial Hearings," B.R.C. 1981, before a judge or a hearing officer appointed by the presiding judge of the municipal court. The city bears the burden of establishing the factual basis for imposing the water waste charge by a preponderance of the evidence, and if that basis is established the hearing officer shall order the charge paid within ten days, subject to the $15.00 administrative fee and the collection procedures of this chapter if not paid within that time. Failure to request a hearing within the time provided or attend any such hearing constitutes a waiver of the right to such hearing and a determination of all issues then existing as supporting the factual basis for imposing the water waste charge.

(b) Additional Remedies: After three notices of a water waste charge have been served upon an owner for violation of any of the provisions of Subsection 11-1-25(a), concerning the duty to maintain service lines and fixtures, or Sections 11-1-48, "Water Conservation Program," and 11-1-49, "Water Conservation Measures," B.R.C. 1981, within any twelve-month period, in addition to or in lieu of a further notice of a water waste charge the city manager may, in the manager's discretion:

(1) Cut off Water: Suspend water service to the premises for a period of time not to exceed thirty days after giving notice and an opportunity for a hearing in accordance with Chapter 1-3, "Quasi-Judicial Hearings," B.R.C. 1981. The owner of the premises is responsible for paying the charges prescribed by Section 4-20-24, "Charges for Terminating and Resuming Water Service," B.R.C. 1981, for termination of service and for resumption of service before service, if suspended, is resumed. The manager may reduce the period of suspension or hold a threatened suspension in abeyance if the owner presents and implements a plan acceptable to the manager to prevent further violations; and

(2) Criminal Penalties: Prosecute violators in municipal court pursuant to the provisions of Section 5-2-4, "General Penalties," B.R.C. 1981, and the normal procedures of a municipal court prosecution.

(3) Proof of Evidence: In order for the manager to proceed under this subsection it is sufficient that the manager prove, by a preponderance of the evidence, that the three predicate notices were properly served and that they were for alleged violations which all took place within twelve months of each other.

APPENDIX I

ENDNOTES AND REFERENCES

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