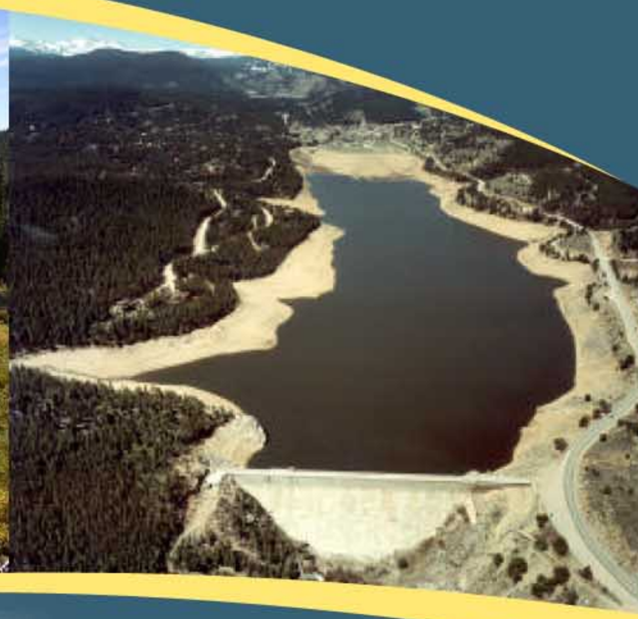
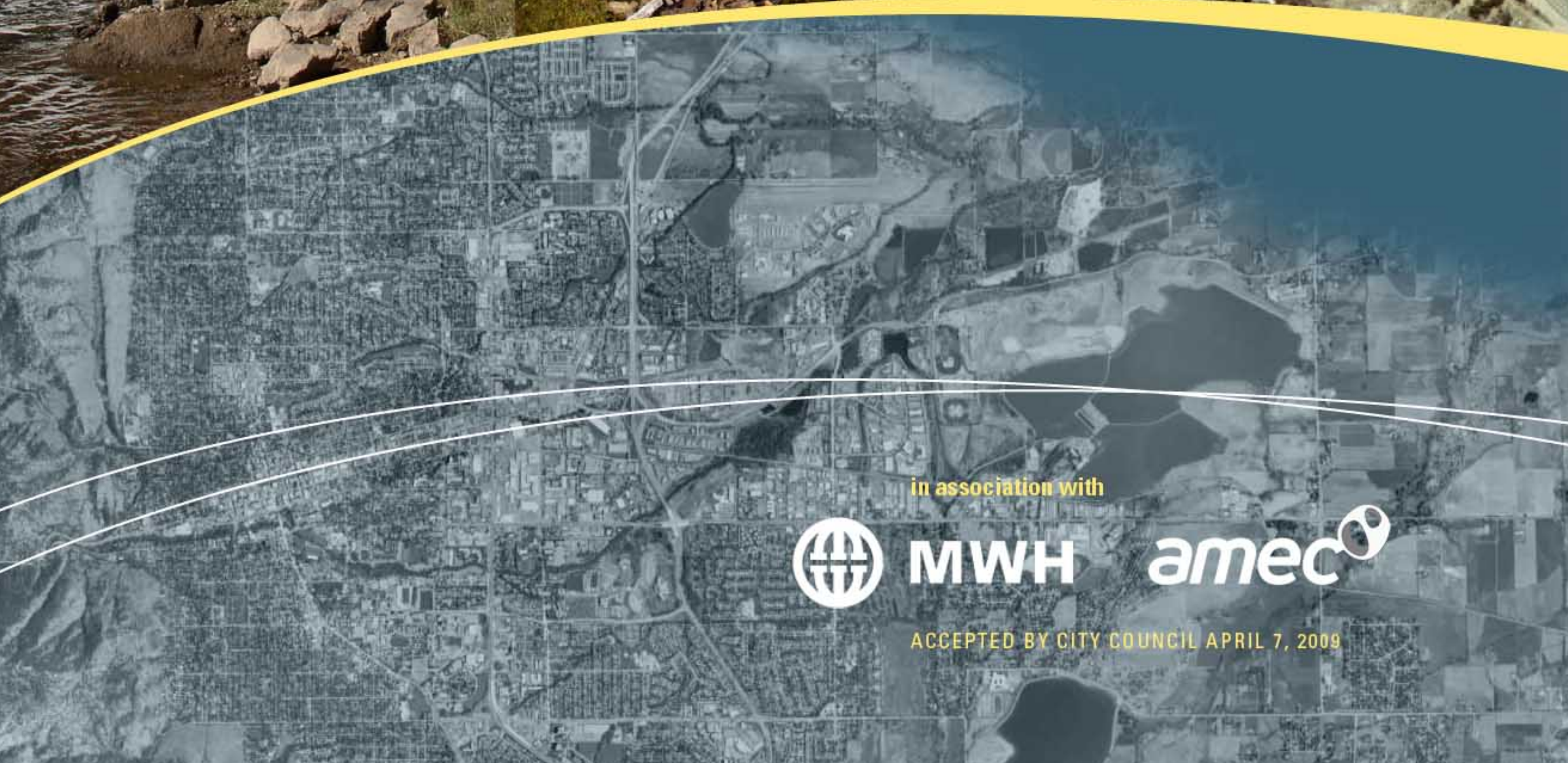
REPORT

SOURCE WATER MASTER PLAN

Volume 2 - Detailed Plan

FINAL | APRIL 2009



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Chapter 1

1 | INTRODUCTION

1.1 | Source Water System Overview

Boulder's water supply system includes many storage, conveyance, hydroelectric and treatment facilities. The city owns approximately 7,200 acre-feet of reservoir storage space in the North Boulder Creek watershed, owns 11,700 acre-feet of storage in Barker Reservoir on Middle Boulder Creek, and has up to 8,500 acre-feet of storage space in Boulder Reservoir. Boulder's two water treatment facilities are the Betasso Water Treatment Facility (WTF), with approximately 45 million gallons per day (MGD) of treatment capacity and the Boulder Reservoir WTF at about 16 MGD. The city operates eight hydroelectric plants located within the municipal water supply system and sells the electricity to Xcel Energy. Four of these hydro plants are located on raw water pipelines and four are on treated water transmission pipelines.

Operation of the city's water system involves intricate relationships between water rights, water quality, State laws, water rights decrees, water delivery contracts, water-related agreements with third parties, streamflows, reservoir storage operations, transmission pipeline operations, treatment capacity, hydropower production, and water demands.

Boulder owns a diverse portfolio of water rights and water delivery contracts which allow the city to use water both from the local Boulder Creek basin and from tributaries of the Colorado River.

Past and current studies predict that as long as current supply and drought management strategies remain in place, the city will have enough water in the future, even with climate change and predicted population increases. Therefore, the focus of the SWMP is not, "Where does the city find more water?" The focus is rather on the future steps and considerations needed to manage the existing source water system, including its aging infrastructure.

1.2 | Source Water Master Plan Contents

The SWMP contains two volumes. The first volume provides a summary level of detail aimed at a general audience. Volume 1 is consistent with other city master plans and planning documents in terms of format, content and level of detail. The second volume contained herein provides much more detail on background, system management, issues and recommendations. Volume 2 provides the details necessary for future execution of programs and projects. Volume 2 also documents critical system information in one place in a way that has never been done before, which will be valuable to current and future staff. The second volume is prepared more for an audience having or desiring detailed institutional knowledge of the source water system.

Volume 2 contains seven chapters as well as appendices. A brief introduction to the SWMP is provided in Chapter 1, and Chapter 2 defines the purpose and scope. Chapter 3 describes the management of the source water system. Background and description of source water assets is provided in Chapter 4, and Chapter 5 provides information on water availability, water use and water quality. Chapter 6 describes issues to be addressed over the next 20 years and beyond, and Chapter 7 contains specific recommendations to address many of the issues described in Chapter 6. The appendices are in electronic format attached to Volume 2 on a DVD.

Chapter 2

2 | PURPOSE AND SCOPE

2.1 | Purpose of the Source Water Master Plan

The SWMP is intended to be a foundation document that will allow informed decision-making regarding one of the city of Boulder's most important assets, its water supplies. Boulder's founders recognized the importance of a reliable water supply and began developing a water supply system for the growing city in the late 1800s[1]. Subsequent generations have expanded and maintained the water system and planned for its future. Current citizens of Boulder are the beneficiaries of these forward-thinking individuals and their efforts in the past. Thoughtful planning for the city's future water needs at this time can help assure that future Boulder citizens also inherit a reliable and sufficient water supply. The SWMP documents the current status of the city's water resources and raw water facilities and defines issues needing to be addressed to provide for the city's future water supply needs.

2.2 | Previous Raw Water Master Plan

The city's previous Raw Water Master Plan (RWMP) was completed in 1988[2]. In 1987, the city initiated a public process to evaluate the water supplies that Boulder owned and discuss options for use of the water. The studies resulted in the 1988 RWMP, which focused more on water yield and water use in the city and less on raw water system infrastructure. Following presentation of the RWMP, City Council adopted specific policies regarding instream flows, meeting water system reliability and water quality goals, water conservation, and disposition of Windy Gap water and replacement with other water sources. Many of the recommendations in the RWMP have been implemented over the past nineteen years. In addition, some changes that affect water supply have occurred and new information is now available. Therefore, it is a suitable time to review one of the key findings of the previous master planning effort, which was that the city owned sufficient water supplies to meet its build-out water needs. Although changes since that time may have affected water supplies, it appears still to be a valid determination. Examples of these changes are:

- **Establishment of reliability criteria for the water system**

  Both in 1988 and the present, the determination that the city's water supplies are believed to be adequate does not mean that there will never be reductions in deliveries to water customers in times of moderate to severe drought. City Council adopted reliability goals in 1989 based on reliability criteria that define the extent to which water should be provided for various uses during droughts. Assuming future hydrology is similar to the past, current modeling shows that Boulder's existing water supplies should be able to meet the reliability criteria and provide sufficient water to meet all municipal water needs in nineteen out of twenty years under build-out demand conditions. However, this conclusion should and will be revisited as new information becomes available about the effects of climate change or as other changes take place that affect Boulder's raw water supplies and system. By setting reliability criteria for the city's water system, Boulder has taken a step toward responsible water planning that has yet to be taken by many other Colorado municipalities. See section 5.1.1.4 for a description of the reliability criteria.

- **Increased preparedness for drought**

In 2003, the city prepared a Drought Plan that defined several drought stages and the steps to be taken in response to a drought declaration to assure that the water system could meet the adopted reliability criteria[3]. For the five years in every hundred that water use can be reduced and still comply with the reliability criteria, water system modeling incorporating the drought responses contained in the Drought Plan shows that voluntary use reductions should be sufficient to address the drought shortages in three to four of those five years.

- **Sale of Windy Gap Project water**

Although City Council did not recommend a permanent reduction in the yield of the city's water portfolio *through* sale of water in 1988, they did recognize that the Windy Gap water was the city's most expensive and least reliable water. City Council recommended that staff attempt to reconfigure the city's water portfolio through sale of Windy Gap water and replacement of the Windy Gap water with water supplies and assets in the Boulder Creek basin that would be capable of multiple uses and would enhance the yield of existing systems. The city pursued this goal through the sale of 43 of its original 80 units in the Windy Gap Project to the city of Broomfield in 1991. The city used proceeds from the sale to purchase additional shares in some ditch companies, to jointly purchase Caribou Ranch with Boulder County, and to purchase the Barker System (Boulder Canyon Hydroelectric Project) from Public Service Company of Colorado (PSCo, now Xcel Energy).

- **Improved water system modeling**

The city has a far greater understanding of the source water supply system water yields and interactions with other water systems due to the development of a detailed model of the city's water system over the past two decades. This model has been refined and updated during that period and is now capable of providing sophisticated operational modeling of the city's water system and yields under many hydrologic conditions.

- **Year-round operation of Boulder Reservoir Water Treatment Facility**

The Boulder Reservoir Water Treatment Facility began operating year-round in the mid 1990's. Prior to that time, it had been operated as a summer peaking plant. The change was due to higher water demands from Boulder's growing population and to support maintenance of a drought reserve in the city's upper Boulder Creek reservoirs.

- **Better management of water supplies to protect drought reserves**

During the 1980's, the city had been taking as much water as possible out of the sources that feed Betasso Water Treatment Facility each year, possibly jeopardizing the city's ability to sustain water deliveries in drier years. Based on recommendations in the 1988 RWMP, the city began maintaining a storage reserve pool in upper Boulder Creek reservoirs to assure that there would be sufficient water supplies available to operate Betasso during drought periods. There are two elements to the storage reserve pool: carry-over water and emergency drought reserves.

Rather than drain reservoirs every year, the city carries water over from wetter years for use during drier years when there is insufficient streamflow available to fill the upper reservoirs. Carry-over goals are 3,000 acre-feet per year in Barker Reservoir and 1,000 acre-feet per year in the Silver Lake watershed. The city maintains an emergency drought reserve pool to provide for a year's worth of essential indoor needs during a severe, unplanned for drought. The city's emergency drought reserve pool is 3,000 acre-feet in the upper reservoirs (Barker and Silver Lake watershed reservoirs) and 800 acre-feet in Boulder Reservoir. In order to provide for carry-over water and maintain emergency drought reserve pools, a larger percentage of municipal water must be delivered through the Boulder Reservoir Treatment Facility than had been prior to the RWMP.

- **More upper basin storage with purchase of Barker Reservoir**

  In 2001, the city purchased the Boulder Canyon Hydroelectric Project, including Barker Reservoir, from Xcel Energy. Although the city had agreements dating back to the 1950's allowing the city to use a portion of the facilities for municipal water supply purposes, the purchase increased Boulder's reservoir storage space by 3,686 acre-feet.

- **Establishment of a Water Conservation Program and Office**

  Based on recommendations in the 1988 RWMP and 1990 Treated Water Master Plan[4] in 1990 City Council approved implementation of an enhanced water conservation program with the primary purpose of deferring the expansion of the Boulder Reservoir Water Treatment Facility. The new Water Conservation Program and Office was established in May 1992 to direct the efforts of reducing overall water consumption within the city and specifically to reduce summer peak demand usage. The Water Conservation Program was designed to promote water conservation through voluntary measures that create a greater public awareness of the resource and encourage wise water use.

- **Water Conservation Futures Study**

  The 2000 Water Conservation Futures Study developed baseline water demands for the city's urban service area for the year 1995 based on monthly metered end use data. Various adjustments were made to accommodate factors such as annual weather variations and unaccounted-for water. Total demand and demand by various end use categories was projected from the base year of 1995 through 2020. The study also developed demand projections for a number of water conservation scenarios of varying degrees of intensity. Ultimately, the City Council selected the Comprehensive Conservation Scenario that was designed to address both indoor and outdoor water use patterns. This scenario was intended to result in a 10% reduction in water use at build-out (approximately 2025) when compared to the water conservation program in place in 2000, and about a 25% reduction in water use when compared to no conservation program being in place.

- **Commitment to instream flow program**

  Based on recommendations in the 1988 RWMP, the city entered into an agreement with the Colorado Water Conservation Board (CWCB) in 1990. Since the CWCB is the only entity that can use water for the specific purpose of providing instream flow, the city donated use of municipal water to the CWCB for instream flow maintenance in North Boulder and main Boulder creeks. This water can be pulled back for municipal use in times of drought or emergency.

- **Concerns about climate change**

  Climate science has expanded enormously over the past decade. Climate change models that once could only roughly approximate possible global-level changes are now providing plausible information at a more local scale. The city recently completed a cutting-edge study that determined a likely range of future increases or decreases in the city's water supplies due to climate change. The study used data generated by a range of climate models for Boulder's watersheds to produce simulated streamflow sequences. This information was then fed into the city's water system model to determine any effects on Boulder's water rights and water yields.

- **Growing awareness of the risks and effects of wildland fire**

  Wildland fire poses a threat to the city's water supply in part because of the severe erosion that can result after an intensely hot fire. If sediment and debris were to accumulate in the city's reservoirs following a wildland fire, the city would experience serious treatment challenges, taste and odor issues, and a potential reduction in the city's usable water supplies. Recent examples of the effects of wildland fire on water supplies in Colorado, such as the effects on Cheesman Reservoir following the Hayman fire in 2002, have increased the city's awareness of protecting its supplies against such risks[5].

2.3 | Scope of the Source Water Master Plan

The City of Boulder was incorporated in 1871 and has over time developed a stable administrative framework including policies that apply to management of the source water system. In 1989 City Council adopted the RWMP, which provides policy direction on a number of items. The RWMP along with numerous other city documents provide the policies that guide management and operation of the source water system. The following list provides some of the key documents:

- Raw Water Master Plan
- Treated Water Master Plan
- Drought Plan
- Middle Boulder Creek Water Source Management Work Plan
- Water Quality Strategic Plan
- Water Conservation Futures Study
- Source Water Impact Assessment
- Boulder Valley Comprehensive Plan
- Instream flow studies
- Historic water system studies

The SWMP does not change previously established policy or direction but rather includes recommendations for minor adjustments and/or enhancements to the established policies. The SWMP includes a policy discussion that builds upon the recommendations, policy directives and principles from the RWMP and other documents that have guided water utility operations for over 20 years.

The SWMP is a general planning process and document. It supports sustainable management of the city's source waters in a manner that provides for the city's needs through drought periods without violating the adopted reliability criteria. The SWMP contains a comprehensive review of all available information regarding the city's water supplies as a basis for future planning efforts and decision-making. The current belief that the city's presently-owned water rights portfolio will be sufficient to meet the city's water needs at full build-out of the city service area will need to be re-visited on occasion in the following decades to assure that it remains valid. The SWMP documents the factors that are the basis for findings of adequate water supply so that future changes that might alter these factors can more readily be identified. It also identifies new studies that may be needed and raw water system facilities that need repair or construction.

The scope of the SWMP includes several different efforts, such as:

- compiling existing information about the city's source water, such as background information, a review of the city's raw water system assets, current operation and maintenance practices, agreements, and other legal constraints on the city's raw water operations;
- documenting current policies for management of the city's source water;
- reviewing water use levels and water rights yields to assist in periodic re-evaluation of future demands;
- defining emerging issues that affect how the city will manage and operate its source water system in the future;
- recommending future studies and actions that should be undertaken;
- providing general budgeting information and project prioritization to guide development of the twenty-year Capital Improvements Program so that source water deliveries are dependable, and;
- recognizing and being compatible with other city master plans and strategic plans.

It is not intended that the SWMP will generate new data, complete new studies, or evaluate projects at a level more appropriate for the city's Community and Environmental Assessment Process (CEAP). The SWMP provides guidance on which future actions should be developed further through more specific efforts such as detailed studies, project implementation teams or a project-specific CEAP. Although the SWMP discusses issues from other areas that are related to source water, such as water conservation or water treatment, any recommendations on related issues are drawn from existing master plans, strategic plans or other documents that have received City Council review.

[1] Fred A. Fair Engineering Association. (1919). *Report to E.O. Heinrich, City Manager, on the water rights of the city of Boulder, Colo. in comparison with the physical facts that affect them*. Boulder, CO.
[2] WBLA, Inc. (1988). *City of Boulder Raw Water Master Plan*. Boulder, CO.
[3] City of Boulder, Aquacraft, Inc., & Hydrosphere Resource Consultants, Inc. (2003). *City of Boulder drought plan volume 1: Drought response plan*. Boulder, CO; ***and*** City of Boulder, Aquacraft, Inc., & Hydrosphere Resource Consultants, Inc. (2004). *City of Boulder drought plan volume 2: Drought plan and technical information and analysis revised November 2004*. Boulder, CO.
[4] Brown and Caldwell Consultants. (1990). *City of Boulder treated water master plan. Phase I*. Denver, CO.
[5] City of Boulder. (2003b). *Wildland fire preparation plan for drinking water watersheds*. Boulder, CO.

Chapter 3

3 | MANAGEMENT OF BOULDER'S WATER SUPPLY

3.1 | Management of Boulder's Raw Water System

The city of Boulder supplies municipal water to all of the developed area within the Boulder Valley Comprehensive Plan boundaries. The city's water utility provides safe and reliable drinking water by diverting raw water from the city's source water basins, treating the water at the city's two water treatment plants and distributing the water through distribution system pipelines.

An extensive system of raw water pipelines, reservoirs and facilities is operated and maintained to assure adequate deliveries to the city's water treatment plants at all times. The city operates eight hydroelectric plants that generate power from the pressure that develops within the water supply system as water is delivered from the mountains. The city also leases raw water supplies to agricultural users and manages the instream flow program for Boulder Creek.

Raw water is diverted for either direct use or for storage in reservoirs for later use. In order for the city to divert water, the city must have a water right that is in priority to take water at the time. Boulder owns a large water rights portfolio that includes both junior and senior rights. All diversions must take place in accordance with decrees and state water administration requirements and must be documented.

The operation of the city's water system involves intricate relationships between the city's water rights, water rights owned by others, water quality, state water laws, the city's water rights decrees, delivery contracts and other agreements, streamflows, reservoir storage operations, transmission pipeline operations, treatment capacity, hydropower production and water demands. There are many restrictions on what can be done with the city's water supplies based on legal or contractual constraints. Some of the city's water supply facilities have capacity or operational limitations. The city operates some of its raw water system based on long-standing practices and philosophies such as the emphasis on protecting water quality at its source that dates back over a century. However, Colorado's semi-arid climate is the over-riding influence on the choices made by the city when managing its water supplies.

Despite the limitations on management of Boulder's water supplies, the city does have a greater degree of flexibility than many other Colorado municipalities. The city's water rights portfolio is robust and should be sufficient to meet the city's needs at its build-out under most future hydrologic scenarios and up to the level of reliability specified by City Council.

3.2 | Historical Factors Affecting Water Management

3.2.1 | HISTORY OF COLORADO WATER DEVELOPMENT

Prior to the settlement of the West, the law controlling water use was based on riparian rights that had been defined through common law. "Riparian rights" meant a land owner adjacent to a stream had a right equal to every other land owner who was adjacent to the stream to make a reasonable use of the water upon his land, for his household needs, or for his livestock while leaving the stream undiminished in quantity or quality[1]. This approach worked in wetter climates with abundant streamflow but proved ineffective in the arid West where it was often necessary to transport water away from streams to use on land under mining claims or land that was agriculturally viable. In the absence of any governmental enforcement authority, early settlers adopted a practice of "first in time, first in right" to settle water disputes. The first settlers to apply water to a beneficial use gained a preferential right to access any available water in times of shortage without regard for the source of water and the point of use. Therefore, a new law based on community custom that came to be known as the prior appropriation doctrine supplanted riparian water allocation methods used in the eastern states. The basis for a water rights claim in Colorado became the continued, non-wasteful application of water to a beneficial use and a right to use water became a transferable property right[2].

In 1861, at the first session of the Colorado Territorial Legislature, an act was passed that allowed a land owner who was not adjacent to a stream to construct a ditch over land lying between his land and the stream to gain access to irrigation water[3]. By 1864, twenty-three ditch companies had initiated claims for water rights on Boulder Creek based on actions taken to physically divert water out of the creek, but there was a long way to go before an enforceable water rights system was developed. Disputes were settled by water diverters between themselves based on self-proclaimed water rights that might or might not have been openly declared or registered with the State. As a last resort, a water user could file a lawsuit with the court, but any decree issued was only binding on the parties to the lawsuit and not to other water users[4]. This sometimes led to controversies during times of shortage such as one that occurred during the dry summer of 1874 between the Union Colony at Greeley and a new settlement located upstream at Fort Collins. Newly constructed ditches at Fort Collins captured all of the water in the Poudre River leaving no water for diversion by the older ditches at Greeley. A meeting of about forty irrigators was held and was described by David Boyd, an attendee, as follows:

> "…the Collins parties were told that if their policy of the ditches highest up stream taking what they wanted was the one to be pursued, then we [Greeley irrigators] could go above them, and there would result an interminable and exhaustive race….Most of the Greeley delegates might have been made to yield but for the defiant attitude of those up stream. At length patience seemed to…cease being a virtue, and he hurled back defiance in hot and unseemly language….Force must meet force….many of us had seen as rough service some ten years ago [in the Civil War] as we were likely to experience in an encounter with these water thieves….Every man to his tent, to his rifle and cartridges….It was finally agreed that they would let us down some water….A promise they did not keep nor mean to keep….A general rainstorm came in about a week afterwards and saved us;

> but from this day forth we had set our hearts on having some regulations looking towards…the principle of priority of appropriation"[5].

Even after the prior appropriation doctrine was written into the Constitution of the newly-formed State of Colorado in 1876, no government entity existed to enforce water rights priorities. In order to address disputes such as on the Poudre, farmers called for an irrigation convention to be held in Denver to discuss possible legislation regarding water diversions. In December 1878, the irrigation convention was held and a committee was formed to draft legislation that was then presented to the legislature in 1879. The proposed legislation provided for:

1. Creation of water districts corresponding to areas irrigable by natural streams;
2. Appointment of water commissioners with the authority to decide the relative priorities of irrigation water rights based on the historic record;
3. A plan for creating a historic record;
4. Reservoir regulations;
5. Appointment of a state engineer, and;
6. Stream gauging.

The legislation was passed without the provisions for a state engineer or stream gauging. In the fall of 1879, the Poudre district was the first to appoint a referee to hear testimony to establish a historic record of water use under the new law[6].

The non-judicial approach was opposed by many because it would provide little or no opportunity for due process through the courts for other water users who objected to decisions regarding priority of rights made by the referee or the water commissioner. The referee's report on the Poudre fueled the controversy because it granted very large diversion rights to ditches of limited capacity based on testimony of farmers with no engineering background in determining water flow or ditch capacities. When an application was made to the district court based on the referee's report, Judge Elliott hinted that the 1879 law was unconstitutional. His ruling stated that the law was defective in its lack of requirement to follow necessary rules for judicial procedure. The Colorado Supreme Court upheld the ruling[7].

Disputes between water users continued, including one that became the basis for a court case called Coffin vs. Left Hand Ditch Company. A downstream water user on the St. Vrain River named Coffin irrigated land adjacent to the river and became frustrated by a lack of flowing water through his property during a dry period in 1879. Believing that ownership of riparian land should give a better right to use of water than the right of the upstream Left Hand Ditch Company to carry water to land away from the river, Mr. Coffin resorted to the self-help method of using dynamite on the Left Hand Ditch headgate and diversion dam. After heated discussions among the parties that may have involved threats of shotgun use, the parties calmed down sufficiently to take the case to the courts[8].

The State Legislature, in an attempt to address the rulings on the Poudre case and to bring some order to state water administration, passed the Adjudication Act of 1881 that firmly established use of the prior appropriation doctrine in Colorado. The act required claims for a water right to be submitted to the courts for recognition so that the State Engineer's Office, created through the legislation, could administer the rights according to priorities established by the courts[9]. Water rights that may have been put to use at an earlier date than others but that did not receive court recognition could not be treated as senior by the water commissioners. The legitimacy of Colorado's use of the prior appropriation doctrine was ultimately confirmed in 1882 when the Colorado Supreme Court issued a ruling in the case of Coffin vs. Left Hand Ditch stating that prior appropriation was the only law recognized for water allocation in Colorado and no riparian rights existed[10].

A round of basin-wide court hearings ensued that were known as general adjudications. Anyone with a water rights claim was to present evidence to the court of the date of their first application of water to beneficial use in order to gain a place in line with an administrable priority date. Water rights claims that missed the first general adjudications and were not recognized by the court until a later adjudication are considered junior to all rights in the prior adjudication even though the water may actually have been put to use at an earlier date.

The first general adjudication in the Boulder Creek basin resulted in a court decree issued by the Boulder County District Court on June 2, 1882. It only involved claims for direct flow irrigation rights and limited rights for domestic uses by irrigation ditch users. The need for decreed water rights for reservoir storage or rights for uses other than agricultural with incidental domestic use would not be recognized until later. Ninety-eight irrigation ditches in the Boulder Creek basin were adjudicated in 1882 and prioritized by their appropriation dates. Later general adjudications incorporated reservoir rights and rights for municipal and industrial users.

This system has evolved into the system we have today where filings for new appropriations of water or changes to existing water rights are filed at any time in Water Court without need for a general adjudication. State law was substantially revised in 1969 to streamline legal procedures for dealing with water rights and to create a special Water Court for each of seven Water Divisions corresponding to the major river basins in the state[11]. Applications to the Water Court are published monthly in a Water Resume. Anyone with concerns about the application then has sixty days to file an objection. Simple or non-controversial cases can be heard in front of a Water Referee to allow review of the proposed beneficial use and to assure no detrimental effects (known as "injury") are caused to other water rights. More complicated or contested cases can be transferred to the Water Judge. The issues in most cases are settled between applicants and objectors with a stipulated decree sent to the Water Court for judicial approval. In a few cases, settlement cannot be reached, so a trial must be held before the Water Judge. If a Water Court ruling is appealed, it goes directly to the Colorado Supreme Court.

3.2.2 | DEVELOPMENT OF CITY WATER SUPPLIES

3.2.2.1 | TOWN OF BOULDER BEGINNINGS

The first settlers arrived in the Boulder Valley shortly after gold was discovered in 1859. The first irrigation ditches that diverted from Boulder Creek were dug that same year. By 1870, so many irrigation ditches were in operation in the Boulder Creek basin that ditch companies with more junior water rights were called out of priority in late summer when there was only enough water in the river for the senior diverters[12]. Ditch companies began building reservoirs to store water during the high spring runoff period to assure water supplies in late summer.

The Town of Boulder incorporated in 1871. At that time, town residents either carried water to their houses in buckets dipped into Boulder Creek, dug small alluvial wells, or obtained water from irrigation ditches for domestic water needs. Small laterals running from ditches such as the Farmers Ditch and Anderson Ditch ran along most of the east-west streets and carried water to individual houses for shareholders in the company[13].

A private water company, the Boulder Aqueduct Company, was formed in May 1872 by Andrew Macky, Alfred Brookfield, and James P. Maxwell for purposes of delivering water to Boulder homes through pipes. The Town Board of Trustees gave the company permission to lay wooden pipes in city streets in 1873. However, some citizens believed that provision of water for Boulder should be publicly controlled[14].

On July 14, 1874, the town's citizens filed a petition with the Town Board of Trustees requesting that a vote be held to issue bonds for a municipal water system, in part because Boulder's citizens were already concerned with water quantity, quality and reliability of water supplies. There was also concern about the possibility of a fire burning through the town without a pressurized water system capable of delivering large amounts of water quickly. In response to these concerns, the town began operating a municipal water system in 1875. The Town of Boulder Reservoir, the town's first storage reservoir, was constructed in 1875 north of the mouth of Boulder Canyon at Red Rocks above the headgate of the Farmers Ditch. The reservoir filled by the newly-constructed Town of Boulder Ditch running from Boulder Creek. Water ran from the reservoir in an eight-inch cast iron pipe down to the intersection of 12th Street (Broadway) and Pearl Street. Many residents collected their domestic water in buckets from public spigots at what is now the old courthouse site.

The ditch that filled the reservoir, named the Town of Boulder Ditch, was granted a decree in the first general adjudication of water rights on Boulder Creek in June 1882 and was given an 1875 appropriation date specifically allowing domestic use. It is unusual that the domestic use of water diverted under the Town of Boulder Ditch right is mentioned in this decree since the Colorado Legislature did not specifically provide for adjudication of domestic or other uses until 1903. Prior to this, domestic water uses were generally considered to have very little consumption and to be incidental to associated agricultural uses[15]. The need for decrees for storage rights was not recognized on Boulder Creek until 1907 since, prior to that time, sufficient water supplies were usually available to fill existing reservoirs at times of the year when direct flow rights were not claiming the entire flow of the creek.

By 1879, Boulder had already begun to have difficulty extending its water system piping fast enough to fulfill the grand visions that some residents had for the young town, which by 1882 would be re-incorporated as the City of Boulder. One of these residents, J.P. Maxwell, owned a great deal of land on Mapleton Hill that he wished to develop into up-scale housing. Maxwell was very familiar with the city water system, having surveyed the route to be taken by the Town of Boulder Ditch and serving as the State Water Commissioner for Boulder Creek. However, he was unable to convince the City Council to expand the municipal water system to serve Mapleton Hill. As a result, Maxwell and his partner, George Oliver, formed the for-profit Silver Lake Ditch and Reservoir Company (Silver Lake Ditch Company) in 1887 to serve their housing developments[16]. They built dams on two natural lakes to create two reservoirs, Silver Lake and Island Lake, near the headwaters of North Boulder Creek just below the Continental Divide. The Silver Lake Ditch Company, formed in 1888, delivered the Silver Lake water into the Silver Lake Ditch, which has a headgate near the mouth of Boulder Canyon and runs north along the western edge of Boulder. J.P. Maxwell later bought out his partner and became the sole owner of the Silver Lake Ditch Company[17]. His company delivered water to individuals who were beyond the service boundaries of Boulder's municipal water system and who entered into water delivery contracts with the Silver Lake Ditch Company.

3.2.2.2 | WATER QUALITY AND THE FIRST CHANGE OF LOCATION OF BOULDER'S INTAKE

Beginning in the early 1880s, Boulder residents complained about cloudy water in the municipal water system that had been polluted by mining in the mountains above and west of Boulder and from discharges into the stream from settlements in the canyon[18]. The problem became so bad that the City Council appointed a committee in 1890 to investigate the means to supply Boulder with clean, reliable water. The committee recommended moving the city's water intake from the existing point on Boulder Creek at the mouth of Boulder Canyon to a point further upstream[19]. Therefore, in 1890, the city constructed a new upstream intake called the "Blanchard intake[i]" or the "lower intake" on a site known as the Horseshoe Placer mining claim[ii], which was located on Boulder Creek about one mile upstream of the confluence with Four Mile Creek[20]. A pipeline was constructed from the new Blanchard intake to the new Sunshine Reservoir. This reservoir was located on the second land purchase from John Brierley at the base of Sunshine Canyon on the Gallup Ranch and was 100 feet in elevation above the old Town Reservoir[21]. Citizens hoped that with these changes, water quality would improve. However, as more and more tungsten mills began operating upstream of the new intake, water quality problems once again became apparent[22].

3.2.2.3 | DEVELOPMENT OF THE SILVER LAKE WATERSHED

Relocating the pipeline intake upstream of Boulder Creek's confluence with Four Mile Creek reduced watershed area contributing to the municipal water supply. This became a problem during the dry winter of 1901-1902 when Boulder experienced its first serious shortage of water. Water stored in Silver Lake was released on an emergency basis to supply the town. As a result, in September 1902, the Council voted to visit Silver Lake and explore the idea of obtaining a high-elevation reservoir for the town. Also in 1902, the City Council discussed the water quality problems caused by having the water system intake located at the lower elevations of Boulder Canyon and began discussing the possibility of again moving Boulder's water intake upstream[23].

In 1903, J.P. Maxwell made a proposal to the City Council for a public-private partnership to build a new municipal water system with high-elevation reservoirs feeding pure water into a pipeline running from a point outside Nederland all the way to Boulder[24]. Maxwell and his son owned land in the area of the proposed reservoirs. The City Council was interested due to the prospect of a clean water supply, but was concerned about the expense of the project. After much public debate, the idea of a public-private partnership was disallowed by a court decision[25].

Maxwell had been involved in the development of city water supplies since the beginning and was determined to see the city proceed with improvements to the municipal water system. However, the motives behind his advice to City Council were questioned since he was City Engineer at the time and

[i] So named after the owner of the nearby Blanchard Inn.

[ii] Although there are multiple documents that support the fact that the city did indeed construct and use the Blanchard intake at this site in 1890, it appears that the city did not purchase the land for the Horseshoe Placer until 1904 and 1952. City Council minutes from June 20, 1890 describe the location of the site as located "westerly and southerly up Boulder Canon, along Boulder Creek, past the mouth of Four Mile to what is called the Gallup Ranch, about one mile south westerly from said mouth of Four Mile, and over and across said ranch… that said…improvement terminating on said ranch."

also owned the land being offered for sale to the city. After several false starts, the Council asserted its desire to control the destiny of the young city and developed a plan to acquire ownership of a high-mountain watershed and water rights and to pipe the pure water, free from the pollution caused by the mines and settlements, to Boulder[26].

The city finalized its first purchases of land in what was to become the city-owned Silver Lake Watershed in 1904 when it acquired lands on North Boulder Creek below Arapaho Glacier from Clint Maxwell, son of J.P. Maxwell[27]. The purchased land contained the Triple Lakes, which were natural lakes, and Oval Lake, which had been raised with a small dam built by Clint Maxwell. A larger dam was later installed by the city at Oval Lake from 1906 to 1908 to create a larger reservoir named Goose Lake[28].

In 1906, the city purchased Albion Lake and surrounding area for $12,000 from J.P. Maxwell[29] and Silver and Island Lakes for $34,000 from the Silver Lake Ditch Company[30], which by then had J.P. Maxwell as its sole owner. Maxwell secured an agreement between the company and the city that obligated the city to continue deliveries of storage water from space reserved in the newly-purchased city reservoirs to the company so that the company could then deliver water through the Silver Lake Ditch to holders of water delivery contracts. The agreement provided that the city's obligation would decline over time as contract holders abandoned their Silver Lake Ditch rights or were "supplied by other sources," such as by annexation into the city[31]. Maxwell then sold the remaining interests of the Silver Lake Ditch Company in 1907. The new owner of the company, W.W. Degge, owned land north of Boulder below the ditch and had dreams of creating a suburban paradise. Degge, through his new company, assumed the obligation to deliver water to holders of the company's water delivery contracts[32].

With a plan for high-elevation reservoirs proceeding, the city began construction in 1906 of the Boulder City Pipeline running from the Blanchard Intake at Orodell up to a tiny mining camp called Lakewood just north of Nederland. A diversion from North Boulder Creek was built at the site along with Lakewood Reservoir, which acted as a forebay for the new pipeline. The site was downstream of Boulder County Ranch (now called Caribou Ranch) where the Primos Tungsten Mill was located. Como Creek was re-channeled to prevent its polluted waters from mixing with the purer water of North Boulder Creek as it flowed into Lakewood Reservoir[33].

The city acquired twenty acres of land where Lakewood Reservoir is now situated in 1906 from T.N. Barnsdall of Pittsburg, Pennsylvania[34]. In addition, the city acquired easements for the Boulder City Pipeline (a portion of which is now called the Lakewood Pipeline) and for diversions from North Boulder Creek and from Como Creek across lands owned by Mr. Barnsdall. Mr. Barnsdall was given the right to construct a pipeline from North Boulder Creek that would drive a hydroelectric plant before discharging into Lakewood Reservoir. City officials were considering the potential need to extend the Boulder City Pipeline further up into the Silver Lake Watershed since the city also acquired the right to connect a future pipeline from Silver Lake Reservoir into Barnsdall's pipeline "should future emergencies require, whether from pollution of the stream or otherwise"[35]. However, Mr. Barnsdall never constructed his pipeline and power plant, so the city never constructed a connecting pipeline.

3.2.2.4 | BOULDER DISTRICT COURT'S 1907 GENERAL WATER RIGHTS ADJUDICATION

In January 1907, the Boulder District Court issued notice of a general water rights adjudication proceeding. The court issued a decree in March 1907 that recognized all water rights that had been developed since the 1882 general adjudication and all rights that had missed the previous general adjudication, and recognized reservoir storage rights for the first time[36]. Prior to this, reservoir owners had just taken water from the stream whenever direct flow rights were satisfied or not calling, but enough reservoirs had been built that priorities to the remaining water needed to be established. In this adjudication, the city was decreed a 20 cubic feet per second (cfs) water right for the Boulder City Pipeline that allowed direct flow use of water diverted from North Boulder and Como Creeks for municipal purposes with an appropriation date of 1904.

The court also issued the first decreed water rights for Silver Lake, with appropriation dates of 1887 and 1906; Island Lake, with appropriation dates of 1890 and 1906; and Goose Lake with appropriation dates of 1901 and 1906 and a conditional water right for enlargement. The decree recognizes the city's right to use the water under each priority for municipal purposes, including "the exhaustion" of the 1887 Silver Lake and 1890 Island Lake rights that were granted priority dates in the decree based on the original use for irrigation by the Silver Lake Ditch Company[37]. The city has interpreted "the exhaustion" of use for municipal purposes of water diverted under each of the specified decrees as allowing for one time municipal use of all of the water, and the city has not historically reused the water after its first municipal use.

3.2.2.5 | BOULDER CANYON HYDROELECTRIC PROJECT

The population in Denver and Boulder doubled between 1890 and 1905 and demand was great for new technology using electricity. In 1906, Myron T. Herrick formed the Central Colorado Power Company to create an extensive network of hydroelectric power plants and transmission lines throughout the Rocky Mountains. In 1909, Eastern Colorado Power Company had combined assets with Central Colorado Power Company and began planning for a hydroelectric dam on Middle Boulder Creek. Construction of the Boulder Canyon Hydroelectric Project power plant was accomplished by sending construction materials by train to Orodell. The materials were off-loaded onto specially constructed wagons that followed a track to the plant site[38]. Teams of up to 16 horses were used to pull the wagons[39]. Workers' quarters, stables, a blacksmith shop and a mess hall were constructed near the site, creating a small village for several years during the construction[40].

A tramway was constructed along the route of the penstock to carry materials up the steep mountain side to Kossler Reservoir[41]. Kossler Reservoir was named for the landowner, one of Boulder County's historic families that owned land in the Flagstaff Mountain and Walker Ranch areas. The penstock's 1828-foot drop between Kossler and the hydroelectric plant created the highest head of any plant in the United States at the time. Upon completion of the penstock, it was found that the riveted butt joints in the steel penstock could not withstand the 800 pounds per square inch water pressure that developed in the pipeline, and it leaked significantly. Using the then-new acetylene welding process, construction workers discovered that hammering the weld while it was still warm prevented the joints from cracking as they cooled. Discovery of this so-called ball-peen welding method is an engineering innovation credited to the project[42].

Barker Dam was completed in August 1910, 18 months after construction began. The dam and reservoir were named for landowner Hannah Barker, who had refused to sell her ranch holdings to the Central Colorado Power Company, necessitating condemnation proceedings to acquire the dam and reservoir site[43]. The hydro plant went into operation on August 4, 1910.

3.2.2.6 | ADDITIONAL SILVER LAKE WATERSHED ACQUISITIONS

Most of the land in the Silver Lake Watershed was purchased by the city from the federal government for $1.25 per acre based on three grants made by the US Congress in 1907, 1919, and 1927. Grants of the right to purchase the land were specifically based on the city's need for a water supply. On March 2, 1907, the U.S. Congress made its first grant of land in the Silver Lake Watershed to the city of Boulder. The act states that "…for purposes of water storage and supply of its waterworks...said city shall forever have the right, in its discretion, to control and use any and all parts of the premises herein conveyed, and in the construction of reservoirs, laying such pipes and mains, and in making such improvements as may be necessary to utilize the water contained in any natural or constructed reservoirs upon said premises"[44]. The Congressional Record for the 1907 bill conveying land to Boulder states, "The object and purpose of this bill are to convey to the city of Boulder, Colo., the lands described in the bill in order to protect the water supply of the said city from pollution, and to accomplish this purpose the land is to be conveyed to the city of Boulder..."[45]. That same day, Medicine Bow National Forest was expanded by Presidential proclamation to include lands in Colorado, including some of the lands adjacent to the Silver Lake Watershed[46].

In November 1907, the city purchased land near the old Albion mining camp on the north fork of North Boulder Creek near Silver Lake from The Cashier Mining and Milling Company with the agreement that The Cashier Mining and Milling Company could capture any water seeping out of Albion Lake to run through a pipeline that he planned to construct to generate hydropower for mining operations[47]. Thomas Wood, manager of The Cashier Mining and Milling Company operation at Albion, filed notice with Boulder County in 1905 of intent to build the Cascade Pipeline. The pipeline was built by 1908 to drive a hydroelectric plant located below Albion Lake[48].

Following the city's acquisition of Albion Lake, the City Engineer, Fred Fair, was authorized by City Council to build a dam at the site in 1911. A contractor was hired and work took place in 1912 and continued until the city ran out of money. Although the dam was originally designed to be sixty-feet high, it was only built to a height of 39 feet and no new work occurred after 1913[49]. The City Council also authorized the construction of a new dam at Silver Lake in 1911. Soon after work started in April 1912, it was halted by the State Engineer. The contractor, who was the low bidder, claimed the delay would substantially increase costs. He did not complete the specified work and the contract was cancelled in 1913[50].

By 1919, it was concluded that a pipeline intake was needed at an elevation even higher than Lakewood Reservoir to avoid contamination of the water supply with mine runoff from the Primos Mill[51]. The Boulder City Pipeline was extended to a point within the boundaries of the Silver Lake Watershed, resulting in two segments that would later be called the Lakewood Pipeline and the Silver Lake Pipeline. The intake to the Silver Lake Pipeline was identified in the city's water rights decrees as Boulder City Pipeline Headgate #3, the diversion from North Boulder Creek into Lakewood Reservoir was Boulder City Pipeline Headgate #1, and the intake from Lakewood Reservoir into Lakewood Pipeline was Headgate #2. When Boulder developed the plan to extend the Boulder City

Pipeline, the new pipeline intake was to be about 4 miles downstream of Silver Lake and of any property owned by the city. The town wanted to protect the quality of water released from Silver Lake as it flowed in the creek prior to diversion into the new pipeline. Boulder again approached Congress and received a new grant in 1919 To Whom It May Concern: purchase more land in what is now the lower part of the Silver Lake Watershed[52].

Boulder sought to protect its new water supply from upper North Boulder Creek to prevent the water quality problems that had been experienced in the past. In 1914, the city hired its first watershed caretaker, in part to keep an eye on recreational users of the area to assure no polluting activities took place. In about 1920, following a typhoid outbreak and amid fear of cholera, the town closed all of its Silver Lake Watershed land to public access and authorized the watershed caretaker to ticket trespassers[53]. The Silver Lake Watershed remains closed to public access not only to protect water quality, but also to protect the fragile alpine environment, wildlife habitat and sensitive university research studies of alpine and climate conditions that began in the 1930s.

In the 1920's, a proposal to build a toll road that would bring commerce and tourists near Arapaho Peak and the Arapaho Glacier was met with dismay by the city. The proposal was followed with a recommendation by the United States Park Service that the Rocky Mountain National Park boundaries be extended southward to include the Arapaho Glacier[54]. A final Congressional grant was obtained in 1927 over the strenuous objection of the Park Service. Both the 1919 and 1927 grants withdrew lands previously reserved to the Medicine Bow National Forest (of which the current Arapaho National Forest was once a part) and granted the right to purchase those lands to the city for inclusion in the Silver Lake Watershed for purposes of municipal water supply. These acts state that the United States gave and granted "the lands, together with all associated rights, privileges, immunities, and appurtenances, of any nature, to the city of Boulder and its successors forever"[55].

Over the years, Boulder has purchased additional parcels of land in the Silver Lake Watershed area from private owners. The city now owns approximately 6,500 acres in the Silver Lake Watershed containing thirteen reservoirs and natural lakes. Almost all of the water supply from the area comes from the melting of the each winter's snowfall. A fraction of a percent of the supply comes from the melting of the Arapaho Glacier. This high-quality source of water supply was sufficient to meet all of Boulder's water needs until the 1950's.

3.2.2.7 | CHANGES OF DITCH COMPANY SHARES TO MUNICIPAL USE

Boulder continued to grow and needed additional water rights of sufficient seniority to allow diversions in late summer. By 1925, the city had acquired 14 ¾ shares in the Anderson Ditch Company and 8 shares in the Farmers Ditch Company. These shares gave interests in the companies' water rights that were only decreed for direct irrigation use on land below the ditches. Much of this land had been annexed into the city and developed into houses and businesses served by the city's municipal water system. The city completed its first change of water right court proceeding in 1925 to allow diversion of the city's interest in the ditch companies' water rights at the city pipeline intakes on North Boulder Creek and to allow use of the water for municipal purposes[56]. Change of use court decrees for additional Anderson and Farmers shares acquired by the city were obtained in 1942, 1963 and 1989. The diversion point for the Town of Boulder Ditch direct flow right was moved upstream to Boulder City Pipeline headgates in a 1942 change of use case[57].

3.2.2.8 | FIRST RECONSTRUCTION OF BOULDER CITY PIPELINE

In 1939, the city began to rebuild the Boulder City Pipeline. The lower portion of the Boulder City Pipeline below Lakewood Reservoir was originally constructed with cast-iron pipe with lead joints. Segments of old pipe were replaced with steel pipe through World War II. The salvaged cast-iron pipe was used to replace the clay tile pipe that had been used in 1919 to construct the upper portion of the Boulder City Pipeline, which would become known as the Silver Lake Pipeline. After the city began the pipeline reconstruction, the US Forest Service (USFS) issued a Special Use Permit for the first time in 1939 for portions of the lower pipeline (about 30 percent) that crossed USFS land[58]. This permit was a land use authorization in addition to the right-of-way that the city had occupied since 1906 based on the Act of July 26, 1866[59] and the Acts conveying land in the Silver Lake Watershed to the city, which had been passed by the US Congress[60].

During and after the war, steel was scarce, so thinner-walled pipe was used for rebuilding the lower portion of the pipeline, which would become known as Lakewood Pipeline. The use of thin steel pipe for Lakewood Pipeline meant that the pipe could not be fully pressurized with the entire head of pressure that developed as water flowed from Lakewood Reservoir into the city. Therefore, air evacuation valves and surge chambers were built at points along the pipeline to let air into and out of the pipeline as water flowed up and down mountains and valleys to avoid the formation of vacuum pressure that would collapse the pipeline. This mode of pipeline flow allowed an enormous amount of air to become entrained in the water, which would eventually cause problems with water treatment processes once Betasso Water Treatment Facility (WTF) was built[61]. Lakewood Pipeline was not fully reconstructed until the 1950s.

3.2.2.9 | FORMATION OF THE NORTHERN COLORADO WATER CONSERVANCY DISTRICT

During the 1930s, a severe drought hit most of the mid-section of the United States and resulted in the Great Dust Bowl years. Water users in north-eastern Colorado experienced severe water shortages. In 1937, they lobbied the state legislature to allow creation of conservancy districts so that they would have the means to finance large water projects. The passage of the Conservancy District Act of Colorado in 1937 provided for conservancy districts to be created and allowed for imposition of up to a one mill general ad valorem tax as a revenue source from the general population of a district rather than directly from water users alone[62].

The Northern Colorado Water Conservancy District (NCWCD) was formed in 1937 for the purpose of delivering West Slope water through the Colorado-Big Thompson (CBT) Project to water users in northeastern Colorado as a supplemental supply to native basin water supplies. The CBT Project was built by the United States Bureau of Reclamation and began operation in 1957. NCWCD agreed to repay the federal government for that portion of the cost of the CBT Project attributable to irrigation, municipal and industrial water supply. The federal government bears all costs related to the hydropower production aspects of the project.

In 1937, it was thought that the construction cost for the CBT Project would be $44 million. Power generation revenues were expected to provide about $19 million toward the cost. It was projected that the project would provide an average annual water delivery to north-eastern Colorado of 310,000 acre-feet at a cost of $80 per acre-foot which could be paid back over forty years with no interest at $2 per acre-foot[63]. In 1938, NCWCD signed a contract to repay a portion of the expected construction cost, "not to exceed twenty-five million dollars" over a period of forty years beginning when the project construction was completed. NCWCD was required by the United States to levy the one mil ad valorem tax allowed under state law and to charge water users no less than $1.50 per acre-foot of water once the project was complete. The contract specifically listed project features planned for the part of the CBT system north of, and including, Carter Lake, but described the southern components of the system only as "conduits from the St. Vrain to Boulder Creek and to South Platte River (now being studied)"[64]. The southern components of the CBT delivery system became an addition to the project that was paid for separately from the base contract[65].

The first water was delivered from Grand Lake to the East Slope through the Adams Tunnel on June 23, 1947. Water was first stored in Carter Lake in February of 1954. The CBT Project became fully functional with its first full year of water deliveries in 1957[66]. The city of Boulder and 30,000 acres of adjacent land became part of NCWCD in 1953.

3.2.2.10 | DEVELOPMENT OF NEW WATER SUPPLIES FOR BOULDER – 1950'S

In 1949, city officials began to realize that the city would soon be facing water shortages due to the extraordinary growth experienced following the end of World War II. Plans began to be developed for expanding the city's water supply[67]. By 1952, the city was concluding that joining the NCWCD and obtaining CBT water was a preferred solution for resolving impending water shortages[68].

Pressure to develop additional water supplies increased in the mid-1950's when a severe drought further strained the limits of Boulder's Silver Lake Watershed and North Boulder Creek water supply. The city's supplies at the time consisted of transferred Farmers and Anderson Ditch rights, its relatively junior direct flow decrees, and storage in the Silver Lake Watershed. The city's direct flow rights were routinely called out by downstream users with more senior rights, and the city was forced to bypass direct flows and use mainly releases from storage reservoirs. During the severe drought year of 1954, streamflows fell to below 50 percent of normal, and the city ran short of water.

In response to the crisis, Water Superintendent E.B. Debler proposed that the city obtain water through exchange from the Public Service Company of Colorado (PSCo, now Xcel Energy), which was by then the owner of the Barker system, and the City of Denver. Under this plan, the city diverted water out of priority at its upstream diversions and replaced it at downstream locations with water leased from PSCo and Denver. The city would later file for a decreed exchange right on Boulder Creek based on these first water exchanges in 1954[69].

The city also made plans to develop additional water supplies, which resulted in two additional water sources in use by the city today – Barker Reservoir and Boulder Reservoir. The city entered into the first of a series of agreements with PSCo in 1955 allowing Boulder to have limited use of the Barker facilities[70]. In 1959, a new agreement was signed with PSCo that gave the city the right to store 4,000 acre-feet of water in Barker Reservoir[71]. Under successive agreements, the storage space allotted to the city gradually increased until 1978 when it reached 8,000 acre-feet out of the 11,686 acre-feet of space in Barker Reservoir[72]. PSCo continued to use the remaining storage space for water to generate electricity at the Boulder Canyon Hydro Plant.

Boulder Reservoir was completed in 1955 as a part of the 1953 agreement that allowed the city to join NCWCD. The city had not joined NCWCD in 1937 at the time when the feasibility of water delivery facilities to the southern part of the CBT system was still under study. Therefore, conditions for the city to join NCWCD were negotiated individually and included payment of the NCWCD ad valorem tax back to 1937 and construction of a new reservoir northeast of Boulder in which NCWCD could buy storage space. NCWCD agreed to pay one-third of the city's construction cost for the "Twin Lakes" Reservoir, later known as Boulder Reservoir, over a period of forty years[73]. The original city/NCWCD agreement allocated one-third of the reservoir storage space to NCWCD, but this amount was modified in later agreements to change seasonally[74]. The city was given a preferential right to use of 90 cfs of capacity in the outlet canal from Boulder Reservoir to Boulder Creek for delivery of the city's CBT water to be exchanged for additional water taken at the city's upper Boulder Creek intakes[75]. The city would use its CBT water only by exchange until the Boulder Reservoir WTF was completed in 1971.

In 1963, the city constructed the Betasso WTF for dual purposes: first to address ever-tightening drinking water standards and increased knowledge of water-borne pathogens following years of minimal treatment for the Silver Lake Watershed water, and second to increase Boulder's water supply by obtaining water from Middle Boulder Creek through PSCo's facilities. Land for the treatment facility was purchased from Ella Rhea Newsome[76]. The treatment plant processes were designed to fit within the confined area at the Betasso site based on the assumption that the quality of water from the Silver Lake Watershed and Barker Reservoir would continue to be protected and the need for plant enlargements would be minimal. The Boulder City Pipeline was re-plumbed to connect to the Betasso WTF, resulting in segments named the Lakewood Pipeline (which carries raw water to Betasso) and the Boulder Canyon Pipeline (which carries treated water into the city). A new pipeline was constructed from Boulder Canyon Hydro up the hill to Betasso WTF. For the first time, Boulder used Barker Reservoir water directly rather than by exchange to the Lakewood Pipeline. In the city's water rights decrees, the series of pipeline segments running from Barker Reservoir to Betasso WTF was called Boulder City Pipeline #3.

3.2.2.11 | DEVELOPMENT OF THE WINDY GAP PROJECT

Population continued to grow in Boulder, as it did throughout the northern Front Range. In the late 1960's, a coalition of six Front Range cities – Boulder, Estes Park, Fort Collins, Greeley, Longmont and Loveland – cooperated in a study of growth, water supply, and demand projections[77]. They concluded that a new water supply project was necessary to specifically meet municipal needs. The cities began the development of the Six Cities Project to pursue trans-mountain diversions to meet those needs. In 1969, the six cities realized that the amount of work and expertise necessary to build the project required a stronger organization than they could provide independently. They petitioned the District Court in Greeley for the formation of a Municipal Subdistrict with the NCWCD[78]. The formation of the Subdistrict was approved on July 6, 1970 and began development of what was now called the Windy Gap Project[79].

A proposed project was developed in which the Windy Gap Reservoir, located near Granby on the West Slope, would divert water from the confluence of the Fraser River and the Colorado River. The water would then be pumped up to Lake Granby and delivered to Windy Gap Project participants through the CBT system. After its formation, the Subdistrict negotiated a Carriage Contract with the U.S. Bureau of Reclamation and NCWCD specifying how Windy Gap water would be stored and carried to the northeastern Colorado cities through the CBT project[80]. The Carriage Contract that was executed in October 1973 allowed the Windy Gap Project to use excess capacity in the existing CBT storage and conveyance facilities, which made the project economically and environmentally viable[81].

In the summer of 1975, the Subdistrict entered into water allotment contracts with each of its six member cities. Each retained a one-sixth share in the project, equivalent to 80 units out of the total 480 units in the project. The Windy Gap Project was anticipated to deliver an average of 48,000 acre-feet of water annually, diverted primarily during the runoff season between April and July. Bonds were sold by the Subdistrict to finance the project. Project costs are discussed in more detailed in section 4.3.2.1. Construction of the project began in 1981 and the facilities became operational in the spring of 1985.

There was opposition from West Slope representatives regarding the effect of the Windy Gap Project on water users of the West Slope. Opposition resulted in lengthy litigation along with extensive environmental impact assessment and mitigation processes. Litigation terminated with the 1980 Windy Gap Settlement Agreement in which the Subdistrict agreed to provide up to $15 million for the study and construction of the Azure Reservoir Project as a means to compensate for any impairment of West Slope water use by the Windy Gap Project[82]. In 1985, the Subdistrict and the Colorado River Water Conservation District reached a supplemental agreement that the Azure Reservoir Project was infeasible and should not be further pursued, and instead, the Subdistrict would pay the Colorado River Water Conservation District $10.2 million so it could construct an alternative storage project for western slope water users[83]. In 1995, the Colorado River Water Conservation District completed construction of this storage project – Wolford Mountain Reservoir – on Muddy Creek[84].

3.2.2.12 | CITY'S PERPETUAL RIGHTS TO USE OF BARKER RESERVOIR

In 1982, a storage restriction was placed on Barker Reservoir by the Federal Energy Regulatory Commission due to concerns about the ability of Barker Dam to withstand an over-topping event from flooding. Over-topping concerns have since been addressed and alleviated with dam anchors. A new agreement was signed with PSCo in 1984 whereby the city partially paid for repairs to stabilize the dam and gained an "equitable servitude," a perpetual interest allowing on-going use, in 8,000 acre-feet of storage space and in two-thirds of the capacity in the Barker pipeline facilities[85].

3.2.2.13 | CITY HYDROPOWER DEVELOPMENT

In the early 1980s, the city began to develop plans for hydroelectric plants that would generate electricity using the high pressures developed within the city's source water and treated water systems. Renewable energy generation by the city began when the Maxwell Hydro Plant began operating in 1985. That year, the city generated just over 400,000 kilowatt-hours of electricity. That amount of electricity is sufficient to supply the annual needs of about 50 Boulder households.

In 1984, the city negotiated a power sales agreement with PSCo for three proposed hydroelectric projects on the city's raw water transmission pipelines—Betasso, Lakewood and Silver Lake Hydros[86]. This agreement was negotiated at the same time as the agreement whereby the city would pay for repairs to Barker Dam discussed above. As a result, the city was able to get very favorable payment terms for the power to be generated once the hydros were built.

During 1986 and 1987, Kohler, Orodell, Sunshine and Betasso hydroelectric facilities were completed. The Silver Lake Hydro was completed in 1998, and the Lakewood Hydro went into operation in June 2004. In 2007, the city generated over 41.5 million kilowatt-hours of electricity or enough to meet the annual needs of about 7,500 Boulder households[87].

By a Council decision, the hydro plants on the treated water system were constructed by the water utility with water utility enterprise funds. The hydro plants on the raw water system were initially to be constructed with general fund money. General obligation bonds were sold[88] and the money was used to construct Betasso Hydro in 1987. Subsequently, federal law changed and no additional general obligation bonds could be sold to fund Lakewood and Silver Lake hydros. Council decided that the general fund would sell ownership of Betasso Hydro and the undeveloped Lakewood and Silver Lake projects to the water utility enterprise[89]. Water utility funds were then used to construct Lakewood and Silver Lake hydros. Accordingly, all income from the hydro facilities is water utility enterprise fund revenue.

3.2.2.14 | CREATION OF THE BOULDER CREEK INSTREAM FLOW PROGRAM

In 1989, Boulder's Raw Water Master Plan identified a goal for the city of achieving instream flows in main Boulder Creek and its tributaries. In July of 1990, an agreement was completed between Boulder and the Colorado Water Conservation Board (CWCB) and was amended in 1992[90]. The agreement conveyed water and water rights owned by the city to the CWCB for use for instream flow purposes (see Table 5-7 for a list of water rights) . Boulder and the CWCB were joint applicants to the Water Court for a change in use of the water rights and storage decrees to allow instream flow. This application was filed in December 1990. A decree approving the change was signed on December 20, 1993[91]. The city has operated the instream flow program as an agent of the CWCB since that time.

3.2.2.15 | PURCHASE OF THE BOULDER CANYON HYDROELECTRIC PROJECT

Throughout the late 1980's and 1990's, the city was interested in acquiring the entire Barker system, but PSCo refused to sell. However, in the late 1990's, PSCo merged into a larger utility company that eventually became Xcel Energy. The new company was interested in disposing of assets that were underperforming for power production purposes. The city purchased the Boulder Canyon Hydroelectric Project, including Barker Reservoir, in 2001 with revenue generated from the sale of 43 Windy Gap units to the city of Broomfield. In late 2000, prior to the city's purchase, the windings on one of the generator units at Boulder Canyon Hydro Plant grounded out, causing extensive damage to the generator and leaving it inoperable. Only one turbine-generator unit is currently functioning in the plant. In addition to the facilities, the city also acquired the associated hydropower water rights. The city continues to use these rights for hydropower generation and has obtained additional water rights for storage of municipal water in Barker Reservoir. The primary benefit of owning the Barker System for the city was gaining the ability to operate and maintain the facilities to the standard of reliability necessary for a water utility rather than as a fully-depreciated hydro project. A secondary benefit is the continued generation of hydropower and the revenues earned by the city from selling the power to Xcel Energy. The Barker System continues to generate electricity when water is available.

3.2.2.16 | RECONSTRUCTION OF THE AGING WATER SYSTEM

During the 1990's and early 2000's, the city focused on re-building much of the aged raw water delivery system infrastructure. The outlet works and part of the dam at Lakewood Reservoir and the dam at Goose Lake were rebuilt, along with the two diversion structures from North Boulder Creek. The Como Creek diversion was also rebuilt. Lakewood and Silver Lake Pipelines were reconstructed. Following purchase of the Barker system, the city embarked on a multi-year repair program for the Barker Gravity Pipeline. Repairs have been made to the Boulder Canyon Hydro penstock and the remaining operational turbine and generator at the hydro plant. In Boulder Reservoir, the intake from the reservoir to the treatment plant was modified to draw water in from a higher elevation to improve water quality.

Boulder Water System Timeline

1875	Town of Boulder Ditch was constructed to carry water from Boulder Creek into the town's new water system. Town of Boulder Reservoir was built by Boulder just west of the town near Red Rocks with an intake from Boulder Creek near the mouth of the canyon.
1877	Boulder's first water supply protection ordinance was passed stating, "No person shall put any carcass or filthy animal or vegetable matter into the reservoir nor shall any person bathe or swim therein or skate upon the ice which may form thereon in cold weather."
1879	Town of Boulder Reservoir capacity was inadequate to serve the growing population and the town sometimes ran out of water.
1884	Water running in Boulder's water system was turned off when dead horses were found in Boulder Creek above the town's intake.
1887	J.P. Maxwell and George Oliver formed the Silver Lake Ditch Company to provide water to their new development on Mapleton Hill following Boulder's refusal to provide municipal water service. They built the Silver Lake Ditch west of town and a dam at Silver Lake below the Arapaho Glacier.
1890	A new reservoir, Sunshine Reservoir, was built at an elevation 100 feet higher than the Town of Boulder Reservoir. The Blanchard intake was constructed upstream on Boulder Creek at Orodell. J.P. Maxwell built Island Lake to serve the Silver Lake Ditch Company.
1902	Planning began for avoiding creek pollution by building a system of reservoirs and pipelines at a higher point in the watershed above mining activity. Boulder rejected J.P. Maxwell's proposal to build the new water system as a public-private partnership. Water use restrictions were instituted because of drought.
1904	The first land for what will become the Silver Lake Watershed was purchased near the Continental Divide, including Triple Lakes and Oval Lake.
1906	Lakewood Reservoir was built near Nederland. Lakewood Pipeline was completed at a cost of $155,000 to carry water from Lakewood Reservoir to Boulder. Boulder purchased Silver Lake and Island Lake Reservoirs from the Silver Lake Ditch Company which was owned by J.P. Maxwell.
1907	The federal government issued the first of three grants that allowed Boulder to purchase 1,557 acres of high altitude land on North Boulder Creek which became Boulder's Silver Lake Watershed. The city began construction and enlargement of municipal water storage reservoirs within the Silver Lake Watershed area.
1908 to 1910	Barker Meadow Dam and the Boulder Canyon Hydroelectric Plant were constructed by an electric power company that is later purchased by PSCo.
1911	The city purchased a mining camp at Albion. Construction began on Albion Reservoir.
1913	The construction of Albion Reservoir was completed.
1914	Following outbreaks of typhoid fever, City Council discussed hiring guards for the Silver Lake Watershed. Council took an inspection tour following reports of pollution in the Silver Lake Watershed from campers and tourists. Based on the Council visit, the area was fenced and closed by 1920 and a watershed caretaker was hired.
1917	Boulder's first "water treatment plant" was built near Lakewood Reservoir consisting of a shed where chlorine and aluminum sulfate were dumped into Lakewood Pipeline at irregular seasonal intervals.
1919	Silver Lake Pipeline was built from the Silver Lake Watershed to Lakewood Reservoir to avoid contamination from tungsten mining above the Lakewood Pipeline intake. A second grant was issued by the federal government allowing Boulder to purchase 400 acres of land to add to the Silver Lake Watershed.

1925	Boulder completed its first water rights change of use proceeding and the court granted the city the right to use water within the municipal water system that had previously been decreed for agricultural use through the Anderson and Farmers Ditches.
1927	Congress approved Boulder's purchase of 3,689 acres of federal land including Arapaho Glacier and 4 peaks along the continental divide for $4,618. The deed to the city is signed by President Herbert Hoover in 1929. This is added to the Silver Lake Watershed.
1928	The outlet for Silver Lake was lowered to gain access to more water for the city. Silver Lake Ditch Company later objected to the city's alteration of the dam.
1935	The city purchased Green Lakes. Civilian Conservation Corps crews worked in the Silver Lake Watershed.
1937	Northern Colorado Water Conservancy District was formed to contract with the Bureau of Reclamation to bring water from the western slope as a supplemental supply for northeastern Colorado.
1939	Work was started on the reconstruction of Lakewood Pipeline. The project was suspended due to a shortage of steel during WW II and was not completed until 1954.
1940	Silver Lake dam was rebuilt.
1949	Chlorine was added to water year-round at Lakewood Reservoir instead of seasonally. Studies showed that increased water needs of Boulder's large post-World War II population would exceed Boulder's existing water supplies.
1953	Boulder became a member of the Northern Colorado Water Conservancy District and acquired contract water delivery rights for the CBT Project.
1954	The most severe drought year in the recorded record until 2002 occurred. The drought continued until 1957. Boulder entered into an emergency agreement with PSCo to exchange water from Baseline Reservoir into Barker Reservoir for later release in exchange for direct diversions at Lakewood Reservoir. Silver Lake Pipeline was rebuilt using 1906 pipe salvaged from the Lakewood Pipeline reconstruction.
1955	Boulder Reservoir was built and filled from Carter Lake with CBT water diverted from the western slope. Boulder entered into an agreement with PSCo allowing on-going city use of 4,000 acre-feet of storage space in Barker Reservoir.
1959	The Barker Reservoir agreement with PSCo was revised to allow Boulder use of 4,000 acre-feet of storage space to be increased to 8,000 acre-feet over time.
1963	Betasso Water Treatment Facility was constructed to filter the drinking water. A pipeline was constructed to allow the city to deliver Barker Reservoir water directly into Betasso.
1966	Skyscraper Reservoir was acquired by the city from Everett Long.
1969	Fluoridation of drinking water was approved by Boulder voters. Six northeastern Colorado cities, including Boulder, initiated the Windy Gap Project to deliver municipal water through CBT facilities.
1971	Boulder Reservoir Water Treatment Facility was built with a capacity of 8 MGD. CBT water was treated and used directly by Boulder for the first time instead of exchanged for Boulder Creek water.
1972	Boulder's right to use Barker Reservoir storage space increased to 8,000 acre-feet.
1976	Betasso Water Treatment Facility was doubled in capacity to 45 MGD.
1982	A pump was added to Boulder Reservoir WTF allowing water to be taken into the treatment plant from both Boulder Reservoir and Boulder Feeder Canal.
1983	A contractor working at Goose Lake caught the timber cribbing on fire and the upper portion of the dam burned.
1984	The first hydroelectric plant on Boulder's water system was built. Boulder entered into an agreement with PSCo allowing the city to permanently use 8,000 acre-feet of storage space in Barker Reservoir.
1986	Efforts to reach an agreement with the USFS for the reconstruction of Lakewood Pipeline began.

1989	The city completed the Raw Water Master Plan and adopted reliability criteria for the raw water supply system.
1990	The city entered into an agreement with the Colorado Water Conservation Board (CWCB) to donate city water for use for instream flows in North and main Boulder Creeks.
1991	Boulder sold 43 units out of its 80 units of Windy Gap water to the city of Broomfield.
1993	A decree was issued by the Water Court approving the city/CWCB instream flow program and program operations began.
1994	The spillway structure at Lakewood Reservoir failed dramatically, causing the reservoir to empty overnight. The spillway, the inlet to Lakewood Pipeline, and the part of the dam over Lakewood Pipeline were rebuilt in 1996.
1995	Extremely high spring runoff flows caused the city's two diversion structures from North Boulder Creek to fail. Both were rebuilt to allow measurement of instream flow releases.
2000	The upstream face of Goose Lake dam was rebuilt. The reconstruction of Silver Lake Pipeline was completed.
2001	Barker Reservoir and Boulder Canyon Hydro Project facilities were purchased from PSCo for $12.4 million. Work to repair the Barker Gravity Line began. An easement agreement for the Lakewood Pipeline was signed as a result of the effort to reach agreement with the USFS that began in 1986.
2002	The most severe drought in three hundred years caused mandatory water use restrictions to be implemented in Boulder. Water use dropped by 20 percent.
2004	The Lakewood Pipeline reconstruction was completed and the new pipeline went into service along with Lakewood Hydro. With the completion, the city, through its water utility, owns and operates a total of eight hydro plants.

3.3 | Management of Irrigation Ditches

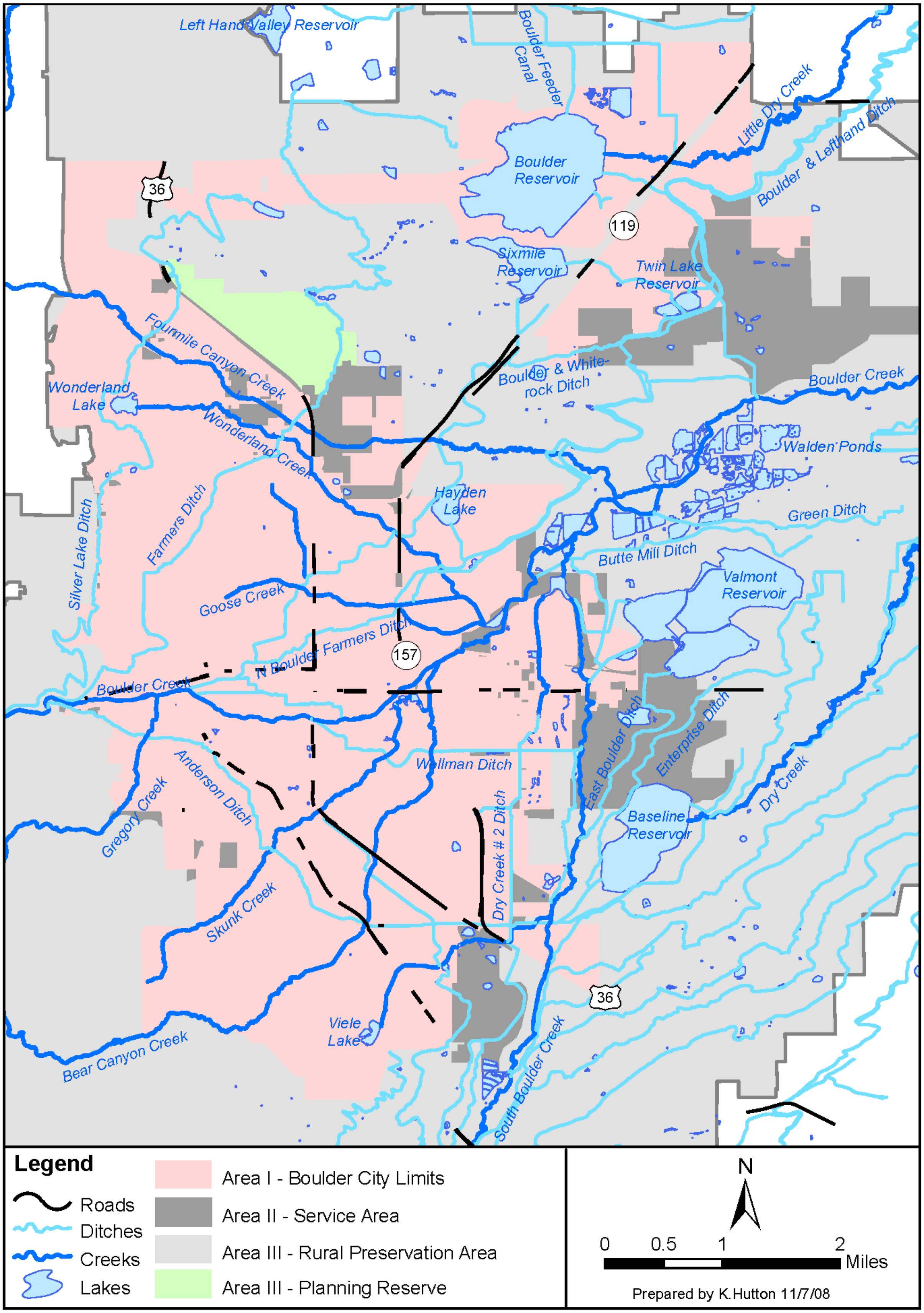
3.3.1 | IRRIGATION DITCH BACKGROUND

Much of the land within the present Boulder city limits was once farmland irrigated by irrigation ditches. Many of these ditches are still in existence and carry irrigation water through the urban areas for use on private yards, parks, campus areas, or farmland at the edge of the city or as far as Weld County. There are over twenty irrigation ditches spanning over thirty miles within Areas I and II as defined in the Boulder Valley Comprehensive Plan[92] (Table 3-1). Within Areas I, II, and III, there are more than thirty irrigation ditches (Figure 3-1).

TABLE 3-1. PARTIAL LIST OF IRRIGATION DITCHES WITHIN THE BOULDER VALLEY

Ditch Ditch	Water Source	Ditch	Water Source
Anderson Ditch	Boulder Creek	Jones and Donnelly Ditch	South Boulder Creek
Boulder and Whiterock Ditch	Boulder Creek	Leggett Ditch	South Boulder Creek
Boulder and Lefthand Ditch	Boulder Creek	McCarty Ditch	Boulder Creek
Boulder Feeder Canal	CBT/Windy Gap	McGinn Ditch	South Boulder Creek
Butte Mill Ditch	Boulder Creek	North Boulder Farmers Ditch	Boulder Creek
Dry Creek No. 2 Ditch	South Boulder Creek	Schearer Ditch	South Boulder Creek
East Boulder Ditch	South Boulder Creek	South Boulder Bear Creek Ditch	South Boulder Creek
Enterprise Ditch	South Boulder Creek	S. Boulder Canon Ditch	South Boulder Creek
Farmers Ditch	Boulder Creek	Silver Lake Ditch	Boulder Creek
Green Ditch	Boulder Creek	Smith and Goss Ditch	Boulder Creek
Howard Ditch	South Boulder Creek	Star Ditch	Left Hand Creek
Howell Ditch	Boulder Creek	Wellman Ditch	Boulder Creek

FIGURE 3-1. DITCHES WITHIN BOULDER VALLEY



3.3.2 | MAINTENANCE OF IRRIGATION DITCHES

Irrigation ditches are owned and maintained by private ditch companies, most of which operate under the provisions for mutual ditch corporations in the Colorado statutes[93]. Shareholders in the companies pay assessments for operation and maintenance of the ditches and are entitled to receive a pro-rata portion of the water carried in the ditch based on their ownership of ditch company shares.

The city is a shareholder in many of these companies, but its shareholder rights are no different than those of the private shareholders. The ditch company remains a private corporation even if a portion of its shares are owned by the city. In many locations where city transportation or drainage activities have affected the ability of the private ditch company to maintain the facilities, the city has entered into an agreement with the ditch company to maintain sections of a ditch. Boulder's Public Works maintenance group has a database to track transportation and utility maintenance activities, including work performed on ditches.

In general, the active ditches within the city are in good to fair condition. There are a few ditch locations where the facilities are in disrepair with significant leakage and are in some danger of collapse. Many sections of the ditches have become part of the natural landscape, while other sections have been piped or lined with concrete. In some locations, the remnants of old laterals that are no longer used to carry irrigation water can still be seen.

3.3.3 | IRRIGATION DITCHES AND URBAN ENCROACHMENT

Although many residents refer to the irrigation ditches as "creeks" and believe they are natural waterways, irrigation ditches have distinct differences from natural streams. Ditches are constructed to run perpendicular to the slope of the land rather than down the slope, as is the natural course for streams. The ditches were constructed in this manner to transport water as far as possible away from the stream and to allow irrigation of the greatest amount of land below the ditches. This configuration results in an unnatural channel with very minimal slope and a large tendency to seep water and create or contribute to locally high water tables. Some ditches have been lined or are periodically sealed to minimize seepage, particularly in urban areas. Ditch companies are not generally liable for damages from what is considered normal seepage, especially to buildings constructed down-slope of the ditch long after the ditch was first established. The unnatural configuration of ditches also means that a great deal of sediment settles out of the water as it flows along the minimally-sloping ditch and that there is constant water pressure against the downhill bank of the ditch. Therefore, irrigation ditches must be rebuilt using heavy equipment every decade or so to remove sediment buildup and restore the downhill bank. If development has encroached on the ditch channel, ditch maintenance efforts using the required heavy equipment can become difficult.

Urban encroachment on irrigation ditches has often created conflicts between ditch companies and their neighbors since urban dwellers may not understand the legal rights of ditch owners. Ditches most often are located on prescriptive easements that arise by use of the land for the given purpose over time. Under Colorado law, "open and notorious" use for a specific purpose for a period of eighteen years creates a prescriptive easement that is binding on the underlying property owner. These prescriptive easements are rarely recorded on public records, so new property owners often do not understand the access and maintenance rights held over their property by the ditch company and may not understand that their property is considered the "subservient estate" and the ditch company's easement is the "dominant estate"[94]. In addition, there are often agreements that have been entered into by prior property owners who desired to move or enclose the ditch that require the property owner and his successors to maintain the ditch structure at their expense.

Prescriptive easements are not limited to a certain width, but instead include the right to access for whatever activity is "reasonable and necessary" to operate and maintain the facility. This is often defined by the easement owner's historical use practices. For ditch companies, this usually includes access to the ditch for ditchriders[iii] and heavy equipment, the right to remove anything that interferes with maintenance or operation of the ditch, including trees, and the right to place material and debris cleaned out of the ditch adjacent to the ditch without obligation to haul it away[95]. The easement continues to exist even if it is only exercised at infrequent intervals. If a resident builds a structure such as a patio or bridge, or plants trees or bushes adjacent to the ditch, the ditch company often has no obligation to protect the structure or landscaping if they are damaged or must be removed during ditch maintenance activities even if they have existed for many years. Property owners with an irrigation ditch running across their land should not move or alter the ditch without the permission of the ditch company[96].

Properties on the down-slope side of a ditch are susceptible to flooding or seepage during normal ditch operations. Solutions to seepage problems for property owners below a ditch bank include sump pumps, French drains, and ditch liners or sealants. It is typically the responsibility of the property owner to install seepage protection for the improvements made after the ditch was in existence. Likewise, it is usually the property owner's responsibility to remove any dead or dying trees near the ditch bank, although the ditch company has the right to remove any vegetation that interferes with ditch operations[97]. Property owners should not cut down the height of ditch banks, destabilize ditch banks by cutting into them or planting trees on them, or throw trash or debris into the ditch because the property owner may then have liability for any ditch overtopping, seepage or flooding caused by these actions. In order to minimize conflicts, the city has established agreements with a few ditch companies stating that, if the company places debris from the ditch at designated deposit sites, the city will remove the debris. Boulder's Utilities Division and Planning and Development Services have been working closely in recent years to develop a protocol to protect ditches from urban encroachment and protect developments from the effects of potentially high water tables. When residents seek a building permit for a permanent structure near an existing ditch bank, the city may require that the residents receive approval from the ditch company to assure that the company's easement rights are not affected.

3.3.4 | STORMWATER AND IRRIGATION DITCHES

Irrigation ditches naturally intercept a large amount of stormwater and natural drainage from the upslope areas above the ditches due to their alignment along a line perpendicular to the slope of the land. In addition, irrigation ditches were often constructed to capture streamflow from gulches and intermittent streams crossed by the ditch in order to increase the ditch water supply. Due to these ditch characteristics, the amount of water flowing in an irrigation ditch often can increase quickly during storm events and may cause flooding of properties downslope of the ditch if the ditch bank is over-topped. It is also possible for stormwater to be carried from one small stream basin into another and cause flooding where it might not otherwise have occurred.

[iii] "Ditchrider" is the traditional term used for the person who operates and maintains an irrigation ditch for a ditch company. It is derived from the time when ditch personnel would ride horses along the ditch bank to monitor the ditch.

In many cities of Boulder's age, no storm sewer system existed until the twentieth-century because typical nineteenth-century city planning processes did not have any standards for dealing with concentrated stormwater discharges from developments and paving of roads. Drainage water was allowed to simply flow downstream however it could. By the time the city began constructing a storm sewer system, a significant portion of Boulder had already been built. In the 1920s, the city developed a plan to pave its streets and build storm sewers in the north-to-south running streets. If the storm sewer intercepted an irrigation ditch before reaching a natural stream channel, the city allowed the pipe to discharge to the ditch.

In 1923, the Boulder and Whiterock Ditch Company sought to prevent the city from discharging stormwater into the ditch from a newly constructed storm sewer that ran along 16th Street. The city had plans to construct additional storm sewers that would discharge to the ditch, and the ditch company sought to enjoin their construction. The company also contended that the stormwater polluted the ditch water and made it unsuitable for domestic use[98]. The Boulder and Whiterock Ditch diverts from Boulder Creek east of Broadway (the 12th Street Diversion) and runs north-easterly through the city. The ditch was constructed to intercept streams that it crossed, including Goose Creek and Wonderland Creek. The company has a decreed water right for agricultural use for diversions from Boulder Creek and Goose Creek and claims rights, though undecreed, to other streams that the ditch intercepts. The trial court ruled that the city had seven months to remove the 16th Street stormwater discharge and that any stormwater pipe discharge above the ditch, even if the water would have reached the ditch under natural conditions, was a trespass and nuisance. The ruling was appealed to the Colorado Supreme Court, which overturned the lower court ruling. The Supreme Court held that the ditch company had no cause for complaint against the city for merely collecting and accelerating stormwater discharge into the irrigation ditch if the ditch was constructed in such a way that it would otherwise naturally intercept the same surface drainage. Furthermore, the city could not be held liable for nuisance based on pollution of domestic water supplies because the ditch company's water rights were only decreed for irrigation purposes, which the city had not made any less valuable through its actions[99].

Following several large flood events in the Denver metropolitan area in the late 1960s, including a major flood on Bear Canyon Creek in Boulder, the Urban Drainage and Flood Control District (UDFCD) was formed to coordinate efforts of metro Denver cities to construct and operate regional flood control and drainage facilities. UDFCD established standards for dealing with increased runoff from new construction that included directing runoff to natural channels and ending reliance on intervening drainage ditches. Almost all new developments built after that time drain to natural channels. However, irrigation ditches still intercept a great deal of stormwater either due to their construction across the lay of the land or due to older development.

Boulder's Stormwater Master Plan includes plans to lessen the stormwater inflow into irrigation ditches over time. However, the amount of remedial work that must be done to address this problem as well as address under-sized or non-existent drainage channels and stormwater system pipelines is large given that decades of development occurred in Boulder with very little thought given to stormwater management and no engineering design standards existed for decades after that. Therefore, the capital investments required for the city's stormwater system are large and will need to be spread out over many years. The existing situation with large amounts of stormwater entering into irrigation ditches is likely to continue for a long time.

The Anderson Ditch intercepts and carries large amounts of stormwater that is generated from University Hill in the area south of Boulder Creek, east of Broadway and north of Bear Creek. Since this situation is likely to continue for a long time into the future, given the greater need to address parts of the city that have no stormwater drainage facilities at all, the city has signed an agreement with the Anderson Ditch Company to carry city stormwater through its facilities. The city pays the ditch company an annual assessment for stormwater carriage. The Anderson Ditch Company has agreed that all excess carrying capacity in the ditch above that needed to carry shareholder or contract water is reserved for the city to carry stormwater[100].

Other ditches running through the city also receive stormwater discharges throughout their length. However, the city has not entered into any other ditch-wide stormwater carriage agreements because these other ditches are not as heavily impacted by storm drainage as is the Anderson Ditch. The city has entered into agreements with other ditch companies regarding specific areas of the ditch that may be impacted by changes in historic storm drainage. For example, the city entered into an agreement with the Farmers Ditch Company regarding the area around the North Boulder Recreation Center so that stormwater discharges from the site could be increased over historic levels[101].

The city and the Farmers Ditch Company have an agreement that allows the city to carry "foreign" water from other sources through Farmers Ditch to Boulder Reservoir for municipal water supply. The city pays an annual assessment related to the ditchrider's salary to allow the city to carry foreign water[102].

3.4 | Legal Factors Affecting Water Management

The city of Boulder operates its water supply system within the legal boundaries of court decrees, state laws, state constitutional provisions, federal laws, contracts, the City Charter and City Council adopted plans and policies. This legal framework both guides and constrains the activities the city conducts through the water utility. This SWMP assumes that any legal constraints will continue in the future. No recommendation will be made for an action that is contrary to a legal constraint without noting in the recommendation that the legal constraint must first be removed.

3.4.1 | COLORADO WATER LAW

Understanding the city's water rights requires some familiarity with Colorado's basic water law doctrine, the prior appropriation doctrine, often summarized as "first in time, first in right." The prior appropriation doctrine is the basis of a property rights-based water allocation and administration system that encourages efficient use of a finite resource. Under this doctrine, anyone can establish a right to divert water from a stream as long as that water is put to a beneficial use. No more water can be taken than can be beneficially used. This system imparts security by defining and protecting the right to use water and providing a predictable method of water allocation during dry periods. It provides reliability by giving assurance that the right to use water will continue to be recognized and enforced over time as a vested property right. The system is flexible because water rights are separate property from the land on which the water is used. They may be bought, sold or changed to another type of use through court proceedings so long as no other water rights are adversely affected or "injured." See section 3.2.1 on the history of Colorado water development for more historical information on Colorado water laws.

A water right in Colorado is characterized by several factors. These include its priority date (based upon both the date on which the right was first appropriated, i.e., put to beneficial use or work begun on the water diversion project, and the date the appropriation was confirmed by court decree), decreed rate of diversion or volume of storage, decreed uses (such as municipal or agricultural), location of its diversion point, association with delivery facilities or storage reservoirs, water quality, institutional restrictions on use, whether water remaining after the first use can be reused, and market competition for purchase of water. Although a right to use water can exist without benefit of a court decree, a water right must have received a decree through an adjudication process with the court to have a priority date that will be recognized and administered against other water rights by the State Engineer's Office (SEO).

3.4.1.1 | USE OF WATER RIGHTS

The SEO administers all water rights within each river basin according to the priority system. For this purpose, Colorado is divided into seven water divisions, corresponding to the major river basins in the state. For purposes of allocating administration duties, these water divisions are further subdivided into water districts which encompass local sub-basins. An SEO employee called a "water commissioner" is assigned to each water district to regulate who is allowed to take water along with when and in what amount. The Boulder Creek sub-basin, which includes Boulder Creek and its tributaries, makes up Water District 6, which lies in Water Division 1, the South Platte River Basin.

A water right can only be used in a manner that does not injure the use of more senior water rights. In order for the owner of a water right to legally divert water, there must be sufficient streamflow to allow all other more senior water rights to concurrently be fully satisfied. The most senior water rights can usually divert at most times during their historical or decreed season of use while more junior water rights often can only divert during high flow periods. In the South Platte River Basin, the most senior water rights are those with priorities in the 1860's and 1870's. A water right is "in priority" when there is sufficient flow to allow it to legally divert water. Otherwise, the diversion is "out of priority," meaning the right cannot legally divert water. If a water right is not being satisfied at a time when more junior rights are diverting, the water right owner can place a "call" against the junior right and cause it to stop taking water; this is known as being "called out" of priority. Following application of the water to beneficial use, as defined by the conditions of the water right decree, any remaining unconsumed water must be allowed to return to the stream for diversion by downstream water rights, unless the decree specifically allows reuse of the unconsumed water.

3.4.1.2 | TYPES OF WATER RIGHTS

Water rights are initially decreed as either direct flow water rights or storage water rights. Direct flow water rights are those that must be used immediately for their decreed beneficial uses, without storage. Storage water rights are those that can be stored first and subsequently placed to their decreed beneficial uses. Water rights that are initially decreed as direct flow water rights can be changed with court approval to allow both direct flow use and storage with subsequent use. This oftentimes occurs when agricultural direct flow water rights are changed to municipal use. Beneficial uses for water rights are not expressly defined or limited under Colorado law, but can be any use that is reasonable, lawful and not wasteful. Recognized beneficial uses include exchange for use of other water and augmentation of out-of-priority diversions. An exchange use allows the holder to satisfy senior water rights by adding water to a stream from a downstream source in exchange for diversion of an equal amount of water upstream. An augmentation use is usually made as part of a court-approved augmentation plan which allows a junior water user to replace depletions to senior water rights with water from another source, so that diversions under the junior right can continue at times when the right is out of priority.

The facilities required to divert and use a water right often take a long time to build. Colorado water law recognizes this, and such facilities need not be in place when a water right and its priority date are confirmed by the water court. Under these circumstances, the right is decreed as "conditional," and will be made absolute after proof is made in water court that actual diversion and beneficial use of water have taken place under the water right[103].

3.4.1.3 | WATER LAW PRINCIPLES AND ADJUDICATION PROCEDURES

Water law principles may be established through legislative action or through court decrees. The implications of a particular water law principle may be complex, so simplified terminology based on phrases from a statute or decree often develops to describe a particular concept.

An example is "Expansion of Use." A water right owner is generally not allowed to make new uses not previously decreed for a water right or to increase the consumptive use associated with the decreed uses of a water right beyond the limits of the historical consumptive use or, in the case of conditional water rights, beyond the contemplated consumptive use of the water right. The reason behind these principles is that return flows from one use provide the water to fulfill another user's water right. A downstream water user would be injured if the amount of water consumed under an upstream water right increased. In this way, water reuse is built into the prior appropriation system, even if an individual water user does not have reuse rights.

A water user may have several water rights with flow rate amounts that when added together appear, on paper, to allow diversions in excess of current needs. In reality, these rights may not be in priority at the same time or may be sufficiently junior that they only yield water for a few weeks during high runoff periods. Beneficial use principles and requirements prevent more water from being taken than is necessary to satisfy the water right owner's immediate needs. Similarly, under decreed use principles and requirements a water user must be able to take water into a decreed structure for decreed purposes to claim the water or else no longer has any right to the water and must allow it to pass by to other water users. For example, if a city has a pipeline with capacity larger than its immediate municipal needs, the city cannot increase diversions under its direct flow rights for other purposes beyond municipal needs. Conversely, if a pipeline is flowing full, yet only meeting part of a city's needs, and the city still has direct flow rights in priority, the additional water that cannot physically fit into the full pipeline can only be taken by the city at another diversion point if that point is included in the decree. The city cannot use the additional water flowing past the full pipeline for other undecreed purposes.

The owner of a water right can change the terms of the decree governing its use by filing an application with the water court and obtaining approval of the proposed changes. Filings for new water rights can be made in the same manner. The court publishes a resume of all filings received monthly. Anyone concerned that a filing may reduce the yield or otherwise injure their water right may file an objection to the application no later than the end of the month after the month of the publication in the resume. The applicants provide information to the objectors. If concerns can be resolved, the objector may stipulate to terms and conditions to be placed on the applicant's water use that will be included in a court decree. If concerns cannot be resolved, then a trial may be held before a Water Judge who is well-versed in water law and water issues. Almost all water court cases are settled between the parties and very few go to trial.

Water diverted under a particular water right must be put to use for the decreed purposes. A change in use requires approval by the water court. For example, when Boulder dedicated use of municipally-decreed water to the Colorado Water Conservation Board (CWCB) for instream flows in Boulder Creek, a court proceeding was required. See section 3.4.9.1 for a description of the instream flow program. It was necessary to set new terms and conditions on the city's existing water decree to limit municipal use under the decree in order to provide water for the new purpose[104].

Reductions in municipal water use that may be temporary, such as through water conservation programs, cannot become the basis for transferring water to another non-municipal use without water court approval. To obtain such approval, the city would likely be required to make a permanent commitment to reduce current water use under the designated municipal right. Changes of water rights are frequently likened to an IRS tax audit and almost always result in new terms and conditions on use of the water rights. Thus future changes of water rights by the city from municipal to other non-municipal uses could reduce the remainder of the water right yield below historical municipal use levels.

3.4.2 | WATER UTILITY ENTERPRISE FUND

The city provides water, sewer and stormwater services by virtue of Article XX of the State Constitution[105] (Home Rule of Cities and Towns) and the City Charter[106]. The Utilities Division of the Public Works Department directs the day to day operations of the three utilities. The city operates its water, sewer, and stormwater systems as individual "enterprises" as defined in Section 11-1 of the City Code and Article X, Section 20 of the State Constitution. This portion of the constitution was amended in 1992 when Colorado voters approved the Taxpayer's Bill of Rights (TABOR). This amendment was designed to restrain growth in government. TABOR limits revenue growth for state and local governments in Colorado and requires that any tax increase in any state or local government must be approved by the voters of the affected government. Designated enterprise funds are exempt from the revenue constraints imposed by TABOR.

The TABOR revenue limit restricts the growth of all general funds and all cash funds. The revenue that a government entity can retain within these funds from all sources, except federal funds, in a year is limited to the amount of the previous year's collections which were allowed under TABOR (not actual collections) plus a percentage adjustment equal to the percentage growth in population plus the inflation rate. If the revenue collected from all sources exceeds the limits of the formula, it must be refunded to taxpayers unless voters grant prior approval to retain and spend the excess funds. TABOR includes in the definition of revenue all general funds, such as revenue collected from taxes, and cash funds, which are generally restricted funds, generated by fees or fines, which can only be used for the purpose or program for which the fee is collected. The types of revenue that are exempt from TABOR restrictions include federal funds, litigation settlements, gifts, and money earned by enterprises. TABOR narrowly defines "enterprise" as any government-owned entity with bonding authority that receives less than 10 percent of its total funding from all grants from Colorado state or local governments combined[107]. While both cash funds and general funds count toward the city's fiscal year spending limit, all excess revenues are refunded out of the general fund. Therefore, if the city's water utilities fund was not exempt as an enterprise fund and water sales revenue in any year drove the city over the TABOR revenue limit, the excess would need to be refunded from the city's general operating budget.

Accordingly, there are distinct benefits both to enterprise funds and to the city's general fund from assuring that the enterprise fund status is not jeopardized. In order to maintain enterprise fund status, each of the three separate city utility enterprise funds must limit both their sources of revenue and the activities on which the revenue is spent. For example, revenue earned by the city that is accounted for within the water utility enterprise fund is mostly derived from water sales and fees for allowing taps into the city water system. This revenue is tracked separately within the city's accounting systems from the general fund or other restricted funds and must be used for activities related to providing the municipal water supply. Likewise, the assets held within the water utility enterprise fund, such as the city's water rights that provide the water for municipal use, must be used for the principal purpose of providing this service.

Money is transferred from the water utility enterprise fund to the general fund to pay for specific services provided by general fund departments that are needed to support water utility operations, such as human resources support or city attorney services. Under the City Charter, other city departments do not pay the water utility enterprise fund for provision of a reasonable amount of water supply to meet their needs, but do pay Plant Investment Fees for water taps into the city system and pay for water usage in excess of what is reasonable. If an asset that is included within the asset list for the water utility enterprise fund, which forms the basis for the Plant Investment Fee calculation, were to be committed to permanent use by another city department, it would no longer be available for the primary purpose of providing municipal water supply. Therefore, that asset would need to be "purchased" from the water utility enterprise fund through transfer of money out of funds available to the city department gaining benefit of the re-assigned asset.

The Boulder Revised Code[108] (BRC) Section 11-1-2 defines the city's water utility as an enterprise:

> "Water utility enterprise" means the water utility business owned by the city, which business receives under ten percent of its annual revenues in grants from all Colorado state and local governments combined and which is authorized to issue its own revenue bonds pursuant to this code or any other applicable law."

The water utility enterprise is further defined by BRC 11-1-55:

> "In addition to any of the powers it may have by virtue of any of the applicable provisions of state law, the City Charter, and this code, the water utility enterprise shall have the power under this chapter:
>
> (a) To acquire by gift, purchase, lease, or exercise of the right of eminent domain, to construct, to reconstruct, to improve, to better and to extend water facilities, wholly within or wholly without the city or partially within and partially without the city, and to acquire in the name of the city by gift, purchase, or the exercise of the right of eminent domain water rights, lands, easements, and rights in land in connection therewith;

(b) To operate and maintain water facilities for its or the city's own use and for the use of public and private consumers and users within and without the territorial boundaries of the city;

(c) To accept federal funds under any federal law in force to aid in financing the cost of engineering, architectural, or economic investigations or studies, surveys, designs, plans, working drawings, specifications, procedures, or other action preliminary to the construction of water facilities;

(d) To accept federal funds under any federal law in force for the construction of necessary water facilities;

(e) To enter into joint operating agreements, contracts, or arrangements with consumers concerning water facilities, whether acquired or constructed by the water utility enterprise or the consumer, and to accept grants and contributions from consumers for the construction of water facilities;

(f) To prescribe, revise, and collect in advance or otherwise, from any consumer or any owner or occupant of any real property connected therewith or receiving service therefrom, rates, fees, tolls, and charges or any combination thereof for the services furnished by, or the direct or indirect connection with, or the use of or any commodity from such water facilities; and in anticipation of the collection of revenues of such facilities, to issue revenue bonds to finance in whole or in part the cost of acquisition, construction, reconstruction, improvement, betterment, or extension of such facilities; and to issue temporary bonds until permanent bonds and any coupons appertaining thereto have been printed and exchanged for the temporary bonds;

(g) To pledge to the punctual payment of said bonds and interest thereon all or any part of the revenues of the water facilities or of wastewater facilities under Chapter 11-2, "Wastewater Utility," B.R.C. 1981, including the revenues of improvements, betterments or extensions thereto thereafter constructed or acquired, as well as the revenues from existing water or wastewater facilities;

(h) To enter into and perform contracts and agreements with other governmental entities and utility enterprises for or concerning the planning, construction, lease, or other acquisition and the financing of water facilities and the maintenance and operation thereof;

(i) To make all contracts, execute all instruments, and do all things necessary or convenient in the exercise of the powers granted in this section or elsewhere in state law, the City Charter, or this code, or in the performance of its covenants or duties, or in order to secure the payment of its bonds if no encumbrance, mortgage, or other pledge of property, excluding any pledged revenues, of the water utility enterprise or city is recreated thereby, and if no property, other than money, of the water utility enterprise or city is liable to be forfeited or taken in payment of said bonds, and if no debt on the credit of the utility enterprise or city is thereby incurred in any manner for any purpose; and

(j) To issue refunding bonds pursuant to this code or other applicable law to refund, pay, or discharge all or any part of its outstanding revenue bonds issued under this article or under any other law, including any interest thereon in arrears or about to become due or yield reduction payments required to be made to the federal government to maintain the tax-exemption of interest on the refunding or refunded bonds, or for the purpose of reducing interest costs, affecting a change in any particular year or years in the principal and interest payable thereon or in the related utility rates to be charged, affecting other economies, or modifying or eliminating restrictive contractual limitations appertaining to the issuance of additional bonds or to any municipal water and wastewater facilities."

3.4.3 | SAFE DRINKING WATER ACT

The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply[109]. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources, including rivers, lakes, reservoirs, springs, and ground water wells[iv]. The SDWA authorizes the United States Environmental Protection Agency (US EPA) to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water. The agency in charge of water quality in Colorado is the Colorado Department of Public Health and Environment. US EPA, states, and water systems work together to make sure that drinking water standards are met.

Originally, the SDWA focused primarily on treatment as the means of providing safe drinking water at the tap. The 1996 amendments greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements and public information as important components of safe drinking water. This approach ensures the quality of drinking water by protecting it from source to tap.

To ensure that drinking water is safe, the SDWA sets up multiple barriers against pollution. These barriers include source water protection, treatment, distribution system integrity and public information. Public water systems are responsible for ensuring that contaminants in tap water do not exceed the standards. Water systems treat the water and must test their water frequently for specified contaminants and report the results to states. If a water system is not meeting these standards, it is the water supplier's responsibility to notify its customers. Many water suppliers, including the city, are also required to prepare annual reports for their customers. The public is responsible for helping local water suppliers to set priorities, make decisions on funding and system improvements and establish programs to protect drinking water sources. Water systems across the nation rely on citizen advisory committees, rate boards, volunteers and civic leaders to actively protect this resource in every community in America.

3.4.4 | SOURCE WATER ASSESSMENT AND PROTECTION PROGRAM

Source water protection is the crucial first barrier against contaminated drinking water and focuses on actively keeping contaminants out of existing and future source water supplies. This is accomplished by reducing or eliminating human activity in and around water supplies, constructing protection barriers between existing land use activity and the water supply, or isolating the source water from contamination within an enclosed structure. The Safe Drinking Water Act has mandated source water

[iv] SDWA does not regulate private water systems that serve fewer than 25 individuals.

protection as a primary barrier against contamination of the nation's drinking water. This mandate is being implemented through the State of Colorado Source Water Assessment and Protection program (SWAP)[110]. SWAP has five essential elements:

- watershed delineation, including trans-basin diversions;
- inventory of all actual and potential sources of contamination, including the name and address of polluters where known;
- determination of susceptibility of a public water supply to those contaminants;
- informing the public of the existence of those contaminants in their drinking water supply through the annual Consumer Confidence Report, and;
- implementing protection of drinking water from those contaminants.

Actual and potential sources of contamination to source waters are to be identified under the SWAP program, including polluted runoff or potential releases from agricultural and industrial activities, manufacturing, services (*i.e.*, gas stations, maintenance shops), utilities, roads, accidental and deliberate hazardous material dumping, residential development, septic systems and recreation activities. Current regulations require reporting all contaminant sources in each annual Consumer Confidence Report.

The city of Boulder has actively participated in the state SWAP program and has developed an internal monitoring program to characterize source water quality and identify sources of pollution. Detailed maps of the city's source water watersheds were delineated as part of Phase I of SWAP program[v]. Phase II efforts identified the location of potential sources of contamination (PSOCs) in relation to surface water and treatment plant intakes within the delineated areas. In Phase III of the SWAP program, the state used computer software to generate PSOC risk and vulnerability assessments based on information from phases one and two.

3.4.5 | FEDERAL ENERGY REGULATORY COMMISSION

The Federal Energy Regulatory Commission (FERC) holds responsibility through the Federal Power Act of 1935, as amended, for issuing licenses for the construction of new hydroelectric projects, issuing licenses for the continuation of existing hydroelectric projects (re-licensing), issuing exemptions from licensing requirements, and oversight of all ongoing hydroelectric project operations within the defined FERC project boundaries, including dam safety inspections and environmental monitoring[111].

FERC issues both licenses and exemptions from licensing for hydroelectric facilities based upon a series of criteria including generation capacity, design and configuration and ownership of affected lands. The city currently holds seven conduit exemptions from licensing issued by FERC for its Silver Lake, Lakewood, Betasso, Orodell, Maxwell, Kohler and Sunshine Hydroelectric Projects. Conduit exemptions apply to hydroelectric projects which use the hydroelectric potential of a conduit that exists for purposes other than hydroelectric power generation. For example, the city's exempt hydroelectric facilities are all located on pipelines or conduits which exist primarily for raw or treated municipal water transmission. The FERC project boundaries under a conduit exemption are limited to little more than the turbine-generator and associated equipment. Exemptions from licensing are issued in perpetuity and contain conditions concerning project operation and maintenance.

[v] Phase I map of SWAP, source water watersheds, is included in the Appendices.

Hydropower licenses are issued by FERC for hydroelectric facilities with more than 5 megawatts of generation capacity, which may include a dam and which generally include more affected area than small hydropower projects. Licenses are generally issued for a term of 30 to 50 years. The Boulder Canyon Hydroelectric Project, which includes Barker Dam and Reservoir, is a licensed facility[112]. The current license, which was issued to PSCo on April 28, 1981, was transferred to the city upon its purchase of the project in 2001 and will expire on August 31, 2009[113]. Following the city's purchase of Boulder Canyon Hydro, the primary purpose for use of the facilities became the provision of municipal water supplies. Generation of hydropower is now a secondary purpose and the facilities meet the FERC requirements for a conduit exemption from licensing. The city is following FERC requirements for authorization to continue operating the Boulder Canyon Hydro after the current license expires in the form of an exemption from licensing. The city filed a Pre-Application document in 2007[114] and submitted an application for an exemption from licensing in November 2008[115].

Dam safety is a critical part of the FERC hydropower program. Prior to construction, FERC reviews and approves the designs, plans and specifications for dams, powerhouses and other structures. Once construction is complete, FERC requires continuing project inspection on a regular basis. All licensed dams are required to have an Emergency Action Plan which must be updated and practiced annually.

3.4.6 | COLORADO RIVER COMPACT

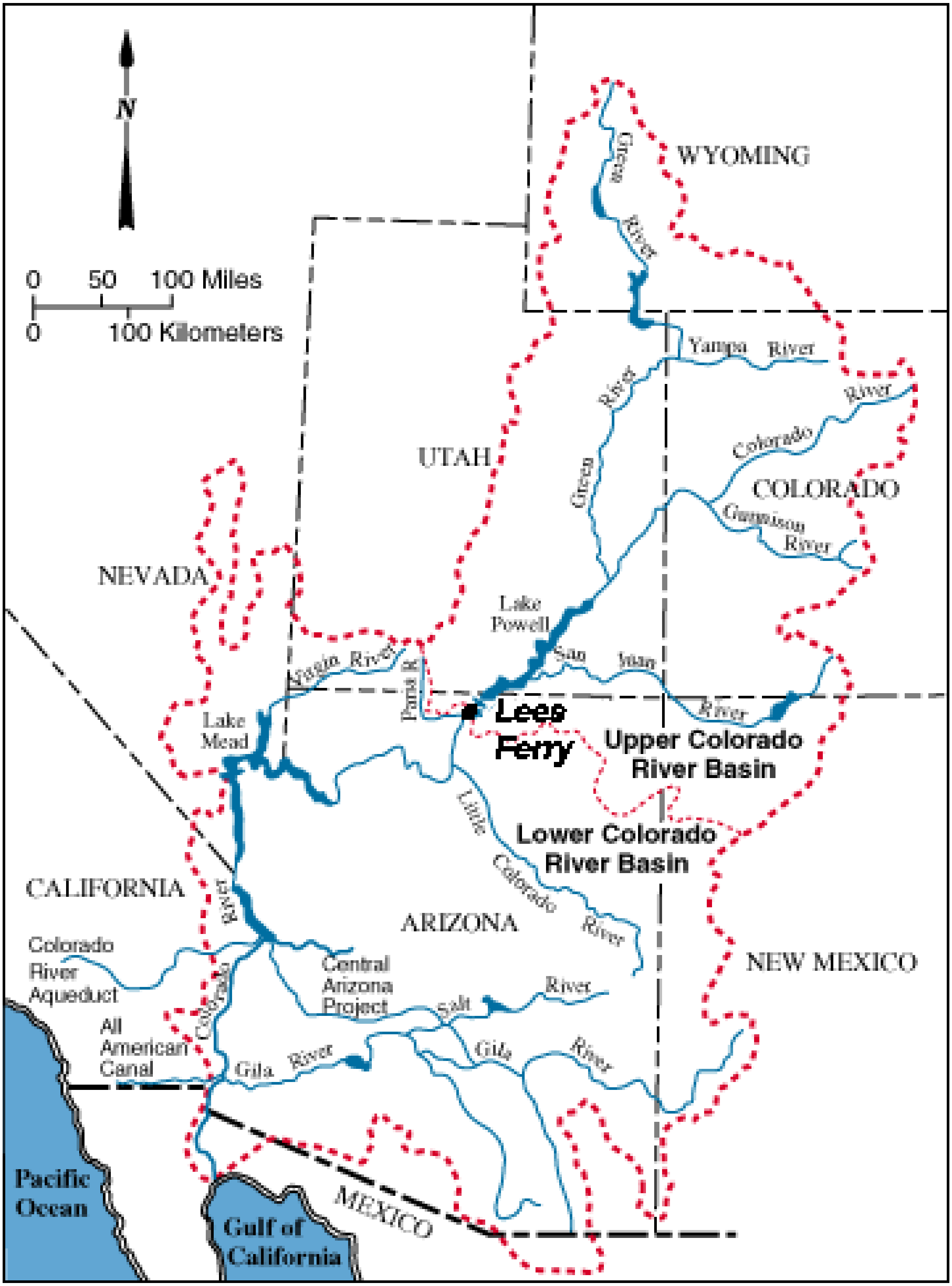
Colorado has legal obligations to provide water to downstream states based on interstate river compacts, which are both state law and federal law. The Colorado River Compact could have an effect on the city's water supplies.

Deliveries of water through NCWCD are affected by the Colorado River Compact of 1922[116]. The compact divided the basin in half, designating Lee's Ferry on the Colorado River near the Arizona-Utah border as the boundary point separating the upper and lower basins (Figure 3-2).

At the time of the compact, it was believed that the average annual flow in the Colorado River above Lee's Ferry was 15 million acre-feet. Therefore, the compact apportions an average of 7.5 million acre-feet per year to the lower basin states, with the remainder, which was believed at the time to be 7.5 million acre-feet, to the upper basin states. The apportionment is implemented by requiring that the flow at Lee's Ferry will not be depleted to less than 75 million acre-feet for any consecutive 10-year period[117]. The result is that the lower basin states of California, Nevada, and Arizona (and parts of New Mexico and Utah below Lee's Ferry) are assured a full allocation and any shortages caused by average flows in the Colorado River basin above Lee's Ferry being less than 15 million acre-feet in any ten year period will be borne by the upper basin states of Colorado, Wyoming, New Mexico and Utah. An additional 750,000 acre-feet of water per year is committed to Mexico-based treaty obligations.

The Upper Colorado River Basin Compact was signed in 1948 to apportion the allocation allowed to the upper basin states under the Colorado River Compact. Under this 1948 compact, Colorado receives 51.75 percent, New Mexico receives 11.25 percent, Utah receives 23 percent, and Wyoming receives 14 percent of the upper basin states' allocation under the Colorado River Compact [118].

FIGURE 3-2. UPPER AND LOWER BASINS UNDER THE COLORADO RIVER COMPACT[119]



In 2005, following five years of drought in the Colorado River basin, negotiations began between the states that were parties to the Colorado River Compact and the Department of Interior to develop rules for addressing the potential for a shortage under the compact. The Upper Basin states feared that Lake Powell could run out of water and that the Lower Basin states might push for a "compact call." This would force Upper Basin water users that were junior to the compact to reduce water use or to release water from reservoirs. In December 2007, an agreement called the "Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operation for Lake Powell and Lake Mead" was signed that included new equalization guidelines for storage in the two reservoirs, established shortage criteria for the Lower Basin and started a program to encourage Lower Basin states to implement water conservation measures that would allow them to stay within their compact allocations. It is believed that the implementation of this agreement will significantly reduce the likelihood of a compact call[120].

3.4.7 | CITY CODE

There are many ordinances contained in the City Code, B.R.C. 1981[121] that affect the water utility. Most of these ordinances are contained in the following sections:

- Section 11-1-13 When Connections with Water Mains are Required
- Section 11-1-14 Permit to Make Water Main Connections
- Section 11-1-19 Water and Ditch Rights
- Section 11-1-20 Taps or Connections to Water Mains
- Section 11-1-42 Agreement to Extend Water Mains
- Section 11-1-43 Reimbursement of Costs for Water Main Extension

This list does not include the sections setting forth the actual fees found in Section 4-20, B.R.C.1981 Most of the ordinances that relate to source water are contained in Section 11-1-19.

Presently, the code requires immediate hook-up to the water utility upon annexation for commercial or public facilities if structures exist or are proposed and if they are adjacent to a water main. Private properties with existing or proposed structures must also connect if they abut a water main. However, Moore's Subdivision properties annexed as of July 11, 1986 are exempt from these requirements, as are any other properties that enter into a written agreement with the city. See Section 11-1-13, B.R.C. 1981.

Section 11-1-19 of the City Code addresses transfer of water and ditch rights upon annexation and subdivision and specific conditions for Silver Lake Ditch. The city has adopted ordinances that require owners of water and ditch rights to offer to sell their rights to the city at the time of application for water service or annexation. Conditioning municipal water service upon the dedication of water rights is a common requirement for both annexation and water service in Colorado so that developing properties are responsible for off-setting impacts caused to public services[122]. Although it has been changed slightly, the city ordinance has been in effect essentially in its current form since 1978 with earlier ordinances requiring water rights donations dating back to the early 1960s.

Other sections of the City Code cover management of the Silver Lake Watershed and protection of source water facilities. Section 11-1 (Water Utility) discusses trespass and interference with the operations of the water utility properties (Section 11-1-11) and prohibits activities that would contaminate or pollute the water supply (Section 11-1-12). Section 11-1-6 (Watershed Patrol Officers) requires the appointment of watershed patrol officers to "enforce city ordinances intended for the protection of the city's watershed and Lakewood properties." The watershed patrol officers "have conferred upon them police powers sufficient to enforce such ordinances." In addition, Sections 5-4, 5-5 and 5-6 include ordinances regarding offenses against property, offenses against government operations and prohibition against camping on public property. The current maximum fine that the Municipal Court can impose for trespassing violations in the Silver Lake Watershed or interference with water utility infrastructure or property at other locations is $1,000 per occurrence.

The Silver Lake Watershed, which provides approximately 35 percent of the city's water supply, has been closed to public access since the 1920s to protect the water source. Reasons for the Silver Lake Watershed closure policy include:

- reduction of wildland fire risk;
- prevention of vandalism to water supply facilities;
- water quality protection (both for environmental and public health reasons);
- homeland security requirements;
- wildlife habitat protection (watershed is an elk calving area);
- protection of lakes from contamination by non-native aquatic plants and animals and whirling disease;
- protection of a fragile alpine ecosystem that is highly vulnerable to damage from uncontrolled human impacts;
- preservation of a rare alpine research site that has on-going research dating back to the 1950s;
- protection of greenback cutthroat trout, which are a listed threatened species, and;
- insufficient resources and staffing for the water utility to manage recreational activities.

3.4.8 | BOULDER VALLEY COMPREHENSIVE PLAN

Since 1970, the city and Boulder County have jointly adopted a comprehensive plan that guides land use decisions in the Boulder Valley. The facilities and services section of the Boulder Valley Comprehensive Plan (BVCP) establishes policies linking growth to service standards and provisions found in the Source Water Master Plan and other master plans. The following paragraphs of the BVCP describe the water resources protection policies that relate directly to water supply[123].

- **Protection of Water Quality**

  The city and county shall protect, maintain and improve water quality within the Boulder Creek basin and Boulder Valley watersheds, as a necessary component of existing ecosystems and as a critical resource for the human community. Efforts will be made to protect the quality of groundwater, surface water, and storm water, and to plan for future needs.

- **Water Resource Planning**

  The city and county shall work together and with other government agencies to develop and implement appropriate water quality standards, water resource allocations, and water quality protection programs. Water resource planning efforts shall include such things as incorporation of water quality protection into land use planning, water conservation, and evaluation of pollution sources.

- **Drinking Water**

  The city shall protect the quality of its water sources, and shall meet all Colorado Primary Drinking Water Standards. It is also the goal of the city to meet Secondary Drinking Water Standards[vi] established by the EPA. The city will work with other water and land use interests as needed to assure the integrity and quality of its drinking water supplies.

- **Minimum Flow Program**

  The city shall pursue expansion of the existing instream minimum flow program to protect aquatic ecosystems within the Boulder Creek watershed.

- **Protection of Aquifer and Groundwater Recharge Areas**

  The city and county shall continue to evaluate aquifers, groundwater recharge areas, and sources of groundwater pollution within the Boulder Creek watersheds and formulate appropriate protection programs.

- **Pollution Control**

  The city and county shall seek to control both point and non-point sources of water pollution through pollution prevention, improved land use configurations, use of wetland detention areas, standards to control degradation of streams and lakes caused by storm runoff in urban and rural areas, and control and monitoring of direct sources of discharge, including those of gravel extraction and wastewater treatment facilities.

- **Discouragement of Private Sewage Systems**

  The city and county support the County Board of Health's policy discouraging the installation of private sewage disposal systems where municipal collection systems are available, or where a potential pollution or health hazard would be created. The city and county will support the development of programs to monitor problems associated with failing septic systems.

3.4.9 | CONTRACTS

The city has entered into many contracts with other entities that influence how the water system operates. Boulder has contracts to deliver water for instream flow purposes and to the Silver Lake Ditch Company for irrigation use. Water from the CBT and the Windy Gap Projects is delivered to the city under contracts with the NCWCD. A contract with NCWCD also governs how Boulder Reservoir is operated. In addition, the city sells power from its hydropower plants to Xcel Energy

[vi] Limits chemicals that cause aesthetic problems such as taste and odor.

based on several contracts. The city also enters into annual contracts to lease water that is not needed for municipal use to local agricultural users. These contracts are discussed in detail below.

3.4.9.1 | COLORADO WATER CONSERVATION BOARD

The city of Boulder, in conjunction with the Colorado Water Conservation Board (CWCB), has developed a program for the maintenance of streamflow within Boulder Creek and its tributaries. The instream flow program preserves fish habitat and enhances the aesthetics of the stream corridor. The city's involvement in the instream flow program is based on dedication of the use of certain senior water rights owned by the city to the CWCB and commitments by the city to releases of water from the city's storage reservoirs. Most of these rights were derived from shares in agricultural ditch companies which divert from Boulder Creek. Boulder had previously changed most of these shares to municipal uses through Water Court proceedings.

In July 1990, an agreement was completed between Boulder and the CWCB. This agreement was amended twice, in 1990 and in 1992[124]. This agreement and the amendments convey to the CWCB a portion of the city's water and water rights to use for instream flow purposes. The city retains title to some of the water rights and pays annual assessments to the original ditch companies associated with the conveyed water rights. The city has the right to use the water and water rights for municipal purposes under some conditions and owns the right to reuse a portion of the water remaining after the instream flow use itself or lease it to downstream users.

The water and water rights are used for instream flows on North Boulder Creek beginning below the city's Silver Lake Pipeline diversion, near the Continental Divide, continuing to main Boulder Creek below the confluence with North Boulder Creek, and down to the 75th Street bridge. The agreement also provides for Boulder to release water that is stored by the city in the Silver Lake Watershed or in Barker Reservoir for fulfillment of the CWCB junior 15 cfs instream flow right on Boulder Creek and the CWCB new instream flow filings on North Boulder Creek and Boulder Creek. During severe droughts (as occurred in 2002) or emergencies, Boulder is allowed to call the water rights back and curtail storage releases for use within the water supply system. In addition to protecting the city's ability to provide water in the event of extended drought, this curtailment will protect reservoir levels in the Silver Lake Watershed to preserve the native species of fish in the reservoirs. The city is also allowed to use the water and water rights for municipal use if they are not needed to satisfy the minimum streamflow requirements at the time.

3.4.9.2 | NORTHERN COLORADO WATER CONSERVANCY DISTRICT

The city joined NCWCD in 1953 and entered into a Water Delivery Contract for 12,700 units[125]. The city water utility presently owns 21,015 units, which is the maximum number of municipal use units Boulder is allowed to own based on rules set by NCWCD. There are 310,000 units total in the CBT Project. A "unit" of CBT reflects a water user contract issued by NCWCD that provides delivery of an amount of water based on the annual allotment set by the NCWCD board. A 100 percent quota provides one acre-foot of water for each unit for that year. The historical average for the annual quota is about 70 percent or 0.7 acre-foot per unit.

The amount of the annual assessment for each unit varies based on the terms contained in water user contracts. The CBT units that were issued prior to 1959, including the city's original CBT units, are "fixed rate" units with an annual assessment amount that does not vary. Units issued to water users after 1959, including the city's other CBT units, are "open-rated" units with annual assessment rates that can be raised by the NCWCD board every year. In 1959, the NCWCD board had reviewed the CBT Project finances and determined that NCWCD would not have enough revenues toward the end of its forty-year repayment period to pay off its obligation to the United States (see section 3.2.2.9). They instituted a new rule providing that assessment rates in newly-issued or modified water user contracts would be variable and could be increased as needed to pay for project expenses. Whenever a CBT unit is transferred from one water user to another or the original water user contract is modified in any way, the unit is converted to an open-rated unit[126].

The assessment for fixed rate units is set at $1.50. Boulder and all other water users on the southern end of the CBT system pay an additional assessment of $0.50 per unit delivered from Boulder Reservoir. The Boulder Reservoir delivery charge is assessed to pay for construction of the southern delivery system components of the project that were not included in the original base project cost of the 1938 agreement between NCWCD and the United States. Therefore, Boulder pays $2.00 per unit for its 12,700 original CBT units. Boulder has 8,085 open-rated Class B (municipal use) units. The assessment for these units in 2007 was $23.30 per unit. The city's water utility also has 30 Section 131 units (general contracts that are renewed annually) for which it was assessed $24.10 per unit in 2007.

City use of CBT water is subject to operating rules of NCWCD. CBT water must be used within the boundaries of the district and, unlike other trans-basin water, may only be used one time by the unit owner. Water may be leased to anyone within the NCWCD boundaries.

CBT system storage space (over 720,000 AF) is operated by NCWCD. Boulder does not own any of this reservoir storage, but has access to the storage benefits through ownership of units in the CBT Project. Boulder can call for delivery of its CBT water up to the limits of the annual quota set for CBT units by the NCWCD Board in any year. Delivery of the full quota amount can be made to Boulder at any point within the CBT system, including from Carter Lake. Boulder's share of water from the Windy Gap Project is also delivered through the CBT system facilities.

Since joining the NCWCD in 1953, the city has signed several operating agreements with NCWCD concerning Boulder Reservoir. Boulder owns an amount of storage space within Boulder Reservoir that varies by season under a contract between the city and NCWCD. Ownership of Boulder Reservoir is within the city's water utility enterprise fund, and the recreational facilities are operated by Boulder's Parks and Recreation Department. The reservoir storage space is owned by NCWCD for the benefit of CBT water users. Boulder's storage space is divided into long-term storage for drought protection and short-term seasonal storage. The long-term storage pool carries over from year to year. The short-term storage space becomes available to the city in the winter season when the Boulder Feeder Canal is off. This storage is presently used to feed the Boulder Reservoir WTF throughout the winter. The Boulder/NCWCD agreements are summarized below.

Annexation Agreement – August 24, 1953

The original size of Boulder Reservoir was to be 11,700 acre-feet, with one-third of the capacity reserved for NCWCD and two-thirds reserved for Boulder. The reservoir was built at Boulder's expense and NCWCD repaid one-third of the construction cost to Boulder over a period of forty years. The 1953 annexation agreement provided for Boulder's annexation into the NCWCD and specifies operating conditions for Boulder Reservoir that were modified in the March 14, 1975 agreement. The annexation agreement emphasizes that the primary use of Boulder Reservoir is water supply. Recreation in the reservoir is allowed, but is subordinate at all times to water supply[127].

Supplemental Agreement to 1953 Agreement – February 6, 1954

The final design for Boulder Reservoir increased the reservoir capacity from the original design of 11,700 acre-feet to 13,100 acre-feet with an operating capacity of 12,000 acre-feet. The capacity of the reservoir was enlarged to ensure flood control protection for downstream properties on Dry Creek and to increase utility of the structure. The operating capacity available to NCWCD from May 1 – Oct 31 is 4,800 acre-feet. The portion of the reservoir allocated for flood control from May 1 – Oct 31 is 7,000 acre-feet. The portion of the reservoir allocated for Boulder's long-term storage is 1,000 acre-feet. An outlet canal and appurtenant structures were constructed to further increase reservoir security and utility. The outlet canal is 3,000 feet in length extending from the termination of the main outlet to the beginning of a siphon near Dry Creek and has a capacity of 200 cfs. Boulder and NCWCD shared in the cost of the outlet canal features[128].

Second Supplemental Agreement to 1953 Agreement – May 14, 1965

The 1965 agreement defined land area boundaries and identified which entity (the city or NCWCD) has control of those lands and associated facilities. The definitions are reiterated in the March 14, 1975 agreement[129].

Filter Plant Operating Agreement – May 9, 1969

In this agreement, Boulder agreed to finance and construct the infrastructure necessary to convey water from Boulder Feeder Canal and from the reservoir to the water treatment facility. Boulder also agreed to install measuring devices in the conveyance lines to produce a continuous record of flow to the water treatment facility.

NCWCD agreed to deliver Boulder's contracted water allotment either to the water treatment facility intake structures or to Boulder Creek. The delivery of water is limited to 90 cfs when necessary to prevent impairment of water delivery to other NCWCD allottees[130].

Obligations of NCWCD and City of Boulder – March 14, 1975

This agreement supercedes the 1953, 1954 and 1965 agreements. The intent and purpose of this agreement is to provide the terms and conditions under which the respective rights and obligations of NCWCD and the city to construction, operation, maintenance, modification, and management of the reservoir and appurtenant facilities will be fulfilled.

In this agreement, the city agreed to design and construct a new spillway at its own expense. NCWCD agreed to control, operate, maintain, and keep the reservoir in repair at its own cost in a manner that benefits all its allottees. NCWCD also agreed to pay $371,561 to the city for the perpetual use of a portion of the storage space in the reservoir, which is an amount equal to one-third the original capital cost of the reservoir.

Additionally, NCWCD assumed exclusive and sole control of the use, occupancy, operation and maintenance of the following land areas that comprise portions of or are adjacent to Boulder Reservoir:

- Tract A: 60 foot buffer along the Boulder Feeder Canal inlet area;
- Tract B: Parcel of land bordered on the east by the North-South County Road (63rd Street), on the west by the North Dam of Boulder Reservoir, on the south by the access road immediately south of Boulder Creek Supply Canal, and on the north by the access road immediately north of Boulder Reservoir, and;
- Tract C: Parcel of land within Boulder Reservoir that lies below the high water mark (or below elevation 5,183 feet).

NCWCD assumed exclusive and sole control of the use, operation, and maintenance of the following structures and facilities that are appurtenances of Boulder Reservoir:

- chute structure at the terminus of Boulder Feeder Canal;
- North Dam, spillway and outlet works;
- South Dam and auxiliary outlet works;
- Boulder Creek Supply Canal from the outlet works in the North Dam to inlet of the siphon;
- all maintenance and access roads located on, over or adjacent to the structures described previously in this list and on, over, or across lands described in Tracts A and B, and;
- fences, gates, cattle guards, drainage structures, or other facilities necessary and convenient to NCWCD in the discharge of it responsibilities and which are or may be located on, over, or adjacent to the facilities described previously in this list.

The city assumed exclusive and sole control of the use, occupancy, operation and maintenance of all lands owned by the city that comprise portions of or are adjacent to Boulder Reservoir except Tracts A, B and C, as listed above.

The city assumed exclusive and sole control of the installation, use, operation, and maintenance of the following facilities:

- all buildings and structures that are located on the lands owned by the city;
- all roads, fences, gates, cattle guards, drainage structures, parking areas, or other facilities necessary and convenient for recreational or other uses made by the city of lands owned by the city;
- the auxiliary outlet works in the South Dam, and;
- the turnout installed by the city in the inlet portion of Boulder Creek Supply Canal and the pipeline from turnout to the filter plant.

Vehicular access by the general public on all NCWCD maintenance and access roads is not permitted. However, public pedestrian traffic over the North Dam is allowed. The city may utilize the land in Tract C below elevation 5,183 feet for municipal, recreational or other water supply purposes. All recreational use at the reservoir is subordinate to the primary use of the reservoir for water supply purposes.

The city retains the right to enlarge the capacity of Boulder Reservoir at its own cost and such additional capacity will be operated by NCWCD as directed by the city.

Boulder Reservoir is operated by NCWCD for municipal and irrigation water storage. The reservoir was constructed to a total capacity of 13,100 acre-feet. Three hundred acre-feet of capacity below the invert of the auxiliary outlet (elevation 5,153.5 feet) is unavailable for use by either party. One thousand acre-feet of capacity between the invert of the auxiliary outlet and the main outlet (elevation 5,159 feet) is available to the city for long-term storage. A capacity of 11,800 acre-feet lies between the invert of the main outlet and the spillway crest (elevation 5,183 feet) and is available for use by both the city and NCWCD. The amount allocated for use by each party varies by season.

NCWCD agreed to deliver the city's water either to the water treatment facility intake structures or to Boulder Creek through the Boulder Supply Canal. The delivery of water is limited to 90 cfs when necessary to prevent impairment of water delivery to other NCWCD allottees[131].

Amended Agreement – August 10, 1979

In this agreement, the portion of the reservoir capacity allocated for flood retention was decreased from 7,000 acre-feet to 3,900 acre-feet due to completion of a spillway hardening project[132]. The State Engineer's Office had acknowledged that the improvements would allow the spillway to withstand a significant spill event during a major storm, so a smaller flood retention pool was acceptable.

Agreement Regarding Left Hand Ditch Company – November 17, 1992

Left Hand Ditch Company (Left Hand) owns water rights on Left Hand Creek. In 1963, NCWCD signed an agreement with Left Hand permitting Left Hand to divert water from Left Hand Creek into the Boulder Feeder Canal in exchange for CBT water to be taken by Left Hand at an upstream point later in the year. Water diverted by Left Hand into the Boulder Feeder Canal was accounted for as being stored in Boulder Reservoir. NCWCD performs the official accounting for water stored in Boulder Reservoir and, each year, NCWCD kept track of the difference in the amount of water diverted into the Boulder Feeder Canal by Left Hand and the lesser amount of water delivered by NCWCD to Left Hand. Boulder objected to this practice because the additional yield to NCWCD was made possible through the use of storage space in Boulder Reservoir and the city owns the reservoir. The agreements that were in place between the city and NCWCD did not allow NCWCD to grant use of Boulder Reservoir storage space to other users.

In 1992, the city signed an agreement with NCWCD allowing the storage of Left Hand water in Boulder Reservoir. Boulder consented to Left Hand's diversion of water into the Boulder Feeder Canal and storage of that water in any available space in Boulder Reservoir. In return, each year Boulder receives 20 percent of the difference between the amount of water provided by Left Hand and the amount of water delivered to Left Hand by NCWCD. The "20 percent water" is accounted for as being the first water used by Boulder out of Boulder Reservoir every year, prior to the city's use of any CBT water[133].

Substitution Agreement – April 8, 1994

This agreement is tied to the city's use of its shares of The Consolidated Lower Boulder Reservoir and Ditch Company (Lower Boulder) water per Case No. 94CW284. The NCWCD has a contract to deliver CBT water its allottees through the Lower Boulder and Coal Ridge ditch systems. NCWCD can deliver the city's pro-rata share of Lower Boulder water to its allottees in substitution for CBT water that would otherwise be delivered from Boulder Reservoir. In return, that portion of water is available to the city for use from Boulder Reservoir[134].

3.4.9.3 | SILVER LAKE DITCH AND RESERVOIR COMPANY AGREEMENTS

The city of Boulder has contracts with the Silver Lake Ditch Company that make the city's relationship with this company different than with other ditch companies. The original 1906 deed and agreement and the subsequent 1955 and 1965 agreements are described in more detail below.

Deed and Agreement – January 15, 1906

In January 1906, the city of Boulder purchased Silver Lake and Island Lake reservoirs for $34,000 from the Silver Lake Ditch Company, through its owner, James P. Maxwell. The 1906 Deed for the transaction includes the sale to the city of the land surrounding the reservoirs in the Silver Lake drainage basin and "…all water rights, storage rights, water decrees, reservoir decrees, and filings, and filings for further storage of water and all other rights of every kind and nature whatsoever…owned by [Silver Lake Ditch Company]…" The Silver Lake Ditch Company reserved the "…right and privilege of storing such a quantity of water as may be contained…" in a defined portion of the storage space in the city's reservoirs, not to exceed one fill each year, for use by the company[135]. The city had use of the first fill of the remaining portion of the reservoir storage and the use of any refill of the entire reservoir space that occurred in any year[136].

An agreement between the city and the Silver Lake Ditch Company, entered into at the same time as the deed, further defined each party's rights and obligations. The 1906 Agreement states that storage water delivered to the Silver Lake Ditch Company by the city was to be used for irrigation of 1,006 1/30 acres of land north of what was then Boulder's city limit. Within this agreement, the city and Silver Lake Ditch Company recognized the "…possibility that a considerable portion of said 1,006 1/30 acres of land will become annexed…" to the city[137]. Through the 1906 Agreement with the city, the Silver Lake Ditch Company agreed it would not enter into any additional water delivery contracts with Silver Lake Ditch water users for delivery of water from Silver Lake and Island Lake Reservoirs. At that time, the Silver Lake Ditch Company was a carrier ditch company, as compared to the other common corporate form for ditch companies known as a mutual ditch company[138]. Carrier ditch companies have a contractual relationship with water users for water delivery. When Silver Lake Ditch Company was first formed, assets remained in company ownership and the contract water users did not have any rights of ownership in the ditch or in the company's water or water rights like shareholders in a mutual ditch company do. Instead, water users entered into a contract with the Silver Lake Ditch Company that allowed use of water owned by the company on a specific property.

The contract water users were not entitled to sell their right to have water delivered for use on their property to any other water user for use on other property.

The city would initially deliver to the company an amount equal to the volume of water stored between certain elevation planes in Silver Lake and Island Lake Reservoirs. The 1906 Agreement provided that, as the Silver Lake Ditch Company's obligation to deliver water under existing contracts with ditch users diminished due to abandonment of contract rights, nonpayment of assessments, or other provision for water, the amount of storage water delivered to the Silver Lake Ditch Company by the city would decrease by the amount of the expired contracts and would become fully available to the city. The agreement recognized that no further transfer or conveyance of title would be required for the city to use any of the storage water no longer used by the Silver Lake Ditch Company.

First Supplemental Agreement – July 20, 1955

The 1955 Supplemental Agreement modified the original agreement by defining a formula that determines the volume of storage water to be delivered to the Silver Lake Ditch Company by the city and allowed the city to deliver the storage water from any source[139]. Since this amendment to the original agreement was made, the water for Silver Lake Ditch has primarily been delivered out of Barker and Boulder Reservoirs.

The need for the 1955 Agreement was triggered for two reasons. The first reason was the Silver Lake Ditch Company's dissatisfaction with how water was being stored under the various water rights for Silver Lake Reservoir. The second was the city's concern that land irrigated by the Silver Lake Ditch had decreased since 1906, but the city's storage water delivery obligation had not decreased. When the city had lowered the Silver Lake outlet pipe in 1928, the lower portion of the reservoir became accessible. Therefore, when water was diverted by the city under the most senior Silver Lake water right that had an appropriation date of 1887, it naturally began filling the reservoir from the bottom up and occupied the space below the elevation of the two planes defined within the 1906 Agreement for storage of water to benefit the Silver Lake Ditch Company. The next water rights to fill storage space in Silver Lake were the city's 1906, 1928, and 1941 water rights. Therefore, water that was actually placed in-between the two elevation planes defined in the 1906 Agreement was derived from more junior water rights that might not yield in dry years, and the amount of water delivered to Silver Lake Ditch could be reduced in dry years. The Silver Lake Ditch Company contended that the city had not been legally allowed to make changes to the reservoir facilities without company approval. The issues were resolved through agreement that Silver Lake Ditch Company would be provided with an amount of storage water to be calculated according to a formula based on acreage still being served by the ditch and up to an amount equal to what the city was allowed by the state to divert under the 1887 Silver Lake and 1890 Island Lake water rights. Both water rights were adjudicated in 1907 and are junior to all water rights adjudicated prior to 1907, even if those rights have a more junior appropriation date. It was agreed that the city could deliver this water from any available source. Therefore, the Silver Lake Ditch Company was no longer confined to deliveries of water that physically existed in a defined reserved storage space within the two reservoirs[140]. The city gained a defined methodology for calculating how much water delivery the Silver Lake Ditch Company was entitled to receive under the contract as irrigated acreage decreased and gained the ability to select the source for the Silver Lake Ditch water deliveries from any water available to the city.

Under the 1955 agreement, the city was initially obligated to provide the Silver Lake Ditch Company with a maximum of 800 acre-feet from any city source, which equaled two acre-feet of water for every irrigated acre under the Silver Lake Ditch. The city's delivery obligation would decrease over time in the following manner:

1. If the area irrigated with water supplied by the Silver Lake Ditch Company exceeds or equals 400 acres, the city will deliver 800 acre-feet.
2. If the irrigated area is less than 400 acres, the 800 acre-feet will be reduced by an amount equal to one and a half times the deficiency in acreage below 400 acres (i.e. for every acre abandoned, the amount delivered is reduced by one and a half (1.5) acre-feet). Therefore, for the last acre of land irrigated with Silver Lake Ditch Company water, 201 acre-feet of water will be delivered.

In the event the city was not allowed by the state water commissioner to divert enough water under the city's 1887 Silver Lake and 1890 Island Lake water rights to fully equal the acreage formula amount to be delivered to the Silver Lake Ditch Company from the city's water sources, then the amount the city must deliver to the ditch is reduced to an amount equal to the city's actual yield from the two water rights[141]. Because of the seniority of the subject water rights as compared to other storage water rights, this situation might only occur in drought years or in years when spring snowmelt occurs so slowly that few storage rights come into priority. For example, in 2002, the city was unable to divert any water under the 1890 right and was only able to divert 148 acre-feet under the 1887 right.

In this agreement, the Silver Lake Ditch Company agreed that it would not carry water in the Silver Lake Ditch for any other person or entity if this water carriage would adversely affect the city's ability to transfer and exchange water from any source for the municipal water system, excluding contracts entered into by the Silver Lake Ditch Company prior to 1954. Additionally, the Silver Lake Ditch Company agreed that the city could make alterations to the Silver Lake or Island Lake reservoir outlets and agreed to drop the company's objections to the city's previous outlet changes.

Second Supplemental Agreement – June 12, 1965

In 1963, the city concluded that the Silver Lake Ditch Company Board of Directors had been approving the transfer of Silver Lake Ditch Company water from properties that were no longer being irrigated by the ditch to new property owners under the ditch that would be willing to use the water[142]. The irrigation of new land using the Silver Lake Ditch would violate the terms of the previous agreements between the Silver Lake Ditch Company and the city because the ditch company was prohibited from entering into any new water delivery contracts. After trying to resolve the issue with the ditch company, the city asked the courts to stop the Silver Lake Ditch Company from transferring water to new land[143]. The Silver Lake Ditch Water Users Association met, replaced the old Board of Directors, appointed a new board, and signed the 1965 Agreement with the city[144]. The 1965 Agreement identified specific parcels of land that had historically been irrigated with water from the Silver Lake Ditch. From that point of identification on, only land associated with a specific Map Number under the 1965 Agreement was allowed to be irrigated with the contract water delivered under the previous agreements[145]. The 1965 Agreement specifies that this water may not be transferred to other parcels of land.

The 1965 agreement provided that the right of individual properties to receive deliveries of storage water under the contractual obligation between the city and the Silver Lake Ditch Company terminates when any one of the following four conditions occur:

1. a written statement of intent to abandon, properly executed by the owner of the property;
2. failure by the water user to pay an assessment when the payment is 5 years overdue;
3. no use of water upon the individual property for a consecutive period of 7 years during which no assessments have been paid for the most recent 2 years out of the 7 years; and
4. a gift or other assignment to the city by the property owner.

Each year, the Silver Lake Ditch Company is required to provide the city with a list of the individual properties on which water was used during the previous year and a list of properties upon which an assessment is in arrears. Included with such information are changes in ownership and any subdivision or re-grouping of separate parcels to the extent reflected in the Silver Lake Ditch Company records. In 2008, there were active contracts for water delivery to 258 acres under the Silver Lake Ditch.

3.4.9.4 | BOULDER AND WHITEROCK DITCH AND RESERVOIR COMPANY AGREEMENT

The city and the Boulder and Whiterock Ditch and Reservoir Company (Boulder and Whiterock) have an agreement for an "internal exchange." When the internal exchange is operating, Boulder and Whiterock diverts less water than it is entitled to take at its Boulder Creek diversion structure and the city increases its diversions at its upper Boulder Creek intakes by an equal amount. The city then pays the ditch company back by delivering an equal amount of the city's CBT water supplies directly into the Boulder and Whiterock Ditch from a channel connecting Boulder Reservoir and the ditch. The city's right to operate the internal exchange is based on an agreement with Boulder and Whiterock that resulted from the settlement of a dispute about whether the city's or the ditch company's exchange right on Boulder Creek was senior. After the city filed to adjudicate its first exchange right on Boulder Creek in Case No. W-7852-74, the court awarded the city a right to exchange 250 cfs with an appropriation date of 1954. The court also recognized that Boulder and Whiterock had a more senior exchange right, dated 1926, but the court limited the Boulder and Whiterock exchange to its historical maximum rate and volume of 100 cfs and 4,620 acre-feet annually[vii]. After the city filed an appeal with the Colorado Supreme Court in Case No. 80SA102, the parties entered into an agreement that allowed for the internal exchange and allowed the CBT water owed to Boulder and Whiterock to be stored in Boulder Reservoir during the irrigation season. This agreement came about because of the limitation on the Boulder and Whiterock exchange and the ditch company's desire to take advantage of the city's storage space in Boulder Reservoir. For the city, the agreement was appealing because of the potential advantage of reducing the Boulder and Whiterock exchange needs even further. The relevant portions of the stipulated agreement were incorporated in the amended decree entered in 1982 in Case No. W-7852-74[146].

[vii] Boulder and Whiterock's exchange limitation is not in the original decree for Boulder's Boulder Creek exchange entered in 1980 by the water court. A limitation on the amount of the Boulder and Whiterock exchange that is senior to Boulder's exchange was put in the amended decree entered in 1982 as a result of the stipulation in Case No. 80SA102, which was an appeal to the Supreme Court of the original 1980 decree.

3.4.9.5 | FARMERS' DITCH COMPANY FOREIGN WATER CARRIAGE AGREEMENT

The city entered into an agreement with the Farmers' Ditch Company[147], dated May 2, 1967, that allows the city to use any available excess capacity in the Farmers' Ditch to carry foreign water (water not attributable to the Farmers' Ditch Company water rights) owned by the city. Therefore, the city is allowed to divert any appropriately-decreed water it might own into the Farmers' Ditch near the mouth of Boulder Canyon and carry that water to Boulder Reservoir at times when the full capacity of the ditch is not needed to carry water to Farmers' Ditch Company shareholders. The city pays one-fifth of the salary of the Farmers' Ditch Company superintendent each year whether or not any foreign water is carried and pays an additional amount for foreign water carriage that actually occurs based on a formula contained in the agreement.

3.4.9.6 | NORTH BOULDER FARMER'S DITCH COMPANY AGREEMENT

Utilities purchased 656.2 shares in the North Boulder Farmer's Ditch Company and sought to change the use of those shares to include municipal use. The ditch company opposed the change of use because the company believed transferring water out of the ditch would negatively affect the long-term viability of the ditch. In an agreement dated November 30, 1993, the city agreed to not take delivery of 96 shares of its stock when the company's June 1, 1863 water right is out of priority. (There is another water right associated with the ditch company dated June 1, 1862). Instead, the city will leave the water associated with the shares in the ditch for the general benefit of the company shareholders. The city may use this 1862 water in its municipal system at times the city determines is necessary, such as in a drought or emergency. When the 1863 right is out of priority, the city can to take delivery of the 1862 water attributable to the remaining 560.2 shares of stock for municipal uses in or through the ditch.

Whenever the company's June 1, 1863 water right is in priority, Boulder may take delivery of water associated with all its shares at any decreed point or for any decreed use[148].

The water utility entered into an agreement with the Parks and Recreation Department to allocate use of the 656.2 North Boulder Farmers shares at Valmont City Park for irrigation[149].

3.4.9.7 | CARIBOU RANCH AGREEMENTS

Caribou Ranch is located north of Nederland adjacent to the city's Lakewood Reservoir property. Through a complex series of agreements in 1996 (known as Caribou 1) and in 2001 (known as Caribou 2), the city and Boulder County jointly purchased 2,181 acres of Caribou Ranch and associated water rights from James Guercio, owner of Caribou Ranch[viii]. The city and Boulder County each had separate agreements with Guercio. An agreement was also entered into between the city and Boulder County in 1996, with revisions in 2001, to address financing of the acquisition, transfer of ownership interests and other issues. A subsequent amendment to the city/ Guercio agreement was made in 2004 to clarify provisions of the earlier agreements. The city, operating through the water utility enterprise fund, used a portion of the revenue from the 1991 sale of 43 of Boulder's 80 Windy Gap units to the city of Broomfield to fund the Caribou Ranch purchase and was reimbursed for much of the cost by Boulder County over a period of years[150].

[viii] The series of agreements that accompanied these purchases can be found in the Appendices.

One of the city's purposes for participating in the purchase of Caribou Ranch land and conservation easements was to gain ownership and easement rights for all of the Silver Lake Pipeline corridor and an understanding with Guercio of how the Silver Lake Pipeline would be reconstructed. In addition, the city desired to protect the quantity and quality of the portion of the city's water supply emanating from Caribou Ranch and diverted directly into Lakewood Reservoir. Provisions mandating the city's right to be involved in any Boulder County management activities that might affect water quality were included in the agreement. The agreements also accomplished several other property trades such as a land trade made to clear up property boundaries adjacent to Lakewood Reservoir.

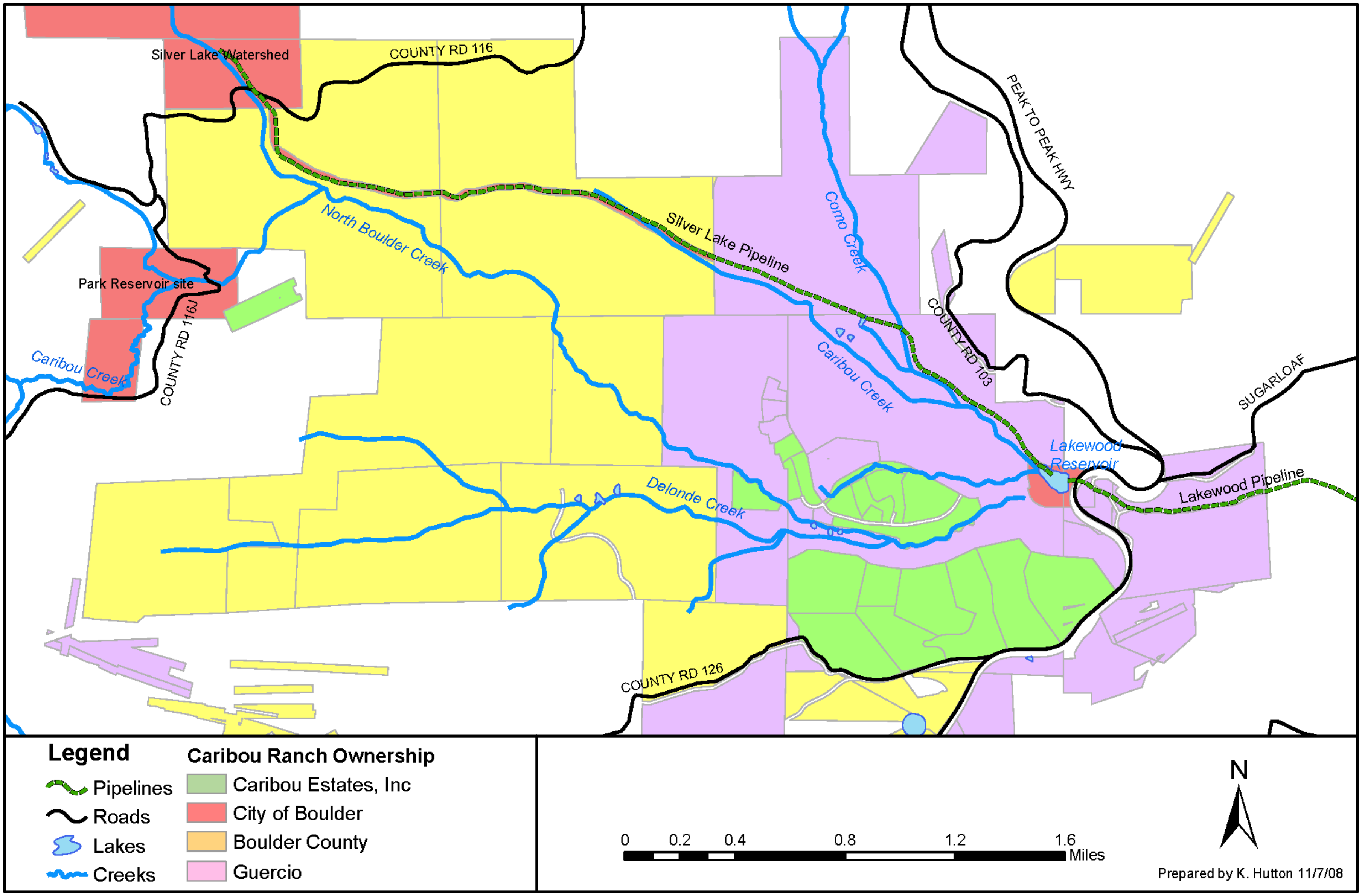
Through the Caribou agreements, the city acquired fee title to a 120-foot wide corridor along the Silver Lake Pipeline where it crosses the purchased Caribou Ranch acreage, and Boulder County received a conservation easement over this parcel. The city gained title from Guercio to a few parcels of land at Lakewood Reservoir necessary to bring property boundaries into alignment with the location of city facilities. Boulder County obtained title to the remainder of the purchased acreage with the city holding a conservation easement over that acreage (Figure 3-3).

The County also acquired some of the water rights used for irrigating the ranch. Guercio retained ownership of about 1,159 acres of Caribou Ranch, water rights for irrigation of his retained acreage and water rights for some ponds. In addition to the fee properties, the city and Boulder County acquired 1,517 acres of conservation easement over the Caribou Ranch property retained by Guercio. Moreover, the city acquired a perpetual easement across the portions of Caribou Ranch retained by Guercio for construction, reconstruction, replacement, monitoring, operation, maintenance, repair and access to the Silver Lake Pipeline, the Lakewood Pipeline, North Boulder Creek diversion facilities, and related water utility facilities by the city.

Negotiations for the Caribou 2 (2001) agreement included discussion of development of a parcel of land owned by Guercio that was adjacent to Caribou Ranch. The property, known as Caribou City, had received plat approval from Boulder County in the 1970's for development of 115 residential lots. Boulder County no longer believed that level of development was appropriate, and the city was concerned about the impact of 115 septic systems located above the North Boulder Creek intake to Lakewood Reservoir. The negotiations resulted in Guercio limiting development to 23 dwelling units plus a fishing lodge and a non-commercial horse barn.

The city of Boulder Open Space and Mountain Parks Department (OSMP) also participated in the complicated Caribou agreements by contributing some funds that were used to purchase a 50 percent interest in the old Beech Aircraft site with Boulder County owning the other 50 percent. In addition, the agreement provided Boulder County with a conservation easement over the Wittemyer Ponds property (owned by the city through the water utility enterprise fund) that would still allow the city to develop the site as a water storage facility. Boulder County agreed to act as the land manager for the Wittemyer Ponds property. Boulder County also acts as the land manager for the purchased Caribou Ranch lands and is required to manage the land in a manner that protects water quality in the watershed that feeds the city's municipal water system.

FIGURE 3-3. MAP OF CARIBOU RANCH PROPERTIES



The city signed an interruptible supply contract stating it would make 170 are-feet of water per year available to Guercio from its water supply for purposes of irrigation of certain meadow areas only. Another five acre-feet was made available to Guercio for augmentation of certain current and future water uses associated with Guercio's property. The city may choose not to deliver the irrigation water during periods of extraordinary drought or emergency conditions as it did in 2002. Moreover, through 2021, the city agreed to lease the amount of Jasper Reservoir water offered by Guercio each year at the city's CBT lease rate[ix].

The city acquired Guercio's interests in water rights he had initiated to develop hydropower on North Boulder Creek, Caribou Creek and on the city's Silver Lake Pipeline. The hydropower rights had been decreed in Case Nos. 81CW419 and 82CW444. The city did not want these competing hydropower rights to interfere with its hydro generation activities and so gave notice to the Water Court of intent to abandon these hydropower water rights in 1999. The court issued orders abandoning the water rights in 2001 and 2007.

The city provided almost all of the initial funding for the Caribou Ranch purchase in 1996. Between 2002 and 2004, the city sold most of its Caribou Ranch fee properties and all associated water rights, except for the hydropower rights, to Boulder County. The city and Boulder County each own a 50 percent interest in the mineral rights that were transferred with the land. Although Boulder County manages the acquired Caribou Ranch property, the city water utility has input to the property's management plan to ensure watershed and water quality protection[151].

3.4.9.8 | TOWN OF NEDERLAND AGREEMENTS

Water Storage Agreement

The town of Nederland operates its municipal water system based on an augmentation plan, approved by the water court in 1980, which includes various water rights, including a 5/8 share of the Farmers Ditch Company[152]. Because Nederland must supply water year-round, yet owns some water rights that only yield water in the spring and summer, Nederland must store some water to replace its fall and winter water use. The decree provides that the water attributable to Nederland's 5/8 share of Farmers Ditch Company may be stored in Barker Reservoir up to an annual maximum amount of 39.6 acre-feet. At the time of the decree, Nederland had an agreement with PSCo (now Xcel Energy) to use storage space in Barker Reservoir for augmentation water. Nederland's agreement was not binding on Boulder and was not transferred to Boulder at the time of the Barker Reservoir system sale in 2001. Boulder did allow Nederland to use otherwise empty Barker Reservoir storage space on an informal basis until a Water Storage Agreement between Boulder and Nederland was signed in 2008.

The 2008 agreement allows Nederland to use the same amount of storage space in Barker Reservoir that was available to it under its prior agreement with Xcel Energy[153]. Releases of this water are to be made by Boulder in accordance with normal operating procedures of Boulder's water system in a manner that does not interfere with those operations. Boulder may satisfy the water delivery obligations with any water that is available to Boulder. Nederland grants Boulder a first right of refusal to purchase any Farmers Ditch water that Nederland chooses to sell or lease during the term of the agreement. Under Nederland's court decree, Nederland projected the amount of water that its

[ix] Documents related to these leases can be found in the Caribou Ranch documents in the Appendices.

service area would consume through at least the year 2010. The decree requires Nederland in 2010, or sooner, to return to water court for a review of its augmentation plan. If any modifications are made to the decree that result in a need for additional water to be stored for augmentation purposes, a new agreement with Boulder will be required for any additional storage. The Water Storage Agreement will terminate in 2026 unless the agreement is extended or a new agreement is negotiated.

Land and Utility Tap Exchange Agreement

The Town of Nederland owns land on the west side of Barker Reservoir, on which it operates a Teen Center. Nederland approached Boulder about building a skate park adjacent to the Teen Center that would extend onto a portion of land owned by Boulder. Boulder agreed to deed this portion of land (approximately 4,386 square feet) to Nederland in exchange for Nederland granting three water taps and three sewer taps to Boulder at no cost[154]. Boulder will use the taps at restroom facilities around Barker Reservoir. One facility will be located along the west end of the reservoir near existing water and sewer pipelines. Nederland will operate and maintain this facility. The other two facilities will be located along Highway 119. Boulder will have the option to exercise its right for taps for these two restroom facilities whenever Nederland extends water and sewer mains to within 200 feet of the facility sites. Boulder will pay for construction of the facilities and for construction of connections to the water and sewer mains.

3.4.9.9 | XCEL ENERGY POWER PURCHASE AGREEMENTS

The city is not an electric utility and therefore, it sells all electricity generated at the eight hydroelectric plants located on the city's water system to Xcel Energy on a wholesale basis. The city has a series of power purchase agreements with Xcel Energy that specify the terms and conditions governing the sale of power from each facility. Most of the agreements pertain to individual facilities, and one pertains to multiple facilities. Each agreement contains rates of payment for generation capacity and actual generation (the latter being subject to annual adjustment). Some of the city's agreements are more favorable in terms of city revenues than others, owing principally to the economics of the time at which they were negotiated with PSCo, Xcel Energy's predecessor. The agreements have varying expiration dates and varying terms for renewal at the city's discretion, and therefore are subject to renegotiation at different times[155]. Specific requirements and details of the individual agreements affect the operation of the individual hydroelectric plants as the city balances goals of maximizing renewable energy generation and hydropower revenues while maintaining electricity generation as a by-product of municipal water supply operation.

Revenue calculation for the hydros, except Boulder Canyon which has a fixed monthly capacity payment, includes two components: capacity and energy. Capacity is the instantaneous rate at which a hydro facility can generate electricity and is measured in kilowatts (kW). Energy is the work available as the electricity is generated over time and is measured in kilowatt-hours (kWh). As an analogy, capacity is like the speed a car can travel and generated electricity is like the number of miles traveled by the car. The speed of a car is the instantaneous rate the car is traveling, for example 60 miles per hour (mph), and the number of miles traveled is the work performed. A car may have the capacity to move at 100 mph, but it only travels at the rate necessary to meet the trip conditions. The speed of the car typically will vary throughout the trip, and over time a certain number of miles will have been traveled.

The methodology for calculating capacity and energy payment is defined in the Xcel Energy tariff. The tariff defines four categories of facilities, one through four, depending on maximum facility output. Maxwell, Kohler, and Orodell Hydros are category two facilities and Betasso, Lakewood, Silver Lake, and Sunshine Hydros are category three facilities. The methodology for calculation of capacity payment is unique to each category.

The energy payment method is the same for both category two and three facilities. Energy payment is the number of kilowatt-hours generated times the energy payment rate ($/kWh). The energy payment rate, adjusted annually, is determined from the operating costs of Xcel Energy's Pawnee I Generating Plant during the previous year.

Contract terms differ between each of the city's contracts as summarized below in Table 3-2. An important contract term to note is the date by which the city is required to give notice of its desire to renew the contract for each facility. This is particularly important for the Betasso/ Lakewood/ Silver Lake Hydros contract because the capacity payment terms are so favorable to the city, and every effort should be made to continue this contract on the same terms.

TABLE 3-2. SUMMARY OF FACILITY-SPECIFIC CONTRACT TERMS

Contract Term	Maxwell	Kohler	Orodell	Sunshine	Betasso/ Lakewood/ Silver Lake	Boulder Canyon
Contract Signing Date	March 11, 1985	August 12, 1986	July 27, 1987	December 1, 1986	March 14, 1984	April 21, 2000
Commercial Operation Date	April 10, 1985	October 31, 1986	September 10, 1987	September 10, 1987**	December 17, 1987	See specifics below
Contract Term from Date of Commercial Operation	30 years	30 years	30 years	30 years	30 years	See specifics below
Summer Seasonal Test capacity (kW)	70	148	220	810	Betasso/ Lakewood=5531 Silver Lake=3043	See specifics below
Extend Contract No Later Than Date *	April 10, 2013	October 31, 2014	September 10, 2015	September 10, 2015**	December 17, 2015	August 31, 2009
Winter Seasonal Test capacity (kW)	70	148	220	200	Betasso/ Lakewood= 2715 Silver Lake=2000	See specifics below
Category IPPF facility	2	2	2	3	3 w/special contract provisions	Not Applicable
Capacity Rate ($/kW-month)	$20.11	$19.38	$17.84	On-Peak= $10.41 Off-Peak= $7.43	$17.84/$8.92	See specifics below
2008 Energy Rate $/kWh	$0.01659	$0.01659	$0.01659	$0.01659	$0.01659	$0.01659

*IMPORTANT NOTE: City must notify Xcel Energy to keep same contract terms.
** This is also the date for the 75th Street Wastewater Treatment Facility Cogeneration Plant.

Maxwell Pump-Generation Facility

- "Seller (city) may extend the agreement, by written notice to Buyer at least two years prior to the expiration of the initial term, under the foregoing terms and conditions in accordance with the methodology set forth in the Company (Xcel Energy) Tariff"[156]. "Seller agrees that Buyer has the right to file with the Commission (PUC) proposed revisions to the current Company Tariff (which the Seller has the right to protest) and that this Agreement shall be deemed to be modified to incorporate any revisions to the Company Tariff, whether resulting from revisions proposed by Buyer or otherwise"[157].
- In the event of a power shortage by Xcel Energy, at Xcel Energy's request, the city shall implement all reasonable steps to provide additional energy as requested, and, if necessary, delay any scheduled maintenance periods.
- The city must submit a schedule showing scheduled maintenance periods annually. Any scheduled maintenance period may be rescheduled upon mutual agreement.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years.
- Induction generator - Must operate within leading or lagging 90 percent power factor
- City must buy all power necessary to operate facility from Xcel Energy.
- Contract is subject to the jurisdiction and applicable regulations of the PUC.

Kohler Pump-Generation Facility

- "Seller may extend the agreement, by written notice to Buyer at least two years prior to the expiration of the initial term, under the foregoing terms and conditions in accordance with the methodology set forth in the Company (Xcel Energy) Tariff. Seller will give Buyer earlier notice of its intent to extend if reasonably feasible"[158]. "Seller agrees that Buyer has the right to file with the Commission (PUC) proposed revisions to the current Company Tariff (which the Seller has the right to protest) and that this Agreement shall be deemed to be modified to incorporate any revisions to the Company Tariff, whether resulting from revisions proposed by Buyer or otherwise"[159].
- In the event of a power shortage by Xcel Energy, at Xcel Energy's request, the city shall implement all reasonable steps to provide additional energy as requested, and, if necessary, delay any scheduled maintenance periods.
- The city must submit a schedule showing scheduled maintenance periods annually. Any scheduled maintenance period may be rescheduled upon mutual agreement.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years.
- Induction generator - Must operate at or within a 90 percent power factor
- City must buy all power necessary to operate facility from Xcel Energy.
- Contract is subject to the jurisdiction and applicable regulations of the PUC.

Orodell Hydroelectric Facility

- "Seller may extend the agreement, by written notice to Buyer at least two years prior to the expiration of the initial term, under the foregoing terms and conditions in accordance with the methodology set forth in the Company [Xcel Energy] Tariff. Seller will give Buyer earlier notice of its intent to extend if reasonably feasible to do so[160]… If the Seller intends to contract with a buyer other than the one stated in this Agreement following the expiration of the 30 year term, Buyer shall have the right to match the provisions of the proposed contract with this third party…"[161]. "Seller agrees that Buyer has the right to file with the Commission (PUC) proposed revisions to the current Company Tariff (which the Seller has the right to protest) and that this Agreement shall be deemed to be modified to incorporate any revisions to the Company Tariff, whether resulting from revisions proposed by Buyer or otherwise"[162].
- In the event of a power shortage by Xcel Energy, at Xcel Energy's request, the city shall implement all reasonable steps to provide additional energy as requested, and, if necessary, delay any scheduled maintenance periods.
- The city must submit a schedule showing scheduled maintenance periods annually. Any scheduled maintenance period may be rescheduled upon mutual agreement.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years.
- Induction generator - Must operate at or within a 90 percent power factor
- City must buy all power necessary to operate facility from Xcel Energy.
- Contract is subject to the jurisdiction and applicable regulations of the PUC.

Sunshine Hydroelectric Facility

- "Seller may extend the agreement, by written notice to Buyer at least two years prior to the expiration of the initial term, under the foregoing terms and conditions in accordance with the methodology set forth in the Company (Xcel Energy) Tariff. Seller will give Buyer earlier notice of its intent to extend if reasonably feasible. Buyer shall have first right of refusal to purchase Metered Capacity Output and Metered Energy Output if Seller intends to contract with a buyer other than the one stated in this Agreement after the initial 30 year period"[163].
- In the event of a power shortage by Xcel Energy, at Xcel Energy's request, the city shall implement all reasonable steps to provide additional energy as requested, and, if necessary, delay any scheduled maintenance periods.
- The city must submit a schedule showing scheduled maintenance periods annually. Any scheduled maintenance period may be rescheduled upon mutual agreement.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years. City must submit certified copy of test results to Xcel Energy.
- Induction generator - Must operate at or within a 90 percent power factor
- City must buy all power necessary to operate facility from Xcel Energy.
- Contract is subject to the jurisdiction and applicable regulations of the PUC

Betasso, Lakewood, and Silver Lake Hydroelectric Facilities

In 1984, the city negotiated a power purchase agreement with PSCo that included all three proposed facilities. Betasso Hydro was constructed in 1987, followed by Silver Lake Hydro in 1988 and Lakewood Hydro in 2004.

- Contract term - 30 years from date of Commercial Operation of first operational facility. The city may, by written notice to Xcel Energy two years prior to the expiration of the initial term and each additional term, extend the contract for additional terms, for additional periods of five years. The city will use its best efforts to give Xcel Energy earlier notice of its intent to extend.
- Billing capacity is the coincident maximum one-hour metered capacity output during the monthly billing period of all three facilities.
- Metered energy output (kWh) and metered capacity (kW) output mean respectively that electrical energy and capacity generated by the facility.
- Capacity Factor is the total net energy produced in kWh divided by the produce of the billing capacity and the hours lapsed between monthly meter readings.
- The capacity rate of $17.84 will be paid on the highest one-hour billing capacity if the combined capacity factor of the three facilities is 50 percent or greater for the monthly billing period. If the three facilities operate at a capacity factor of less than 50 percent, the capacity rate will be 50 percent ($8.92).
- In the event of a power shortage by Xcel Energy, the city shall implement all reasonable steps to provide additional energy as requested.
- The city must submit a schedule showing scheduled maintenance periods annually. Any scheduled maintenance period may be rescheduled upon mutual agreement.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years. City must submit certified copy of test results to Xcel Energy.
- Synchronous generators - Must operate at a power factor equal to1.
- City must buy all power necessary to operate facility from Xcel Energy.

Boulder Canyon Hydroelectric Facility

- Contract commencement date - March 7, 2001.
- The contract shall terminate August 31, 2009 subject to the early termination provisions.
- Xcel Energy shall own and maintain the facilities necessary from Xcel Energy's transmission facilities from the contract defined interconnection point and the 115-25 kV distribution facilities.
- Facility capacity is 10 MW.
- The energy payment rate is $35/MWh for the on-peak hours in the months of June, July, August, and September and $18/MWh for the on-peak hours in all other months. During off-peak hours year round, the energy rate shall be the Qualifying Facilities energy payment

rate that is filled annually with the CPUC. The 2008 energy payment rate is $0.01659 / KWh.

- No payment will be made for energy produced in excess of 87,840 MWh in any year.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years. City must submit certified copy of test results to Xcel Energy.
- Synchronous Generator—must be capable of operating at power factor of 90 percent leading or lagging.
- Xcel Energy has metering, bus relay protection, transmission line relaying and communications equipment associated with Xcel Energy's facilities.
- Annual trip test performed on the protective relay equipment and a full calibration test a least once every three years. City must submit certified copy of test results to Xcel Energy.

3.4.9.10 | PLATTE RIVER ENDANGERED SPECIES RECOVERY AGREEMENT

In 2006, the states of Colorado, Nebraska and Wyoming and the U.S. Department of the Interior completed an agreement to implement a basin-wide recovery program for several species of endangered birds and one endangered fish that rely on habitat in the Platte River Basin in Nebraska[164]. These species included the whooping crane, the interior least tern, the piping plover and the pallid sturgeon. The recovery program was developed to address the need for a coordinated approach to resolving problems faced by water users seeking any type of federal permit. The United States Fish and Wildlife Service (USFWS) had issued the opinion that any depletion of water flowing in the Platte River Basin and its tributaries jeopardized the endangered species. Prior to establishment of the recovery program, individual water users had been asked to replace all depletions to the South Platte River with a like amount of water. Water users had found it difficult or impossible to meet the USFWS requirements on an individual basis.

Background

Controversy developed in the early 1990's when several water system operators sought land use authorizations from the USFS for portions of their water projects that were on USFS land. This group included the city of Boulder, PSCo and several other northeastern Colorado cities. Boulder was seeking authorization for an easement for the Lakewood Pipeline. PSCo had applied for a special use permit for the Barker Gravity Line as it crosses U.S. Forest land. As a part of the USFS process, the USFWS was consulted under Section 7 of the Endangered Species Act (ESA)[165].

In 1994, USFWS issued a biological opinion for the Boulder Canyon Hydroelectric Project, the Lakewood Pipeline and for the facilities owned by the other cities[166]. The USFWS found that water depletions from projects in Colorado caused deterioration of habitat for the endangered species listed above on the Platte River in Nebraska. The USFWS opinion concluded that the water projects caused "jeopardy" to the species and that the "reasonable and prudent alternative" to address the jeopardy was to replace all water depletions to the South Platte River on a one-for-one basis at the Colorado-Nebraska state line[x].

[x] Under the "jeopardy" standard in Section 7 of the Endangered Species Act, water project owners undergoing an individual consultation with the USFWS would be responsible for providing the water to fully offset their own project depletions to the Platte River

Water users in Colorado did not agree with the USFWS analysis that depletions to the South Platte River were affecting the species and formed a group to address the issue. This group hired engineers and scientists who provided information to the USFWS demonstrating that there was more water in the river at the Colorado/Nebraska state line during most times of the year than there had been historically. This increase in flow has occurred due to changes in return flows into the river from human water use and due to imported water from the West Slope. USFWS agreed that the South Platte River in eastern Colorado had historically been dry in late summer prior to pioneer settlement and had run at very low levels during much of the rest of the year. However, USFWS scientists argued that the target species had become adapted to the stream temperatures resulting from year round streamflows with the new flow regime. They also contended that the species remained dependent on the very large flushing flows in the springtime that had moved sediment down the river prior to the construction of reservoirs. These seemingly contradictory positions resulted in a claim by USFWS of a need for an annual flow regime for the Platte River in Nebraska that would have required reservoir storage in the spring to be greatly curtailed and any remaining stored water to be released for the benefit of the species in late summer.

After much debate over differing scientific opinions, several alterations in the USFWS theories, and threats of lawsuits by some water users in the three states over what they deemed was "arbitrary and capricious" decision-making by the USFWS, it was determined that the problem might be better addressed in a comprehensive manner involving participation by the three state governments rather than through requirements placed on individual water users. This approach could also allow for adaptive management or changes in the recovery efforts made for the species based on evolving science and measurement of species response to previous recovery efforts.

Therefore, the biological opinion led to negotiations that resulted in an agreement in 1997 to develop a species recovery program. The agreement was signed by the United States Department of Interior (which includes USFWS) and the governors of Colorado, Nebraska and Wyoming. The Platte River Recovery Program was developed, went through an Environmental Impact Study (EIS), and was put into operation in January 2007. The recovery program serves as the reasonable and prudent alternative identified in any biological opinion for a water project requiring federal authorization in the three states.

Description of the Recovery Program

The recovery program will purchase land for habitat use by the species and will supply water that can be managed to provide peak flow periods in the Platte River that may improve habitat conditions. Scientists will monitor the effects of the recovery program so that modifications can be made as needed through adaptive management. During the first 13 years of the recovery program, the goal is to reduce shortages to the USFWS target flows in the Platte River by 130,000 to 150,000 acre-feet per year and to provide 10,000 acres of land in central Nebraska for habitat.

Recovery program costs consist of cash and cash-equivalent contributions such as water supplies. Total costs will be shared with a 50/50 split between the U.S. Department of the Interior and the states. Colorado's share of the costs is 20 percent of the total recovery program budget. The program is

basin in the same amount and timing with which they occur. In addition, land acquisition and river sedimentation supplementation could be required of project owners needing federal authorizations. Meeting these requirements on an individual basis would be onerous, if not impossible.

projected to cost $317 million. Colorado state government will provide part of Colorado's share and water users will provide the rest through the South Platte Water Related Activities Program (SPWRAP) non-profit organization. The state of Colorado will also provide water to the program through construction of the Tamarack Project (see below) and other groundwater recharge projects. Wyoming and Nebraska will provide much more water than Colorado due to the much higher level of natural flow in the North Platte River in Wyoming and the Platte River in Nebraska.

The state of Colorado is presently completing the development of a recharge project in eastern Colorado, called the Tamarack Project. This project will generate accretions from groundwater diversions to change the timing of some lower South Platte River flows from periods when flows exceed what can benefit the species to times when it will enhance species habitat. During the first 13 years of the recovery program, the state of Colorado and South Platte River water users will be responsible for completing the Tamarack Project at a cost of about $15 million and contributing an additional $24 million in cash or cash-equivalents for funding recovery program activities such as acquiring additional land and water, performing monitoring and research, and doing operation and maintenance activities.

South Platte Water Related Activities Program (SPWRAP)

The SPWRAP is a Colorado non-profit corporation that has been formed by Colorado water users to assist the state in fulfilling its recovery program responsibilities. These include accounting and reporting requirements, obtaining interests in facilities and land, obtaining water rights and water recharge credits, and providing cash for recovery program operations and research. Both the state of Colorado and SPWRAP will have representation on the recovery program Governance Committee and its advisory groups.

The city of Boulder was contacted by the USFWS and the USFS in early 2007 about a previous biological opinion that had been issued to PSCo in 1994 for the Boulder Canyon Hydroelectric Project. The USFWS stated that the prior biological opinion would only remain active if the city participated in the recovery program and joined SPWRAP. As the current owner of the Barker system, the city joined SPWRAP at this time to maintain the viability of the previously completed biological opinion and all of its associated studies. The Biological Opinion can serve to meet the Section 7 compliance requirements for the city resulting from the USFS land use authorization for the Barker Gravity Line and the Federal Energy Regulatory Commission (FERC) re-licensing process for the Boulder Canyon Hydroelectric Project.

Membership in SPWRAP is the only means by which individual Colorado water users can participate in the recovery program. Participation provides the benefit of certainty of ESA compliance for a participant's water project and avoids individual mitigation requirements as a result of an ESA Section 7 consultation. Membership payments in SPWRAP for municipalities are calculated using a formula based on the number of water taps served as converted into single-family residential tap equivalents. The city of Boulder's annual payment for 2008 was $71,000. Payments in future years are likely to be similar if the city chooses to continue as a recovery program participant. Water users who do not become members of SPWRAP at this time will be required to pay SPWRAP assessments for all prior years when they join later due to any future ESA Section 7 consultations they may face.

The city may withdraw from participation in SPWRAP and the recovery program with written notice to USFWS. However, if the city withdraws, the USFWS may initiate consultation on the operation of all or part of the city's municipal water supply system. Participation in the recovery program does not constitute any admission by the city regarding the application of the ESA to the depletions of the city's municipal water system or the validity of the facts or analyses relied upon by the USFWS. It also does not require the city to agree that the USFWS flow recommendations for the Platte River are biologically or hydrologically necessary to recover the target species or meet the needs of designated critical habitat in Nebraska. Therefore, the city retains all of it rights to object if implementation of the recovery program were to fail.

3.4.9.11 | USFS LAKEWOOD PIPELINE EASEMENT AGREEMENT

The city's current easement for Lakewood Pipeline on National Forest land was signed in 2001[167]. As discussed in section 4.2.1.12, Lakewood Pipeline was reconstructed from 2002 to 2004, and portions of the pipeline include manufacturing welds which do not meet the contract specifications. In addition, there appear to be abnormalities in the internal cement mortar lining of the pipeline. On May 12, 2004, the USFS issued a Notice of Noncompliance for the Lakewood Pipeline easement. The letter states that "….the pipeline, as constructed, does not comply with the requirements of the Easement and related documents because it does not meet the original contract specifications and construction plans as accepted by the USFS……" The USFS desires to terminate the existing easement and replace it with a new one which would require the city to carry additional liability insurance and include provisions for suspension of the easement under certain circumstances.

The acquisition of the 2001 easement agreement was laborious. The need for an easement was first raised in 1986 because the city wanted to replace the lower four miles of the pipeline due to water quality and pipeline reliability concerns. At issue was the city's assertion that the Act of July 26, 1866 entitled Boulder to maintain and protect rights for the construction of ditches or canals that had been established, as provided by the doctrine of prior appropriation (see section 3.2.1 "History of Colorado Water Development" for more information on the prior appropriations doctrine). The Act states, "That whenever, by priority or possession, rights to the use of water for mining, agricultural, manufacturing, or other purposes, have vested…the…owners of such vested rights shall be maintained and protected in the same; and the right of way for the construction of ditches and canals for the purposes aforesaid is hereby acknowledged and confirmed"[168]. It was therefore the city's position that it has a legal right to maintain the pipeline over the land with an express easement because it had an implied "prescriptive easement." The USFS contended that the city had abandoned any 1866 Act rights it may have had by implementing a few minor pipeline alignment variations during pipeline reconstruction in the 1940s and 1950s. In addition, the USFS intended to require the city to bypass significant quantities of water for the purpose of mitigating impacts to aquatic habitat resulting from city water diversions. Both the city and USFS have sought to avoid litigation over the validity and scope of this right of way. Therefore, the city agreed in 1994 to complete an environmental impact statement for the establishment of an express easement. Ultimately, language to address the 1866 right-of-way and instream flows was carefully negotiated with the USFS with Congressman David Skaggs mediating.

Other terms of the 2001 easement agreement are:

- annual payment of $3,314.28 based on the fair market value of the use rights until further notice;
- perpetual easement with 30-year review for as long as the land is used for water conveyance in accordance with the terms and conditions of the agreement (instead of 20-year revocable Special Use Permit);
- instream flow parameters, including a limit on the average pipeline flow of 20 million gallons per day from May 20 through June 20 in order to achieve minimum streamflow identified in the CWCB Agreement;
- conducting maintenance in accordance with a USFS approved O&M plan, to be updated and revised every five years;
- a minimum of $1,000,000 in liability insurance in the event of death or injury to one or more individuals and $50,000 for property damage, and;
- a provision that the easement preclude the city from asserting its 1866 Act rights but not allow the USFS to dispute these rights. The provision also affirms that the easement does not change the scope of the 1866 rights, to the degree that they existed prior to execution of the easement.

The city rejected a proposed draft of the new easement in 2004 due to concerns over liability provisions and vague easement suspension language. Staff and USFS representatives negotiated a new draft agreement in February 2008 refining liability provisions and conditions for easement suspension.

In a March 2008 letter to the Boulder City Manager, the USFS included revised liability provisions in a proposal for a new easement based on successful negotiations with city and USFS staff. The liability insurance for the new easement is increased from $1 million to $3.5 million for death or injury of one or more individuals; however the difference in insurance premiums is minimal. Other important additions to the 2008 easement include that the immediate suspension clause require a threat that is both "imminent and dire;" that the potential for immediate suspension include consideration of "the threat to public health and safety of the residents of the city of Boulder who are dependent upon the pipeline for drinking water;" and clarification that the failure to maintain instream flows as required by the easement would not justify invocation of the immediate suspension clause. In addition, the annual payment to the USFS is adjusted to $460 per year and may be adjusted annually to "…reflect more nearly the fair market value of the use…" of the land[169].

At the July 2008 Water Resources Advisory Board meeting, the board raised concerns about third party indemnification and strict liability but recommended in a motion that City Council approve the revised 2008 Lakewood Pipeline agreement with the proviso that the approval reference the USFS' "interpretation of the immediate suspension clause and liability provisions" in the easement and affirm that the easement does not diminish the city's rights under the Act of July 26, 1886. Council is next scheduled to review the new terms of the easement in 2009.

3.4.9.12 | FIRE DISTRICT COOPERATIVE AGREEMENTS

The city's North and Middle Boulder Creek source water facilities are located west of Boulder in unincorporated Boulder County. Water utility land and infrastructure are located within various Fire Protection Districts, which are special taxation districts formed to provide emergency services outside of cities and towns. The Fire Protection Districts support fire departments, most of which are volunteer-based. Because the city is a tax-exempt municipality, the districts do not collect tax revenues for city lands and facilities. Some city facilities (e.g., Betasso WTF and several hydroelectric facilities) involve response dangers that are beyond the normal volunteer fire fighter familiarity. Therefore, the city has entered into separate agreements with several Fire Protection Districts to ensure timely and appropriate response to emergencies which could arise at its source water facilities.

Fire Protection Districts are required to provide response to all properties within their district boundaries, regardless of whether those properties are taxable or tax-exempt. In the absence of a mutual agreement with a tax-exempt property owner, it is common for districts to bill tax-exempt property owners for the actual cost of response to those properties. A major incident such as a wildland fire requiring a large and lengthy response could easily cost the city hundreds of thousands of dollars. The city therefore prefers to enter into agreements with districts and attempts to base payments on land and facility value, such that the districts receive payment approximately equivalent to what they would receive were the properties taxed.

The city first provided for fire protection of the Silver Lake Municipal Watershed in 1916 by entering into a cooperative agreement with the USFS for the purposes of conserving and protecting the city's water supply. In addition to providing for mutual aid in the suppression of forest fires, this agreement placed partial responsibility on the USFS to patrol the area and monitor activities within the watershed. It allowed the USFS to remove timber that could be removed without injury to the water supply. This agreement became obsolete upon the city's closure of the watershed to public access during the 1920s. However, due to the large tracts of National Forest land surrounding the city's watershed, under current forest fire management structure, the USFS would no doubt participate in any fire suppression efforts required within the city's watershed property.

The Silver Lake Municipal Watershed, including dams, reservoirs and the Silver Lake residence is located within the boundaries of the Indian Peaks Fire Protection District. Indian Peaks entered into an agreement with the city in 2004 to provide watershed fire suppression and rescue services free of charge for 20 years in exchange for the city selling 5 shares of the capital stock of the Left Hand Ditch Company to the Town of Ward for $10.

The Sugar Loaf Fire Protection District encompasses the Betasso WTF, Betasso and Lakewood Hydros and much of the Lakewood Pipeline. In 2002, the city entered into a 20-year agreement with Sugar Loaf to provide the full range of fire protection and other services which are normally provided to other properties to all city lands, facilities and employees, contractors, vehicles and equipment within District boundaries. The agreement requires the water utility to pay Sugar Loaf Fire Protection District $155,000 between 2002 and 2021 for these protections. The city also provided Sugar Loaf with two fire hydrants installed on the Lakewood Pipeline within the District's boundaries.

Boulder Canyon Hydro, Orodell Hydro, various pipelines and water utility land are located within the Four Mile Fire Protection District. In 2006, the city entered into a 10-year agreement with Four Mile to provide the full range of fire protection and other services which are normally provided by the District to all city lands, facilities and employees, contractors, vehicles and equipment within District boundaries. The agreement requires the water utility to pay Four Mile Fire Protection District $30,000 between 2006 and 2015.

Kossler Reservoir and portions of the Barker system fall within the boundaries of the Rocky Mountain Fire District (formerly Cherryvale Fire Protection District). While the water utility does not have a formal agreement with Rocky Mountain Fire, the city facilitates the District's use of Kossler Reservoir as a fire suppression water supply by allowing Rocky Mountain to construct fire suppression water supply infrastructure on its Kossler Reservoir property.

Lakewood Reservoir, Silver Lake Pipeline, Silver Lake Hydro, the Lakewood and Barker residences, several North Boulder Creek diversions, portions of the Lakewood Pipeline and Barker Reservoir fall within the boundaries of the Nederland Fire Protection District. The water utility has proposed but has not finalized a formal agreement with Nederland for the protection of water utility lands and facilities. The water utility provided Nederland with one fire hydrant on the Lakewood Pipeline within the District boundaries.

The water utility works with the Boulder Fire Department Wildland Fire Division to provide fire hazard mitigation for its wildland-urban interface properties. Projects have included removal of dead trees and downed fuel at the Silver Lake Municipal Watershed and forest thinning efforts at the Betasso WTF and on Boulder Canyon Hydro and Kossler Reservoir lands.

The Boulder Fire Department has mutual aid agreements with most Boulder County Fire Protection Districts. These help to ensure that sufficient manpower will be available for fire suppression on water utility lands outside the city limits.

3.4.10 | WATER AND DISTRICT COURT CASES

3.4.10.1 | DITCH COMPANY ISSUES

The city of Lafayette and the Base Line Land and Reservoir Company sued the Anderson Ditch Company and the city of Boulder in 1996 and 1997[xi]. There were two lawsuits. One focused on Lafayette's claimed acquisition of one-eighth of one percent interest in Anderson Ditch and Lafayette's associated claimed unlimited right to use unused capacity in Anderson Ditch to carry Lafayette's water other than its Anderson or Base Line water (foreign water). The other concerned Base Line's claim for reinstatement of its 1911 agreement for carriage of water in the Anderson Ditch, which was terminated by Anderson in early 1997 because of Anderson's belief that Base Line had violated the agreement in 1996, and its claim that the Anderson Ditch capacity should be increased to allow carriage of greater amounts of water to Baseline Reservoir. The initial lawsuit involved Base Line and Anderson; however, the cities of Lafayette and Boulder, as well as all other Anderson shareholders, were also parties to the case.

[xi] Two binders of information on the lawsuit and resulting settlement can be found in the Utilities library located in the Park Central building.

The Base Line case was decided in 1999. The court reinstated the 1911 Base Line agreement, but found that the Anderson Ditch Company has no obligation to enlarge the capacity of the Anderson Ditch for the Base Line Company[170]. Prior to trial in the Lafayette case, Lafayette and Boulder entered into an Intergovernmental Agreement in 2001 that resulted in settlement of the Lafayette case. The agreement provided for Boulder to move its wastewater effluent discharge to a new point several hundred feet downstream of its then-current location near 75th Street and for Lafayette to construct a new pipeline from Goose Haven Ponds to a diversion point on Boulder Creek above the new effluent discharge. In return, Lafayette gave up all of its claims to an ownership interest in the Anderson Ditch and any associated rights to use the ditch capacity to carry Lafayette's water, other than its rights as a Base Line shareholder for carriage of Base Line water under the 1911 Base Line agreement. Boulder and Lafayette completed construction of the new facilities in 2003.

The dispute between Anderson Ditch and Base Line arose because in 1997, Anderson discovered that during 1996, Base Line had run water through the Anderson Ditch at flow rates above the safe carrying capacity set by Anderson and had also run water not diverted under Base Line's water rights. Anderson terminated its 1911 agreement with Base Line under the belief that Base Line's actions were in violation of that agreement.

Base Line and Lafayette's major claims against Boulder were that Anderson is the alter ego of Boulder, which is majority shareholder in Anderson, and that the Boulder's use of the Anderson Ditch to carry stormwater is unlawful. The city successfully defended against these claims, and therefore, the city cannot be held directly liable for Anderson's actions up to the time of the lawsuit and the city's use of Anderson Ditch to carry stormwater cannot be attacked by Base Line or Lafayette again. Lafayette was denied its claim to use the Anderson Ditch to carry water owned by Lafayette other than its Baseline Reservoir water.

Base Line's claim that the 1911 agreement was unlawfully terminated was granted and the agreement was reinstated. The court ordered the following concerning the issues of operational control of the ditch and Anderson's responsibilities for maintenance and capital improvement of the ditch under the 1911 agreement:

- Anderson does not have a duty under the 1911 agreement to maintain the Anderson Ditch at 25 cfs or any other specific capacity;
- Anderson has the sole and exclusive discretion to set a reasonable and safe carrying capacity for the ditch;
- Anderson's obligations to Base Line under the 1911 agreement to clean the Anderson Ditch is generally limited to removing trash and debris and occasionally to removing sediment accumulation, and;
- Anderson has no obligation to enlarge the Anderson Ditch from its current maximum safe carrying capacity of 15 cfs.

3.4.10.2 | SOUTH PLATTE IRRIGATION WELLS

Boulder is an objector in several cases filed in Water District 1 Water Court by irrigation well users on the lower South Platte River for approval of augmentation plans. Many well users have operated for decades based on substitute supply plans approved annually by the State Engineer. Between 2003 and 2008, settlements were reached in many of the well user cases.

Several of these cases were filed by Central Colorado Water Conservancy District (Central). Settlement was reached in 2005 in a case for the augmentation plan for one of Central's two subdistricts—the Groundwater Management Subdistrict. A scheduled May 2006 trial in the matter involving the other Central Subdistrict—the Well Augmentation Subdistrict (WAS) - was postponed at Central's request on the condition, proposed by Central, that 440 Central WAS wells had to be turned off due to the lack of an approved augmentation plan.

In June 2006, other agricultural water users in the area of the wells reported that some of the Central WAS wells were still being operated despite the water court's order implementing the shutdown proposed by Central in exchange for postponement of the May 2006 trial. The State Engineer's Office investigated and later sent notice to several irrigators to stop well use and filed actions in court against a few irrigators.

The re-scheduled Central WAS trial was held in February 2007 and the Water Court issued a decree in 2008. Central has filed an appeal of the decree with the Colorado Supreme Court, which is still pending.

Water augmentation plans allow junior water right owners to take water at times when they otherwise would not be allowed to divert because it would take water away from senior water right owners. Under an augmentation plan, the junior water user provides replacement water to senior water users to substitute for the water taken by the junior user. The time delay between use of a well and the resulting reductions in river flow that must be replaced can range from days to years depending on distance of the well from the river. Water augmentation plans must be approved by the Water Court.

Two groups of water users that hold water rights senior to the South Platte wells are impacted if the well owners fail to pay back water owed:

- thousands of downstream farmers in northeastern Colorado from Brighton to Fort Morgan and beyond, and other lower South Platte River water users like the city of Sterling, and;
- upstream users like Boulder and others who have to send water downstream due to calls for water from senior water rights owners.

For many decades, South Platte irrigation wells pumped water under augmentation plans approved by the State Engineer. Well owners had committed under the plans to offset any reduction in water available to senior water rights owners when the delayed effect of previous well use reached the river. However, the State Engineer had not been requiring the well users to make sufficient water payments.

Central WAS wells had pumped for many years and had created a large deficit in river flows that occurred years after the original pumping took place due to the distance of the wells from the river. In 2006 and again in 2007, the South Platte River had a shortage of about 15,000 acre-feet of water each year due to the delayed effect of Central WAS wells.

In prior years when Central operated under substitute water supply plans, the State Engineer directed that water that Boulder should have been legally entitled to keep had to be passed along to more senior water rights owners downstream from Central WAS, even though Central WAS should have been responsible for replacing this water to the river. In effect, Boulder's water has been used to pay the water debt of the Central WAS well owners. Central WAS did not have enough water available to them to pay the part of the water debt that came due in 2006, 2007 or 2008.

The issue of the State Engineer's authority to approve temporary substitute supply plans, particularly those that operate year after year with no apparent intention to seek Water Court approval, has been a matter of much discussion in recent years. In 2000, in a case in Water Division No. 2, Empire Lodge vs. Moyer, the Water Court determined that Empire's approved temporary substitute supply plan was unlawful. The case was appealed to the Colorado Supreme Court.

Boulder challenged the State Engineer's contention that the state legislature intended to create a "parallel track" to the water court process that would allow the State Engineer to approve temporary substitute supply plans and to do so over extended periods of time with no opportunity for other water users to comment or assess the extent of their injury. In December 2001, the Supreme Court ruled that the State Engineer has no statutory authority to approve temporary substitute supply plans except for replacement of evaporation losses from unlined gravel pits. In 2002, the legislature enacted substitute water supply plan statutes that gave the State Engineer authority to approve temporary substitute supply plans in limited and narrowly-defined circumstances, including where an application for approval of a plan for augmentation is pending in a water court case.

In response to the Supreme Court ruling, the State Engineer proposed Amended Rules and Regulations for the issuance of substitute supply plans within the South Platte basin. The proposed rules appeared to Boulder to continue to claim more authority for the State Engineer to approve these plans than was allowed by statute and as had been found to exist by the Supreme Court. In July 2002, Boulder and approximately 50 other water users filed protests with the Water Court to the State Engineer's proposed rules. In December 2002, the Water Court judge ruled that the proposed rules were not within the State Engineer's authority. The State appealed the ruling to the Supreme Court which affirmed the Water Court ruling in 2003.

South Platte River well owners, led by Central, sought new legislation in 2003 that would extend the State Engineer's authority and would allow the well users to continue well pumping under substitute supply plans without a requirement that the wells owners ever go to Water Court for approval of permanent augmentation plans. Such legislation was introduced as Senate Bill 03-73. Many owners of senior water rights in the South Platte River basin who are injured by the continued operation of the wells under substitute supply plans lobbied against the legislation, including Boulder.

Following negotiations between senior water rights owners and junior well irrigators, a modified version of the bill was approved that allowed wells to continue operating under annually-approved temporary substitute supply plans for a period of three more years without filing an application in water court for approval of a permanent augmentation plan. Because the requirements under this new statute were very stringent, hundreds of applications for new augmentations plans were filed before and shortly after December 2003 so that the well owners could apply for substitute supply plan approval under the portion of the 2002 substitute water supply plan statute that allows State Engineer approval of such plans during the time a water court application is pending.

Central and other South Platte well users have continued to seek new legislation in almost every year since 2003 that would ease requirements that they pay the full amount of the depletions to the river that affect senior water rights. These efforts have been successfully opposed by senior water rights owners. In 2007, the governor formed a task force to study the issue and propose legislation that might assist the well owners without injuring senior water rights owners[171]. The task force recommended several minor statutory changes, none of which were subsequently adopted by the legislature. The task force also recommended review of water court procedures which is currently being undertaken by the Supreme Court's Water Court Reform Committee.

3.4.10.3 | CONTRACTS ASSOCIATED WITH WATER PURCHASES

From time to time, the city has entered into lease-back agreements or other arrangements with entities from which it has purchased water shares. One example is an agreement with Lakeview Village from whom the city acquired Lower Boulder water shares and agreed to lease instream flow water[172]. A second example is an interruptible supply contract with Boulder Creek Farms from whom the city purchased Lower Boulder water shares[173].

3.5 | Operational Considerations for Water Management

The city's water supply sources vary greatly from one year to the next due to the semi-arid climate of the region. This creates a need to carefully balance use of the city's available water sources to assure that sufficient supplies will be available both during seasonal periods of low streamflow and during extended drought periods.

Boulder's water supply is dependent on streamflows in Boulder Creek and the Colorado River, both of which exhibit a high degree of annual variability. Droughts in the Colorado River basin generally coincide with droughts on Boulder Creek, but this is not always the case.

By design, the water system components work together to produce the total system yield. Some parts of the system will be used more extensively than other parts in different years depending on the hydrology of the particular year. For example, one of the city's source watersheds may be experiencing dry conditions while the others are not, or the city may have more carry-over storage in one source basin than another. This means that a particular source that is part of the system can be talked about in terms of its average contribution to total system yield over many years, but the yield from any one source can vary widely from year to year, depending on the hydrologic conditions of a year and its preceding years. Judicious management and flexibility in the selection of which city water source to draw on at any given time is necessary to assure that the maximum yield can be obtained from the city's water rights.

On average over the course of several years, under the present level of water demands in the city, approximately 35 percent of the city's annual municipal water supply is diverted from the North Boulder Creek basin, approximately 35 percent is diverted from the Middle Boulder Creek basin, and approximately 30 percent is direct use of water from the CBT and Windy Gap projects and from the Farmers Ditch through the Boulder Reservoir WTF. CBT and Windy Gap water can also be used indirectly as an exchange source for some of the diversions from North Boulder and Middle Boulder Creeks when the city's native basin water rights would otherwise be out of priority. A portion of the diversions from Middle and North Boulder Creeks could not occur without the availability of CBT and Windy Gap water. The combined direct and indirect use of CBT and Windy Gap water transported from the western slope supports 50 percent of the city's annual diversions on average with the other 50 percent derived from use of native basin water rights. The Silver Lake Watershed and Barker sources are fully used, considering the need to maintain sufficient storage reserves in the upper reservoirs to protect against drought, but the city is believed to own enough water at Boulder Reservoir to meet all of Boulder's future needs. As Boulder grows, the percentage of direct use of CBT, Windy Gap and Farmers Ditch water at Boulder Reservoir WTF will increase to about half of the city's supply.

3.5.1 | MANAGEMENT OF CITY WATER RIGHTS

Boulder owns a diverse portfolio of water rights and water delivery contracts, which allow the city to use water both from the local Boulder Creek basin and from tributaries of the Colorado River to provide municipal water supply. These include direct flow rights, storage rights, exchange rights, and contract water delivery rights.

The city's water rights that are decreed for municipal use are held within the water utility enterprise fund. Assets held within the enterprise fund are constrained in their use for the primary purpose of providing municipal water supply. The city also owns water rights that are decreed for agricultural use and are used for irrigation of open space and parks. These rights cannot be directed through the water treatment facilities and are held as a general use asset within the general fund or as an asset restricted for Open Space use.

Use under Boulder's many water rights is defined and limited by the terms of each water decree. These terms include limitations on types of use, diversion location, if and where water can be stored, season of diversion, if reuse after the first municipal use is allowed, maximum flow rate for the diversion, maximum storable amount, minimum instream flow levels and the all-important priority date as compared to other water rights. Municipal use includes a broad variety of allowable uses such as residential uses, commercial uses, manufacturing, parks irrigation, fire-fighting and filling swimming pools, but most uses are limited to within the designated municipal treated water system service area. Very few of Boulder's water rights allow the water remaining after the city's first use to be claimed by the city for reuse or augmentation of other uses, either because the rights were originally decreed for a one-time municipal use or were agricultural rights that were changed to municipal use prior to the time that change decrees commonly provided for reuse. Some of the city's municipally-decreed water, such as CBT water or the city's Lower Boulder Ditch water can be leased for agricultural use.

In order for the city to divert water at any of the various diversion points in the Boulder Creek basin, the city must own a water right that is in priority to take water at the time. If downstream water users have more senior water rights that are not being satisfied, the city must either allow water to pass its diversion points or meet the water rights call with water provided from another source. The amount of water the city derives from the water rights for each of its municipal water supply sources varies from year to year based on several factors including calls placed by other water rights, hydrologic conditions in each water basin, and storage levels in the city's reservoirs. The city keeps a daily record of the diversion amounts at each municipal water system diversion or storage location and records the associated water right that allows the water to legally be taken[174]. These records are then submitted to the State Engineer's Office (SEO), which is responsible for administering all water diversions and water rights in Colorado. Boulder's water managers are in frequent contact with the SEO water commissioner to determine how much water the city is allowed to take and at what location. Particularly during the irrigation season, there is daily coordination with the water commissioner because the call on the river can be different everyday due to quickly changing streamflow levels and water demands.

The city determines which of its in-priority water rights will be diverted at a particular time based on several factors including current municipal water demand, reservoir storage levels, water quality, volumetric diversion limits in decrees, treatment plant staffing and service status of facilities. The delivery of water to the city under these rights may, at times, be further limited by the physical capacity of the city's conveyance, storage and treatment facilities, and by the actual need for water in the city. The city's choice of which available water to use is also influenced by economics and secondary benefits of the use.

Under normal operations at times of plentiful streamflow, the higher quality, more easily treated, gravity-fed waters derived from North Boulder Creek, Silver Lake Watershed and Barker Reservoir water rights are used preferentially to meet the water demands of the city to the extent that necessary storage reserves are not reduced. The city retains a portion of its annual Boulder Creek water yield within its upper reservoirs rather than using every drop possible of this water because storage releases will be necessary during winter periods and droughts to maintain a continuous water supply to Betasso WTF. Once a determination has been made that the maximum safe level for use of Boulder Creek water sources has been reached, the balance of the water demand is met by Boulder Reservoir sources. Betasso WTF very rarely shuts down for more than a few hours because the upper pressure zones of the city's treated water distribution network heavily rely on a continuous feed of water from Betasso[175].

3.5.2 | OPERATIONAL "SEASONS"

Although greatly simplified, the city can be considered to have four operational seasons for its raw water supply system. Three of these seasons are "nested" within each other. First, municipal water demand on a particular day will usually be met by using in-priority, direct flow water rights before pulling water out of storage. All of the city's water needs can often be met this way during spring snowmelt periods and the early summer when streamflows at the city's upper pipeline diversion points are high. This "direct flow season" (when the city meets all its needs directly from streamflow with no reservoir storage releases) usually runs from about mid-May to late July, although it varies greatly from year to year depending on the amount of winter snowpack accumulation and how quickly snowmelt occurs.

Second, most of the water in Boulder's municipal reservoirs is placed in storage during the spring runoff period when streamflows are usually high. The city's high elevation Boulder Creek reservoirs have a very short window to fill during a "reservoir fill season." There may be only four to eight weeks between the time high altitude snowmelt begins in the springtime and when senior rights lower on the river, such as direct flow agricultural irrigation rights, call out the city's storage rights.

The third season comes into play if storage rights are called out before reservoirs are full. In such a case, the city can use its exchange rights to release water from Boulder and Baseline Reservoirs to fulfill downstream calling rights and take additional water into the city's upper reservoirs as long as there is streamflow physically flowing into the reservoirs. Additional water can be taken directly into the city's pipelines in this manner as well. The "exchange season" may be limited to just a few weeks during the reservoir fill season. In dry years or years when the snowpack melts so slowly that streamflows don't reach high levels, the river call will remain senior. In these years, the exchange season may comprise the entire reservoir fill season, and any water placed in reservoirs will be solely due to exchanges.

Lastly, as streamflows at the city's upper diversion points drop in the summer, there is insufficient physical supply to meet all of the water demand using direct flow. Therefore, usually starting sometime in July or August, the fourth season begins when the city supplements direct flow diversions with reservoir releases. By mid-October, all of the city's water rights derived from shares in irrigation ditches that have been changed to municipal use are no longer allowed to divert. The city can continue to make direct flow diversions under its original municipal water rights. By wintertime, streamflow levels are so low that most of the city's demand is met with storage water. The "reservoir release season" lasts until the following spring. City reservoirs are not completely drained every year in order to assure enough water supplies in dry years, which is a reality in this semi-arid climate. Committing to water uses that would claim all water available in wet years would use up water that should be stored, like a savings account, to sustain water needs in drought years.

Reducing water demand through water conservation efforts improves the ability to fill reservoirs in the reservoir fill season and slows the decline in the reservoir release season, thereby improving the city's ability to weather droughts by maintaining storage reserves. However, in any given year, once the city's storage reservoirs are full, reductions in water demand during the direct flow season have no benefit for sustainability of the city's raw water supply. Savings from water conservation during this period reduce the amount of water the city diverts to its municipal system, but the city cannot store the savings for later use or assign the saved water to another use. The effect is that streamflow levels below the city's intakes increase when demand is reduced during the direct flow season, which may be noticeable during low streamflow periods but during high streamflow periods, there is no significant habitat benefit from a little more flow[176]. The additional streamflow will benefit downstream water users.

3.5.3 | RESERVOIR MANAGEMENT

As discussed above, because much of the water available to the city can only be captured in May and June during spring runoff from the melting of the winter snowpack, the city's water system is greatly dependent on reservoir storage. Much of the water stored in these reservoirs is used from late summer through the following early spring period to supplement water available from direct flow sources. The water levels in the reservoirs are the lowest in the spring, just before the mountain snowmelt begins. Prior to 1994, all of Boulder's mountain reservoirs operated on a "low-point" administration basis for purposes of the SEO's one-fill rule that limits storage rights to diversion of the volumetric limit only once a year. In 1994, Boulder selected fixed starting dates for the "reservoir year" for two of its reservoirs. The reservoir year start date affects the determination of which storage water right may be exercised at a particular time. Fixed starting dates were selected for Barker Reservoir and Silver Lake Reservoir as a result of the decree in Case No. 90CW193 (the instream flow program case). The fixed starting dates for these two reservoirs can be and have been adjusted to new dates occasionally in cooperation with the Water Commissioner. The remaining reservoirs continue to operate based on low-point administration for purposes of the one-fill rule. The new water year for these reservoirs begins when the water level in the reservoir reaches the low point each year. This means that some water storage years will be shorter than others, but will average 365 days over time.

The reliable yield of a reservoir is the maximum demand that can be consistently and reliably met year after year without jeopardizing the ability to provide the same level of supply in dry years. Therefore, the reliable yield is less than the full capacity of the reservoir. If the reservoir is intended to provide protection against the possibility of a multi-year drought, the reservoir contents must be apportioned to provide water for use in successive drought years. For example, to prepare for a potential three-year drought period, the drought reserve pool of a reservoir with very junior rights, which will not yield during a drought, should not be drawn down by more than one-third of its capacity (less expected evaporation and seepage) during the first drought year. Taking more water than this out of the pool could jeopardize water availability in the third year of a multi-year drought if it should occur. Boulder manages its reservoirs to achieve the adopted reliability criteria[177] through conditions as severe as those found within the historic streamflow record for Boulder Creek as extended back to the early 1500s using tree-ring records. This record contains several multi-year drought periods[178]. In addition, due to the potentially severe jeopardy to human health if no water is available for essential indoor needs such as drinking water and toilet flushing, Boulder maintains an emergency drought reserve pool of no less than 3,000 acre-feet in upper reservoir (Barker and Silver Lake watershed reservoirs) storage and 800 acre-feet in Boulder Reservoir to provide a year's worth of water for essential public health needs that will not be accessed except in a drought worse than any planned for or in the historical record.

The city's units in the CBT Project act as a storage reserve for the city's system. The city owns enough CBT units to equate to about 7.5 percent of the 720,000 acre-feet of storage space in the CBT Project reservoirs[179]. CBT water is managed by the NCWCD Board of Directors as a supplemental supply to native basin water. Each year the NCWCD board sets the amount of water, or the quota, to be delivered to each CBT unit. High quotas are typically set when East Slope runoff is projected to be below normal and West Slope reservoirs are at or above average storage levels. Low quotas are set when East Slope basin runoff is expected to be above normal or West Slope reservoirs are significantly below normal storage levels[180]. Modeling of the CBT system has projected that it can deliver a 100 percent quota through the first two years of a three-year drought period similar to 1954-1957, which is one of the worst multi-year drought periods in the documented streamflow record, before having seventy percent available in the third drought year when a 100 percent quota would otherwise be expected[181]. In practice, the quota in the severe drought year of 2002, which was worse than 1954, was set at 70 percent due to low water levels in the CBT system reservoirs. Recorded streamflows are not generally available prior to 1900, but tree-ring reconstructions have shown that more severe droughts than in the 1950s occurred on several occasions in the preceding centuries[182].

The city operates its municipal water system with the goal of maximizing water yield from the Boulder Creek watershed while maintaining enough carry-over storage that continuous water supply to Betasso WTF is never jeopardized. In addition to the jeopardy to adequate water supplies that empty upper reservoirs would cause for the entire city, the effects on the upper pressure zone (Zone Three) of the treated water distribution network on the west side of Boulder would be even more challenging. If no water is available for delivery into the upper side of the city's distribution system from Betasso, then Zone Three would need to be fed by pumping water up from Boulder Reservoir WTF. Although Boulder Reservoir WTF is sized at 16 MGD to provide sufficient water to meet the essential indoor water needs of the entire city under build-out conditions, this water has to travel through two other pressure zones and a series of pumping stations to make it up into Zone Three.

Upgrades to the capacity of these pumping stations are planned in the future, but they are not presently capable of moving sufficient water supplies into Zone Three to meet essential needs. In addition, if the water users within Zones One and Two do not cut back all water use to essential indoor need levels, the water provided by Boulder Reservoir WTF will be depleted before reaching Zone Three[183]. Therefore, the city's emergency drought reserve supply of not less than 3,000 acre-feet is maintained in the upper Boulder Creek reservoirs to assure that water deliveries can be made to Betasso WTF even under the most extreme conditions.

In the years when the Silver Lake Watershed reservoirs and Barker Reservoir fill and spill, the city can be relatively confident that it will have sufficient water available to the municipal system until the next year's spring snowmelt period and that the city will have less vulnerability to water shortage in the event of drought. In drier years, the city cannot store much, if any, water under its junior storage rights, such as the 1956 and 1966 Barker Reservoir storage rights, which are often called out of priority. In this situation, the city often relies on the ability to exchange other water to fill its reservoirs, particularly Barker, by early summer. Factors that affect when and if the reservoirs fill include physical water supply and municipal water demand. Physical supply is determined by spring and summer precipitation at high elevations, mountain snowpack throughout the winter, temperature in the mountains, streamflow runoff pattern, water rights yields and river conditions that affect the ability to exchange water released from Boulder Reservoir or Baseline Reservoir for increased diversions at the upper reservoirs. Water demand is influenced by the weather within the service area of the municipal water system. For example, if weather conditions are wet and cold, irrigation water demand drops and more water can be stored or kept in storage.

3.5.4 | MANAGEMENT OF EXCHANGES

Some of the city's most important water rights allow the city to divert water out of priority at its upstream diversion points in the Boulder Creek basin and replace it with an equal amount of other water released by the city at downstream locations through what is called an "exchange." When exchanging, the city trades water from Boulder Reservoir, Baseline Reservoir, or several ditches for additional water at the city's upper Boulder Creek intakes or reservoirs. In many years, most of the water the city stores in Barker Reservoir has been exchanged with CBT water released from Boulder Reservoir[184].

Exchanges help to maintain the carry-over water levels in the city's Boulder Creek reservoirs to protect against major water shortages during drought periods. In addition, when water is exchanged for direct diversions into the city's pipelines, stored water that would otherwise have to be released from reservoirs to meet the city's water needs can be retained for later use. The city could not meet the established water system reliability criteria without use of the exchange rights.

Use of Boulder's exchange water rights is necessary in some years when the city's native basin water rights are called out of priority by more senior water rights from lower on Boulder Creek or from the South Platte River. Only water rights calls coming from a point below the discharge point of the exchange source can be satisfied by exchange. Senior calls occurring above this point on the river must be answered by allowing water to pass by the city's storage reservoirs and pipeline diversion points. Therefore, the exchange mechanism can rarely be used outside of the higher flow periods on the creek and is frequently limited by the physical flow in Boulder Creek in the intervening portions of the stream between the city's diversion points and the downstream senior rights.

The city has used an exchange water right since 1954, which allows exchange of up to 250 cfs from Boulder and Baseline Reservoirs up to its diversion points on upper Boulder Creek[185]. A limitation to the city's 1954 exchange right is the physical space available in the Boulder Creek Supply Canal, which carries water from Boulder Reservoir to Boulder Creek. Under the city's contract with the NCWCD, the city has a guaranteed right to preferential use of up to 90 cfs of the canal's 200 cfs capacity for its exchange[186]. It may use more than 90 cfs only if it is not needed for deliveries of CBT water to others. Thus, including the city's 50 cfs exchange right out of Baseline Reservoir, the city's total exchange capability under its 1954 right can be limited to 140 cfs at certain times.

The city can also exchange against the Boulder and Whiterock Ditch and Reservoir Company diversions through an "internal exchange" (see section 3.4.9.4 for more information on this exchange).

Portions of the city's Baseline Reservoir, North Boulder Farmers Ditch, and Lower Boulder Ditch water are decreed as sources of exchange water and can only be used for municipal water supply purposes through exchange since their diversion points are located downstream of the city's water treatment facilities. Boulder can also exchange the limited portion of its wastewater effluent that is allowed to be fully consumed under the city's water rights decrees (see section 4.3.1.3 "Exchange Rights" for more information on Boulder's exchange rights).

The city's ability to use its exchange rights at any given time is limited by the minimum flow between the city's upstream "exchange-to" points (e.g. Barker Reservoir) and the city's downstream "exchange-from" points (e.g. the Boulder Creek Supply Canal outlet to Boulder Creek), which is known as the "exchange potential." This is because the city cannot operate its exchange in a manner that would injure water rights that divert between the city's upstream "exchange-to" points and downstream "exchange-from" points. Also, even though the city's exchange rights are senior to the CWCB instream flow rights on Boulder Creek, it has been the city's operating policy to not operate its exchanges in a manner that would cause instream flows on Boulder Creek between Orodell and 75th Street to drop below 15 cfs, which is the amount of the CWCB instream flow right in this stream reach. In average to moderately dry years, the exchange potential is relatively high and the city's upper reservoirs are likely to completely fill. In more serious drought years, the exchange potential is low, either because there is little streamflow above Barker or Silver Lake or most of that supply is needed to satisfy senior water rights located on Boulder Creek between the exchange points. In this situation, the city has difficulty filling its upper reservoirs.

In years when the ability to exchange water to fill the city's upper reservoirs is limited, the ability to exchange water from Boulder Reservoir to meet the city's obligation to provide water to Silver Lake Ditch is also limited[187]. Therefore, the city must deliver water to Silver Lake Ditch by releasing stored water from Barker Reservoir. This increases the risk that the city will face shortages if drought conditions were to continue.

The exchange rights allow the city to cost-effectively move water from the city's lower water system into its upper water system without the need to construct an expensive pipeline or pumping system. The increase in water available to the city's upper water system also increases hydropower generation. Water treatment costs are reduced due to use of the exchange because it is less expensive to treat the higher quality water available to Betasso WTF than water at Boulder Reservoir WTF. Also, water from Betasso WTF can be delivered into the city by gravity instead of by pumping, as is required for Boulder Reservoir WTF water. This both saves money and reduces greenhouse gas emissions associated with the electricity for the pumps.

3.5.5 | INSTREAM FLOW EFFECTS ON MANAGEMENT OF CITY WATER SUPPLIES

The city donated use of some water rights to the CWCB for instream flows in Boulder Creek and its tributaries. A condition of the new decree resulting from this donation was that Boulder had to limit its municipal use of these rights to times when they are not being used for instream flow. To replace this deficit in the water supply, Boulder treats more water at the Boulder Reservoir WTF. However, it costs more to treat and deliver water from Boulder Reservoir WTF than it does from Betasso WTF. The operational costs of the municipal water supply system have increased in order to support the instream flow program. (See section 4.3.2.3 “Municipal Use of Instream Flow Water” for more information).

3.5.6 | MANAGEMENT OF HYDRO OPERATIONS

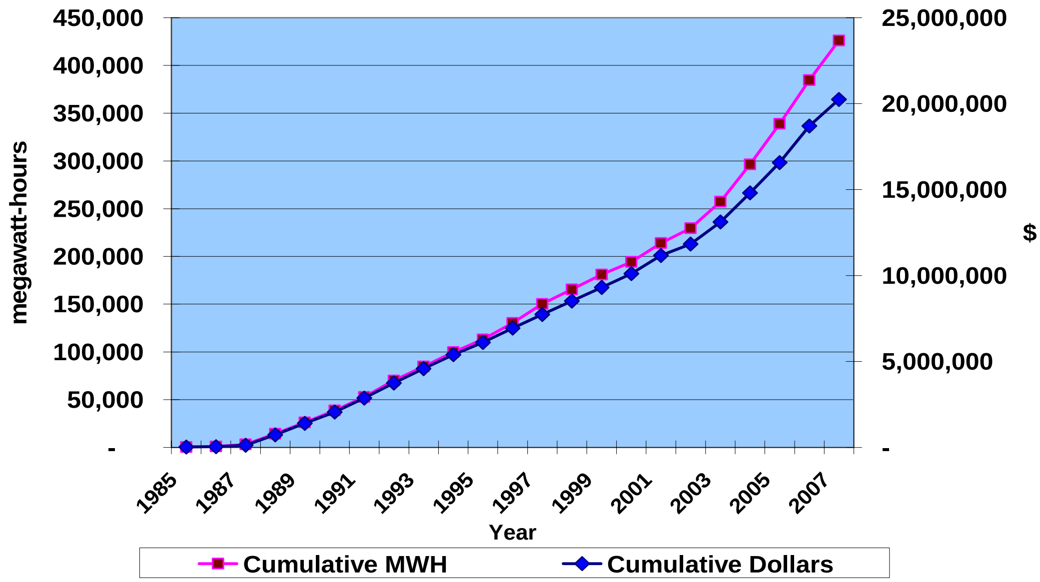
The city has developed much of the environmentally and economically feasible hydroelectric generation potential in its raw and treated water delivery system. This potential exists because of large changes in elevation between the city’s diversion points and delivery points for its municipal water pipelines. The city’s eight hydroelectric generators have a combined rated capacity of 20.1 megawatt-hours (MWh) and produce electricity with minimal environmental impact since the water supply infrastructure is already in place.

The city’s Silver Lake Watershed and Middle Boulder Creek municipal water deliveries generate hydroelectricity at the Silver Lake, Lakewood and Betasso Hydroelectric Plants above the Betasso WTF. After the water is treated, it generates additional electricity at four small hydroelectric plants on the treated water system below Betasso WTF. These turbine-generators were installed adjacent to pressure reducing valves that are necessary for proper water supply operations, but that waste this source of energy. Electricity is also generated from water returned to Boulder Creek at Boulder Canyon Hydro. The generation capacity for each plant depends on available flow, turbine flow limits, gross head, head loss and equipment efficiency. Available flow is set by the demand for municipal water supply in Boulder. Much of the generation potential in the Boulder water system results from high municipal water demand during the summer months.

The hydro plants generate about 45 million kilowatt-hours (kWh) of electricity a year that is sold to Xcel Energy for about $2 million per year. Each year, the hydro plant generation offsets the need to burn about 20,500 tons of coal and provides sufficient power to serve about 7,500 homes. Since the first hydro plant went into service in 1985, 426,240,788 total kWh have been generated that produced $20,242,118 of revenue for the water utility as shown in Figure 3-4 and displaced the need to burn 213,332 tons of coal[188].

Except for Boulder Canyon Hydro and on rare occasions with Silver Lake Hydro, the same amount of water would be conveyed through the pipelines to meet municipal demand with or without hydropower generation facilities. Therefore, water flowing through the city’s hydroelectric facilities is mostly unavailable for other non-municipal uses because it is subsequently delivered for municipal supply.

FIGURE 3-4. TOTAL GENERATION AND REVENUE FOR BOULDER'S HYDROS



The city purchased Boulder Canyon Hydroelectric Project in 2001 to gain more control over the maintenance of the facilities and to increase the amount of reservoir storage space available for Boulder's municipal water supply. Previously, up to one-third of the water stored in Barker Reservoir was used solely to generate power at the Boulder Canyon Hydro plant. PSCo (and later, Xcel Energy) placed most of this water in storage during the spring snowmelt of each year. The water was held for later release to generate peaking power within the PSCo power grid, most typically by releasing surges of water through the hydro plant to Boulder Creek for several hours on most winter evenings. The city uses Barker Reservoir storage primarily as a municipal water supply and secondarily for power generation. Although the city has continued to generate power at the Boulder Canyon Hydro, the surge flows from power peaking operations no longer occur. Almost all of the power currently generated at the Boulder Canyon Hydro is derived from water that is flowing into Barker Reservoir, but that must be released to Boulder Creek to meet demands of water users with senior water rights downstream of Barker Reservoir.

3.5.6.1 | MAXIMIZING HYDRO REVENUES

The city receives a small fixed monthly capacity payment for generation capacity at Boulder Canyon Hydro[189]. For the other hydros, monthly hydro capacity calculations are required under the city's power purchase agreements with Xcel Energy to determine the amount of payments to the city. The agreements contain provisions for payment for two different aspects of the ability to generate electricity (see section 3.4.9.9). A payment is made at a set rate for every kWh that is generated and an additional variable payment is made for demonstrating the capacity to generate electricity available to Xcel Energy. The capacity payments provide considerable revenue to the city. Capacity payments have increased as each hydro facility included in the contract has come on line. Capacity payments since completion of the Lakewood Hydro Plant through 2007 are summarized in Table 3-3.

TABLE 3-3. CAPACITY TEST REVENUE FOR SILVER LAKE, LAKEWOOD, AND BETASSO HYDROS SINCE LAKEWOOD HYDRO BEGAN OPERATION IN JULY 2004 TO 2007[190]

Month	2004	2005	2006	2007
January		$84,147	$84,147	$94,755
February		$84,147	$42,073	$30,447
March		$42,073	$39,252	$38,608
April		$47,921	$30,738	$53,288
May		$67,141	$134,353	$54,288
June		$129,127	$133,134	$54,288
July	$151,332	$134,353	$129,768	$109,763
August	$134,353	$133,157	$131,721	$102,093
September	$60,212	$134,353	$133,416	$75,294
October	$84,147	$37,918	$84,147	$42,073
November	$84,147	$42,073	$84,147	$32,057
December	$84,147	$48,467	$42,073	$45,420
TOTALS	**$598,338.00**	**$986,882.00**	**$1,070,975.00**	**$732,374**
Shaded figures represent payment for <50 percent of the maximum hour instantaneous combined capacity; the remainder of the payments are for 100 percent.				

The city's highest yielding power sale contract includes the Betasso, Lakewood and Silver Lake Hydros[191]. During capacity tests under this contract, flows to Betasso WTF are regulated to produce the best possible calculation of the formula in the contract. This maximizes capacity payments from Xcel Energy while maintaining treated water quality. The combined capacity of the three plants is demonstrated each month through a capacity test involving the simultaneous operation of all three facilities during a one-hour period. In addition to the monthly capacity tests, a four-hour-long capacity test is conducted in the summer and in the winter every four years to prove the reliable performance of the three units and to establish the average capacity for the upcoming seasons[192]. The four-hour tests are supervised by the city of Boulder and Xcel Energy engineers.

Following the monthly capacity test, the capacity payment for the month can be calculated based on formulas in the power sale contract that rely on a capacity factor. The capacity payment is maximized by causing the calculated capacity factor to show that the hydro plants were generating at their maximum amount for more than half of the month. This is done by carefully regulating inflow to Betasso WTF during the capacity test to reach the highest hourly generation possible without causing the capacity factor to be less than 50 percent of the calculated formula. The capacity factor is a significantly higher payment when above than below the 50 percent margin. During these tests, the flow of water through the hydro plants and into Betasso WTF must be increased to the desired maximum flow rate over a one-hour period, sustained for a one-hour period and then reduced back down to the previous flows for treatment. Thus, continuous chemical adjustments are needed for good water quality through the WTF. At present, all of the water released from Betasso and Lakewood Hydros during the capacity tests must be delivered into Betasso WTF for treatment as mentioned above then released into the treated water delivery system since there is no significant raw water storage at tasso WTF and no means by which to discharge excess water elsewhere. The completion of the Betasso Pipelines project, scheduled to begin in 2009, will rectify this situation by providing a means to discharge excess raw water flows to Boulder Creek.

3.5.6.2 | RUN-OF-RIVER OPERATIONS

Silver Lake Hydro and Boulder Canyon Hydro are the only two of the city's eight hydropower plants that are currently able to generate power with water not destined for municipal use due to their ability to discharge back into a natural stream (see section 4.3.1.5 " Hydropower Rights" for information on Boulder Canyon Hydroelectric Project hydropower rights). These two hydro plants can use direct diversions of streamflow and return the water to the creek following discharge from the turbine-generators ("run-of-the-river" operation). All of the water run through Boulder Canyon Hydro returns to Boulder Creek at Orodell with none of the discharge capable of being delivered into Betasso WTF. Silver Lake Hydro has the capability to generate power from the small amount of additional diversions that could be added to the city's municipal diversions into Silver Lake Pipeline when pipeline capacity is available. These additional diversions would otherwise be left to flow down the creek below the Silver Lake Pipeline Diversion. The Silver Lake Hydro has very rarely been operated as a run-of-river facility. Any run-of-river flows in excess of municipal water needs that are carried through Silver Lake Hydro would be returned to North Boulder Creek through Lakewood Reservoir.

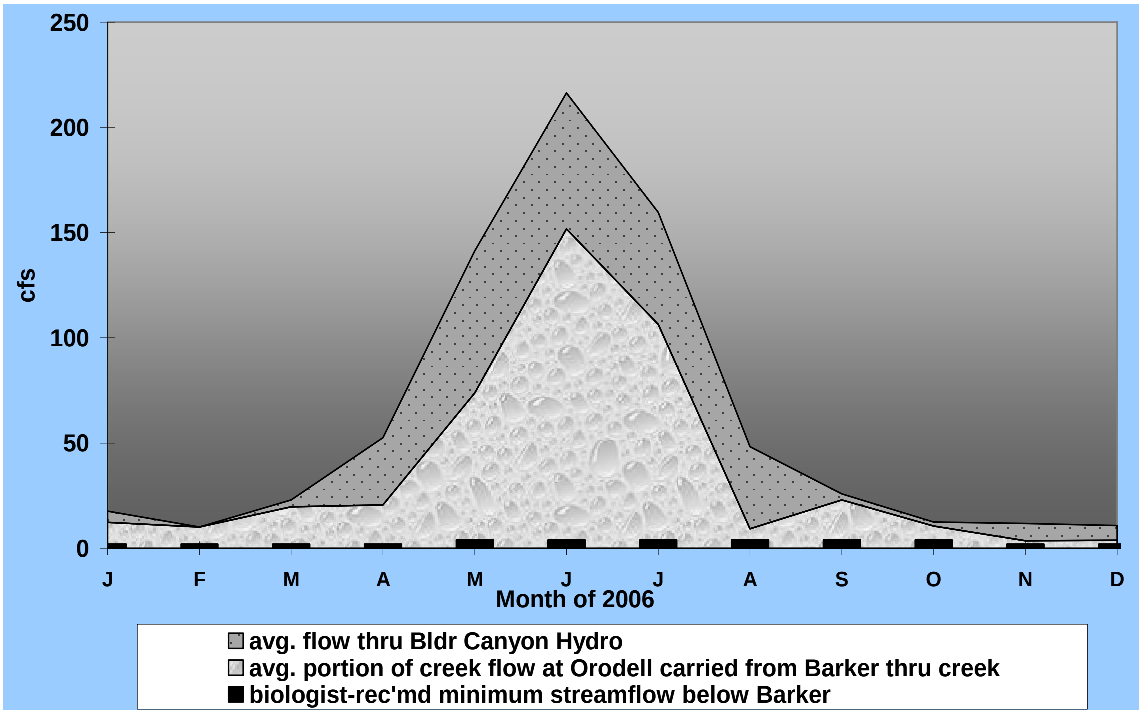
The maximum amount of water than runs through Boulder Canyon Hydro is limited by the capacity remaining in the Barker Gravity Line after municipal water delivery needs are met and by the city's commitment to provide a minimum flow in Middle Boulder Creek below Barker Reservoir of three cfs. The minimum flowrate at which the Boulder Canyon Hydro turbine can generate power is five cfs, so the ability to produce power is essentially limited to times when the city's municipal water rights at Barker Reservoir are not in priority and streamflow into Barker Reservoir is greater than eight cfs (*i.e.* minimum turbine flow amount of five cfs plus the minimum flow provided below Barker of three cfs). At these times, the water flow in excess of the instream flow amount of three cfs must be delivered to downstream water rights owners and cannot be stored or diverted by the city for municipal purposes. There is a trade-off in that the water can either be used to generate power at Boulder Canyon Hydro prior to release for downstream users or it can be released into Middle Boulder Creek at Barker Reservoir and flow in the stream down to Orodell. As an example, Figure 3-5 illustrates the relative amounts of flow that were carried in the stream below Barker Dam to Orodell versus carried through Barker Gravity Line to Boulder Canyon Hydro in 2006. In this year, there was sufficient in-channel flow to meet minimum streamflow requirements to protect aquatic habitat as well as quite a bit of water run through the hydro. Table 3-4 summarizes the monetary, energy and environmental benefits derived from operating Boulder Canyon Hydro in 2006.

TABLE 3-4. BOULDER CANYON HYDRO FACTS (2006)[193]

Total Generation (kWh)	Revenue	Energy Equivalency (Average Households)[xii]	Coal Offset (Tons)[xiii]	CO_2 Emissions Avoided (Tons)[xiv]
11,451,441	$283,600	2,045	5,725	11,995

[xii] This number is based on the assumption that a home uses approximately 5,600 kWh of electricity per year.
[xiii] Calculation based on assumption that one pound of coal generates one kWh of electricity.
[xiv] Calculation based on assumption that 1 kWh of electricity generated by a coal burning plant produces 2.095 pounds of CO_2.

FIGURE 3-5. STREAMFLOW INCREMENTS AT ORODELL DELIVERED THROUGH MIDDLE BOULDER CREEK AND THROUGH BOULDER CANYON HYDRO[194]



3.5.7 | MANAGEMENT OF SURPLUS WATER LEASING

The city leases surplus raw water on an annual basis to support agriculture or, on a limited basis, environmental needs or augmentation. The majority of the water leased by the city is from the city's annual CBT allotment. The city also leases water derived from shares it owns in the Left Hand Ditch and Reservoir Company, Base Line Land and Reservoir Company, the Anderson Ditch Company, and the Silver Lake Ditch Company. For lessees desiring fully-consumable water, the city may lease effluent derived from the city's use of its Windy Gap Project units or the leasable portion of instream flow water. The city has an agreement with District 6 Water Users' Association to give it the preferential right to lease the instream flow reuse water[195]. The city rarely enters into long-term leases, but may consider doing so for leases of Windy Gap effluent.

The amount of water available for lease is generally determined each year by the end of June and is based on the sufficiency of each year's water supply to meet the city's municipal water needs. Since 2000, the city has leased approximately 18,000 acre-feet of water for agricultural use[196]. Water rights available for agricultural lease are listed in Table 3-5.

TABLE 3-5. WATER RIGHTS AVAILABLE FOR AGRICULTURAL LEASE[xv]

Water	Notes	Location
CBT	Portion not needed for municipal use that year or carried-over in CBT system for municipal use in next year	Anywhere in NCWCD area
Windy Gap	Reusable portion remaining after first use for municipal purposes	Boulder Creek downstream of WWTF
Instream flow	Reusable portion remaining at end of protected instream flow reach	Boulder Creek downstream of 75th Street
Left Hand Ditch	408 shares, not transferred into municipal water system	Anywhere in Left Hand Ditch system
Base Line	75.94 shares or portion not exchanged into municipal water system	Downstream of Baseline Reservoir
Lower Boulder Ditch and North Boulder Farmers Ditch effluent	Reusable portion of water remaining after city's first use of water – derived from most recent Water Court changes cases of ditch water	Boulder Creek downstream of WWTF

3.6 | Supporting Studies and Information

The following section provides a summary of the 1988 Raw Water Master Plan and the 2003 Drought Plan. It also provides a list of additional summaries included in the Appendices of studies and plans of the city's source water supplies and raw water delivery system.

3.6.1 | 1988 RAW WATER MASTER PLAN

The 1988 RWMP[197] recommended improved management of the city's water holdings and some capital projects. City Council adopted specific policies as a result of the RWMP regarding implementation of an instream flow program that would not detrimentally affect the Water Utility, meeting water system reliability and water quality goals, implementation of a water conservation program, and disposition of Windy Gap water and compensation with other replacement water sources[198]. The RWMP also included several recommendations for future actions. A few of the key recommendations and subsequent actions are as follows:

1. ***Exercise water rights and agreements to meet increasing municipal demands. The city has:***

   - maximized exchange yields, including exchanges with the Boulder and White Rock Ditch and Boulder Left Hand Ditch systems for purposes of drought protection and maximizing water available to Betasso WTF to minimize cost of water treatment and delivery;
   - maintained a storage reserve in the upper Boulder Creek reservoirs;
   - extended the operation of the Boulder Reservoir WTF to a year-round basis;
   - acquired the Barker system;
   - purchased shares in ditch companies and completed water court cases to allow municipal use, and;
   - continued to retire Silver Lake Ditch Company acres to implement intent of 1906 Agreement.

[xv] Information was compiled from Boulder's water rights decrees, which can be found in the Appendices.

2. ***Achieve instream flow goals for Boulder Creek and its tributaries. The city has:***
   - implemented an instream flow program in conjunction with the CWCB for North Boulder Creek and main Boulder Creek based on agreements entered into in 1990 and 1992;
   - applied for and received a joint city/CWCB Water Court decree allowing instream flow use of the water rights donated for this purpose by the city;
   - successfully operated the instream flow program since 1993 when the Water Court approved the decree;
   - maintained minimum flow levels in Middle Boulder Creek below Barker Reservoir since city purchase in 2001, and;
   - obtained an agreement with the Denver Water Board allowing use of storage space in Gross Reservoir for storage of water to be released for instream flows in South Boulder Creek.
3. ***Maintain, repair and replace raw water transmission pipelines and storage reservoir. The city has:***
   - reconstructed Silver Lake Pipeline;
   - reconstructed Lakewood Pipeline;
   - repaired sections of and siphons on Barker Gravity Line;
   - initiated development of the Carter Lake Pipeline to Boulder Reservoir;
   - maintained dams in the Silver Lake Watershed;
   - rebuilt Lakewood Reservoir dam;
   - increased storage at Goose Lake through repairs to the dam, and;
   - completed preliminary design of repairs to the dam at Green Lake No. 2.
4. ***Establish a water conservation office***

   A water conservation program was implemented in 1992. The city successfully postponed the construction of additional water treatment capacity-related facilities until 2004 in part due to the water conservation program[199].
5. ***Develop a drought recognition and response plan***

   City Council adopted goals for reliability of the raw water system in 1989 based on reliability criteria that specify acceptable levels of frequency and amount of reduction in water availability due to drought. A Drought Plan was presented to City Council in 2003[200].
6. ***Pursue the sale of Windy Gap supplies and with proceeds from the sale of Windy Gap supplies develop insurance against hydrologic drought***

   The city sold 43 of its 80 Windy Gap units to the city of Broomfield in 1991[201]. Proceeds of the sale were used to buy the Barker System and other water rights.

7. ***Develop hydroelectric potential in the water system***

   The city completed construction of the Silver Lake and Lakewood Hydro facilities and purchased the Boulder Canyon Hydro plant. Hydroelectric generation within the system is maximized to the extent possible without interfering with the primary purpose of the water system for municipal water supply or with stream habitat conditions.

3.6.2 | DROUGHT PLAN

The city of Boulder Drought Plan, completed on February 20, 2003 and updated with revised Drought Alert Triggers in November 2004, provides guidance for recognizing droughts that will affect water supply availability for the city and for responding suitably to these droughts[202]. Volume 1 is the Drought Response Plan, which includes summary information on the city's water system, a categorization of drought levels according to the severity of shortage of city water supplies, and detailed information on the particular actions that might be taken to respond to each drought alert level. Volume 2 is the Drought Technical Information and Analysis that provides the technical basis for recognizing drought occurrences and supporting documentation for the Drought Response Plan. Specifically, Volume 2 contains the detailed analysis, hydrologic data and history to help assess the status of the city's water supply each year and support declaration of Drought Alert Stages if necessary.

The Drought Plan is separate from and has a different purpose than the Water Conservation Plan[203], which addresses the city's on-going efforts to promote wise water use during non-drought periods. The Drought Plan is intended to help staff, customers, stakeholders, City Council and WRAB prepare for a drought, recognize drought conditions as they occur and respond effectively in the event of a drought. The water system operational analysis in the Drought Plan was conducted using the most recent demographic assumptions and resulting water demand estimates available at the time from Scenario 1 of the Jobs and Population Project memorandum dated September 18, 2002[204]. Scenario 1 projected a population of 140,500 people, an employment level of 164,600 jobs, and a treated water demand of 26,800 acre-feet at build-out. This level of build-out demand assumed that a goal of a 10 percent reduction in overall water demand as compared to levels in 2000 will be achieved by the city's on-going water conservation program. The analysis also incorporated natural (virgin) streamflow records, which represent undeveloped conditions, reconstructed from tree ring data for the period 1703 to 1987 and natural streamflow records reconstructed from stream gages and diversion records for the period 1910 to 2002[205].

3.6.3 | ADDITIONAL PLANS AND STUDIES

Summaries of the following studies, bibliographical information, and/or complete documents may be found in the Appendices to this plan.

- Treated Water Master Plan
- Watershed Dams Evaluation
- Lakewood Pipeline EIS and Pipe Evaluations
- Barker facility assessments
- Drought Plan

- Middle Boulder Creek Water Source Management Work Plan
- Water Quality Strategic Plan
- Boulder Reservoir Watershed Management Resource and Information Guide
- Water Conservation Futures Study
- Source Water Impact Assessment
- Integrated Evaluation of Boulder Reservoir Water Treatment Facility Source Water Protection and Treatment Improvements
- Boulder Valley Comprehensive Plan
- Instream Flow Studies
- Water Conservation Plan
- Historic water system studies
- Utilities Division annual reports

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Chapter 4

4 | RAW WATER SUPPLY SYSTEM ASSETS

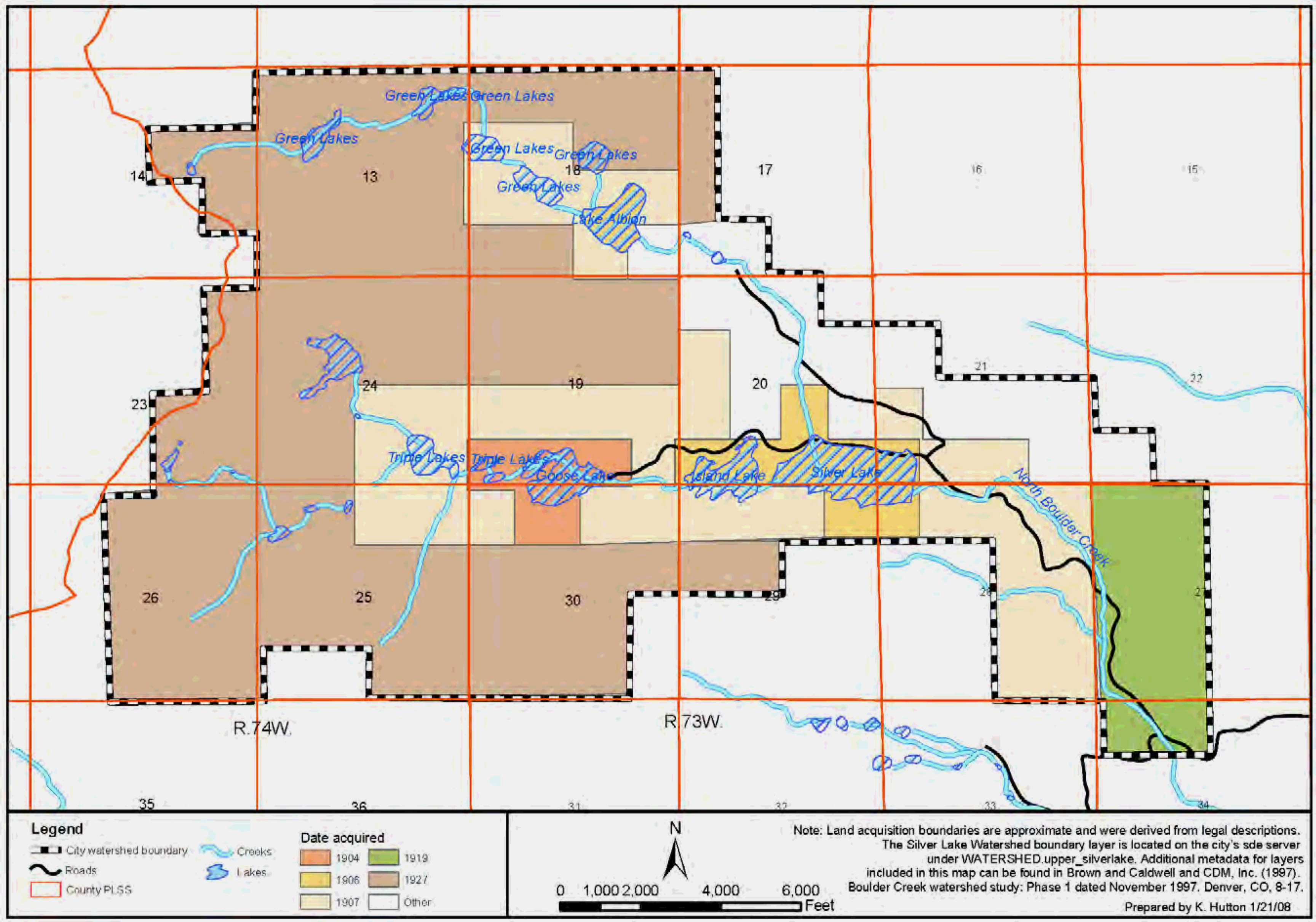
4.1 | Land

Beginning in 1875 Boulder began purchasing land to support the development of its municipal water utility. The first "Town Reservoir" was built on land purchased from John Brierley in 1875 and 1876[1] and was located "south of Red Rocks, about halfway between Farmers and Silver Lake Ditches[2]." Shortly thereafter in 1878, another purchase of land was made from John Ryan who owned the land "on which the reservoir is located." This purchase granted about 10 acres of land and rights-of-way for water mains and "supply and waste ditches"[3]. The supply from the Town Reservoir was not sufficient, however, and on June 20, 1878, the town Board resolved to build an additional reservoir for fire and domestic purposes[4]. Therefore, in 1890, Boulder acquired another site from John Brierley that was located just west of the town to build Sunshine Reservoir[5]. The city of Boulder also constructed a new intake from Boulder Creek just upstream of the confluence with Four Mile Creek called the Blanchard intake[6]. In 1904, Boulder made the first purchases of land along the upper reaches of North Boulder Creek near the Continental Divide in what would become the city-owned Silver Lake Watershed. In the 1950's, the city sought to expand its ability to provide water supplies in drought years by joining NCWCD and purchasing land to construct Boulder Reservoir. The Park Reservoir dam site was purchased in the 1960's. Later, the city purchased the Wittemyer Ponds in order to increase Boulder's ability to reuse the limited amount of fully-consumable water available to the city. In 2001, Barker Reservoir was acquired to increase the city's water yield from its existing water rights and to provide the city more flexibility in managing its Middle Boulder Creek water supply. The city purchased certain lands in Caribou Ranch to protect water quality along North Boulder Creek and to better manage and maintain some of the North Boulder Creek water facilities. The city's water utility now manages over 7,000 acres of land at locations ranging from the Continental Divide west of Boulder to the eastern Boulder County line.

4.1.1 | SILVER LAKE WATERSHED

The Silver Lake Watershed is located on the eastern slope of the Continental Divide north of Nederland at the headwaters of North Boulder Creek. Beginning in 1904, the city purchased land, reservoirs and water rights in the area that would later become the Silver Lake Watershed (Figure 4-1). The first land acquisition included the Triple Lakes and Oval Lake, which would later be raised with a dam to become Goose Lake[7]. In 1906, the city purchased Silver Lake, Island Lake, and Albion Lake Reservoirs[8] (see section 3.2.2.3).

FIGURE 4-1. LAND ACQUISITIONS IN THE SILVER LAKE WATERSHED



Following the city's initial acquisitions of land within the Silver Lake Watershed, the U.S. Congress granted the city the right to purchase additional lands within the Silver Lake Watershed pursuant to three Congressional Acts in 1907, 1919, and 1927. The 1907 Act granted 1,557 acres to the city[9], the 1919 Act granted 400 acres[10,] and the 1927 Act granted 3,689 acres[11], all for the price of $1.25 per acre. These grants were made to the city for the specific purposes of water storage, supply of its waterworks, and protection of its water supply from pollution (see section 3.2.2.6). The associated grants dated June 15, 1908, June 18, 1920, and July 23, 1929 expressly recognized the purposes of water supply and storage and included within the grant to the city "all the rights, privileges, immunities and appurtenances of whatsoever nature thereunto belonging, unto the said City of Boulder, and to its successors, forever"[12]. The U.S. Congress retained no federal discretionary authority over the city's operation of the watershed grants for these water supply purposes. The grants were qualified only in terms of a reversion to the United States if the grants were not used for the specified purposes and by reservations for certain preexisting claims and timber and mineral rights. Congress rejected the Department of Agriculture's position at the time that these federal grants of vested property rights were unnecessary because the city could obtain subsequent authorizations from the agency for water projects.

Over time, the city acquired additional smaller parcels of land within the Silver Lake Watershed from other entities. The total amount of land now held in the Silver Lake Watershed is approximately 6,500 acres.

4.1.2 | PARK RESERVOIR DAM SITE

The Park Reservoir dam site is located on Caribou Creek (*i.e.*, the south branch of the south fork of North Boulder Creek) approximately three and one half miles upstream of Lakewood Reservoir and just west of Caribou Ranch (Figure 3-3). Construction of a dam was first attempted by the private owners of the site prior to 1909. The dam was washed out by a flood and the private owners never completed the dam[13]. Dam reconstruction was proposed by the property owners in the 1960's, but no construction ensued. Instead, the property owners and the city began discussions of the potential for the city to use the site for a municipal water supply reservoir that would provide additional drought protection for the city. In 1970, the city purchased the Park Reservoir site through a condemnation of 120 acres of property for a price of $250,900[14].

In 1971, the city developed plans for a new dam that would impound 8,220 acre-feet and have a surface area of180 acres. The city owns 54 percent and the U.S. Forest Service (USFS) owns the remaining 46 percent of the 180 acres that would be inundated by the proposed dam[15]. Therefore, the city would likely need to obtain land use authorization from the Forest Service prior to construction of a dam with the same configuration as the 1971 proposed dam. However, a lower dam, a series of dams, or a dam further to the east of the old dam site could be constructed that might not raise water levels sufficiently to cover USFS land.

4.1.3 | LAKEWOOD RESERVOIR SITE AND LAKEWOOD HOUSE

Lakewood Reservoir is located on 20 acres of land north of Nederland and east of Caribou Ranch (Figure 3-3). The city purchased this land and constructed the reservoir in 1906[16]. In 1996, a land exchange was made as part of the Caribou Ranch agreements (see sections 3.4.9.7 and 4.1.4) that cleared up areas where the property boundaries did not align with facilities locations. The Lakewood

Reservoir property is also the site of the Silver Lake Hydroelectric Project and the Water Resources Facilities Manager's residence with garages and outbuildings. The residence was originally constructed in the 1950s and was renovated in 1996. Silver Lake Hydro was completed in 1998[17].

4.1.4 | CARIBOU RANCH

The city entered into several agreements with James Guercio, the owner of Caribou Ranch, and Boulder County in 1996 (Caribou 1) and in 2001 (Caribou 2) through which the city and Boulder County jointly purchased 2,181 acres of Caribou Ranch and associated water rights (see section 3.4.9.7 for details of the agreements). The city sold most of the property to Boulder County and received a conservation easement across the property. A map of Caribou Ranch properties is show in Figure 3-3. A summary of the outcomes of the Caribou Ranch agreements is below[i].

Boulder County

- acquired fee title to approximately 2,154 acres of the original 2,181 acres purchased and water rights for irrigation of the property;
- received a conservation easement across the 27-acre, 120-foot-wide Silver Lake Pipeline corridor parcel that crosses the County's purchased Caribou Ranch acreage;
- owns 50 percent interest in the mineral rights on the 2,181 acres purchased;
- jointly acquired with the city 1,517 acres of conservation easement across Caribou Ranch property retained by Guercio;
- purchased a 50 percent interest in the old Beech Aircraft site;
- received a conservation easement across Wittemyer Ponds property; and
- acts as land manager for the purchased Caribou Ranch property and is required to manage the land in a manner that protects water quality for the city's municipal system.

City of Boulder Utilities Division

- acquired fee title to a 27-acre, 120-foot-wide Silver Lake Pipeline corridor parcel that crosses the County's purchased Caribou Ranch acreage;
- received a conservation easement across 2,154 acres of the original 2,181 acres purchased;
- owns a 50 percent interest in the mineral rights on the 2,181 acres purchased;
- jointly acquired with the County 1,517 acres of conservation easement across Caribou Ranch property retained by Guercio;
- acquired a perpetual easement across land retained by Guercio for activities related to Silver Lake Pipeline, Lakewood Pipeline, diversion facilities, and related water utility facilities;
- traded land with Guercio to acquire fee title to property adjacent to Lakewood Reservoir;

[i] The Appendices contain the following documents associated with the Caribou Ranch property transaction: Caribou Ranch 1 and 2 property transaction, conservation easement and water rights agreements; summary of property closings between city, Boulder County and Guercio; documents pertaining to transactions solely between city and Guercio such as use of city water by Guercio, city lease of Jasper Reservoir water from Guercio, city-Guercio exchange of property adjacent to Lakewood Reservoir, and pipeline easements.

- acquired interests in water rights Guercio had initiated to develop hydropower on North Boulder Creek, Caribou Creek and on the city's Silver Lake Pipeline. The city subsequently officially abandoned the rights, and;
- retained the right to develop the Wittemyer Ponds property as a water storage facility.

James Guercio

- retained fee title to approximately 1,159 acres of Caribou Ranch and water rights for irrigation and ponds;
- agreed to limit development of a retained parcel of land (Caribou City) to 23 dwelling units plus a fishing lodge and horse barn;
- can request delivery of up to 170 acre-feet of water per year from city water supply for purposes of irrigation of certain meadow areas except in periods of severe drought;
- can request delivery of up to 5 acre-feet of water per year from the city for augmentation of uses associated with Guercio's property except in periods of severe drought, and;
- through 2021, the city will lease from Guercio any Jasper Reservoir water offered by Guercio each year at the city's CBT lease rate.

City of Boulder Open Space and Mountain Parks Department

- purchased a 50 percent interest in the old Beech Aircraft site.

4.1.5 | BARKER SYSTEM

Barker Meadow Reservoir (Barker Reservoir) is located on Middle Boulder Creek just east of the Town of Nederland in Boulder County. In 1907, the Eastern Colorado Power Company purchased property for a dam and reservoir site from Hannah Barker. The acquisition was made through a condemnation, as Hannah Barker refused to sell her ranch holdings[18]. In the summer of 1908, the Central Colorado Power Company (formerly Eastern Colorado Power Company) began construction of Barker Dam and the Boulder Canyon Hydroelectric Plant for the purpose of providing electricity to thriving mining camps and the booming city of Denver. The Boulder Canyon Hydroelectric Project (Barker System), which includes Barker Reservoir, Barker Dam, the Barker Gravity Pipeline, Kossler Reservoir, Boulder Canyon Penstock and the Boulder Canyon Hydroelectric Plant, was completed in 1910[19].

One of the findings of the 1988 Raw Water Master Plan (RWMP)[20] was that staff should attempt to reconfigure the city's water portfolio through the sale of Windy Gap water and its replacement with water supplies and assets in the Boulder Creek basin that would be capable of multiple uses and would enhance the yield of existing systems. The city pursued this goal through the sale of 43 of its original 80 units in the Windy Gap Project to the city of Broomfield in 1991[21]. The city used some of the proceeds from the sale to purchase the Barker System from Public Service Company of Colorado (PSCo, now Xcel Energy), a successor of Central Colorado Power Company.

The city acquired the Barker System, associated water rights, easements, and rights-of-way on March 7, 2001 for a price of $12.4 million[ii]. The purchase included land encompassing Barker Reservoir, Kossler Reservoir, the Boulder Canyon Penstock, and the Boulder Canyon Hydro plant site. The Barker Gravity Pipeline is on easements, either deeded or prescriptive, and on land designated as a Power Withdrawal across USFS lands.

Along with the Barker System, the city acquired decades of records from PSCo. Most of those records have been catalogued and scanned. Hard copies of the records are stored at Betasso Hydro or in the Park Central 2nd Floor library. Examples of these records include inspection reports, operation reports, and construction reports[iii].

4.1.6 | WATER SOURCE OPERATIONS MANAGER'S HOUSE

The city purchased a 1.28-acre lot and single family residence in St. Anton Highlands in 2002 as a residence for the Water Source Operations Manager[22]. This position was added as a result of the purchase of the Barker System in 2001. In keeping with the practices of other owners of large reservoirs in the state of Colorado, the city determined it prudent to have personnel located in the immediate vicinity of the Barker/Boulder Canyon facilities for quick response to any need both day and night. The residence was originally constructed in 1996 and a garage/office was added in 2000.

4.1.7 | BETASSO WATER TREATMENT FACILITY SITE AND BETASSO PENSTOCK CORRIDOR

On April 4, 1961, voters of Boulder approved a bond issue to finance an increased water supply program for the city[23]. The Betasso Water Treatment Facility (WTF) and Betasso Penstock were constructed in 1964 to add Middle Boulder Creek water, through use of PSCo's facilities, to Boulder's water supply[24]. The treatment facility and Betasso Penstock are located on 80 acres purchased from Ella Rhea Newsome on March 23, 1862[25].

4.1.8 | ORODELL HYDRO PLANT SITE (BLANCHARD INTAKE)

Mine tailings were a perennial problem for Boulder's early water system. Therefore, in 1890, City Council agreed to enlarge and improve Boulder's water works. This decision included moving Boulder's intake further upstream on Boulder Creek, about a mile upstream of the confluence with Four Mile Creek, to a point known as the "Blanchard intake," also sometimes referred to as the "lower intake" [26] on the site of the Horseshoe Placer mining claim (see Figure 4-2). The town constructed a new diversion dam and headgate for the municipal water system[iv]. This site was later used for a surge chamber on the Boulder Canyon Pipeline, which has since been replaced with a pressure reducing valve and a hydro plant[27].

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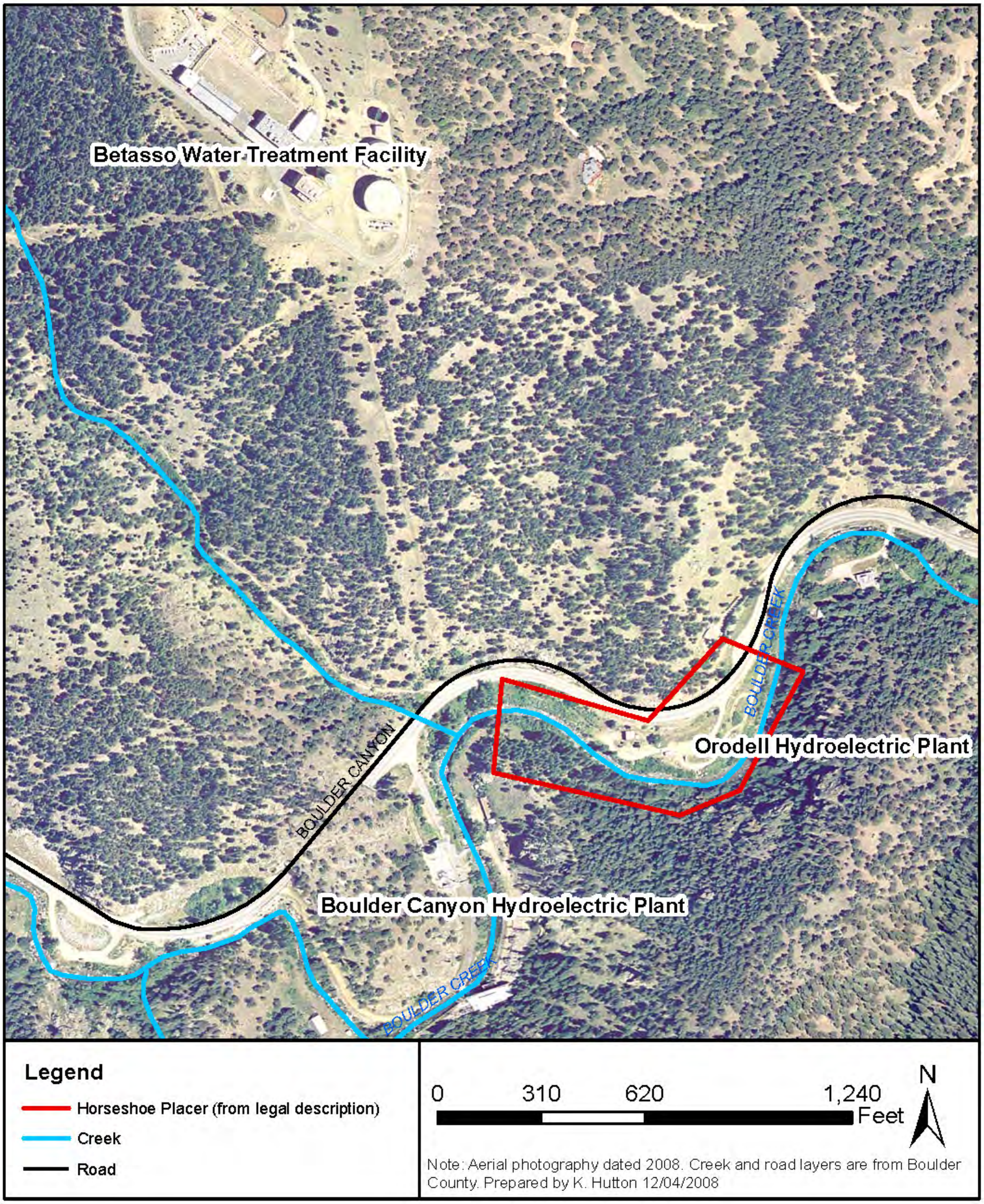
ii Purchase agreements between the city and PSCo and documents related to water rights, mineral rights, deeds, easement, and rights-of-way for the Barker System are included in the Appendices.

iii The file "Barker Folders" in the Appendices lists those records stored at Park Central.

iv Although there are multiple documents that support the fact that the city did indeed construct and use the Blanchard intake at this site in 1890, it appears that the city did not purchase the land for the Horseshoe Placer until 1904 and 1952.

FIGURE 4-2. LOCATION OF HORSESHOE PLACER MINING CLAIM AND BLANCHARD INTAKE



4.1.9 | SUNSHINE RESERVOIR SITE

In 1890 the city proceeded with condemnation of land owned by John Brierley at the mouth of Sunshine Canyon to use as the site of a municipal reservoir to be known as Sunshine Reservoir[v] (Figure 4-3)[28]. Sunshine Reservoir went into service in 1891[29]. The reservoir was filled by a pipeline that diverted water from Boulder Creek at the Blanchard intake. It served the city's needs until Lakewood Reservoir and the Boulder City Pipeline were built to take water from North Boulder Creek in 1906[30]. At this point, the use of Sunshine Reservoir as an active part of the water supply system was abandoned. The Sunshine Pipeline from Betasso WTF into the city was constructed through the land in the 1960s when the land was still managed by Boulder's Utilities Division. When the city of Boulder Open Space Department was formed in the late 1970s, management of the land was transferred from the water utility to Open Space with the understanding that utilities' use of the land would continue and the water utility would continue to have full access to maintain its facilities[31]. Sunshine Hydro was built just southwest of the Sunshine Reservoir site in 1987 to parallel a pressure reducing valve[32]. The depression that was once actively operated as Sunshine Reservoir and the scar from the pipeline that ran into town are still visible. The Sunshine Reservoir depression can still capture water releases from Sunshine Pipeline and Sunshine Hydro if needed, such as during hydro capacity tests.

4.1.10 | BOULDER RESERVOIR LANDS

Boulder Reservoir is the terminal reservoir for the southern end of the CBT Project. The project was authorized in 1937[33] and constructed in the early 1950s[34]. Boulder's citizens voted to join the Northern Colorado Water Conservancy District (NCWCD) in June 1953 in order to increase its water supplies. As a condition of annexation to the NCWCD, Boulder constructed a new reservoir, which would become known as Boulder Reservoir, on the southern end of the CBT system[35]. For more information on Boulder's agreements with NCWCD, see section 3.4.9.2.

Several sites for the new reservoir were investigated before settling on a site at Big Dry Creek northeast of Boulder. Water utility revenue bonds were issued to provide $1.2 million for purchase of the necessary land and for construction of the dams. The city purchased the majority of the land comprising the Boulder Reservoir area between 1954 and 1956. Land for the Boulder Reservoir WTF was acquired with water utility revenues in 1970[vi][36]. A map of land ownership in the Boulder Reservoir area is shown in Figure 4-4.

Although most of the land at Boulder Reservoir is held by the city through its water utility enterprise fund, the city owns several properties adjacent to Boulder Reservoir that were purchased with general fund monies for parks and recreation purposes[vii]. The Pauline Axelson property (71 acres located northwest of the reservoir) was acquired between 1971 and 1974 through funding provided by the Parks and Recreation Department and the Bureau of Outdoor Recreation. In 1983, the Kane property (5 acres located north of the reservoir) was acquired with funds from the Parks and Recreation Department and Utilities Division.

[v] Incidentally, the city had previously bought land from the same John Brierly 15 years earlier to construct the first "Town Reservoir." Although these parcels of land are located close to one another, they were separate land purchases to build separate reservoirs, "Town Resevoir," and "Sunshine Reservoir."

[vi] A complete documentation of Boulder Reservoir land purchases is included in the Appendices.

[vii] Deed and parcel information for the Boulder Reservoir area is included in the Appendices.

FIGURE 4-3. LOCATION OF HISTORIC TOWN AND SUNSHINE RESERVOIRS

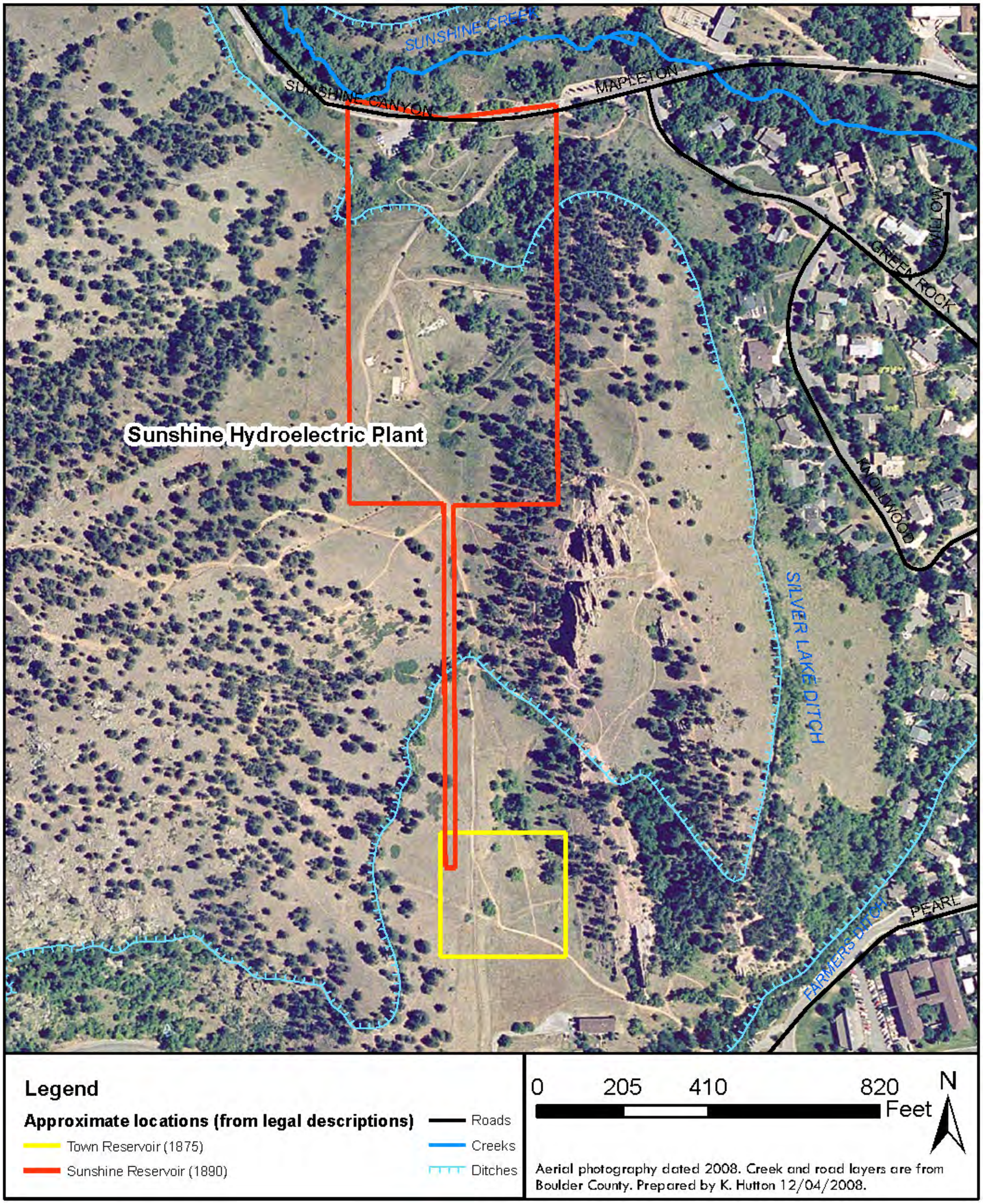
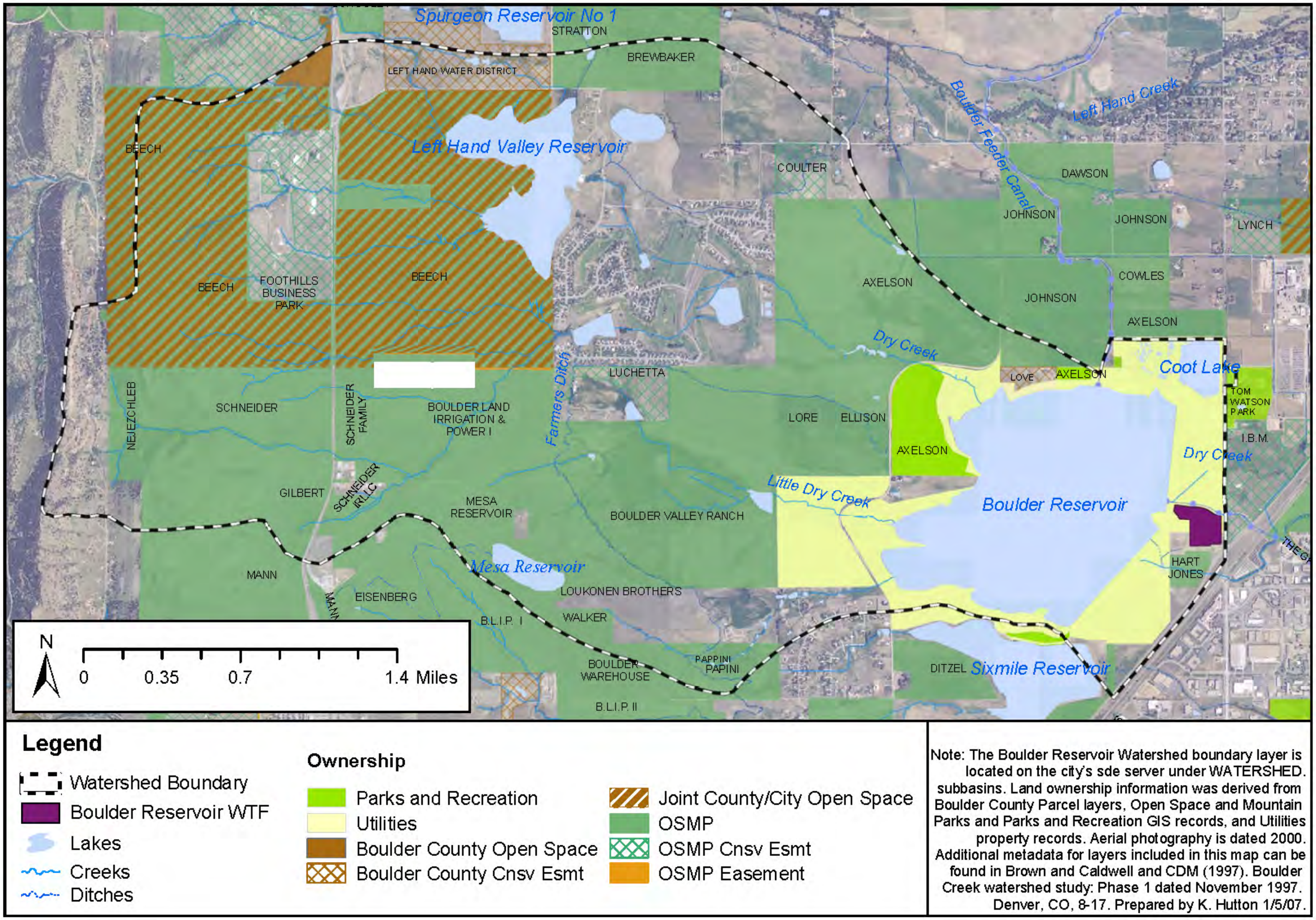


FIGURE 4-4. BOULDER RESERVOIR LAND OWNERSHIP



NCWCD operates and maintains the Boulder Reservoir dams and water conveyance facilities[37]. The city, through its water utility, has the overriding management role in coordinating activities between NCWCD, city Utilities staff, and city Parks and Recreation staff. In addition, the water utility is responsible for ordering the city's deliveries of water from NCWCD to be used directly at the Boulder Reservoir WTF, to be delivered to Boulder Creek for exchange to the city's upper Boulder Creek intakes or to be stored in Boulder Reservoir in the city's designated storage space. The water utility is also responsible for protecting water quality for municipal purposes. The Parks and Recreation Department is the management entity for the recreation facilities, wildlife, weed and pest control, and certain fencing[38]. This department also monitors water quality in the reservoir for management of recreational activities such as the swim beach.

4.1.11 | WITTEMYER PONDS

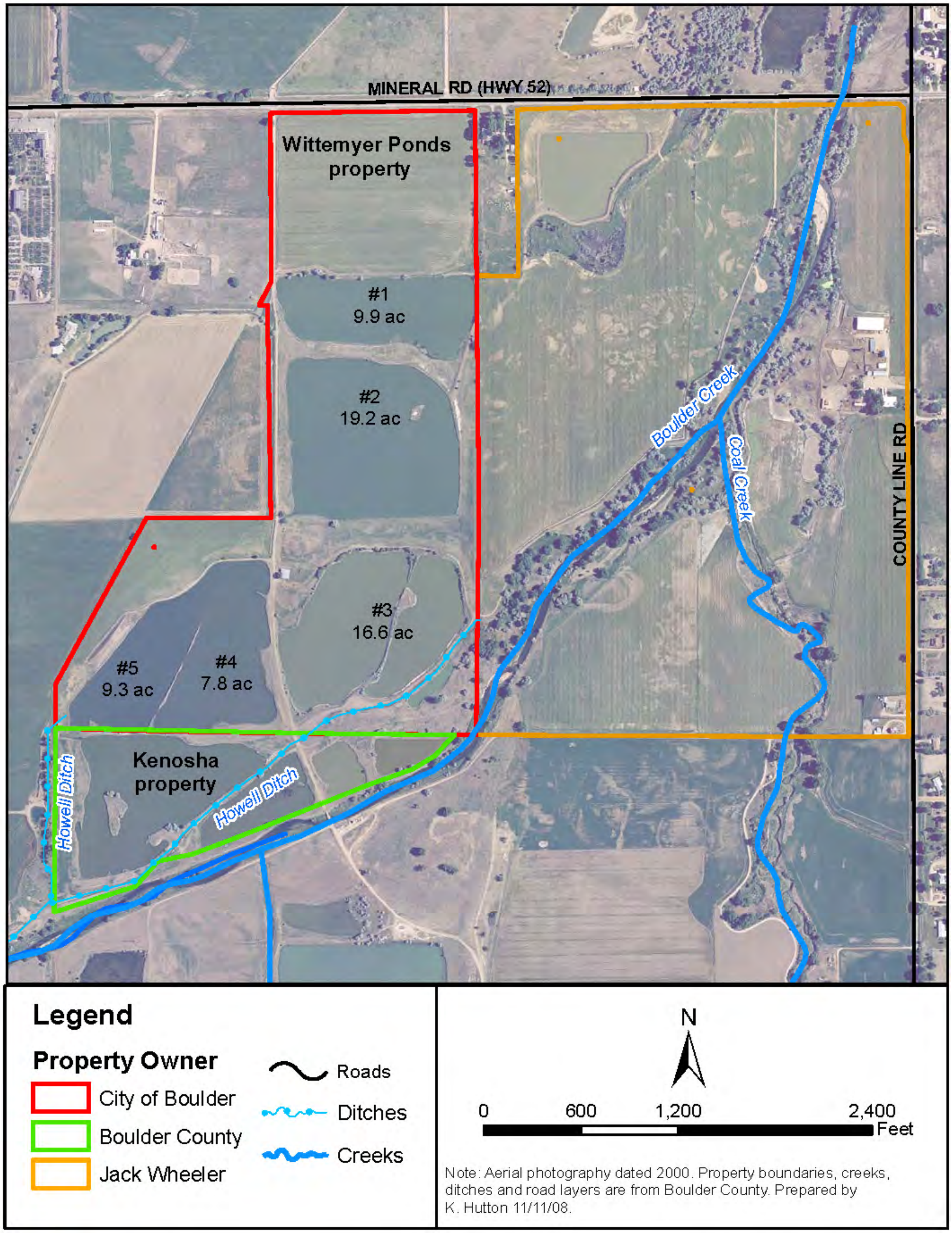
In 1986, the Public Works Department purchased 159 acres known as the Wittemyer Ponds property including mineral rights and water rights for $380,000[39]. The Wittemyer Ponds property lies south of Highway 52 (also known as Mineral Rd.), north of Boulder Creek, west of the Boulder/Weld County Line road and east of 115th St (Figure 4-5).

Prior to acquisition by the city, 68 acres of the property had been mined for gravel. The gravel pits have since filled with groundwater, creating a series of five ponds on the property. The gravel mining occurred prior to 1980, so the ponds are considered to be "grandfathered" under Colorado statutes and are exempt from requirements to replace losses to Boulder Creek from surface evaporation of the exposed groundwater[40].

The city purchased the Wittemyer Ponds property with the intention of lining the gravel pits and using them to store reusable water for later exchange into the city system or lease to downstream water users. The pits will need extensive work before they can be lined and used for water storage.

Through an arrangement formalized in the 1996 Caribou Ranch property transaction and a conservation easement, Boulder County manages the Wittemyer Ponds property for the city in a manner that does not interfere with the use of the property for water utility purposes[41]. The city granted Boulder County a conservation easement over the property. The conservation easement establishes that the Wittemyer Ponds property shall be used in perpetuity for city water utility purposes. No other development may occur on the property except that the conservation easement will expire, and the city may sell the property for development if the County denies the city the necessary authorizations for improvements to the ponds needed for water utility use.

FIGURE 4-5. WITTEMYER PONDS PROPERTY



4.2 | Municipal Water Supply Infrastructure

Boulder's water supply system includes many storage, conveyance, hydroelectric and treatment facilities. The city owns approximately 7,200 acre-feet[viii] of reservoir storage space in the North Boulder Creek (Silver Lake) watershed, which supplies on average 35 percent of the city's water. Barker Reservoir on Middle Boulder Creek provides 11,700 acre-feet of storage space and supplies another 35 percent, on average, of the city's water. Boulder Reservoir has up to 8,500 acre-feet of storage space to store water supplied through the CBT Project, which has several large reservoirs of its own.

Boulder's two water treatment facilities are the Betasso WTF with approximately 45 million gallons per day (MGD) of treatment capacity and the Boulder Reservoir WTF at about 16 MGD. The city operates eight hydroelectric plants located within the municipal water supply system and sells the electricity to Xcel Energy. Four of these hydro plants are located on raw water pipelines and four are on treated water transmission pipelines. The infrastructure associated with each of the three water sources is discussed below. Additionally, summaries of dam and reservoir information, pipeline information, and hydroelectric facilities information can be found in Table 4-2, Table 4-3 and Table 4-4, respectively. A map of Boulder's water supply system is shown in Figure 4-6.

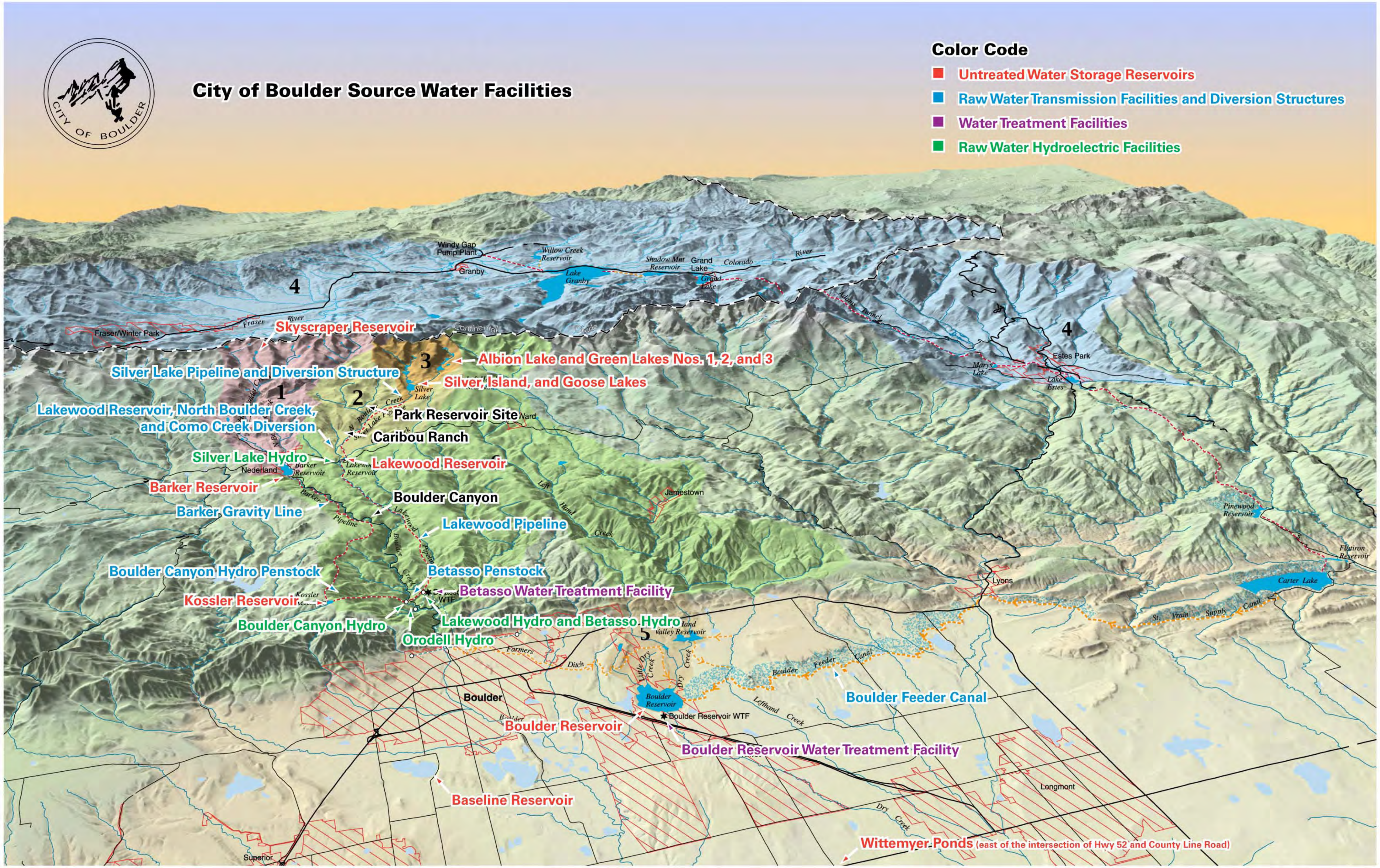
4.2.1 | NORTH BOULDER CREEK WATER FACILITIES

The Silver Lake Watershed contains 13 reservoirs and natural lakes that are fed by annual snowmelt. Only a fraction of a percent of water is contributed by melting of the Arapaho Glacier (personal communication, Nel Cain, 2008). This high-quality water source was sufficient to meet all of Boulder's water needs until the 1950s. Facilities associated with the North Boulder Creek water source are listed in sequence from the Silver Lake Watershed lakes and reservoirs to Betasso WTF below.

The water from the upper Silver Lake Watershed reservoirs is delivered into Silver Lake. From there, water can be released for delivery through Silver Lake Pipeline and Lakewood Pipeline to Betasso WTF. Additional direct flow diversions from North Boulder Creek and Como Creek can be made into Lakewood Pipeline at a small regulating reservoir known as Lakewood Reservoir outside of Nederland.

[viii] An acre-foot of water could meet the water needs of about three typical Boulder households for a year.

FIGURE 4-6. MAP OF BOULDER'S WATER SUPPLY SYSTEM[42]



4.2.1.1 | GREEN LAKES

Green Lakes #1, 2, 3, 4, and 5[ix] were purchased by the city in 1935[43]. A private developer had constructed dams at Green Lakes #1, 2 and 3 from 1902 to 1906 to raise the natural lake levels. The Green Lakes, along with Albion Lake, occupy the northern valley of the Silver Lake Watershed. This drainage is called both the North Fork of North Boulder Creek and Albion Creek.

Green Lake #1 is the city's smallest Silver Lake Watershed reservoir with a current maximum operating capacity (amount above dead storage pool) of about 92 acre-feet. It has a decreed water right based on an original volume of 175 acre-feet. Current normal operating capacity is 88 acre-feet. Surface area is approximately 11 acres. Green Lake #1 is classified as a low-hazard dam.

Green Lake #1 Dam is a rock-fill embankment with 25-foot-high steel facing (Figure 4-7). The dam is 217 feet long, with a 9-foot crest width. The upstream face consists of hand-placed rip-rap. There is no spillway.

The outlet works consist of a 12-inch pipe with control valve and operator that discharges to a natural drainage, then to Albion Lake. The outlet works are located 100 feet to the right of the left abutment. The inlet is a low-level conduit with control valves. There is no trash rack at the inlet[44].

FIGURE 4-7. GREEN LAKE #1[45]

[ix] Smith, P. (1986). *A history of water works of Boulder Colorado*. Boulder: City of Boulder Public Works Department is wrong on the dates of the Green Lakes No. 5 purchase. The original deeds show that all of the Green Lakes were purchased in 1935 and none in 1937.

Green Lake #2 has a design capacity of 333 acre-feet and at its full volume the reservoir surface area is about 17 acres[46]. Due to concerns about the condition of the Green Lake #2 dam, the reservoir level was lowered on October 4, 1985[47]. The reservoir is not currently in active service pending repairs to the dam, and therefore, the current active capacity is 0 acre-feet.
Green Lake #2 Dam is a rock-fill and earth-fill dam with steel facing. It has a 40-foot ogee spillway. The dam was rebuilt by the Works Progress Administration (WPA) from 1941 to1944. This effort resulted in a 220-foot long dam[48].

Green Lake #3 is created by a 290-foot-long, 30-foot high rock-fill embankment with an upstream steel face. Its design capacity is 360 acre-feet, with an active operating capacity (amount above dead storage pool) of 285 acre-feet[49].

The dam was constructed in 1906. In 1939, the WPA constructed a 35- to40-foot high steel facing for the dam. In 1956 and 1960, repairs to the upstream dam face, including the installation of expansion joints and splash plates on the dam facing, were completed[50].

The crest width of the dam is 5 feet. Steel splash plates extend from the top of the steel facing about 2 feet above the embankment crest.

The spillway is a rectangular, sharp-crested weir with a 12-foot crest length at the right abutment. The spillway depth is 1.3 feet. The spillway discharges to a steep channel downstream of the dam. The weir is a metal plate embedded in the concrete floor and abutments of the spillway.

The outlet works are located in a vault excavated into bedrock approximately 50 feet downstream of the dam crest. The outlet consists of an 18-inch steel pipe which empties into a 4-foot diameter rock tunnel. The control valve for the outlet is located in the vault. Discharges are made approximately 100 feet downstream of the dam[51].

Green Lakes #4 and #5 are natural impoundments with decreed volumes of 116.1 and 73.8 acre-feet, respectively. Their surface areas are 13 and 7 acres, respectively[52].

4.2.1.2 | ALBION LAKE

The reservoir at Albion Lake is formed by a 506-foot long concrete dam that is approximately 39 feet high at its maximum section. The dam is curved and has a crest width of 14 feet. The dam was placed at the outlet to a natural lake and was originally designed to have a maximum section height of approximately 60 feet. The city ran out of money during the original construction and the dam was never completed above a height of 39-feet. The dam is classified as a moderate hazard structure, primarily because of the large sudden inflow to Silver Lake that would result from failure of the Albion Lake dam.

Albion Lake has a capacity of 1,111 acre-feet and drains an area of about 2 square miles[53]. A portion of the Albion Lake area was part of the 1907 watershed grant to the city[54]. Additionally, James Maxwell deeded all "right, title, and interest" in Albion Lake to the city in 1906[55]. The last remaining mining claims in the area were purchased by the city in 1970[56].

Although there is some discrepancy in the construction history, it appears the original construction of Albion dam was begun by the city in 1910[57]. Claire Victor Mann, an assistant city engineer, supervised development of a permanent construction camp and construction of the dam. In the years following 1910, steam powered tramways were built to transport construction materials along cables, thereby avoiding 2,000 feet of steep road[58]. Mine dump and mill tailings from the Cashier Mine and Milling Company's Snowy Range Tunnel and Albion Mill were used as material for the dam[59]. Construction of Albion Dam is estimated to have been completed in 1915[60].

A crest repair was made in 1938[61]. In 1978, epoxy was applied to cracks in the upstream face of the dam, which eliminated much of the leakage occurring at that time.

Flood releases are made through the rectangular, broad-crested weir spillway located 96 feet south of the left dam abutment. The spillway is 28 feet wide and the weir section of the spillway is 3.6 feet deep and 34 feet long. Spillway capacity is 500 cubic feet per second (cfs). The spillway discharges to a steep cobble- and boulder-lined channel[62].

Normal releases are made through two 24-inch diameter pipes comprising the outlet works. During 1987, the existing outlet works were demolished and replaced with a modern structure containing four 24-inch diameter gate valves. Two valves were mounted on each line for control and guard valve purposes respectively. The new structure replacement project was completed at a cost of $262,000. The new outlet works solved operational and safety problems associated with the old structure and valves. A 1988 study determined that the spillway is inadequate to pass the Probable Maximum Flood (PMF) outflow of 3,370 cfs but that the dam could safely be allowed to overtop. The PMF would overtop the dam by 1.5 feet for 7 hours. The existing dam is acceptably stable at its present height[63].

4.2.1.3 | GOOSE LAKE

Goose Lake is located in the southern valley of the Silver Lake Watershed. Goose Lake has a surface area of approximately 34 acres. It has a decreed storage of 1036 acre-feet and an active storage (amount above dead storage pool) of 900 acre-feet. Its drainage area is approximately 4 square miles.

Goose Lake Dam is a 385-foot long, rock-fill dam with a timber-crib core, a concrete upstream facing, and a roller-compacted concrete downstream face. The crest width is 20 feet. At its maximum section, the dam is approximately 35 feet high. Goose Lake Dam is classified as a moderate hazard dam[64].

Goose Lake was created at the site of a natural lake called Oval Lake. A small, eight-foot high dam was originally constructed at Oval Lake to raise the natural lake level and create Goose Lake. Construction of the original dam at Oval Lake began on October 1, 1901 and impounded 198.5 acre-feet[65]. Following the city's purchase of the land and reservoir from Clint J. Maxwell[x] in 1904[66], the city began improvements to Goose Lake by extending the road from Silver Lake to Goose Lake. Once the road was completed in 1905, John Teagarden started actual construction on Goose Lake Dam by cleaning gravel and rock debris from the stream outlet. Construction continued in 1906 under the direct supervision of Fred Fair and raised the dam to a height of 30 feet[67]. A toe trench for the dam, measuring twenty-four inches deep by thirty inches wide, was cut into solid bedrock and filled with concrete. Timber cribbing was placed on top with cross ties every ten feet. The cribs were then

[x] Both the Findings and Decree and the Warranty Deed cite Clint J. Maxwell as the seller of Goose Lake and associated lands. City Council minutes recorded by Fred Fair refer to the seller as James Maxwell.

filled with broken stone. When the dam was partially completed to a height of 16 feet, it caught on fire and all of the timber cross ties in the lower eight feet of the dam were destroyed[68].

In 1925, the dam was enlarged through the addition of a concrete facing on the lower 13 feet of the upstream dam face and placement of rock fill on the downstream face[69]. The WPA made repairs to Goose Lake Dam in 1935. In 1952, a 5-inch layer of reinforced gunite was applied to the upper part of the upstream face of the dam.

In 1983, a portion of the dam was to be repaired by shotcreting. In preparation for the work, the contractor removed and burned several piles of rotten timber sheathing. Wind spread the fire to the exposed timber cribbing of the dam, and the dam was damaged for its entire length along the upper portion. In 1984, the damage was repaired with welded wire fabric tied to the 1952 gunite and to the welded wire fabric reinforcement of a new splash wall. Deadman anchors were placed in the rock fill to help tie the welded wire fabric to the dam and stabilize the 6-inch shotcrete layer that was placed on a 10- by 385-foot section of the dam[70].

In 1989, repairs were made to the outlet works, a new outlet house was constructed, and repairs were made to the spillway. Also in 1989, in order to increase the ability of the dam to pass the PMF, the downstream face was covered with roller-compacted concrete[71]. Seepage continued, however, and the upstream gunite face began crumbling and failing. In 1999, a geo-membrane was attached to the upstream face and covered by a zoned earthfill and rockfill slope significantly altering the upstream face. Seepage was reduced considerably[72].

Spillway channels are located at each abutment. The left abutment and right abutment spillway crest elevations are approximately 2.9 and 5.1 feet, respectively, below the top of the splash wall located on the crest of the dam. The left (auxiliary) spillway is controlled by a concrete overflow wall while the right (main) spillway is a 35-foot wide channel cut through natural rock. The peak PMF discharge at Goose Lake Dam is estimated to be 6,750 cfs, while the spillway capacity is 750 cfs. Goose Lake Dam can be overtopped to safely pass the design flood[73].

4.2.1.4 | ISLAND LAKE

Island Lake is located in the southern valley of the Silver Lake Watershed immediately above Silver Lake. Island Lake Dam is a 747-foot-long concrete buttress (upstream face) and rockfill (downstream face) structure that was constructed in three sections separated by rock outcrops.

The main section of the dam is 619 feet long and contains the main spillway and outlet works. The main spillway is located 170 feet to the left of the right abutment of the main dam and consists of a 28-foot wide, boulder-covered chute in the concrete buttress with wing walls on either side. The auxiliary spillway is the middle portion of the dam and is 107 feet long, with a crest elevation 0.9 feet lower than the main dam. The south section of the dam is 21 feet long. The concrete buttress varies between 1.5 and 2 feet thick, and the rock fill has a crest width of about 10 feet. Spalled concrete was repaired in 1979 and 1980, and the crest width was increased from 1.5 to 2 feet on the downstream face of the dam. A skim coat of mortar was also applied over the dam crest.

There are two separate outlets in the main dam located on either side of the main spillway. The north outlet is a 24-inch steel pipe, and the south outlet is a 12-inch steel pipe. Both are located in valve vaults that are part of the concrete buttress. The inlets are located on the upstream face of the dam and consist of concrete boxes covered by trash racks[74].

The original dam was built by J. P. Maxwell and George Oliver for the Silver Lake Ditch Company in 1890[75]. The city bought the reservoir in 1906 and enlarged it at that time[76]. According to an article written by the WPA for the Daily Camera newspaper, WPA workers reconstructed Island Lake Dam with concrete between 1936 and 1937[77]. In 1957, it was proposed that the city could buy western slope water and create a trans-basin diversion, but the proposal was deemed too expensive[78].

Island Lake is decreed for 372 acre-feet and has a current operating capacity (amount above dead storage pool) of 333 acre-feet. It is classified as a low-hazard dam. It has a surface area of 33 acres and is about 14 feet deep[79].

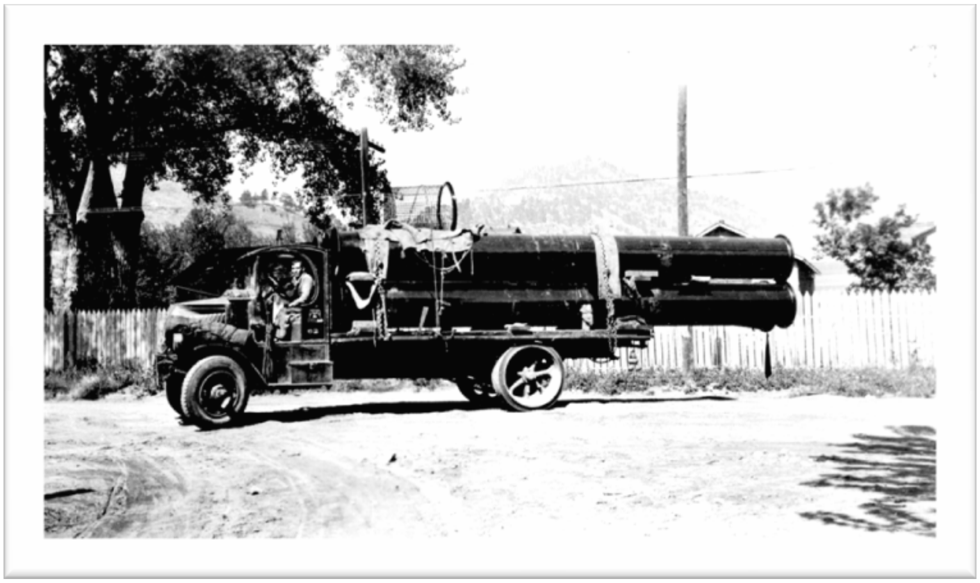
4.2.1.5 | SILVER LAKE

Silver Lake is located in the southern valley of the Silver Lake Watershed and is the lowest lake in the watershed (Figure 4-8). Silver Lake receives water from both the north and south watershed valleys and discharges to North Boulder Creek[80]. The decreed capacity is 4,150 acre-feet[81] and the current operating capacity (amount above dead storage pool) of Silver Lake is 3,996 acre-feet (personal communication, Craig Skeie [City of Boulder Water Resources], 2008). Silver Lake's surface area is approximately 104 acres[82].

FIGURE 4-8. SILVER LAKE RESERVOIR[83]

Silver Lake is formed by a 1,450-foot long earth fill embankment which is approximately 70 feet high at its maximum section. The dam was originally constructed by J. P. Maxwell for the Silver Lake Ditch Company in 1887 as a timber crib, rock fill dam[84]. The city acquired the reservoir in 1906[85] and did some repair work at that time. The dam was damaged by fire in 1910 and City Council authorized repairs[86]. The outlet through the existing dam was lowered with construction of a siphon structure in 1929. The new pipe, shown in Figure 4-9, extending through the dam allowed the city to gain access to more water in the reservoir[87]. In 1940, the original rockfill timber crib structure was replaced by an earthen embankment[88].

FIGURE 4-9. 1929 SILVER LAKE OUTLET PIPE[89]



The dam was enlarged in 1956 and 1966. The design crest width is 20 feet. The impervious core of the dam is composed of a dense, blue clay, glacial till. The pervious shell is silty, sandy glacial moraine. Silver Lake Dam is classified as a high-hazard dam.

The spillway is a vertical-faced ogee weir with a side discharge channel cut into the right abutment of the dam. It is about 8.5 feet below the dam crest. The crest of the weir is 80 feet long, and the concrete weir wall is anchored in bedrock. The discharge channel is reinforced concrete for 130 feet, then bedrock- and riprap-lined for 200 feet[90]. The 1988 PMF study identified the maximum discharge at Silver Lake Dam to be 10,800 cfs, while spillway capacity is 6,350 cfs[91].

Releases are made through the outlet works which pass through the dam. The outlet works consist of a trash rack-protected intake; a 470-foot-long, 48-inch inside diameter reinforced concrete conduit leading to the control valves located in a shaft beneath the crest of the dam; and a discharge pipeline which conveys releases to an outlet structure located at an earth-cut, rip-rapped channel downstream of the dam. A 36-inch steel pipe has been placed inside the concrete conduit. The conduit bifurcates in the valve house, and each branch has two 24-inch control valves in tandem. There is also a 12-inch bypass pipe with two valves in tandem. The outlet works were installed in 1956 and raised and extended in 1966.

In 1977, a number of piezometers and settlement monuments were installed after a slough developed to the left of the left wall of the spillway along the downstream toe of the dam. A perforated pipe toe drain was installed in 1978[92].

Inspection in 2002 revealed that the valve chamber was flooded with about five feet of water to just below the bottom of the grating above the valves. A second small diameter (approximately 1-inch) piping system was discovered that is probably being used as a venture draining system to keep the water level in the valve chamber from rising to the phreatic water surface in the dam. It was also determined that the steel transition pipes upstream of the 24-inch guard valve and downstream of the 24-inch control valves were significantly corroded and might need replacements. Valve replacement was recommended by the consulting engineer[93].

4.2.1.6 | SILVER LAKE DIVERSION STRUCTURE

The North Boulder Creek diversion into Silver Lake Pipeline was reconstructed in 1995 to incorporate instream flow measurement and discharge facilities into the structure for compliance with the North Boulder Creek instream flow program. As a part of the construction, the old regulating structure and Parshall flume were removed and disposed of. The need for diversion structure reconstruction was accelerated by extensive flood damage to the previously existing structure that occurred during the high runoff in the spring of 1995.

The new structure was built to withstand the 100-year flood. The new structure is reinforced concrete with a prefabricated steel Parshall flume. A PVC stilling well and plastic coated steel conduit contain the flow monitoring equipment. The new diversion structure is configured differently than the previous one but has essentially the same footprint. There was no enlargement of capacity. The new instream flow measuring components provide accurate scientific measurement of low flows up to 10 cfs and discharge into the stream. The Parshall flume ices up at times during the winter[94].

4.2.1.7 | SILVER LAKE PIPELINE

Silver Lake Pipeline was originally constructed of clay pipe in 1919. At that time it was known as the Boulder City Pipeline Extension. Some of the upper portions of the pipeline were replaced in the 1940s with pipe dating to 1906 salvaged from the Lakewood Pipeline replacement[95]. In 1997-1998, the city removed the existing line and replaced Silver Lake Pipeline with a fully-gravity-pressurized, welded steel, cement mortar-lined and tape-wrapped pipeline. The pipeline is 27 inches in diameter and has a nominal capacity of 20 MGD. The pipeline extends approximately 3.6 miles from the Silver Lake Diversion on North Boulder Creek (located about 2 miles below Silver Lake) to the Silver Lake Hydroelectric facility and Lakewood Reservoir. The pipeline carries both water released from Silver Lake and direct flow diversions from North Boulder Creek. The pipeline is buried to a depth of 4 feet to prevent freezing. The pipeline crosses city-owned land and lands under private and Boulder County ownership, over which the city holds a conservation easement[96].

During completion of the Silver Lake Hydroelectric facility, the Silver Lake Pipeline experienced a hydraulic transient (water hammer) event of sufficient magnitude to damage air valves along the line. The pipeline itself was undamaged[97].

4.2.1.8 | SILVER LAKE HYDRO

Information concerning the Silver Lake Hydroelectric Project is contained in Table 4-4 at the end of this section. Silver Lake Hydro is FERC Project P-11531 and received a conduit exemption from licensing on December 24, 1998[98].

The Silver Lake Hydro building was designed to blend with the local rural ranch architectural styles.

4.2.1.9 | NORTH BOULDER CREEK DIVERSION TO LAKEWOOD RESERVOIR

Like the Silver Lake diversion structure, the North Boulder Creek diversion into Lakewood Reservoir was reconstructed in 1995 to incorporate instream flow measurement and discharge facilities into the structure for compliance with the North Boulder Creek instream flow program[99]. As a part of the construction, the old regulating structure and Parshall flume were removed and disposed of. The need for diversion structure reconstruction was accelerated by flood damage to the previously existing structure that occurred during the high runoff in the spring of 1995.

The new structure was built to withstand the 100-year flood. The new structure is reinforced concrete with a prefabricated steel Parshall flume. A PVC stilling well and plastic coated steel conduit house the flow monitoring equipment. The new diversion structure is configured differently than the previous one but has essentially the same footprint. There was no enlargement of capacity.

During construction, it was discovered that the pipeline from the North Boulder Creek diversion structure to Lakewood Reservoir had been damaged. The pipeline was replaced with equivalent sized reinforced concrete pipe.

The new instream flow measuring components provide accurate scientific measurement of low flows between 2 and 10 cfs and discharge into the stream.

4.2.1.10 | COMO CREEK DIVERSION

The original Como Creek diversion structure, located on the southwest side of Lakewood Reservoir approximately 3 miles north of Nederland on Colorado Highway 72, was built in 1907. Como Creek was re-routed around Lakewood Reservoir to prevent discharge of water contaminated with mine tailings into the reservoir[100]. The diversion structure allowed selective diversion of Como Creek water at times that it was clear. In addition to allowing diversion of Como Creek water when desired, the structure carried water from the North Boulder Creek diversion structure into Lakewood Reservoir through a pipe culvert. By 1995, the diversion gates in the structure were no longer functioning and the entire structure was in danger of collapse. The structure consisted of two manually operated slide gates, a concrete weir across the creek, corrugated steel pipes and various other appurtenances. There was also a support structure that consisted of a concrete stilling basin, a metal Parshall flume, and an aerial crossing conduit on the west side of Como Creek immediately adjacent to the diversion structure.

Como Creek Diversion maintenance was included in the Lakewood Pipeline construction contract and was completed in 2002-2003[101]. As part of this contract, the original structures along with all of their appurtenances were removed and disposed of off-site.

The new Como Creek diversion structure is functionally similar to the original structure and has three distinct functions:

- to provide a method to divert and measure the flow from Como Creek before it is discharged into Lakewood Reservoir;
- to isolate Como Creek from Lakewood Reservoir at times of poor water quality in the creek, and;
- to measure flow diverted from North Boulder Creek before it discharges into the reservoir.

Riprap was placed on the banks upstream and downstream of the diversion structure to prevent undercutting due to erosion and to protect the Lakewood Reservoir embankment[102].

4.2.1.11 | LAKEWOOD RESERVOIR

Lakewood Reservoir was constructed by the city in 1906 as the inlet regulating reservoir for the Boulder City Pipeline[103] (Figure 4-10). The Boulder City Pipeline, also built in 1906[104], was the first of the city's pipelines in the North Boulder Creek Basin. Lakewood Reservoir also served as a settling basin built across Como Creek on the Boulder County Ranch (now Caribou Ranch). Due to water contamination, principally from tungsten processing at the Primos Mill, Como Creek was diverted around Lakewood Reservoir soon after the reservoir completion[105].

Since reconstruction of the Boulder City Pipeline, Lakewood Reservoir continues to serve as a regulating reservoir for Boulder's Silver Lake Watershed and North Boulder Creek raw water supplies. It functions to regulate flows between two city raw water pipelines (Silver Lake Pipeline and Lakewood Pipeline which operate in series) and as a capture point for the city's North Boulder Creek water rights. Water is conveyed to Betasso WTF through Lakewood Pipeline.

FIGURE 4-10. LAKEWOOD RESERVOIR[106]

The original Lakewood Dam was constructed of native soil and rock pushed into place. The dam was raised about 4 feet subsequent to the original construction. Currently, the dam is an earth embankment type structure approximately 250 feet long with a maximum height of about 20 feet. The reservoir has a surface area of about 4 acres, contains about 35 acre feet of water, and creates a small mountain lake about 720 feet long by 320 feet wide. The dam raises the water surface approximately 17 feet above the bottom of the reservoir, the maximum normal operating water surface being at elevation 8,181 feet, which is the crest elevation of the uncontrolled spillway. The dam is classified as a low hazard structure[107].

The spillway was rehabilitated in 1994 after it suffered a catastrophic overnight failure[108]. Due to ongoing seepage through Lakewood Reservoir Dam and associated safety concerns, the city reconstructed most of Lakewood Reservoir Dam in 1996. The Lakewood Pipeline intake structure and pipe were also replaced[109].

The existing valve house was demolished and a new concrete block valve house was constructed in its place. The valve house contains the Lakewood Pipeline inlet valve and flow meter. The inlet pipe passes through the basement level of the valve house and connects to the Lakewood Reservoir bypass pipeline downstream of the valve house. The junction of the inlet pipe and bypass pipeline is the start of the Lakewood Pipeline. A separate drain line was constructed from the inlet pipe in the valve house to an adjacent small drainage to allow the short section of pipe above the valve house to be drained for inspection and maintenance.

The Lakewood Reservoir bypass pipeline was installed at the same time and later incorporated into Silver Lake Hydro. Silver Lake Hydro and Silver Lake turbine bypass line discharge to a common chamber under the Silver Lake Hydro turbine floor. From that chamber, water is discharged into Lakewood Reservoir or into the Lakewood Reservoir Bypass Pipe. The Lakewood Reservoir Bypass Pipe then connects into Lakewood Pipeline downstream of Lakewood valve house[110].

4.2.1.12 | LAKEWOOD PIPELINE

Lakewood Pipeline carries water approximately 11 miles from Lakewood Reservoir to the Lakewood Hydro plant and Betasso WTF. Lakewood Pipeline was originally part of the Boulder City Pipeline constructed in 1906[111]. The pipeline was substantially replaced in the 1930s through 1950s, and the old pipe was used to rebuild the Silver Lake Pipeline[112] (see section 3.2.2.8).

The next replacement of the Lakewood Pipeline was initiated in the1980s. Lakewood Pipeline crosses U.S. Forest Service lands, private lands and a Boulder County road right-of-way. The city initially proposed pipeline replacement in 1986, but the project became mired in a U.S. Forest Service environmental impact statement and decision process. After the U.S. Forest Service process was completed, the city completed an Areas and Activities of State Interest (1041) review with Boulder County, which resulted in relocation of a significant portion of the proposed pipeline alignment to coincide with the Sugar Loaf Road corridor[113].

The city reconstructed Lakewood Pipeline in three phases. Phase I reconstruction was exempted from the Boulder County 1041 permitting requirements and does not affect federal land. Construction began in the fall of 1994 and was completed in the summer of 1995. This phase of construction was located between the intersection of Kelly Road West and Sugar Loaf Road and the Betasso WTF. Phase I encompassed about 1.1 miles.

The second phase of reconstruction began in July 2000. Phase II reconstruction included the westernmost 8,500 feet of pipeline from Lakewood Reservoir to approximately the point where the pipeline leaves the Cold Spring Road corridor and begins ascending Peewink Mountain. The Phase II alignment was common to all alternatives under consideration by Boulder County in the 1041 process and did not cross federal land, so it was allowed to proceed in advance. Pipeline installation was completed in November 2000 with final revegetation activities completed in the spring of 2001.

The city executed the contract for Phase III pipeline reconstruction in November 2001. Phase III construction was completed in July 2004. Phase III extends approximately 8 miles from the south side of Peewink Mountain, up and over Peewink Mountain to Sugar Loaf Road. From its intersection with Sugar Loaf Road to the junction with Phase I at Kelly Road West, the pipeline is located beneath the surface of or immediately adjacent to Sugar Loaf Road.

Lakewood Pipeline is a welded steel, cement mortar-lined and tape-wrapped pipeline varying in diameter from 27 to 36 inches. Pipe wall thickness varies from 0.25 inches to 0.5+ inches. The pipe is buried beneath a minimum of 4 feet of cover to prevent freezing.

The Lakewood Pipeline design flow is 20 MGD (8 feet per second), with a nominal minimum flow of 8 MGD and "emergency" flow of 30 MGD (12 feet per second). Pressures in the lower portion of the pipeline reach 850 pounds per square inch (psi).

In addition to the pipe, there are drain vaults containing sleeve type valves to allow drainage of water from low points along the pipeline. The pipeline has redundant (2 valves per vault) air/vacuum and air release valves situated along the line. Passive corrosion protection is provided by sacrificial anodes with test stations at regular intervals along the alignment. Three fire hydrant assemblies (discharge to a holding tank with provisions for automatic tank refill) were installed along the upper (lower pressure) section of the pipeline. Installation of the fire hydrants, which was required by Boulder County as a condition of 1041 permit issuance, required voter approval of a charter amendment to allow the city to provide water above Boulder's "blue line." A second surge relief valve was added to the Lakewood Pipeline in 2006 to provide additional protection over and above the original design against failure of this critical city infrastructure[xi].

Phase III pipe installed during 2002 is known to have numerous weld defects of a variety of types that occurred during manufacture of the spiral welds. Weld defects were also observed in the pipe's accessway fabrication welds. The accessways were replaced. Select pipe bends were inspected and no significant defects were found. Pipe installed during 2003 and 2004 was manufactured under careful inspection and is believed to be free of manufacturing weld flaws. However, interior mortar defects appear to occur throughout the Phase III pipe. In accordance with the recommendations of a team of experts retained by the city, internal inspections of the Lakewood Pipeline were completed in September 2004, April and October 2005, March and April of 2006 and October of 2007. The city will continue to monitor mortar condition and spiral weld corrosion[114].

[xi] A compilation of documents related to Lakewood Pipeline reconstruction is included in the Appendices.

4.2.1.13 | LAKEWOOD HYDRO

Information on the Lakewood Hydroelectric Project is contained in Table 4-4 at the end of this section. Lakewood Hydro is FERC Project P-09922 and was issued a conduit exemption from licensing on February 9, 1987[115]. The Lakewood Hydro equipment is co-located with Betasso Hydro at the Betasso Water Treatment Facility.

4.2.2 | MIDDLE BOULDER CREEK/BARKER RESERVOIR WATER FACILITIES

Middle Boulder Creek water facilities include the Boulder Canyon Hydroelectric Project and Skyscraper Reservoir. The Boulder Canyon Hydroelectric Project (often referred to as the Barker system) was completed in 1910 by a predecessor to PSCo. Beginning in the 1950s, the city had a series of agreements with PSCo regarding use of Barker Reservoir storage and its associated water transmission facilities (discussed in section 3.2.2.10). Facilities associated with the Middle Boulder Creek water source and the Boulder Canyon Hydroelectric Project are discussed below.

4.2.2.1 | SKYSCRAPER RESERVOIR

Boulder purchased Skyscraper Reservoir in 1967[116]. The reservoir is located on Woodland Creek within the Indian Peaks Wilderness area at an elevation of 11,221 feet and is authorized by the US Forest Service under a Special Use Permit with no expiration date[117]. Skyscraper's current storage capacity is 146.4 acre-feet. The dam is a 122-foot-long, 24-foot-high rock masonry gravity arch. The crest width at the top of the dam is 3 feet. A survey of the reservoir site was first made on July 24, 1940. Everett Long constructed the dam by raising the level of an existing lake, which was completed in 1950, to irrigate Long's Gardens[118].

Skyscraper Reservoir has an 11.5 acre surface area and drains an area of about 0.4 square miles. It is classified as a low-hazard dam. The dam includes a 38-foot-wide spillway section located near the center of the dam which is 3.2 feet lower than the top of the dam. It has an 18-foot-long discharge channel and a capacity of 651 cfs. There are two outlets. One outlet consists of an 8-inch inside diameter, 10-foot long conduit with a wooden plug located 14 feet below the dam crest. The capacity of this outlet is 6 cfs. A second, low-level conduit with a control valve is located 18 feet below the embankment crest. It is 13 feet long and 12 inches in inside diameter, with a capacity of 15.9 cfs[119]. A Parshall flume downstream of the dam measures dam releases.

While the reservoir is nominally functional, the city has not actively operated 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. The City of Boulder Drought Plan[120] recommends that the city formally incorporate the operation of Skyscraper Reservoir into its water supply system on a normal basis.

4.2.2.2 | BARKER RESERVOIR

Barker Reservoir has a surface area of approximately 200 acres and can hold approximately 11,700 acre-feet of water. While the shoreline of Barker Reservoir is open to public access and recreation, no camping, boating or swimming are currently allowed.

FIGURE 4-11. BARKER RESERVOIR[121]

Barker Dam was built in 1909-1910 and is located 11.5 miles west of the Betasso WTF. The dam is 175 feet high with a crest of 720 feet and is made of cyclopean concrete. It has two 36-inch diameter floodgates that discharge down the spillway and into Middle Boulder Creek. The outlet works include 10 outlet gates on the upstream face of the dam that discharge into a vertical, stair-step shaft in the dam that can release flows to Middle Boulder Creek and the Barker Gravity Pipeline. In the past, FERC has required that the reservoir be emptied every 5 years to allow outlet works inspection. The city is currently investigating improvements to the outlet works in order to eliminate the loss of water which occurs when the reservoir is drained. As part of this investigation, the city is considering sealing 7 of the 10 original outlet gates and constructing new reservoir outlet pipes.

In 1946 and1947, PSCo modified the outlet works on Barker Dam and made improvements to the upstream face of the dam. In 1971, the spillway was enlarged with a new 125-foot ogee crest with a curved channel and a warped floor. The new spillway was designed to pass flood flows from a 6-hour storm generating 2.45 inches of precipitation and peak flood outflows of 4,544 cfs. Cosmetic improvements were made to the downstream face of the dam in 1971. The dam was secured in the early 1980s with post-tensioned anchors to increase the factor of safety[122]. The city paid for the repair at a cost of $3,315,000 and received a perpetual right to use 8,000 acre-feet of Barker Reservoir storage space from PSCo in return[123]. The downstream face of the dam is cosmetically flawed but the structure of the dam is sound[124].

Leakage and ice build-up on the downstream face of Barker Dam were noted during the 2003-2004 winter season. The city has attempted to clear the vertical drains of debris and extended the drain outlet below the dam by approximately 250 feet. The city has concluded that the condition of the vertical drains has no negative impact on dam stability, and the drains continue to function, although at a reduced rate[125].

The ninth safety inspection of Barker Dam was completed in 2006. This included a Probable Failure Modes Analysis (PFMA). The PFMA concluded that there are no credible flood related Potential Failure Modes for any of the Boulder Canyon Hydroelectric facilities, the seismic stability of Barker Dam should be verified for peak ground accelerations, and all the Boulder Canyon Hydroelectric facilities are well constructed and well operated[126].

In response to public comment, the city completed a non-motorized boating feasibility study for Barker Reservoir in 2003. The study identified concerns regarding safety, water quality, and facility security. Allowing non-motorized boating on Barker Reservoir would greatly accelerate the need to upgrade Betasso WTF to advanced water treatment processes compared to maintaining the current no boating policy. In addition, revenue generation capability from a boating program was found to be poor. While the Boulder City Council declined in 2003 to subsidize a boating program, the Town of Nederland was invited to submit a proposal to manage a boating program. To date, Nederland has not submitted any proposals[127].

4.2.2.3 | BARKER GRAVITY LINE

The intake for the Barker Gravity Line is at the outlet works for Barker Dam. The pipeline runs from the addit tunnel of the dam to the "Farmers' Gate" located near the base of Barker Dam. The Farmers' Gate allows water to be discharged either into a continuation of the pipeline or into Middle Boulder Creek below Barker Dam. In 2007, the Farmers' Gate wooden timbers were replaced with a stainless steel gate. The continuation of the Gravity Line is a buried (close to grade), 36-inch diameter, concrete pipeline that extends approximately 11.7 miles to Kossler Reservoir. Its current capacity is approximately 43 cfs. The pipeline includes five tunnels and seven inverted siphons. Water flows by gravity in open channel mode in most sections of the pipeline[128]. Pressurized flow in the siphons ranges from 20 psi to 90 psi depending upon the specific siphon[129].

The Barker Gravity Line was in a seriously deteriorated condition when the city purchased the Boulder Canyon Hydroelectric Project in 2001. Leaks accounted for approximately 10 percent total water loss. The city has since developed and implemented an annual maintenance program to address the most critical problems. Repairs are generally limited to times of the year when the Barker Gravity Line is not needed to deliver water to meet municipal demand. Primitive access and rugged terrain require use of a helicopter to deliver pipe and other supplies in some areas. The major repairs completed from 2001 through 2007 include:

- drain valves and valve vaults for Siphons 1, 2, 3, 5, 6 and 7 were replaced with new 8-inch ball valves and new valve cans;
- 121 manhole frames and lids were replaced with new steel frames and lids;
- HDPE pipe was removed from both sides of siphons 5 and 6;
- concrete pipe was removed from the lowest 40- to 50-foot sections of both sides of Siphon 5 and was replaced with mortar-lined steel pipe;
- HDPE-lined concrete pipe was removed from the upper 100-foot section of the west side of Siphon 6 and was replaced with epoxy-lined steel pipe;
- HDPE-lined concrete pipe was removed from the upper 300-foot section of the east side of Siphon 6 and was replaced with mortar-lined steel pipe;

- three heavily damaged sections of pipeline were removed and replaced with mortar-lined steel pipe;
- damaged, hand-stacked rock retaining walls supporting the pipe bench were replaced with reinforced concrete counterfort style retaining walls in three locations along the pipeline;
- numerous leaking joints in the existing concrete pipe have been repaired with grout and/or internal pipe seals, and;
- the entire pipeline has been cleaned of debris and root mass has been removed[130].

In February 2006, an overflow event was discovered in the Barker Gravity Line that caused large amounts of muddy water and silt to spill into Boulder Creek. Due to an ice blockage that formed in Siphon 4 during a maintenance shutdown, water backed up and spilled out of a manhole during pipeline refilling operations. Significant erosion damage occurred between the pipeline and the creek below. Cleanup and restoration took place in 2006 and 2007. The section of pipe just upstream of Siphon 4 was replaced and a timber-plank, mechanically stabilized earth (MSE)-fill retaining wall below the pipeline bench was constructed. Other than a shutdown to accommodate ice removal in Siphon 4, no other disruption in flow capability occurred as a result of the overflow damage[131].

According to the ninth safety inspection of Barker Dam in 2006 of all the components of the Boulder Canyon Hydroelectric Project, Barker Gravity Line has the highest potential for failure[132].

4.2.2.4 | KOSSLER RESERVOIR

Kossler Reservoir is the forebay for the Boulder Canyon Hydroelectric Penstock and is located 2 miles south of the Betasso WTF. Very little design and construction documentation is available for the Kossler Reservoir dams and appurtenant facilities. The Barker Gravity Line ends at the southwest side of Kossler where there is a weir and a measuring device. The penstock gatehouse is located on the north side of the reservoir where there is another measuring device.

Kossler is a 165 acre-foot, crater type reservoir formed by one main dam and two smaller dams. The main dam is a 450-foot-long, 18-foot high embankment with an 8-foot-wide crest located on the southeast edge of the reservoir. The upstream face of the main dam is covered with concrete. The northeast dam is 9 feet high and 160 feet long. The west dam is 5 feet high and 420 feet long. The west dam includes the outlet structure and an earth channel spillway. An earth-cut overflow spillway was constructed near the middle of the west dam alignment. There does not appear to be any design information for the spillway[133].

In 2006, the Kossler inlet structure was repaired. Old lumber and concrete were removed and sand and silt were excavated from the inlet. Treated lumber was installed for a hydraulic dissipater and a new inlet structure and concrete for a retaining wall under the stilling shack was installed. Rip-rap was placed around the spillway and inlet[134].

Following the September 2006 inspection of the Boulder Canyon Hydroelectric Project, FERC requested that the city prepare a plan for addressing the deterioration of the concrete on the upstream face of the main dam and rodent disturbance of the dams. The city plans to complete the concrete repairs during 2009 and will continue to monitor rodent activity[135].

The PFMA identified potential risk reduction actions for Kossler Dam, such as upgrading instrumentation, including water level and flow indicators and telecommunications equipment. The report also advised repairs to the intake and outlet structures, more frequent inspections and observations to understand reservoir seepage, and identification of the exact location of piezometers in relation to the concrete core wall of the main dam. Lastly, the hazard classification of the Kossler Reservoir dams should be reviewed, and the size and capacity of the overflow spillway on the west dam at Kossler Reservoir should be determined[136].

4.2.2.5 | BOULDER CANYON HYDRO PENSTOCK

The steel penstock to the Boulder Canyon Hydro serves as the outlet from Kossler Reservoir. The penstock drops approximately 1,835 feet from Kossler Reservoir to the Boulder Canyon Hydro[137]. The pipeline is 44 to 56 inches in diameter and consists of welded and riveted steel pipe. Penstock operating pressure is approximately 800 psi at Boulder Canyon Hydro[138].

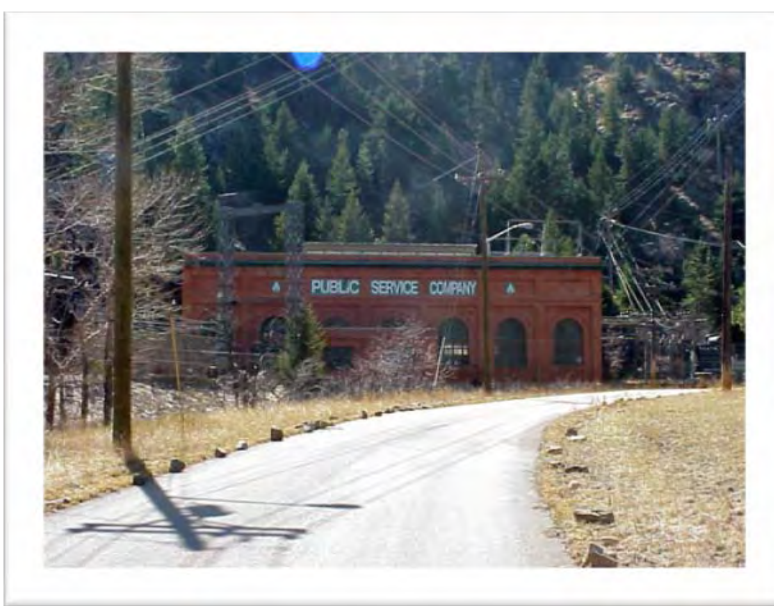
When constructed in 1909, Boulder Canyon was the highest head hydroelectric project in the U.S. High water pressure caused the riveted steel pipeline to leak profusely. The "ball peen" welding process was developed on-site to eliminate the leaks in the penstock[139]. For this (and other) reasons, the Boulder Canyon Hydroelectric Project is considered to be a significant historic site and has been determined eligible for nomination to the National Register of Historic Places.

The Boulder Canyon Penstock was externally inspected in 2005· A surficial internal inspection was completed in 2005-2006. An access manway was installed just above the steep portion of the penstock alignment in 2005. In 2006, a second access manway was installed just upstream from the hydro building. A small leak was repaired upstream of the hydro plant building during 2006[140].

4.2.2.6 | BOULDER CANYON HYDRO

Information on Boulder Canyon Hydro is contained in Table 4-4 at the end of this section. Boulder Canyon Hydro was purchased from PSCo on March 7, 2001[141].

FIGURE 4-12. BOULDER CANYON HYDRO[142]



The Boulder Canyon power plant went into operation on August 4, 1910. The original capacity of the single turbine generator was 10,000 kilowatts[143]. A second turbine generator was added in 1936, increasing the capacity to 20,000 kilowatts[144]. In late 2000, prior to the closing on the city's purchase of the facilities, the windings on one of the generator units grounded out. This event caused extensive damage to the generator and left it inoperable. Therefore, current actual capacity at Boulder Canyon Hydro is 10 megawatts (MW). When it was purchased by the city, hydroelectricity became a by-product of project operation as a component of the municipal water supply system and the 10 MW capacity is no longer supported.

Boulder Canyon Hydro is FERC Project P-1005. The license for the project that was issued to PSCo on April 28, 1981 was transferred to the city at the time of purchase (the official transfer date is March 21, 2001[145]). The license expires in August 2009[146]. The city is seeking a conduit exemption from licensing for the project rather than renewal of the license.

4.2.2.7 | BETASSO PENSTOCK

Betasso Penstock transmits Middle Boulder Creek basin and Barker Reservoir water from a bifurcation located under the Boulder Canyon Hydro turbine floor to Betasso Hydro or the Betasso WTF. The head losses in Betasso Penstock are high due to the high operating water velocity. Water at Betasso Hydro is at a pressure of 556 psi[147]. The pipeline, built in the 1960s, originally consisted of an unlined, 20-inch-diameter welded steel pipeline with exterior coal tar enamel coating. With the construction of Betasso Hydro in the mid-1980s, the pipe was lined with cement mortar. An external condition assessment of this pipeline conducted in 2005 concluded that the exterior is in good condition. An internal video inspection during the fall of 2006 verified that the lining is in good condition, although it has a rippled or ridged surface[148].

The city intends to construct a new, 30-inch diameter, welded steel and cement mortar lined pipeline to replace the existing Betasso Penstock during 2009. The existing penstock will be reused in place to replace the upland (non-floodplain) portion of the Orodell Pipeline. The new pipeline will increase water system reliability and allow Betasso Hydro to achieve its intended generation capacity of 3.2 MW. Reuse of the existing pipeline will significantly delay replacement of the Orodell Pipeline.

The upper portion of Orodell Pipeline will be reused in place to create a means to discharge raw water from the Betasso and Lakewood Hydros to Boulder Creek. This will help to alleviate pressure placed on the Betasso WTF resulting from rapid increases and decreases to plant inflows during contractually-required, monthly hydroelectric generation capacity tests.

The Howell-Bunger pressure reducing valve on the Betasso Penstock was installed prior to construction of the Betasso Hydroelectric Facility and continues to be used during periods when Betasso Hydro is out of service. The current valve is not the proper valve for the installation, and the operating mechanism is out of date. Extensive repairs have been required in the past, and replacement parts must be custom fabricated. Design and installation of a new pressure reducing valve will be completed in conjunction with the replacement of Betasso Penstock (personal communication, Joe Taddeucci, 2008).

4.2.3 | BETASSO FACILITIES COMPLEX AND SMALL HYDROS

4.2.3.1 | BETASSO HYDRO

Information on Betasso Hydro is presented in Table 4-4 at the end of this section. Betasso Hydro is FERC Project P-06282 and was issued a conduit exemption from licensing on August 20, 1984. Betasso Hydro went into commercial operation on December 17, 1987[149]. The Commercial Operation Date of Betasso Hydro establishes the beginning of the 30 year term of the power sales contract with Xcel Energy. Betasso, Lakewood and Silver Lake hydros are all included in the same power sales contract[150].

FIGURE 4-13. BETASSO AND LAKEWOOD HYDROS[151]

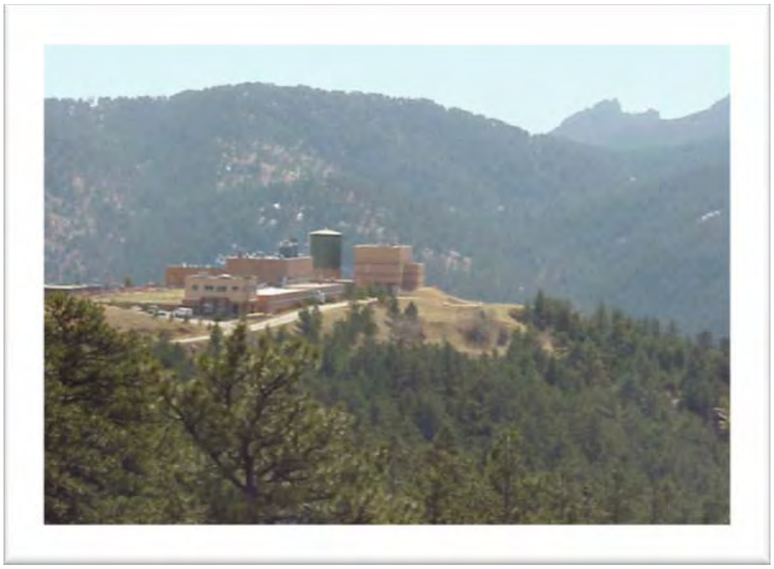
While the Betasso unit has a rated capacity of 3.2 MW, the plant currently can only achieve about 2.4 MW due to operating constraints in the Betasso Penstock. Replacement of the Betasso Penstock, scheduled for 2009, will allow Betasso Hydro to achieve its intended capacity and will increase hydropower revenue to the city.

Both the Lakewood Hydro and Betasso Hydro facilities are located in the same building adjacent to the Betasso WTF.

4.2.3.2 | BETASSO WATER TREATMENT FACILITY

The Betasso WTF, located west of the city near Sugarloaf Mountain, was originally constructed in 1964. At that time, the Boulder City Pipeline, which ran from Lakewood Reservoir directly into the city, was re-plumbed so that the upper portion of the pipeline, Lakewood Pipeline, would carry raw water into Betasso and the lower portion of the pipeline, the Boulder Canyon Pipeline, would carry treated water into the city. In addition, the Sunshine Pipeline was built to provide an alternative means to carry treated water into the city[152].

FIGURE 4-14. BETASSO WATER TREATMENT FACILITY[153]



Betasso WTF was expanded to its present capacity in 1976. At about the time of the expansion, 50 MGD became widely accepted as the design capacity of the Betasso facility. However, hydraulic limitations and the need to limit flow into the filter beds to meet drinking water standards cause actual maximum facility capacity to be closer to 45 MGD[154].

The city's North and Middle Boulder Creek basin water supplies are treated at Betasso WTF. Water from the North Boulder Creek basin passes through the Lakewood Hydro or a pressure reducing valve to the tailrace and flows at atmospheric pressure into the treatment facility. Water from the Middle Boulder Creek basin passes through the Betasso Hydro or a Howell-Bunger pressure reducing valve to the tailrace and flows at atmospheric pressure into the treatment facility.

4.2.3.3 | SMALL HYDRO FACILITIES

The city's four smallest hydros are located on major treated water distribution pipelines that carry treated water from Betasso WTF into the city. They are paralleled by pressure-reducing valves to provide pressure reduction when the hydros are not operating. Although the small hydros are located on the treated water system, they are managed by the same hydroelectric staff as the hydros on the raw water system.

4.2.4 | BOULDER RESERVOIR RAW WATER FACILITIES

4.2.4.1 | BOULDER RESERVOIR

The city finished construction of Boulder Reservoir in 1955[155]. Almost all of the water in Boulder Reservoir comes from the CBT and Windy Gap Projects through Carter Lake, although water substituted by Left Hand Water District from St. Vrain Creek and deliveries from the Farmers' Ditch add to the water supply. Farmers' Ditch diverts from Boulder Creek near the mouth of the canyon.

The city issued $1.2 million of water utility revenue bonds to purchase land and fund construction of the dams for the reservoir. NCWCD subsequently paid Boulder one-third of the construction cost of the reservoir in exchange for use of storage space. Although Boulder owns the entire reservoir, the

NCWCD use of the storage space for which it paid is contracted in perpetuity. Boulder has the right to use 8,500 acre-feet of Boulder Reservoir storage space in the winter months and 5,143 acre-feet in the summer months[156]. The reservoir was originally built to store agricultural and industrial water for downstream CBT users and to store water for subsequent exchange by the city to its North Boulder Creek and Middle Boulder Creek facilities for municipal use. Having the potential to exchange water in Boulder Creek is of vital importance since it allows the city to make full use of the physical supply of water available at its upper diversion points on North and Middle Boulder creeks. This increases the city's ability to reliably meet its water supply demands.

The reservoir was constructed to a capacity of 13,100 acre-feet. When full, the reservoir has a surface area of approximately 700 acres. The reservoir is contained by two rolled earth-fill dams averaging 3,000 feet in length, 50 feet in height, and 150 feet in width at the crest. The embankment materials are sand and gravel placed with more permeable soils toward the outer slopes. A centerline cutoff trench that extends to unweathered clay shale bedrock controls foundation seepage. Downstream toe drains control seepage through the embankments[157].

The spillway was originally an earth channel upstream and downstream of a concrete labyrinth weir crest section situated on the left abutment of the north dam. Prior to 1985, the State Engineer's concern about erosion of the earthen spillway crest caused the imposition of a reservoir storage restriction to create a flood storage pool[158]. The city paid $939,000 to modify the spillway in 1985 to add height to the concrete crest and to harden the earthen spillway with a concrete face. By hardening the spillway against erosion during high flows, the State Engineer's storage restriction was lifted to allow storage of 13,100 acre feet as originally planned. The spillway modification increased the maximum discharge capacity (at a pool elevation of 5,188.50 feet) to 25,500 cfs[159]. This discharge capacity is considered adequate to pass 61percent of the PMF[160].

Boulder Reservoir has two outlets. The main outlet, in the north dam, is operated by NCWCD and leads to the Boulder Creek Supply Canal. The maximum discharge capacity of the main outlet is 940 cfs. The auxiliary outlet, in the south dam, is owned and operated by the city and serves as the intake to the water treatment facility. The city's outlet is 6 feet lower than the main outlet and allows the city to access about 1,000 acre-feet of the city's long-term storage water in the event of an extended drought. The maximum discharge capacity of the auxiliary outlet is 475 cfs[161].

Boulder Reservoir offers full recreation amenities, with swimming, boating, picnicking, fishing, and special event permits. It has the largest guarded swimming facility in the state. Recreation at the reservoir is managed by the city through the Parks and Recreation Department.

4.2.4.2 | CBT PROJECT FACILITIES AT BOULDER RESERVOIR

Boulder Feeder Canal

The portion of the Carter Lake delivery canal from Carter Lake to Lyons is called the St. Vrain Supply Canal and the portion from Lyons to Boulder Reservoir is called the Boulder Feeder Canal. The canal was constructed in the late 1950s and is operated by NCWCD. The canal is located on land either owned in fee or easement by NCWCD, with a few areas under the jurisdiction of the Bureau of Reclamation (Reclamation), and some other exceptions at siphon locations (sites where the canal is underground in order to avoid conflicts with the larger drainages). The capacity of the Boulder Feeder Canal is 200 cfs (personal communication, Dennis Miller [NCWCD], 2008).

Water can be diverted from the Boulder Feeder Canal to the Boulder Reservoir WTF. The diversion consists of removable stop planks across the canal bottom; a partially submerged, 5-foot wide, manually cleaned bar screen (2-inch openings) built into the side of the canal, and a stainless steel, woven wire basket (½-inch openings) that can be winched up to grade for cleaning. A manual sluice gate was installed to isolate the WTF from the canal. A 42-inch diameter, 5,600 foot long pipe connects the diversion inlet to the Boulder Reservoir WTF. The raw water line was designed for a flow of 30 MGD, and provisions were made for a parallel 42-inch line at the diversion inlet in the future. The raw water line drops almost 70 feet to cross under the Boulder Creek Supply Canal north of the WTF. The raw water line then rises 35 feet to the WTF[162].

FIGURE 4-15. BOULDER FEEDER CANAL[163]

Canal operation is dictated primarily by the amount of demand for CBT deliveries for municipal and irrigation uses. The canal is typically out of service between November and April each year due to freezing.

The water from the canal is typically easier to treat than water from the reservoir due primarily to the high mineral content of the soils surrounding the reservoir, the constituents in runoff from intermittent North and South Dry Creeks, and evaporation. However, the runoff into the canal and lack of security along the open canal make the pathogen risk with using canal water very high (personal communication, Jim Shelley [City of Boulder Water Quality], 2008).

The land adjacent to the Boulder Feeder Canal has historically been closed to public use. In 2006, an 11-mile recreational trail was proposed along the Boulder Feeder Canal from U.S. Highway 36 southeast of Lyons to Boulder Reservoir. This trail connection would link open space and trails near Boulder Reservoir with recreation areas in northern Boulder County. A trail along the canal has been on the Boulder County Trails Map since 1978. The city of Boulder Open Space and Mountain Parks Department and Boulder County Parks and Open Space Department are now pursuing trail development in this corridor to complete a regional trail between Boulder and Lyons, eventually connecting to Hall Ranch and Longmont[164].

Boulder Creek Supply Canal

The Boulder Creek Supply Canal transfers water from Boulder Reservoir to Boulder Creek just upstream of the 75th St. Wastewater Treatment Facility. It was constructed to supply CBT water to the South Platte Supply Canal, which transports CBT water from Boulder Creek at 95th Street to the South Platte River. The city uses the Boulder Creek Supply Canal to deliver the city's exchange water to downstream senior water rights and the city's agricultural lease water. The supply canal is owned by the United States Bureau of Reclamation and operated by NCWCD. It has a carrying capacity of 200 cfs. The city is guaranteed the use of up to 90 cfs of the capacity and may use additional capacity on an as-available basis[165]. Water delivered through the supply canal significantly increases streamflow in Boulder Creek downstream of 75th Street during the warmer months of the year.

4.2.5 | FARMERS DITCH

The headgate for the Farmers Ditch lies on the north side of Boulder Creek just upstream of Eben G. Fine Park. The ditch runs north through the west side of Boulder, starts heading northeast around Iris Ave, runs north through Boulder Valley Ranch, and terminates at the southern edge of Lake Valley Estates. Numerous laterals branch off the ditch including one at the end of the ditch that carries water to Boulder Reservoir. The city measures the amount of water delivered to Boulder Reservoir via Farmers Ditch in a two foot Parshall flume located on the northeastern most lateral of the ditch, which lies on Boulder Valley Ranch property near the old Open Space and Mountain Parks fire cache on 51st Street.

The city uses the Farmers Ditch to carry up to 24.602 shares of Farmers Ditch water to the reservoir for municipal use. The water is decreed for direct use only and so must be used immediately upon delivery into Boulder Reservoir. If the Boulder Reservoir WTF is not in operation at the time the Farmers Ditch water is available, then the city cannot take the water since it must be used directly. If the WTF is not drawing directly from Boulder Reservoir at the time, then the Farmers Ditch water is counted against the deliveries into the WTF from the Boulder Feeder Canal. In effect, the water is exchanged for CBT water and is then accounted for as CBT water stored in Boulder Reservoir and available for later use by CBT allottees.

The city may also carry water other than decreed Farmers Ditch water (*i.e.* foreign water) through the Farmers Ditch according to the terms and conditions in a carriage contract signed on May 2, 1967 by the city and the Farmers Ditch Company[166]. The contract permits the city to utilize excess capacity in the ditch to carry city-controlled foreign water. In exchange for this usage right, the city pays the ditch company one-sixth of the company ditchrider's annual cost and an annual surcharge based on the number of days the ditch carried city-controlled foreign water.

4.2.6 | BOULDER RESERVOIR WATER TREATMENT FACILITY AT 63RD STREET

The Boulder Reservoir WTF at 63rd Street was originally constructed in 1971 to provide additional water treatment capacity during summer peak flow periods by treating water from the city's CBT/Windy Gap source. Prior to construction of the facility, Boulder's CBT water was only used by exchange to the city's North and Middle Boulder Creek facilities. The facility is normally operated in the range of 5 to 8.5 MGD but is commonly run at up to 11.5 MGD during peak demand periods and can be run down to 4 MGD[167]. The current capacity is 16 MGD.

From 1972 until 1996 the Boulder Reservoir WTF operated mostly during the peak demand summer months and was shut down for the remainder of the year. Since 1996, the facility has operated year round; 24 hours per day during the peak demand summer months (May - October) and 12 hours per day during the low demand winter months (November - April). When factors such as the costs of the treatment chemicals and water pumping are considered, the cost of treated water from the Boulder Reservoir WTF is approximately twice the cost of treated water from Betasso (see Table 4-1).

TABLE 4-1. TREATED WATER UNIT PRODUCTION COSTS (PER MILLION GALLONS) [168]

	1996	1997	1998	1999	2000	2001	2002	2003	2004*	2005*	2006
Betasso	$239	$274	$316	$317	$319	$334	$360	$365	$352	$456	$428
Boulder Reservoir	$576	$560	$583	$645	$487	$534	$716	$860	$1289	$876	$905

*2004 and 2005 included capital improvement budgets. The Boulder Reservoir WTF was out of service for two months in 2005 and four months in 2004. The facility is staffed year round.

Water is transported to the Boulder Reservoir WTF from one of two intake structures, either from the Boulder Feeder Canal or from Boulder Reservoir itself. Because Boulder Reservoir is at a lower elevation than the treatment facility, raw water must be pumped to the influent structure. The raw water pumping station was constructed in 1981 and is connected to the auxiliary outlet trash rack structure in Boulder Reservoir[169].

FIGURE 4-16. BOULDER RESERVOIR WATER TREATMENT FACILITY AT 63RD STREET[170]

The trash rack structure was modified in 2005 and is a concrete, octagonal, upturned bell-mouth design located a foot above the bottom of a rock-lined channel, about 20 feet below the normal pool elevation. Each peripheral face of the raw water intake has a two-foot by four-foot trash rack (1¾-inch openings) over the inlet port. A 54-inch square trash rack cover is installed on the top of the structure. Provisions were made for water withdrawal at a lower depth if needed, but this can only be accomplished by sending a diver to manually remove the inlet apron. The raw water passes through a 48-inch diameter conduit through the dam. Three vertical diffusion vane raw water pumps, each installed in a 48-inch diameter suction can, pump water to the treatment facility. One pump is rated at 4 MGD; the other two are rated at 8 MGD each. The pumping station was designed for five 8 MGD pumps at build-out[171].

TABLE 4-2. CITY OF BOULDER DAM AND RESERVOIR SUMMARY DATA[172]

Name	Lakes and Reservoirs					Dams					Spillways				
	Surface Area (acres)	Depth (feet*)	Decreed Volume (acre-feet)	Maximum Operation Capacity (acre-feet)	Drainage Area ($miles^2$)	Type	Crest Length (feet)	Crest Width (feet)	Height (feet)	Hazard Classification	Type	Crest Elevation (feet)	Bottom Width (feet)	Length (feet)	Discharge Capacity (cfs)
Green #1	11	14	175	92	0.2	Rockfill with steel facing	217	9	25	Low	None				
Green #2	17	37	333	0		Rockfill and earthfill with steel facing					Ogee				
Green #3	19	29	285	285	1.1	Rockfill with steel facing	290	5	30	Low	Sharp crested weir	0.12 feet below embankment crest	12	50	50
Green #4	13	15	116			Natural					Natural				
Green #5	7	10	74			Natural					Natural				
Albion	32	35.3	1,111		2.03	Concrete Gravity Arch	506	14	38.9	Moderate	Broad crested weir	3.6 feet below dam crest	28	48	500
Goose	34	27.8	1,036			Rockfill/Timber crib with concrete U/S face									
Island	33	14	334			Concrete Buttress and rockfill	619 (main) 107 (auxiliary spillway) 21 (south)	1.5-2.0 (buttress); 10 (rockfill)	16	Low	Main- rockfill chute; Auxiliary - broad crested weir	Main - 1.5 below crest; Auxiliary - 0.9 below crest			
Silver	105	62	3,987		8.8	Earthfill	1,450	20	70	High	Ogee crest	10,262	80	130	7,241
Lakewood			NA			Earthen	400		19.3	Low		8181			
Skyscraper	11.5			146	0.4	Rock masonry gravity arch	122	3	24	Low	Ogee concrete weir	3 below crest	38	18	651
Barker	200		11,686			Cyclopean concrete	720		175	High	Ogee crest				4,544
Kossler			NA			Earthen (3); main has concrete U/S face	45		20	Low	None				
Boulder	700				10	2 rolled earthfill	3000 (avg.)	150 (avg.)	50 (avg.)		Concrete labyrinth weir				25,500

*At crest of main spillway.

TABLE 4-3. CITY OF BOULDER RAW WATER PIPELINE, PENSTOCK AND CANAL SUMMARY[173]

Name	Start	End	Construction	Length (as stated)	Diameter (inches)	Flow	Normal Operating Pressure (psi)	Capacity (MGD)	Last Major Repair
Silver Lake Pipeline	Silver Lake Diversion	Silver Lake Hydro/ Lakewood Reservoir	Welded steel/CML	3.6 miles	27	Gravity-pressurized	660	20	Replaced – 1997-1998
Lakewood Pipeline	Lakewood Reservoir	Lakewood Hydro/ Betasso WTF	Welded steel/CML	10.8 miles	27-36	Gravity-pressurized	800	20 (normal) 30(emergency)	Replaced – 1994-2004
Barker Gravity Line	Farmers Gate (at the base of Barker Dam)	Kossler Reservoir	Concrete	11.7 miles	36	Open channel gravity flow with pressurized inverted siphons	Up to 86 psi in siphons	30.1	On-going since 2001
Boulder Canyon Penstock	Kossler Reservoir	Boulder Canyon Hydro	Welded and riveted steel	10,000 feet	44-56	Gravity-pressurized	800	30.1	Original construction (1909-1910)
Betasso Penstock	Boulder Canyon Penstock	Betasso Hydro/ Betasso WTF	Welded steel/CML	2,900 feet	20	Gravity-pressurized	500-900	Up to 40 during capacity tests	1964 (CML added- 1985)
Boulder Feeder Canal[174]	St. Vrain Supply Canal	Boulder Reservoir/ Boulder Res. WTF	Open canal with siphons	13.2 miles	NA	Open channel	NA	200	Maintained on an annual basis by NCWCD

TABLE 4-4. CITY OF BOULDER HYDROELECTRIC FACILITY SUMMARY[175]

Name	Pressure Source	Head on U/S Side Turbine (ft)	Type of Turbine	Nameplate Capacity (kW)[176]	Generator Make	Commercial Operation Date	2006 Generation (kWh)	2006 Revenue	Construction Cost
Maxwell (Pump/Generator)	Treated Water (Zone 3)	200	Reaction (Francis)	95	General Electric	March 1985	482,840	$21,366	$300,000
Kohler (Pump/Generator)	Treated Water (Zone 3)	140 -240	Reaction (2 Francis)	150	Marathon XRI	November 1986	797,120	$35,051	$526,000
Orodell.	Treated Water (Orodell Pipeline)	413	Reaction (Francis)	225	Primeline	September 1987	540,400	$18,600	$540,000
Sunshine	Treated Water (Sunshine Pipeline)	750	Reaction (Francis)	800	Unimega-Hitachi	September 1986	3,049,600	$136,045	$1,100,000
Betasso	Raw water (Betasso Penstock)	1,094	Impulse (Pelton)	3,100	Kumming Elec	December 1987	18,055,360 (combined with Lakewood)	$1,634,770 (includes Lakewood and Silver Lake)	$3,200,000
Silver Lake	Raw water (Silver Lake Pipeline)	1,406	Impulse (Pelton)	3,309	Alconza	March 1998	11,520,214	See Betasso	$4,400,000
Boulder Canyon	Raw water (Kossler/Barker)	1,847	Impulse (Pelton)	10,000	General Electric	August 1910 (COB Purchased March 2001)	11,451,441	$283,543	$3,000,000
Lakewood	Raw water (Lakewood Pipeline)	1,554	Impulse (Pelton)	3,695	Alconza	June 2004	Included with Betasso	See Betasso	$5,000,000
Total				***20,985***			***45 896,975***		***$18,092,503***
Since beginning operation through 2007 these hydros have displaced 213,120,394 tons of burning coal and generated 426,240,788 kilowatt hours. Total revenue through 2007 was $ $20,242,118 177.									

4.3 | Water Rights and Water Contracts

The city's water rights and contract rights that are used for municipal water supply are held by the city as an asset within a restricted budgetary fund called the water utility enterprise fund. These assets are restricted under the City Charter for preferential use for water utility purposes and are listed separately from general fund assets in the city's accounting system. Most of the city's water rights that are used for irrigation of open space or for parks are held within the general fund, but Utilities fund water rights that are not immediately needed for municipal water supply purposes are sometimes leased to other city departments. Historically, the city has also leased to farmers, on an annual basis, any CBT water and some ditch share water that is not needed for municipal supply in any given year.

4.3.1 | CITY OF BOULDER MUNICIPAL WATER RIGHTS

The city's municipal water rights portfolio includes rights on North Boulder Creek, Middle Boulder Creek, and main Boulder Creek. The water rights in these basins range in priority date from 1859 to 2001 (very senior to very junior). The Middle Boulder Creek and North Boulder Creek water rights are fed by watersheds on the eastern slope just below the Continental Divide. The rights in the Middle Boulder Creek basin are associated with Barker Reservoir, Skyscraper Reservoir, and the Barker Gravity Line. Rights in the North Boulder Creek basin are associated with Albion Lake, Goose Lake, Island Lake, the Green Lakes, Silver Lake, Park Reservoir, the Silver Lake Pipeline, and the Lakewood Pipeline. In addition, the city has contract delivery rights from the CBT Project and Windy Gap Project that supply water delivered to Boulder Reservoir. Both of these projects divert water from the western slope and deliver it through the CBT facilities, which are operated by the NCWCD. The city also holds decreed exchange rights which, in effect, allow the trade of CBT and Windy Gap water in Boulder Reservoir, water in Baseline Reservoir, and water from some irrigation ditches for Boulder Creek basin water high in the mountains. The city's water rights located on main Boulder Creek are either used by exchange or are carried to Boulder Reservoir through Farmers Ditch. Additionally, in droughts or emergencies, the city can draw on water rights that have been dedicated for use in most years for instream flow purposes. The city's municipal water rights portfolio is summarized in Table 4-5 through Table 4-10.

There are many different court decrees associated with the city's water rights. These include original decrees issued to the city, original ditch company decrees and change decrees obtained by the city for water rights represented by shares it acquired in ditch companies. A description of the city's municipal water rights including copies of relevant decrees is included in the Appendices.

4.3.1.1 | DIRECT FLOW RIGHTS

The city's most senior direct flow municipal rights, amounting to about 45 cfs if all were in full priority, are derived from shares in irrigation ditches located in the Boulder Valley (e.g. Anderson, Farmers, Harden, Smith & Goss, and McCarty). The city purchased shares from prior agricultural water users, changed the water rights to municipal use, and moved the diversion points upstream to the city's facilities on Middle and North Boulder Creeks. These changed irrigation rights may be used only during the irrigation season to reflect their original pattern of use.

The city also owns direct flow rights that were originally decreed for municipal use totaling about 86 cfs if all were in full priority at the same time. Since the original use of the rights was for municipal purposes, they have a history of year-round water use and can be taken at any time of year. However, they are decreed for direct use only and cannot be stored after diversion for later use. The city's most senior year-round direct flow water right is the Town of Boulder Ditch (6.2 cfs), which is normally in priority all winter. However, during low flow winter months, the physical supply in the creek is often the limiting factor on how much water can be diverted.

TABLE 4-5. MUNICIPAL DIRECT FLOW RIGHTS – BOULDER CREEK/NORTH BOULDER CREEK/ MIDDLE BOULDER CREEK[xii]

Water Right	Amount	Appropriation Date	Adjudication Date	Case No.
Anderson Ditch	3.50 cfs	10-01-1860	06-02-1882	8407 (1925 change)
Anderson Ditch	2.67 cfs	10-01-1860	06-02-1882	10518 (1942 change)
Anderson Ditch	5.83 cfs	10-01-1860	06-02-1882	15012 (1963 change)
Anderson Ditch*	1.81 cfs	10-01-1860	06-02-1882	W-7569, W-7570, W-8520 (1989 change)
Anderson Ditch*	0.59 cfs	10-01-1860	06-02-1882	90CW193
Boulder City Pipeline No. 3 (Barker Pipeline)	50.00 cfs	05-15-1956	03-04-1964 (12-07-1970 (18.0 cfs absolute) and 05-16-78 (11.5 cfs absolute) and 06-24-85 (20.5 cfs absolute))	14622, W-76, W-2358, 82CW83
Boulder City Pipeline, Headgates No. 1 and 2* (Lakewood Pipeline)	20.00 cfs	02-09-1904	11-03-1909	5563
Boulder City Pipeline, Headgate Nos.1, 2, and 3 (Lakewood and Silver Lake Pipelines)	10.00 cfs	12-31-1947	09-28-1953	12111
Farmers Ditch	5.57 cfs	10-01-1862	06-02-1882	8407 (1925 change)
Farmers Ditch	4.88 cfs	10-01-1862	06-02-1882	10518 (1942 change)
Farmers Ditch	4.14 cfs	10-01-1862	06-02-1882	15012 (1963 change)
Farmers Ditch*	13.52 cfs	10-01-1862	06-02-1882	W-7569, W-7570, W-8520 (1989 change)
Harden Ditch*	1.80 cfs	06-01-1862	06-02-1882	W-7569, W-7570, W-8520 (1989 change)
Howell Ditch 1 Enlargement∮	35.00 cfs	09-25-1979	12-31-1979	79CW363
Howell Ditch 1 Enlargement∮	2.00 cfs	09-25-1979	12-31-1979	79CW363
Lower Boulder Ditch∮	0.88 cfs	10-01-1859	06-02-1882	94CW284
Lower Boulder Ditch∮	4.31 cfs	06-01-1870	06-02-1882	94CW284
McCarty*	0.64 cfs	06-01-1862	06-02-1882	W-7569, W-7570, W-8520 (1989 change)
McCarty*	0.03 cfs	06-01-1862	06-02-1882	90CW193
North Boulder Farmers Ditch∮	1.23 cfs	06-01-1862	06-02-1882	94CW285
North Boulder Farmers Ditch∮	4.26 cfs	06-01-1863	06-02-1882	94CW285
Smith & Goss Ditch*	0.40 cfs	11-15-1859	06-02-1882	W-7570, 90CW193
Smith & Goss Ditch*	0.05 cfs	11-15-1859	06-02-1882	90CW193
Town of Boulder Ditch	6.19 cfs	06-17-1875	06-02-1882	10518 (1942 diversion point change)
Notes: * Rights conveyed to CWCB for instream flow subject to terms of city/CWCD agreement ∮ Conditional in whole or in part for city's use				

[xii] Individual water rights decrees are included in the Appendices.

4.3.1.2 | STORAGE RIGHTS

The city has storage rights on both North and Middle Boulder Creeks, in Boulder Reservoir, and (by virtue of ownership of shares in the Base Line Land and Reservoir Company) Baseline Reservoir. The North Boulder Creek storage rights, which amount to over 7,000 acre feet when fulfilled, are associated with Albion Lake, Goose Lake, Island Lake, the Green Lakes, and Silver Lake in the city-owned Silver Lake Watershed. These water rights are sufficiently senior to produce a fairly reliable source of supply. The city also owns conditional storage rights[xiii] for Park Reservoir, Wittemyer Ponds and Barker Reservoir.

In 1906, the city purchased Silver Lake and Island Lake from the Silver Lake Ditch and Reservoir Company, along with all associated water rights[178]. Water rights for the two reservoirs were applied for after the city's purchase and were adjudicated by the Boulder District Court in 1907. These rights included a storage right for Silver Lake Reservoir appropriated in 1887, a storage right for Island Lake appropriated in 1890, a storage refill right for Silver Lake Reservoir and a storage refill right for Island Lake Reservoir. Both refill rights carried an appropriation date of 1906[179]. Boulder later filed for and received decreed storage rights for expansions to Silver Lake Reservoir made by the city.

The city's Middle Boulder Creek storage rights are associated with Barker and Skyscraper reservoirs and amount to over 12,000 acre-feet of storage space. Although these storage rights are relatively junior, Barker Reservoir fills in most years because the city's exchange rights can be used for continued storage when the junior storage water rights are called out.

The city owns about 13 percent of the shares (75.938 shares) in the Base Line Land and Reservoir Company. Of the 75.938 shares, 68.265 shares have been changed to include, amongst other rights, exchange. The city uses Baseline Reservoir as a source of water for exchange to the upper Boulder Creek reservoirs and diversions points. When not needed for exchange, the Baseline water is leased to downstream farmers. The number of shares that have not been changed from the original irrigation decree is 7.611 shares. All of these shares are leased to farmers.

Some of the city's water rights that were originally acquired as shares in agricultural ditch companies have been changed through Water Court proceedings to allow both direct municipal water use and storage in the city's reservoirs for later use. These include the water rights in the city's most recent Water Court change cases for North Boulder Farmers Ditch, Lower Boulder Ditch, and Baseline Reservoir shares.

Conditional Water Storage Rights

The city owns the undeveloped Park Reservoir site located on the Caribou Creek tributary of North Boulder Creek, and holds a conditional storage right for the site. When the city purchased the site in the 1960's, it acquired title to the land and appropriated a 6,766.815 acre-foot conditional water right for storage in the proposed Park Reservoir[180]. The conditional water right was appropriated on October 11, 1960 for irrigation, domestic, mechanical, sanitary, fire protection, municipal, fish propagation, recreation, storage reserve, re-regulation, and multiple other uses[181]. Water sources for Park Reservoir include Caribou Creek, the south branch of North Boulder Creek, Horseshoe Creek,

[xiii] A conditional water right is a water right with a date held in the priority system but the water has not been put to beneficial use.

and an unnamed creek. In order to continue the existence of a conditional water right, it is necessary to obtain a finding by the Water Court every six years that the development of the necessary facilities and factors to make use of the conditional water right has proceeded with due diligence. This conditional right was most recently reviewed for due diligence by the Water Court in Case No. 99CW090 with continuation of the right for the next diligence period until March 31, 2010[182]. In 1993, in order to settle with an objector to a prior diligence case (Case No. 90CW49), the city agreed to reduce the amount of the conditional decree to 3,000 acre-feet.

The city acquired conditional water rights for the Wittemyer Ponds when it purchased the Wittemyer Ponds property[183]. Along with ownership of the property, the city acquired a one-half interest in the absolute direct flow water right for Howell Ditch, a conditional water right for storage in the Wittemyer Ponds and conditional direct flow rights for the Howell Ditch 1st Enlargement. The original direct flow right for the Howell Ditch is very senior, having been appropriated on December 1, 1859 for the amount of 47.55 cfs and designated as Priority No. 3 on Boulder Creek. However, the water right was later modified in Boulder District Court Case No. 10324 on February 17, 1941 to limit diversions into the ditch to no more than 5 cfs[184]. The remainder of the decree was found to be abandoned due to non-use. The conditional storage water right was appropriated in 1979 for 656.8 acre-feet for the five ponds (Case No. 79CW363). The conditional direct flow rights for the Howell Ditch 1st Enlargement were also decreed in this case for 37 cfs. The conditional water rights associated with the Wittemyer Ponds property have not been exercised and the steps required by the decree in order to use the rights have not been implemented. The ponds continue to exist as gravel pits completed prior to 1980 subject to exemption from augmentation requirements in accordance with state statutes[185]. The city intends to eventually line these gravel ponds to store reusable water.

Finally, the city appropriated conditional first-fill and refill rights for Barker Reservoir storage in 1999 while the city was negotiating the city's purchase of the facility. These rights are pending confirmation by the Water Court. If confirmed, the first-fill right would allow the city to store Middle Boulder Creek water in the additional 3,686 acre-feet of storage space in Barker Reservoir that the city acquired in 2001 and would allow the city to refill Barker Reservoir each year after its first fill was completed and space became available in the reservoir after use of some or all of the first-fill water by the city.

TABLE 4-6. MUNICIPAL STORAGE RIGHTS – BOULDER CREEK/NORTH BOULDER CREEK/MIDDLE BOULDER CREEK/SOUTH BOULDER CREEK[xiv]

Water Right	Amount	Appropriation Date	Adjudication Date	Case No.
Albion Lake	1,110.94 af	07-01-1910	06-21-1926	6672
Barker Meadow Reservoir	4,000 af	05-15-1956	03-04-1964 (12-07-1970 (828 af absolute) and 12-30-1975 (3,172 af absolute))	14622, W-77, W-2359
Barker Meadow Reservoir*	4,000 af	04-22-1966	12-31-1972 (12-30-1975 (2,000 af absolute) and 04-02-1980 (2,000 af absolute))	W-2361
Barker Meadow Reservoir∱	3,687 fill and 11,687 af -- refill	11-17-1999	Pending	99CW217
Baseline Reservoir (68.265 city shares)∱	2,929.9 af	11-04-1904	06-21-1926 (06-21-1926 (57 shares absolute))	6672, W-7852-74 (57 shares), 94CW284 (11.265 shares)
Baseline Reservoir (68.265 city shares)∱	1,671.68 af	11-29-1922	01-09-1935 (01-09-1935 (57 shares absolute))	6672, W-7852-74, 94CW284
Baseline Reservoir (68.265 city shares)∱	847 af	11-30-1935	09-28-1953 (09-28-1953 (57 shares absolute))	12111, W-7852-74, 94CW284
Baseline Reservoir Refill (68.265 city shares)∱	1,395 af	12-31-1929	09-28-1953 (09-28-1953 (57 shares absolute))	12111, W-7852-74, 94CW284
Goose Lake	198.50 af	10-01-1901	03-13-1907	4842
Goose Lake	261.20 af	09-03-1906	03-13-1907	4842
Goose Lake	576.60 af	09-03-1906	11-03-1909	5563
Green Lake No. 1	197 af	10-02-1906	06-21-1926 (183.3 af) and 9-28-1953 (14.07 af)	6672, 12111
Green Lake No. 2	332.68 af	10-02-1906	06-21-1926 (139.97 af) and 09-28-1953 (192.71 af)	6672, 12111
Green Lake No. 3	248.84 af	10-02-1906	06-21-1926	6672
Island Lake	371.80 af	07-15-1890	03-13-1907	4842
Island Lake Refill	371.80 af	09-03-1906	03-13-1907	4842
Lower Boulder Ditch (storage of city shares)∱	0.875 cfs (see decree for volumetric limits)	10-01-1859	06-02-1882	1282, 94CW284
Lower Boulder Ditch (storage of city shares)∱	4.31 cfs (see decree for volumetric limits)	06-01-1870	06-02-1882	1282, 94CW284
North Boulder Farmers Ditch (storage of city shares)∱	1.23 cfs (see decree for volumetric limits)	06-01-1862	06-02-1882	6582, 94CW285
North Boulder Farmers Ditch (storage of city shares)∱	4.26 cfs (see decree for volumetric limits)	06-01-1863	06-02-1882	6582, 94CW285

[xiv] Individual water rights decrees are included in the Appendices.

Water Right	Amount	Appropriation Date	Adjudication Date	Case No.
Park Reservoir∮	3000.00 af (reduced from 6766.815 af in 1993)	10-11-1960	03-04-1964	14622
Silver Lake Reservoir	807.30 af	09-23-1887	03-13-1907	4842
Silver Lake Reservoir	322.70 af	09-06-1928	09-28-1953	12111
Silver Lake Reservoir*	3,020.00 af	12-31-1941	09-28-1953 (03-03-1960 (1,181 af absolute) and 12-07-1970 (1,839 af absolute))	12111, W-75
Silver Lake Reservoir Refill	807.30 af	09-03-1906	03-13-1907	4842
Skyscraper Reservoir	146.40 af	07-24-1940	09-28-1953	12111
Wittemyer Pond No. 1∮	100.90 af	09-25-1979	12-31-1979	79CW363
Wittemyer Pond No. 2∮	194.60 af	09-25-1979	12-31-1979	79CW363
Wittemyer Pond No. 3∮	182.70 af	09-25-1979	12-31-1979	79CW363
Wittemyer Pond No. 4∮	80.70 af	09-25-1979	12-31-1979	79CW363
Wittemyer Pond No. 5∮	97.90 af	09-25-1979	12-31-1979	79CW363

Notes:
* Rights conveyed to CWCB for instream flow subject to terms of city/CWCD agreement

∮ Conditional in whole or in part for city's use

4.3.1.3 | EXCHANGE RIGHTS

Boulder owns several exchange water rights that allow the substitution of water delivered to Boulder Creek from one source for diversion of water from Boulder Creek at another location higher up in the basin on a one-to-one basis. The city can divert water by exchange into storage in its upper reservoirs or can divert water for direct use by exchange into the raw water pipelines feeding Betasso WTF. All of the city's most recent exchange rights have at least a portion that is still conditional and must be made absolute.

TABLE 4-7. MUNICIPAL EXCHANGE RIGHTS – BOULDER CREEK[xv]

Water Right	Amount	Appropriation Date	Adjudication Date	Case No.
Boulder Creek Exchange (CBT & Baseline Reservoir 57 shares)	250.00 cfs	12-31-1954	12-31-1974	W-7852-74, 86CW123, 88CW007
Boulder and Whiterock Internal Exchange	100 cfs	12-31-1954	12-31-1974	W-7852-74, 80SA102
Baseline Reservoir Exchange (11.265 shares)∮	50.00 cfs	12-30-1993	12-31-1994	94CW284
Lower Boulder Ditch Exchange (Boulder Creek Farms)∮	2.14 cfs	12-30-1993	12-31-1994	94CW284
Lower Boulder Ditch Exchange (Hummel)∮	3.05 cfs	07-19-1994	12-31-1994	94CW284
North Boulder Farmers Exchange∮	4.50 cfs	12-29-1994	12-31-1994	94CW285
Windy Gap Exchange	200.00 cfs	12-20-2000	12-31-2000	00CW226
Notes: ∮ Conditional in whole or in part for city's use				

4.3.1.4 | REUSE RIGHTS

Boulder's water rights change applications and new appropriations within the past two decades include the right to reuse a portion of the water remaining after the first use of the water. The reusable portion of the city's water can be delivered to downstream lessees or it can be exchanged for additional diversions into the city's municipal water system intakes or reservoirs. For reuse decrees with municipal use as the first use, municipal reuse is accomplished by exchanging wastewater effluent from the 75th Street WWTF that is attributable to the initial municipal use for additional upstream municipal diversions. The decreasing increment of reusable effluent attributable to the initial diversion can be tracked and accounted for through additional exchanges and uses until the water is fully-consumed and used to extinction. The city also can reuse a portion of the water that is first used for instream flow purposes under the city/CWCB instream flow decree. The fully-consumable portion of the instream flow water that is available to the city at the end of the instream flow reach in Boulder Creek at 75th Street is that amount of water that would be consumed through use within the municipal system if the water was used in the municipal system instead of for instream flow purposes. The city can either exchange this consumptive use amount back into the municipal system or can lease it for use downstream. Details of instream flow reuse are found in the Findings of Fact, Conclusions of Law, Judgment and Decree in Case No. 90CW193[186].

[xv] Individual water rights decrees are included in the Appendices.

TABLE 4-8. REUSE RIGHTS – BOULDER CREEK[xvi]

Water Right	Amount	Appropriation Date	Adjudication Date	Case No.
North Boulder Farmers Reuse∮	1.23 cfs	06-01-1862	12-31-1994	94CW285
North Boulder Farmers Reuse∮	4.26 cfs	06-01-1863	12-31-1994	94CW285
Lower Boulder Ditch Reuse (Boulder Creek Farms)∮	3.355 cfs	10-01-1859 (0.875 cfs) and 06-1-1870 (2.48 cfs)	12-31-1994	94CW284
Lower Boulder Ditch Reuse (Hummel)∮	1.83 cfs	06-01-1870	12-31-1994	94CW284
Barker Reservoir∮	3,687 af fill, 11,687 af refill	11-17-1999	Pending	99CW217
Baseline Reservoir (11.265 shares)∮	59.5 af	11-04-1904	12-31-1994	94CW284
Baseline Reservoir (11.265 shares)∮	34.0 af	11-29-1922	12-31-1994	94CW284
Baseline Reservoir (11.265 shares)∮	17.2 af	11-30-1935	12-31-1994	94CW284
Baseline Reservoir Refill (11.265shares)∮	28.3 af	12-31-1929	12-31-1994	94CW284
Instream Flow Smith & Goss Anderson Harden McCarty Farmers Silver Lake Reservoir Refill Silver Lake Reservoir Silver Lake Reservoir Barker Meadow Reservoir Barker Meadow Reservoir Boulder City Pipeline	Historically consumed amounts up to 15 cfs from the various water rights	 11-15-1859 10-01-1860 06-01-1862 06-01-1862 10-01-1862 09-03-1906 09-06-1928 12-31-1941 05-15-1956 04-22-1966 02-09-1904	12-31-1990	90CW193
Notes: ∮ Conditional in whole or in part for city use				

4.3.1.5 | HYDROPOWER RIGHTS

When the city purchased the Boulder Canyon Hydroelectric Project from PSCo in 2001[187], it also acquired the associated hydropower water rights. The rights were owned by the predecessors of PSCo, the Eastern Colorado Power Company followed by the Colorado Power Company, when they were originally decreed and made absolute.

TABLE 4-9. SUMMARY OF BOULDER CANYON HYDROELECTRIC PROJECT WATER RIGHTS[xvii]

Water Right	Amount	Appropriation Date	Original Adjudication Date	Made Absolute Adjudication Date	Case No.
Boulder Power Pipeline (Barker)	50.00 cfs	09-09-1905	11-03-1909	08-30-1920	5563
Barker Meadow Reservoir	11,686.6 af	12-18-1906	11-03-1909	08-30-1920	5563
Barker Meadow Reservoir Refill	3,163 af	12-31-1929	09-28-1953	09-28-1953	12111
Kossler Reservoir	128.9 af	11-17-1906	11-03-1909	08-30-1920	5563

[xvi] Individual water rights decrees are included in the Appendices.
[xvii] Individual water rights decrees are included in the Appendices.

The city can also use any of its municipally decreed water rights to generate hydropower because that use is one of the types of specific uses included within the more general municipal use designation.

4.3.2 | WATER CONTRACTS

Boulder Reservoir can be filled with water from the CBT Project and the Windy Gap Project. Boulder is also entitled to a portion of the water derived from an agreement between NCWCD and the Left Hand Water District known as the "20 percent water"[188]. In addition, Farmers' Ditch water associated with some of the city's share ownership in the ditch company can be carried through the reservoir for direct use at the Boulder Reservoir WTF at times when the water is not needed by the CWCB to provide instream flows in Boulder Creek.

4.3.2.1 | WESTERN SLOPE WATER

Western slope water is derived from the CBT and Windy Gap projects, the histories of which are described in section 3.4.9.2. The city has contractual agreements to receive delivery of this water to Boulder Reservoir.

TABLE 4-10. MUNICIPAL WESTERN SLOPE WATER DELIVERED AT BOULDER RESERVOIR

Water Right	Amount
Colorado-Big Thompson	21,015 units
Windy Gap	37 units

City Open Space and Mountain Parks also holds CBT units that are used for irrigation of Open Space lands.

Colorado-Big Thompson Project Water

The CBT Project collects and stores the water of the upper Colorado River for subsequent delivery to water users in northeast Colorado. The majority of CBT Project facilities and all of its water rights are owned by Reclamation, which built the project. The remainder of the facilities is owned by NCWCD which operates the project. NCWCD delivers CBT water to the entities with which it has water delivery contracts, called allottees, or to lessees of the allottees.

CBT facilities located west of the Continental Divide include Willow Creek and Shadow Mountain Reservoirs, Grand Lake and Lake Granby. The water is pumped into Shadow Mountain Reservoir where it flows by gravity into Grand Lake. From there, the 13.1 mile Alva B. Adams Tunnel transports the water under the divide to the East Slope[189].

Once the water reaches the East Slope, it is used to generate electricity as it falls almost half a mile through five power plants on its way to Colorado's Front Range. Carter Lake, Horsetooth Reservoir and Boulder Reservoir store the water. CBT water is released as needed to supplement native water supplies in the South Platte River basin. The CBT Project delivers on average 213,000 acre feet of water annually to northeastern Colorado for agricultural, municipal and industrial uses.

Carter Lake is the main reservoir feeding the southern end of the CBT system. Carter Lake water is delivered to cities and agricultural users in Boulder, Larimer, Weld and Broomfield Counties. Water from Carter Lake is carried to Boulder Reservoir through the St. Vrain Feeder Canal and the Boulder Feeder Canal. The two canals comprise a part of the 98-mile network of canals within the CBT

Project[190]. Although officially designated as two separately named canals, the entire reach from Carter Lake to Boulder Reservoir is often referred to just by the name Boulder Feeder Canal. CBT project facilities are shown in Figure 4-17.

NCWCD allottees own units of the CBT Project which entitle them to water deliveries based on the quota set by the NCWCD Board every year. Boulder owns 21,015 municipal class[xviii] units out of 315,000 units in the CBT project. The city's CBT water can be used for municipal purposes directly through treatment at the Boulder Reservoir WTF or as a source of exchange water for Boulder's exchange rights on Boulder Creek. Boulder also leases CBT water to agricultural users on Boulder Creek below the Boulder Supply Canal outlet. CBT water is limited to a single use, so there is no opportunity for reuse of this water by the city.

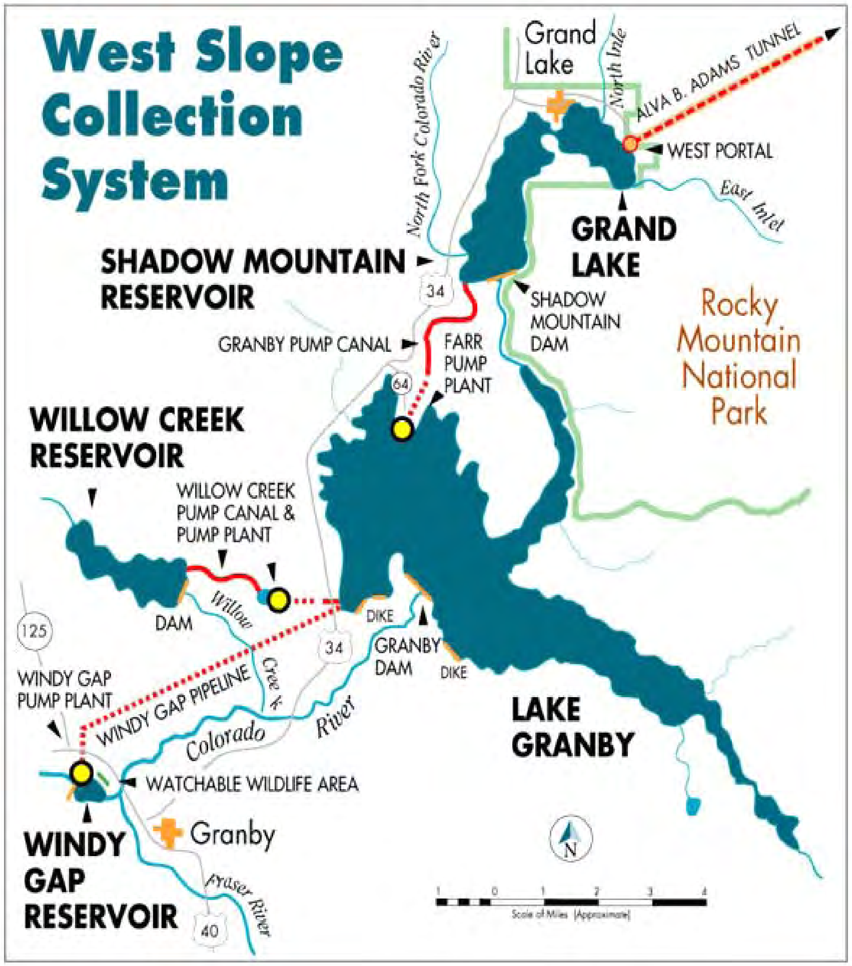
Windy Gap Project Water

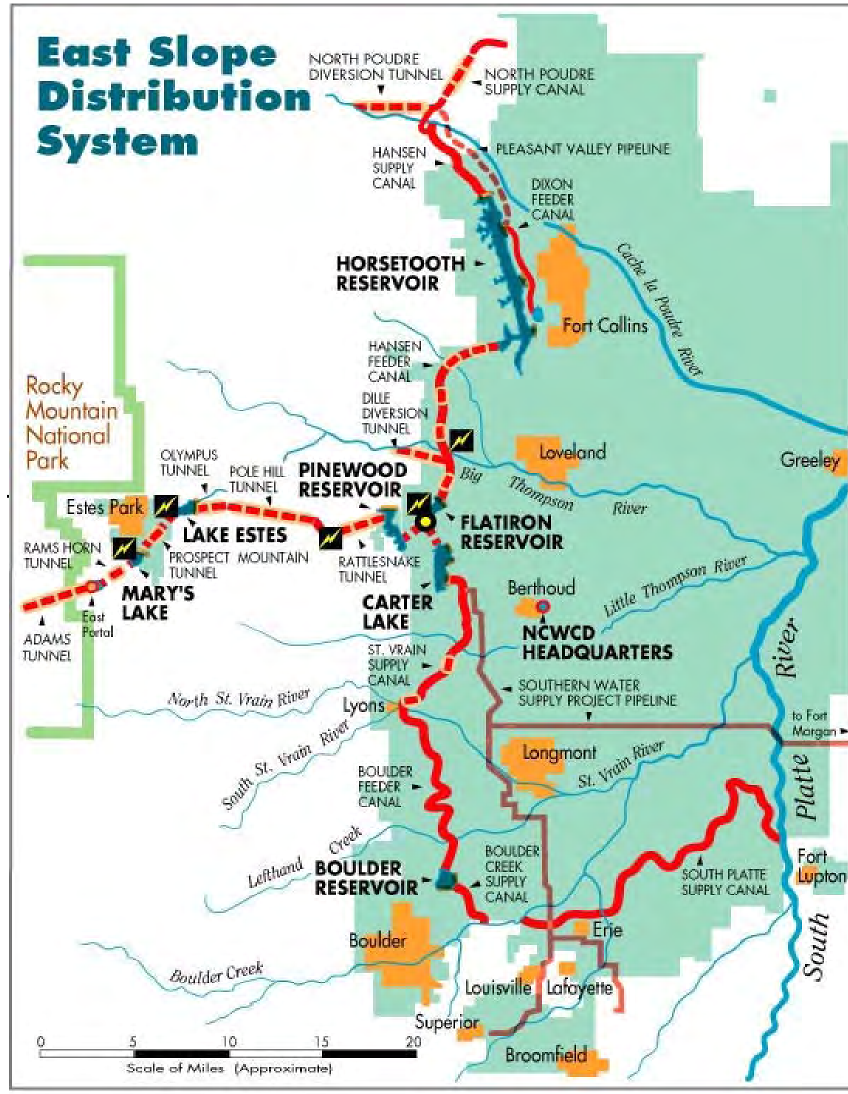
Windy Gap Reservoir is located just west of the Town of Granby on Colorado's West Slope. The Windy Gap Project consists of a diversion dam on the Colorado River that creates the 445-foot Windy Gap Reservoir, a pumping plant, and a six-mile pipeline to Lake Granby. The system was anticipated to deliver an average of 48,000 acre-feet of water annually, diverted primarily during the spring runoff season. During the high flow periods of the spring runoff season between April and July on the Colorado and Fraser Rivers, water is pumped from Windy Gap Reservoir to Lake Granby, where it is stored for delivery through the CBT Project facilities to water users on the Front Range. Construction of the project began in 1981 and the facilities became operational in the spring of 1985[191].

The Windy Gap Project is operated by the Municipal Subdistrict of NCWCD. Each participant in the project has entered into a water allotment contract that provides for participants to annually receive their proportional share of Windy Gap water. There are 480 units in the project and Boulder owns 37 units. Every unit can provide up to 100 acre-feet of water annually or 1/480 of the annual average yield produced, whichever is less. Each water allotment contract requires participants to make annual payments equal to the corresponding share of the costs related to the Subdistrict's acquisition of water rights, and operation, maintenance and replacement of Windy Gap Project features, as well as carriage charges to the NCWCD and Reclamation for using the CBT Project facilities for storing and delivering Windy Gap water. Bonds were sold by the Municipal Subdistrict for the initial financing of the project and are expected to be paid off by 2017[192]. Boulder's actual costs through 2008 for its portion of the Windy Gap Project are approximately $18,563,000 (present worth $28,794,000 in 2008 dollars). At final payoff in 2017, Boulder's actual costs will total $25,488,000 (present worth $34,643,000 in 2008 dollars).

[xviii] CBT units are categorized into classes based on type of use. The city also owns agricultural class CBT units that are held by the Open Space and Mountain Parks Department for irrigation purposes. NCWCD policies dictate that agricultural class units cannot be used for municipal water supply purposes on an on-going basis without undergoing a process to change the class and paying additional assessments. However, municipal class units can be used for agricultural purposes.

FIGURE 4-17 .COLORADO-BIG THOMPSON PROJECT FACILITIES[193]





With Subdistrict Board approval, participants may transfer all or part of their water allotment to another entity within the Subdistrict. In 1975, the Platte River Power Authority acquired one-half of the Loveland and Estes Park allotments as well as all of the water designated for Fort Collins. Five additional water suppliers have since become Windy Gap Project participants. Broomfield purchased 43 of Boulders units and Louisville, Superior, the Left Hand Water District, and the Central Weld County Water District have also acquired allotments.

A benefit to Subdistrict allottees is that allotment contract holders are allowed to totally consume their Windy Gap water. Allottees can use and reuse Windy Gap water because it is imported water that is not native to the South Platte Basin. After first use within Subdistrict boundaries, participants may lease, transfer or sell the reuse or successive use rights for use within or outside Subdistrict boundaries.

The Windy Gap water is subordinate to CBT water in the CBT system, so it is possible that the Windy Gap water stored in the system can be spilled to make room for CBT water. It is also possible that the Windy Gap Project water rights may yield very little in dry years because they are junior to many other water rights. Achieving the anticipated maximum annual project yield of 100 acre-feet per unit of the Windy Gap Project depends on the ability to either "borrow" against the CBT project or have storage available outside the CBT system for use in those years when all storage in the CBT system is filled with CBT water. Boulder does not presently plan to participate in any reservoir construction projects to firm the city's Windy Gap units, but rather plans to use storage space in Barker and Boulder Reservoirs for this purpose. The city has obtained a water decree allowing use of Windy Gap water by exchange into the city's municipal system.

4.3.2.2 | LEFT HAND "20 PERCENT WATER"

NCWCD has an agreement with Left Hand Ditch Company allowing Left Hand to divert water from Left Hand Creek into the Boulder Feeder Canal in exchange for CBT water to be taken by Left Hand at an upstream point later in the year. In effect, Left Hand Creek water is being stored in Boulder Reservoir.

In return for providing storage space, each year the city receives 20 percent of the difference between the amount of water provided by Left Hand and the amount of water delivered to Left Hand by NCWCD. The "20 percent water" is accounted for as being the first water used by the city out of Boulder Reservoir every year prior to the city's use of any CBT water[194].

The total water deliverable by the District to Left Hand Ditch Company during a water year is determined as shown in Table 4-11.

TABLE 4-11. DETERMINATION OF NCWCD DELIVERIES TO LEFT HAND DITCH COMPANY

Water diverted from Left Hand Creek to Boulder Feeder Canal (acre-feet)	Percentage of diverted water deliverable to Left Hand Ditch Company
500 or less	65
501 to 1000	60
1001 to 3000	50
Over 3000	45

Any water made available to Left Hand Ditch Company that remains undelivered as of November 1 of each year is turned over to NCWCD to become part of the CBT water supply.

4.3.2.3 | MUNICIPAL USE OF INSTREAM FLOW WATER

The city entered into agreements with the Colorado Water Conservation Board (CWCB)[xix] in 1990 and 1992 to convey certain senior water rights and to provide use of water derived from specified city-owned direct-flow and storage water rights to maintain streamflow levels in North Boulder and main Boulder Creeks. The conveyed water rights were derived from shares the city owns in ditch companies including Farmers Ditch, Anderson Ditch, Smith and Goss Ditch, McCarty Ditch, and Harden Ditch. Most of the conveyed water rights had previously been changed to allow municipal use, but a portion of these water rights was still decreed for the original agricultural use. All of the water and water rights were taken through a Water Court proceeding that resulted in a decree allowing both municipal and instream flow use of the water and water rights[195]. These shares are included in Table 4-5 and Table 4-6 above.

The city can use the conveyed water rights for municipal needs when they are not needed to maintain instream flow levels. In addition, the city has the right to use, reuse, or lease the portion of the water derived from the conveyed water rights that would be consumed by the city if the water was used for municipal use instead of instream flow use once that water reaches the downstream end of the specific instream flow reach and has served its instream flow purpose[196].

Under the city/CWCB agreements, the city may interrupt delivery for instream flow purposes of water derived from the city-owned water rights and may use the conveyed water rights for municipal purposes in the event of extraordinary drought or emergency conditions. The city exercised this right of interruption during the drought year of 2002 and used the conveyed water rights to meet municipal needs.

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[1] Contract between John Brierley and Town of Boulder. (1887). *For lands for Reservoir dated April 8, 1875* [Reception No. 80093389]. Boulder, CO: Boulder County Clerk Book 93 Page 389; ***and*** Quitclaim Deed from John Brierley to the Town of Boulder. (1875). *In consideration of the sum of fifty dollars for real estate dated April 8, 1875* [Reception No. 80030357]. Boulder County, CO: Boulder County Clerk Book 30 Page 357; ***and*** Quitclaim Deed from John Brierley to the Town of Boulder. (1876). *In consideration of the sum of fifteen dollars for strip of land dated May 9, 1876* [Reception No. 80039097]. Boulder County, CO: Boulder County Clerk Book 39 Page 97.

[2] Fred A. Fair Engineering Association. (1919). *Report to E.O. Heinrich, City Manager, on the water rights of the City of Boulder, Colo. in comparison with the physical facts that affect them*. Boulder, CO: City of Boulder. Report, 1.

[3] Fred A. Fair Engineering Association. *op. cit.*, Exhibit B: Book 2, page 142 City Council minutes dated May 13, 1878; ***and*** Quitclaim Deed from John Ryan to the Town of Boulder. (1878). *In consideration of the sum of three hundred dollars for real estate dated May 14, 1878* [Reception No.80045559]. Boulder County, CO: Boulder County Clerk Book 45 Page 559.

[4] Fred A. Fair Engineering Association. *op. cit.*, Book2, Page 149 City Council minutes dated June 20, 1878.

[5] Deed from John Brierley to City of Boulder. (1890). *Regarding the condemnation of a tract of land for the purpose of the construction, maintenance, and operation of the work for the enlargement and improvement of the water works of the City of Boulder dated July 21, 1890* [Reception no. 80138011]. Boulder, CO: Boulder County Clerk, Book 138 Page 11; ***and*** Lis Pendens John Brierley vs. City of Boulder. (1890). *To obtain condemnation of a tract of land by right of imminent domain for the purpose of the construction, maintenance, and operation of the work of the enlargement and improvement of the water works section of the City of Boulder dated July 11, 1890* [Reception No. 800130579]. Boulder, CO: Boulder County Clerk Book 130 Page 576.

[6] Fred A. Fair Engineering Association. *op. cit.*, Report 4.

[7] Warranty Deed from Clint J. Maxwell to City of Boulder. (1904). *In consideration of the sum of $15,000 for Goose Lake land and water storage dated February 16, 1904* [Reception No. 90033072]. Boulder, CO: Boulder County Clerk, Book 279 Page 416.

[8] Warranty Deed from J.P. Maxwell to the City of Boulder. (1906). *In consideration of the sum of $12,000 dated January 15, 1906*. Boulder County, CO: Boulder County Clerk, Book 304 Page 279; ***and*** Deed from The Silver Lake Ditch and Reservoir Company to City of Boulder. (1906). *In consideration of the sum of $34,000 dated January 15, 1906*. Boulder County, CO: Boulder County Clerk, Book 296 Page 104.

[xix] Under Colorado law, the CWCB is the only entity that can use water that is specifically decreed for non-recreational instream flow purposes.

[9] An Act to grant certain lands to the City of Boulder, Colo (Public No. 185), H. R. 22599, 59th Cong., 2nd Sess., Ch. 2526. (1907).
[10] An Act authorizing the City of Boulder, Colorado, to purchase certain public lands (Public No. 55), H.R. 6410, 66th Cong., 1st Sess., Ch. 67. (1919).
[11] An Act authorizing the City of Boulder, Colorado, to purchase certain public lands (Public No.786), H.R. 10467, 69th Cong., 2nd Sess., Ch. 492. (1927).
[12] Grant from the United States of America to City of Boulder of certain public lands authorized by an Act of *Congress (Public No. 185), H. R. 22599, 59th Cong., 2nd Sess., Ch. 2526. (1907)*. Signed June 15, 1908; and Grant from the United States of America to City of Boulder of certain public lands authorized by an Act of *Congress (Public No. 55), H.R. 6410, 66th Cong., 1st Sess., Ch. 67. (1919)*. Signed June 18, 1920. Patent no. 757998; and Grant from the United States of America to City of Boulder of certain public lands authorized by an Act of *Congress (Public No.786), H.R. 10467, 69th Cong., 2nd Sess., Ch. 492. (1927)*. Signed July 23, 1929. Patent no. 1029632.
[13] City of Boulder. (1967). *Memorandum from Assistant City Attorney: Regarding Park Reservoir water rights to City Attorney dated June 19, 1967*. Boulder, CO: Boulder City Clerk; ***and*** Nelson, Haley, Patterson, and Quirk, Inc. (1967). *Report on Park Reservoir and dam site, Boulder County, Colorado dated September 1967*. Greeley, CO.
[14] State of Colorado Boulder County District Court. (1970). *Judgment: In the matter of Park Reservoir site condemnation* [Civil Action No. 22279]. Boulder, CO: Clerk of District Court.
[15] Alden, H.R. *et al*. (1972). *Potential impact of the proposed Park Reservoir on the environment. A report prepared for the City of Boulder Water Utility*. Boulder, CO: Boulder City Clerk.
[16] Warranty Deed from T.N. Barnsdall to City of Boulder (1906). *In consideration of the use of water for power purposes per contract dated July 18, 1906*. Boulder County, CO: Boulder County Clerk, Book 306 Page 46; ***and*** R.J. Tipton Associated Engineers, Inc. & Phillips-Carter-Osborn, Inc. Engineers. (1957). *Compilation of reports concerning long range program of development of water resources and water supply*. Denver, CO, 2.
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Chapter 5

5 | WATER USE, AVAILABILITY AND QUALITY

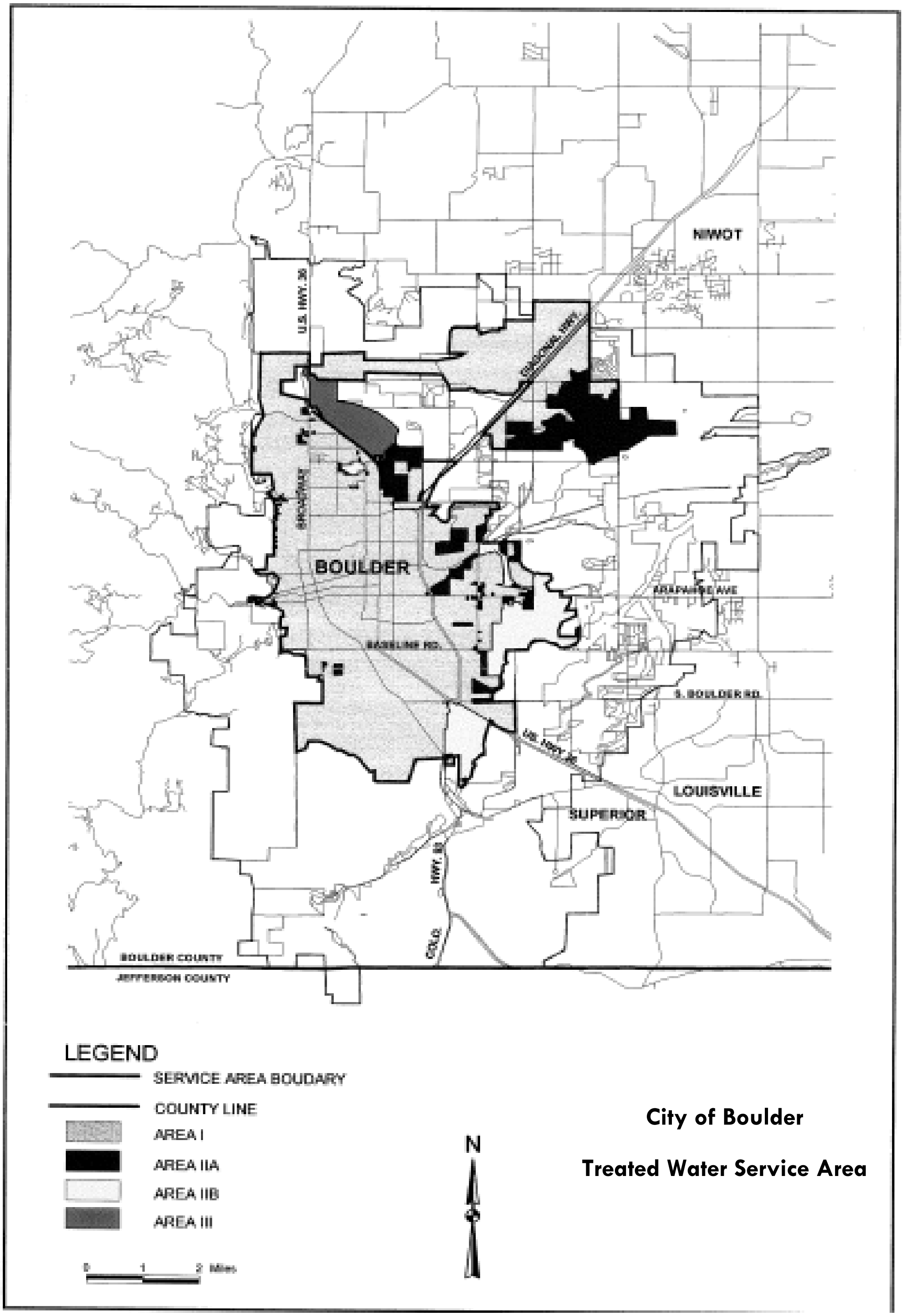
5.1 | Water Use

5.1.1 | TREATED WATER USE

Boulder presently provides treated water service to about 113,000 people residing within the city limits and outside the city in areas included in the Boulder Valley Comprehensive Plan (BVCP) area.[1] The service area consists of approximately 26 square miles, including all of the area within the city limits and certain adjacent areas such as Gunbarrel, as shown in Figure 5-1. In addition, the city provides water service to area employers with about 100,000 employees, 50,000 of whom commute into the city from other areas[2]. In 2007, the city served 21,597 single family accounts, 2,489 multi-family accounts, 2,067 commercial and industrial accounts, and 1,533 irrigation accounts[3]. The average annual water use for Boulder since 2002 has been about 20,000 acre feet[4]. According to 2008 estimates by the city of Boulder and the Denver Regional Council of Governments (DRCOG), the projected build-out population for the city's water service area is 129,600 people and the projected number of employees at build-out for the area is 166,000[5].

Information on characteristics of Boulder's water use patterns was compiled as part of the Water Conservation Futures Study in 2000[6]. Current information on actual water deliveries is tracked on a daily basis. AMEC Earth and Environmental, Inc. (AMEC, previously Hydrosphere), a water resources engineering consultant for the city, has used this information to produce annual tracking statistics on key data such as peak-day to average-day use ratio. In addition, a great deal of information on Boulder's past water use exists in prior studies. Much of this information is summarized below.

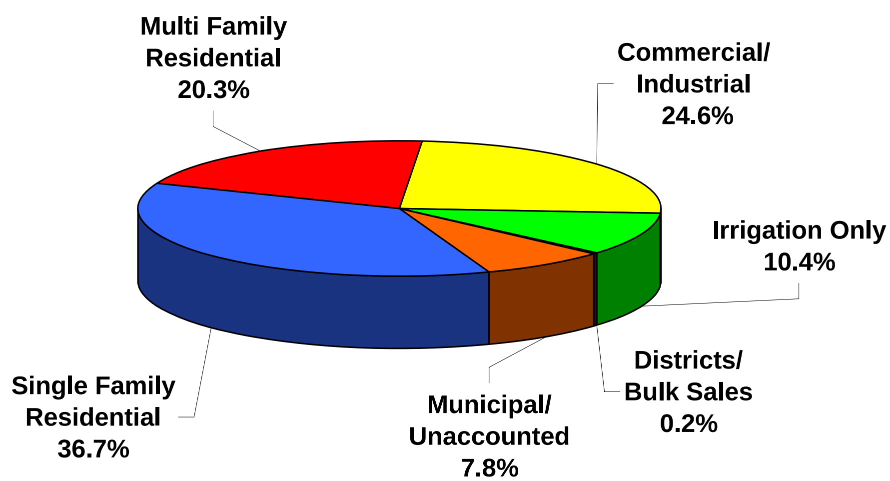
FIGURE 5-1. CITY OF BOULDER TREATED WATER SERVICE AREA[7]



5.1.1.1 | CURRENT TREATED WATER USE PATTERNS

Within Boulder's service area, the residential sector (both single and multi-family) consumes the largest amount of water, using 57.0 percent of the total in 2007as shown in Figure 5-2. The commercial, industrial, and institutional sectors use 24.6 percent of the total. Some of the city's largest individual water customers are in this sector, including a number of water-intensive industries such as bio-chemical firms like Roche and others. About 10.4 percent of the city's water is delivered to irrigation only accounts, such as for irrigation of common areas at condominium complexes and business parks. Boulder sells about 0.2 percent of its water in bulk to several small water districts outside the city limits and to entities that use water trucks such as water hauling and construction businesses. Approximately 7.8 percent of the treated water is delivered for use in the municipal sector, which includes park irrigation, recreation centers, street median irrigation, public swimming pools, and all city buildings, or is unaccounted use or system losses (such as fire protection, leaks, or main breaks)[8].

FIGURE 5-2. BOULDER'S 2007 WATER USE BY TYPE (%)[9]



Over the course of a normal non-drought year, about two-thirds of the water used in Boulder is for indoor purposes and about one-third is for outdoor use as shown in Figure 5-3. The percentage of the total that is for indoor use has shown a slight upward trend over the past several decades as shown in Figure 5-4[10]. The majority of outdoor use is for lawn irrigation. Based upon data collected for the Metropolitan Water Supply Investigation conducted by the Colorado Water Conservation Board (CWCB), the percentage of water used for irrigation in Boulder is less than in other cities in the region (personal communication, Lee Rozaklis, January 2009). This difference likely occurs because Boulder is an older city with smaller residential lots, many multi-family units and a compact urban form.

FIGURE 5-3. COMPARISON OF INDOOR AND OUTDOOR USE[11]

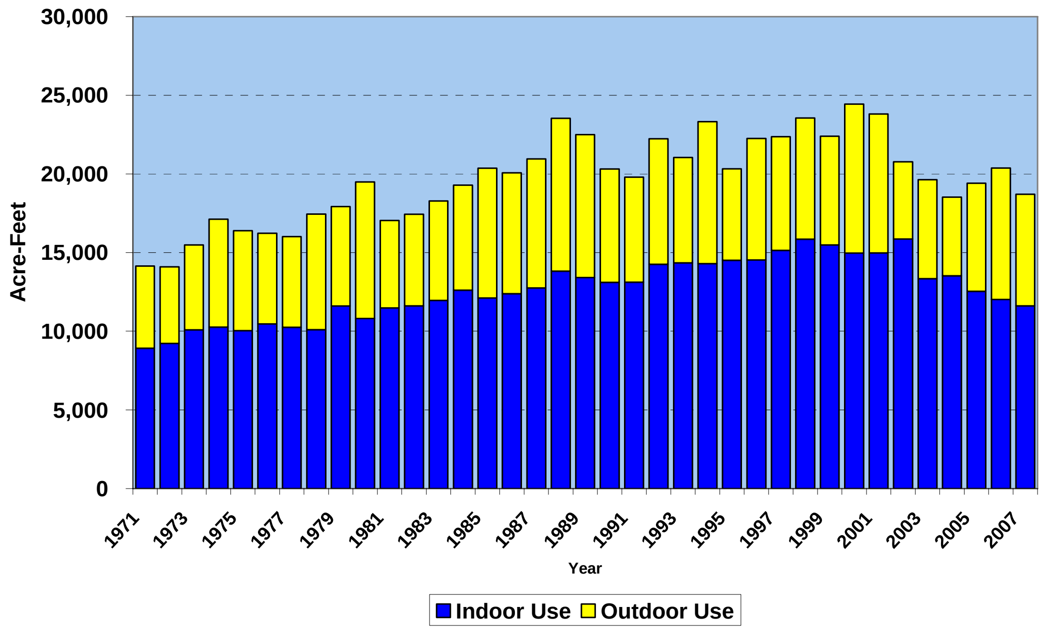
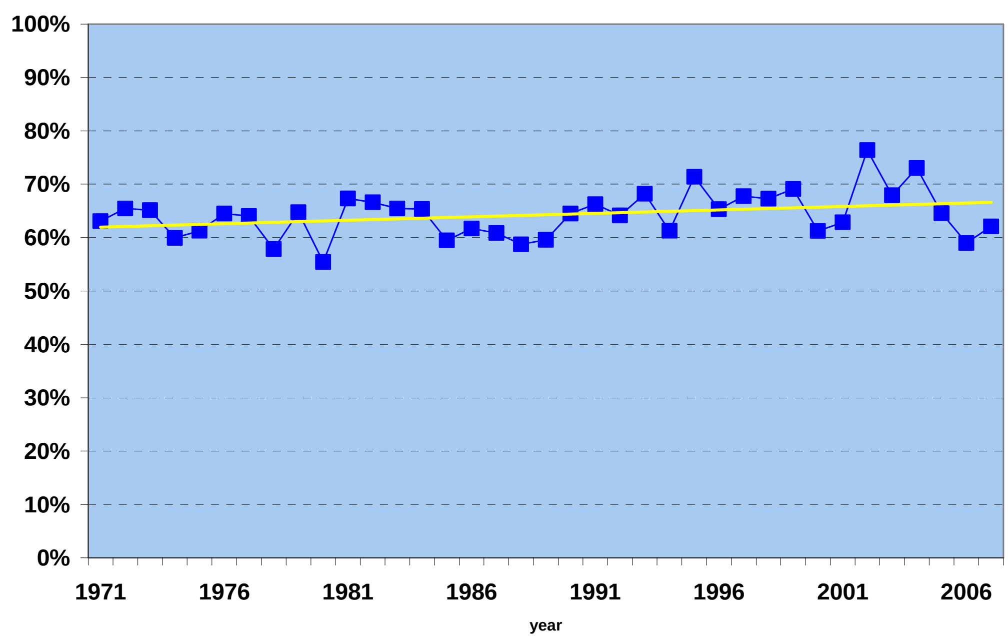


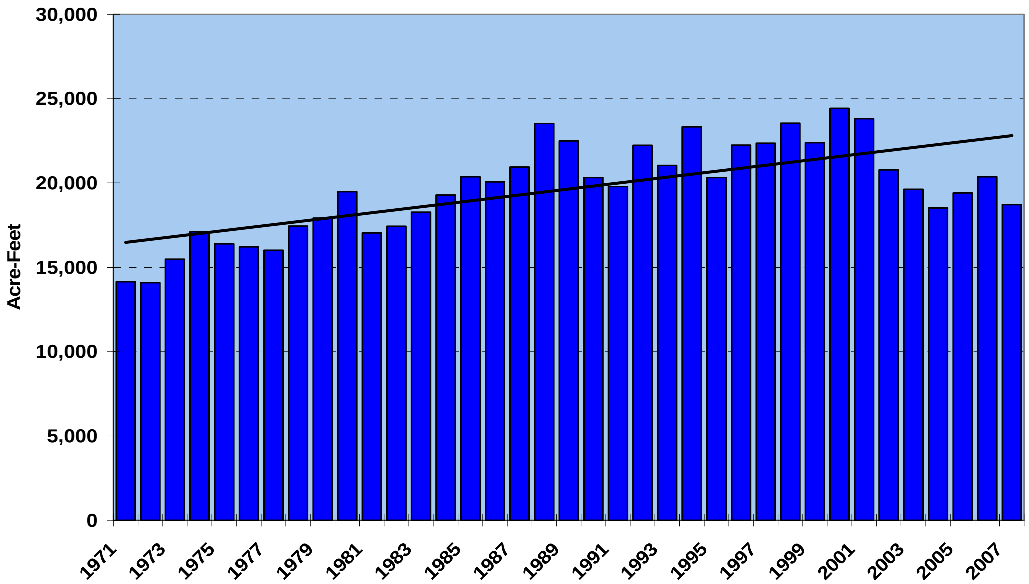
FIGURE 5-4. INDOOR USE AS A PERCENTAGE OF TOTAL WATER USE[12]



In the commercial, industrial, and institutional sector, about 63 percent of the water is used indoors and 37 percent outdoors. In the municipal water use sector over 85 percent of water use is for outdoor purposes, such as park and street median irrigation[13].

Current total water use in the city is lower than 1990s levels, having increased from 1995 to 2001 and then decreased following the 2002 drought year as shown in Figure 5-5. The overall trend since the 1970s for total indoor and outdoor water uses in the city has been upward despite the significant reduction in overall water use of the past few years[14].

FIGURE 5-5. BOULDER'S TOTAL TREATED WATER USE, 1971-2007[15]



Although summer irrigation use can vary greatly from year to year based on weather, winter water consumption in the city in the past few years has consistently been lower than pre-drought levels. This indicates that permanent structural changes may have been made throughout the city since the drought, such as homeowners installing low-flow toilets or showerheads. If so, then the lower water use levels are likely to continue, and the upward trend for indoor water use shown in Figure 5-6 may be broken or stalled[16].

Outdoor water use decreased in 2002, but then has increased in the past few years as shown in Figure 5-7, although it remains below pre-drought levels. Some permanent changes in outdoor use may have occurred since 2002 through repair or replacement of leaky irrigation systems and xeriscaping. Much of the outdoor use reduction could be a residual effect of the water use education efforts during and since the 2002 drought. The upward trend for outdoor use could resume as new residents move into the city who have not experienced a drought year or residents return to old irrigation habits. Any movement toward an upward trend might be offset by the recent implementation of the city's water budget rate structure.

FIGURE 5-6. BOULDER'S TOTAL INDOOR USE, 1971-2007[17]

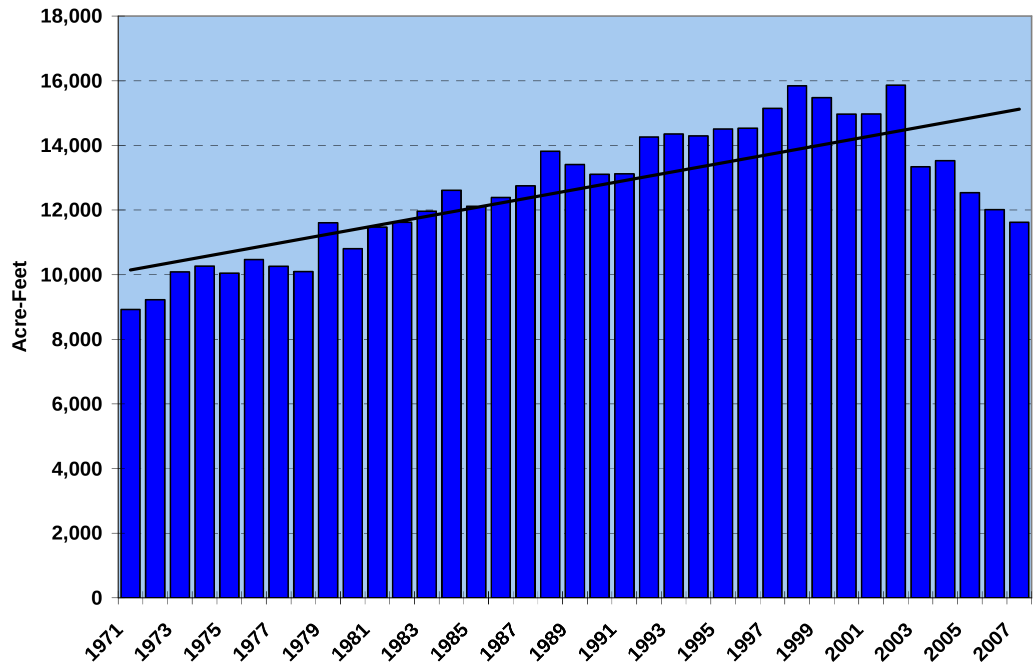
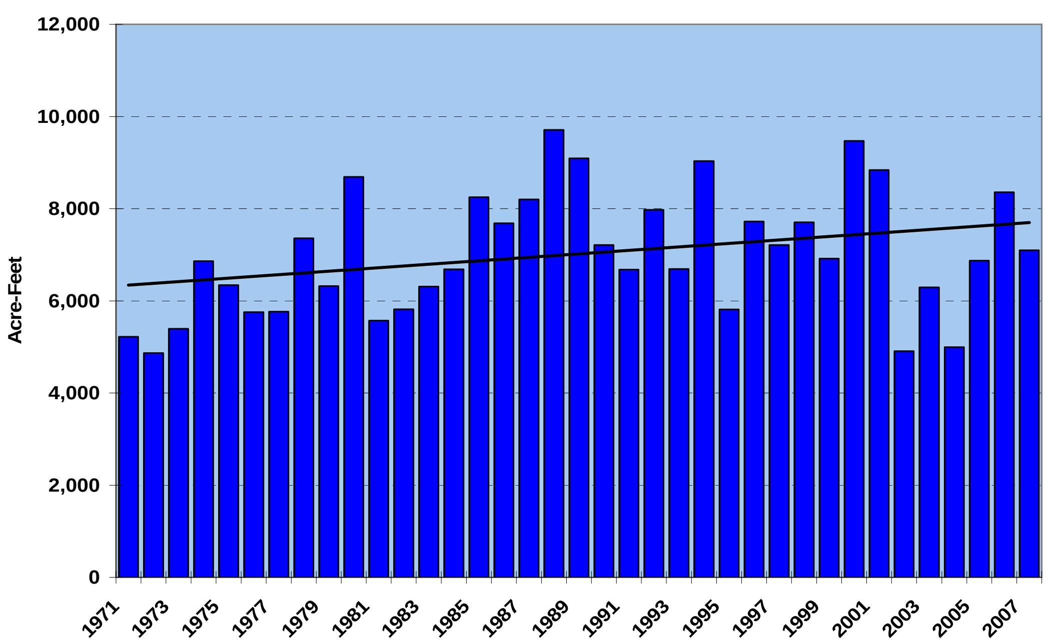


FIGURE 5-7. BOULDER'S TOTAL OUTDOOR USE, 1971 - 2007[18]



5.1.1.2 | CURRENT TREATED WATER USE AMOUNTS

Overall annual demand in 2007 was more than 20 percent less than the highest water use years of 2000 and 2001 as shown in Figure 5-8. Total annual treated water deliveries were 18,621 acre-feet in 2007, 20,311 acre-feet in 2006 and 19,408 acre-feet in 2005 as shown in Figure 5-9. In every year since 2002, less treated water was delivered than was delivered in 2002 (20,773 acre-feet) when drought restrictions limited use in the city. In 2001, before the drought, 23,466 acre-feet were delivered out of the treatment plants[19].

FIGURE 5-8. COMPARISON OF RECENT USE WITH PRE-2002 DROUGHT USE[20]

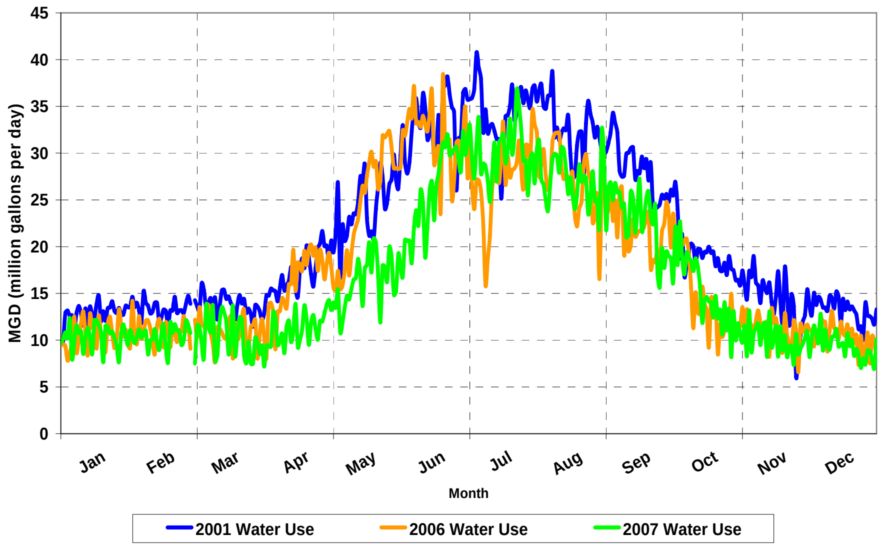
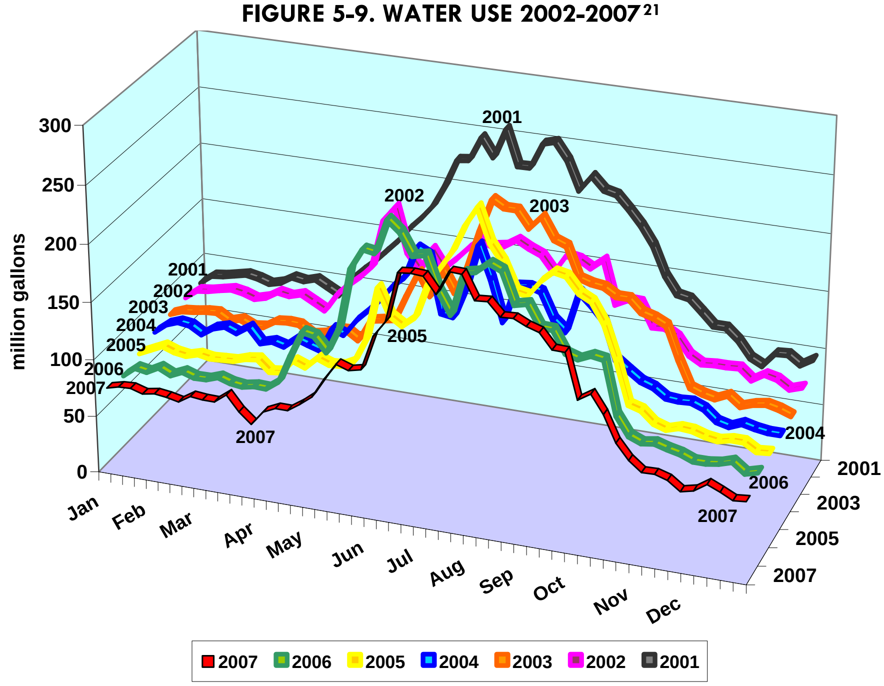


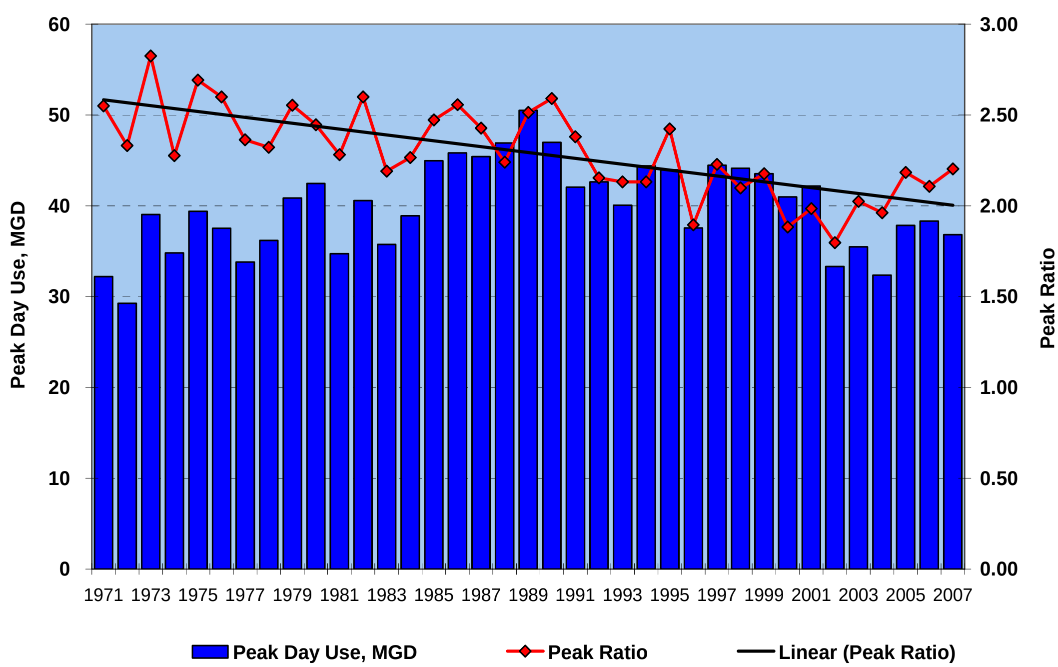
FIGURE 5-9. WATER USE 2002-2007[21]



Peak day water use is the maximum water demand on any one day during a year. The peak day usually occurs in mid-summer. The peak ratio is the ratio between the peak day use and the average day use. A high peak ratio indicates significant irrigation water use compared to other uses that are more constant throughout the year.

Boulder's peak day water use has trended downward since 1990 as shown in Figure 5-10. A change in the peak day use value indicates that the relation between amounts of indoor and outdoor use has changed as viewed against the background of any overall change in water deliveries. A decrease in the peak day value could occur either because relative amounts of outdoor water use decreased or indoor water use increased. In Boulder's case, both occurred prior to 2002. The decreased outdoor use might be due to a reduction in total irrigated area or may reflect more efficient irrigation practices such as watering lawns early in the morning or at night. More efficient irrigation use may have occurred due to water use education from the city's water conservation program, increased use of xeriscaping, or replacement of leaky irrigation systems. Boulder's peak ratio has been trending downward for decades despite overall increases in both indoor and outdoor total treated water deliveries. However, the notable increase in the ratio since 2002 is attributable to significantly reduced indoor water use as compared to the constantly increasing indoor use prior to the drought year.

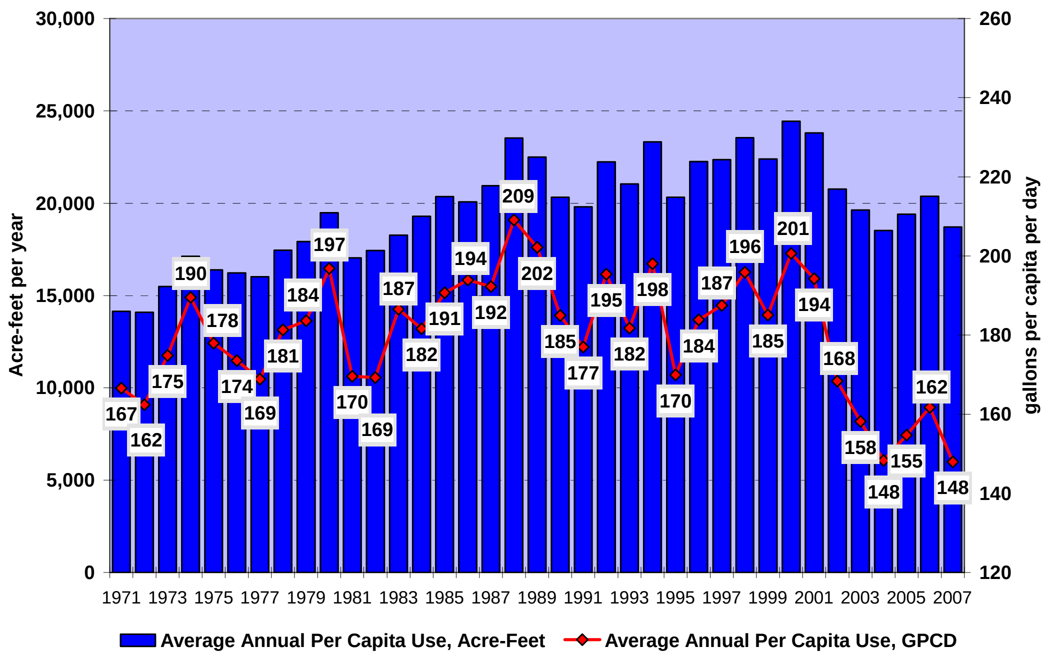
FIGURE 5-10. BOULDER'S PEAK DAY USE AND PEAK RATIO, 1971 - 2007[22]



Per Capita Water Use

Boulder's per capita water use has varied greatly from year to year and has decreased since 2000. Per capita water use is calculated by dividing total city-wide treated water deliveries, including water uses such as parks irrigation, commercial, and industrial uses, by the total city service area population. Part of the wide variation in per capita water use is due to the large variation in lawn irrigation needs that occurs with varying annual weather conditions. The marked reduction since 2000 could be due to more efficient irrigation practices by city residents and city parks staff. If less irrigation water is required for parks in a particular year due to weather conditions, it will be reflected in a lower per capita use value for each resident[23]. Boulder's per capita water use is shown on the right axis of Figure 5-11 as compared to the overall treated water deliveries on the left axis to allow observation of the differing trends in the two values.

FIGURE 5-11. BOULDER'S PER CAPITA USE, 1971 - 2007[24]



Changing per capita use values also reflect variation in the resident jobs to population ratio (J/P ratio) since no per capita water use is directly attributed to the influx of workers Boulder experiences each day. A balanced J/P ratio for an average community is generally considered to be 0.65 jobs per resident because some residents are not part of the workforce. The J/P ratio in Boulder was 0.94 in 2000 which reflects the city's status as an employment center. The J/P ratio decreased to 0.90 between 2000 and 2004 as a result of increased population and a higher commercial and industrial vacancy rate. Employment in the city was 102,485 in 2000, 96,938 in 2002, 98,394 in 2003 and 101,077 in 2004[25]. Due to the higher J/P ratio in Boulder than in other communities, water demands expressed as per capita use per resident may appear higher than in cities that are not employment centers.

5.1.1.3 | TREATED WATER USE BY CITY DEPARTMENTS

The Boulder City Charter, Article VIII Section 128, states "No free water service shall hereafter be given to any person, persons, firms, corporations, or institutions whatever other than the corporate City of Boulder." This Charter section allows different arrangements regarding payment for water service to be made for the corporate city of Boulder (city departments) than for other water customers[26].

Beginning in 1992, the Utilities staff worked with the two largest city "corporate" outdoor irrigation water users (*i.e.* the Parks and Recreation Department and the Transportation Division of the Public Works Department) to implement a water allocation program. The Parks Department and the

Transportation Division were each given an annual irrigation water allocation based upon their city-wide acreage. The program initially allotted a water usage of 18 gallons/square foot of irrigated area in 1992, the base year. For the next five years, the allotment was reduced 5 percent each year until a "75 percent of base" was reached in 1996 (*i.e.*, 75 percent of 18 gallons/square foot is 13.5 gallons/square foot of irrigated area). Any usage over the allowed allotment is to be paid for by the respective department[27]. Since this water allocation program was implemented, neither Parks nor Transportation has exceeded their allocations.

In 2002, during public meetings for the Drought Plan development, strong public support was voiced for the proposal of setting different, more lenient, standards for the irrigation of public landscapes than for private areas[28]. The public commented that they highly value the city's many parks and playing fields. A vast majority of residents shared the desire to have a high level of maintenance for these properties so that they can be used at all times, even during a severe drought. Members of the public also said that some park properties, such as the soccer fields at Pleasant View Park, may have a greater public value than a small, less-used neighborhood pocket park. These large public areas, such as community parks and athletic fields, may need to have a greater water supply to combat the effects of high use on the landscape. There was a general public consensus that a high degree of flexibility should be allowed for water use in public areas during drought periods in order to preserve the ability to use these areas.

Beginning in 2007, the city implemented a new water budget billing system for water users other than city departments that established a budget for each metered account based on water need. The city has now begun modifying the water allocation program for municipal uses to be philosophically similar to the water budget billing methodology used for other customers. In 2008, budgets were determined for each city department based on use measured at individual meters. Part of this effort involved setting new budgets for indoor water use by city departments since the previous water allocation program was only applied to the city's outdoor irrigation water use. The new methodology also alters the previous method of allocating an overall amount of water for irrigation of parks and street medians throughout the city. With the water budget methodology, specific water budget goals have been set for each individual park and median based on actual water usage measured at individual meters. Previously, if the Parks Department reduced water use at one park, the savings could be used to increase irrigation at another park while still staying within the overall annual allocation.

It is anticipated that city departments will be expected to meet the newly-established water budget amounts beginning in 2009. Information on the ability of city departments to meet the city's overall water conservation objective while still having the flexibility to manage maintenance of differing landscapes under the new water budget system will be reviewed annually. This information will be presented to the advisory boards (such as the Water Resources Advisory Board and the Parks and Recreation Advisory Board) and to City Council for consideration. Water budgets can be adjusted if the water budget for a particular metered area is shown to be insufficient. This process will include a discussion on whether or not city departments should pay for water. If so, options for determining how much should be paid will be evaluated. Options are using the same rate as used for city water customers, a reduced rate, or making payment only if the department goes over the allowed water budget.

5.1.1.4 | BOULDER'S WATER SUPPLY RELIABILITY CRITERIA

In 1989, when developing a drought management strategy, City Council recognized that it was not cost-effective to design a system to meet unrestricted water 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 due to water development as compared to the inconveniences and minor damages that would result from occasional demand reductions in response to droughts. It was expected that there would be drought years when Boulder's water supply would not be sufficiently robust to provide for unlimited water demands.

Following extensive public input, the Boulder City Council 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. The reliability criteria recognize that greater value was placed on water availability for indoor needs as compared to providing water for irrigation purposes. These criteria were the subject of extensive public meetings and reflected the near-consensus of public opinion. The reliability criteria for the source water supply adopted by City Council in 1989[29] are as follows:

- 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. (This means the city strives to assure water for all essential indoor needs in all drought years except a drought so severe that it might happen once in 1000 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 subsequently been interpreted to mean the city will provide, at a minimum, the amount of water necessary to meet the basic survival needs of outdoor landscaping in general, including trees and shrubs, although landscaping may go dormant or suffer some damage).
- 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. (This translates into a goal of instituting water use restrictions, either voluntary or mandatory, no more often than five years out of every one hundred years).

These reliability criteria are the basis of the city's goal to assure sufficient water to allow landscaping to survive, though possibly with some damage or in a dormant state, in drought years of a severity that might happen a few times in one hundred years. The city strives to provide sufficient water to meet all municipal demands in nineteen out of twenty years on average over a long period of time. During droughts with recurrence intervals between 1-in-20 years and 1-in-100 years, watering of lawns may be restricted to such an extent that grass goes dormant and other landscape vegetation may become stressed, but 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.

If a single drought year of such severity occurs that water use restrictions are required in response, it does not mean that no use restrictions will be needed the next year. Provision of water at a reduced level could occur in two successive years within a forty-year period and still meet the first criteria of provision of water for all uses in nineteen out of twenty years. The criteria allow for reduced water availability in five years out of one hundred with the possibility that two years of greatly restricted water use, at a level that still allows for landscape survival, could occur in sequence or on two separate occasions. By setting the criterion for provision of all water necessary to meet essential indoor needs at a level where it is not to be interrupted any more than once in a one thousand year period, it establishes the goal that such a drastic shortage of municipal water supply will only happen once, if ever, in the lifetimes of Boulder's residents.

The 2003 Drought Plan[30] developed drought stage definitions with associated reductions in municipal water demand based on these reliability criteria. 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 as shown in Table 5-1. Outdoor irrigation use is the most discretionary water use and will be the area comprising the bulk of the reductions achieved during a drought. Therefore, the proportion of the annual water use that is derived from changes in irrigation season use (May 15 to October 15) will be higher than that obtained in the winter when water use is almost all indoors. The goals for percentages of reduction are based on the current split for total annual water use of 34 percent outdoor use and 66 percent indoor use for Boulder's water customers.

TABLE 5-1. DROUGHT REDUCTION GOALS FOR TYPES OF WATER USAGE DROUGHT ALERT STAGE[31]

Water Use Reduction Percent (%)	I Moderate	II Serious	III Severe	IV Extreme
Total City-wide Annual Use	8	14	22	40
City-wide May 15 – October 15	10	20	30	55
City-wide October 16 – May 14	5	5	10	15
Commercial / Industrial / Institutional Average Annual Use	8	14	22	40
City-wide Indoor Use (Year-round)	5	5	10	15
Outdoor Use (mostly May 15 – October 15)	16	32	46	87

The performance of the city's water supply system during the 2002 drought was consistent with the city's reliability criteria. During 2002, streamflows in Boulder Creek were at the lowest levels in about 300 years[32]. In this 1-in-300 year drought, the system performed better than expected by providing more than 50 percent of the normal outdoor use. This drought year was severe enough that, under the drought stages that were later adopted, it was between a Stage III and a Stage IV level of severity and very little 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.

In the 2002 drought year, the actual reductions in water use achieved by Boulder's citizens exceeded the goals for a Stage II/Serious drought declaration and about achieved the goals for a Stage III/Severe drought. Total city-wide irrigation season use (May 15, 2002 until October 15, 2002) was reduced by 28 percent. This was made up of a 10 percent reduction in indoor use during the irrigation season and a 50 percent reduction in outdoor use during the irrigation season. 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 percent reduction in indoor use was achieved mostly through education and providing information regarding the severity of the drought. The reduced water use continued after the irrigation season with a reduction of 12 percent in overall use from October 16, 2002 until May 14, 2003 when use was almost all for indoor needs. The city achieved a total annual reduction in water use from May 15, 2002 to May 14, 2003 of 20 percent[33].

5.1.1.5 | FUTURE TREATED WATER USE

The city's current water demand forecasting method is based on an examination of the types of activities that take place in different areas of the city that affect water use, as well as the distribution of the population, as defined in the BVCP[34]. General land use categories in the BVCP for the city water service area include residential, business, industrial, and other. The "other" category includes parks and open space, agricultural, and public uses. During BVCP updates, the city makes a projection for "realistic build-out" which is based on likely development under current land use and zoning regulations and does not include a specific timeline. In addition, the city Planning Department publishes population and employment projections on a yearly basis. Although the Planning Department does not specify a year for build-out of the city's service area, it is estimated that it will occur between 2035 and 2050. Revised water demand projections rely on recent unit water demand values for each type of water use and can be adjusted for projected changes in employment ratios and the Council-adopted goals for water conservation savings to be achieved by build-out.

Previous Water Use Projections

Projection of future water needs is an inexact science. Past studies of the water system have made projections of future use with varying degrees of success. Early projections made in 1919 greatly under-estimated the growth that would ultimately occur in Boulder following World War II and the construction of the Boulder Turnpike (also known as US Highway 36)[35]. In contrast, studies made in the 1960s prior to Boulder's first growth control ordinance over-estimated the city's future growth[36].

The 1988 RWMP[37] included water demand projections that were based on projected zoning capacity population levels that pre-date two major city planning efforts. Both the Integrated Planning Project (1993) and the Comprehensive Rezoning Project (1996) resulted in reduced expectations for water needs at build-out[38]. Projections of water needs that followed relied on future land use and population numbers derived primarily from data presented in the city's 2000 Water Conservation Futures Study[39]. That study, in turn, relied on data from the 1996 BVCP[40], the 1990 Census[41] and the resulting job and population projections made by the city Planning Department. Additional information was obtained from the 1999 Summary of Information about Boulder published by the city's Center for Program and Policy Analysis[42].

The Water Conservation Futures Study developed baseline water demands for the city's urban service area for the year 1995 based on monthly metered end use data. Various adjustments were made to accommodate factors such as annual weather variations and unaccounted-for water. Total demand and demand by various end use categories were projected from the base year of 1995 through 2020. The study also developed demand projections for a number of water conservation scenarios of varying degrees of intensity[43]. Ultimately, the City Council selected the Comprehensive Conservation Scenario as described in the plan for implementation[44]. This scenario is more conservation-intensive than the city's program that existed in 1999.

The Treated Water Master Plan and the Water Conservation Futures Study were being prepared at the same time and used the same population, employment and water demand projections. Table 5-2, derived from the 2000 Treated Water Master Plan, provides values for actual demand by customer class at the time and projected values based on then current information[45].

TABLE 5-2. HISTORICAL AND PROJECTED WATER DEMAND IN ACRE-FEET BY CUSTOMER CLASS AS PRESENTED IN 2000 TREATED WATER MASTER PLAN[46]

	1995	2000[i]	2005	2010	2015	2020
Residential Single Family Multi-Family	 8,390 6,791	 8,418 6,754	 8,447 6,718	 8,476 6,681	 8,504 6,645	 8,533 6,608
Total Residential	15,181	15,172	15,165	15,157	15,149	15,141
Business	6,471	6,794	7,117	7,439	7,762	8,085
Other	793	821	849	877	905	933
Totals – Acre-feet (MGD)	**22,445** (20.0)	**22,788** (20.3)	**23,131** (20.6)	**23,473** (21.0)	**23,816** (21.3)	**24,159** (21.6)

Actual water demands have varied from those projected in the Treated Water Master Plan. In 2000 and 2001, demands were higher than projected. In 2000, 24,533 acre-feet were delivered from the treatment plants. Following the severe drought year of 2002, water use dropped dramatically in the city. Actual water demands in 2005 (19,415 acre-feet) were lower than projected. Data from 2003 and 2007 indicate that per capita water use in the city has remained lower than pre-drought levels. However, per capita water use at build-out is expected to be similar to pre-2000 levels simply because of the expected significant increase in a daytime population in the city reflected in a higher jobs to population ratio[47].

Although actual water demand has varied, the water demand projections for 2015 and 2020 contained in the Treated Water Master Plan are still believed to be valid. The majority of the savings from the water conservation program that were projected to occur during the 2000 to 2020 period may have been pushed to the earlier years of the period due to the drought in 2002. However, the total projected savings over the period was based on specific types and levels of fixture and behavior changes and is likely to be the same as projected. In other words, the achievement of the water conservation targets has progressed non-linearly, but the end target has not changed. Build-out water demand levels will be larger than the level shown for 2020 in the above table due to continued increases in population and employment beyond 2020.

In 2002-2003 a Jobs to Population project (also known as the Jobs to Housing project) was conducted by the city Planning Department after growing concerns about the continued expansion of employment growth without equal residential growth. The project was on-going in 2003 when revised water use projections were developed through the Drought Plan process. The Jobs to Population project had not yet resulted in a consensus on the build-out conditions to pursue or the adoption of a growth scenario by City Council. Therefore, the Drought Plan water use projections were based on the Jobs to Population project Scenario 1 for build-out conditions because that appeared to be the most favored scenario. This projection corresponded to a service area population of 140,500 people and

[i] The Treated Water Master Plan was published in early 2000 prior to availability of full data for the year.

employment of 164,600 jobs[48]. The water use projections were also based on the unit demand factors from the 2000 Water Conservation Futures Study and 2000 Census data[ii,49].

Water demand projections contained in these previous studies were updated based on the changed population and employment projections available at the time. Therefore, the water demand values differ within each plan, but represent the best available information at the time. Table 5-3 summarizes the population and employment projections used for each study.

TABLE 5-3. PREVIOUS POPULATION AND EMPLOYMENT PROJECTIONS

Plan (Adoption Year)	Population Projection	Employment Projection
Raw Water Master Plan (1988)	157,600	118,500
Water Conservation Futures Study (2000) and Treated Water Master Plan (2000)	126,230	115,193
Jobs and Population Project Current Trends Scenario (2003)	134,500	218,700
Drought Plan (2003)	140,500	164,600
* All values are for the BVCP designated Service Area (Areas I and II).		

Adopted Comprehensive Conservation Scenario

In 2000, the City Council adopted the Comprehensive Conservation Scenario as identified in the Treated Water Master Plan and Water Conservation Futures Study[50]. The new conservation program was implemented in 2003. The city has continued to develop its water conservation program for indoor and outdoor water use to achieve or exceed the adopted goals for overall reduction of water use needs at build-out. An additional city goal that has emerged from the adoption of water budget-based rates by City Council in 2007 is for all water customers in the service area to live within their individualized allocated water budget[51].

Implementation of the Comprehensive Conservation Scenario elements should result in achieving the following specific performance targets by build-out. These targets include:

- a 22 percent reduction in per-meter use for the single-family residential sector;
- a 26 percent reduction in per-meter use for multifamily residential sector;
- a 14 percent reduction in per-meter use for the commercial/industrial sector;
- a one percent reduction in overall municipal use, and;
- a 15 percent reduction in unaccounted-for water.

[ii] In 2001, Boulder filed a challenge to the 2000 Census count of Boulder's population for an undercount of 2,014 housing units and 4,420 people. Although the Census Bureau did not accept the challenge, the Colorado State Demographer's Office approved the increase.

Achievement of these targets will result in an expected overall reduction in total annual demand in the range of 19 percent at build-out as compared to water use at build-out absent the Comprehensive Conservation Program[52]. Per capita water use at build-out will be greater than 2007 levels due to increases in the jobs to population ratio, but will be less than without the water conservation program.

Current Water Use Projections

The build-out projections in Boulder's Planning Department's "2008 Existing and Projected Housing Units, Population, and Employment: 2008, 2030 and Build-Out" are the most current population projections and include approximately 65,500 more jobs and 16,500 more residents than actual 2008 levels[53]. The updated population and employment projections for the Boulder service area (Areas I and II) were developed by assessing specific areas where growth is anticipated and are shown in Table 5-4. The 2008 Existing and Projected Housing Units, Population, and Employment numbers project that the jobs to population ratio at build-out in Boulder will be as high as 1.28.

TABLE 5-4. 2008 ACTUAL BOULDER SERVICE AREA POPULATION AND EMPLOYMENT[54]

	Population	Employment
2008 Actual	113,100	100,500
Projected 2030	129,600	120,800
Projected Build-out	129,600	166,000
*All values are for the BVCP designated Service Area (Areas I and II).		

Specific water demands based on these build-out projections have not yet been calculated, but, based on comparison with previous population and employment projections, updated water demands will be equal to or less than projections made in the Drought Plan.

The Drought Plan contains the most current projection for Boulder's build-out water demand. This projection is that 28,600 acre-feet per year would be needed to meet all treated water needs in non-drought years[55]. Declaration of drought years and the associated amount of reduction in water use required would be made in accordance with the parameters in the Drought Plan.

Further analysis of the Drought Plan system operations modeling showed that the city's present water rights portfolio would provide sufficient water to meet all demands at full build-out of the BVCP area during 290 years out of a period of 300 modeled years, assuming that future regional hydrology is similar to past hydrology. According to the modeling, voluntary use reductions or moderate use restrictions would be necessary in about eight years out of the modeled 300 years due to reduced supplies during drought. Severe use restrictions would be required in only two years out of the modeled 300 years when drought conditions would reduce water yields significantly. At no time during the modeled scenario did water yields drop below the level of meeting essential indoor needs. This model outcome meets the adopted reliability criteria for the city's water supply system[56].

Factors Affecting Future Demands

The conclusions from the Drought Plan might be modified in the future by changes in demand due to climatic factors that influence landscape irrigation requirements and potential changes in customers' water use habits and preferences. Outcomes of climate change may include warmer summers that result in higher irrigation demands, but this might be offset if it also rains more in the summer. There may be increased use of swamp coolers to replace air conditioning and heat pumps given greenhouse gas concerns. There may also be an increase in water-based private residential amenities such as fountains and swimming pools. On the other hand, in the face of warmer summers and higher water prices, many residences may voluntarily shift to smaller lawns, more xeriscaping and limited courtyard-style landscaping.

If the average income in Boulder continues to increase, it may also affect residential water users' habits and preferences, although it is difficult to predict in what way. Installation of backyard fountains and water features often occurs at higher income levels. Water intensive indoor plumbing features, such as soaking tubs and rain showerheads, are often favored in more expensive homes.

Boulder is an employment center with many workers commuting into the city for the day. Future increases in water demand will be derived from increases in both the number of residents and the amount and type of employment in the city. At the conclusion of the Jobs and Population project in 2003, City Council adopted Resolution 922, which encouraged a more balanced jobs to population ratio than would occur if the existing trends continued[57]. The resolution presented recommendations for increasing mixed use development, increasing the overall amount of housing, preserving service commercial uses, and converting industrial land use zoning to residential or mixed use in appropriate locations. In 2002, the jobs to population ratio was 0.92[58]. In 2008, following implementation of the resolution, the jobs to population ratio was 0.89. By 2030, the jobs to population ratio is expected to be 0.93[59].

Increased employment in the city will affect water use to a greater or lesser extent depending on the industrial or commercial nature of the new jobs. Water use for the city's industrial and commercial water accounts in 2007 was about 4,600 acre-feet or an average per account of about 41 gallons per capita per day (g/c/d) for each of the approximately 100,500 employees in the city and their associated work product and building maintenance[60]. This gallon per day value varies a great deal across the range of commercial/industrial accounts in the city from a low of about 14 g/c/d for small office buildings, sufficient to meet each individual employee's personal water consumption needs, up to more than 100 g/c/d for water-intensive manufacturing plants[61].

If employment growth results in an additional 20,300 employees by 2030 as the 2008 Existing and Projected Housing Units, Population, and Employment numbers project, the increased water demand from new employment could vary from the minimum of 320 acre-feet per year (based on water usage of 14 g/c/d) to serve only employees' personal needs if all new employment was office-type work up to something higher than 930 acre-feet per year (based on 41 g/c/d) if the new employment is concentrated in water-intensive industries that use more water than the present average.

Estimate of Future Water Demands

The city's current water demand forecasting method is based on an examination of the types of activities that take place in different areas of the city that affect water use as well as the distribution of the population, as defined in the BVCP[62]. General land use categories in the BVCP for the city water service area include residential, business, industrial and other. The "other" category includes parks and open space, agricultural and public uses. Through annual housing unit, population and employment projections, the city makes a projection for "realistic build-out" which is based on likely development under current land use and zoning regulations and does not include a specific timeline.

Although the city's Planning Department does not specify a year for build-out of the city's service area, it is estimated that it will occur between 2035 and 2050.

Future water demand projections can be updated whenever necessary using the most recently adopted population and employment projections. The amount of source water required to serve this projected level of population and employment can be estimated based on data derived using information such as past unit water demand values for each type of water use, patterns of use, and peak day use as adjusted by expectations for changes in these factors due to societal trends and achievement of the Council-adopted water conservation goals for reductions in water use at build-out.

A current estimate of water demand can be made based on:

- the build-out numbers from the 2008 Existing and projected housing units, population, and employment: 2008, 2030 and build-out[63];
- the 1994-1996 unit demand factors developed in the Water Conservation Futures Study[64];
- reductions in overall water use as anticipated with the adopted Comprehensive Conservation Plan[65], and;
- a 10 percent safety factor to allow for generalizations inherently necessary for modeling and for unknown factors.

The resulting demand would be close to 27,000 acre-feet per year.

The city has experienced consistently lower water demands as an after-effect of the 2002 drought. If it were assumed that about half of the anticipated decrease in water demand due to conservation had already been achieved, an estimate of water demand could be made based upon:

- the build-out numbers from the 2008 Existing and projected housing units, population, and employment: 2008, 2030 and build-out[66];
- the lower 2002-2006 average unit demand factors;
- an assumption of a 9.5 percent further reduction in water use by build-out due to water conservation beyond that already achieved in response to the 2002 drought, and;
- a 10 percent safety factor.

The result would be about 25,000 acre-feet per year.

However, the 25,000 acre-feet of demand does not reflect any increase in unit irrigation demand that may occur due to climate change, depending on what temperature and precipitation changes actually come about. If one of the more severe climate change scenarios occurred and resulted in a 20 percent increase in the unit demand for irrigation (and no change in customers' lawn sizes or selections of landscaping species), the 25,000 acre-feet demand value would increase to about 27,000 acre-feet. This is still below the 28,600 acre-feet of demand modeled for the Drought Plan.

5.1.2 | RAW WATER IRRIGATION USE

Several irrigation ditch systems that are owned by private ditch companies and can deliver untreated water for irrigation purposes run through the city limits. If the water is used by Boulder residents, businesses, or city departments that would otherwise be irrigating with treated water, these separate irrigation water delivery systems reduce the demand on the city's water treatment and treated water distribution facilities. However, use of raw water irrigation delivery systems for all irrigation purposes is a more complex subject. The overall effect on the city's water supply may be positive or negative based on the degree of competition between the alternative irrigation delivery system facilities or water supplies and the city's raw water facilities or water supplies. This competition may occur due to the seniority of ditch water rights compared to the city water rights, the degree of efficiency of the raw water distribution system relative to the treated water distribution system, and the source of the raw water if it is from city reservoirs instead of an independent system.

Each raw water irrigation delivery system must be evaluated individually to determine its net positive or negative effect on the city's overall ability and cost of delivering treated water supplies. If competition from the raw water delivery system causes a reduction in water availability for Betasso Water Treatment Facility (WTF), the net change in treatment and distribution costs could increase since it is more expensive to treat and deliver water from the Boulder Reservoir WTF and no hydropower revenue can be gained from Boulder Reservoir WTF water deliveries. However, if summer peak demands for treated water are sufficiently reduced by taking large irrigators off the treated water system through use of alternative raw water systems, it can provide a financial benefit by delaying the need for expansion of the treated water pumping station out of Boulder Reservoir WTF and upsizing distribution pipelines and pumping stations on the eastern side of the city.

Approximately 37 acres of city parks are currently irrigated to varying degrees by raw water. All parks with raw water irrigation systems are also connected to the city treated water system to provide an alternate source of water supply if raw water is unavailable. Those parks supported by raw water irrigation include Martin Park, Foothills Community Park, Valmont City Park and Tom Watson Park. The ditch rights used for irrigating those parks include Anderson, Silver Lake, North Boulder Farmers and Left Hand ditches, respectively. Scott Carpenter Park may be a good candidate for future raw water irrigation development using Smith and Goss Ditch or McCarty ditch water. Such a project would be more feasible if teamed with development of raw water irrigation on the University of Colorado East Campus properties.

In addition to reducing the demand on the water treatment and treated water distribution facilities, raw water irrigation of city parks provides an appropriate use of city-owned ditch company shares that may not otherwise be capable of providing water for the city's uses either temporarily or long term. City use of raw water irrigation at city parks whenever feasible directs the municipal investment in resources for treating and delivering potable water toward those water needs that must be met with potable water.

There are many properties not owned by the city within the treated water service area that are irrigated with raw water from ditch companies operating independently of city water supplies, such as the University of Colorado main campus, NOAA and NIST Broadway campus, various Boulder Valley School District properties, specific residential properties and small farms. The University of Colorado recently converted a number of athletic fields and landscaped properties to raw water irrigation, reducing their treated water demand on the city system by 30 million gallons annually. The NOAA/NIST property contains approximately 35 acres irrigated using Anderson Ditch water. Outside of the treated water service area, thousands of acres of farm land and open space surrounding the city are irrigated by raw water.

5.1.3 | INSTREAM FLOW USE

Streamflow in the waterways of the Boulder Creek basin is a major ecological and economic concern to the city and the citizens of Boulder. A viable trout fishery exists in most of the creeks. The city's network of open space and trails is focused around Boulder Creek and its tributaries. Also, the use of Boulder Creek for recreational boating and tubing has long been a popular activity. Therefore, the adequacy of streamflows and the aesthetics of Boulder Creek and its tributaries are important to the community.

Boulder Creek is typical of the higher-elevation snowmelt-driven streams along the Front Range in that its highly variable natural streamflows provide challenging habitat for most species. The main creek flows out of the mountains immediately west of Boulder and through the center of the city. The drainage area that feeds Boulder Creek above the city's western boundaries is about 110 square miles. Streamflows in Boulder Creek are generated primarily by melting of the snowpack that accumulates in the mountains every winter. Therefore, spring runoff flows are up to two orders of magnitude larger than flows during the balance of the year. Typical winter streamflow below Barker Reservoir, located on Middle Boulder Creek, ranges from 3 to 8 cubic feet per second (cfs). The typical late spring and early summer peak runoff streamflow varies from 300 to 400 cfs. Typical late summer and fall streamflows range from 12 to 40 cfs. The streamflow in Boulder Creek and its tributaries normally increases naturally as the stream drops in elevation. In other words, it is a "gaining" stream. On main Boulder Creek as it flows through the city, winter streamflows typically range from five to 15 cfs. The streamflows usually peak in early summer in the range from 400 to 600 cfs[67].

Establishing and maintaining streamflows approximating a natural regime in the Boulder Creek basin was emphasized as a priority issue in the 1988 RWMP, which recommended establishing an instream flow program along Boulder Creek and its tributaries[68]. During much of the year, there is sufficient streamflow to maintain the stream habitat because of natural runoff levels or due to water rights calls from downstream senior water users. At other times, streamflows would drop to unsatisfactory levels due to naturally dry conditions or water diversions unless an instream flow program provides water for streamflow needs.

Extensive studies, as described in the following sections, have been done, both by CDOW and the city's consultants, to establish the appropriate amount of water needed for instream flow maintenance on Boulder Creek and its tributaries. Both of the most recognized methodologies for evaluating fisheries and macro-invertebrate habitat (*i.e.* R2Cross and Instream Flow Incremental Methodology (IFIM)) were used to arrive at optimum minimum flow levels. Based on these studies, the city developed an instream flow program for North Boulder Creek and Boulder Creek in conjunction with the CWCB in 1990, has maintained minimum flow levels below Barker Reservoir on Middle Boulder Creek since 2001, and continues to seek opportunities to develop instream flow programs along other tributaries.

Habitat studies have determined that the two periods of greatest disturbance to stream species and their habitats in the Boulder Creek basin are low-flow periods in late summer and winter and the high-flow periods in the spring. In 1992, Chadwick and Associates completed a study for the Environmental Impact Statement (EIS) process done by the USFS for an easement for Lakewood Pipeline[69]. This study used IFIM to evaluate habitat needs for trout species and macro-invertebrates. This method collects information on habitat characteristics within the studied stream segments to determine the percentage of habitat types such as riffle, run, or pool. This information is combined with historic hydrologic data to determine which period of the year results in the lowest habitat levels for fish. Decisions on minimum flow levels to be maintained in each season can then be made. The report states, "In Rocky Mountain streams the bottlenecks to fish populations generally occur during extreme flow conditions, either the high flow period in late spring or the low flow period in winter."[70]. Also, "…habitat levels for trout and macro-invertebrates peak at intermediate flows with lower levels of habitat at high and low flows."[71]. If high flow periods are the limiting life stage for the studied species, then "developing a minimum flow regime to benefit the non-limiting life stages will, theoretically, have no resulting effect on the fish population as there is already "excess" habitat for these life stages relative to the limiting life stage."[72].

Based on these studies, the present instream flow program and amount of water provided by the city to North Boulder Creek and Middle Boulder Creek addresses low-flow needs and maximizes the amount of fish habitat that can be maintained. The exception to this maximization is the high peak flow during spring runoff that still occurs and can negatively affect fish habitat. A sediment transport study showed that no additional streamflow is needed for channel maintenance purposes[73], meaning that the minimum flows established under the Boulder Creek instream flow program are sufficient.

5.1.3.1 | DESIRABLE INSTREAM FLOW LEVELS

In 1973, the state of Colorado passed legislation declaring instream flow a beneficial use of water under Colorado's prior appropriation doctrine and allowing for use of water and water rights for instream flow purposes by the CWCB. The enabling legislation specifies the criterion for determining the amount of water to be used for instream flows as the amount "necessary to preserve the natural environment to a reasonable degree"[74]. For higher-elevation streams, this has been interpreted by CDOW as sufficient water to provide for a cold-water fishery and has typically been determined by establishing the needs of trout species and macro-invertebrates. Early CWCB water rights filings, such as its 1973 filing on main Boulder Creek, did not distinguish between seasons when establishing habitat needs. Later CWCB filings recognized that stream species could tolerate lower flow levels in winter, but needed higher minimum levels in the warmer months.

Since the CWCB instream flow water rights are relatively junior in priority, they usually are not in priority during low flow periods. However, senior water rights can be donated to or acquired by the CWCB and these water rights can be changed to include instream flow as a use. While the CWCB's junior instream flow rights prevent streamflows from being depleted by future water rights filings, changed senior water rights are responsible to attaining the decreed minimum streamflows.

Others who are interested in stream conditions for purposes other than habitat protection may have an interest in preserving the higher flow levels that now occur at some times of the year. Kayakers and tubers enjoy higher flow periods for recreation. Flows sufficient for maintenance of the stream channel presently occur during the high spring runoff period on Boulder Creek. Since adequate flow levels already exist for most needs other than habitat during low flow periods, the focus for establishing an instream flow program for Boulder Creek and its tributaries has been on providing for minimum streamflow levels when the stream might otherwise be dry.

Provision of water to meet desired minimum streamflow levels in main Boulder Creek and its tributaries is being pursued using several different mechanisms such as junior instream flow filings by the CWCB[75], donation agreements between the city and the CWCB (see section 5.1.3.3) and voluntary water releases by the city as shown in Table 5-5.

In the upper segments of North Boulder Creek, the combination of natural inflow and city contractual instream flow releases are usually sufficient to fully satisfy the maximum flow rate protectable under the CWCB junior filing. Desirable minimum levels can be achieved on North Boulder and Middle Boulder creeks under most conditions, but they may not always be attained during a drought or municipal water system emergency. On occasion, natural (virgin) flows in these stream segments have been less than desirable minimum streamflow levels because, given Colorado's semi-arid climate, even under completely natural conditions, flows in these reaches would periodically be less than those levels identified as desirable. At times, the city's donated rights may yield more than is able to be protected from diversion by others under the CWCB junior filing.

On main Boulder Creek, desirable winter minimum levels have not been definitively established using current methodologies for habitat studies. Study methods have been refined to include a seasonal component since this reach was studied in 1973. However, the existing minimum winter levels are likely in the range equal to or higher than what is considered to be a true minimum flow necessary for habitat protection of 1.5 cfs[76]. Flows on main Boulder Creek often drop below 15 cfs during late summer, but are sustained above significantly depleted flow levels by the city's contractual instream flow water deliveries. On occasion, the minimum levels may not be met for a few days when it should otherwise be feasible to achieve them due to operational challenges with water administration (*i.e.,* it takes a day or two for operators to assess and respond to the river and it takes a day or two for the river to respond to changes made by operators).

South Boulder Creek frequently drops below desirable levels in the fall, winter, and late summer. Often, several stream segments below major diversion points are dry. The CWCB instream flow water rights on South Boulder Creek protect against any new water rights filings from further depleting the stream but are too junior to do more.

The below table lists minimum levels that are desirable for designated stream reaches on North Boulder, Middle Boulder and main Boulder Creeks during times of the year when low flows are normally expected, such as winter and late summer. Flow regimes during periods of higher flow will continue to be protected by the calls of existing water rights owners for water to be delivered to their headgates through stream reaches above and through the city. Uncontrolled peak flows will continue to occur in Boulder Canyon in most years once Barker Reservoir fills and all inflow to the reservoir spills into the creek over the reservoir spillway.

TABLE 5-5. DESIRABLE MINIMUM INSTREAM FLOW LEVELS: MIDDLE BOULDER, NORTH BOULDER AND MAIN BOULDER CREEKS[77]

Reach of Stream	Maximum Flow Rate Protected Under CWCB ISF Right	City Releases Required by Contract	City Voluntary Releases	Maximum Flow Rate Protected Under CWCB ISF Right	City Releases Required by Contract	City Voluntary Releases
	Winter			Summer		
Main Boulder Creek: *Orodell to 75th Street*	15 cfs* (likely in the range of 1.5 cfs under current study methods)	1.5 cfs	When not needed for municipal uses, allowable amount not to exceed 15 cfs from all sources	15 cfs	Yield of conveyed rights in priority, not to exceed 15 cfs from all sources	When not needed for municipal uses, allowable amount not to exceed 15 cfs from all sources
Main Boulder Creek: *North and Middle Boulder Creeks confluence to Orodell*	6 cfs	1.5 cfs	When not needed for municipal uses, allowable amount not to exceed 15 cfs from all sources	15 cfs	3.96 to 5.12 cfs (varies by month, maximums when all conveyed rights in priority)	When not needed for municipal uses, allowable amount not to exceed 15 cfs from all sources
Middle Boulder Creek: *Barker Dam to confluence with North Boulder Creek*	None	None	Amt. added to assure 3 cfs, except in drought or emergency	None	None	Amt. added to assure 4 cfs, except in drought or emergency
North Boulder Creek: *Silver Lake Pipeline diversion to Lakewood Reservoir*	1.5 cfs	0.5 cfs	Not allowed to exceed 0.5 cfs from decree sources for this segment	4 cfs	3.96 to 5.12 cfs (varies by month, maximums when all rights in priority)	Not allowed under decree
North Boulder Creek: *Lakewood Reservoir to confluence with Middle Boulder Creek*	2 cfs	1.5 cfs	Not allowed to exceed 1.5 cfs from decree sources for this segment	5 cfs	3.96 to 5.12 cfs (varies by month, maximums when all rights in priority)	Not allowed under decree

*The CWCB habitat protection criteria of 15 cfs year-round on main Boulder Creek was established prior to the time that seasonal designations were made. This amount of flow is likely more than is necessary for adequate winter habitat protection.

5.1.3.2 | COLORADO WATER CONSERVATION BOARD INSTREAM FLOW WATER RIGHTS

Under Colorado statutes, the CWCB is the only entity permitted to use a water right or water specifically decreed for instream flow use for habitat protection purposes[78]. When water is simply released for instream flows, or "bypassed," without benefit of a water right that is decreed for instream flow purposes, the water can be re-allocated to other water rights holders under Colorado's system of water administration and diverted out of the stream according to their water rights priorities when it reaches their headgates. To be protected from diversion and available for the intended purpose, water rights for instream flows must be decreed and administered under their own priorities within the state water administration system. The CWCB owns instream flow rights for stream segments on Boulder Creek, Middle Boulder Creek, North Boulder Creek, and South Boulder Creek Table 5-6.

TABLE 5- 6. CWCB WATER RIGHTS FOR INSTREAM FLOW IN BOULDER CREEK AND TRIBUTARIES[79]

Stream	Reach	Decree Case No.	Appropriation Date	Decree Amount	Season
Boulder Creek	Broadway diversion structure to 75th Street	79CW308	6-1-1862	1.0 cfs	April 1 – October 31
Boulder Creek	Orodell gage to 75th Street	W-7636-74	10-1-1973	15.0 cfs	Year round
Middle Boulder Creek	Confluence of North and Southy forks of Middle Boulder Creek to Barker Reservoir	W9375-78	7-11-1978	12.0 cfs	Year round
South Boulder Creek	Gross Reservoir to Eldorado Springs gage	80CW379	12-2-1980	6.0 cfs	October 1 – April 30
South Boulder Creek	Gross Reservoir to Eldorado Springs gage	80CW379	12-2-1980	15.0 cfs	May 1 – September 30
South Boulder Creek	Eldorado Springs gage to South Boulder Road	80CW379	12-2-1980	2.0 cfs	October 1 – April 30
South Boulder Creek	Eldorado Springs gage to South Boulder Road	80CW379	12-2-1980	15.0 cfs	May 1 – September 30
North Boulder Creek	Silver Lake Pipeline diversion to Lakewood Reservoir	94CW20	11-10-1993	1.5 cfs	November 1 – March 31
North Boulder Creek	Silver Lake Pipeline diversion to Lakewood Reservoir	94CW20	11-10-1993	4.0 cfs	April 1 – October 31
North Boulder Creek	Lakewood Reservoir to confluence with Boulder Creek	94CW19	11-10-1993	2.0 cfs	November 1 – March 31
North Boulder Creek	Lakewood Reservoir to confluence with Boulder Creek	94CW49	11-10-1993	5.0 cfs	April 1 – October 31
Boulder Creek	Confluence of North and Middle Boulder creeks to Orodell gage	94CW18	11-10-1993	6.0 cfs	November 1 – March 31
Boulder Creek	Confluence of North and Middle Boulder creeks to Orodell gage	94CW18	11-10-1993	15.0 cfs	April 1 – October 31

Since 1973, the CWCB has held a water right for an instream flow of 15 cfs in Boulder Creek from the Orodell gauging station west of Boulder to the 75th Street bridge east of the city[80]. This 15 cfs right is very junior to other water rights which divert within and above this reach of Boulder Creek. This means that it is called out by more senior rights during critical times of low streamflow. The CWCB junior 15 cfs right has served to maintain existing stream conditions and protect against new water development or water rights changes that could affect current minimum flow levels on the protected stream reaches.
The CWCB acquired an 1862 senior water right of 1 cfs, called the G. Berkley Ditch right, which was changed through the Water Court from agricultural use to allow instream flow use in Boulder Creek from the 12th Street diversion structure (east of Broadway) to 75th Street[81]. However, this right can sometimes be called out during extremely low flow periods. Except for this 1 cfs water right, the CWCB-owned instream flow water rights are very junior and are only in priority when there is a significant amount of water in the creeks or very little water user demand. Therefore, the donation of the use of water and water rights owned by the city to the CWCB is instrumental in maintaining minimum flow levels.

The CWCB junior decree amounts were established based on recommendations by the CDOW as the minimum amount of flow necessary and available to maintain fish habitat for cold water fisheries. The protectable flow level varies for each creek section based on parameters for each stream reach. The flow amounts were based solely on habitat analyses conducted on each stream reach by CDOW using R2Cross methodology, with one exception. The exception is South Boulder Creek where the CWCB right was limited by statutory requirements to consider water availability factors resulting from existing upstream diversions. On South Boulder Creek between Eldorado Springs and South Boulder Road, the CWCB right was set at 2 cfs for October 1 through April 30 because of water availability limitations[82]. The minimum flow needed to maintain fish habitat for this reach according to R2Cross methodology is 7 cfs[83].

5.1.3.3 | JOINT BOULDER/CWCB BOULDER CREEK INSTREAM FLOW PROGRAM

In 1990 and 1992, the city and the CWCB entered into a series of agreements through which the city dedicated water rights and assigned interests in water to the CWCB for instream flow purposes on Boulder Creek[84] (see Table 5-7). The dedication to the CWCB of water rights owned by the city and commitments to releases of water from the city's storage reservoirs assists the CWCB in satisfying its junior instream flow rights by providing use of more senior water rights. The CWCB authorized the city to be its agent for administration of instream flow rights on Boulder Creek.

In 1993, a decree for Case No. 90CW193 was entered by the Division 1 Water Court that changed the water rights donated to the CWCB by the city and water owned by the city to allow instream flow use on Boulder Creek and allow for reuse of instream flow water rights below 75th Street in addition to municipal use[85]. The joint city/CWCB instream flow program was designed to operate within the state water administration system in order to assure that the water donated by the city would be used for instream flows. See section 3.4.9.1 "Colorado Water Conservation Board" for more information on the city/CWCB agreements and the Boulder Creek instream flow program.

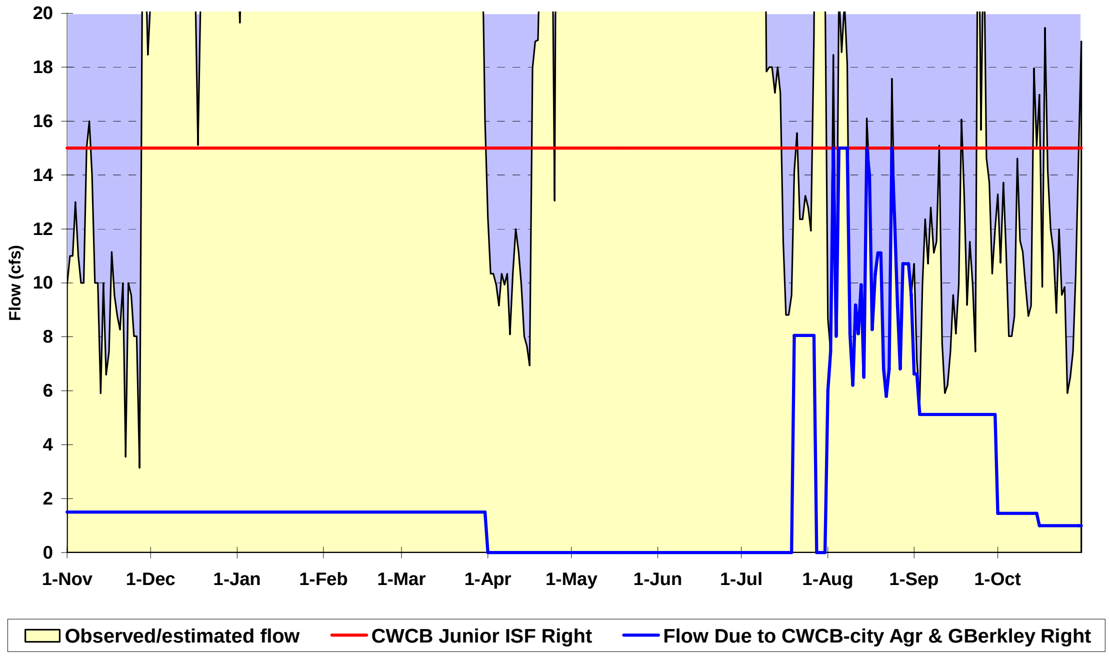
The water rights the city provided for use by the CWCB had an estimated market value of greater than $12 million at the time of the donation[86]. Most of these rights were derived from shares in agricultural ditch companies which divert from Boulder Creek. Boulder had previously changed most of these shares to municipal uses through Water Court proceedings and has depended on this water to meet municipal water supply needs. Based on City Council direction, delivery of municipal water supply consistent with the city's water supply reliability criteria takes precedence over instream flow support during times of extreme drought or emergency[87]. Therefore, the city/CWCB agreements allow the city to call use of the donated water rights back and to curtail instream flow storage releases during a severe drought or an emergency so that the water can be used within the municipal water supply system. The city is also allowed to use the water rights for municipal purposes if they are not needed to satisfy minimum instream flow requirements.

TABLE 5-7. CITY WATER RIGHTS PROVIDED TO THE CWCB TO USE FOR INSTREAM FLOW[88]

Water Right / Source	Appropriation Date	Stream Reach	Flow Amount	Season
Smith and Goss Ditch	11-15-1859	From Silver Lake Pipeline diversion to 75th Street	0.451 cfs	May 1-October 15
Anderson Ditch	10-1-1860	Same as above	May: 1.07 cfs June: 2.23 cfs July: 2.16 cfs August: 1.62 cfs September: 1.23 cfs	May 1-September 30
Harden Ditch	6-1-1862	Same as above	1.8 cfs	May 1-September 30
McCarty Ditch	6-1-1862	Same as above	0.64 cfs	May 1-September 30
Farmers Ditch	10-1-1862	Farmers Ditch headgate to 75th Street	12.17 cfs	May 1-September 30
Silver Lake Reservoir	9-6-1928 12-31-1941	Silver Lake Pipeline diversion to 75th Street	As needed to maintain 0.5 cfs below Silver Lake Pipeline diversion and voluntarily to maintain up to 15 cfs from Orodell to 75th Street from all sources	October 1-April 30
Boulder City Pipeline	2-9-1904	Lakewood Reservoir inlet to 75th Street	As needed to maintain 1.5 cfs below Lakewood Reservoir	November 1-April 30
Barker Reservoir	5-15-1956 4-22-1966	Orodell gage to 75th Street	At the city's discretion to maintain up to 15 cfs from all sources	Year round

The CWCB junior water rights combined with the city's dedication of senior water rights and use of other city water have a significant positive effect on instream flows. Since the establishment of the instream flow program, North Boulder and main Boulder Creeks rarely drop below the minimum levels needed for healthy fish habitat. The creeks continue to flow at much higher than the minimum levels during the natural high flow periods as they historically have done. Unless the physical supply is unavailable or there is a severe drought or emergency, flows rarely drop below 0.5 cfs in North Boulder Creek from Silver Lake Pipeline diversion to Lakewood Reservoir and 1.5 cfs in Boulder Creek and North Boulder Creek from Lakewood Reservoir to 75th Street in the winter. Flows rarely drop below about 5 cfs at any point from the Silver Lake Pipeline diversion to 75th Street during the summer. Figure 5-12 illustrates the contribution of the water rights and water dedicated by the city for instream flow in Boulder Creek.

FIGURE 5-12. FLOW IN BOULDER CREEK BETWEEN ORODELL AND 75TH STREET IN 2006-2007[89]



5.1.3.4 | NORTH BOULDER CREEK INSTREAM FLOWS

The instream flow needs for the reach of North Boulder Creek below Lakewood Reservoir have been extensively studied. A study of habitat needs for trout species and macro-invertebrates in North Boulder Creek was completed by Chadwick and Associates during the Lakewood Pipeline reconstruction permitting process[90]. The CDOW completed other studies in support of the instream flow filings made by the CWCB[91].

Fish sampling done for the Chadwick study showed the dominant species in North Boulder Creek to be brook trout and rainbow trout[92]. Fry of both species are vulnerable to being displaced by high spring runoff flows. Sampling demonstrated that fry and juvenile trout were relatively numerous in North Boulder Creek and adult fish were limited. This observation supported the study conclusion that adult winter survival of the fish during low flow periods is the limiting life stage. The study stated that a minimum winter flow of 0.3 cfs was needed below Lakewood Reservoir to meet the USFS criteria of maintaining 40 percent of habitat for fish species. However, the minimum flow needed to sustain macro-invertebrates was about 1 cfs[93]. The study recommended limiting high flow to the 70 to 80 cfs range because it would “result in suitable habitat conditions that would not limit the enhancing efforts of increased winter flow”[94]. In other words, limiting high flows in the spring would result in a habitat level equivalent to that achieved by increasing minimum winter flows. Sufficient fry would survive the high flows to assure the presence of the maximum number of adult fish that the stream channel characteristics could support in the winter.

The high flow periods on North Boulder Creek do not contribute to limitations on fish population. Spring peak flows are in the range of 65 to 75 cfs with the city’s municipal water diversions. The city’s diversions during high flow periods in the spring and early summer help bring habitat into the most desirable range for survival of fry and juvenile fish. The city operates its Boulder Creek exchange, where Boulder Reservoir water is substituted for additional diversions in the upper Boulder Creek watershed, during high streamflow periods. The exchange can only occur when streamflows are high enough to satisfy all other diverters between the upper watershed and the Boulder Creek Supply Canal outlet. The exchange reduces peak flow levels in the spring and early summer and, therefore, serves to enhance habitat.

In 1993, CDOW performed an evaluation of instream flow needs for North Boulder Creek below Lakewood Reservoir using R2Cross methodology[95]. This work was done in support of CWCB instream flow filings for the creek. CDOW also found that rainbow and brook trout were the dominant species based on sampling done by CDOW from 1988 to 1991. The CDOW found that a minimum flow of 5 cfs from April 1 to September 30 met all three criteria CDOW believed necessary to preserve fish habitat in this reach. A lower winter flow requirement of 2 cfs was set based on the CDOW biological recommendation[96].

These studies were used to establish the flow levels for the city's commitment to provide the CWCB with water for instream flow purposes. The Water Court decree obtained by the city and the CWCB in 1993 (90CW193) for main Boulder Creek also included instream flow on North Boulder Creek as an allowed use for the city's donated water. North Boulder Creek is a gaining stream, so it was determined that minimum streamflow levels could be achieved through the city's provision of 1.5 cfs at Lakewood Reservoir in winter. In the summer, the water rights donated by the city have priority dates ranging from 1859 to 1862 which is sufficiently senior that the rights typically yield about 5 cfs[97].

Channel Maintenance Flows

The question of a need for channel maintenance flows for purposes of maintaining sediment transport and preventing vegetation encroachment was raised during the USFS Environmental Impact Study process. Resource Consultants and Engineers studied the question in November 1992 and found that the channel maintenance flow needs associated with lower elevation plains streams were not applicable to a stream with the characteristics of North Boulder Creek for several reasons[98].

First, the valley and channel containing North Boulder Creek was not initially formed by flowing water, but rather by glacial movement. Later, huge amounts of water were released when a natural dam created by glacial deposits gave way. Flow levels typically seen today are much smaller than these pre-historic channel-forming events. Second, the glacial origin of the North Boulder Creek channel has created a step-pool configuration that, as stated in studies by Larrone, Carson, Grant, et. al., is "formed by clusters of large rocks that can only be transported by extreme flow events"[99]. Additionally, Jarrett and Costa point out that "coarse sediments that form the beds of the upper elevation channels are unlikely to experience flows sufficient for their mobilization"[100] because snowmelt-dominated streams have little difference in flow between normal high spring flows and more frequently occurring flood events (in the range of 20 to 100 year recurrence intervals). In contrast, flows in rainfall-dominated streams at lower elevations during flood events can greatly exceed average flows. Third, the existing stream channel of North Boulder Creek is capable of carrying much more fine sediment than the surrounding geologic landforms supply.

The report concludes that North Boulder Creek is one of many mountain streams whose form is dominated by factors other than the interaction of frequently occurring flows and the channel boundary materials[101]. "The overbank areas along North Boulder Creek are not the product of floodplain accretion, but rather the product of the stream incising into the valley floor materials that, for the most part, were not deposited by the range of frequently occurring flows [seen today]"[102]. The report goes on to say that "…the material being transported by the stream is significantly finer than that making up the bed"[103]. Additionally, there is considerable field evidence that the reaches of North Boulder Creek downstream of Lakewood Reservoir have the capacity to transport significantly more of the relatively small caliber sediment than is being supplied from upstream[104]. Ultimately, a reduction in flow in such streams will not result in significant aggradation or loss of channel capacity therefore, artificial provisions for channel maintenance flows are not necessary[105].

5.1.3.5 | MIDDLE BOULDER CREEK INSTREAM FLOWS

Since purchasing Barker Reservoir in 2001, the city has maintained minimum flow levels in Middle Boulder Creek below the dam. One of the city's instream flow goals is to maintain a minimum of 3 cfs in Middle Boulder Creek below Barker Dam in the winter and 4 cfs in the summer. The city has been and will continue to release water from Barker Dam at this level.

The city and CWCB have discussed the possibility of a CWCB filing for a junior water right for instream flow purposes along a reach of Middle Boulder Creek. The stream reach would extend from Barker Dam to the confluence of Middle Boulder Creek and Boulder Creek. If a CWCB instream flow right is in place, the water voluntarily released by the city can be protected from diversion by other water users in this stream reach. Fortunately, only a few small water rights exist in this location, so it is not critical that the CWCB make an instream flow filing and it is not necessary for the city to contractually dedicate use of water rights for instream flow to the CWCB.

Habitat analyses were conducted on Middle Boulder Creek between Barker Dam and its confluence with North Boulder Creek at Boulder Falls by the CDOW using the R2Cross methodology. The CDOW recommended winter flows (November 1 – April 30) of 4 cfs and summer flows (May 1 – October 31) of 9 cfs[106].

The city also hired a fisheries consultant to perform an IFIM analysis for the stream reach below Barker Dam (see Figure 5-13 and Figure 5-14)[107]. The analysis showed the optimum habitat occurred between 20 and 50 cfs for all life stages of fish in the stream. Peak flows during runoff in Middle Boulder Creek can exceed 200 cfs and normally exceed 50 cfs. The peak flow regime makes it impossible to attain the optimum habitat level without imposing an unnatural, "designer river" flow regime that would significantly raise winter flow levels and significantly reduce summer flow levels. Year-round flows held within the range of 20 to 50 cfs would deviate greatly from the natural flow regime that occurred prior to human stream management activities in which flows were typically below 5 cfs during the winter and would reach hundreds of cubic feet per second during peak spring runoff.

The IFIM study concluded that a minimum instream flow of 2 cfs in the winter and 4 cfs in the summer should protect the aquatic system within this stream reach[108]. The limiting habitat for this section of stream is pool depth, mainly for the juvenile and adult fish that would be over-wintering in the areas. This limitation still exists even at the higher flows specified by the R2Cross methodology of 4 cfs in

FIGURE 5-13 HABITAT PERCENTAGES IN MIDDLE BOULDER CREEK STUDY AREA[109]

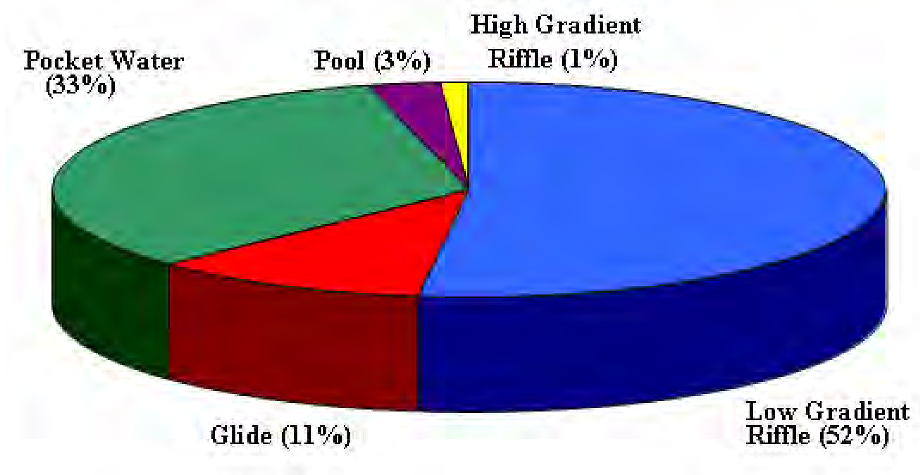
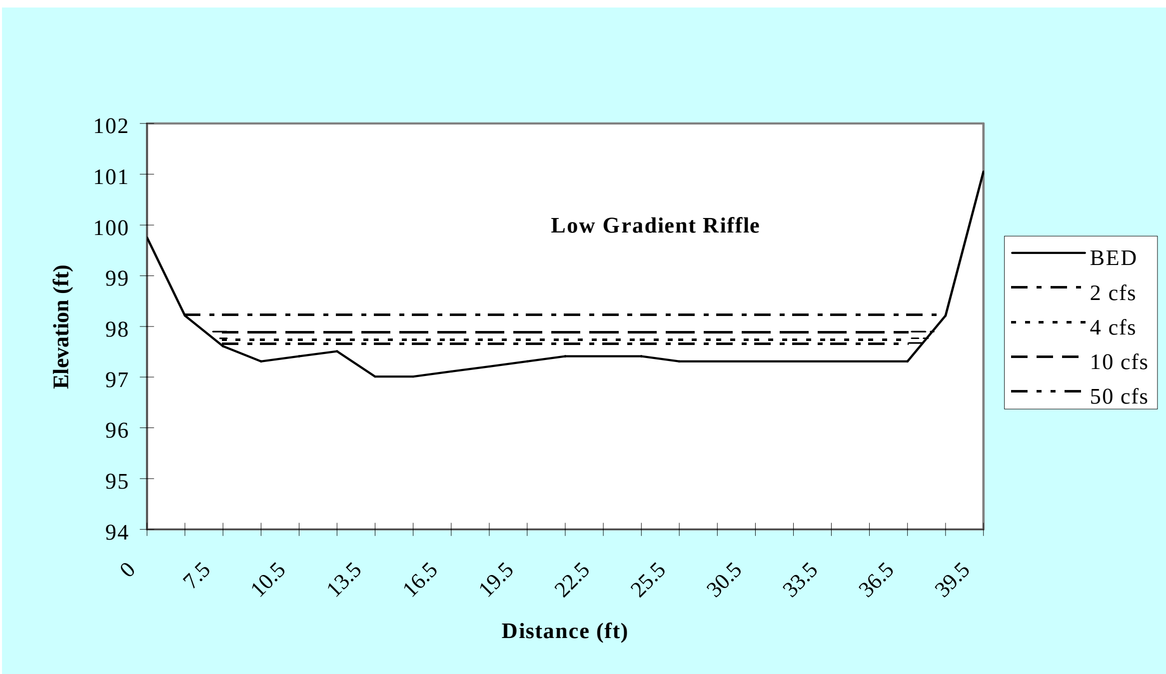


FIGURE 5-14. STREAM CROSS SECTION, WATER DEPTH AND WATER SURFACE ELEVATIONS AT 2, 4, 10, AND 50 CFS IN MIDDLE BOULDER CREEK[110]



winter and 9 cfs during summer. The minimum flow levels voluntarily supported by the city below Barker Reservoir are 3 cfs during the winter and 4 cfs during the summer. By maintaining this level of minimum flow protection and insuring that the stream sections are not dewatered and then re-watered, productivity should be maintained in the system.

5.1.3.6 | SOUTH BOULDER CREEK INSTREAM FLOWS

The city has had ongoing efforts to develop an instream flow program on South Boulder Creek. The OSMP Department has taken the lead in program development due to the large amount of Open Space land along South Boulder Creek. The city water utility does not own water rights along South Boulder Creek.

OSMP owns water rights along South Boulder Creek that are used for irrigation of Open Space lands. However, due to operational constraints under the OSMP charter, it is difficult for OSMP to dedicate any water rights to the CWCB. Nevertheless, OSMP has the ability to manage its irrigation diversions in a manner that keeps certain reaches of South Boulder Creek wet. These informal management practices assist with streamflow maintenance. Additionally, since 1992, OSMP has worked with Boulder Flycasters and several ditch companies to construct structural improvements to the stream channel and to seal leaky headgate structures that drained water out of the creek in the winter.

The development of an instream flow program for South Boulder Creek began in 1980 with a CWCB filing for instream flow rights. The Water Court issued a decree in 1983 that adjudicated a water right with priority date of December 2, 1980 for instream flows in South Boulder Creek in the amount of 15 cfs from Gross Reservoir to South Boulder Road for the period from May 1 through September 30 of each year[111]. The amount that was decreed for the winter period from October 1 to April 30 of each year varied by reach: 6 cfs from Gross Reservoir to Eldorado Springs and 2 cfs from Eldorado Springs to South Boulder Road. The CWCB did not seek a decree for South Boulder Creek from South Boulder Road to the Boulder Creek confluence because of a requirement that CWCB filings be limited to actual water available for instream flow purposes. There is very little water available for instream flow protection below the diversion points for Baseline Reservoir.

Under the CWCB decree, protection of instream flows at the decreed levels is subject to all "uses or exchanges of water being made by other water users pursuant to appropriation or practices in existence on [December 2, 1980][112]." Given the seniority of most water rights on South Boulder Creek and the over-appropriated status of the stream, the effect of the CWCB right was mostly to prevent instream flow levels from being further depleted.

City staff continued efforts to develop instream flows on South Boulder Creek during the 1990's. On South Boulder Creek, the major storage reservoirs, which are needed to supply a winter instream flow, are not operated by the city. Because there are so many diverters other than the city on South Boulder Creek, instream flow development will take cooperative efforts among many parties and cannot proceed based on relatively independent efforts by the city as it has on North Boulder and Middle Boulder creeks.

City staff approached Denver Water in 1992 with a proposal to use Gross Reservoir storage space for purposes of providing South Boulder Creek instream flows. In 1994 and 1995, Denver Water participated in joint studies with the city and PSCo (now Xcel Energy) to investigate the feasibility of an integrated instream flow program for Middle Boulder Creek below Barker Reservoir and South Boulder Creek below Gross Reservoir[113].

In 1996, discussions resumed with Denver Water as they entered into a FERC licensing process for Gross Reservoir. These discussions resulted in an agreement in 1998 to progress toward meeting South Boulder Creek instream flow needs through the creation of the Environmental Pool in Gross Reservoir[114]. The Environmental Pool consists of 2,500 acre-feet of water storage space for purposes of providing winter instream flows for South Boulder Creek. The water to be stored has not yet been identified and would ultimately need to be provided by Boulder or other interested parties. Additionally, operational experience has demonstrated that the limited seasonal availability of the Environmental Pool makes it potentially unusable.

Instream Flow Amounts Needed

Flow amounts decreed in the CWCB filing were based on a requirement that any CWCB filing be limited to actual water available for instream flow purposes. Field studies done in the late 1970's and early 1980s by the CDOW using the R2Cross method defined South Boulder Creek's physical capacity to provide habitat for fish at given flow levels[115]. The 15 cfs summer level represents a desired low flow condition and the 2 cfs winter level is considered an absolute minimum level for fish survival. Based on the habitat studies and assuming water could be made available, a more desirable winter level for South Boulder Creek would be 7 cfs from Gross Reservoir to South Boulder Road. Desirable instream flow levels from South Boulder Road to the confluence with Boulder Creek would be 2.5 cfs in the winter and 4 cfs in the summer[116].

During the winter, the city of Lafayette has historically diverted approximately 1.5 cfs of water out of South Boulder Creek at the headgate of the Lafayette Pipeline near Eldorado Canyon. Prior to 1996, this water was carried to Lafayette's Marshall WTF. In 1996, Lafayette discontinued use of the Marshall WTF rather than invest in extensive upgrades. Water that Lafayette had previously diverted out of South Boulder Creek at Eldorado Canyon in the winter now periodically remains in the creek down to Lafayette's diversion point into Baseline Reservoir at South Boulder Road. This diversion occurs only intermittently because of winter operational constraints (*i.e.,* freezing). It is possible that a portion of the winter instream flow need could be met if Lafayette continues this operational mode for its water system as is expected and when the water is physically able to flow. However, this water would only provide a small portion of the desired 7 cfs and would only be available intermittently throughout the winter instream flow season.

Availability of Gross Reservoir Environmental Pool

In most years, Denver Water completely fills Gross Reservoir with spring runoff from the west slope delivered through the Moffat Tunnel. Space in the Environmental Pool is created as Denver Water draws water out for municipal use following the spring fill. The agreement for Gross Reservoir use for instream flow purposes provides that as soon as reservoir space becomes available after May 1 of each year due to Denver Water withdrawals, Boulder can store up to 2,500 acre feet of water in Gross Reservoir on a space-available basis. Space usually starts becoming available in mid-July. Between November 1 and April 30, Boulder can call for releases of this water from the reservoir to create flows of up to 7 cfs in South Boulder Creek between Eldorado Springs and the confluence with Boulder Creek. Any water remaining in the Environmental Pool on the next May 1 becomes available for Denver Water to use for its municipal needs. Under the agreement, once Denver Water resolves water delivery problems within its northern water distribution area caused by water storage limitations, the full 2,500 acre-feet capacity of the Environmental Pool will be available beginning on July 15 of each year based on increases of 42 acre-feet per day in storage space. The agreement allows for efforts by Boulder to place water in the Environmental Pool to be enhanced by others interested in providing water for instream flow.

Although the city has made multiple attempts to use the Environmental Pool since 1998, operating experience has made it clear that the Environmental Pool arrangement as it stands now is problematic because of limited seasonal availability of the pool. Negotiations are continuing with Denver Water regarding a South Boulder Creek instream flow program.

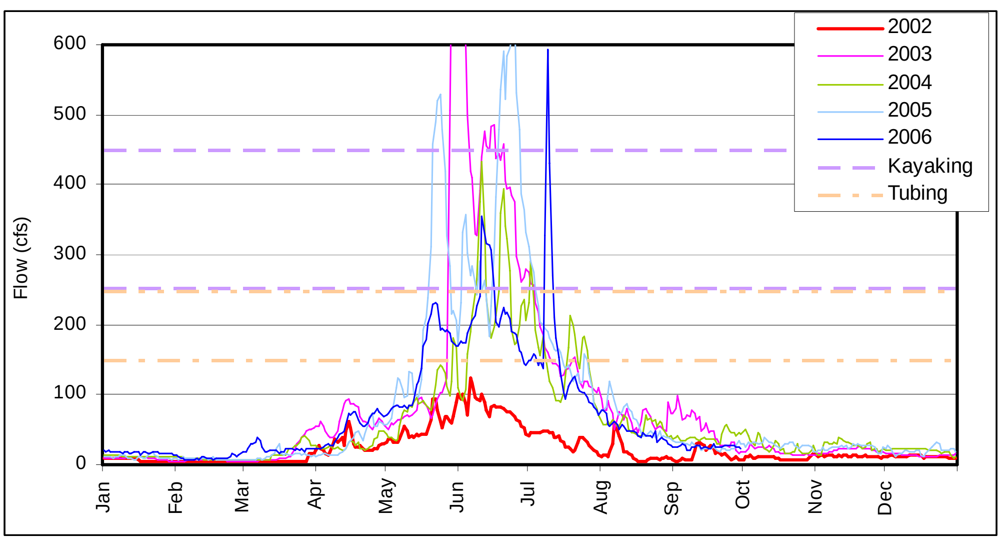
5.1.4 | FLOW-BASED RECREATION

Maintaining the existing flow regime from Eben G. Fine Park to 75th Street in the month of June during normal to above-normal flow years will provide sufficient peak flow levels for recreational kayaking and tubing on Boulder Creek. Preferred flow levels for kayaking and tubing are:

- Kayaking: 250 – 450 cfs (class IV) and down to 150 cfs (class III) below Orodell through Water Park to 30th Street
- Tubing: 150 – 250 cfs from Eben G. Fine Park to Broadway

Figure 5-15 shows daily mean streamflows in Boulder Creek near Orodell[117]. In dry years, such as 2002, summer flows do not reach the recreation goals. In other years, flows tend to reach the tubing range for one to two months. Flows within the ideal kayaking range are less frequent and less sustained.

FIGURE 5-15. HISTORICAL DAILY MEAN STREAMFLOW – BOULDER CREEK NEAR ORODELL[118]



The flow amounts desired for recreational use are large. A 24-hour period of flow within the kayaking range is equal to about ten days of water supply for the entire city. Therefore, the city has little ability to increase recreational flows without jeopardizing municipal supply.

5.2 | Hydrology

Boulder's municipal water supplies come from the headwaters of the Boulder Creek basin and the Colorado River basin. Within the Boulder Creek basin, Boulder uses its water rights to store water in reservoirs and divert water to its treatment plants via pipelines and ditches, which are identified in sections 4.2.1, 4.2.2, 4.2.4 and 4.2.5. Boulder also owns a substantial portion of the units in the CBT and Windy Gap projects, which divert water from the Colorado River to the South Platte River through the Adams Tunnel. The source watersheds for Boulder's water system are shown in Figure 4-4.

Knowledge of the hydrology of the Boulder Creek and Colorado River source watersheds is useful in understanding the physical water supplies available to Boulder and the effects of other water rights and interstate compacts upon Boulder's water supplies. Because the South Platte River basin is over-appropriated, Boulder's water rights are subject to curtailment by calls from downstream senior water rights at times when demands exceed supplies. Similarly, the CBT and Windy Gap projects are subject to calls from downstream senior water rights within Colorado and to limits imposed upon Colorado's use of the Colorado River by the River Basin Compacts (see section 3.4.6).

The surface water hydrology of Boulder Creek, the South Platte River and the headwaters of the Colorado River reflects a general pattern of snow accumulation from November through March or April, snowmelt (coupled with spring season precipitation) from April or May through June, and relatively dry summers and falls. Streamflows resulting from this general pattern are variable and uncertain, and reflect a complex interaction of continental/hemispheric weather systems, elevation, topography, soils, geology and land cover.

5.2.1 | FACTORS AFFECTING HYDROLOGY

5.2.1.1 | GENERAL CLIMATE

The climate of the Boulder Creek and Colorado headwaters is highly variable, characteristic of their mid-continental setting. Sudden changes in weather can occur hourly, daily or seasonally, and from year to year. While prevailing weather patterns are generally westerly, air masses can move in from every direction, each producing a characteristic type of weather.

Cold fronts from the north typically move southward parallel to the mountains, creating strong regional temperature inversions with relative warm sunny weather above and dark, colder weather below. Cold front storms sometimes produce significant precipitation, especially when there is a concurrent influx of warm Gulf air above the cold air mass.

Pacific air masses enter Colorado along several westerly tracks. Most precipitation from Pacific storms typically occurs at elevations above 9,000 feet. Pacific storms are responsible for most of the precipitation on the West Slope of Colorado and a substantial portion on the East Slope. Pacific air masses frequently produce strong winds along and east of the Continental Divide. These winds can significantly redistribute snowpack in the Boulder Creek headwaters, which can affect subsequent spring season runoff patterns. Under certain winter and spring conditions, unseasonably warm and dry "Chinook winds" occur that cause significant loss of snowpack in a short period of time.

Gulf air masses, often interacting with other weather systems, typically move into Colorado from the south and east during the spring and fall. As they rise against the mountains or are elevated by cold fronts, they produce much of the precipitation along the East Slope. Many of these storms dissipate above 10,000 feet, but some reach to the Continental Divide and spill over into adjacent West Slope headwater areas. Occasionally these "up-slope" storms produce spectacular amounts of precipitation over the extensive portions of the East Slope.

Summer convectional storms produce locally abundant amounts of precipitation, although their frequency and extensiveness can vary significantly from year to year in response to regional drought conditions. The East Slope often experiences a monsoonal weather pattern in late summer with brief, light rain showers in many late afternoons. These storms can also produce only dry lightning storms or hail.

5.2.1.2 | ELEVATION EFFECTS

One of the key factors affecting hydrology is the interaction of weather and land surface elevation. As weather systems are forced upward by Colorado's mountain terrain, precipitation increases because cooler air has less ability to hold water. Throughout Colorado, precipitation is greater at higher elevation, as shown in Figure 5-16. Conversely, evaporation decreases with elevation due to decreased temperature at higher elevations. Only those lands above approximately 9,000 feet produce significant amounts of runoff, as shown in Figure 5-17. Combined with their relatively steep topography and shallow soils, these high-elevation watersheds produce the vast majority of natural stream flows in the Boulder Creek basin and throughout Colorado. For example, more than 60 percent of the precipitation falling in the Barker Reservoir and Silver Lake watersheds leaves those watersheds as streamflow. Those watersheds represent only 38 percent of the Boulder Creek drainage area above the city of Boulder, but they produce more than 70 percent of the annual flow at this location.

Consequently, headwaters precipitation is much more relevant to Boulder's water supply than precipitation in Boulder's service area. Headwaters precipitation is often quite different than in urban areas. This can be a source of confusion to municipal water users as media coverage of weather and drought conditions usually does not differentiate between headwaters precipitation and precipitation in the Front Range urban corridor. A heavy rainfall occurring in Boulder will not increase the city's Boulder Creek water supplies, but will reduce demand on the system.

FIGURE 5-16. ANNUAL PRECIPITATION IN COLORADO[119]

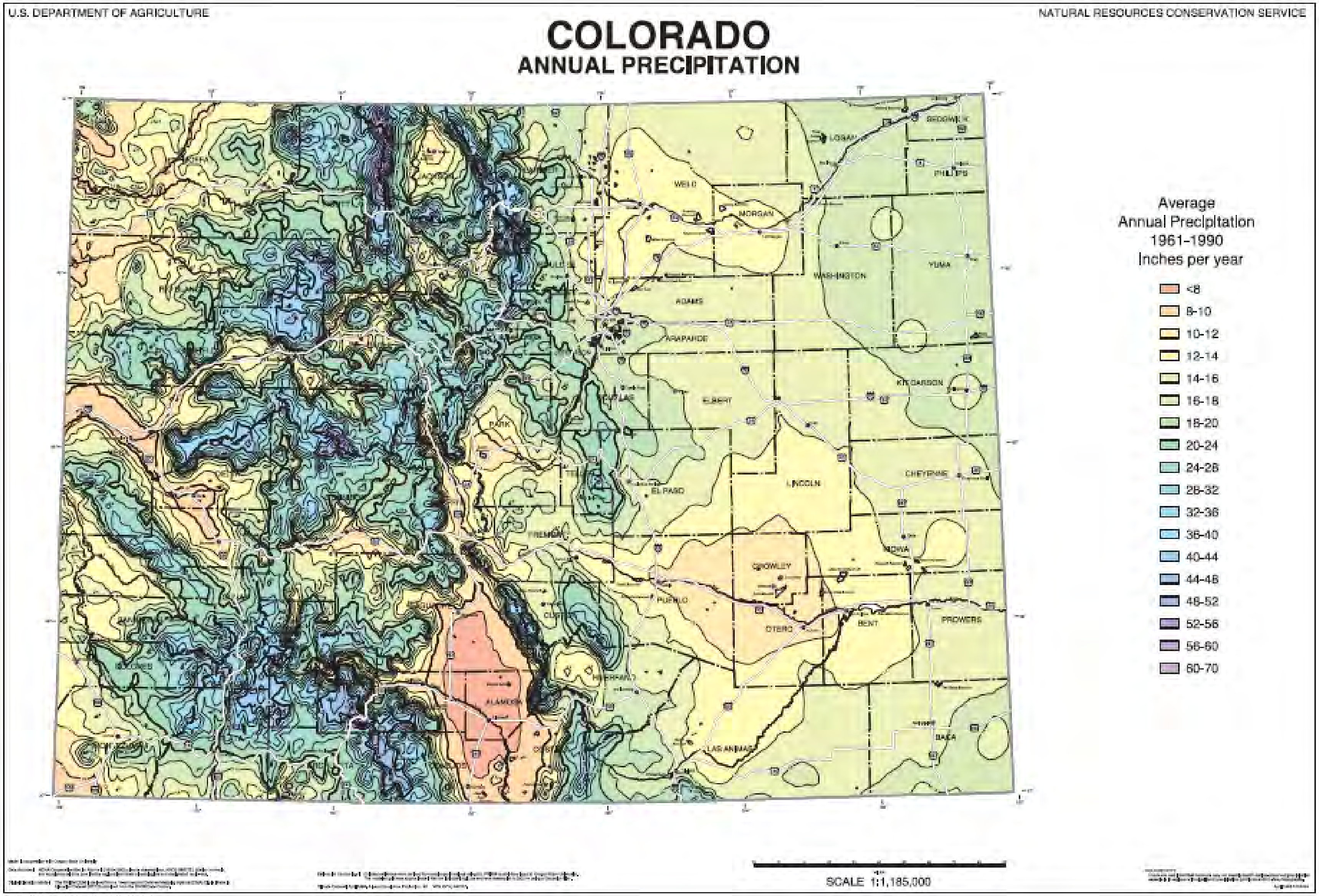
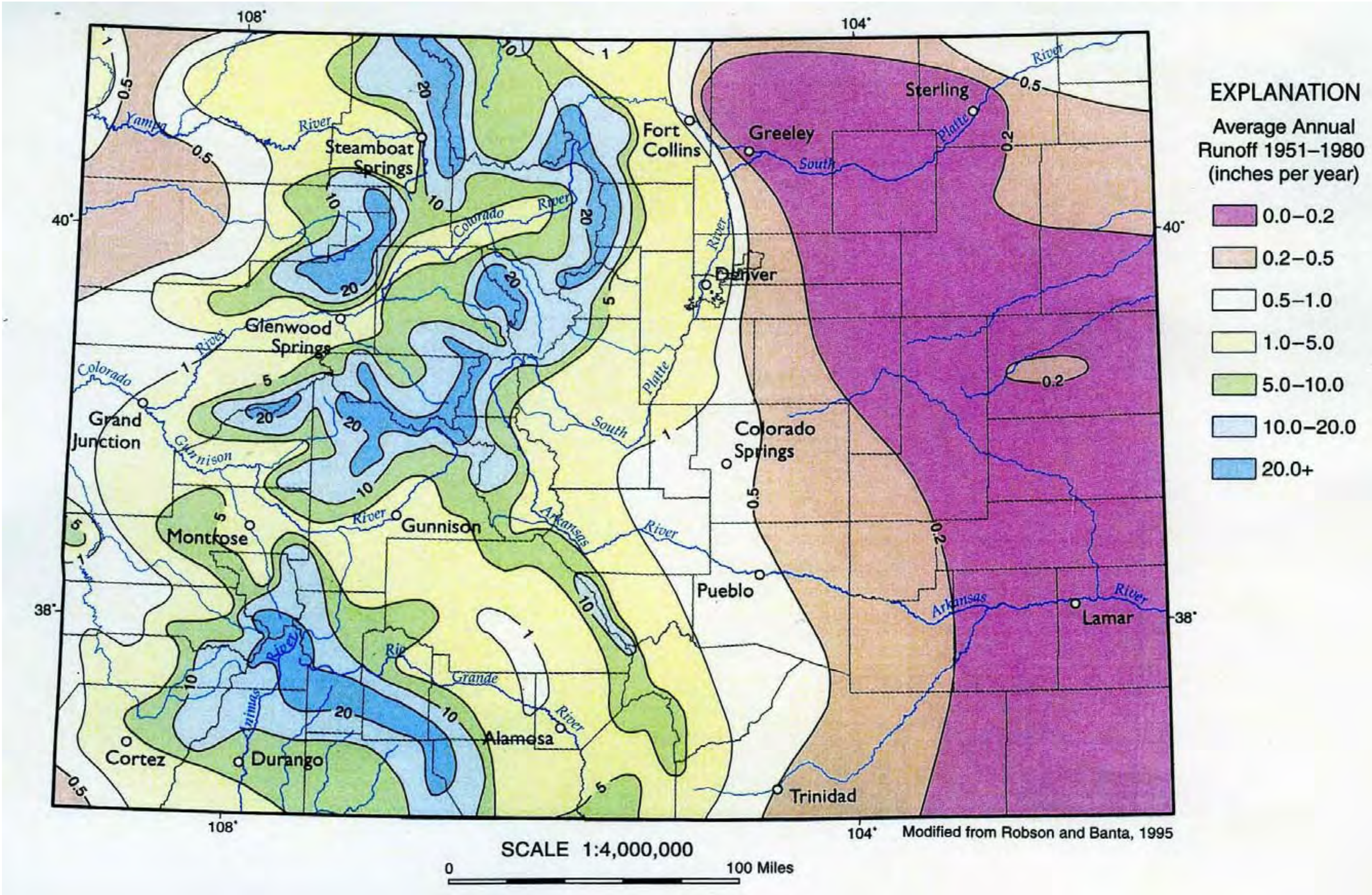


FIGURE 5- 17. AVERAGE ANNUAL WATER RUNOFF IN COLORADO[120]



5.2.1.3 | BOULDER CREEK BASIN PRECIPITATION

Headwaters Precipitation

Precipitation in the Boulder Creek headwaters has historically been measured for extended periods at four principal locations. The University of Colorado's Mountain Research Station[121] has measured precipitation at several sites on Niwot Ridge, which constitutes the northern boundary of the North Boulder Creek sub-basin and of the city's Silver Lake Watershed. Niwot Ridge sites C-1 and D-1, located in sub-alpine and alpine ridge-top settings at 9,900 feet and 12,300 feet elevation, respectively, have the most continuous records of daily precipitation, beginning in October 1952. Since 1979, daily precipitation has also been measured at two SNOTEL sites operated by the Natural Resources Conservation Service: the Lake Eldora SNOTEL site, situated on a ridge at 9,700 feet in the Middle Boulder Creek basin and the University Camp SNOTEL, situated in a valley at 10,300 feet in the North Boulder Creek sub-basin[122]. Average annual precipitation and runoff for these four sites is shown in Figure 5-18 and Figure 5-19, respectively. Precipitation data for these sites are included in the Appendices.

Precipitation patterns at these four stations illustrate the variability created by elevation, topography and weather systems. Three of the sites (Lake Eldora SNOTEL, Niwot Ridge Site C-1 and University Camp SNOTEL) are located within a relatively narrow band of elevation; 9,700 feet to 10,300 feet. However, the University Camp SNOTEL has significantly more precipitation compared to the other two sites. This is due to University Camp's valley setting, which experiences increased wind deposition of blown snow and reduced wind losses. Precipitation is greater at all four sites during the winter and spring than the summer and fall.

Headwaters precipitation typically accumulates as snowpack from November through March or April and then melts within a relatively brief time period typically beginning in April and ending in June. Snowmelt and associated stream runoff varies considerably from year to year. Spring runoff is influenced by variables such as the amount and spatial distribution of snowpack at the end of winter, spring season temperatures, winds, cloud cover and rain events. Snowpack in Colorado (in the form of Snow-Water Equivalent or SWE) is measured on a daily basis at 103 automated SNOTEL sites and monthly at 137 manually read snow courses distributed throughout mountainous areas of the state at elevations ranging from 7,800 feet to 11,900 feet[123]. There are two SNOTEL sites and two snowcourses located in the headwaters of the Boulder Creek basin. Historical snowpack data have been collected on a daily basis at the Lake Eldora and University Camp SNOTEL stations since 1979 and on a monthly basis at the Boulder Falls and University Camp snowcourses since 1952 and 1938, respectively.

Figure 5-20 illustrates the average daily snowpack accumulation and loss patterns for the precipitation and SNOTEL sites in the upper Boulder Creek basin. Daily and monthly snowpack data for these SNOTEL stations and snowcourses are included in the Appendices.

FIGURE 5- 18 AVERAGE ANNUAL PRECIPITATION, BOULDER CREEK HEADWATERS[124]

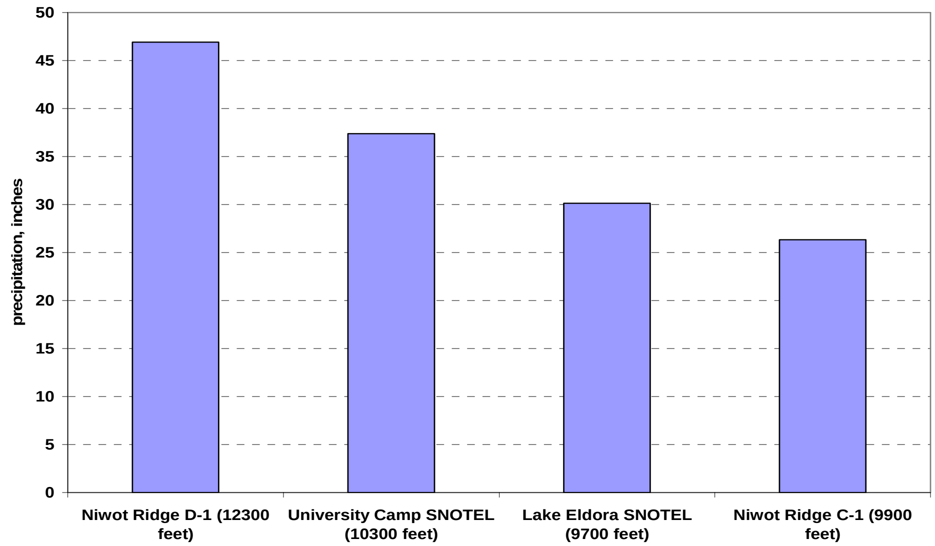


FIGURE 5-1912. AVERAGE MONTHLY PRECIPITATION, BOULDER CREEK HEADWATERS[125]

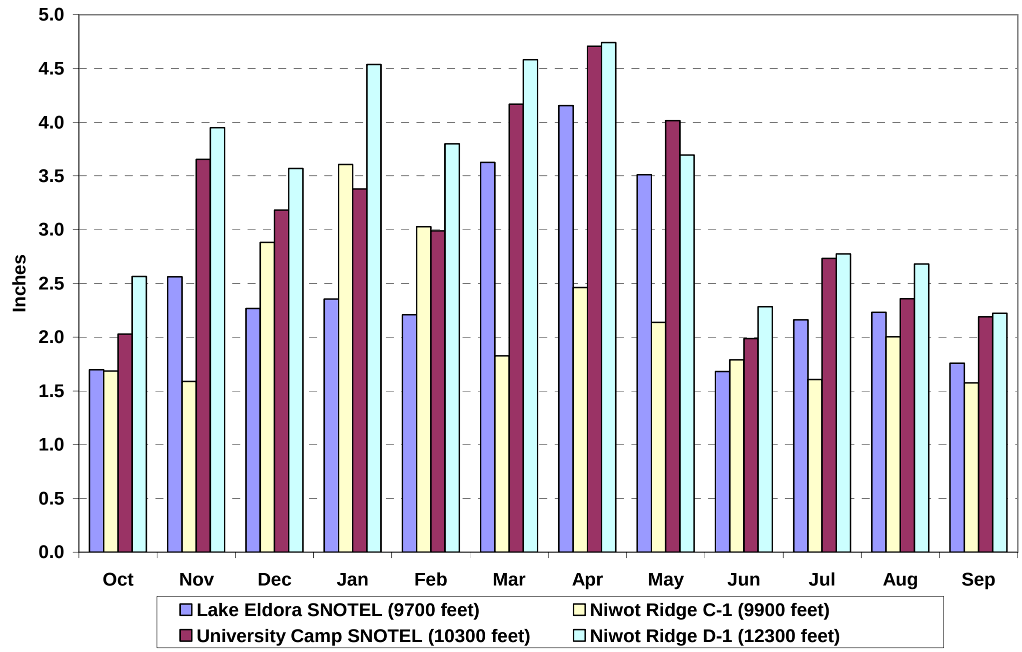
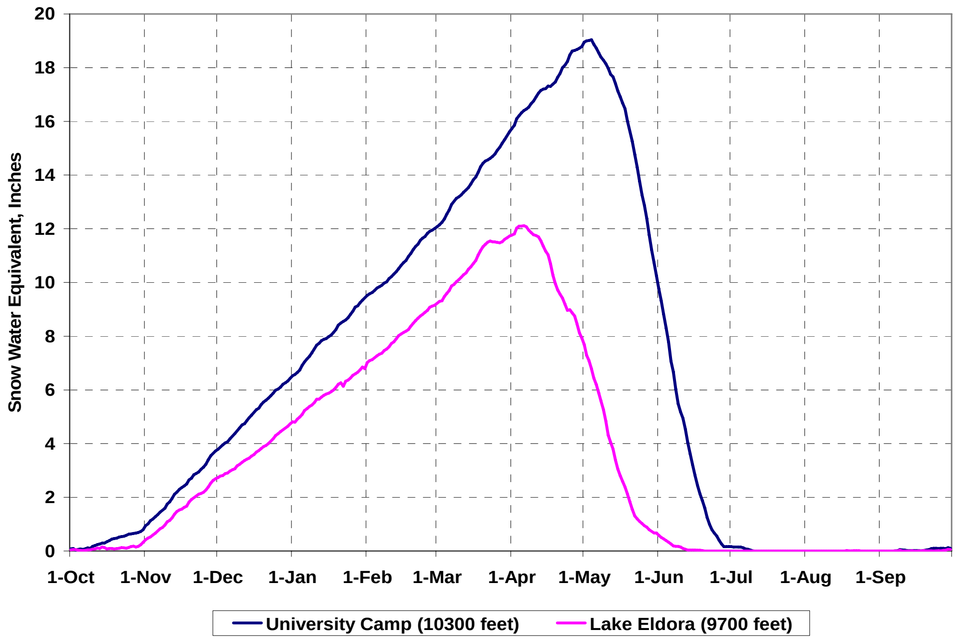
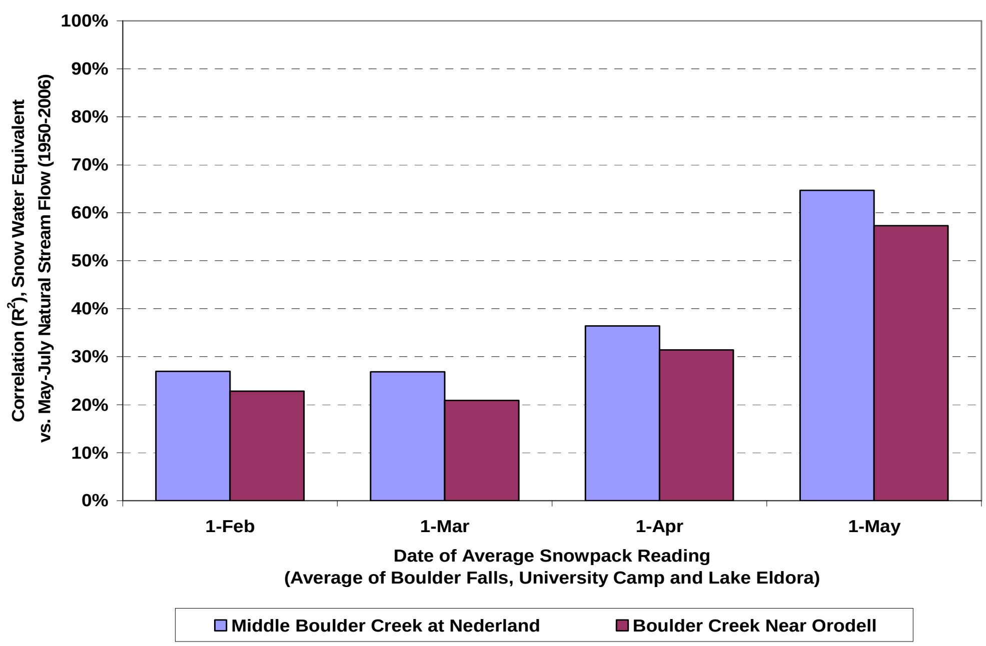


FIGURE 5-2013. AVERAGE SNOWPACK ACCUMULATION PATTERNS AT BOULDER CREEK SNOTEL SITES[126]



While snow accumulation and snowmelt are the major determinants of Boulder Creek hydrology, runoff volumes and patterns are also affected by spring season weather conditions occurring as the snow begins to melt. Warm, sunny and windy conditions during April and May can significantly diminish the volume of runoff and accelerate its timing, while cool, wet springs can increase the volume of runoff and extend its duration. Consequently snowpack data alone are not meaningful predictors of runoff until at least May 1st, as shown in Figure 5-21.

FIGURE 5-21. PREDICTION VALUE OF SNOWPACK TO ACTUAL BOULDER CREEK RUNOFF VOLUME[127]



Precipitation and Temperature in the City of Boulder

While precipitation and temperature in the Boulder water supply service area have little to do with streamflow runoff patterns in the Boulder Creek headwaters, they have a significant effect on outdoor water demands in the service area. Precipitation and temperature in the city have been measured and recorded since 1893[128]. Annual precipitation in Boulder averages about 18.9 inches per year, and has ranged from a low of 11 inches per year (1939, 1954, and 1966) to a high of 30 inches per year (1995), as shown in Figure 5-22. April and May are typically the wettest months and December through February are typically the driest months, as shown in Figure 5-23.

FIGURE 5-22. 1894-2006 ANNUAL PRECIPITATION, CITY OF BOULDER[129]

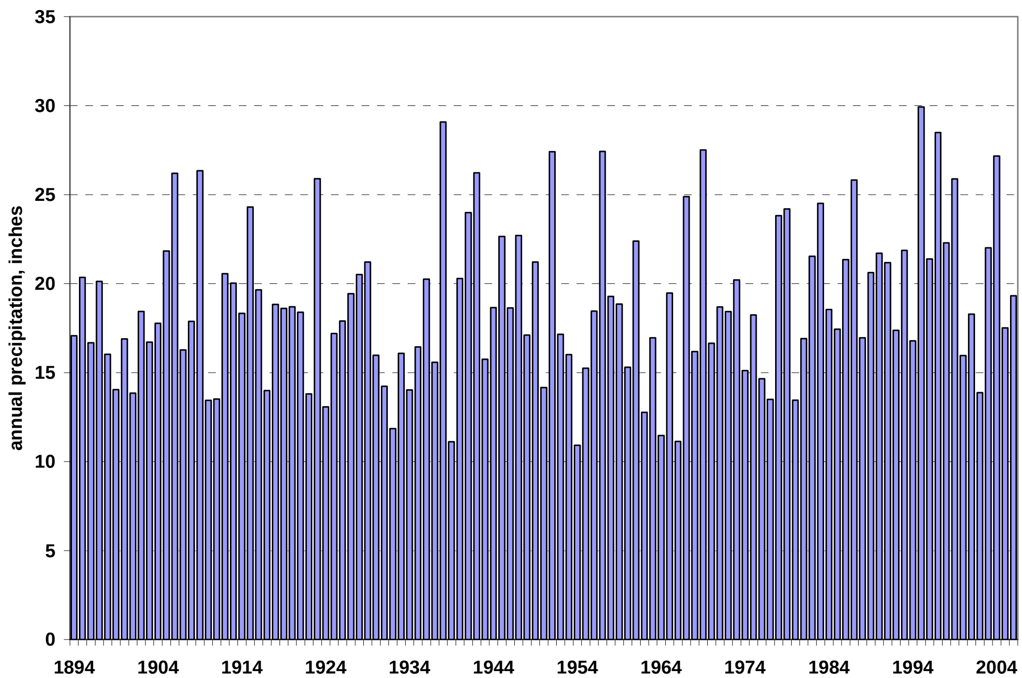
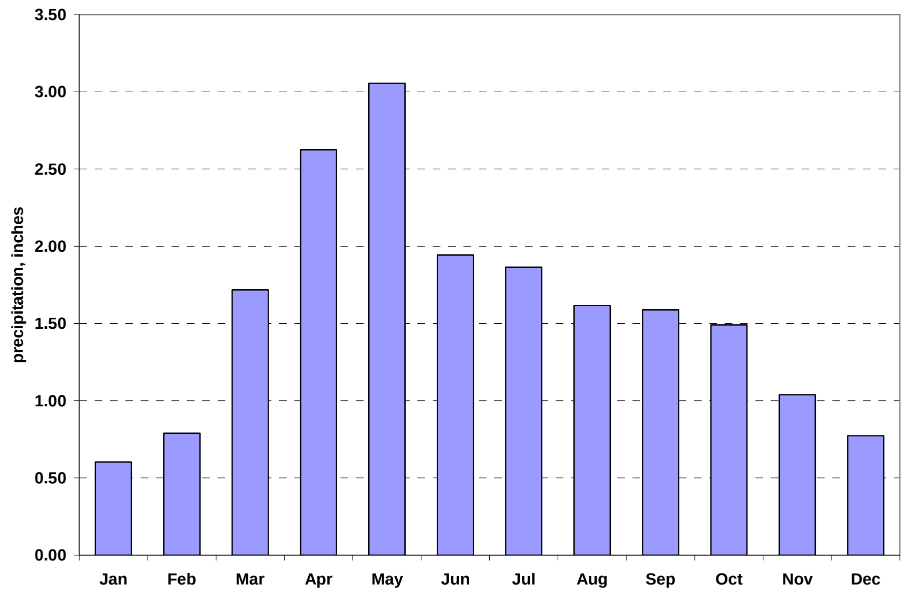


FIGURE 5-23. 1894-2006 AVERAGE MONTHLY PRECIPITATION, CITY OF BOULDER[130]

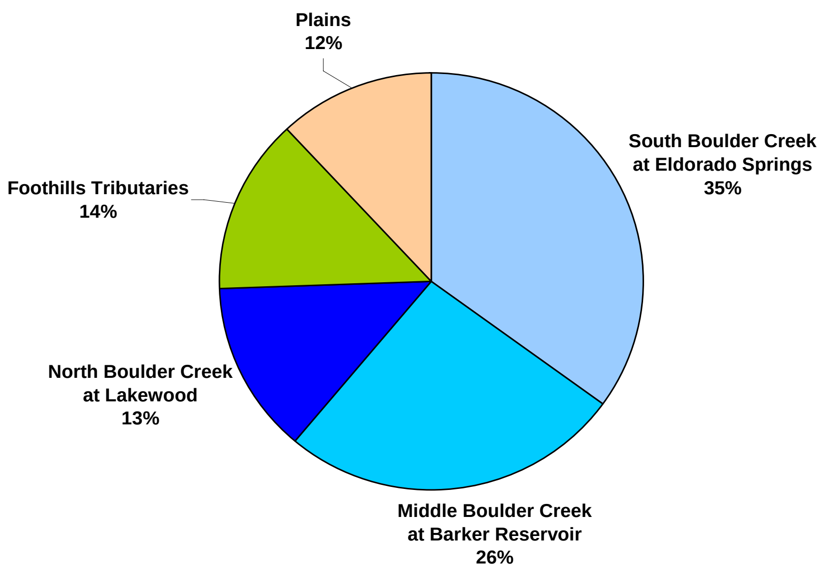


Four additional weather stations, located in the northwest, southwest and eastern portions of Boulder, have been operated by the Northern Colorado Water Conservancy District since 2002. Precipitation data for the city of Boulder are included in the Appendices.

5.2.2 | HISTORIC HYDROLOGY OF THE BOULDER CREEK BASIN

The Boulder Creek basin includes about 439 square miles ranging in elevation from over 13,000 feet to under 4,900 feet above sea level. Boulder's three main tributaries, North, Middle and South Boulder Creeks, contribute about 13 percent, 26 percent and 35 percent, respectively, of the basin's average natural flow of approximately 155,000 acre-feet per year, with the balance supplied by other minor tributaries, as shown in Figure 5-24.

FIGURE 5-24. BOULDER CREEK WATERSHED NATURAL FLOW PRODUCTION BY SUB-BASIN[131]



Historic streamflows have been measured at locations in the Boulder Creek basin, as summarized in Table 5-8. Most of the streamflow records for these gages are available from the CDOW or the USGS and have been included in the Appendices. Streamflows are also measured at other locations by individual water users as part of the operations of their water rights and water supply systems, although those data may not be readily available.

TABLE 5-8. STREAMFLOW GAGES IN THE BOULDER CREEK BASIN[132]

Station ID No.	Station Name	Drainage Area (sq. mi.)	Elevation (ft.)	Period of Record
06725500, BOCMIDCO	Middle Boulder Creek at Nederland	36.2	8,186	1907-present
06726000	North Boulder Creek at Silver Lake	8.7	10,210	1913-1932
	North Boulder Creek above Silver Lake Pipeline(1)	11.3	9,740	1959-1985
NOBOLACO	North Boulder Creek below Lakewood	32.9	8,080	1972-1985
06726500	North Boulder Creek near Nederland	26	8,135	1929-1931
06726900	Bummers Gulch near El Vado	3.87	5,986	1983-1995
06727000	Boulder Creek near Orodell	102	5,826	1906-present
06727500	Fourmile Creek at Orodell	24.1	5,750	1947-1953, 1983-1995
06729000	South Boulder Creek near Rollinsville	42.7	8,380	1911-1918, 1945-1949
06729300	South Boulder Creek at Pinecliff	72.7	7,930	1979-1980, 2005-present
06729500, BOCELSCO	South Boulder Creek near Eldorado Springs	109	6,080	1896-present
	Boulder Creek below Broadway(1)	135	5,344	1994-present
	Boulder Creek Below Wellman Canal(1)	136	5,280	1994-present
	Boulder Creek Below Butte Mill Ditch(1)	162	5,185	1994-present
	Boulder Creek below Green Ditch(1)	299	5,151	1994-present
06730200	Boulder Creek At North 75th Street near Boulder	304	5,106	1986-present
06730300	Coal Creek near Plainview	15.1	6,540	1959-present
06730400	Coal Creek near Louisville	27.3	5,280	1997-present
06730500	Boulder Creek at mouth, near Longmont	439	4,860	1927-1955, 1978-present
(1) Operated by the city of Boulder Water Resources Work Group				

The four most important gages in the Boulder Creek basin from Boulder's municipal water supply perspective are located on:

- Middle Boulder Creek at Nederland (Nederland gage);
- North Boulder Creek above the Silver Lake Pipeline - operated by Boulder (Silver Lake gage);
- North Boulder Creek below Lakewood Reservoir - previously operated by Boulder (Lakewood gage), and;
- Boulder Creek near Orodell (Orodell gage).

Several other gages in the Boulder Creek basin are also important for modeling the Boulder Creek basin and the operation of Boulder's water supply system. These are located on:

- South Boulder Creek near Eldorado Springs (Eldorado gage);
- Boulder Creek below Broadway (Broadway gage);
- Boulder Creek below Wellman Canal (Wellman gage);
- Boulder Creek below Butte Mill Ditch (Butte Mill gage), and;
- Boulder Creek below Green Ditch (Green gage).

These gages are collectively known as the instream flow gages. Lastly, the Boulder Creek at North 75th Street (75th Street gage) and Boulder Creek gage at the mouth of Boulder Creek are also used for modeling.

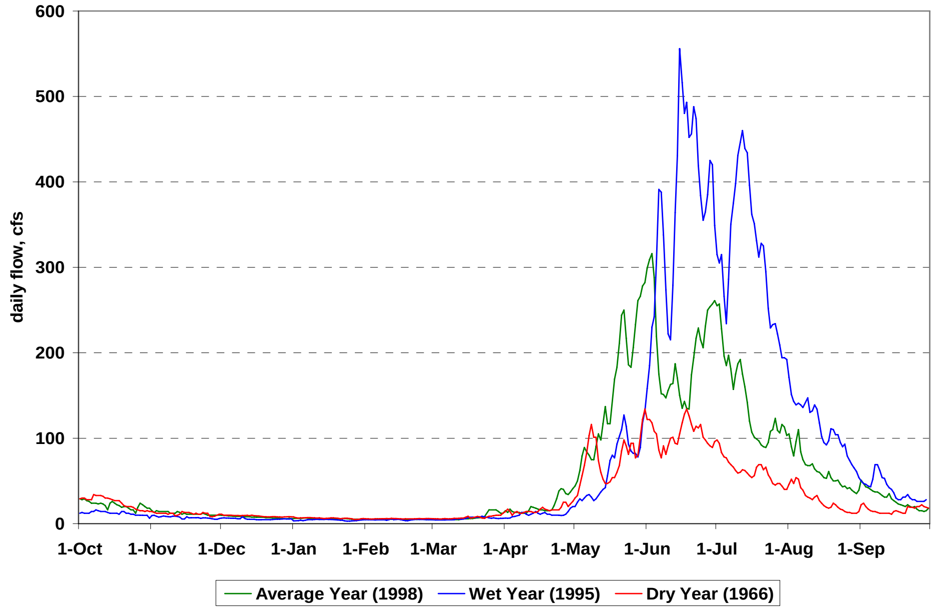
5.2.2.1 | MIDDLE BOULDER CREEK HYDROLOGY

Middle Boulder Creek flows from its headwaters in the Indian Peaks Wilderness Area to Barker Reservoir just east of Nederland with very little disturbance. The flow of Middle Boulder Creek as it enters Barker Reservoir is measured by the Nederland gage. At this point, the creek has a tributary area of 36 square miles and an annual flow of approximately 40,000 acre-feet per year. Flows at the Nederland gage represent almost all of the physical supply potentially available for diversion into Barker Reservoir and the Barker Gravity Line[iii]. The Nederland gage has been operating virtually continuously since 1907. The Nederland gage essentially measures natural flow, as there are only a few small diversions located upstream, including three reservoirs with a total storage capacity of about 700 acre-feet and irrigation of less than 50 acres. The Nederland gage is very important for planning purposes because of its long period of record and relatively natural flow regime. Streamflow data from this gage are critically important in assessing drought recurrence frequencies and long-term trends associated with climate variation[133]. Figure 5-25 shows typical average year, dry year and wet year hydrographs for the Nederland gage.

In an average year, streamflows typically range from a winter season base flow of about 5 cfs to a peak runoff flow of about 300 cfs in June. Winter season base flows do not normally fluctuate significantly, although base flows as low as 2 cfs have infrequently occurred during extreme cold periods. Streamflows during the runoff season vary greatly depending upon spring season snowpack, precipitation and temperature conditions. Alternating periods of hot, clear weather and cloudy, cool weather can result in multiple episodes of peak flows within a single runoff season, as shown in Figure 5-25.

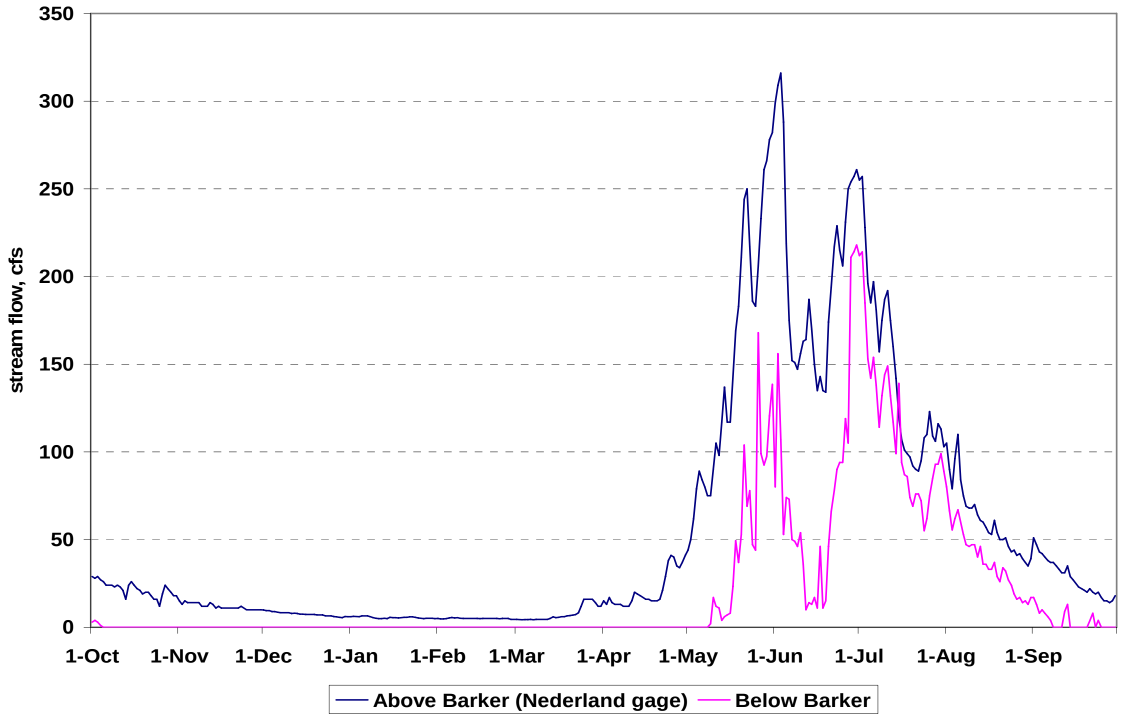
[iii] In addition to stream flows measured by the Nederland gage, Barker inflows also include a small amount of runoff from the local watershed around Barker Reservoir and wastewater discharges from the Town of Nederland.

FIGURE 5-25. WET, DRY AND AVERAGE YEAR HYDROGRAPHS - MIDDLE BOULDER CREEK AT NEDERLAND[134]



Downstream of Barker Reservoir, flows in Middle Boulder Creek are significantly affected by the operation of Barker Reservoir and the Barker Gravity Line (formerly known as the Boulder City Pipeline No. 3), which deliver water from Middle Boulder Creek to both Boulder's Betasso WTF and to the Boulder Canyon Hydro to generate hydropower. Prior to the city's purchase of the Barker System in 2001, the entire flow of Middle Boulder Creek was diverted into storage at Barker Reservoir or into the Barker Gravity Line except when calls from downstream senior water rights were greater than the available capacity in the Barker Gravity Line, which typically occurred from May through August. In other months, flows in Middle Boulder Creek immediately downstream of Barker Reservoir were historically near zero, increasing to about 1 or 2 cfs at its confluence with North Boulder Creek at Boulder Falls. Typical historic flows in Middle Boulder Creek above and below Barker Reservoir when the facilities were owned by PSCo are shown in Figure 5-26.

FIGURE 5-26. MIDDLE BOULDER CREEK AT BARKER RESERVOIR, WATER YEAR 1998



Sources: AMEC used data derived from PSCo's "Boulder Hydro Daily Water Records," which include incomplete daily readings for the channel weir located on Middle Boulder Creek downstream of the Farmers Gate outlet on the Barker gravity line. For days with missing channel weir data, AMEC calculated the flow below Barker via mass balance from USGS records of Nederland gage flows, and Barker contents and Barker Gravity Line flows (both from PCSO's Boulder Hydro Daily Water Records).

Since the 2001 acquisition of the Barker system, the city has released at least 3 cfs into Middle Boulder Creek below Barker Reservoir to protect the creek's aquatic habitat. Another change to the operation of Barker Reservoir under the city's ownership is that significant amounts of water are no longer drawn out of Barker Reservoir storage for hydropower generation at the Boulder Canyon Hydro Plant. Instead, the city uses Barker storage water primarily to meet its municipal demands and as a drought reserve pool. Hydropower generation at the Boulder Canyon Hydro Plant continues using water available on a direct flow basis. Under the city's ownership and use of the Barker system, streamflows in Middle Boulder Creek below Barker Reservoir have been depleted by an average of about 23 percent compared to natural inflows to Barker[iv].

5.2.2.2 | NORTH BOULDER CREEK HYDROLOGY

North Boulder Creek originates along the Continental Divide between Niwot Ridge and the Arapaho Peaks in the area of Boulder's Silver Lake Watershed. Headwater streamflows are regulated by seven city-owned reservoirs.

The Silver Lake gage measures flows in North Boulder Creek just upstream of the Silver Lake Pipeline intake[135]. Streamflow data from the Silver Lake gage, combined with upstream storage records can

[iv] This percentage was calculated based on flows derived from the same process as described in Figure 5-26 and virgin flow data, which AMEC calculated using AMEC. (n.d.a). *Orodell_Monthly_Virgin_Flows_V9.xls* data file. Boulder, CO.

be used to quantify natural stream flows at this location. The drainage area tributary to the Silver Lake pipeline is about 11 square miles. Natural flows for this area average about 15,000 acre-feet per year. Natural flows have fluctuated from less than 9,000 acre-feet in 1954 to over 23,000 acre-feet in 1984. The natural streamflow at this location constitutes about 70 percent of the physical supply potentially divertible by Boulder from North Boulder Creek. The watershed area below the Silver Lake Watershed at Caribou Ranch provides the remainder of the physical supply that is available to the city from North Boulder Creek at Lakewood Reservoir

The correlation between North and Middle Boulder Creeks natural flows is very high due to their similar drainage area characteristics and close proximity. The natural flow of North Boulder Creek at the Silver Lake gage is roughly equal to 38 percent of the natural flow of Middle Boulder Creek at Nederland.

There is an 8-foot Parshall flume, stilling well and recording house at the Silver Lake gage, which have been in existence since at least the mid-1950s. From 1959 through 1987, daily streamflows were recorded, generally for the months of June through October, by the city's watershed operator in the city's daily operation records. Readings during the winter were difficult to obtain due to the difficult alpine conditions at the site.

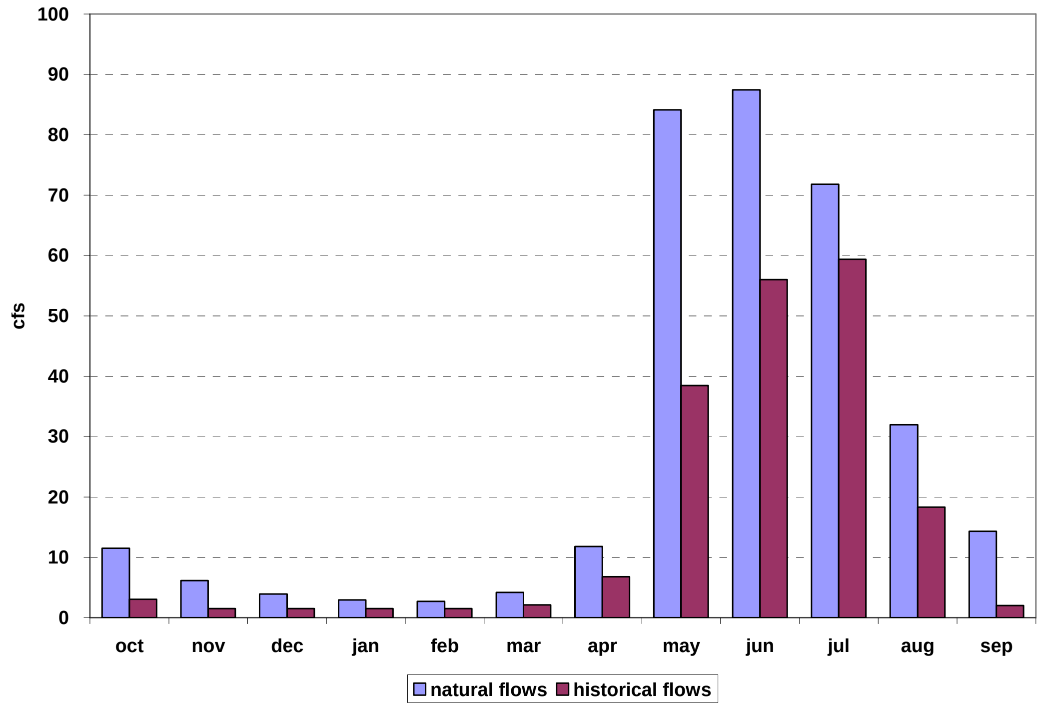
Streamflow records for the Silver Lake gage were generally not recorded from October 1987 through May 2001. In June of 2001 the city installed stilling wells at several locations on North Boulder Creek as part of its Supervisory Control and Data Acquisition (SCADA) system, including in the pool upstream of the 8-foot Parshall flume and the pool at the Silver Lake Pipeline diversion structure. Since June of 2001, streamflows at the Silver Lake gage (or equivalent locations) have been measured and recorded by the city's SCADA system.

From the Silver Lake Pipeline, North Boulder Creek flows about 4.5 miles to Lakewood Reservoir. Along this reach, North Boulder Creek is joined by Caribou Creek, DeLonde Creek and Como Creek to form a drainage area of about 30 square miles at Lakewood Reservoir. Natural flows at Lakewood Reservoir average about 20,000 acre-feet per year.

Approximately two-thirds of a mile downstream of Lakewood Reservoir, North Boulder Creek is joined by Sherwood Creek, a small tributary. When it was active, the Lakewood gage measured the flows on North Boulder Creek just below the Sherwood Creek confluence. Natural streamflows at the Lakewood gage basically comprise the total supply potentially divertible by Boulder from North Boulder Creek. The Lakewood gage historically operated only during the summer months (generally from June through September) from 1972 through 1985. While the accuracy of the gage data is questionable and the historical period of record is limited, data from the gage have been helpful in estimating the increment of physical supply divertible only at the city's lower elevation intakes at Lakewood Reservoir.

Streamflows in North Boulder Creek are heavily influenced by the operation of Boulder's reservoirs and pipelines. Figure 5-27 shows typical natural flow and historical flow conditions for North Boulder Creek below Lakewood Reservoir. Streamflows in North Boulder Creek below Lakewood are depleted by an average of about 45 percent compared to natural flows.

FIGURE 5-27. NATURAL VS. HISTORICAL FLOWS, NORTH BOULDER CREEK BELOW LAKEWOOD RESERVOIR, WATER YEAR 1998



Source: AMEC derived natural flows from data in AMEC. (n.d.a). *Orodell_Monthly_Virgin_Flows_V9.xls* data file. Boulder, CO. AMEC derived historical flows from both the city's annual instream flow reports to the CWCB and data from Boulder's daily water rights accounting data.

There are two critical instream flow reaches on North Boulder Creek. One reach is approximately 0.7 miles long and is located below the Silver Lake Pipeline intake and above the confluence with Caribou Creek. Prior to the Boulder Creek Instream Flow Program, there was rarely flow in this reach from September through mid-April because the city's water demands were great enough and the city's water rights were sufficiently senior to divert the entire supply of the creek. Under the Instream Flow Program, Boulder maintains a minimum flow of at least 0.5 cfs through this reach in the winter and about 3 cfs minimum in the summer. During May through September, reservoir spills and calls from downstream senior rights are generally sufficient to maintain flows well above 4 cfs, sometimes reaching hundreds of cubic feet per second.

Another reach of about 4 miles exists downstream of Lakewood Reservoir and above Gordon Gulch. Prior to the Instream Flow Program, there was rarely flow along this reach from September through April. Under the Instream Flow Program, Boulder generally maintains a minimum flow of 1.5 cfs through this reach in the winter and 3 cfs or more in the summer. During May to September, streamflows exceed this level much of the time, reaching hundreds of cubic feet per second on some days.

5.2.2.3 | MAIN BOULDER CREEK – UPPER SEGMENT

The upper segment of main Boulder Creek is defined as that stream segment below the confluence of North and Middle Boulder Creeks at Boulder Falls and above the Boulder Canyon Hydro discharge at Orodell. Runoff season flows in this segment, while significant, are lower than natural flow conditions due to storage and direct flow diversions on both Middle and North Boulder Creeks. Flows during late summer, fall, winter and early spring are reduced by direct flow diversions on both Middle and North Boulder Creeks. Streamflows in this segment of main Boulder Creek are depleted by an average of about 24 percent compared to natural flows. Currently, Boulder's bypasses on Middle and North Boulder Creeks, combined with local inflows, are usually sufficient to maintain a 5 cfs flow through this segment.

5.2.2.4 | MAIN BOULDER CREEK – MIDDLE SEGMENT

The middle segment of main Boulder Creek is defined as that stream segment below Orodell and above 75th Street. The Orodell gage measures flows in Boulder Creek at the upper end of this segment, just downstream of the discharge of the Boulder Canyon Hydro plant and about one mile upstream of the confluence of Boulder Creek and Fourmile Creek[136]. Streamflows at the Orodell gage are very useful for estimating the overall yield of the upper Boulder Creek basin. Natural flows tributary to Boulder's points of diversion on North and Middle Boulder Creeks comprise approximately 85 percent of the natural flow at the Orodell gage. The Orodell gage has been operating almost continuously since 1907. Streamflows at the Orodell gage are affected by diversions and storage releases at Barker Reservoir and the city's North Boulder Creek watershed reservoirs, and by diversions at the Silver Lake Pipeline, Lakewood Pipeline and the Barker Gravity Line. Because operation records for these facilities are available and relatively complete, natural flows at the Orodell gage can be readily constructed. Natural flow at the Orodell gage averages about 72,000 acre-feet per year.

Approximately one mile downstream of the Orodell gage, Boulder Creek is joined by Fourmile Creek, which increases its flow by an average of 4,900 acre-feet per year. Natural flows in Fourmile Creek are affected by residential well pumping and by the Pinebrook Water District, which diverts water from Fourmile Creek to its service area in Two-mile Canyon.

Historical flows through the middle segment of main Boulder Creek reflect the effects of upstream diversions by the city of Boulder and by diversions into 10 irrigation ditches[v] within the segment. Figure 5-28 compares 1997-2006 average natural flow and historical flow conditions for Boulder Creek below Broadway, which is downstream of the diversion points for eight of the ten ditches. Streamflows in this segment of main Boulder Creek are depleted by an average of about 60 percent compared to natural flows. It should be noted that the average monthly winter season historical flows shown in Figure 5-28 reflect Xcel Energy's historical hydropower peaking operations at the Boulder Canyon Hydropower Plant, which added up to 140 cfs of water to Boulder Creek below Orodell for to 4 hours per day. The actual flows in Boulder Creek were significantly lower than the averages shown.

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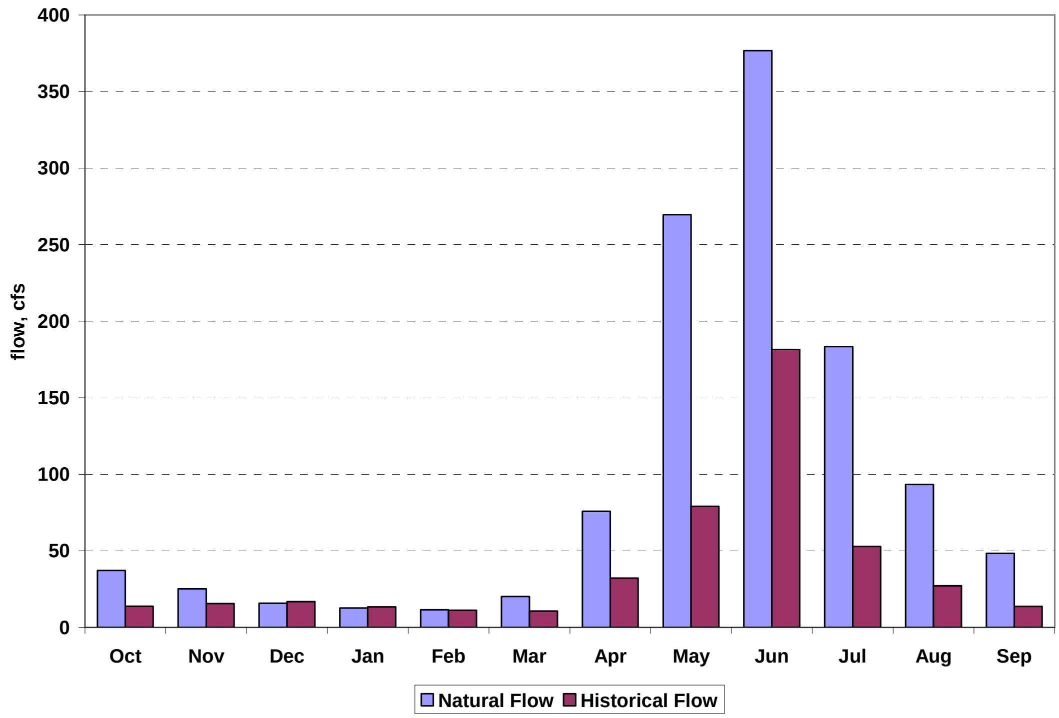
[v] The Silver Lake Ditch, Anderson Ditch and Farmers Ditch divert within a 1-mile reach of Boulder Creek at the mouth of Boulder Canyon. The Boulder and White Rock, North Boulder Farmers, Boulder and Left Hand, Smith & Goss, and McCarty Ditches divert via a combined headgate at Broadway (12th Street). The Butte Mill Ditch diverts from Boulder Creek near 55th Street. The Green Ditch diverts from Boulder Creek near 63rd Street.

FIGURE 5-28. AVERAGE NATURAL VS. HISTORICAL FLOWS, BOULDER CREEK BELOW BROADWAY, 1997-2006



Source: AMEC derived natural flows below Broadway from the sum of Fourmile Creek estimates and Orodell gage site estimates, which used USGS gage records and accounted for all upstream diversions by Boulder and PSCo. AMEC derived historical flows using data from the Orodell gage plus Four Mile Creek estimates minus what the state's water records show being diverted by ditches, storage in Barker, and the city's North Boulder Creek watershed reservoirs, and by diversions at the Silver Lake Pipeline, Lakewood Pipeline and the Barker Gravity Line. Upstream diversions on Four Mile Creek were not accounted for since they are so minor that they are considered negligible.

High flows occur during spring runoff periods and can last from May through July in average and wet years. Prior to 1994, flows of less than 1 cfs occurred below Broadway for much of the summer due to irrigation diversions. During the fall and winter, there were several dry-up points on Boulder Creek in this segment due to diversions by the Anderson, Boulder and White Rock and Wellman ditches to fill off-stream reservoirs. Since the implementation of the Boulder Creek Instream Flow Program, minimum flows in Boulder Creek have generally been maintained above 4 cfs during May through September and above 1.5 cfs during October through April[137].

The Boulder Creek Instream Flow Program gages and the 75th Street gage are important in administering the operation of instream flows and Boulder's exchange rights. The instream flow gages have been in operation since 1994 and 75th Street gage has been in operation since 1986. The 75th Street gage measures flows in Boulder Creek just upstream of the bridge at 75th Street[vi]. Streamflow data at this gage are useful in quantifying streamflow accretions between the Orodell gage and 75th Street. Flow data at the 75th Street gage are also useful for a range of water quality assessment and wastewater treatment facilities permitting purposes.

[vi] Prior to March 5, 2003, the gage measured flows in Boulder Creek just downstream of Boulder's wastewater discharge location. On March 5, 2003, Boulder moved its wastewater discharge to a location downstream of the gage.

5.2.2.5 | MAIN BOULDER CREEK – LOWER SEGMENT

The lower section of main Boulder Creek is defined as that segment downstream of 75th Street and above the confluence with the St. Vrain River. Flows in this reach are affected by agricultural ditch diversions, CBT deliveries from the Boulder Creek Supply Canal, discharges from municipal wastewater treatment plants, and releases from Leggett, Baseline and Panama Reservoirs. High flows generally occur in May through July of average and wet years. Low flows (including dry-up points) typically occur during August and September due to agricultural ditch diversions and exchange operations. Winter season flows typically range from 25 to 30 cfs due to wastewater discharges and the absence of irrigation diversions.

The gage at the mouth of Boulder Creek has been in operation intermittently since 1927, and continuously since 1978. Measured flows at this gage reflect diversions and return flows from numerous upstream agricultural, municipal and industrial uses, as well as imports from other basins and exports to other basins. The gage at the mouth of Boulder Creek is useful in estimating the stream accretions (primarily due to irrigation return flows) between the 75th Street gage and the mouth of Boulder Creek for modeling purposes.

5.2.2.6 | SOUTH BOULDER CREEK

South Boulder Creek is important to Boulder's water supply system because it supplies a portion of the water needed to meet downstream senior water rights, thereby affecting the yield of Boulder's municipal water rights. The Eldorado gage measures flows in South Boulder Creek as it emerges from the foothills[138]. Streamflows have been measured at the Eldorado gage since 1896. Natural flows at the Eldorado gage are estimated to average 53,000 acre-feet per year, which comprises about 35 percent of the entire surface water supply of the Boulder Creek basin. Prior to 1930, measured flows at the Eldorado gage were essentially natural flows. Since then, flows at the gage have been affected by upstream direct flow and storage diversions by Denver Water and by importation of water from the Colorado River basin through the Moffat Tunnel.

Historical flows on South Boulder Creek between Denver Water's diversion upstream of Eldorado Springs and the confluence with Boulder Creek are affected by 18 irrigation ditches, five off-stream reservoirs and five municipal intakes that divert water from the creek. Boulder does not directly divert any of its municipal supply from South Boulder Creek, however, Boulder owns about 13 percent of the shares in Baseline Reservoir, which does divert from South Boulder Creek. Boulder uses its Baseline Reservoir allotment as an exchange supply to increase its municipal diversions from Middle and North Boulder Creeks. Boulder also leases its Baseline allotment to local farmers when it is not needed by the city as an exchange supply. Boulder's OSMP Department owns substantial portions of the shares in most of the irrigation ditches that divert from South Boulder Creek[vii].

South Boulder Creek is very heavily appropriated and periods of no flow have occurred along extensive reaches of South Boulder Creek below Eldorado Springs during all months of the year. Dry reaches of stream mostly occur during November through March when combined diversions by the Community Ditch, the Lafayette Pipeline, the Louisville Pipeline and the South Boulder and Bear Creek Ditch divert the entire flow of the creek at Eldorado Springs.

[vii] Information on the city of Boulder's ownership of ditch shares is included in the Appendices.

5.2.2.7 | SOUTH PLATTE RIVER

The hydrology of the South Platte River downstream of Boulder Creek is heavily influenced by irrigation diversions, alluvial well pumping, return flows from water uses and interactions with alluvial groundwater aquifers. During average and below average hydrologic conditions, the South Platte River mainstem and the lower portions of the South Platte's major tributaries are "return flow-dominated" meaning that their flows are comprised primarily of irrigation and municipal return flows.

5.2.3 | HISTORIC HYDROLOGY OF THE UPPER COLORADO RIVER BASIN

In addition to its Boulder Creek supplies, Boulder owns shares in the CBT and Windy Gap projects. The CBT project diverts water from the Colorado River at Lake Granby and from Willow Creek at Willow Creek Reservoir. The CBT project's water rights are sufficient to allow the project to divert almost all of the entire physical supply of the Colorado River and Willow Creek at these two points of diversion, subject only to bypasses for local downstream senior water rights and fisheries releases according to an agreement with the U.S. Department of Interior.

The Windy Gap project diverts from the Colorado River just downstream of its confluence with the Fraser River. The Windy Gap project's water rights are relatively junior. Its diversions are limited both by its junior priorities and the terms and conditions of its decrees to an average of approximately 54,000 acre-feet per year which is about 11 percent of the natural flow at its point of diversion.

Historic streamflows have been measured at locations in the Upper Colorado River basin, as summarized in Table 5-9. Most of the records for these gages are available from the CDOW or the USGS and have been included in the Appendices. Streamflows are also measured at other locations by individual water users as part of the operations of their water rights and water supply systems, although those data are not always readily available.

While the gages listed in Table 5-9 are relevant to the operation of the CBT and Windy Gap projects, the two most important gages for determining Boulder's water supply are located on the Colorado River at Hot Sulphur Springs and at Windy Gap[139]. These two gages measure about the same size drainage area, and between them they have a continuous period of record of more than 100 years. The divertible supplies available to the CBT and Windy Gap projects are highly correlated to the natural flow at these two gages. The gages are therefore very useful in modeling the operations of these two projects and Boulder's yields from these projects over a range of hydrologic conditions.

TABLE 5-9. USGS AND CDWR STREAM FLOW GAGES IN THE UPPER COLORADO RIVER BASIN[140]

Station ID#	Station Name	Drain-age Area, sq. mi.	Elevation, feet	Period of Record
09010500	Colorado River Below Baker Gulch, near Grand Lake	53.4	8,750	1952-2005
09011000	Colorado River near Grand Lake	102	8,380	1904-1909, 1910-1918, 19331986
09015000	Colorado River below Shadow Mountain Reservoir	190	8,320	1948-1959
09019000	Colorado River below Lake Granby	312	8,050	1950-1982
09019500	Colorado River near Granby	323	7,960	1907-1911, 1933-1953, 1961-2005 (May-September only)
09020000	Willow Creek near Granby	109	8,234	1934-1954
09020500	Willow Creek above Willow Creek Reservoir	127	8,135	1953-1960
09021000	Willow Creek below Willow Creek Reservoir	134	8,024	1953-1982
09024000	Fraser River at Winter Park	27.6	8,906	1909-2005
09034000	Fraser River at Granby	297	7,900	1904-1909, 1936-1955
09034250	Colorado River at Windy Gap, near Granby	789	7,790	1982-2005
09034500	Colorado River at Hot Sulphur Springs	825	7,670	1904-1994; (1910,1913, 1925, 1929 missing)

5.2.4 | DEVELOPMENT OF NATURAL STREAMFLOW HYDROLOGIC DATA

The natural flow of a stream (sometimes called the "virgin flow") is defined as the streamflow as it would be if undisturbed by human activities. Natural flows can be readily reconstructed at stream gage locations where good records exist of all major upstream diversions, uses, return flows, imports and exports of water. Natural flows are useful in modeling the operation of water supply systems under varying assumptions regarding supplies, demands, facilities and operating rules. Gage-based natural flow reconstructions are useful in tracking long-term hydrologic trends that may reflect changes in climate or land uses. They can be combined with tree-ring studies and global atmospheric circulation models to explore the effects of paleo-droughts or potential climate variation on water supply systems. The city has constructed a detailed computer model of its water system operations that uses reconstructed natural streamflows as the base.

5.2.4.1 | RECONSTRUCTION FROM STREAM GAGES

As part of previous studies for the city, Hydrosphere Resource Consultants (now AMEC) reconstructed natural flows on a monthly basis for all major stream segments in the Boulder Creek basin and for the Colorado River at Hot Sulphur Springs/Windy Gap. Natural flow reconstructions are used to model the Boulder Creek basin and the operation of Boulder's water supply system. Natural flow reconstructions based on stream gages were developed and refined in several iterations over the past two decades as more information became available. They currently cover the period from 1970-2004 and are being updated to cover through 2006. Specific data and methods used for natural flow reconstructions are described in memoranda and workbooks contained in the Appendices. Natural flows in the Boulder Creek basin were reconstructed from stream gages at 14 locations as shown in Table 5-10.

TABLE 5-10. LOCATION OF RECONSTRUCTED NATURAL FLOWS IN BOULDER CREEK BASIN

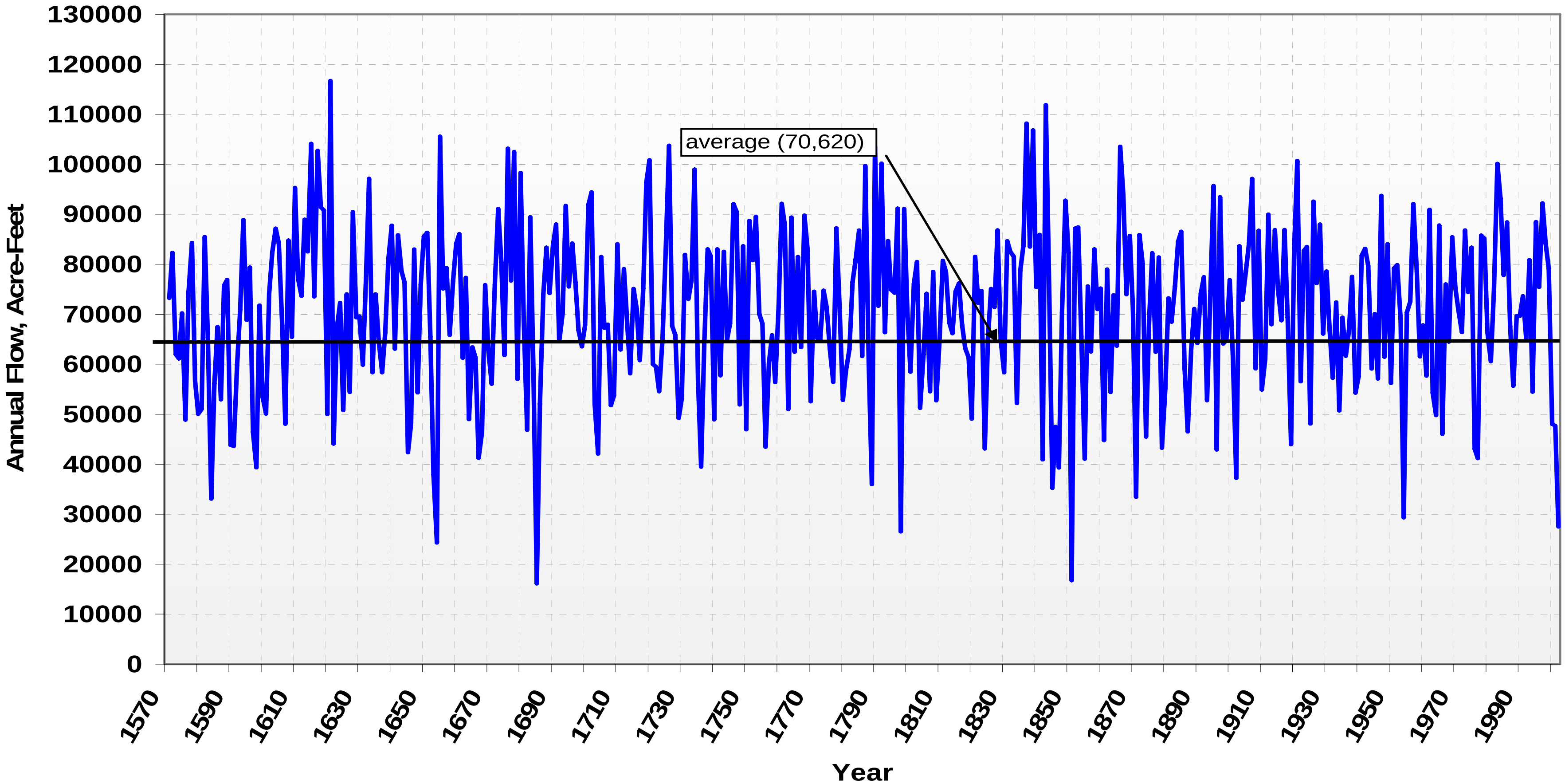
Watershed Sub-basin	Minimum Elevation	Maximum Elevation	Average Elevation	Drainage Area (sq. mi.)	Average Annual Flow, AF
North Boulder Creek at Silver Lake Reservoir	10,240	13,500	11,600	8.7	13,600
North Boulder Creek gains at Silver Lake Pipeline headgate	9,740	11,300	10,300	2.6	1,400
North Boulder Creek gains at Lakewood Reservoir	8,200	12,740	9,800	19.0	4,700
Sherwood Creek at Lakewood	8,100	10,200	8,500	2.6	700
North Boulder Creek gains at North/Middle Boulder confluence	6,900	9,240	8,200	12.7	4,300
Barker Reservoir inflow (with local inflows below gage)	8,050	13,400	10,300	38.7	40,600
Middle Boulder Creek gains at North/Middle Boulder confluence	6,900	8,940	8,100	6.0	2,700
Boulder Creek gains at Orodell	5,830	8,920	7,100	11.8	3,900
Four Mile Creek at Orodell	5,740	11,560	8,300	24.1	4,900
South Boulder Creek at Gross Reservoir	7,290	13,290	9,300	91.6	50,200
South Boulder Creek gains at Denver Water diversion	6,280	8,740	7,200	14.1	3,100
South Boulder Creek gains at Lafayette Pipeline diversion	5,600	8,950	7,000	4.2	900
Gains between Orodell/Eldorado and 75th Street	5,130	8,550	5,700	67.9	8,200
Boulder Creek gains between 75th Street and mouth	4,860	10,511	5,600	135.0	15,800
Source: United States Geological Survey. (n.d.b). *Water resources of Colorado*. Retrieved June 23, 2008 from http://co.water.usgs.gov/; ***and*** United States Geological Survey. (n.d.a). *Annual water data reports*. Lakewood, CO; ***and*** AMEC used GIS data to calculate the minimum and maximum elevations.					

5.2.4.2 | NATURAL FLOW RECONSTRUCTION FROM TREE RING DATA

Streamflows have been measured in the Boulder Creek basin and the Upper Colorado River basin for approximately 100 years. While significant droughts have occurred within this 100-year period, it is unlikely that the full range of potential streamflow variability has been captured. Additional, indirect evidence of streamflow variability over much longer time periods can be obtained from tree ring data. Certain tree species that grow in open stands on dry, rocky sites well above the river channel are particularly sensitive to variations in precipitation. Variations in the widths of annual growth layers within such trees correlate well with annual variations in streamflow. The first studies quantitatively relating tree-growth to streamflow in the western US were done in the 1930s. Numerous tree-ring reconstructions of climate and streamflow, which use computers and multiple linear regression techniques, have been developed since then, and techniques for calibrating and validating reconstruction models have been progressively refined.

Boulder has collaborated with scientists through the University of Colorado (Western Water Assessment) to develop tree ring-based reconstructions of annual natural flows for Boulder Creek near Orodell, South Boulder Creek near Eldorado Springs and the Colorado River at Hot Sulphur Springs that extend back to the year 1566. A report describing the data and methodology used in these reconstructions is included in the Appendices[141]. Hydrosphere (now AMEC) has developed methodologies for disaggregating these annual flows into monthly and quarter-monthly time series at the inflow locations used in the Boulder Creek model. Tree ring reconstructions of annual flows for Boulder Creek near Orodell are shown in Figure 5-29.

FIGURE 5-29. TREE RING-BASED RECONSTRUCTION OF ANNUAL FLOWS FOR BOULDER CREEK NEAR ORODELL[142]

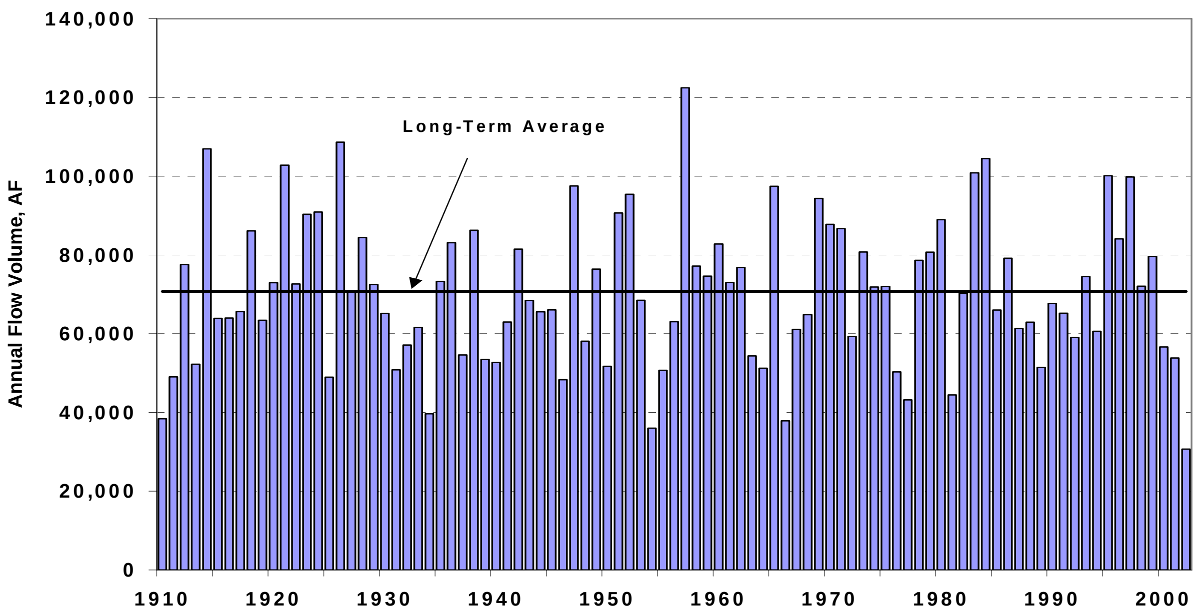


5.2.5 | DROUGHTS IN THE HISTORIC RECORD

Stream gage records provide direct evidence of historic streamflow and droughts. The stream gage on Boulder Creek near Orodell is useful for evaluating drought effects on the city's Boulder Creek water supply system. This gage measures the combined stream flow from North and Middle Boulder Creeks, which provide the majority of Boulder's physical water supply.

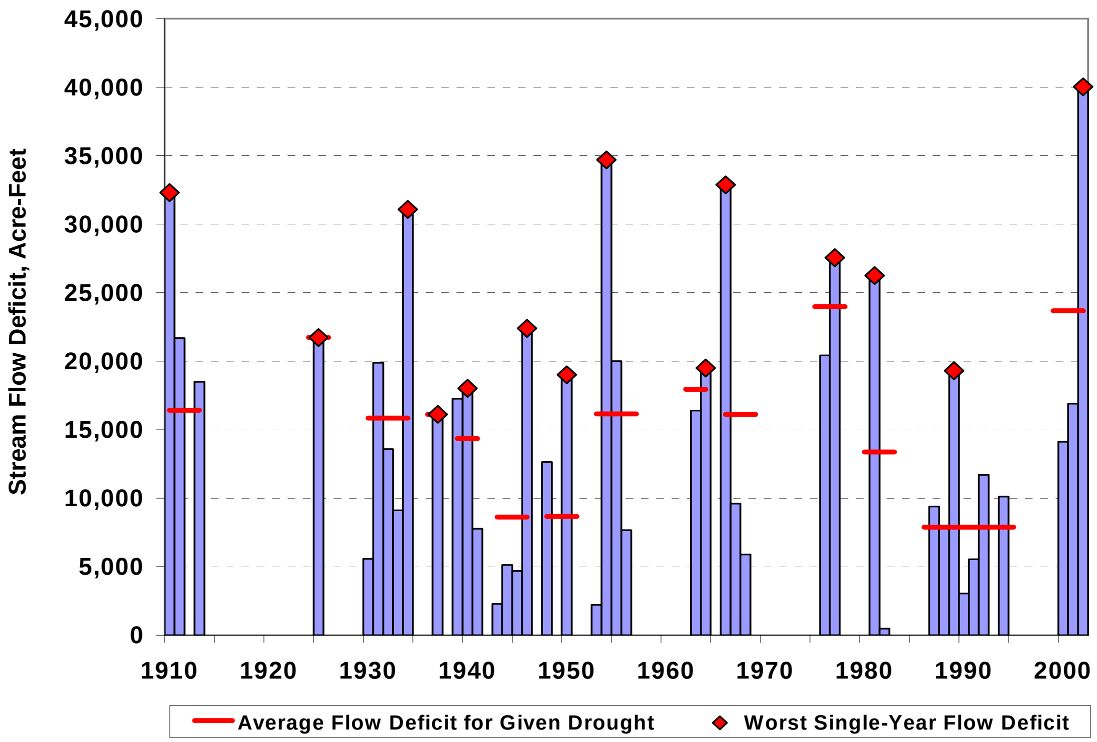
Reconstructed natural flows at Orodell are shown in Figure 5-, which illustrates that Boulder Creek streamflow volumes are highly variable and significant droughts occur regularly. The latest drought in the Boulder Creek basin began in 2000 and includes the lowest streamflow year (2002) of the past century.

FIGURE 5-30. NATURAL FLOW FOR BOULDER CREEK NEAR ORODELL RECONSTRUCTED FROM GAGE RECORDS[143]



For 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 5-31.

FIGURE 5-3114. FLOW DEFICITS AND DURATION OF MAJOR DROUGHTS FOR BOULDER CREEK NEAR ORODELL[144]



The worst single year flow deficit of a drought is defined as the volume of flow deficit in the 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 reservoir storage to meet water demands.

The duration of a drought is sometimes defined as the number of consecutive years of below average streamflow. As a practical matter, a drought should not be considered over until it is followed by a year with sufficiently high streamflows 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.

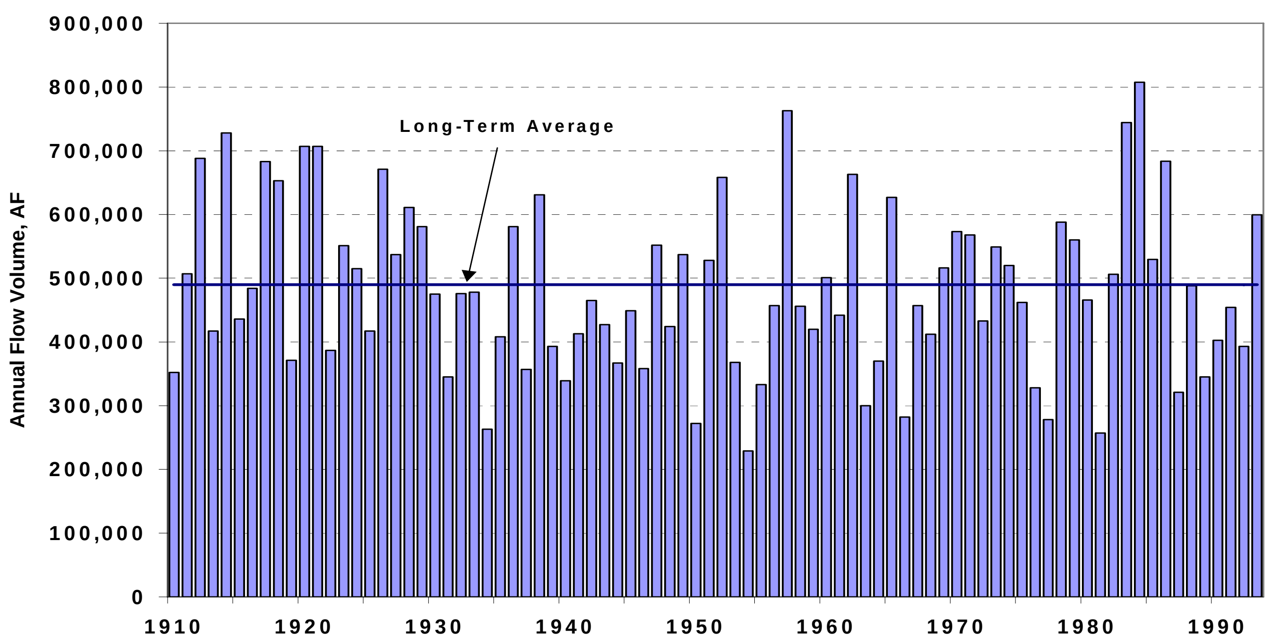
Table 5-11 provides numeric data regarding duration, worst single-year deficit and average deficit for the significant hydrologic droughts on Boulder Creek as measured at the Orodell gage. These data show that the 2002 drought is the worst within the actual recorded data in terms of single year flow deficit and the second worst 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 5-11. COMPARISON OF SIGNIFICANT HISTORICAL DROUGHTS, BOULDER CREEK NEAR ORODELL[145]

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
2000-2002	3 years	41,100 AF	23,700 AF

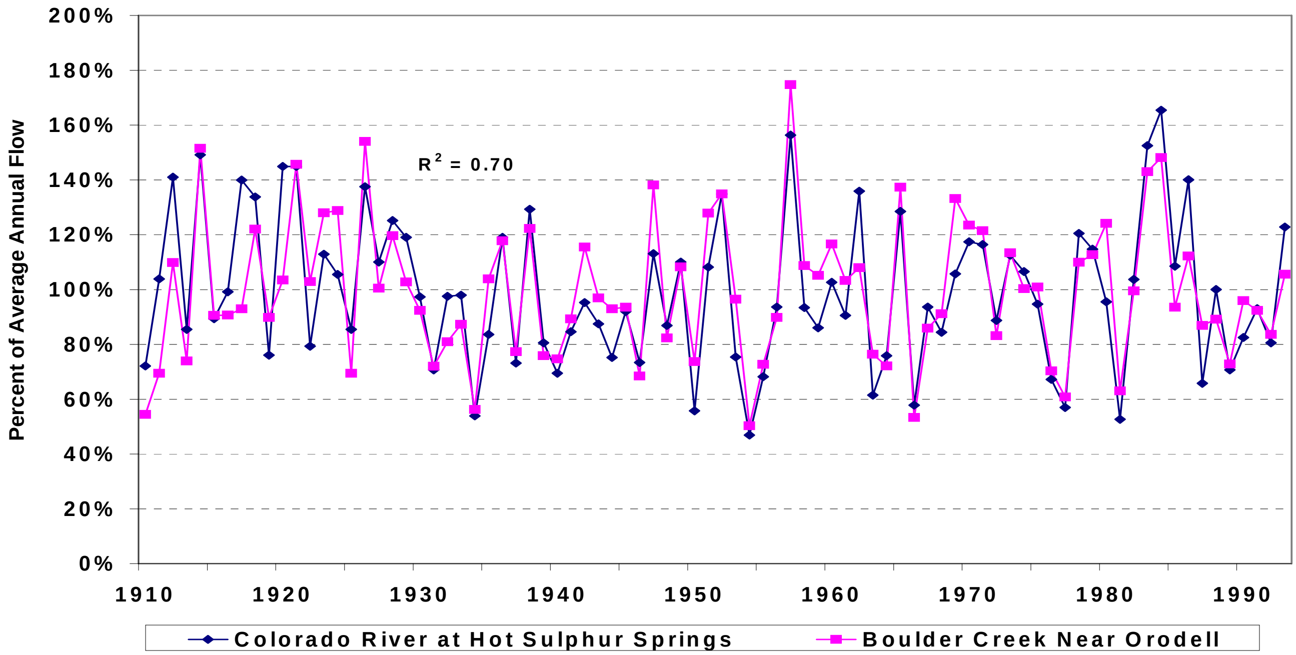
Boulder's water supply system is dependent on streamflows in both Boulder Creek and the Colorado River because much of Boulder's water supply comes from the CBT and Windy Gap Projects. Flows in the Colorado River at Hot Sulphur Springs have been recorded since the early 1900s. Natural flows at this location are a good index of the divertible supply for the CBT and Windy Gap projects. The reconstructed natural flows for the Colorado River at Hot Sulphur Springs are shown in Figure 5-32.

FIGURE 5-32. RECONSTRUCTED NATURAL FLOW, COLORADO RIVER AT HOT SULPHUR SPRINGS[146]



This figure shows that streamflows 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, as shown in Figure 5-33. 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.

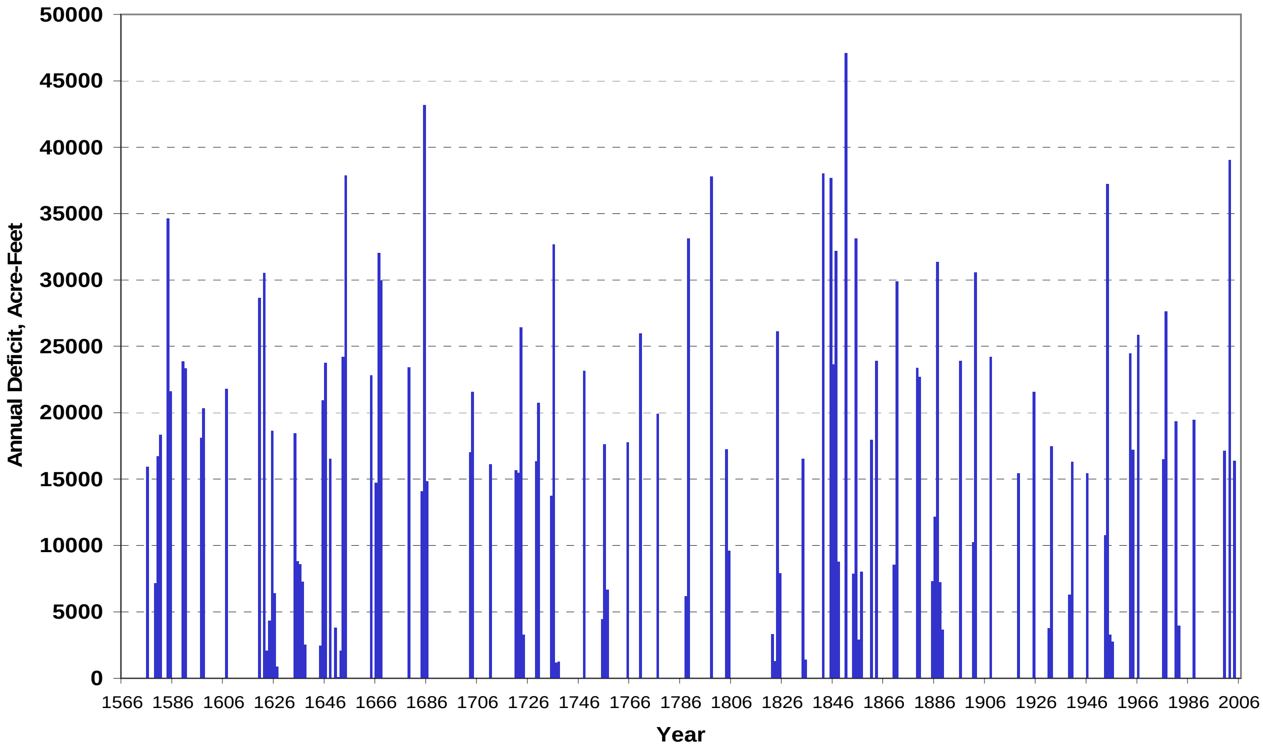
FIGURE 5-33. COMPARISON OF NATURAL FLOWS – BOULDER CREEK VS. COLORADO RIVER[147]



5.2.5.1 | TREE RING EVIDENCE OF DROUGHTS

As mentioned above, tree ring-based reconstructions of hydrologic data have allowed Boulder to assess the reliability of its water supply system in a more rigorous manner to address potential droughts over a 450-year hydrologic period. Figure 5-34 highlights the significant droughts that occurred from1566 to 2006 based on tree ring data. For the purposes of this figure, a significant drought is defined as one or more years of consecutive below-average streamflow with at least one year being more than one standard deviation below average.

FIGURE 5-34. SIGNIFICANT DROUGHTS AS EVIDENCED BY TREE RINGS, BOULDER CREEK NEAR ORODELL[148]



5.2.6 | HYDROLOGIC TRENDS ATTRIBUTABLE TO CLIMATE CHANGE

5.2.6.1 | CLIMATE CHANGE EFFECTS ON BOULDER CREEK HYDROLOGY

Recent research on climate variability has indicated that the inter-mountain western United States is experiencing a warming trend that is very likely to persist and intensify in the next 50 to 100 years. While the research is less certain about whether the future will be wetter or drier in the Boulder Creek basin or whether Boulder Creek streamflows will increase or decrease on an annual volumetric basis, it is likely that mountain snowmelt will occur earlier in the year and that late summer flows will be significantly lower. Mountain streams throughout the West may already be showing trends in the amount and timing of runoff that may be attributable to climate change. The Nederland gage provides an excellent source of data for assessing such trends since the gage has been in operation for 100 years and streamflow at the gage is close to natural flow conditions.

Figure 5-35 shows the dates of peak daily flows at the Nederland gage for 1907 through 2006. The average peak flow date has advanced approximately six days over the last 100 years from June 13th to June 7th. Annual flow volumes at the Nederland gage show a slight increasing trend, as shown in Figure 5-36.

FIGURE 5-35. DATES OF PEAK DAILY FLOW, MIDDLE BOULDER CREEK AT NEDERLAND[149]

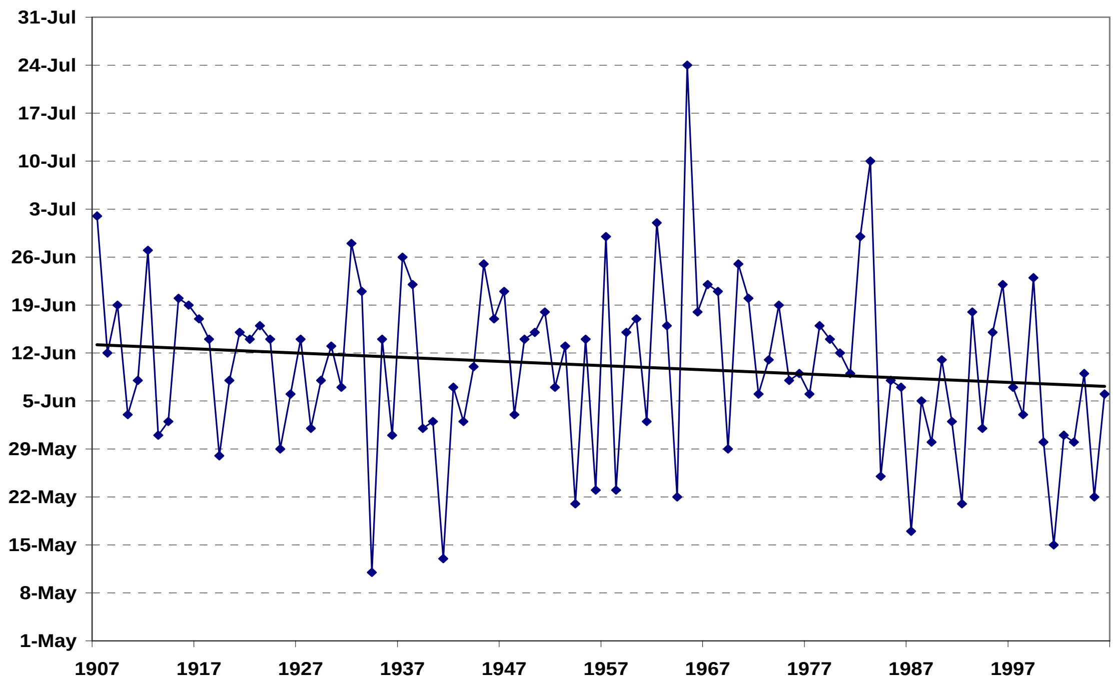
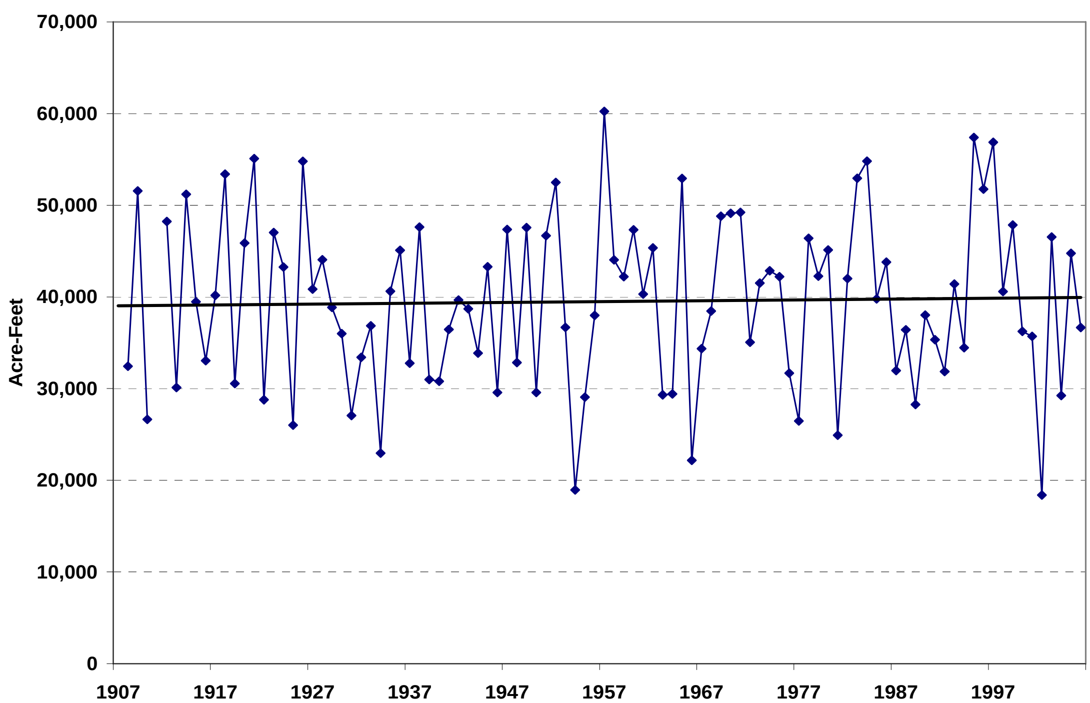


FIGURE 5-36. ANNUAL FLOW VOLUMES, MIDDLE BOULDER CREEK AT NEDERLAND[150]



5.2.6.2 | CLIMATE CHANGE EFFECTS ON COLORADO RIVER HYDROLOGY

In 2005, the National Research Council's Water Science and Technology Board initiated a study of the Colorado River. The National Research Council is the principal operating agency of the National Academy of Sciences. The study evaluated existing scientific information and its relation to Colorado River water supplies, demands, and drought. A report of the study findings was published in 2007 by the National Academy of Sciences through the National Academies Press[151]. The following excerpts from the report summarize information in several key areas.

Climate Trends

- "A severe, multiyear drought across much of the western and southwestern United States in the early 21st century had substantial impacts on Colorado River basin water supplies… Reduced amounts of precipitation and inflows resulted in substantial drops in reservoir storage levels in the late 1990s and early 2000s. In 1999, reservoirs on the Colorado River were more than 90 percent full, but by 2005 system-wide storage had fallen to about 50 percent—a decrease in volume of some 25 million acre-feet of water… The drought of the early 2000s was severe by any measure; in terms of climate statistics, the probability is very low—less than 0.1—that any 5-year drought period since 1850 had been as dry as 2000-2004. During the early 21st century drought, the Colorado River storage system performed much like it had been designed to do and, even after 5 consecutive below-average years of precipitation and inflows, still held roughly 2 years of annual Colorado River flows."[152]
- "Colorado River basin precipitation exhibits high year-to-year variability…there has been a tendency toward greater variability in the latter decades of the 20th century. The past 30 years of data include the highest and lowest annual precipitation in the 100-year record… Despite these variations, there in no significant trend in inter-annual variability of precipitation over the past 110 years."[153]
- "…since the late 1970s the Colorado River region has exhibited a steady upward trend in surface temperatures…temperatures across the basin today are at least 1.5° F warmer than during the 1950s drought."[154]
- "…the Colorado River basin has warmed more than any region of the United States…increases in temperature over the West are consistent with rising greenhouse gases, and will almost certainly continue… Key manifestations of warmer temperatures…are a shift in the peak seasonal runoff (driven by snowmelt) to earlier in the year, increased evaporation, and correspondingly less runoff."[155]

Climate Model Projections

- "…long-term projections of precipitation constitute a greater modeling challenge than temperature projections. Over the West and the Colorado River basin, precipitation projections from climate models suggest a wide range of potential changes in annual precipitation…generally forecast precipitation futures that show relatively little annual change…relatively little change in annual precipitation amounts forecast for the headwaters regions of the Colorado River…unanimity among the different models that temperatures will rise in the future…strong likelihood of warmer future climate across the Colorado River basin."[156]

Implications of Warming

- "...more winter precipitation will fall as rain rather than snow… shorter seasons of snow accumulation…less snow pack accumulation…earlier melting…lowered water availability during the late summer…more runoff during winter…longer growing seasons….increased water demands by plants…greater losses to evapotranspiration…."[157]
- "A 2000 assessment of…changes in climate on runoff in the Colorado River basin…included forecast increases of 66-128 percent in upper Colorado River flows…the majority of the results from other hydroclimate modeling exercises project future decreases in runoff for the upper Colorado River and inflows into Lake Powell….even in the absence of changes in precipitation patterns, higher temperatures resulting from increased greenhouse gas concentrations lead to higher evaporation rates, reductions in streamflow, and increased frequency of droughts… A more recent study used average values from 12 different GCMs (global circulation models)… Almost all the model runs projected future decreases in runoff over the…Colorado River region. These decreases are projected to be on the order of 20 percent…A 2006 paper employed 11 different climate change models…used for two global emissions scenarios: an A2 (relatively unconstrained growth…) and a B1(elimination of global emissions by 2100) scenario. Results showed that Colorado River discharge would decrease by up to 11 percent for A2 emissions and up to 8 percent for B1 emissions. Over all ensembles, 9 of 11 showed streamflow decreases…for A2 and 8 of 11 for B1…"[158]
- "Earlier studies suggested substantial decreases in Colorado River annual flow volumes over the next century; more recent studies have generally projected more modest declines, with a few modeling exercises suggesting increases… Modeling results across the region show little consensus regarding changes in future precipitation amounts or seasonality. Any future decreases in Colorado River streamflow, driven primarily by increasing temperature, would be especially troubling because the quantity of water allocation under the Law of the River already exceeds the amount of mean annual Colorado River flows."[159]

River Flows at Lees Ferry

- 'The time period used in Colorado River Compact negotiations—1905-1922—included some particularly wet years…the 1905-1922 period contained the highest long-term annual flow volume in the 20th century, averaging 16.1 million acre-feet per year at Lees Ferry."[160]
- "…tree-ring-based reconstructions…for Lees Ferry flow…support the following…Long-term Colorado River mean flows…are significantly lower than both the mean of the Lees Ferry gage record upon which the Colorado River Compact was based and the full 20th century gage record."[161]

Resolution of Compact Shortage Issues

- "…drought of the early 2000s brought the issue of interstate cooperation on coping with Colorado River water shortages to a head...The drought prompted the basin states to request the Secretary of the Interior to operate Lake Powell and Lake Mead differently; namely, the upper basin states requested that Lake Powell releases be reduced from the traditional minimum of 8.23 million acre-feet per year if the drought continued…the seven basin states via a February 3, 2006 letter…developed a preliminary shortage management proposal…attempts to balance competing demands with the existing law of the River framework…The cooperation reflected by the February 2006 letter…will be an increasingly important part of viable drought preparedness strategies."[162]

- "Our recommendation is designed to provide input…to; 1) delay the onset and minimize the extent and duration of shortages in the Lower Division States; 2) maximize the protection afforded the Upper Division States by storage in Lake Powell against possible curtailment of Upper Basin users; 3) provide for more efficient, flexible, responsive and reliable operation of the system reservoirs for the benefit of both the Upper and Lower Basins by developing additional system water supplies through extraordinary conservation, system efficiency and augmentation projects; 4) allow the continued development and use of the Colorado River resource in both the Upper and Lower Basins…."[163]
- "The Seven Basin States have worked together to recommend interim operations to the Secretary that should minimize shortages in the Lower Basin and avoid the risk of curtailment in the Upper Basin through conservation, more efficient reservoir operations, and long-term alternatives to bring additional water into the Colorado River community…First, the States propose to manage the reservoirs to minimize shortages and avoid curtailments. Second, the States have identified actions in the Lower Basin to conserve water. Third, the States recommend a specific proposal for implementing shortages in the Lower Basin."[164]

5.3 | Municipal Water Rights Yields

5.3.1 | PHYSICAL AND INSTITUTIONAL FACTORS AFFECTING YIELDS

Under Colorado's prior appropriation doctrine, the yields of Boulder's water rights are influenced by relative supply and demand conditions, the priority of the water rights, and the other decreed terms and conditions associated with the water rights. Occasionally, such as during runoff periods of wet years, the supply exceeds demand and all water rights can divert without restriction. However during the low flow season (at least nine months of each year) and during all months of average and dry years, a water right's potential diversions are determined by its relative priority and the physical supply, both of which can be significant limitations.

Individual water rights must operate according to the terms of their respective decrees, which typically specify the right's priority, type of use, maximum rate and/or volume of diversion, and season of diversion (either implied or explicitly stated). Boulder's water rights portfolio includes water rights that were originally decreed for municipal use by Boulder and water rights that were changed from irrigation use to municipal use. Decrees for changed water rights typically have more extensive and explicit terms and conditions that are designed to prevent expanded use and to maintain historical return flows of the changed water rights.

5.3.2 | WATER RIGHTS YIELD ESTIMATES

5.3.2.1 | HISTORICAL WATER RIGHTS YIELDS

As part of the operation of its water supply system, the city maintains daily records of its diversions under its various water rights. The historical deliveries made by Boulder from each of its water sources for the period of 1995 through 2007 are summarized in Figure 5-37. From a hydrologic perspective, this is a suitable period for assessing the yields of Boulder's water rights because it includes both wet years (1995-1999) and dry years (2000-2006). Table 5-12 shows the water rights that have been used to meet the city's water demands each year. Table 5-13 summarizes the city's historical water deliveries based on water source. Figure 5-38 and Table 5-14 show the city's potential yields from its water rights during the period from 1995 to 2007 including water used in each year for municipal purposes, water stored for use in subsequent years, water leased to farmers in the Boulder Creek basin, and water available to the city that was not taken.

The combined yield of Boulder's direct flow rights did not vary significantly between wet and dry years. This is because most of Boulder's direct flow rights are very senior in priority, and during dry years, the lack of supply is borne disproportionately by junior water rights. Thus, even in 2002, when natural flows were less than 50 percent of average, Boulder's direct flow rights yielded 88 percent of their average. In contrast, the combined yield of Boulder's storage rights show a marked difference between wet and dry years, which reflects their relatively junior priorities.

The yields of Boulder's exchange rights generally complement the yields of the direct flow and storage rights. In most dry years, the exchange yields are much greater because Boulder uses them to fill its reservoirs when its storage rights do not come into priority. But in extreme dry years (such as 2002), the yields of Boulder's exchange rights are themselves limited by the overall lack of physical supply.

Boulder's CBT yield is defined as the annual CBT project quota times the number of CBT units that Boulder owns. The CBT quota is usually set to help offset the prevailing hydrologic conditions in the South Platte basin: a high quota (80 percent to 100 percent) is usually set in dry years, and a lower quota (60 percent to 70 percent) is usually set in wet years. However, 2003 was a year when the CBT quota was limited by the diminished amount of water in storage in the CBT project, which was due to three previous years of drought.

Boulder's Windy Gap yields vary considerably. This reflects the Windy Gap project's junior water rights priorities and the lack of reservoir storage dedicated solely to equalizing Windy Gap yield.

It should be noted that the potential yields of several of Boulder's direct flow rights were limited during a portion of the period from 1995 to 2007 by temporary capacity bottlenecks in the Lakewood Pipeline and the Farmers Ditch. Three of Boulder's most senior direct flow rights (Anderson and Farmers Ditch rights changed to North Boulder Creek, Town of Boulder Ditch[165]) have a combined allowable rate of diversion of approximately 32 cfs but can only be diverted from North Boulder Creek via the Lakewood Pipeline. From 1995 through 2003, the capacity of the Lakewood Pipeline was only 23 cfs (15 million gallons per day) due to age and wear. By 2004, the pipeline had been restored to its original capacity of 31 cfs (20 million gallons per day). Thus Boulder's historical yields during 1995-2003 would have been greater given the pipeline's restored capacity.

FIGURE 5-37. SUMMARY OF BOULDER'S HISTORICAL MUNICIPAL DELIVERIES BY SOURCE[166]

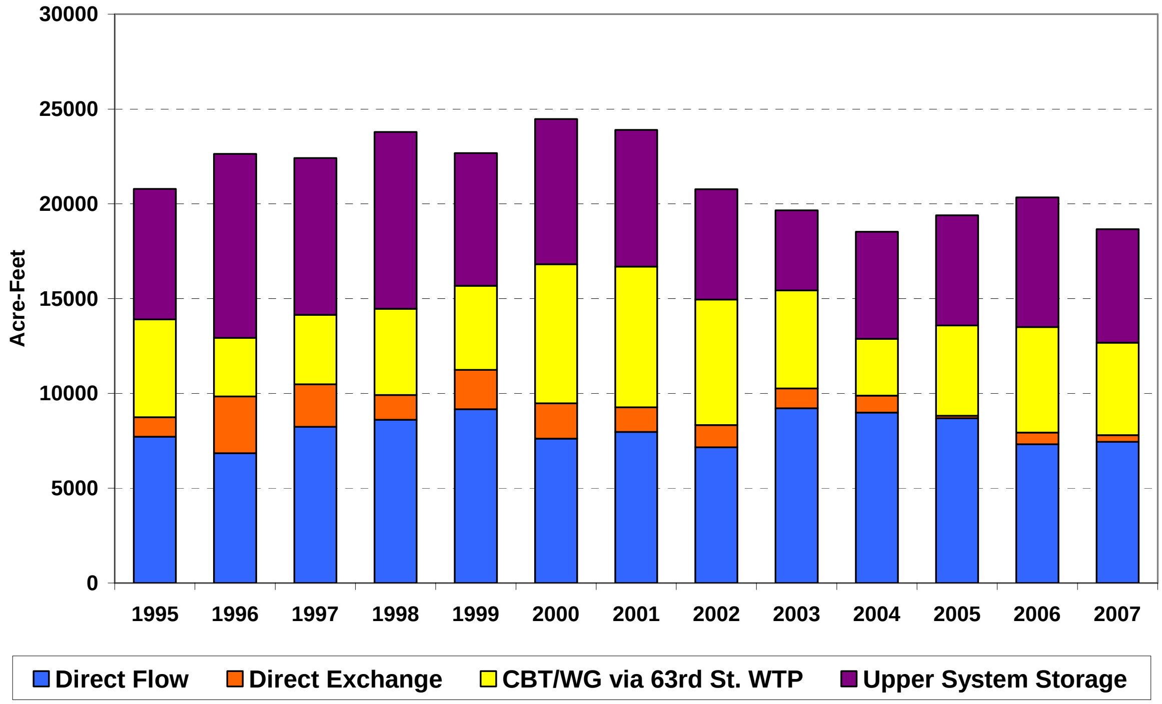
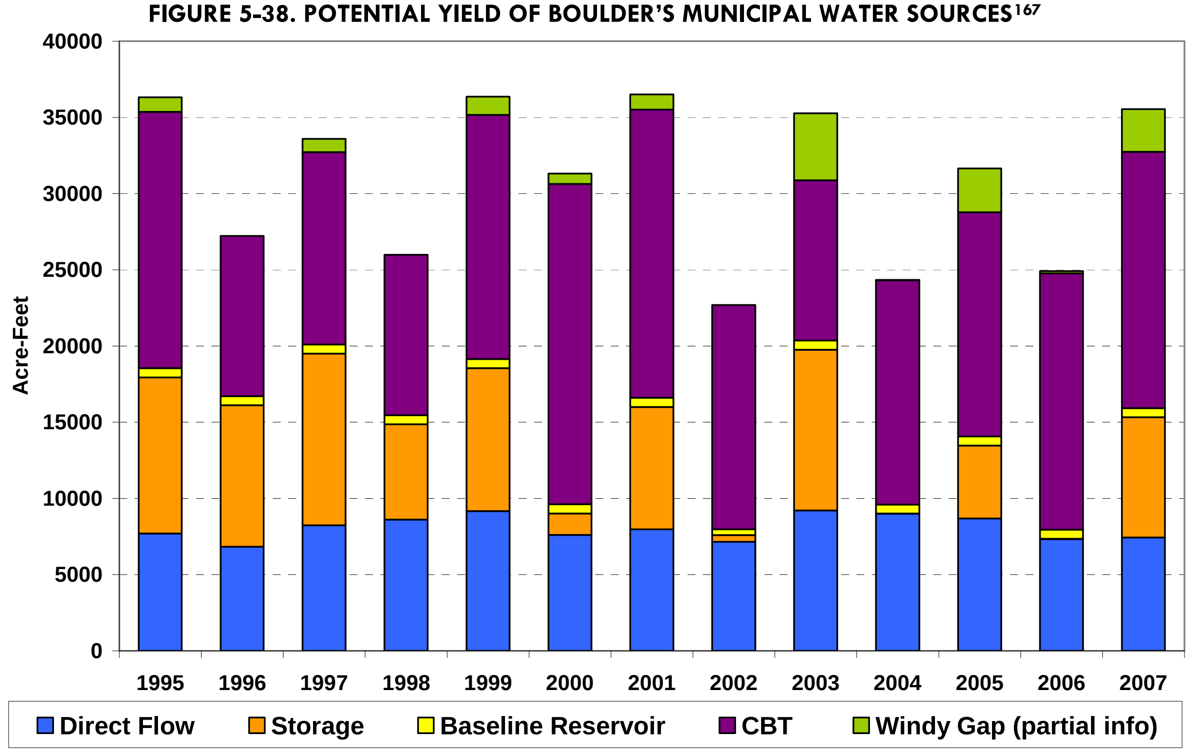


FIGURE 5-38. POTENTIAL YIELD OF BOULDER'S MUNICIPAL WATER SOURCES[167]



Similarly, Boulder's right to municipal use of 12.17 cfs of the Farmers Ditch water right at times when the right is not being used for instream flow purposes has been limited by capacity bottlenecks along the Farmers Ditch and difficulties with enforcing pro-rata allocations among shareholders. These bottlenecks and enforcement difficulties have temporarily prevented Boulder from fully using this water right for municipal purposes. During the subject period, Boulder's municipal diversions did not exceed 6 cfs. Once the Farmers Ditch capacity is restored and effective enforcement equipment and procedures are in place, Boulder's diversion potential will increase significantly.

The historical yields of Boulder's water rights were also limited by Boulder's demands during this period, which ranged from a high of 24,469 acre-feet in 2000 to a low of 18,523 acre-feet in 2004[168]. Given the expected growth in population and employment projected in the BVCP, the remaining development and ongoing redevelopment of lands within Boulder's service area, and expected increases in temperature due to climate change, Boulder's build-out demands may increase significantly beyond current levels. At increased demand levels, Boulder's diversions under its water rights would also increase to some degree due to greater drawdowns of reservoir storage over the winter freeing up space for additional diversions under the city's storage water rights during average and wetter years.

The potential yield of Boulder's water rights in recent years is compared to water demands at build-out in Figure 5-39. The water demand values used in the figure are based on the build-out estimate of 28,600 acre-feet demand in non-drought years that was used in the Drought Plan[169]. The reductions in demand for each drought stage reflect the percentage reduction goals in the Drought Plan[170].

TABLE 5-12. BOULDER'S HISTORICAL MUNICIPAL WATER RIGHTS DIVERSIONS AND STORAGE RELEASES (ACRE-FEET) [171]

	(CALENDAR YEAR)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Avg
Direct Flow Rights														
Anderson	1562	2906	2691	3944	2790	3690	4433	4203	4385	4199	3573	3286	3541	3477
Farmers	207	573	866	1724	1180	1919	1324	1294	1600	1542	1523	2125	1502	1337
TOB Ditch	617	857	958	979	1031	0	759	438	743	985	813	700	230	701
BCP	2340	31	162	84	435	865	55	0	29	210	0	213	417	372
BCP#3	2981	1062	2178	466	2399	0	941	10	0	211	465	0	1218	918
Harden (1)	0	358	401	269	382	293	111	367	329	333	358	314	139	281
McCarty (1)	0	128	144	104	137	105	40	134	118	111	128	112	49	101
Smith and Goss (1)	0	118	110	102	97	74	28	122	83	86	90	61	27	77
Anderson (1)	0	409	413	298	396	288	133	466	344	278	359	315	169	298
Farmers (1)	0	398	310	644	319	46	145	0	88	0	130	137	146	182
LBD/NBF (2)	0	0	0	0	0	326	0	120	1491	1037	1252	61	0	330
Subtotal	7707	6840	8233	8614	9166	7606	7969	7154	9210	8992	8691	7324	0	8073
Storage Rights														
Watershed (3)	3933	2578	4616	2820	4440	1408	2286	433	2853	14	2748	30	3156	2409
Barker (3)	6298	6690	6651	3429	4932	0	5744	0	7694	0	2024	0	4731	3707
Subtotal	10231	9268	11267	6249	9372	1408	8030	433	10547	14	4772	30	7887	6116
Exchange Rights														
to Direct Use MBC	1036	2990	2242	1293	2066	1867	1297	1063	1011	829	135	610	353	1370
to Direct Use NBC	0	0	0	0	0	0	0	118	36	53	0	0	0	17
to Storage MBC	0	728	0	2716	0	4713	1736	1947	0	3972	1347	4434	0	1799
to Storage NBC	0	224	0	0	0	2809	0	730	0	2626	397	2662	0	787
Subtotal	1036	3942	2242	4009	2066	9389	3033	3858	1047	7480	1879	7706	353	3974
Storage Releases														
CBT/WG at BRWTF	5156	3095	3660	4555	4437	7334	7419	6619	5171	2992	4758	5558	4874	5048
from Barker	4759	6634	5052	6013	4029	4913	3867	4271	2406	3612	2986	3280	4533	4335
from Watershed	2126	3071	3229	3306	2978	2749	3336	1544	1822	2045	2821	3565	1459	2619
Subtotal	12031	12800	11941	13874	11443	14996	14622	12435	9399	8649	10565	12403	10866	12002

(1) Reflects Boulder's municipal use of these rights as allowed under CWCB donation agreements
(2) Includes direct use of Lower Boulder Ditch and North Boulder Farmers rights and related exchange diversions of reusable return flows
(3) 2003 storage diversions occurred out of priority against downstream reservoir calls but Boulder was allowed to keep the water because South Platte alluvial wells did not replace their depletions during the 2002-2003 storage filling season and Boulder's rights would otherwise have been in priority

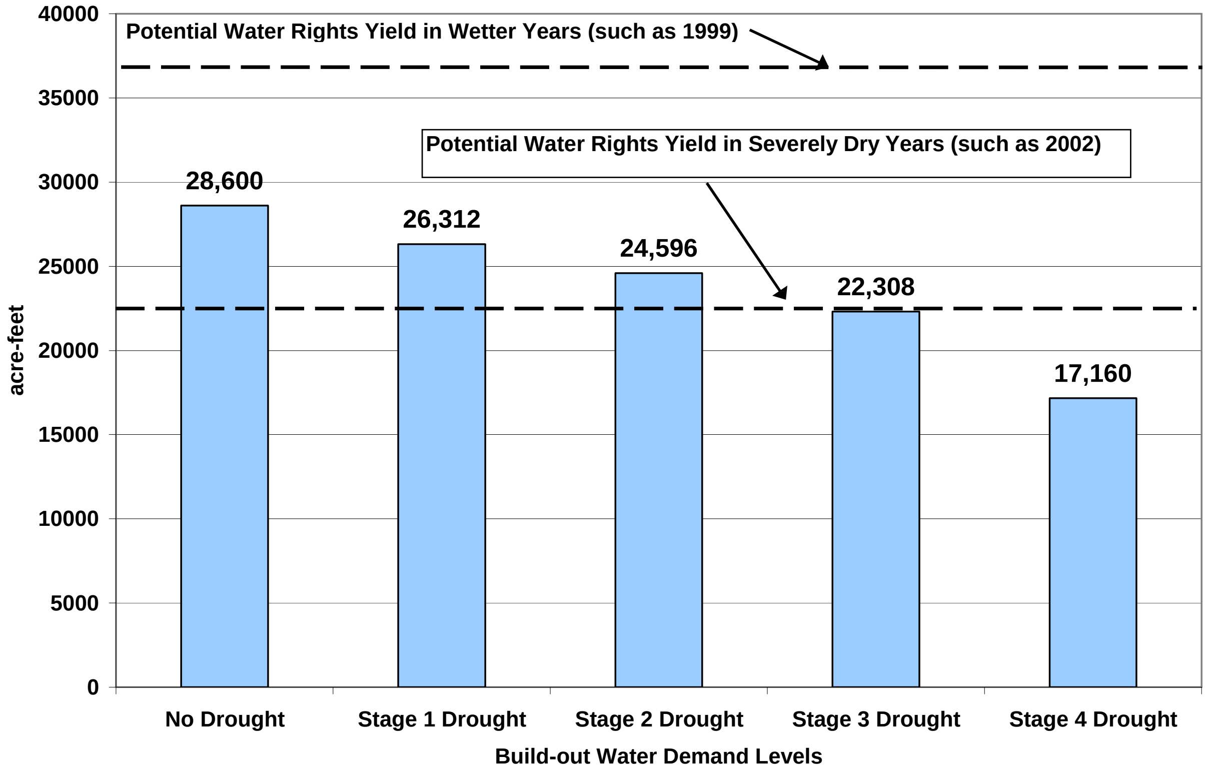
TABLE 5-13. HISTORICAL MUNICIPAL WATER DELIVERIES BY SOURCE (ACRE-FEET)[172]

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Avg
Direct Flow	7707	6840	8233	8614	9166	7606	7969	7154	9210	8992	8691	7324	7439	8126
Direct Exchange	1036	2990	2242	1293	2066	1867	1297	1181	1047	882	135	610	353	1387
CBT/WG via BRWTF	5156	3095	3660	4555	4437	7334	7419	6619	5171	2992	4758	5558	4874	5063
Upper System Storage	6875	9704	8281	9319	7007	7662	7203	5815	4228	5658	5807	6845	5992	7034
Total Delivered	**20774**	**22630**	**22416**	**23781**	**22675**	**24469**	**23888**	**20770**	**19656**	**18523**	**19391**	**20337**	**18658**	**21609**

TABLE 5-14. POTENTIAL YIELD OF BOULDER'S MUNICIPAL WATER RIGHTS AND SUPPLIES (ACRE-FEET) [173]

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Avg
Direct Flow	7707	6840	8233	8614	9166	7606	7969	7154	9210	8992	8691	7324	7439	8073
Storage	10231	9268	11267	6249	9372	1408	8030	433	10547	14	4772	30	7887	6116
Baseline Reservoir	608	608	608	608	608	608	608	388	608	594	608	608	608	590
CBT	16812	10508	12609	10508	16812	21015	18914	14711	10508	14711	14711	16812	16812	15034
Windy Gap	963	0	867	0	1201	679	993	0	4397	23	2864	1736	2791	1651
Total	**36320**	**27223**	**33584**	**25978**	**37159**	**31316**	**36513**	**22686**	**35269**	**24333**	**31645**	**24916**	**35536**	**31082**

FIGURE 5-39. WATER DEMAND LEVELS AT BUILD-OUT COMPARED TO BOULDER'S WATER SUPPLY[174]



5.3.2.2 | YIELD ESTIMATES USING THE BOULDER CREEK WATERSHED MODEL

Since the late 1980s, Boulder has used the Boulder Creek Watershed Model (BCWM) to estimate the yields of its water rights for general planning purposes. The BCWM was developed for the city by Hydrosphere Resource Consultants (now AMEC Earth and Environmental) as part of the city's 1988 RWMP and has been refined on an on-going basis since that time.

BCWM is a network model that represents the surface water hydrology, stream segments, water rights, water diversion and storage facilities, water demands, and return flows in the Boulder Creek basin as a system of connected links and nodes. The model uses collections of variables associated with quarter-month periods, called time steps. Historical data is input into the model for each time step and can be modified as needed to analyze various planning scenarios. Primary inputs are natural streamflows at gage sites, climate variables and demands associated with the water rights in the Boulder Creek basin. The model calculates values for variables, such as streamflow, return flows and diversions at each network node for each step in time. These time series of data can be analyzed to determine information such as projected water rights yield or minimum reservoir levels reached under various assumed operating conditions for the city's water system.

BCWM explicitly represents all major stream segments and water rights in the Boulder Creek basin except for Coal Creek, a small tributary with relatively little natural flow. Coal Creek inflows to the model are assumed to be made up of wastewater return flows from Lafayette and Louisville. Calls from downstream water rights on the South Platte River are represented based upon historical South Platte call records obtained from the Colorado Division of Water Resources covering the years 1940-2006. For years prior to 1940 and for tree ring-based hydrology for a longer historical period, South Platte calls are generated based upon the historical relationship between overall South Platte water supply conditions and call patterns. Natural flows in Boulder Creek are highly correlated to overall South Platte water supply conditions and are used as a proxy. Additional descriptions of BCWM are included in the Appendices.

The primary use of BCWM is for assessing the reliability of Boulder's water supply system. However, it is also used for a wide range of other purposes, including environmental analysis (hydrologic and water quality impacts), reservoir operation studies, cooperative planning, water rights analysis and short-term forecasting.

BCWM simulates the operation of all major water rights and water diversion/storage facilities in the Boulder Creek basin (including Boulder's water supply system) under varying hydrologic conditions. It also includes a representation of the CBT and Windy Gap project systems for the purpose of estimating Boulder's annual allotments from those projects. Natural streamflow time series data have been developed for the years 1907-2006 based upon stream gage data and for the years 1566 to 2002 based upon tree ring data to depict historical conditions.

In any given model run, demands associated with water rights reflect fixed assumptions regarding municipal service area land use, populations and agricultural irrigated acreages. However, demands differ annually according to variations in irrigation season temperature and precipitation. Time series of natural streamflows, temperature and precipitation, and downstream South Platte calls represent climatic and hydrologic variability based upon historical data (gage records, tree rings) or climate change modeling, depending on the modeling scenario. Within the model, demands associated with Boulder's water supply system are reduced in times of significant drought in accordance with Boulder's drought response triggers as depicted in Boulder's Drought Plan. For any given BCWM modeled scenario, the simulated performance of Boulder's water supply system is assessed to determine if the number of years with water shortages exceed the number allowed under Boulder's water supply reliability criteria.

Previous Modeling Results

The most recent assessment of the reliability of the city's water supply system was done as part of the city's revised Drought Plan in 2004 and is described in Volume 2 of the Drought Plan[175]. In that assessment, the operation of the city's water supply system was simulated against a 300-year period of hydrologic record comprised of tree ring-based reconstructions of natural flows for Boulder Creek and the Colorado River for the years 1703-1987 and gage-based reconstructions of natural flows for 1988-2002. The city's water demands were assumed to be 28,600 acre-feet per year[8,176]. The city's four-tiered drought response triggers and strategies were also incorporated into the assessment.

The results of the assessment showed that Boulder's water supply system would be capable of meeting its projected build-out demands, plus a 10 percent safety factor, in a manner consistent with Boulder's adopted reliability criteria. Over the 300-year modeled period, Boulder's projected build-out demand was fully satisfied in all but 10 years. This equated 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. The reliability assessment was presented in the Drought Plan

[8] Demands based on a service area population of 140,500 people, service area employment numbers of 164,600 jobs, per-capita and per-job water use factors consistent with the city's recently adopted Comprehensive Water Conservation program, plus a safety factor of 10 percent.

from a whole system perspective and did not include information on the yields of the city's individual water rights.

Differences from Previous Yield Estimates

Estimates of the reliability of Boulder's water supply system have changed over time. Boulder's 1988 RWMP examined this issue by estimating the firm yield of Boulder's water supply. The firm yield was defined as the maximum annual demand that could be met with no shortages. This would represent very aggressive management of the water system with the minimum amount of water carried over from wet years to dry years with municipal reservoirs being completely drained in drought years. For the RWMP, the water system was modeled under two hydrologic scenarios; historical hydrology from 1950 through 1985, and ten 100-year long traces of synthetic hydrology. In each scenario, Boulder's system was modeled as having a fixed annual demand that was the same from year to year. Boulder's demand was iteratively increased in repeated model runs until Boulder's reservoirs were empty in drought years and shortages occurred. The RWMP estimated the firm yield of Boulder's water supply system to be 50,000 acre-feet per year given historical 1950-1985 hydrology, and 32,000 acre-feet per year given ten 100-year long traces of synthetic hydrology[177].

Boulder no longer uses a firm yield approach to assess the reliability of its water supply system because firm yield is a fundamentally unrealistic way to depict the operation of a municipal water system. The city's water supply system would not be operated in a manner that allowed its reservoirs to be drawn down to zero while still delivering the full annual demand for all water uses. Realistically, increasingly stringent water use restrictions would be imposed as municipal reservoirs dropped to critical levels due to the extreme health, environmental and economic consequences of having insufficient water supplies to meet essential indoor needs.

Further changes to the assumptions and methodologies used in the RWMP modeling are discussed below.

- Based upon discussions with the District 6 Water Commissioner in the 1980's, it was assumed that calls from downstream water rights on the South Platte River did not affect water rights in the Boulder Creek basin. While this may have been true prior to the late 1980s, it is no longer true as calls from South Platte water rights have subsequently affected Boulder Creek water rights on many occasions. The current model now includes South Platte River calls.
- The firm yield of Boulder's Windy Gap project allotment was assumed to be 8,000 acre-feet per year, based upon an assumption that the CBT and Windy Gap projects would be operated in a unified manner that maximized the combined yields of the two projects. Given the current operating policies of NCWCD and its Municipal Subdistrict and the Windy Gap carriage contract with the United States, the yield of Boulder's Windy Gap allotment as delivered from the CBT project system is not reliable, and Boulder must rely on its own storage to firm its Windy Gap supplies. Additionally, Boulder has sold 4,300 acre-feet of its Windy Gap supply to Broomfield. The current maximum Windy Gap yield is 3,700 acre-feet and the average yield is approximately 1,600 acre-feet.

- At the time of the RWMP, Barker Reservoir was owned by PSCo. Boulder's right to store water in Barker Reservoir was limited to 8,000 acre-feet, although an agreement between Boulder and PSCo allowed Boulder to borrow additional water stored in Barker Reservoir under PSCo's 1906 storage right. Boulder has since acquired full ownership of the Barker system and has increased usable storage space in Barker Reservoir to 11,686 acre-feet.
- In 1991, Boulder donated water rights to the CWCB for protection of instream flows on Boulder Creek and North Boulder Creek. This donation was made with the agreement that Boulder can use those rights for municipal purposes when not needed for instream flow protection and can use those water rights exclusively for municipal purposes during extraordinary droughts.
- Boulder has acquired additional water rights in the North Boulder Farmers Ditch, Lower Boulder Ditch, Baseline Reservoir and the CBT project. Boulder appropriated additional exchange rights on Boulder Creek.
- Boulder has entered into agreements to provide lease water to other water users in the Boulder Creek basin, including Xcel Energy (Valmont Reservoir) and Jim Guercio (Caribou Ranch).
- The current model's representation of Lafayette's and Louisville's water supply systems has been improved.
- The current model's natural flow database has undergone refinements and minor computational errors in the model have been corrected.

The RWMP used two separate models that both operated using monthly data. One model estimated the supplies available to Boulder's water rights, and the other simulated the operation of Boulder's water supply system. These models were subsequently integrated into a single model (the BCWM), which uses quarter-monthly time series data. This change in the type of data the model uses has significantly improved the BCWM's overall accuracy.

Firm yield estimates included in the RWMP are no longer considered valid, and the firm yield approach is no longer used to formally assess the reliability of Boulder's water supply system. However, for comparison purposes, an updated firm yield estimate for Boulder's water supply system would be approximately 35,000 acre-feet per year based upon currently projected build-out water demand conditions and using the historic stream gage record with the 1950s drought as the most severe water supply limitation.

5.4 | Source Water Quality

While there are currently no regulations on the quality of source water, one of the fundamental principles of providing high quality drinking water is to draw raw water from the cleanest sources available. As an essential function of water system management, Boulder's multi-barrier approach begins with protecting water quality at the source. Preventing contamination is better than increasing or changing treatment after the fact. Such protection maximizes public health protection and avoids or delays costly treatment plant improvements that are needed to maintain treated water quality and regulatory compliance.

5.4.1 | SOURCE WATER QUALITY GOALS

The draft 2009 Water Quality Strategic Plan[178] identifies five basic water quality goals:

1. Provide safe and high quality drinking water.
2. Control point source pollutants from wastewater and other sources.
3. Control pollutants from stormwater and other non-point sources.
4. Protect, preserve and restore natural water systems.
5. Conserve water resources.

Through an on-going source water planning process, Utilities developed internal source water protection goals that are listed in Table 5-15. Although the goals have not been presented to City Council for formal adoption of an ordinance or policy statement, staff uses them as guidelines for operations and management. One of the city's primary source water quality goals is to continue to find ways to protect the quality of water at its source to the greatest extent possible.

The source water quality goals described in the Water Quality Strategic Plan are intended to help integrate water quality considerations into capital projects and decisions regarding land use policies and activities.

5.4.2 | ABILITY TO MEET CURRENT DRINKING WATER QUALITY STANDARDS

The city of Boulder is able to consistently treat all of its drinking water sources to acceptable regulatory standards. The city's Drinking Water Program performed more than 14,000 tests on drinking water in 2007. This monitoring was done to ensure that the water delivered to the tap met the standards set by the U.S. Environmental Protection Agency (EPA) and the Colorado Department of Public Health and Environment (CDPHE), and met the expectations of the drinking water customers.

Bacteria and other pathogens were removed or reduced to acceptable levels through disinfection and treatment processes. Previous monitoring detected the presence of *Cryptosporidium* in the source waters but pathogens were not detected in treated water.

Colorado drinking water regulations include the National Primary Drinking Water Standards (NPDWS) that consist of all regulated contaminants and the Maximum Contaminant Level (MCL) or the Treatment Technique (TT) that must be met for each contaminant in drinking water supplies. In addition to the NPDWS list of contaminants, the EPA maintains a list of National Secondary Drinking Water Standards, which are non-enforceable guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water. Colorado recommends secondary standards to water systems as "reasonable goals" but does not require compliance.

Because of geography and source water protection efforts, many regulated water quality constituents are not commonly found in Boulder's source waters. Therefore, while the city does not operate under any regulatory variances or exemptions from meeting drinking water standards, the city has been granted waivers to reduce monitoring frequency for contaminants that are not commonly found in the city's source waters.

TABLE 5-15. CITY OF BOULDER SOURCE WATER PROTECTION GOALS

Source Water Protection Goals	Action	Measurable Criteria	Corresponding Water Quality Goal
Protect source water from point and non-point pollutants. *A basic tenet of water supply and treatment is to use and maintain the best quality source possible. Keeping contaminants out of the water is generally more cost effective than removing them through additional water treatment*	Develop and implement a source water pollution prevention program which will: ▪ Contain and secure treatment plant and water supplies from potential contamination per vulnerability assessment ▪ Consider human and domestic animal access to water supplies when considering land use access and changes ▪ Secure intake structures ▪ Initiate water quality patrol position for Boulder Reservoir and Boulder Feeder Canal ▪ Implement Middle Boulder Creek Water Source Management Work Plan ▪ Develop and implement Boulder Reservoir Management Plan ▪ Coordinate with Parks on S. Shore Business Plan to include water quality protection measures ▪ Participate in point and non-point pollution regulatory development permits and source assessments ▪ Reduce potential water quality impacts from septic systems by promoting proper installation and management through the Boulder County Septic Smart Program and converting to existing collection system ▪ Reduce risk of emerging contaminants by reducing controlling contamination from wastewater sources ▪ Implement best management practices where needed to protect water supplies from existing potential contamination	▪ Reduced acute and chronic contaminant risk ▪ Reduce facility shut downs and source changes due to poor source water quality resulting in less optimized processes ▪ Reduced treatment process capital and O&M costs ▪ Less complex and more reliable treatment processes ▪ Consistent source water quality with fine tuned treatment facilities 365 days of the year ▪ Positive feedback from consumer confidence surveys ▪ Uniform water quality in the distribution system ▪ Improved operator safety ▪ Lower monitoring costs by eliminating constituents of concern ▪ Maintain and protect an adequate water supply of the highest quality ▪ Improved knowledge of source water contaminants and treatment alternatives ▪ Reduced vulnerability as identified in State and internal source water assessments ▪ Reduce sediment load to treatment facilities	(1) Provide safe and high quality **drinking water** (2) Control point source pollutants from **wastewater** and other sources (3) Control pollutants from **stormwater** and other non-point sources (4) Protect, preserve and restore **natural water systems.**

Adopt a Watershed Ordinance to protect source water *Such an ordinance identifies water supply and quality as a priority consideration in land use activities*	Develop and implement a city approved Watershed Protection ordinance for all raw water sources and up-gradient areas, which will: ▪ Designate source water protection areas to be regulated ▪ Prohibit land use activity in designated source water areas which may creates risk of contamination or injury to the City's water supply or waterworks[ix] ▪ Restrict public access to protected watersheds and maintain closure of the Silver Lake Watershed to public access ▪ Provide regulatory mechanism to enforce illegal discharges into source water areas ▪ Prohibit illegal discharges and regulate land-use activities in designated source water areas ▪ Manage recreation uses to protect drinking water supplies Establish watershed permitting system to regulate activities within the designated source water protection areas	▪ Improved restriction of public access of key or vulnerable source water areas	(1) Provide safe and high quality **drinking water;** (2) Control point source pollutants from **wastewater** and other sources; (3) Control pollutants from **stormwater** and other non-point sources; (4) Protect, preserve and restore **natural water systems;** (5) **Conserve water** resources.
Foster stewardship and regional cooperation *The city does not own or control most of the lands that affect its water supplies and cooperation with land-use management entities and interests is necessary*	▪ Educate and coordinate with local governments and private landowners to protect drinking water supplies ▪ Coordinate with local environmental groups to protect water supplies ▪ Coordinate with Boulder County on Boulder Feeder Canal recreational uses ▪ Investigate and cooperatively resolve of pollution issues ▪ Coordinate with Northern Colorado Water Conservancy District on diverting outfalls to canal and general maintenance ▪ Work with Forest Service on Boulder Creek Watershed management issues	▪ Increase public participation and input ▪ Better information on community needs	(1) Provide safe and high quality **drinking water;** (2) Control point source pollutants from **wastewater** and other sources; (3) Control pollutants from **stormwater** and other non-point sources; (4) Protect, preserve and restore **natural water systems;** (5) **Conserve water** resources.

[ix] An example is the Grand Junction watershed ordinance, which establishes watershed and water supply standards, requires watershed permits for various activities within the watershed, prohibits any person from polluting the watershed, and encourages the City Council to adopt ordinances or resolutions. Retrieved January 15, 2009 from http://cogcc.state.co.us/RuleMaking/PreDraftComments/CommentDocs/LocalGovernment/GJwatershedinitiative%20language.pdf

Adopt a city-wide source water anti-degradation policy	Develop and implement an anti-degradation policy[x] which will: ▪ Give preference to alternatives that maintain, protect, or enhance the quality of the water supply sources for decisions regarding resource use and resource development ▪ Consider public water supply use as the highest priority when evaluating competing uses for the water sources ▪ Improve communication and coordination to treat the highest quality water source available	▪ Improved water quality protection	(1) Provide safe and high quality **drinking water.;** (3) Control pollutants from **stormwater** and other non-point sources**.**
Enhance, protect, and maintain source water riparian and wetlands areas *Restoring riparian corridors reduces soil loss from erosion and filters pollutants from non-point runoff* *Riparian zones are estimated to remove 80-90% of sediment, reduce nitrogen by 80-90%, reduce phosphorus by 50-75%, and, when stream banks are stabilized, riparian zones reduce total suspended solids (TSS) by 80%*[179]	Develop and implement a riparian and wetlands protection and enhancement program which will: ▪ Establish conservation easements and riparian and wetlands buffer zones in source water areas ▪ Maintain and improve stream channels and wetland features to reduce erosion and enhance treatment by natural systems ▪ Develop outreach and education programs regarding the importance of riparian areas and soil and water conservation practices	▪ Reduced unexpected acute and chronic contaminant risk ▪ Reduced vulnerability as identified in state Source Water Assessment Report ▪ Reduce sediment load to treatment facilities	(1) Provide safe and high quality **drinking water.;** (3) Control pollutants from **stormwater** and other non-point sources (4) Protect, preserve and restore **natural water systems** (5) **Conserve water** resources
Monitor source water quality	▪ Continue source water monitoring and evaluation program to track water quality conditions ▪ Continue to track unregulated contaminants to determine risk and evaluate monitoring need ▪ Improve knowledge of emerging contaminant occurrence and prevention and treatment option	▪ Reduced risk of unregulated and emerging contaminants ▪ Improved knowledge of source water contaminants and treatment alternatives	(1) Provide safe and high quality **drinking water**

[x] An example is the American Water Works Association Statements of policy on public water supply matters retrieved January 15, 2009 from http://www.awwa.org/files/about/OandC/PolicyStatements/1209426115078.pdf

5.4.3 | SOURCE WATER CHARACTERIZATIONS

Boulder's two water treatment facilities are served by different water sources: the upper Boulder Creek watershed supplies the Betasso WTF, and the CBT and Windy Gap projects supply the Boulder Reservoir WTF (Figure 4-4). As a result of both natural and man-made conditions, the quality of source waters being treated is distinctly different, and therefore the quality of the resulting treated water varies.

5.4.3.1 | BOULDER CREEK WATERSHED WATER MONITORING

Boulder has performed monthly monitoring in the Boulder Creek watershed for the past eight to 15 years. The city uses monitoring data to evaluate basic water quality conditions and trends, and to gain an understanding of treatment capabilities. The city monitors the following locations to characterize source water for the Betasso WTF:

- Lakewood Reservoir Tributaries:
  - Como Creek
  - North Boulder Creek
  - Silver Lake Pipeline
  - Barker Reservoir Tributaries:
  - North Beaver Creek
  - Middle Boulder Creek (above weir)
  - Nederland wastewater effluent
- Barker Reservoir:
  - Top water
  - Bottom water
- Betasso WTF Influent

Upper Boulder Creek Watershed Source

In general, the Boulder Creek Watershed provides a good quality, high mountain water supply. The water has moderately low hardness and alkalinity, as well as low dissolved and suspended solids. However, natural and man-made influences impact the water quality. Spring snowmelt can cause significant increases in turbidity and organic carbon, and wildlife can introduce pathogens. Barker Reservoir has also seen measurable impairment from stormwater runoff and wastewater effluent, particularly from nutrients.

5.4.3.2 | COLORADO-BIG THOMPSON AND WINDY GAP PROJECTS MONITORING

Boulder's portion of CBT water is stored in Carter Lake and transferred to Boulder Reservoir through 21 miles of open, unlined canals. The two sequential canals are called the St. Vrain Supply Canal and the Boulder Feeder Canal, although the city most often refers to the entire canal length as the Boulder Feeder Canal as a matter of convenience. The Boulder Reservoir WTF has the ability to draw water from Boulder Reservoir or directly from the Boulder Feeder Canal prior to entering Boulder Reservoir.

Boulder has a source water monitoring program which focuses on the Boulder Feeder Canal, Boulder Reservoir and the Boulder Reservoir tributaries. Over time the monitoring program has expanded to address new regulatory requirements for drinking water and to assess potential impacts to source water quality from various watershed activities. Samples are collected on a monthly basis for multiple constituents and special studies are conducted on an as needed basis. The Appendices contain a summary of the water quality of Boulder Reservoir and its tributaries.

CBT/Windy Gap Source Waters

A study conducted in 2003 by the city and Black & Veatch[180] concluded that the water quality of Carter Lake was superior to both the Boulder Feeder Canal and Boulder Reservoir as a drinking water source. Carter Lake water is of a consistent and high quality. Conveyance through the Boulder Feeder Canal and storage in the reservoir can lead to degradation of water quality. Water in the Boulder Feeder Canal is subject to influences from canal maintenance and runoff. Water in Boulder Reservoir is affected by nutrients, turbidity, residence time, and taste and odor compounds. The quality of water in the Boulder Feeder Canal and Boulder Reservoir can be significantly different, depending on the constituent, even though the original source of water is the same. This is primarily due to the function of a canal versus a reservoir and the potential for dilution in the reservoir.

Dissolution of naturally occurring mineral deposits in Boulder Reservoir sediments increases total dissolved solids (TDS), which include hardness, alkalinity, sodium and sulfate. TDS concentrations vary with season and generally decrease when the Boulder Feeder Canal is operating. During summer months when Boulder Reservoir water temperature increases, the hypolimnion (i.e., bottom layer of the reservoir) becomes anaerobic and manganese is mobilized from the bottom sediments. Dissolved solids increase in Boulder Reservoir after Carter Lake – a low TDS water supply – is shut off for the winter.

The Appendices include a general characterization of source water quality from the upper Boulder Creek watershed and the CBT/Windy Gap source waters.

5.4.4 | CURRENT AND FUTURE LAND USES AFFECTING WATER QUALITY

Access to and activities in the North Boulder Creek watershed are somewhat limited by city or county owned property and wilderness designations that help reduce the potential for many types of water quality impacts. The Middle Boulder Creek watershed is experiencing an increase in impacts due to pressures from development, access and traffic. These human influences can increase wastewater and septic discharges, introduce chemical and fuel use, impact protective vegetation and increase wild land fire danger associated with increased access.

The following sections provide a summary of land uses affecting water quality. Additional analyses can be found in more detailed evaluations conducted by the city (*i.e.*, Boulder Feeder Canal Trail Proposal Health and Safety Analysis[181], Source Water Quality Planning Study[182], Middle Boulder Creek Water Source Management Work Plan [183], Boulder Creek Watershed Study Phase II [184] and Water Source Impact Assessment[185]). CDPHE conducted a Source Water Assessment that evaluates the susceptibility of the city's water supplies based on a broad evaluation of available regulatory databases. The city submitted comments on the draft assessment report but the state has not issued a final draft. A final draft is expected in 2009.

5.4.4.1 | SILVER LAKE WATERSHED AND NORTH BOULDER CREEK

The Silver Lake Watershed has been closed to public access since the 1920s initially for the purpose of protecting drinking water quality and source water facilities; however, there are now a number of reasons why public access is restricted (see section 3.4.7). The city enforces this closed status by patrolling the watershed for trespassing and imposing fines on trespassers. While opening the Silver Lake Watershed to public recreation has been proposed in the past, the City Council has continued to reaffirm the importance of restricting use of this area.

The Boulder County Parks and Open Space Department manages the Caribou Ranch Open Space, located west of Lakewood Reservoir along North Boulder and Delonde Creeks (Figure 3-3). Access is limited to pedestrian and equestrian traffic on the 4.5 miles of designated trails. No dogs or bicycles are allowed. There is a single point of access to North Boulder Creek through the property, although the trails cross Delonde Creek in several locations. Caribou Ranch Open Space is closed to the public yearly from April 1 to June 30 to avoid disturbance of migratory birds and elk herds during the calving season. Some of the restrictions on the use of Caribou Ranch Open Space were conditions of the sale of the property to the city and Boulder County and therefore are expected to remain in effect permanently.

A series of agreements signed in 2001 between the city, county, and property owner, James Guercio, focus on how Guercio may develop the property he retained in the Caribou Ranch transaction (see section 3.4.9.7). According to the agreements, Guercio is limited to developing 23 dwelling units plus a fishing lodge and a noncommercial horse barn. The city and Boulder County acquired conservation easements over 1,159 acres. Boulder County is the primary monitor of the conservation easements[xi].

Future: As long as the existing access restrictions and agreements are in place, existing land use activities should remain and not increase or change in the future.

[xi] The series of agreements that accompanied the Caribou Ranch purchases can be found in the Appendices.

5.4.4.2 | MIDDLE BOULDER CREEK AND BARKER RESERVOIR

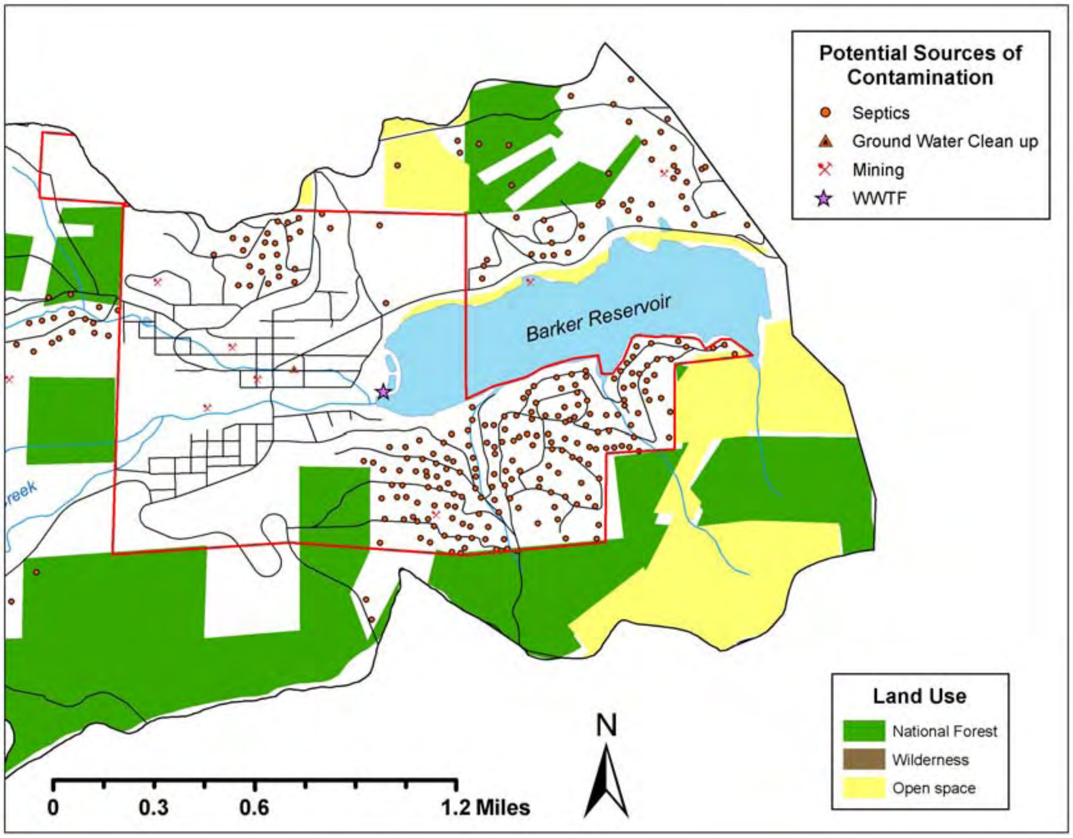
Middle Boulder Creek provides a high quality water supply for multiple beneficial uses. The land use practices (e.g., Boulder County Open Space and USFS land) and wilderness designation in the upper reaches of the watershed provide protection for source water quality. However, the Nederland Wastewater Treatment Plant discharges directly into Barker Reservoir. Table 5-16 describes water quality in the Nederland Wastewater Treatment Plant effluent and Barker Reservoir. Although the amount of influent is relatively small, degradation of reservoir water quality is possible over the long term from the continued contribution of the treatment plant discharge as well as upstream sources of non-point contamination into Middle Boulder Creek.

Residential development of the areas surrounding Barker Reservoir has continued in recent years, increasing human use of the reservoir area as well as vehicular access to the slopes above the reservoir. Many of the surrounding houses use septic systems for wastewater disposal (see Figure 5-40).

Future: Increased human use of the area also increases the risks for traffic accidents resulting in petroleum product spills, septic or sewer system failure, fire and other accidental contamination. The Big Springs development located on the south side of Barker Reservoir is planned for connection to the sewer system, which could reduce the likelihood of contamination from septic systems that are not functioning correctly.

Despite the city's efforts, existing and potential water quality impacts to Boulder's raw water sources remain. In addition, evolving science is discovering more about emerging contaminants (e.g., personal care products and pharmaceuticals) and their persistence in the environment and ability to be removed from water by current treatment processes. Although the city's water supplies are located upstream of any major wastewater treatment plant, researchers are finding traceable levels of chemicals from products such as sunscreen and insect repellent in these source waters. Reducing or preventing contaminants that may pose health risks from entering the water supply gives treatment processes the opportunity to produce a higher quality drinking water.

FIGURE 5-40. LAND USE AND POTENTIAL WATER CONTAMINATION SOURCES NEAR BARKER RESERVOIR



Notes: Data for this map comes from the city of Boulder's internal SWAP assesssment (2002). Septic data was derived from AIRPHOTO.AIRPHOTO_image_index_for_2000 on the city's sde server. City water quality staff assumed that all residential houses have a septic system. Mining and ground water cleanup data came from EPA region 8. Further metadata for this map can be found in Brown and Caldwell and CDM Camp Dresser and McKee, Inc. (1997). *Boulder Creek watershed study: Phase 1 dated November 1997*. Denver, CO, 8-17. The original SWMP assessment maps are located at S:/pw/63rd/arcmap/arcmapprojects.
* *Although the city submitted septic system data to the state for the SWAP program, the state did not incorporate this data into their published maps.

Boating on Barker Reservoir

The possibility that Barker Reservoir could be opened to non-motorized boating increases the risk for degradation of the Middle Boulder Creek water source. The 2003 Barker Reservoir Boating Feasibility Study concludes:

> "Based on the [modeled] water quality impacts associated with boating use on Barker Reservoir, a clear conclusion is that both [use level] options represent important potentials for the degradation of water quality in Barker Reservoir. Neither scenario leads to an improvement in or maintenance of water quality in Barker Reservoir and therefore conflicts with the city goal to improve or maintain existing drinking water source quality……..three key areas of water quality concern [are]…eutrophication processes, pathogen diversity and load, and accidental or intentional contamination events"[186].

In addition, boats transported from other locations could introduce non-native and invasive species to Barker Reservoir. To date, zebra and quagga mussel veligers have been identified in 6 lakes and reservoirs in Colorado on the east and west slopes, all of which allow boating. Non-native species upset that natural flora and fauna of the reservoir and downstream waters and can clog water supply infrastructure, make water treatment more difficult, and decrease the recreational and aesthetic value of waterfronts.

The city is implementing more intensive monitoring in Barker Reservoir to assist in identifying potential water quality concerns early and tracking potential contaminant sources. Protecting water quality to maintain high quality drinking water and existing uses will require coordination and planning among the multiple stakeholders within the watershed.

5.4.4.3 | CBT, BOULDER FEEDER CANAL AND BOULDER RESERVOIR

Historically, water quality at the Boulder Feeder Canal intake to the Boulder Reservoir WTF, compared to the quality of water in Carter Lake, shows degradation for various constituents, but most notably for bacteria (*E. coli* and fecal coliform)[187]. Bacteria levels in the canal also vary temporally with a positive correlation to precipitation events that generate runoff into the canal. Historic sampling demonstrates a causal link between bacterial contamination in Boulder Reservoir and operation of the Boulder Feeder Canal. For example, fecal coliforms are present at or below the detection limit during the months when the canal is not in operation. However, during the months it is in operation, fecal coliforms are typically present at measurable concentrations.

A general characterization of the three water sources serving the Boulder Reservoir WTF is given below. Specific attention is given to land use factors and geography that can influence water quality.

Carter Lake

Water quality in the Carter Lake has historically been excellent. Carter Lake is open to the public and permits year-round activities including motorized boating, fishing and swimming; however, the high the water quality can be attributed to a number of factors. Carter Lake is large and deep at 112,230 acre-feet of storage and 140 feet in depth. The lake's geography limits the potential for non-point source inputs as it is an upland reservoir surrounded by Bureau of Land Management lands with no natural tributaries and a small natural watershed.

Carter Lake water quality vulnerabilities can be summarized as:

- open for recreational uses and public access year-round, and;
- Boulder does not have control over lake operations or recreational activities conducted on or around the lake.

Future: A new outlet from Carter Lake was completed in 2008, which allows for deliveries from three depths. On-line water quality monitoring data can be tracked and used for decisions regarding deliveries to the Boulder Feeder Canal. Growth in the Front Range will likely increase recreation activities on the reservoir.

Boulder Feeder Canal

The Boulder Feeder Canal is bordered by public and private lands that have agricultural, residential, industrial and recreational uses. The Boulder Feeder Canal is an open canal that collects diffuse surface runoff at various locations from both agricultural runoff and storm events. There are 45 outfalls that direct this runoff into the canal (Figure 5-41). Significant water quality degradation occurs along the 21 mile length of the canal prior to entering Boulder Reservoir.

Boulder Feeder Canal water quality vulnerabilities can be summarized as:

- non-point source drainage from the earthen canal prism, surrounding agricultural land, residential development and industrial/commercial development;
- multiple (45) potential direct discharges from surrounding lands;
- algaecide and herbicide applications for attached algae and weed control as administered by the NCWCD;
- multiple road crossings and public access, and;
- Left Hand Creek water, which is susceptible to land use contamination between the mouth of the canyon and the diversion into the Boulder Feeder Canal.

Future: A regional trail along the BFC is being developed, which will increase access to the BFC along the length of the trail.

Boulder Reservoir

Water quality in Boulder Reservoir is affected by recreation allowed on and around the reservoir and wildlife that frequent the reservoir. Boulder Reservoir is open for swimming and motorized boating and there are multiple access points for pedestrians and car-top boats. Body-contact recreation activities are a potential source of pathogens, and motorized boating allows the potential for fuel spills. The nutrient loading to the reservoir make the reservoir susceptible to algal blooms and noxious weeds, particularly since the reservoir has a large surface area to depth ratio. Algae causes difficult-to-treat taste and odor problems.

Boulder Reservoir water quality vulnerabilities can be summarized as:

- open year-round for recreation and to public access;
- overland flow to the reservoir from surrounding lands, including recreational events;
- naturally occurring dissolved manganese during critical summer months when temperature stratification occurs followed by anoxic conditions in the bottom water;
- algae bloom, and;
- high wind events substantially increase turbidity thereby impacting treatment operations.

Future: Increased visitation and activity may adversely impact water quality over time, and the continued nutrient load will influence the eutrophication of the reservoir.

FIGURE 5-41. OUTFALLS TO BOULDER FEEDER CANAL[188]

5.4.5 | SOURCE WATER QUALITY MANAGEMENT

The city has developed working documents that identify and prioritize source water quality concerns and management needs (e.g., Carter Lake Pipeline Weekly Information Packet[189], Boulder Reservoir Water Treatment Facility Source Water Contaminant Mitigation Costs[190], Middle Boulder Creek Water Source Management Work Plan[191], Utilities Annual Reports (particularly 2006), Boulder Feeder Canal Drainage Projects[192] and Intergovernmental Agreement City Council Agenda Item Regarding Nederland Wastewater Treatment Facility[193]). These documents acknowledge the city's limited jurisdictional authority in its source water supply watersheds, but identify specific actions the city can take and include coordination with other local, regional, and state entities.

At a policy level, this Source Water Master Planning effort has identified a need to develop and formalize a source water protection policy and goals. Specific capital projects and programs are identified in Chapter 7.

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[152] *Ibid.*, 61-64.
[153] *Ibid.*, 81-82.
[154] *Ibid.*, 82.
[155] *Ibid.*, 83.
[156] *Ibid.*, 86-87.
[157] *Ibid.*, 88.
[158] *Ibid.*, 89-91.
[159] *Ibid.*, 91-92.
[160] *Ibid.*, 97.
[161] *Ibid.*, 103.
[162] *Ibid.*, 140-141.
[163] The States of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming Governor's Representatives on Colorado River Operations. (2006). *Letter to Gale A. Norton, Secretary of the Department of the Interior dated February 3, 2006 re: Development of lower basin shortage guidelines and coordinated management strategies for the operation of Lake Mead and Lake Powell under low reservoir conditions*. Washington, D.C., 175. Also retrieved January 15, 2009 from http://www.nap.edu/catalog.php?record_id=11857#toc
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172 *Ibid*.
173 *Ibid*.
174 Derived from data in *Ibid*., 40 & 48; ***and*** City of Boulder. (2007g). *op. cit*.
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Chapter 6

6 | ISSUES

Operation of Boulder's raw water supply system and management of its source watersheds takes place within the context of numerous policies, goals, legal constraints, facilities capabilities, hydrologic conditions, source water impacts and development patterns. Topics to be addressed in the future have been identified through the SWMP process, including issues identified by the CSG as well as on the basis of staff input. Issues described in this chapter are categorized as follows:

- Water Management and System Operations Issues;
- Water Rights Yield Issues;
- Water Use Issues;
- Watershed Management Issues, and;
- Facilities Condition and Improvement Issues.

Issues currently under discussion that need further evaluation or are the subject of a recommendation for future action within the SWMP identified herein. Actual recommendations are in Chapter 7.

6.1 | Water Management and System Operations Issues

6.1.1 | OPERATIONAL FLEXIBILITY

In addition to the city's reservoirs, the large storage volume (over 720,000 AF) of the CBT project is vitally important to act as a supplemental supply during droughts. Careful selection of which available water source to use at any given time and maintenance of adequate reservoir carryover storage levels is important because of the unpredictability of Colorado's present climate and the likelihood that predictability will be further reduced as the effects of climate change become more apparent.

The city's water supply sources are highly variable from year to year due to the semi-arid climate of the region. The high variability in annual water supply is an issue that has created the need for a flexible water supply system. A flexible system is one that maximizes Boulder's ability to use direct flow sources and select from various reservoir storage pools in a manner that maintains sufficient carry-over storage to assure that Boulder will have adequate supplies in drought years.

At present, it appears that regional effects due to climate change are likely to include higher temperatures that lead to increased irrigation demands and earlier mountain snowpack melting in the spring. It is unknown if the Boulder area will experience a net annual increase or decrease in precipitation. The area could experience an increase in variability between wet and dry years and an increased number of extreme weather events. Climate change effects could become an issue requiring even more flexibility in the future system operations.

6.1.1.1 | YEAR-ROUND ACCESS TO CARTER LAKE DELIVERIES

The seasonal operation of the Boulder Feeder Canal limits flexibility of the city's operations and may limit the city's drought-year water yield. Achieving the ability for the city to access west slope source water during the winter would maximize use of this source and may be necessary to fully use the city's Windy Gap water. The city's use of west slope water during the winter is currently limited by the amount of storage space available to the city in Boulder Reservoir under the contracts with NCWCD. The ability to store water in Boulder Reservoir during the winter is further limited by the need to maintain winter reservoir levels below the point where high winter winds can damage the rip-rap on the dam and cause erosion. While improvements to the Boulder Reservoir WTF have been discussed as an alternative to the proposed Carter Lake Pipeline, an expansion of the water treatment facility capacity would not eliminate Boulder Reservoir's storage limitation. Full winter use of the currently planned 16 MGD capacity at the Boulder Reservoir WTF would require more water than can be stored in the city's Boulder Reservoir accounts during the winter. Without the ability to access west slope water directly from Carter Lake during the winter to supplement what can be stored in Boulder Reservoir, the city will be unable to fully use the 16 MGD capacity of the Boulder Reservoir WTF on a year-round basis and may be unable to fully use its allocation of west slope water in drought years.

6.1.1.2 | USE OF RIVER EXCHANGES

The exchange mechanism provides an important function in maintaining operational flexibility within the city's source water system. The exchange mechanism is used to continue taking water during the critical spring and summer high flow periods in those years when water is physically available at the high mountain reservoirs and pipeline diversion points but the city's native basin water rights are called out by more senior water rights. This is accomplished by providing the other water rights with an alternative supply such as CBT water. The city does not need to use its exchange rights in every year, but in some years the city's upper reservoirs will only fill through use of the exchange. Use of the exchange rights enhances drought protection, reduces the water utility's capital and operating expenditures and provides for renewable hydroelectric power generation which reduces greenhouse gas emissions. In deciding the current and future balance between east slope and west slope water supplies and in re-evaluating the current state of Boulder Creek's fisheries habitat, the city must consider the value of exchanges. Operational flexibility could become an issue with a reduction in the city's ability to use the exchange mechanism.

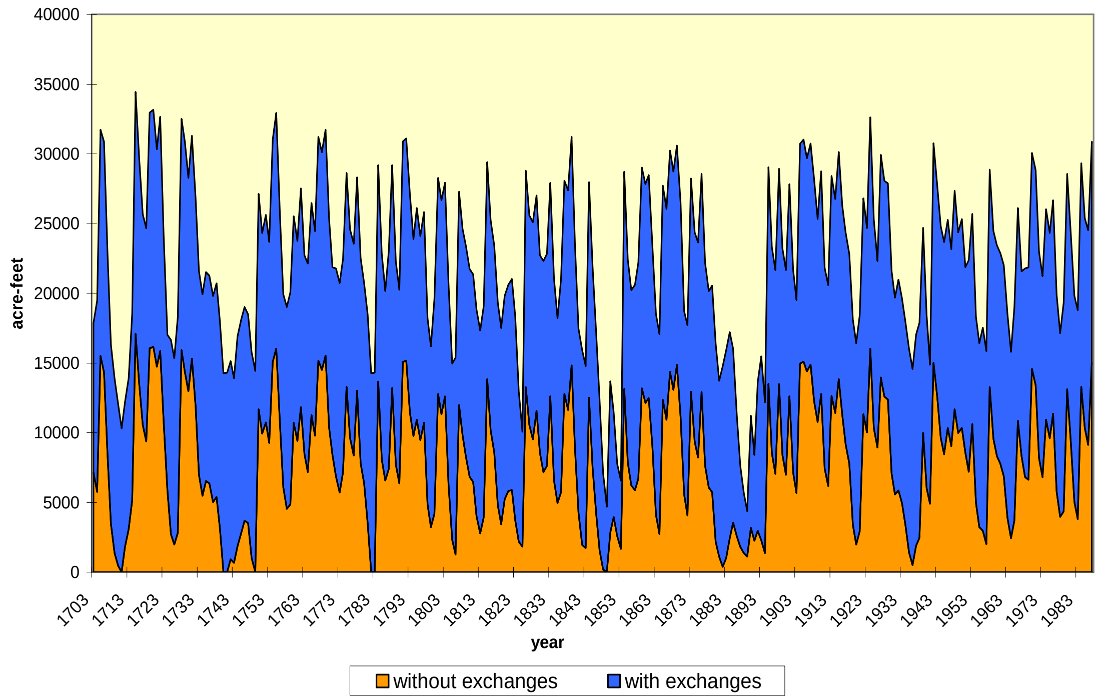
The city's use of its Boulder Creek exchanges results in lower streamflows in a portion of Boulder Creek. The benefits of exchanges and the effects on habitat in Boulder Creek are summarized as follows:

- High streamflow periods can be habitat-limiting because high peak streamflow levels in the spring flush out food sources, fish eggs and fingerlings. The city's exchanges are limited by water rights factors to high flow periods, so to the extent the exchanges reduce streamflow during high flow periods, habitat would either be beneficially affected or not impacted.
- Without use of the exchange rights, the city's upper reservoir storage space would be used much less effectively and would occasionally be emptied.
- If use of exchanges were discontinued, it would increase the frequency of mandatory drought water use restrictions in Boulder because the upper storage reservoirs would fill less often.

- The amount of water available to satisfy downstream agricultural users if the city's exchanges were discontinued would be decreased during drought periods due to municipal water use restrictions as was seen in 2002. Already low streamflow levels in the reaches of Boulder Creek downstream of the city as a result of lack of snowpack were compounded by decreased municipal lawn water returns. These reduced flows triggered senior calls by agricultural users that shut down most irrigation ditches and called out some of the city's most senior direct flow water rights[1].
- Modifying the foundation for the water system design by reducing use of exchange rights would require enlarging treated water transmission pipelines from Boulder Reservoir WTF, enlarging key water distribution pipelines leading from Zones 1 and 2 up into Zone 3, adding pumping capacity to pump stations throughout Boulder and increasing treated water storage capacity.
- Not using the city's exchange rights would negatively affect the cost of providing municipal water service. Water treatment costs are reduced due to use of the exchanges because it is less expensive to treat the higher quality water available to Betasso WTF than water at Boulder Reservoir WTF.
- The city is able to generate electricity from hydropower plants using the pressure developed within the upper part of the city's municipal water supply system. These power plants generate up to 45 million kWh per year, which is enough to supply about 7,500 homes in Boulder with their annual power needs and offset the burning of 20,500 tons of coal each year. The revenue from the power sales has provided up to $2,100,000 to the city's water utility fund each year that would otherwise have to come from increased water rates[2]. If water exchanges were reduced, the amount of hydropower generated would be reduced. In addition, power demands (and associated coal burning) would increase due to the need to pump a like amount of water into Boulder Reservoir WTF and through pumping plants up into the city's treated water distribution system. Decreased use of the city's exchange rights would increase greenhouse emissions and work against the city's adopted goals for reducing global warming.

Based on modeling of Boulder's water system using the tree ring hydrology for a 285-year period of operation under build-out water demand conditions, the city would experience 12 years with reduced water deliveries caused by drought if the exchange rights are used as planned[3]. If the exchange rights were not used in the future, there would be 75 years with reduced water deliveries due to drought out of the 285 modeled years. The reliability criteria for the water system that were adopted by City Council specify that water use restrictions due to drought should not occur more often than 14 times in a 285-year period[4]. Therefore, the city could not meet the established water system reliability criteria without use of the exchange rights. The increased number of years with shortages is illustrated by comparison of Figure 6-1 below.

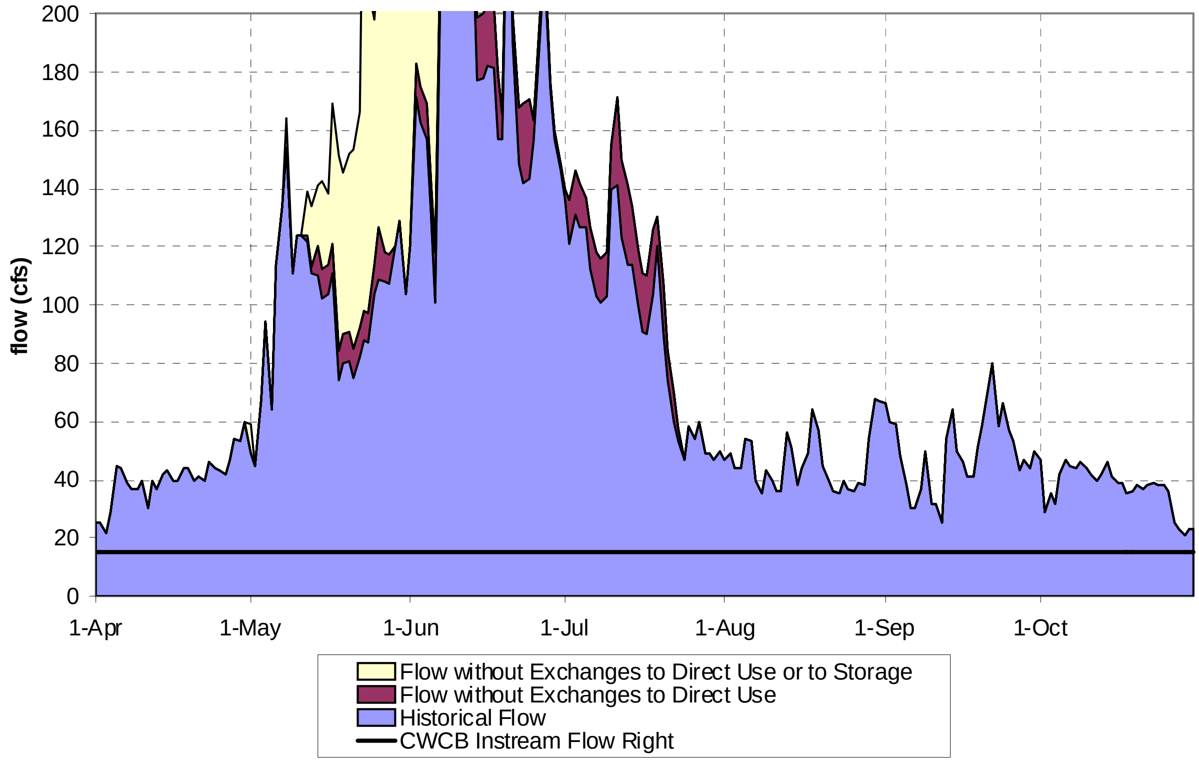
FIGURE 6-1. CITY OF BOULDER MODELED WATER SYSTEM OPERATIONS WITH AND WITHOUT EXCHANGES: MINIMUM STORAGE LEVEL IN UPPER BOULDER CREEK RESERVOIRS[5]



Some concerns have been expressed that the operation of Boulder's exchange rights might adversely affect streamflow and habitat on Boulder Creek. An analysis of the effects of Boulder's river exchanges on Boulder Creek habitat has been completed by AMEC (formerly Hydrosphere). The analysis concludes that the operation of Boulder's exchange rights has not reduced streamflows at the Orodell gage below 15 cfs, which is the amount of the decreed CWCB instream flow right for the stream reach below this point. Figure 6-2 below shows streamflows below Orodell with and without exchanges in one of the more heavily impacted years – 2000. Only rarely has the operation of Boulder's exchange rights reduced streamflows at Orodell below 40 cfs[6].

The operation of Boulder's exchange rights has generally not reduced streamflow downstream of Broadway below 15 cfs. While the city's exchanges did reduce flows to below 15 cfs on occasion in most of the years studied, these reductions usually occurred for brief periods (4 to 5 days) and occurred most often when streamflows were declining rapidly in mid to late summer. In nearly all of the instances where the city's exchange operations coincided with streamflows of less than 15 cfs downstream of Broadway, the Farmers Ditch right was in priority in sufficient amounts to provide a full 15 cfs to Boulder Creek between the Farmers Ditch headgate and 75th Street. Therefore, at times, the city has a number of options for how it operates its municipal system including operating the Boulder Creek exchange and maintaining minimum streamflows with the conveyed Farmers Ditch right or not operating the exchange and using the conveyed Farmers Ditch right for municipal purposes.

FIGURE 6-2. BOULDER CREEK STREAMFLOW AT ORODELL WITH AND WITHOUT EXCHANGES IN 2000[7]



Note: This graph is intended to show what the possible increase in streamflow would be without Boulder's exchanges. The historical flow depicts streamflow amounts with exchanges in use. Because exchanges are made during the irrigation season, the flow with and without exchange is the same during the low flow season. It should also be noted that flows without exchanges are not the same as natural flows since they still account for direct flow diversions on the stream.

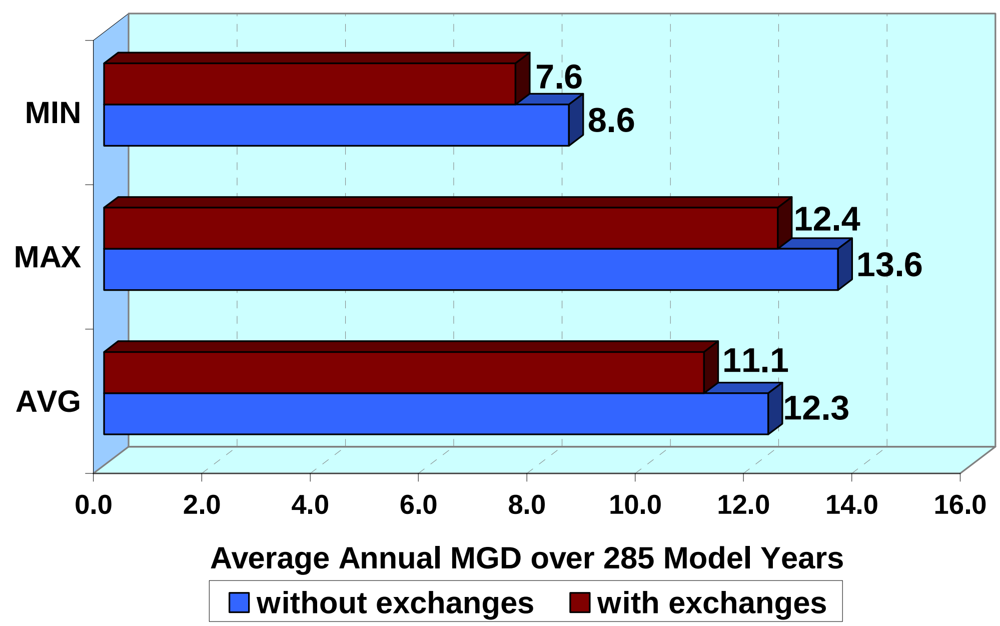
Another alternative to the city's current use of exchange-water supplies is to instead deliver water the city would otherwise use for exchange to Boulder Reservoir via the Boulder Feeder Canal so that Boulder could realize the equivalent of the yield of its exchange rights by taking direct delivery of its exchange supplies at the Boulder Reservoir WTF without causing reductions in Boulder Creek streamflows. As shown in Figure 6-3, the potential for additional production at the Boulder Reservoir WTF when the exchange is not operating is slightly more than that with exchange[i]. This alternative does not address a fundamental purpose of use of an exchange right, which is to provide a means to divert water at other locations to maximize use of existing facilities or for operational concerns. Boulder's exchange rights allow it to divert additional supplies at its upstream points of diversion, which provides for diversion of higher quality water, gravity flow delivery, and more water stored in the city's 18,000 acre-feet of mountain reservoirs. None of these benefits can be attained by diverting the city's exchange supplies it Boulder Reservoir for subsequent use at the Boulder Reservoir WTF[8].

This alternative also does not consider operational and facilities design factors of Boulder's water supply system that have developed in part due to the ability to exchange water supplies. Boulder frequently exchanges water for direct delivery to Betasso WTF at rates of more than 13 MGD (more

[i] For an explanation of the modeling assumptions and methods, see AMEC. (2008b). *Review draft memorandum to City of Boulder Utilities concerning stream flow effects of operation of Boulder's exchange rights dated June 20, 2008*. Boulder, CO.

than 20 cfs) while concurrently delivering water via the Boulder Reservoir WTF (16 MGD capacity) at rates of 8 to 12 MGD in order to meet Boulder's summer demands. Shifting the delivery of the water used to drive Boulder's direct use exchanges to the Boulder Reservoir WTF would therefore require an increase in the treatment capacity of that plant by 13 MGD up to a total capacity of at least 25 MGD. Other facilities, such as pumping plants and transmission pipelines from the Boulder Reservoir WTF into the city, would also need to be increased in size. Therefore, significant capital investment would be required on one side of the water system along with abandonment of full use of existing facilities' capacity on the other side of the water system in order to eliminate or significantly reduce use of the exchange mechanism. This capital expenditure is difficult to justify given the inability to show any significant detrimental impact to Boulder Creek habitat due to the city's exchange practices[9].

FIGURE 6-3. AVERAGE ANNUAL MODELED PRODUCTION AT BOULDER RESERVOIR WATER TREATMENT FACILITY WITH AND WITHOUT EXCHANGES[10]



6.1.2 | EMERGENCY RESPONSE PLANNING

The city presently has individual emergency response plans for each of its major dams[11]. The emergency response plan for Barker Reservoir and the Boulder Canyon Hydro Project is exercised every year based on FERC requirements. Although this exercise is specific to the Barker system, it is also useful in understanding the type of response that might be required for an emergency with the other dams. The city also has an annual exercise for a response during a major flood event on Boulder Creek.

There are many other types of events other than dam failure or flood that could affect the city's ability to provide municipal water supplies. Events such as climate change, localized drought, a Colorado River compact call, wildland fire, infrastructure failure or contamination event could also have a major impact on Boulder's water supply. The city does not presently have a comprehensive emergency response plan that can help to ensure a rapid, appropriate response to source water system and raw water facility emergencies.

Emergency response planning should evaluate risks to the water deliveries if there is a reduction in yield or quality of one or more of the city's water sources. The plan should outline emergency response measures to be taken and define the city's ability to deliver water if a catastrophic event were to disable a portion of the source water system. The plan should also consider water system modeling of various emergency scenarios.

The Middle Boulder Creek Management Work Plan recommended developing and testing a Betasso WTF Notification Plan to provide warnings to water treatment plant operators in the event of a source water emergency or event such as loss of use of a key facility or sudden change in water quality[12]. This concept could also be extended to the Boulder Reservoir WTF.

6.1.3 | MAINTENANCE AND STAFFING

Operation and maintenance needs were gathered through staff survey responses as well as direct information from city staff[13]. The overall response from the survey was that operation and maintenance have been steadily improving over the last 10 years, but that the city is lacking staff, training and tools to be able to follow a maintenance plan in a systematic manner.

6.1.3.1 | MAINTENANCE

Survey respondents suggested that the water utility is moving from a reactive mode to a proactive maintenance mode gradually as facilities have been updated, and fewer demands are placed on staff for keeping up with the maintenance backlog from old facilities. However, the following maintenance issues were listed:

- There are "stranded facilities" such as air relief vaults and the raw water fire suppression systems for which maintenance responsibility is unclear;
- Most facilities are informally inspected, but formal documentation is not always completed;
- Maintenance staff with daily interaction with facilities know what problems are developing, but information is not always conveyed to management personnel so adequate budgets can be developed for fixing the problems;
- Not all of the knowledge of watershed facilities and operations is written down because the same staff members have been managing the facilities for many years. Training of transition employees often occurs on the job, sometimes after the previous holder of a position has retired or accepted a new position. Lack of documentation of operations could leave the city in a vulnerable position if the transition from older to existing younger staff members does not occur as expected, and;
- A formal raw water pipeline inspection program is needed.

6.1.3.2 | STANDARD OPERATING PROCEDURES

The city does not have written standard operating procedures and maintenance schedules for all raw water system facilities. Written standard operating procedures have been completed for the raw water transmission pipelines and associated facilities, but should be regularly reviewed and updated. Maintenance staff for the city distribution and sewer systems has developed a maintenance tracking database that could be adapted to the raw water supply system.

6.1.3.3 | STAFF AND TRAINING

Although the staff survey focused on the raw water supply system, the potential needs for additional staff were identified in the following areas

- Another water resources specialist and/or project manager should be considered to accommodate increased water accounting needs, on-going maintenance, climate change and modeling needs and increased public interest in water supplies;
- Utilities staff identified a need for administrative support in the areas of document production and basic project support;
- Another full-time employee may be needed for the water conservation program;
- A staff member able to focus on day-to-day needs of water utility GIS analysis and mapping is needed, and;
- Water system security may warrant a part- or full-time employee who can focus solely on this important issue.

An additional need that was subsequently identified through the AWWA QualServe Utilities Peer Review that was conducted for the city in October 2008 was additional staffing to inspect and maintain high pressure transmission pipelines and right-of-ways[14]. Transmission pipelines have two categories--raw water and treated water. Raw water pipeline right-of-ways are regularly inspected, at least annually. Treated water transmission line inspection and maintenance is not assigned to any one work group, so attention to these pipelines varies and is done on an "as needed" basis by Water Treatment, Hydro, Utilities Maintenance or Project Management. A more organized and frequent inspection program of treated water transmission pipelines and more inspections of valves on the raw water pipelines could delay the need to replace a transmission pipeline by twenty or more years with the resultant savings in interest costs possibly reaching hundreds of thousands to millions of dollars.

Despite the city's efforts to track industry-wide salaries and pay employees in the 75th percentile, staff perception is that maintenance staff is under-paid and under-trained. The more technical equipment and computer systems that are continually being added to the system require experienced and well-trained technical staff.

6.1.4 | SECURITY, REMOTE OPERATION, AND MONITORING

Not all of the source water facilities have remote operation and monitoring capabilities. There are communication needs, including fiber optic back-up for Betasso WTF to hydros and reservoirs, to increase reliable operations and security.

The 2008 Security & Vulnerability Report documents security and monitoring issues with the source water system, which are not described in this report for security reasons. Since 2001, the Federal Energy Regulatory Commission, which has jurisdiction over the city's hydroelectric facilities, has increased security planning requirements for hydroelectric projects[15].

6.2 | Water Rights Yield Issues

6.2.1 | RELIABILITY CRITERIA

The current reliability criteria used to evaluate the adequacy of the city's raw water supplies were established in 1989 through the RWMP as discussed in section 5.1.1.4 of the SWMP. The reliability criteria set goals for water system performance that establish acceptable levels of water service and influence the amount of water available for non-municipal purposes such as instream flows. These criteria were somewhat theoretical at the time they were adopted and represented a general estimation of what might be acceptable occurrence intervals for various levels of water use restrictions. Since that time, more detailed information has been developed about what the reliability criteria might mean in terms of the specifics of operating Boulder's water supply system both through the 2003 Drought Plan (see section 5.1.1.5) and recent climate studies (see section 5.2.6).

One criticism of the reliability criteria is that they do not specifically define what is meant by providing sufficient water to meet all municipal demands in almost all years. Further definition and clarification of the reliability criteria can be done in the future, incorporating the influence on water use following the recent implementation of the city's water budget rate structure which details appropriate levels of indoor and outdoor water use for each water account. Chapter 7 includes a recommendation concerning further refinement of the reliability criteria.

6.2.2 | FACTORS THAT COULD AFFECT WATER RIGHTS YIELD

6.2.2.1 | CLIMATE CHANGE

The complexity of factors affecting water rights yields and the highly-interactive nature of the Colorado water rights administration system can make it difficult to predict the impact of changes in temperature or precipitation patterns on the yield of a particular water right or portfolio of water rights. A change in the timing or amount of available streamflow due to climate change will alter which water rights are satisfied and to what degree. Therefore, even if the average annual precipitation amount remains the same in the future, a change in the pattern of streamflows will cause a re-distribution of water supplies. Some water rights decrees, such as older water rights used for the originally decreed-purposes, will allow water users to shift diversion practices with changing climatic conditions, while other decrees, such as water rights that have been changed in use and given a fixed yearly start date for diversions, could see water yields shrink. Climate change is likely to create water rights winners and losers, and poses the question of whether and to what degree water re-allocation will occur within the existing Colorado system.

The current state of knowledge regarding climate modeling and expected effects on the city's watersheds is developing, but is not yet sufficient for use as a base for determining the advisability of any significant capital investments that might solely address climate change. Global circulation models (GCMs) have relatively large grid sizes that make detailed, local predictions uncertain. Carbon dioxide emissions scenarios also vary greatly. Just as many of the GCMs predict an increase in future average annual precipitation for the local watersheds as predict a decrease. With such uncertainty, the city may wish to direct capital funds toward more pressing needs that have more certain outcomes. At the present time, it appears to be premature to make extensive capital expenditures to mitigate potential climate change effects of unknown magnitude or direction. The National Resources Defense Council has recommended that, whenever possible, flexibility (as discussed in section 6.1.1 above) is the desirable management strategy for current efforts to address climate change due to the uncertainty regarding how quickly and extensively climate change effects will manifest and whether variables such as precipitation will increase or decrease. The Council notes that locking in large, long-term capital investments under these conditions of uncertainty is a risky strategy[16].

Some climate-driven changes that seem to be very probable are an increase in local average temperatures and the occurrence of earlier runoff in the mountain watersheds that supply Boulder's water. A shift to earlier runoff and lower late summer streamflow will put pressure on the city's reservoir operations by creating a need for use of more reservoir storage space for seasonal flow regulation. Higher temperatures may result in a higher rate of evaporation from reservoir surfaces.

6.2.2.2 | STATEWIDE AND LOCAL WATER RIGHTS ISSUES

The heavily over-appropriated South Platte River basin continues to experience population growth and associated increased demands for water. Municipal water providers along the Front Range are using strategies to meet new water demands including acquiring irrigation rights for municipal use, reusing return flows via exchange and direct reuse, developing alluvial and non-tributary groundwater and developing additional storage capacity. Likewise, farmers who do not own senior water rights are continuing to rely heavily on alluvial wells and augmentation plans for their supply. Most of these strategies, including those involving changes of water rights, plans for augmentation for wells and new exchange appropriations, require water court approval. The State Engineer's Office is under continual pressure to administer water rights for "maximum utilization" of water supplies while maintaining adherence to Colorado's prior appropriation system. It is the responsibility of owners of existing water rights to monitor and protect the yields of their water rights through active participation in water court proceedings and involvement in legislation and development of rules and regulations by the State Engineer. Boulder has taken an active role in acquiring water supplies and in protecting and monitoring its water rights throughout its history. Although this high degree of past planning has placed Boulder in the position of likely owning sufficient water rights to meet its build-out needs, this condition can only be maintained if the expected yields of the city's water rights can be protected against deterioration due to insufficient administration of more junior water rights or changes to senior water rights of others that deviate from historic water use patterns. Boulder's efforts to protect its water rights yields have at times been unpopular with other water users, but it would likely be even more unpopular if Boulder were forced to acquire additional water rights from agricultural users to replace yield lost from the city's current water rights portfolio. Some CSG members noted that balancing relationships with other water users and maintenance of an adequate water supply by protecting the city's water rights is an area where Boulder has an opportunity to modify its approach in the future in order to improve public relations, but other CSG members believed protecting the city's water yields for future generations outweighed any temporary discomforts due to negative press.

6.2.2.3 | WATER RIGHTS FILINGS AND ACQUISITIONS

Keeping abreast of advances in climate change science and refined modeling of likely effects on Boulder's water supplies will be needed to identify when or if the city will need new water supplies. In the interim, the city will continue to acquire shares in local ditch companies that are of utility to the current water system as they become available. It is not advisable to acquire new water rights at this time solely to address concerns regarding climate change because, as noted in section 6.2.2.1 above, making capital investments under the conditions of uncertainty surrounding the current level of knowledge of climate outcomes is a risky strategy

The city's acquisition of shares in the Silver Lake Ditch Company has often caused concern. The city purchased Silver Lake and Island Lake Reservoirs from the Silver Lake Ditch Company in 1906 with the intention that the city's obligation to deliver water out of municipal reservoirs to the Silver Lake Ditch Company would be reduced over time and the water would eventually become available to the city for use in its municipal water system. Varying interpretations of the series of agreements concerning Silver Lake Ditch have occasionally caused disagreements between the city and the Silver Lake Ditch Company in the past and led to a need to clarify these agreements. The city is currently negotiating a new agreement with the Silver Lake Ditch Company concerning the city's acquisition of ditch rights which could resolve some issues related to the previous city/Silver Lake Ditch Company agreements.

New water rights may be needed if existing facilities are modified or to increase the ease of water portfolio management. For example, if Albion Lake is enlarged, the city will need to determine if its existing exchange rights are sufficient to fill the new storage capacity or if a new water right will be needed.

6.2.2.4 | CONDITIONAL WATER RIGHTS

Some of the city's water rights are conditional, pending proof that the city has diverted or stored water under the conditional water rights and placed that water to the decreed beneficial use. In order to convert conditional rights to absolute rights, the city must exercise the conditional rights according to their specific decrees and be able to provide evidence of such use through water accounting records. Prior to actually using the water for beneficial use, the city must continue to actively pursue perfecting the rights. The city should continue to develop and plan for the use of its conditional water rights within its system and, when hydrological and decree conditions permit, should exercise the conditional water rights so that they may be made absolute as soon as practical.

6.2.3 | YIELD ISSUES RESULTING FROM FACILITIES LIMITATIONS

6.2.3.1 | GREEN LAKE NO. 2 OPERATING RESTRICTIONS

Operation of Green Lake No. 2 was reduced in 1986 as a preventive measure because of dam structure problems. The temporary reduction in availability of 140 acre-feet of storage capacity has resulted in a reduction in yield of a particularly high quality and gravity-supplied portion of Boulder's water supply system. Restoring this facility would increase the utility of the city's Windy Gap water and allow the city to increase the yield from its exchange rights. Removal of operating restrictions would increase system flexibility and increase the reliability of source waters which feed Betasso WTF. Modeling is needed to determine how much yield would increase if Green Lake No. 2 were restored to full operation.

6.2.3.2 | FARMERS DITCH CAPACITY LIMITATIONS

The city has made limited use of its available Farmers Ditch water since 1993 because of capacity limitations in the ditch.

Boulder has diverted water for municipal use under the conveyed Farmers right in 12 of the 14 years since the 90CW193 decree[17] was entered, averaging 178 acre-feet per year. The instream flow use of the right has averaged 312 acre-feet per year during that same period[18]. In comparison, the historical use of the right averaged 1,982 acre feet per year.

The results of an analysis by AMEC Earth and Environmental, Inc. (AMEC), the city's water resources consultant, indicate that restoration of the capacity of the Farmers Ditch would result in an average additional yield to Boulder of approximately 988 acre-feet per year. This additional yield would be very reliable in all but extreme drought years like 2002, given the October 1, 1862 priority of the ditch.

6.2.3.3 | SKYSCRAPER RESERVOIR OPERATING RESTRICTIONS

Skyscraper Reservoir has a storage capacity of 146 acre-feet. Skyscraper Reservoir is not currently operated by the city because the outlet works are inoperable. Valve repairs are needed for the city to integrate this water supply into the city's source water system. Removal of operating restrictions would increase system flexibility and increase the reliability of source waters which feed Betasso WTF. Modeling is needed to determine how much system yield would increase if Skyscraper Reservoir were fully operational.

6.2.3.4 | YIELD FROM REUSABLE WATER EXCHANGES

The city can increase its overall water system yield by making use of its fully consumable water supplies. Although Boulder does not own many water rights that allow the associated water to be used by the city more than once, there are some supplies that can be reused following discharge of the water from the 75th Street WWTF. This fully-consumable portion of the city's water supplies can be exchanged from the WWTF outfall directly to the city's upper water system intakes or storage reservoirs. However, the reusable effluent may not be available at the same time that exchange potential exists. Lining of Wittemyer Ponds would provide a place downstream of the WWTF outfall for the reusable water to be stored until exchange potential exists for exchanging the water to the city's upper basin facilities. A lined Wittemyer Ponds complex is therefore essential to fully realizing the yield of the city's available water supplies.

6.2.3.5 | FIRMING OF WINDY GAP WATER

The Windy Gap water right is relatively junior and does not yield anything in dry years. During wet years when water is available for pumping at Windy Gap Reservoir on the Colorado River, Lake Granby is often full of CBT water with little or no capacity for Windy Gap water.

When Boulder purchased the Barker Reservoir system in 2001, it acquired additional reservoir storage space that, if empty, could be filled through exchange of Windy Gap water in the moderately dry years when the city's junior Barker Reservoir rights are not yielding, and there is Windy Gap water available.

Current staff thinking is that the city should retain ownership in 37 WG units rather than sell them until modeling demonstrates fit in the system and yield with and without construction of firming storage and more is known about climate change effects on Boulder water supply.

6.2.3.6 | LIMITS ON EXCHANGE POTENTIAL

The city's use of its exchange rights is currently limited by senior water rights calls above 75th Street, which is generally the location at which the city can make exchangeable water supplies available. While CBT and Windy Gap water may be released from Boulder Reservoir to satisfy senior water rights calls below 75th Street, the only way to satisfy calls between the mouth of Boulder Canyon and 75th Street is to release water from the city's Boulder Creek basin storage. A means to pump water from Boulder Reservoir to the mouth of Boulder Canyon such as a pipeline would remove that current limitation on the city's ability to utilize the exchange mechanism. Such a system could become very valuable if there is significant loss of upper system yield in the future due to climate change, wildfire, or other factors. However, it is presently premature to make such a significant capital investment based on the current level of knowledge regarding climate change effects on the city's water supplies.

6.2.4 | RELIANCE ON WEST SLOPE WATER SUPPLIES

In the event of severe and extended drought conditions in the Colorado River Basin, the Colorado River Compact might require the upper basin states to restrict water use. At this time, there is a great deal of uncertainty regarding what could occur in terms of compact calls. To date the city's modeling has assumed that the city's ability to obtain its allotments of west slope water will not change drastically in the future.

It is possible that changes in administration of the Colorado River Compact in response to climate change effects on the west slope of Colorado and on the overall Colorado River basin could significantly reduce the reliability of Boulder's west slope water. Boulder's climate change analysis did not address this issue because of funding limitations and because the Colorado Water Conservation Board is conducting a basin-wide analysis of this issue. Boulder's water consultants (AMEC) are part of the consultant team that is doing this study and will be able to keep Boulder apprised of the progress and results of the state's study. Should future action be required, it will not be a problem affecting Boulder alone and the means to address the problem will likely be best undertaken by the state or by large groups of water users with similar interests, such as CBT water users working through NCWCD. This approach would insulate Boulder from the potential of being singled-out in the face of a significant impact on CBT yields with rules changes that negated the benefit of acquisitions or actions that Boulder made acting on its own. One action that could be taken by NCWCD or the state in the event of a compact call is to purchase the right to interrupt some of the approximately 1,000,000 acre-feet of water rights on the western slope that are senior to the Colorado River Compact and that are used for low-value agricultural purposes. The interrupted water supplies could allow continued diversions by the CBT Project through an extended drought.

6.3 | Water Use Issues

6.3.1 | MUNICIPAL WATER DEMAND PROJECTIONS

The city's most recent water demand projections do not capture the recent updates to the demographic projections in the Boulder Valley Comprehensive Plan. The current annual demand projection at build-out is 28,600 acre-feet. Updated projections would probably be lower. Updating the demand projections and additional modeling may identify additional areas in which the city could increase the flexibility of its source water system.

6.3.2 | WATER CONSERVATION

Reducing water demand through water conservation efforts improves the city's ability to fill reservoirs in the spring reservoir fill season and slows the decline during the city's reservoir release season from about August until May. Therefore, water conservation efforts at most times of the year can improve the city's ability to weather droughts by maintaining storage reserves. However, in any given year, once the city's storage reservoirs are full and the city is meeting the entirety of its water needs through direct diversion of water from the stream, reductions in water demand from water conservation efforts have no benefit for sustainability of the city's raw water supply. Savings from water conservation during the direct flow period reduce the amount the city diverts, but the city cannot store the savings for later use or assign the saved water to another use. Streamflow below the city's intakes would increase until the water reached the next headgate of an in-priority water rights owner able to make use of the water.

CSG members raised the question of why the city conserves water in non-drought situations. There was some concern that current conservation efforts could be used to support future growth by making it appear that the city's water demand to water supply ratio was low enough to allow additional water taps. A broad evaluation of reasons to conserve water is needed to understand the benefits and disadvantages of water conservation efforts when they are not needed due to supply limitations. While water conservation produces savings in terms of treatment and distribution costs, its effects may not be entirely beneficial. Reducing irrigation when it is not necessary in order to conserve stored supplies (when the city is meeting its water needs through its direct flow rights), for example, may reduce aquifer recharge and negatively affect streamflows in Boulder Creek that are dependent on these return flows. When Boulder's direct flow rights are insufficient to fully supply the city's immediate needs, conservation lessens the amount of water the city has to draw from storage and preserves carry-over storage. A thorough understanding of when it is good to conserve and when it either does not matter or it negates assumed benefits is needed. One aspect that could be evaluated is the potential benefit of encouraging irrigation use during the direct flow season (typically late May and June) so that the alluvial aquifers under the city are filled and capable of enhancing Boulder Creek streamflows during low flow periods later in the summer and throughout the winter. Increasing streamflow at these times could not only improve riparian habitat, but could reduce the seniority of the water rights call on the river and possibly enhance the yield of the city's water rights that might otherwise be called out due to low river flows.

There is a need to quantify current conservation efforts to determine how close the city is to achieving the goals of the current water conservation plan and to determine if there is potential for additional conservation. If Boulder can consistently demonstrate that more water is conserved than is already built into the system reliability modeling based on the current water conservation goals, it may be possible to increase the water savings goal and commit that water to other uses. How firm a commitment to make to other uses would depend upon an assessment of the reliability of the city's system.

6.3.3 | NON-MUNICIPAL AND NON-POTABLE USES

In some years, the city's water supplies exceed the current municipal demand, and the city places water in storage for protection against future droughts. In these years, after present and future municipal water supply needs are met to the extent possible, there are opportunities to use the city's excess municipal water supply for other purposes when allowed under water rights decrees. In these cases, there may be multiple potential beneficial uses of the water, which can be fulfilled at the same time or which can be met sequentially with the same water supplies. For instance, water that is used for instream flow under the city/CWCB contracts can be used downstream of the instream flow reach for agricultural irrigation. Also, water delivered for municipal needs from the city's Boulder Creek supplies can generate hydropower during delivery. In other cases, alternative non-municipal water needs can only be fulfilled to a higher degree by reducing the amount of water used for another purpose; for example, providing discretionary instream flow water for Boulder Creek decreases hydropower generation.

The BVCP has a provision suggesting that the city consider other water use objectives when meeting utilities needs:

> The city will consider the importance of other objectives of the comprehensive plan in the planning and operation of water, wastewater, stormwater and flood management utilities. These other objectives include instream flow maintenance, enhancement of recreational opportunities, water quality management, preservation of natural ecosystems, open space and irrigated agricultural land, and implementation of desired timing and location of growth patterns[19].

The city currently supports non-municipal uses of water based on formal policy direction from City Council regarding water uses of value to the city. Policy direction has been provided multiple times in different forms such as following the completion of the RWMP in 1989, approval of the city/CWCB instream flow agreements in 1990 and 1992, and completion of the Drought Plan in 2003. Operational decisions on non-municipal uses of water are based on determinations of the most effective or practical use of any excess municipal water that may be available at any given time.

6.3.3.1 | INSTREAM FLOW PROTECTION

The current status of instream flows is described in detail in Chapter 5. The majority of stream reaches in the Boulder Creek basin affected by the city's municipal water supply activities have been protected by efforts of the city and the CWCB.

North Boulder Creek and Main Boulder Creek

On North Boulder Creek and main Boulder Creek, a combination of natural flow levels, calls by senior agricultural water rights, the CWCB's senior G. Berkley water right and city water and water right donations have successfully maintained a wet stream for the entire year since 1993. However, fisheries studies have not been conducted since that time to quantify the improvements in fisheries habitat and the effectiveness of the current instream flow program. In addition, stream reaches such as North Boulder Creek at the Caribou Ponds diversions on Caribou Ranch may require more careful monitoring to assure that dedicated instream flow water is not diverted out of the stream.

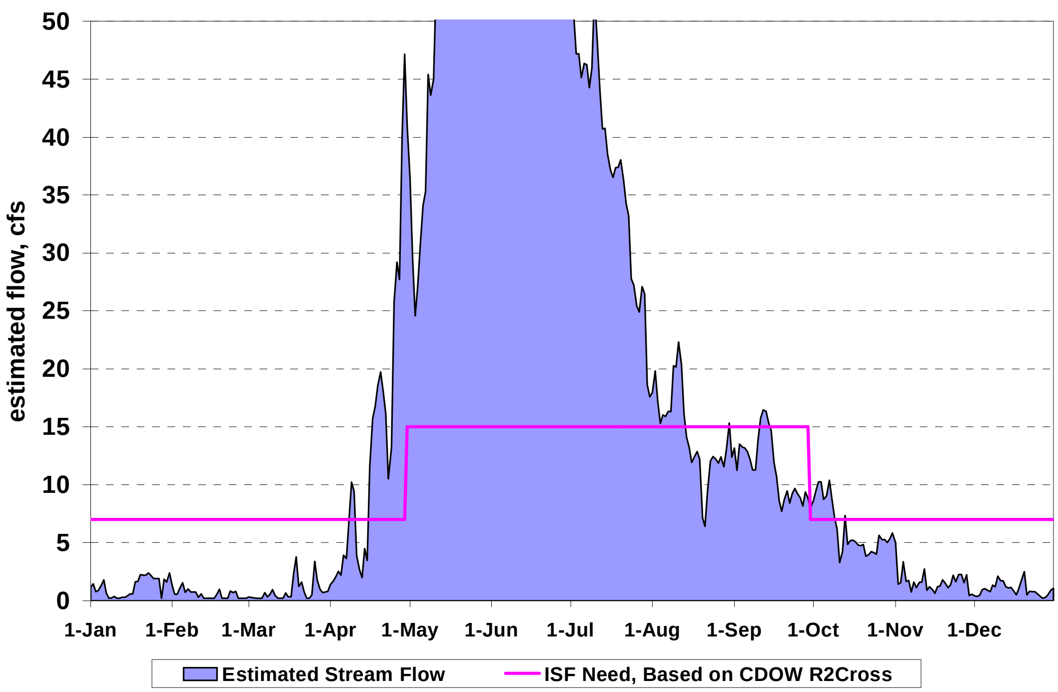
Middle Boulder Creek

On Middle Boulder Creek, since 2001, the city has released water from Barker Reservoir to assure a minimum flow of three cfs below Barker Dam to address instream flow needs as determined by habitat studies, but this is not done through a formal instream flow program and the released water is not protected from diversion by other water users. Flows below Barker Dam exceed three cfs during much of the year due to calls from senior water rights that require much or all of the streamflow entering the reservoir to be passed.

South Boulder Creek

The South Boulder Creek watershed and its ecosystem are important to residents of the city. CSG members and city staff expressed concern about the lack of an active program on South Boulder Creek to supplement the decreed CWCB junior instream flow rights. Estimated mean daily flow in South Boulder Creek at U.S. Highway 36 from 2001 to 2004 indicates that from November to mid-April, there are flow deficits in South Boulder Creek between Gross Reservoir and South Boulder Road (Figure 6-4). According to data provided by the Colorado Division of Wildlife, the desirable level of water between Gross Reservoir and South Boulder Road during from November to mid-April is 7 cfs[20].

FIGURE 6-4. SOUTH BOULDER CREEK MEAN DAILY FLOWS COMPARED TO INSTREAM FLOW NEED[21]



As discussed in Chapter 5, although an environmental pool in Gross Reservoir with 2,500 acre-feet of water storage capacity has been set aside by Denver Water to provide winter instream flows, water rights have yet to be identified to be stored in this pool and operational experience has shown that the limited seasonable availability of the pool is problematic. The major storage reservoirs on South Boulder Creek that are needed to supply a winter instream flow are not operated by the city of Boulder. Coordination with other South Boulder Creek water users (Denver Water, Farmers Reservoir and Irrigation Company, Base Line Reservoir Company, Xcel Energy, and the cities of Lafayette and Louisville) will be required to create a successful instream flow program.

Any efforts by the city to address instream flow concerns in South Boulder Creek must recognize that it is difficult to use water utility assets and staff to address this creek's instream flow issues without jeopardizing the water utility's enterprise fund status. Therefore, city of Boulder Open Space and Mountain Parks (OSMP) Department staff has generally taken the lead. OSMP manages a great deal of land owned by the city in the South Boulder Creek basin.

6.3.3.2 | HYDROPOWER

The city currently operates its hydropower facilities along with its municipal diversions and water deliveries and does not make substantial excess diversions for the purpose of generating hydropower alone. However, it has the potential to do so now at the Silver Lake Hydroelectric Plant and will have the ability to do so at the Lakewood and Betasso Hydro plants once the Betasso Area Pipelines Project is completed.

Although the Betasso Area Pipelines Project will make such operation possible, it is not presently considered to be part of the project since the Water Resources Advisory Board (WRAB) has requested that additional evaluation of the economics and possible environmental effects be completed first. Based on similar reasoning, staff has not made such diversions through the Silver Lake Hydro Plant.

The power purchase contract between the city and Xcel that includes Lakewood Hydro contains provisions for payment to the city for every kilowatt hour of energy that is generated. Additional generation at Lakewood Hydro, Betasso Hydro and Silver Lake Hydro from run-of-the-river operations would increase generation payments. Updated aquatic habitat studies are included under recommendations in Chapter 7. Based on previous findings concerning aquatic habitat, it is likely that such studies will demonstrate that the city could use additional diversions to generate more hydro revenue and offset water rates without adverse environmental effects. Until such studies are completed, potential revenue is likely being lost.

Locations exist both on the raw water system and on the treated water system with potential for new hydroelectric generation facilities. These opportunities include the base of Barker Dam (Hannah Barker Hydro), the Betasso discharge pipeline (Tram Hill Hydro), and the PRV station at 101 Pearl Street. These hydropower generation opportunities could become economically feasible depending on future power sales markets. The CSG suggested that longer payback periods for hydroelectric investment should be considered as long as a project pays for itself during its useful life.

6.3.3.3 | WATER LEASES FOR AGRICULTURAL AND OTHER USES

The city's current leasing program is discussed in section 3.5.7. When water is available, the city leases water to various individuals and ditch companies north and east of Boulder for irrigation on an annual basis. The city's leasing policy has been to meet the needs of water users diverting from Boulder Creek first, then to lease any additional water to other users. In most years, there is not enough water to meet the demands of all agricultural irrigators, and there is rarely any leasable water remaining after meeting the needs of Boulder Creek water users. Although South Platte Basin irrigators have expressed an interest in leasing water from any available lessor in recent years, their needs are great. If Boulder were to make water available for South Platte basin agricultural users, it would lessen the lease water available for local farmers.

6.3.3.4 | WETLANDS

The maintenance of municipally-owned ponds and wetlands could potentially be improved by the city in terms of physically improving water supply and using water rights for this purpose. If enterprise fund limitations are respected, then the city could lease surplus potable water to fulfill needs identified at Thunderbird Lake, or to provide temporary lease of water to OSMP for Arapahoe Pit D.

6.3.3.5 | RAW WATER IRRIGATION

Raw water irrigation at parks or city facilities could potentially be enhanced by the use of water and water rights not needed for municipal use.

6.4 | Watershed Management Issues

The city owns over 7,000 acres of land that are managed through the water utility as part of the raw water system. In addition, the water utility manages easements and other forms of interest in land. Most, but not all, of these lands are in the city's source watersheds. As a land and water manager, the city water utility conducts various watershed management activities and coordinates extensively with other city and county departments as well as outside organizations in the planning and execution of these activities. The primary focus of the water utility's land management efforts is to assure a safe and reliable water supply. Activities are first focused on operation and protection of water supply facilities. In terms of source water, watershed management activities are geared toward protecting the quality of the city's waters for drinking water safety, assuring sufficient water supply and keeping the costs of water treatment low. These activities inherently enhance the environment, even though the water utility seeks to minimize the impact of its operations on the environment.

6.4.1 | LAND USE AGREEMENT AND EASEMENT MANAGEMENT ISSUES

6.4.1.1 | BARKER GRAVITY LINE EASEMENTS

Barker Gravity Pipeline occupies approximately 34.96 acres of National Forest land administered by the Roosevelt National Forest (USFS)[22]. Historic occupation of federal land was authorized under the Federal Power Act license for the Boulder Canyon Hydroelectric Project. If the Boulder Canyon license is replaced with a conduit exemption, the Barker Gravity Pipeline will no longer be under FERC jurisdiction, and a separate authorization for use of National Forest land will be required. In October 2008, the city submitted an Application for Transportation and Utility Systems and Facilities on Federal Lands to the USFS for Barker Gravity Pipeline[23]. USFS anticipates issuing an easement for the Barker Gravity Pipeline after review and analysis of the proposal.

Barker Gravity Pipeline is operated in accordance with a USFS-approved Operating Plan which describes the frequencies of various maintenance activities and associated disturbance as well as notification requirements[24].

The city has an easement agreement with Boulder County for portions of the Barker Gravity Pipeline that cross Boulder County Parks and Open Space property[25]. This agreement has very few restrictions on pipeline operation and maintenance or on access to the pipeline at any point across the property as is reasonably necessary.

6.4.1.2 | BARKER GRAVITY LINE LAND EXCHANGE

Ideally, it would be preferable in terms of future Barker Gravity Pipeline operation and maintenance if the pipeline did not occupy federal land. The city has informally discussed the potential for a land exchange with the USFS through which the city would acquire the Barker Gravity Pipeline easement in exchange for other property which the USFS finds more consistent with forest administration policies and management goals. The Barker Gravity Pipeline area is a complex mix of discontinuous federal, city, county and private lands which creates a difficult management situation for the USFS. If the pipeline easement could be exchanged for property that is contiguous with a larger tract of federal land, both the city and the USFS would benefit.

Land exchanges are a low priority for the USFS, and timing of such a transaction cannot be predicted. The city will continue to work with USFS concerning a proposed land exchange.

6.4.1.3 | SKYSCRAPER RESERVOIR SPECIAL USE PERMIT

The city has a Special Use Permit from the USFS for Skyscraper Reservoir[26]. This permit has no expiration date. It is not currently known if the USFS will attempt to modify the permit term in the future.

6.4.1.4 | CARIBOU RANCH EASEMENT

The city's Caribou Ranch easement agreement with Boulder County contains provisions intended to protect the water quality of North Boulder Creek[ii]. The city needs to continue coordination with the county to ensure these provisions are respected.

6.4.1.5 | WITTEMYER PONDS AGREEMENT WITH BOULDER COUNTY

Boulder County has a conservation easement on the Wittemyer Ponds property[27]. The city monitors to ensure the county is managing the conservation easement correctly and that the county's lessee is using the water rights appropriately.

Modification of Wittemyer Ponds would have to go through some form of land use review by Boulder County. The city's agreement with Boulder County contains provisions for county review and acceptance of any city proposal to line Wittemyer Ponds. Boulder County can lose its conservation easement if approval for lining the ponds is denied.

6.4.1.6 | LAKEWOOD PIPELINE EASEMENT

On May 12, 2004, the U.S. Forest Service (USFS) issued a Notice of Noncompliance for the Lakewood Pipeline easement[28]. The letter states that "…the pipeline, as constructed, does not comply with the requirements of the Easement and related documents because it does not meet the original contract specifications and construction plans as accepted by the Forest Service…"[29]. The USFS desires to terminate the existing easement and replace it with a new one which would require the city to carry additional liability insurance and include provisions for suspension of the easement under certain circumstances. The USFS easement for Lakewood Pipeline is tentatively scheduled for council action in early 2009.

In July 2008, staff presented proposed new easement language to the Water Resources Advisory Board[30]. Staff recommended terminating the existing easement and entering into the currently proposed easement agreement. In reaching its recommendation, staff considered: 1) clarification of USFS intent concerning suspension in the currently proposed easement; 2) preservation of the city's ability to later argue that it retains its historic Act of July 26, 1866 rights; 3) an assessment that additional insurance requirements would not be burdensome and would have some independent merit and; 4) the value to the city of maintaining a constructive relationship with the USFS. WRAB voted 3-2 to recommend that City Council accept the 2008 Easement Agreement and include specific language concerning suspension of the easement and preservation of the city's 1866 Act rights in the approval.

[ii] The appendices contain a complete list of documents associated with the Caribou Ranch property transaction.

Lakewood Pipeline is operated in accordance with a USFS-approved Operating Plan which describes the frequencies of various maintenance activities and associated disturbance as well as notification requirements. The plan is subject to USFS review and modification every five years[31].

6.4.2 | CONTAMINATION SOURCES

The city monitors potential sources of contamination in its source water watersheds to protect water quality where possible. This section describes potential contamination sources that have been identified in each of the city's three source water watersheds.

6.4.2.1 | NORTH BOULDER CREEK

Figure 6-5 shows locations of potential sources of contamination to the North Boulder Creek water supply, which were identified through the state directed Source Water Assessment and Protection Program in 2003[32]. In general, the North Boulder Creek basin has few contamination sources and is a low-risk water supply. This low-risk status is primarily due to the Silver Lake Watershed being closed to public use. Other than the Silver Lake Watershed, development and land use activities are limited by wilderness, forest land, open space and conservation easement designations.

The primary area of concern in the North Boulder Creek watershed is the part of Caribou Ranch above Lakewood Reservoir that is privately owned and slated for residential development. The amount of development that can occur was limited through the Caribou 2 agreement among Caribou Ranch owner, James Guercio, the city and Boulder County[iii]. If this development does occur, it will need to be planned and maintained to minimize the threat to the city's water quality. In the event of contamination at Lakewood Reservoir, the reservoir volume is small and does not provide for substantial dilution of contaminants.

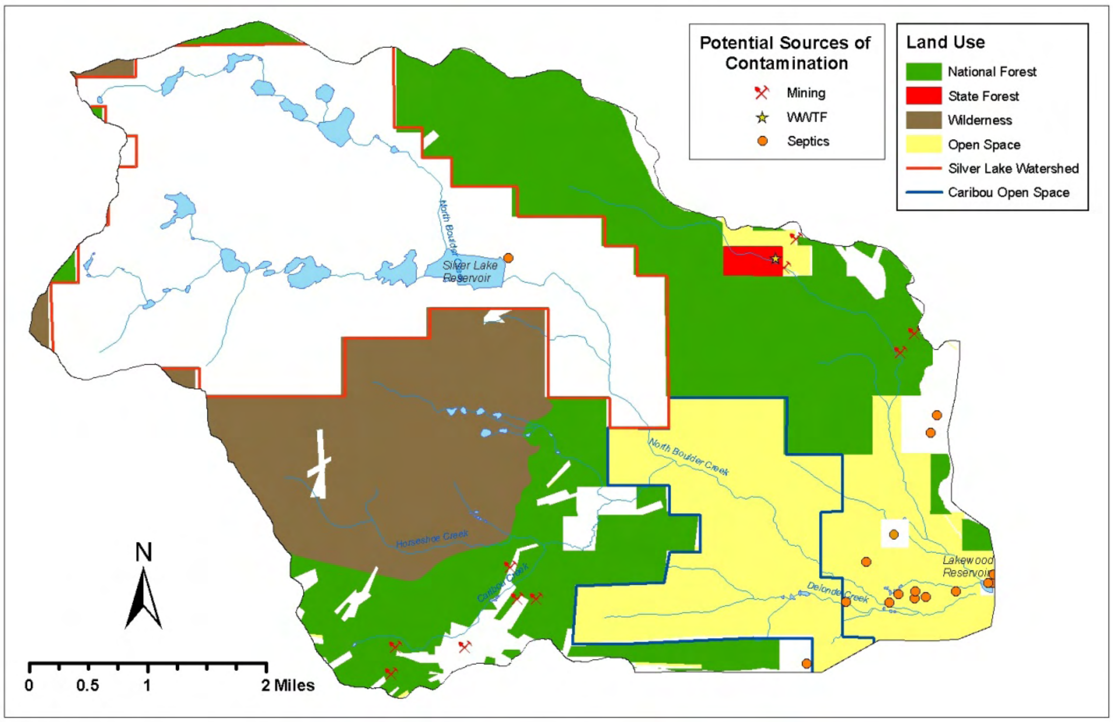
Currently, no water quality problems from existing septic systems and abandoned mine sites have been identified in North Boulder Creek. The area with existing septic tanks is in the part of Caribou Ranch that remained in private ownership by James Guercio following the purchase of most of the ranch by the city and Boulder County. The city has a conservation easement over most of the property that gives the city the right to influence management of the property for water quality protection. Boulder County manages both the city-owned and the county-owned Caribou Ranch Open Space using a management plan that considers water quality protection[33]. Access through open space is "on-trail" only, trails are located away from riparian zones and the areas are seasonally closed to protect wildlife.

[iii] The series of agreements that accompanied the Caribou Ranch purchases can be found in the appendices.

Water quality concerns in the North Boulder Creek watershed include the following:

- the use of pesticides and herbicides by Boulder County on open space land;
- effects of Caribou Ranch ponds and diversions on water quality;
- pathogen loading from Caribou Ranch livestock, and;
- effects of future development, such as the proposed Caribou City, above Lakewood Reservoir.

FIGURE 6-5. NORTH BOULDER CREEK SOURCES OF CONTAMINATION

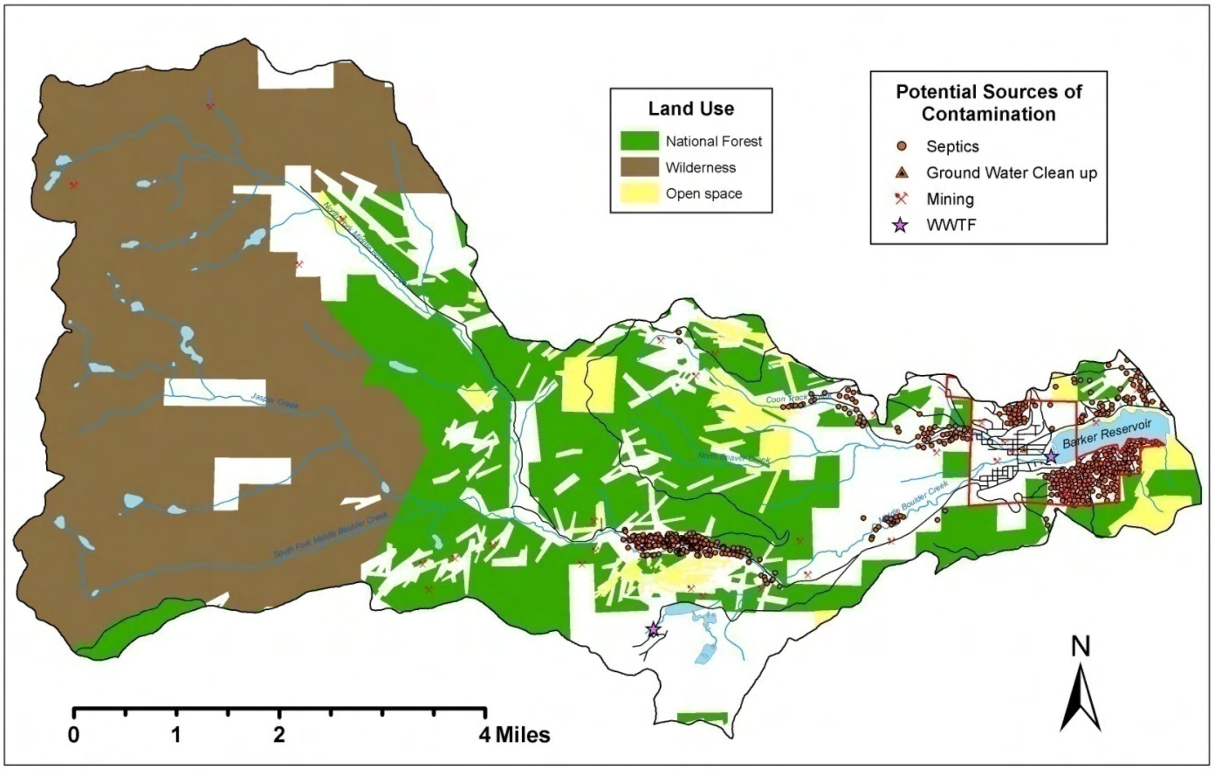


Notes: Data for this map comes from the city of Boulder's internal SWAP assessment (2002). Septic data was derived from AIRPHOTO.AIRPHOTO_image_index_for_2000 on the city's sde server. City water quality staff assumed that all residential houses have a septic system. Mining and ground water cleanup data came from EPA region 8. Further metadata for this map can be found in Brown and Caldwell and CDM Camp Dresser and McKee, Inc. (1997). *Boulder Creek watershed study: Phase 1 dated November 1997*. Denver, CO, 8-17. The original SWMP assessment maps are located at S:/pw/63rd/arcmap/arcmapprojects.

6.4.2.2 | MIDDLE BOULDER CREEK

Potential sources of contamination in the Middle Boulder Creek watershed are shown in Figure 6-6. Middle Boulder Creek watershed has few contamination sources due to land use restrictions associated with National Forest and wilderness areas that comprise most of the watershed.

FIGURE 6-6. MIDDLE BOULDER CREEK SOURCES OF CONTAMINATION



Notes: Data for this map comes from the city of Boulder's internal SWAP assesssment (2002). Septic data was derived from AIRPHOTO.AIRPHOTO_image_index_for_2000 on the city's sde server. City water quality staff assumed that all residential houses have a septic system. Mining and ground water cleanup data came from EPA region 8. Further metadata for this map can be found in Brown and Caldwell and CDM Camp Dresser and McKee, Inc. (1997). Boulder Creek watershed study: Phase 1 dated November 1997. Denver, CO, 8-17. The original SWMP assessment maps are located at S:/pw/63rd/arcmap/arcmapprojects.

Community members in Nederland regularly express interest in non-motorized boating on Barker Reservoir. Boulder Revised Code section 8-3-17 prohibits boating and swimming on all water bodies controlled by the city, with the exception of Boulder Reservoir[34]. Additionally, the Boating Feasibility Study[35] found that the additional contaminants from boating on Barker Reservoir would hasten upgrades to advanced water treatment at Betasso WTF from 20 years to five years. The study determined that a boating program would not generate revenue, but rather would require an outside funding source. Finally, the study identified security and safety concerns.

Concerns about Barker Reservoir water quality include nitrogen and phosphorus enrichment, pathogens, suspended sediments, heavy metals, herbicides and pesticides from the following causes:

- Nederland Waste Water Treatment Facility (WWTF) discharges to Barker Reservoir; Lake Eldora Water and Sanitation District discharges effluent to Peterson Lake (located four miles upstream of Barker Reservoir). Average monthly discharge is generally less than one cfs indicating that the discharge is a relatively small volume that would be substantially diluted in the Peterson Lake and Barker Reservoir. Although there were no permit violations between 2001 and 2007, there were elevated fecal coliform densities reported in winter months based on data available from EPA[36];
- groups of septic systems upstream of Barker Reservoir along Middle Boulder Creek and along the south bank of Barker Reservoir in the Big Springs development;
- urban land uses near Barker Reservoir and dog waste that is not disposed of;
- unevaluated and/or abandoned mine sites within the Barker Reservoir drainage area. The 1992 City of Boulder Water Source Impact Assessment identified 22 acres of disturbed land and tailings piles, but did not quantify loadings of acid mine drainage potentially associated with these sites[37], and;
- Beaver Creek erosion and runoff. City staff have measured and observed high turbidity during storm events and snowmelt because of land use[38].

Concerns were raised in reports[39] and by staff survey responses[40] regarding the degradation of the city's water supply from Nederland WWTF discharges to Barker Reservoir. Nederland is in the process of upgrading the WWTF to include processes that will significantly reduce nitrogen and phosphorus concentrations in the effluent. The idea of piping Nederland's discharge downstream of Barker Reservoir was found to be a technically difficult and high cost option

6.4.2.3 | BOULDER RESERVOIR WATERSHED

Source water entering the Boulder Reservoir WTF is generally of a lower quality than the water treated at the Betasso WTF. Naturally occurring water quality impacts to Boulder Reservoir come from the mineral content of the soils, wind events and eutrophication. During periods of stratification and hypolimnetic anoxia in the summer, manganese is released from reservoir bottom sediments causing taste and odor problems. Human influenced contaminants involve the use of the reservoir for swimming and boating, which can introduce organics, pathogens and invasive species. These issues present water treatment challenges when water is withdrawn for treatment from the reservoir directly.

However, when the Boulder Feeder Canal is operating, most of the water entering the Boulder Reservoir WTF is diverted directly from the roughly 21-mile open canal[iv] rather than from the reservoir. Potential contamination sources to Boulder Feeder Canal are shown in Figure 6-7. The primary area of concern for potential contamination is the section south of Lyons. Contamination sources in this reach include:

- eight major road crossings (sources of intentional contamination or contamination via runoff);
- clusters of septic systems, which, if not functioning properly, could leech contaminants into the unlined canal;
- residential, commercial, industrial and agricultural lands that drain directly into the canal. The largest drainage outfalls are piped over the canal but the city is working to prioritize the conversion of the remaining outfalls into pipes over the canal;
- earthen banks that are inhabited by animals. Water quality data suggest storm events wash animal waste from the banks into the canal[41];
- NCWCD application of herbicides along sections of the canal right of way and algaecide in the canal (NCWCD continues to work with municipalities to reduce the effects of their maintenance activities on water quality);
- a limited number of sanctioned recreation events use the canal between the reservoir and Niwot Road, and;
- the proposed recreational trail along the canal would further open the water source up to intentional and unintentional sources of contamination.

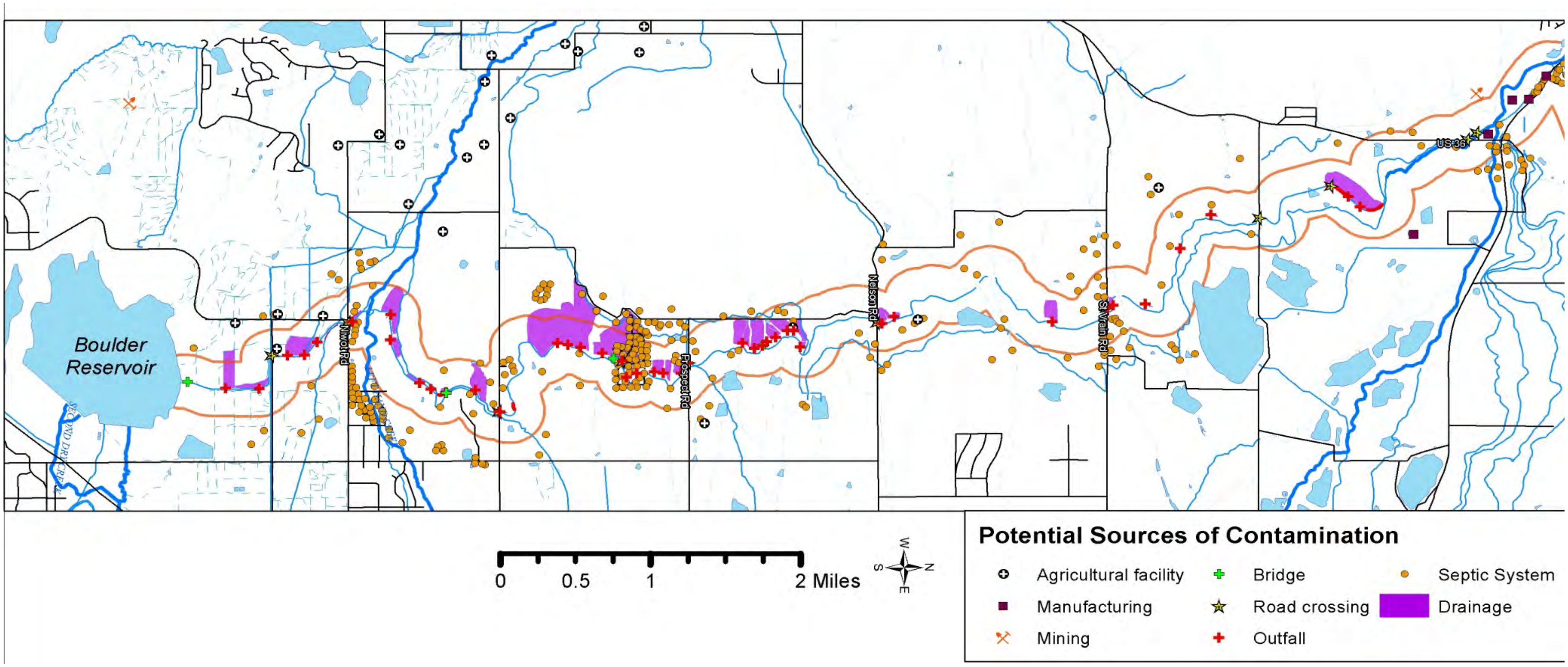
Farmer's Ditch is another open channel that transports municipal water to Boulder Reservoir with security vulnerability issues. However, associated concerns are not high priority because the ditch contributes less than 1 percent of the total volume of water in Boulder Reservoir.

Potential causes of water contamination to the city's CBT and Windy Gap water sources above Carter Lake and on the west slope include development and future increases in water demands that will result in increased wastewater discharge and, potentially increased contaminated runoff. The city supports NCWCD's activities to proactively protect the quality of west slope source waters.

An additional 10 percent of water enters Boulder Reservoir from its native topographic basin, which can be an issue in terms of contamination.

[iv] This length includes the entire distance from Carter Lake to Boulder Reservoir, which includes both the St. Vrain Supply Canal and the Boulder Feeder Canal.

FIGURE 6-7. BOULDER FEEDER CANAL SOURCES OF CONTAMINATION



Notes: Data for this map comes from the city of Boulder's internal SWAP assesssment (2002). Septic data was derived from AIRPHOTO.AIRPHOTO_image_index_for_2000 on the city's sde server. City water quality staff assumed that all residential houses have a septic system. "Ground-truthing" of this information was also conducted in 2002. Mining and ground water cleanup data came from EPA region 8. Further metadata for this map can be found in Brown and Caldwell and CDM Camp Dresser and McKee, Inc. (1997). *Boulder Creek watershed study: Phase 1 dated November 1997*. Denver, CO, 8-17. The original SWMP assessment maps are located at S:/pw/63rd/arcmap/arcmapprojects.

6.4.3 | INVASIVE AND NON-NATIVE SPECIES

Due to the heavy recreational use of Boulder Reservoir and its primary water source, Carter Lake, Boulder Reservoir is particularly vulnerable to invasive and non-native species. These species can be transported from contaminated to non-contaminated water bodies on recreational equipment. Non-native species that have been problematic in Colorado reservoirs include Eurasian watermilfoil and curly leaf pondweed. In 2008, the zebra mussel was identified for the first time in a Colorado reservoir, Pueblo Reservoir[42]. This mussel has caused problems in the Great Lakes region for over 20 years, and has now been found, along with its relative the quagga mussel, in seven lakes in reservoirs throughout Colorado including Grand Lake, Shadow Mountain Reservoir, Willow Creek Reservoir, Lake Granby, Jumbo Reservoir, and Tarryall Reservoir[43]. Zebra and quagga mussels cause physical problems such as coating structures and clogging water treatment intakes, biological problems including the creation of a monoculture and removal of a portion of the food web, and drinking water quality problems including creation of more favorable conditions for blue-green algae. Zebra mussels, quagga mussels and other invasive species can be transported from one water body to another on boats and other equipment. Such species can survive outside of the water for long periods and can particularly live in equipment and boats that are not carefully cleaned between uses[44].

6.4.4 | WILDLAND FIRE

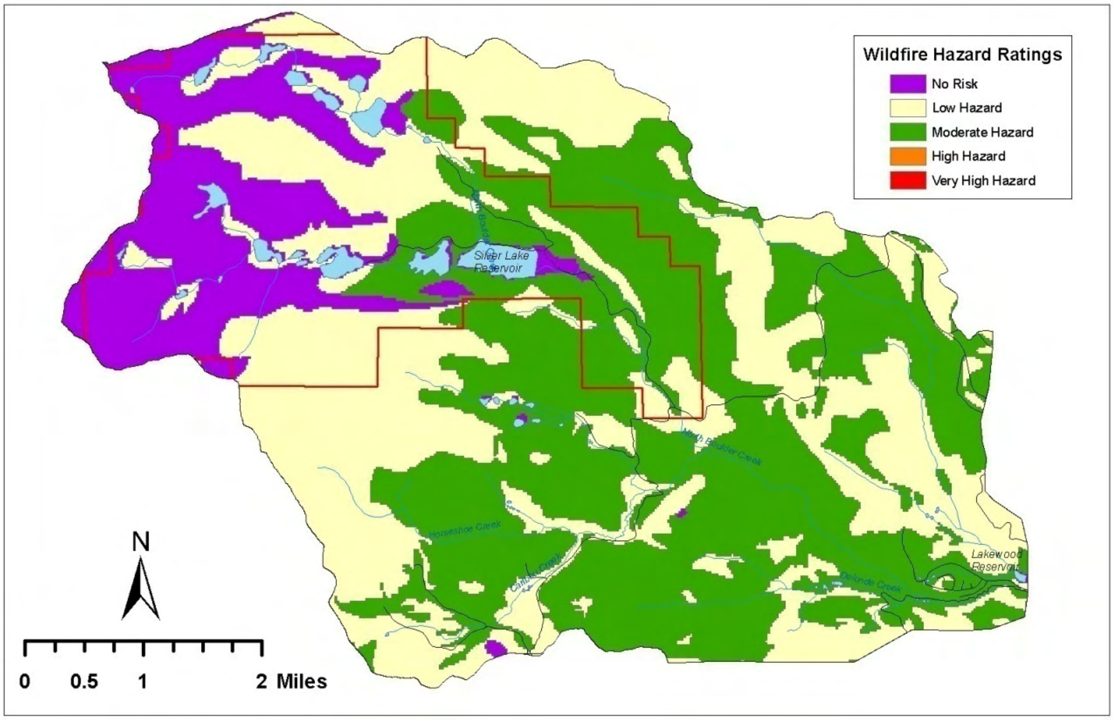
A wildland fire in Boulder's source water watersheds could affect the water delivery and water treatment facilities as well as affect Boulder's finished water quality. After large fires, high sediment loads can accumulate in the catchment areas of water storage reservoirs and reduce storage capacity and potentially plug the reservoir outlet system. In addition, fish and wildlife habitat would be affected. Following large, hot fires, streams tend to carry high sediment loads, as well as high total organic carbon and nutrients concentrations. This makes water difficult to treat as the sediments clog filters. Water taste can be affected as a result of wildland fire. Typically, water managers strive to minimize the high hazard fire[45].

The spread of the mountain pine beetle in Colorado from 2007- 2008 affected 400,000 new acres, bringing the total number of acres impacted to nearly 2 million since the outbreak was first detected in 1996[46]. Pine beetles are a natural part of the Arapaho and Roosevelt National Forests' ecosystem. However, due to drought conditions and a stressed forest, the current outbreak of Mountain Pine Beetles has reached epidemic levels[47]. In general, large groups of dead, dried trees represent a greater risk for forest fires.

6.4.4.1 | NORTH BOULDER CREEK WATERSHED

Figure 6-8 shows the North Boulder Creek watershed wildland fire risk. The upper reaches of the Silver Lake watershed are rated as no-risk to low-hazard wildland fire areas because of the density and type of vegetation cover, slope and aspect. The lower portion of the Silver Lake watershed and the rest of the North Boulder Creek basin are rated as low and moderate hazard wildland fire areas. Fire hazards have not been substantially increased due to vegetation modification, suppression, human use or development. The risk in this watershed is associated with fire as a natural ecological process. The city currently maintains fire breaks in the Silver Lake Watershed.

FIGURE 6-8. NORTH BOULDER CREEK WILDLAND FIRE RISK48

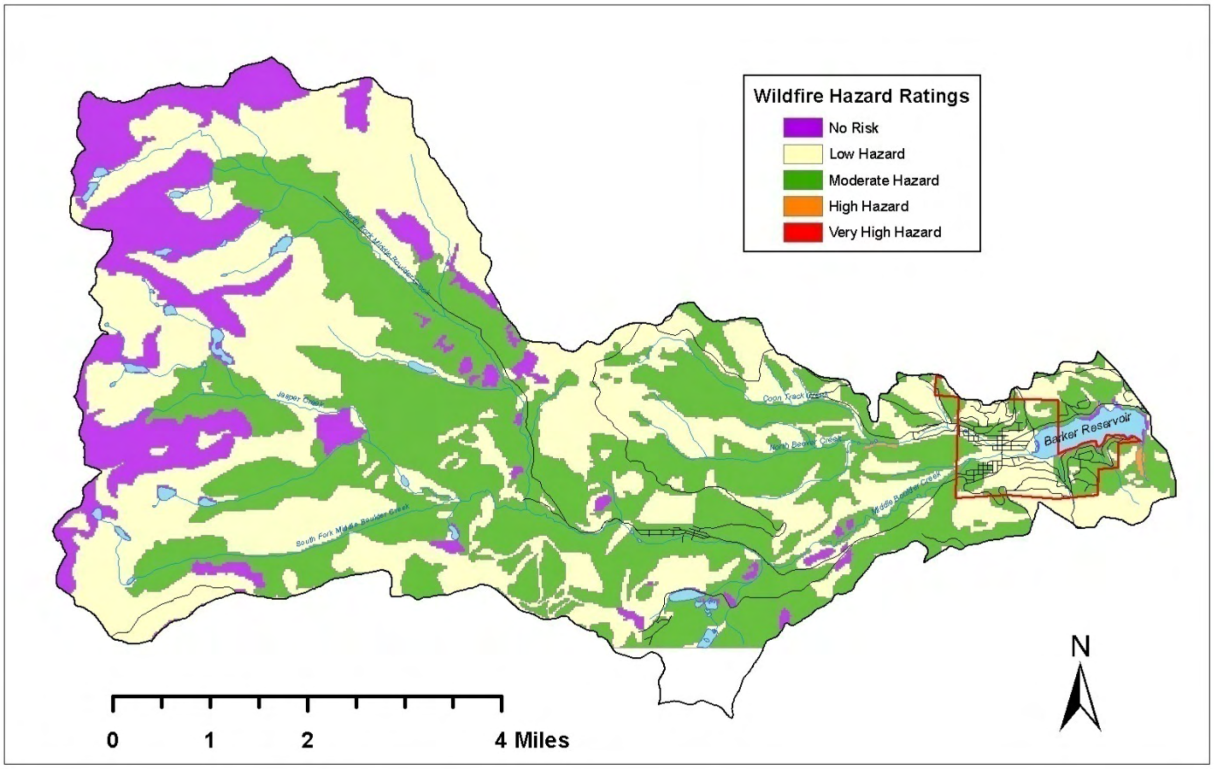


Note: The wildfire maps in this section represent a classification of the expected relative wildfire severity under the assumption of the occurrence of a moderate to high severity fire weather event within Boulder County. These assessments are based on the physical attributes of slope, aspect and vegetation fuel type and are based on the USDA Forest Service's fire behavior model BEHAVE and Van Wegner's crown fire spread equations. This classification does not at present take into account the location of dangerous topographic features such as chimneys and V-shaped canyons. The maps represent only a hazard classification and do not take into account any risk assessment that would show the probability of where a wildfire could occur. It should be noted that some sites having a high hazard may have a low risk and vice versa. The hazard model used on these maps is comparable to the Wildfire Hazard Information Extraction (WHINFOE) model used in calculating the wildfire hazard rating within Boulder County Wildfire Hazard Identification and Mitigation System (WHIMS) project.

6.4.4.2 | MIDDLE BOULDER CREEK WATERSHED

Figure 6-9 shows Middle Boulder Creek watershed wildland fire risk. Most of Middle Boulder Creek watershed has a low to moderate wildland fire hazard rating with no-risk areas in the upper reaches of the watershed. There is a high hazard area just south of Barker Reservoir adjacent to the Big Springs development. The high hazard rating is a result of a number of factors including proximity to residential development and type and density of vegetation.

FIGURE 6-9. MIDDLE BOULDER CREEK WILDLAND FIRE RISK[49]



6.4.4.3 | BOULDER RESERVOIR WATERSHED

As shown in Figure 6-10, the topographic drainage basin of Boulder Reservoir has low wildland fire hazard rating throughout most of the watershed. Figure 6-11 shows the wildland fire risk in the area draining to the Boulder Feeder Canal downstream of Lyons. Most of the area that drains directly into the Boulder Feeder Canal has a low wildland fire hazard rating. The higher elevation areas that drain to Left Hand Creek and potentially into Boulder Feeder Canal have a mixture of low, moderate, high and very high wildland fire hazard ratings.

FIGURE 6-10. BOULDER RESERVOIR WATERSHED WILDLAND FIRE RISK[50]

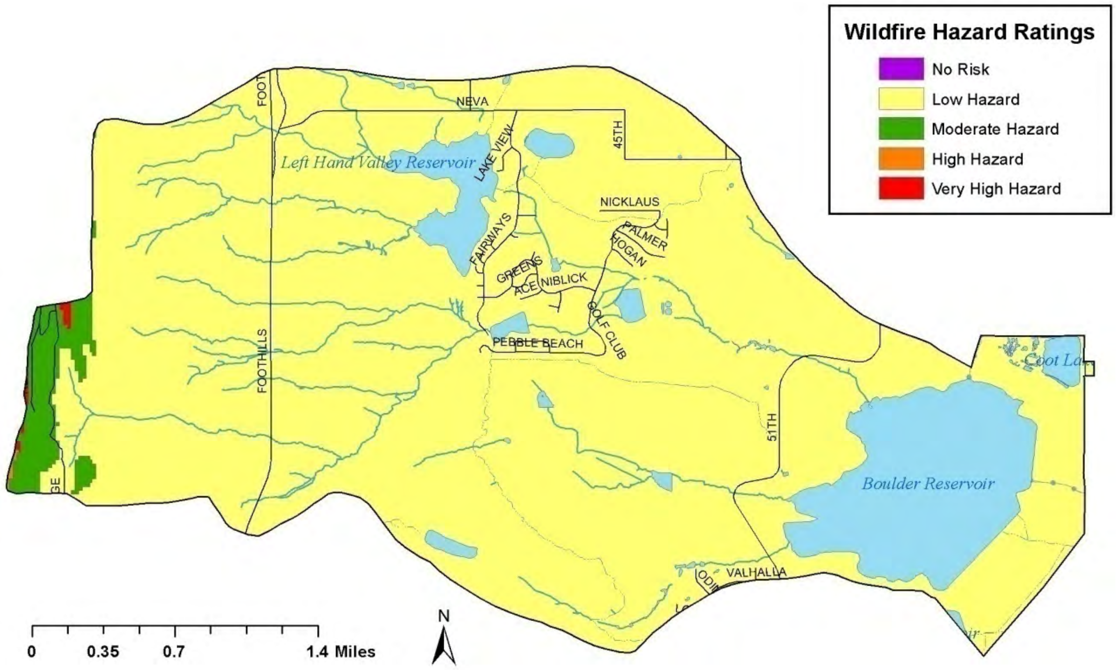
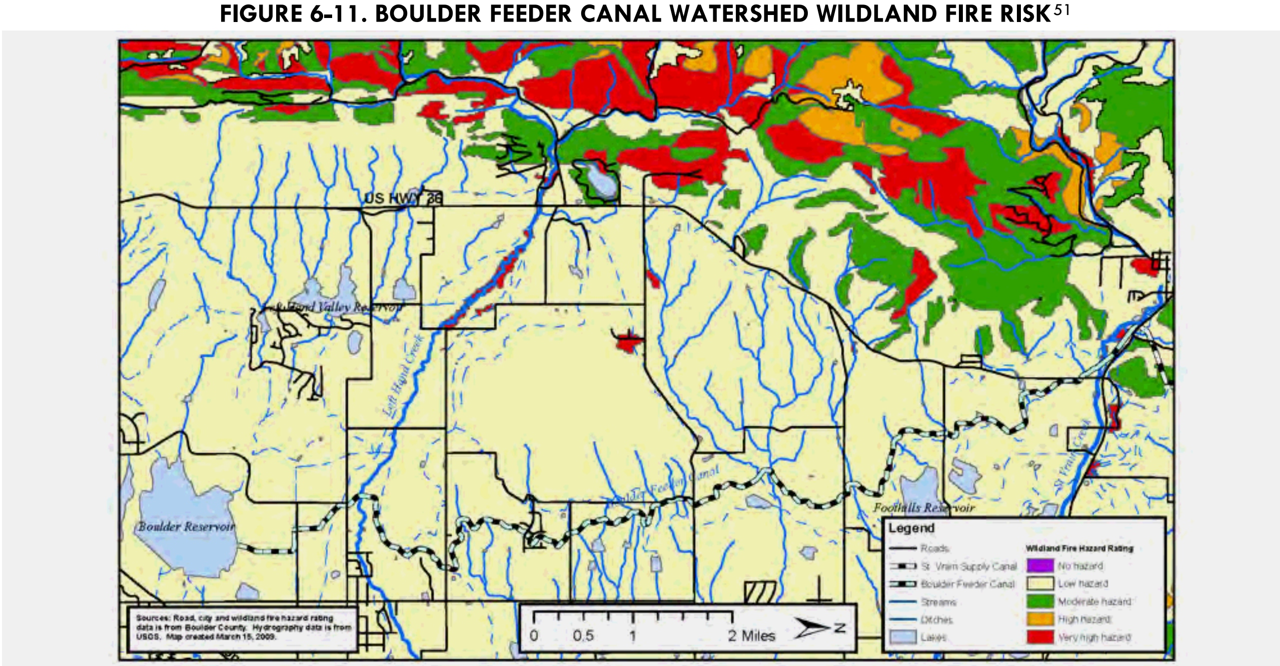


FIGURE 6-11. BOULDER FEEDER CANAL WATERSHED WILDLAND FIRE RISK[51]



6.4.5 | HABITAT PROTECTION AND LAND MANAGEMENT POLICIES

As part of the city's land management for water supply, the city realizes that riparian areas and wetlands support rich populations of plant and animal life. Although limited by staff and resources, the city supports land management policies to protect and enhance the natural resources of its source water lands.

6.4.5.1 | NORTH BOULDER CREEK WATERSHED

Although the city-owned land in the Silver Lake Watershed is well-protected, the watershed area above Lakewood Reservoir is more vulnerable. Acquisition of the Caribou Ranch lands by the city and Boulder County and the associated development agreement served to protect the watershed from extensive degradation in the future. However, the potential still exists for degradation due to public access to the Boulder County Open Space lands on Caribou Ranch. The city agreements with Boulder County provide the city with the right to specify management methods that protect its drinking water quality and the condition of the watershed lands feeding North Boulder Creek and Como Creek. The city has already exercised this right through the cooperative development with Boulder County of an agreement on pesticide and herbicide use on the Open Space[52]. The city should continue to carefully monitor Boulder County's management of the land and collaborate with staff to assure protection of the watershed.

6.4.5.2 | MIDDLE BOULDER CREEK WATERSHED

The city maintains trash receptacles, trails, picnic areas, and bathrooms around Barker Reservoir. The city continues to cooperate with the town of Nederland regarding dog regulations and design of the town park. However, land management policies and practices related to urban contaminants from Nederland entering Barker Reservoir could likely be strengthened to further protect the water supply.

The inlet structure of Barker Reservoir inhibits fish passage above the reservoir. The city maintains the structure on behalf of the state. The structure could be redesigned to promote fish passage.

6.4.5.3 | BOULDER RESERVOIR WATERSHED

The city OSMP owns over 70 percent of the land within the topographic drainage basin of Boulder Reservoir. Parks and Recreation and Utilities own all the land surrounding and underneath the reservoir. The Boulder Reservoir Watershed Management Group was established under the direction of the directors of the three departments to enhance communication and coordination of activities. The quarterly meetings are consistently attended by staff from Parks and Recreation and Utilities and periodically by staff from OSMP, the Colorado Division of Wildlife and NCWCD.

Although the city owns all the land around the reservoir, NCWCD manages the lands and facilities associated with delivery and storage of water supplies[53]. NCWCD attempts to coordinate its work efforts with the city to promote a mutually respectful relationship.

Many acres of land drain into the Boulder Feeder Canal south of Lyons. While the city cannot manage land activity along the canal, it has started a program to divert land outfalls across the canal. NCWCD has been assisting the city with the program. There are landowners on the downstream side of the canal that have refused to allow water to be diverted to their property. There are outfalls, such as at road crossings in the Boulder Heights development, for which there is no place for discharge on the downstream side of the canal.

6.5 | Facilities Condition and Improvement Issues

Many of the city's facilities were originally constructed in the early 1900s. The older facilities that have not undergone substantial renovation are reaching the end of their useful life and should be repaired or replaced in the next three to 10 years to avoid unplanned periods when these facilities must be taken out of service. Other facilities are in acceptable and operable condition, but modernization, including remote and/or powered operation would provide for additional flexibility and potentially improved worker safety.

Closer to buildout conditions, the city will need to make changes at facilities owned but not fully utilized at this time, including Wittemyer Ponds and Skyscraper Reservoir. In addition, the city will need facilities improvements to fully use existing water rights that are currently limited, such as in the Farmer's Ditch and Green Lake No. 2.

The facilities condition assessment and improvement discussion is based on the following:

- tour of most source water facilities for superficial review of condition;
- staff survey;
- review of historical city documents documenting facility condition, and;
- additional information provided by staff.

Only those facilities with identified condition issues are discussed in this section.

6.5.1 | NORTH BOULDER CREEK WATER FACILITIES

All of the North Boulder Creek facilities upstream of Lakewood Reservoir are located at high elevations with a short construction season and difficult access for heavy machinery. The challenges associated with the remote location should be considered in recommendations for any repairs or upgrades.

6.5.1.1 | WATERSHED DAMS

Some of the valves on watershed dams are aging. If these valves were to fail, water storage could be interrupted, and future dam repairs would likely be much more costly:

6.5.1.2 | GREEN LAKE #1

The outlet slide gate is not functional.

6.5.1.3 | GREEN LAKE #2

Dam repairs are needed to return this reservoir to full function.

6.5.1.4 | ALBION DAM

On the 2007 site visit, concrete spalling was visible on the crest and downstream face of the dam. Seepage was observed via joints and freeze thaw zones (see Figure 6-12). The access path to the valve house has been eroded such that valve house door must be reached via wood planks or a ladder (see Figure 6-13). The guard rail was bent, apparently by snow load years ago. There is no staff gage for measuring reservoir levels.

FIGURE 6-12. ALBION DAM UPSTREAM FACE [54]

FIGURE 6-13. ALBION DAM VALVE HOUSE[55]

A structural inspection of Albion Dam was performed in 2002[56]. This inspection noted extensive spalling on the upstream lower half of the dam and excessive concrete deterioration along construction joints (see Figure 6-14 and Figure 6-15). A 1986 investigation[57] found that below the crest cap, the dam was mostly rubble for an estimated 10 feet in some areas. The ultimate conclusion was that if the dam is not repaired, it will continue to deteriorate, leading to additional leakage and potentially future instability.

FIGURE 6-14. SPALLING AND CRACKING ALONG UPSTREAM FACE OF ALBION DAM[58]

FIGURE 6-15. EXPOSED REINFORCEMENT ON UPSTREAM FACE OF ALBION DAM[59]

6.5.1.5 | GOOSE DAM

The membrane repair conducted in 1999[60] appeared to be working well during the 2007 site visit. Crumbling concrete was observed on the downstream face of the dam (see Figure 6-16). The valve house location downstream of the dam makes access in the winter difficult due to snow accumulation. The snow must be dug out in order to access the valve house. A control panel could potentially be added at the top of the dam to actuate the valves via a portable generator.

FIGURE 6-16. GOOSE LAKE DAM[61]

6.5.1.6 | ISLAND DAM

On the 2007 site visit a slow leak was observed and debris was built up on the downstream face and spillway (see Figure 6-17). There is concrete degradation on the upstream face of the splash wall. A piece of the splashwall concrete fell off during the winter of 2007 and must be repaired in order to use the entire reservoir capacity in the future. The wall will need immediate repair and potentially future replacement or buttressing.

FIGURE 6-17. ISLAND DAM DEBRIS BUILDUP AND LEAK[62]

6.5.1.7 | SILVER LAKE DAM

Both the spillway and dam appeared to be in good condition on the 2007 site visit. Access to the valve house can be difficult in the winter because the lock will freeze. High winds across the crest make access to the valve house difficult. The main valves are in working order. However, the bypass valves for low flows are not in working order. Low flows currently pass through a gate valve, which isn't meant for low flows and therefore could cause cavitation of the valve. Actuators, lighting, and ventilation could be updated in the valve house. The system could be improved by allowing valves to be electrically actuated via a portable generator. In 2002, an inspection revealed that the valve chamber was flooded and the transition pipes were corroded. At that time, valve replacement was recommended[63].

6.5.1.8 | SILVER LAKE RESIDENCE AND BUNK HOUSE

New metal roofs will be needed for these two buildings in the next few years. Access to the city's System Control and Data Acquisition (SCADA) system and the internet from the Silver Lake caretaker's residence would increase operational efficiency.

6.5.1.9 | SILVER LAKE DIVERSION

During the 2007 site visit the diversion appeared to be in good working order. A solar panel charges the batteries that operate the instruments (*i.e.* pressure transducers and heater in stilling well) that measure flow through the structure. After consecutive cloudy days, the batteries lose their charge and there are no instrument readings. Moreover, the Parshall flume ices up from time-to-time in the winter. During those times, the pressure transducer reading in the stilling well is very high. It is likely that ice blocks flow and cause water to back up in the flume thereby creating a falsely elevated reading. In general, survey respondents recommended that the instrumentation be better protected from the elements[64].

6.5.1.10 | NORTH BOULDER CREEK DIVERSION TO LAKEWOOD

Siltation caused by recent construction activity was apparent on the upstream side of the diversion structure. Otherwise, the diversion appeared to be in good working order. According to the survey[65] and similar to the Silver Lake Diversion, the pressure transducer sometimes freezes during the winter.

Flow measurement in North Boulder Creek downstream of Lakewood Reservoir does not work well at flows less than two cfs. The stilling wells for instrumentation are connected to the Parshall flumes by tubes with inlets a few inches off the bottom of the channel. This prevents the tubes and stilling wells from clogging with sediment, but flows at depths below the holes are not recorded by the transducer. These flows can be estimated by manually measuring the depth in the Parshall flume, but then are not continuously recorded, which is not optimal for the instream flow program.

The diversion structure for the city's pipeline leading to Lakewood Reservoir was designed to include constant head orifices to measure head differential, which when combined with the orifice gate setting, can be used to regulate low flow releases. During the summer, the city can use the constant head orifices to assure that sufficient instream flow water passes the diversion dam when the release amount exceeds two cfs. However, during the winter, use of the constant head orifices is problematic since ice floes in the pool behind the diversion dam cause inaccurate water elevation readings or the stilling wells for the instrumentation freeze. Therefore, the city releases 1.5 cfs from Lakewood Reservoir to North Boulder Creek in the winter using a metered pipe that runs through the reservoir spillway.

6.5.1.11 | LAKEWOOD RESERVOIR

The reservoir and dam appeared to be in good working order on the 2007 site visit. Longitudinal cracks had been noted in January 2001[66]. The observed cracks may be due to the inclusion of excess road base that dried out after work on the structure. A follow-up engineering review is necessary to address the concerns noted in the 2001 evaluation.

6.5.1.12 | LAKEWOOD PIPELINE

The Phase III section of the pipeline has known spiral manufacturing weld defects and interior mortar defects (see section 4.2.1.12). The city follows a regular inspection program, which could identify major problems before they require taking the pipeline out of service for unplanned maintenance. The survey responses indicated that not all staff are aware of the inspection results and do not have a high level of confidence that the pipeline is sound[67].

During the 2007 site visit a crack and low/soft spot in the pavement of Sugar Loaf Road was observed downstream from Wither's Corner near a drain vault. Water was in the manway with no immediately apparent water sources, suggesting a potential leak in the drain vault piping or fittings.

At the Betasso WTF, staff discussed leaks in the nitrogen system for the Flexflo surge protection system. Survey responses indicated that the flow meter on Lakewood Pipeline at Betasso does not work correctly[68]. The flow meter problem was corrected during 2007[69].

6.5.1.13 | SILVER LAKE HYDRO

The Silver Lake Hydro facility appeared to be in good working order on the 2007 site visit. According to survey responses[70] and discussion with the SCADA administrator, the SCADA system at Silver Lake Hydro does not have the same type of Programmable Logic Control (PLC) or software as the Betasso WTF. This does not cause major problems for the treatment plant or hydro operators at this time, but might become an issue in the future.

6.5.2 | MIDDLE BOULDER CREEK / BARKER RESERVOIR WATER FACILITIES

6.5.2.1 | SKYSCRAPER RESERVOIR

The Drought Plan[71] recommended that Skyscraper Reservoir be integrated into regular use as part of the city's long-term supply development strategy. Skyscraper is likely needed for water supply closer to when the city reaches its maximum water demand near buildout. In an August 2008 inspection, the State Engineer thought that the dam was structurally sound[72]. Substantial seepage was observed through the mid-section of the dam apparently due to lack of grout between the rocks that make up the dam (see Figure 6-18). A geomembrane would likely stop the seepage. The two outlet gates in Skyscraper Dam have bent stems rendering them inoperable. The upper outlet is plugged with wood; however, water was observed trickling from this outlet. The lower outlet was open and releasing 30-50 gallons per minute. Both outlet gates will probably need to be replaced. The Parshall flume located downstream of the dam is in good condition and can be used in the future. Currently, water undercuts the flume, so the flume will need to be reinstalled. Cracking was noted on the spillway concrete cap and spalling was noted on the right and left buttress concrete caps. Mortar leachate is visible on the dam face[73]. Skyscraper Dam is in a remote location which will present a challenge for operation and renovation efforts.

FIGURE 6-18. SEEPAGE THROUGH SKYSCRAPER DAM AND BENT OUTLET GATE STEM[74]

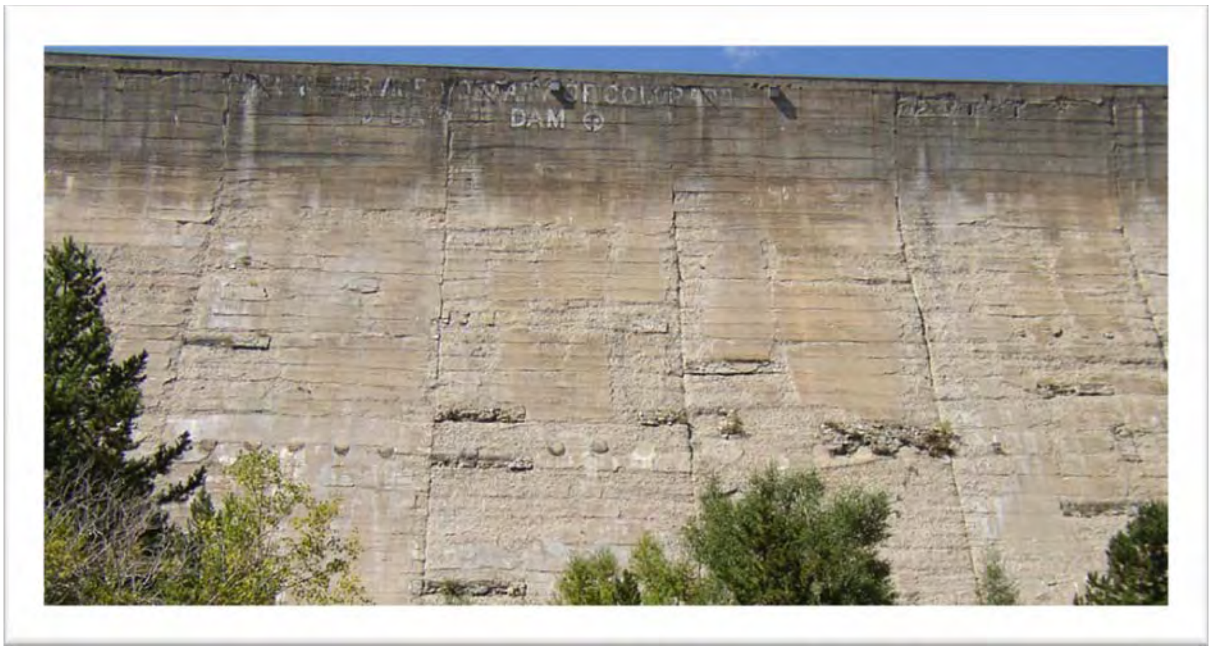
6.5.2.2 | BARKER RESIDENCE

Survey responses indicated that the residence was at a distance from the dam that increased staff travel time and decreased surveillance ability[75]. No other issues were noted.

6.5.2.3 | BARKER DAM / RESERVOIR

The FERC Part 12D Report and PFMA[76] indicated that the dam is in good structural condition. The downstream face is cosmetically flawed (see Figure 6-19), but generally in adequate condition. Grout plugs topping the stabilization anchors are spalling. The lower seven sluice gates are not regularly exercised, and their functionality is not known. The vertical drains have limited functionality due to clogging, but they should not pose a safety issue. There may not be sufficient high water alarms downstream of Barker Dam to detect and warn of unexpected releases.

FIGURE 6-19. BARKER DAM DOWNSTREAM FACE[77]



Spalling of the anchor head concrete caps (see Figure 6-20) was observed on the dam crest during the 2007 site visit. This spalling is not likely to affect dam function or stability in the near future. However, as spalling worsens, the anchors could potentially deteriorate.

FIGURE 6-20. BARKER DAM ANCHOR[78]

6.5.2.4 | BARKER GRAVITY PIPELINE

Barker Gravity Pipeline is located in terrain that is difficult to access with heavy machinery. Survey responses[79] indicated that most of the pipeline is in poor condition and that it has numerous leaks due to its age. In addition, the FERC Part 12D Report and PFMA[80] suggested that the pipeline may not have enough earth or other coverage to prevent damage from rock falls or freeze thaw action.

6.5.2.5 | MIDDLE BOULDER CREEK WEIR

Sediment deposition was observed on the upstream side of the weir during the 2007 site visit but otherwise the structure appeared in good working order (see Figure 6-21).

FIGURE 6-21. FLUME DOWNSTREAM OF BARKER DAM[81]

6.5.2.6 | KOSSLER RESERVOIR

Minor undercutting was observed on the 2007 site visit at the floor of the concrete outlet structure of the Barker Pipeline to the outlet basin structure which empties into Kossler Reservoir. Erosion was also visible at the rock wall transition (see Figure 6-22).

FIGURE 6-22. BARKER GRAVITY OUTLET TO KOSSLER RESERVOIR[82]

There is little information on the design, material properties and historical maintenance of Kossler Reservoir. The spillway capacity is not known[83].

Rock walls placed at the main dam abutments to tie in the concrete parapet wall at the top of the dam show signs of wear and may need to be adjusted. The concrete panels on the upstream face of the main dam show substantial concrete degradation (see Figure 6-23). The concrete panels below an elevation of 7,717 feet are near the end of their useful life. Those above 7,717 feet are generally in acceptable condition, but need localized repairs[84].

FIGURE 6-23. KOSSLER MAIN DAM UPSTREAM FACE[85]

Seepage is evident downstream of the dam and is measured via a weir. Flows may bypass the seepage weir. Also, the piezometers may not be correctly located to measure the phreatic surface through the dam embankment. Woody shrubs growing on the upper downstream face of the dam could indicate a high phreatic surface. The upstream dam face shows severe spalling and cracking at and below the normal water level[86].

The city has considered a bypass system from the Barker Pipeline Outlet Structure directly to the Boulder Canyon Penstock to improve flexibility of system operation.

The gate house needs paint on the reservoir side and lighting could be improved. The concrete wing walls and headwall of the outlet show concrete damage and degradation (see Figure 6-24). The inlet to the Boulder Canyon Hydro Penstock could be modernized with remote actuation and remote monitoring capabilities. The gate and stop-log system could be updated with more modern equipment. There is seepage along the upper, low-head portion of the Boulder Canyon Penstock likely from the cracked concrete at the Kossler outlet[87].

FIGURE 6-24. KOSSLER RESERVOIR GATE HOUSE AND OUTLET FOREBAY[88]

6.5.3 | BOULDER RESERVOIR RAW WATER FACILITIES

The city does not have control over much of the Boulder Reservoir source water infrastructure because it is maintained by NCWCD.

6.5.3.1 | BOULDER FEEDER CANAL

The canal is maintained by NCWCD. On the 2007 site visit vegetation was observed clogging the Boulder Feeder Canal inlet to the Boulder Reservoir WTF. The vegetation was manually removed by a treatment plant operator from the side of the canal. Operator safety while removing vegetation was improved in 2008 with the installation of a platform at the inlet (see Figure 6-25).

The Source Water Quality Planning Study[89] and survey responses raised concerns about security vulnerability, particularly from multiple road crossings, contamination from runoff and proposals to add recreational trails along the canal alignment. Water quality has the potential to be degraded during transmission in the open Boulder Feeder Canal. Sources of contamination are discussed in more detail in section 6.4.2.3.

Water deliveries through the canal are limited to the irrigation season (April 1 through October 31), which affects the yield of Boulder's water rights at this location (see section 6.1.1).

FIGURE 6-25. PLATFORM AT BOULDER FEEDER CANAL INLET TO BOULDER RESERVOIR WTF[90]

6.5.3.2 | FARMERS DITCH

The city does not receive its full share of water rights through Farmers Ditch (see section 6.2.3.2 for a discussion of the potential water rights yield increase available). The city uses its Farmers Ditch shares by carrying the water through the ditch to Boulder Reservoir and treating the water at the Boulder Reservoir WTF. Small ditch shareholders on the upper part of the ditch often take more than their share of the water due to a lack of effective means of regulating their diversions. Most of the larger ditch users, including the city, are at the lower end of the ditch, but the capacity of the ditch in places through town is too small to satisfy all ditch users. One particular constraint is the culvert under the bike path behind the North Boulder Recreation Center. This culvert may be replaced in 2009 during stormwater system improvements to be made as part of a city Transportation Division project to rebuild the north Broadway roadway. In addition, the ditch bottlenecks at a poorly aligned and undersized siphon on Boulder Valley Ranch. The capacity of the siphon is currently five cfs.

6.5.3.3 | WITTEMYER PONDS (NOT OBSERVED IN FIELD VISIT 2007)

The Wittemyer Ponds comprise a gravel pit complex that was purchased by the city in the late 1980s with the intent that the ponds could serve as a collection point for the city's small amount of fully-consumable water (see sections 6.2.3.4 and 6.4.1.5 for more information). The ponds are located near Highway 52 and County Line Road downstream of the city's 75th Street WWTF. The reusable portion of Boulder's WWTF effluent could be captured in the ponds and held until an exchange opportunity exists to credit water releases from the ponds against additional diversions at the city's upper water intakes. Before this type of use can occur the ponds need to be lined to isolate water stored in the ponds from groundwater. Other structural improvements will need to be implemented before the ponds can be put into regular service for Boulder's water system needs.

6.5.4 | HIGHEST PRIORITY FACILITIES CONDITION ISSUES

Table 6-1 combines the facility condition level with the facility's importance in supplying source water to the city's water treatment facilities. Those facilities with a medium or high level of importance and medium or high issues will likely require capital or other improvements within the next 20 years.

TABLE 6-1. SUMMARY OF FACILITY CONDITION AND CRITICAL POSITION IN WATER SUPPLY

PROJECT	CRITICAL TO WATER SUPPLY	FACILITY REPAIR/PROJECT NEED
Watershed dam valves	**MEDIUM** – watershed dams are each a small part of overall supply	**HIGH –** some (not all) of the watershed valves are old with limited life spans
Green Lake #1	LOW – small volume, upstream of several other reservoirs	**HIGH –** outlet is not functional
Green Lake #2	LOW – small volume, upstream of several other reservoirs	**HIGH –** dam structure not functional
Albion Dam	**MEDIUM** – moderate volume, upstream of Silver Lake	**MEDIUM** – downstream face in poor condition and will continue to degrade
Goose Dam	**MEDIUM** – moderate volume, upstream of Silver Lake	LOW – dam is fully functional, operator access and operations could be improved
Island Dam	**MEDIUM** – small volume, but has 1890 senior water right	**HIGH –** concrete on crest needs immediate repair
Silver Lake Dam	**HIGH –** large volume, critical location at bottom of Silver Lake system	LOW – dam generally in good condition, bypass for low flows and mechanical operation could be improved
Lakewood Dam	**MEDIUM** – water can be supplied to Betasso via the Silver Lake Pipeline bypass to Lakewood Pipeline	LOW – appears to be in good condition, although reported cracks should be evaluated
Silver Lake Diversion	**MEDIUM** – water can be supplied to Betasso from Lakewood Reservoir via North Boulder Creek	LOW – generally functional with some problems due to freezing
North Boulder Creek Diversion to Lakewood Pipeline	**MEDIUM** – water can be supplied to Betasso via the Silver Lake Diversion	LOW – generally functional, but not ideal due to freezing issues and low flow measurement issues
Lakewood Pipeline	**HIGH –** one of three major water supply conduits in Boulder's system	LOW – there are known weld flaws, but regular inspection program is followed
Skyscraper Dam	LOW – critical to supply, but not until build-out	**HIGH –** valve and dam repairs are needed for future operation
Barker Dam	**HIGH –** large volume, critical storage component of system	**MEDIUM** – dam structure is sound, but outlet works need improvement
Barker Residence	LOW – not a component of water supply	LOW – location is not ideal for reservoir operations
Barker Canyon Hydro System Permitting	**MEDIUM** – water supply operations could continue without use of hydro facilities	**HIGH –** permit needed for continued operation of hydro facilities
Barker Gravity Pipeline	**HIGH –** one of three major water supply conduits in Boulder's system	**HIGH –** advanced age and poor condition could result in need to take offline
Middle Boulder Creek Weir	LOW – does not affect water supply	LOW – some sedimentation observed
Kossler Reservoir	**HIGH –** no bypass available	**HIGH –** degradation of main dam concrete panels, concrete cracking at outlet and seepage downstream
Boulder Canyon Hydro Penstock	**HIGH –** no bypass for this segment	LOW – recent visual inspection did not show any significant unexpected problems
Boulder Canyon Hydro	LOW – water can bypass hydro	**HIGH –** reaching end of useful life and concerns regarding operator safety
Boulder Feeder Canal	**HIGH –** one of three water sources in Boulder's system	**MEDIUM** – water quality concerns and seasonal limitations on use
Wittemyer Ponds	LOW – will be critical to supply closer to build-out demand	**MEDIUM** – will need substantial improvements for water exchange

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Chapter 7

7 | RECOMMENDATIONS

One of the goals of the SWMP is to develop recommendations for the management of the city's raw water supply system and source watersheds for the next 20 years, including estimating project costs and timing of expenditures. The SWMP provides guidance on which future actions should be developed further through more specific efforts such as detailed studies, cost-benefit analyses, a project-specific CEAP, or development of capital projects.

A number of recommendations have been developed as a result of work efforts associated with this master plan. The recommendations presented herein have been developed with input from the following sources:

- city Utilities Division staff and consultants involved in developing the master plan;
- CSG, including members of the WRAB and City Council;
- a survey of selected city departments and staff members, and;
- an inspection of the condition of existing facilities.

Minutes of the CSG meetings include detailed discussion and recommendations, some of which were beyond the scope of this master plan. The CSG prepared a final memo summarizing its work[1] that contained a table of recommendations that the group and staff agreed should be brought forward in the master plan. The final recommendations of the CSG are included in this chapter.

The staff survey contained numerous pages of comments and input from selected city departments and staff members. In general, this chapter brings forward recommendations that received the most emphasis from surveyed staff and that were within the scope of this master plan. Individual suggestions that do not appear in the SWMP will be followed up on separately.

The recommendations have been grouped into the following categories:

- policy assessment;
- facilities improvements, and;
- studies and plans.

The policy assessment section addresses current policies to be continued, changes to be evaluated for existing policies or identification of the need for new policies. The facilities improvements section covers physical infrastructure needs. The studies and plans section discusses information needed for future raw water system and source watershed management decisions.

7.1 | Policy Assessment and Recommendations

Over time, the city of Boulder has developed policies that guide the management of the raw water system and source watersheds. Recommendations in this section of the SWMP address areas where adjustments and/or enhancements to the established policies could be considered. The SWMP document itself will not implement any new policies as these will require specific approval by the City Council or the City Manager and designated staff as is appropriate. More information on current city policies regarding source water is included in sections 3.4 and 3.6 of this SWMP.

Policies implemented as a result of the previous source water planning effort, the 1988 RWMP[2], continue to provide focus to management of the raw water system and source watersheds. In the past 20 years the city's water supply system has changed and new information is available. Therefore, it is an appropriate time to revisit some of the policies that will guide future raw water system and source watershed management.

Many of the items described as studies and plans later in this section may have eventual policy implications following in-depth evaluation. The specific direction such policies would take will not become apparent until the studies and plans are complete. Table 7-1 presents the policy-related items for which near-term council direction is needed.

TABLE 7-1: SOURCE WATER POLICY RECOMMENDATIONS

POLICY RECOMMENDATIONS	WATERSHED	SOURCE OF RECOMMENDATION	ISSUE(S) TO BE ADDRESSED
Continue taking reasonable steps to increase water supply reliability and system flexibility without causing negative economic impacts to the water utility.	System Wide	Staff	Water supply quantity
Reaffirm or modify current water supply reliability criteria.	System Wide	CSG	Water supply quantity
Formalize policy guiding intended uses for conserved water that can be retained by the city.	System Wide	CSG	Water supply quantity and non-municipal uses
Develop source water protection policy or goals.	System Wide	Staff	Water supply quality
Do not pursue any further sales of Windy Gap water until studies re-evaluating its utility to the city are complete.	Colorado River	Staff	Water supply quantity

SYSTEM FLEXIBILITY (1) - With regard to system flexibility, the policy direction would be for the city to pursue "no-regrets" actions that would increase system reliability and flexibility in a way that provides value to the community and is sustainable for the future. No-regrets actions would be considered good now and still good if things change in the future. They would be actions that can be taken without unnecessary impacts to water rates and might easily be incorporated into projects or actions undertaken to meet water system needs.

Examples of potential no-regrets actions are as follows:

- Continuing to develop hydropower potential where opportunities exist within the city's water system;
- Improving municipal water system facilities such as rehabilitating Green Lake #2 Dam to eliminate operating/storage-level restrictions;
- Pursuing non-municipal water use arrangements for annual excesses of the city's water supplies that avoid municipal water supply reliability impacts even if higher build-out water demand is realized or water yield is reduced by climate change. For example, interim arrangements for non-municipal uses of water, as opposed to permanent commitments, could be considered until build-out demand is realized. More permanent commitments to non-municipal uses should contain clauses reserving the right to use the water for municipal needs in the event of drought (e.g., allowing for instream flow pull-back in drought years). Future commitments to non-municipal uses must be flexible to assure municipal needs can be reliably met;
- Establishing downstream storage facilities to recapture the city's fully-consumable municipal water and reusable instream flows for later exchange upstream for municipal and non-municipal uses;
- Establishing formal reservoir reserve levels as a fail-safe for providing for essential health and safety water needs in the event that drought recognition criteria prove to be insufficiently conservative or need modification due to climate change;
- Recharging alluvial aquifers during high streamflow to increase returns to the stream in low flow periods. Recharge facilities might be required for such a program, but this could also be accomplished through establishing large water budgets for irrigation for the city's water customers in May and June, and;
- Assuming an acceptable funding/water rate plan can be accomplished, construction of Carter Lake Pipeline.

Each project or program, including the examples listed above, would undergo its own approval process to determine whether or not it is cost effective and truly is a no-regrets action.

RELIABILITY CRITERIA (2) - The CSG (2008) recommended revisiting public support for the current water supply reliability criteria policy[3], which expresses the city's goals for adequacy of water supply during droughts of varying recurrence intervals. It was recommended that in order to effectively define community preferences, the reliability criteria need to be refined to define the embedded quantitative assumptions concerning indoor and outdoor water use. The current reliability criteria employ qualitative standards without defining the quantity of water necessary to meet those standards. "Essential needs," "exterior landscaping needs" and "all water uses" could be quantified to allow residents to reach an informed opinion concerning whether the current reliability criteria are acceptable or require adjustment. For example, how many gallons of water per person per day are considered sufficient to meet essential needs without jeopardizing health in the event of an extreme drought? Is viability of exterior landscaping achieved when plants typically found throughout the city go into dormancy or suffer limited damage, but still survive? These refinements would allow the community to more fully understand the impacts that could be expected under various drought conditions and determine whether the frequencies of restrictions allowed under the current criteria are acceptable

USE OF CONSERVED WATER (3) - The CSG (2008) desired policy clarification on the intended uses for water made available by the city's water conservation efforts. Are we conserving water now to ensure that there will be sufficient supply available to support population and employment at build-out? To what extent does water conservation improve water system reliability in the event of drought? Does the community's water conservation translate directly to long-term increased streamflow or water available for other non-municipal uses? A clear understanding should be developed for why we currently conserve water during non-drought years given that the extent to which any conserved water directed by the city to any particular non-municipal use is limited.

SOURCE WATER PROTECTION (4) - The policy directive for this topic would be to actively pursue protection of the city's source water quality. Issues to be addressed might include wildland fire hazard mitigation, point and non-point source pollution and nuisance aquatic species. Land management strategies should be adopted in association with Nederland, Eldora Ski Area, Boulder County, CDOT and State and US Forest Services for Middle Boulder Creek Watershed Management.

The water source that supplies water to the Boulder Reservoir WTF includes both West Slope supplies and local drainage area contributing to the Boulder Feeder Canal and Boulder Reservoir. For the West Slope supplies, the city should support NCWCD and other CBT users in their development and implementation of source water protection strategies. The city should undertake a parallel effort with other stakeholders to protect the Boulder Reservoir and Boulder Feeder Canal water sources.

The North Boulder Creek Watershed consists of an upper and a lower basin. No recommended policy changes were identified for the upper basin. For the lower basin, however, the city should take an active role in oversight of activities associated with the Caribou Ranch Management Plan[4].

WINDY GAP UNITS(5) - Although City Council did not recommend a permanent yield reduction of the city's water portfolio through sale of water in 1988, they did recognize that the Windy Gap water was the city's most expensive and least reliable water. Council recommended that staff attempt to reconfigure the city's water portfolio through sale of Windy Gap water and replacement of the Windy Gap water with water supplies and assets in the Boulder Creek basin that would be capable of multiple uses and would enhance the yield of existing systems. Based on these recommendations, the city sold 43 of its original 80 units[5]. The proceeds were used to purchase the Barker system[6], additional shares in ditch companies, and joint ownership with Boulder County of Caribou Ranch[i]. Purchase of the Barker system in 2001 has increased the city's water rights yield, increased operational flexibility, allowed improvements that increased system reliability, allowed for instream flows in Middle Boulder Creek and provided additional hydroelectric generation. Given uncertainties in future water yields due to potential climate change and other currently indefinable factors, policy direction concerning retention of the remaining Windy Gap units should be re-evaluated and updated. Staff recommends not pursuing any further sales of the city's remaining Windy Gap units until a re-evaluation of the yield and utility of this water is completed unless more attractive alternative water supply opportunities arise.

[i] Documents associated with the complicated Caribou Ranch purchase are included in the Appendices.

7.2 | Facilities Improvements

The facilities improvements discussion is separated into two sections: 1) capital improvement projects and 2) minor projects. Each section presents a summary table of projects followed by a narrative discussion of the projects. Capital improvement projects are those estimated at over $50,000 and minor projects are under $50,000. Capital improvement projects would be listed in the annual CIP and typically would require a formal approval process including a CEAP. Minor projects would likely be funded out of operating budgets and would not require a formal approval process.

7.2.1 | Capital Improvement Projects

During development of the SWMP, source water facilities (physical infrastructure) were evaluated to identify needed improvements and modifications. Recommended capital projects are summarized in Table 7-2. Prioritization is based on the facility condition and how important the facility is to the water supply system (see Chapter 6, Table 1). Priority 1 projects should be accomplished in the next six years; Priority 2 projects in years seven to 20; and Priority 3 projects should be completed after 20 years. Top priority improvements have been indicated in bold type in Table 7-2.

The WRAB and the CSG recommended that the CIP be expanded to a 20-year period to allow for evaluation of proposed near-term expenditures against long term capital project needs and the timing of expenditures. The 20-Year CIP is included at the end of this chapter as Table 7-5. Opinions of probable construction costs and timing are shown in the 20-Year CIP in Table 7-5.

As discussed in section 6.2.2.1, the current state of knowledge regarding climate modeling and expected effects on the city's watersheds is developing, but is not yet sufficient for use as a base for determining the advisability of any significant capital investments that might solely address climate change. With such uncertainty, the city should direct capital funds toward more pressing needs that have more certain outcomes. At the present time, it appears to be premature to make extensive capital expenditures to mitigate potential climate change effects of unknown magnitude or direction.

TABLE 7-2. LIST OF CAPITAL IMPROVEMENT PROJECTS AND PRIORITY

Item #/ Funding Plan	Project	Priority	Project Description
North Boulder Creek Water Source			
1a/AP	**Green Lake #2 Engineering Evaluation**	**1**	**Evaluation of dam structure and study to determine best method and likely cost for repairs**
1b/AP	Green Lake #2 Structural Maintenance	2	Structural maintenance to dam
2a/AP	Albion Dam Engineering Evaluation	2	Evaluation of dam structure and study to determine best method and likely cost for repairs or potential dam raise
2b/AP	Albion Dam Liner, Crest and Spillway Repair	2	a) Repair crest and spillway concrete b) Evaluate and potentially repair poorly cemented rubble below crest cap c) Apply membrane to upstream face to seal off seepage
2c/VP	Albion Dam Raise and Liner	3	Same as 2b with concrete dam raise
3/FCP	**Island Dam Minor Repairs (patches)**	**1**	**Patches in 5 to 7 locations on upstream face and splash wall generally around high water mark**
4a/FCP	**Miscellaneous watershed valve replacement - Phase 1**	**1**	**Proactive valve replacement program in next 6 years**
4b/FCP	Miscellaneous watershed valve replacement - Phase 2	2	Proactive valve replacement program for years 7 through 20
5/FCP	**Lakewood Pipeline†**	**1**	**Ongoing maintenance recommended in 5th inspection report**
Middle Boulder Creek Water Source			
6a/AP	Skyscraper Dam Evaluation and Gate Replacement	2	a) Video inspection of gates to create gate replacement plan b) Use diver to open gates to drain reservoir c) Replace gates and stem d) Evaluate dam structure to determine best method and cost for completing repairs
6b/AP	Skyscraper Reservoir Lining and Spillway Repair	3	Line reservoir and grout loose boulders on spillway
6c/AP	Barker Residence	2	Purchase a residence within sight of Barker Dam to improve access to and response time for operating the system
7a/FCP	**Nederland WWTF Upgrade**	**1**	**Funds for advanced treatment at WWTF upstream of Barker Reservoir**
7b/AP	Hannah Barker Hydro	2	Add hydro unit at toe of Barker Dam
7c/FCP	Barker Dam Outlet Works Replacement	2	Construction of vertical shaft near left abutment, inlet tunnels and one outlet tunnel, an outlet distribution facility, pipeline to Barker Gravity Line, and valve house
7d/FCP	**Barker Dam anchor grout repair**	**1**	**Repair grout topping stabilization anchors (55 total)**
7e/FCP	**Barker Permitting**	**1**	**FERC Exemption and USFS Land Use Authorization**
8a/FCP	Barker Gravity Line Land Exchange	2	Land exchange for Barker Gravity Line lands with the USFS
8b/FCP	**Barker Gravity Pipeline Repair - Phase 1**	**1**	**Ongoing repair of sections with most critical needs**
8c/FCP	Barker Gravity Pipeline Repair - Phase 2	2	Repair of remaining sections with less critical needs
9a/FCP	**Kossler Reservoir Main Dam Repairs**	**1**	**Replace degraded concrete panels on upstream face**

Item #/ Funding Plan	Project	Priority	Project Description
9b/FCP	**Kossler Reservoir Minor Repairs**	**1**	**e) Maintenance of the seepage weir** **f) Determine capacity of overflow spillway** **g) Upgrade topographic surveys** **h) Hydraulic instrumentation and remote monitoring capability** **i) Tree growth control on north dam** **j) Gate house paint and lighting**
9c/FCP	**Kossler Outlet Repairs**	**1**	**k) Evaluate source of water downstream of road and implement appropriate fix** **l) Repair concrete damage at reservoir outlet and add seepage controls**
9d/AP	**Kossler Bypass**	**1**	**Connect Barker Gravity Line to Boulder Canyon Hydro Penstock**
10a/AP	Boulder Canyon Hydro Penstock Evaluation	2	Study to evaluate need for replacement or targeted repairs with metallurgy and corrosion experts
10b/VP	Boulder Canyon Hydro Penstock Replacement	3	Eventual section by section replacement (if evaluation deems necessary)
10c/AP	Boulder Canyon Hydro Replacement	2	Replace with appropriately sized hydro unit
Colorado River Water Source			
11a/FCP	**Boulder Feeder Canal Stormwater Diversions - Phase 1**	**1**	**Diversions of stormwater outfalls over canal described in Black & Veatch (2007)***
11b/AP	Boulder Feeder Canal Stormwater Diversions - Phase 2	3	Diversions of stormwater outfalls over canal described in Black & Veatch (2007)*
11c/AP	**Carter Lake Pipeline**	**1**	**Construction of pipeline from Carter Lake to Boulder Reservoir for transbasin water supply**
11d/VP	Carter Lake Pipeline Hydro	3	Hydro added upstream of Boulder Reservoir water treatment plant
12/VP	Farmer's Ditch Exchange Potential Pipeline	3	Low pressure pipeline from Boulder Reservoir to mouth of Boulder Canyon along Farmer's Ditch alignment.
13/AP	Wittemyer Ponds	2	Line Wittemyer ponds to use for exchange
14/AP	Farmers Ditch Capacity Restoration	2	Restore Farmers Ditch capacity sufficient to allow city to fully divert the conveyed 13.52 cfs during times when that water is not needed for instream flow

Priority Levels: 1 = next 6 years, 2 = next 7 to 20 years, 3 = long-term
Rows are shaded based on the Funding Plan: FCP = Fiscally Constrained Plan, AP = Action Plan, VP = Vision Plan
†Maintenance efforts for Lakewood Pipeline are funded through a separate account from capital improvement projects
*Black & Veatch. (2007b). Technical Memorandum 1: Boulder Reservoir Water Treatment Facility Source Water Contaminant Mitigation Costs dated August 21, 2007. Aurora, CO.

GREEN LAKE #2 (1A, 1B) - Structural maintenance to the dam should be completed in the next seven to 20 years. While Green Lake #2 has a relatively small storage volume, it has existing senior storage rights. Restoration of Green Lake #2 storage capacity would increase the reliability of the city's source water system. The reservoir site has already been impacted by previous construction and storage, so impacts would be relatively minor compared to new reservoir construction. Project alternatives and cost opinions were developed by ECI[7]. They found that the two lowest cost alternatives could be completed in one construction season. An engineering evaluation prior to final design and construction is recommended.

ALBION DAM (2A, 2B) - Within the next 20 years, the city should address the current seepage problem and make concrete repairs at Albion Dam. Harza recommended efforts on the downstream side of the dam[8]. However, newer membrane technology could be used to seal the upstream face from seepage, alleviating existing freeze/thaw damage and spalling. Carpi provided a cost proposal to install a geomembrane to cover and waterproof the upstream surface of the dam[9]. The system would include a stainless steel watertight perimeter, a geotextile to cover the irregular surface of the dam face, a drainage layer and plate, and the PVC geomembrane (see Figure 7-1).

Prior to installation of the geomembrane, the dam structure should be evaluated. In addition to evaluating any repairs needed prior to membrane application, this analysis could evaluate the feasibility of raising Albion Dam in the future. Raising the crest height of Albion Dam is likely to be an expensive project for the amount of storage gained due to the remote location of the dam and is considered a low priority project at this time. Unlike Green Lake #2, where the city has existing senior storage rights, an enlargement of Albion would need a new (junior) storage right which wouldn't yield as much per acre-foot of storage.

The crest and spillway concrete should also be repaired in the next seven to 20 years. Harza recommended low pressure grouting[10] because removal and replacement of the concrete would be difficult in this remote location, but this option will need to be confirmed by an updated engineering evaluation.

FIGURE 7-1. INSTALLATION OF GEOTEXTILE AND MEMBRANE OVER MASONRY FACE DAM[11]

ISLAND DAM (3) - Damage to the dam crest wall and upstream face need immediate repair in order to prevent additional damage and to continue operation of the dam (Staff facilities tour, September 20, 2007). Island Dam is a very important facility. Despite its small storage volume, the water rights associated with Island Lake are very senior. Patches are recommended in five to seven locations near the high water mark.

WATERSHED DAM VALVES (4A, 4B) - The individual watershed dams each represent a small part of the overall water supply, yet collectively, they comprise some of the city's most senior and reliable water rights. In order to maintain the reliability of this important water source, ongoing maintenance of valve works is needed. The city should replace the valves in greatest need over the next five years and continue valve replacement for the next 20 years. Replacement before the valves fail will substantially reduce the overall maintenance effort.

LAKEWOOD PIPELINE (5) - Lakewood Pipeline is a critical component of the city's source water system, and it is the only means to transport water from the Silver Lake Watershed and North Boulder Creek to Betasso WTF. Lakewood Pipeline was replaced in phases between 1995 and 2004. Portions of the final phase of pipeline replacement contain weld and mortar lining defects. The effects of these defects on pipeline longevity are not currently known. Therefore, the city should continue to follow the established regular inspection program and steps recommended in the 5th inspection report[12]. Lakewood Pipeline monitoring and maintenance are paid for by a separate fund established from a construction settlement agreement.

SKYSCRAPER RESERVOIR (6A, 6B) - Skyscraper Reservoir is not actively operated due to its small size and remote location. The city has generally regarded it as a last resort supply to be utilized in the event of severe drought. While it currently is not relied upon as a water source, there is value in maintaining the dam so that the water can be used if it is needed. The Drought Plan recommended that the city formally incorporate the operation of Skyscraper Reservoir into its water supply system[13].

In the next year, staff should perform a site visit to Skyscraper Reservoir to evaluate its current condition and the magnitude of seepage. A closed-circuit television (CCTV) system and/or diving could be used to view the state of the outlet gates.

In the next 20 years, an engineering evaluation of the dam should be conducted, and the gates should be replaced. If needed, a diver could be used to open the gates and drain down the reservoir to the gate level, and a pump could further reduce the storage level so that the upstream dam face can be inspected. Alternatively, the pipe could be plugged and new equipment could be installed underwater.

It is likely that in addition to the gate repairs and grouting to secure loose boulders, a membrane will be needed to reduce seepage for eventual integration of the reservoir into the city's operations. Due to the remote location, either mules or a helicopter are likely needed to mobilize supplies for construction at Skyscraper Reservoir. Because the current water demand projections indicate that the city will be able to meet its build-out water demand without fully incorporating Skyscraper Reservoir into the source water system, the reservoir lining project is not recommended in the next 20 years, unless the recommended inspection discovers significant dam safety issues.

BARKER RESIDENCE (6C) - The city should consider renting or purchasing a residence within sight of Barker Dam to improve access to and response time for operating the system.

BARKER DAM (7A, 7C, 7D) - Barker Dam is a component of the Boulder Canyon Hydroelectric Project currently licensed by FERC. In the past, FERC has required the reservoir to be significantly drawn down about every five years in order to inspect the outlet gates. During those years, the city forfeits a large quantity of stored water.

The outlet works should be replaced within the next seven to 10 years (7c) to eliminate the need to empty the reservoir for gate inspection. A design for outlet works replacement was completed by GEI, and initial bids were received in 2002[14]. The cost of the outlet works replacement could be substantially reduced by eliminating one of the proposed microtunnels (potential for optimization and value engineering).

Within the next six years, the 55 concrete caps over the anchor heads on the dam crest should be chipped out, the anchor heads inspected and then regrouted with air-entrained concrete or another material that would resist the continuous weathering conditions (7d).

The city should support the Town of Nederland in its efforts to upgrade the wastewater treatment facility (WWTF), which discharges into Barker Reservoir (7a). Nederland considered construction of a conventional wastewater treatment plant as well as more advanced technology and options. Use of MBR technology produces a better water quality effluent in terms of Cryptosporidium, Giardia, and suspended solids reduction when compared with other conventional technologies. Current research suggests that MBRs may be better for removal of microconstituents (e.g., pharmaceuticals) than conventional systems, though this is not conclusive at this time[15]. Although Boulder's source water is highly diluted by mixing in Barker Reservoir, several studies have suggested that the Nederland WWTF is a substantial source of nutrients to Barker Reservoir resulting in eutrophication and a potential source of pathogens to the city's Betasso water supply[16].

HANNAH BARKER HYDRO[ii] (7B) - The design for the Barker Dam outlet works modifications also includes space in the valve house for future hydro units. The turbine and generator could be installed after the outlet works replacement based on economic feasibility and/or direction from City Council. TCB concluded that available flow from Barker Reservoir that is currently released from Barker Dam (releases for instream flow and a portion of the water released over the spillway) could be used to generate hydroelectric power[17]. Assuming capacity payments would not be made for this facility, the project would be economically feasible if the city could sell the energy for $0.035 per kilowatt-hour. The city should continue to monitor electricity prices to determine if and when Hannah Barker Hydro should be constructed.

BARKER GRAVITY PIPELINE (7E, 8A, 8B) - Barker Gravity Pipeline is a critical component of the city's source water system because it conveys the city's Barker Reservoir/Middle Boulder Creek water to Betasso WTF. Stored water from Barker Reservoir and direct flows from Middle Boulder Creek are used to meet approximately 35 percent of the city's annual water needs. The city has, as part of an ongoing maintenance effort, already replaced and rehabilitated segments of the 11-mile Barker Gravity Pipeline that showed the most degradation or highest likelihood of failure. The city should continue its annual maintenance program, prioritizing based on the most critical needs, and also considering the recommendations of the FERC Part 12D inspection report[18] to provide enough cover to protect the pipeline, and anchor the pipeline in areas prone to landslides or other damaging

[ii] Staff named this hydroelectric project in honor of the woman who owned the land under Barker Reservoir.

events. Section replacement or lining in place are options that may each work well in different parts of the pipeline. The city should coordinate with the USFS concerning maintenance activities on federal land.

The city is in the process of replacing the license for the Boulder Canyon facilities with a license exemption[19]. The exemption would reduce the area under FERC jurisdiction to only the power plant structure and its immediate surroundings. Therefore, the city will need to obtain a separate land use authorization from the USFS for occupancy of federal land. The city will need to regularly coordinate with the U.S. Forest Service regarding maintenance and other project activities on USFS land. Within the next 20 years, the city should consider initiating a land exchange with the USFS to obtain the approximately 36 acres of federal land occupied by the Barker Gravity Line. Such an exchange might contribute to USFS efforts to consolidate currently fragmented land ownership and would eliminate federal involvement in Barker Gravity Line maintenance.

KOSSLER RESEVOIR (9A, 9B, 9C, 9D) - There are several improvements at Kossler Reservoir that need to be completed by 2010 based on recommendations in the FERC Part 12D Inspection Report[20]. Several of the recommendations are related to the cracked concrete at the reservoir outlet and the seepage that occurs along the low-head section of the penstock. A bypass pipeline connecting the Barker Gravity Line to the Boulder Canyon Hydro Penstock could meet several objectives:

- allow operation of the Barker System during times when Kossler Reservoir is out of operation for repair or other reasons;
- if connected downstream of Road 77, the bypass could reduce the seepage in the upper part of the penstock, and;
- halt erosion at the current Barker Gravity Line outlet to Kossler Reservoir.

If the bypass structure is constructed, the cracked outlet structure should still be repaired and upgrades should be made to the gate house in order to have multiple methods of operating Kossler Reservoir. GEI prepared construction cost estimates for Kossler Reservoir main dam concrete panel replacement[21]. This estimate recommended replacing panels below elevation 7,717 feet with localized repairs above that elevation by 2009.

The FERC Part 12D report also recommended additional maintenance on the main dam seepage weir (by 2009), installation of piezometers (by 2010) and installation of additional hydraulic monitoring equipment (by 2010). These efforts could be combined with replacement of the concrete panels on the main dam. The integrity of the rock walls at the dam abutments should also be evaluated. Additionally, tree growth needs to be controlled on the north dam, the capacity of the overflow spillway should be determined, and topographic surveys should be updated within the next six years[22].

BOULDER CANYON PENSTOCK (10A, 10B) - The Boulder Canyon Hydro Penstock was visually inspected in 2007, and no unexpected issues were discovered. However, the Boulder Canyon Penstock is approaching 100 years in age, and a more detailed inspection involving metallurgy and corrosion experts should be conducted within the next 20 years. In conjunction with detailed evaluation of the penstock, a review of the life spans and histories of similar structures could help the city anticipate problems which might arise in the future.

BOULDER CANYON HYDRO (10C) - The Boulder Canyon Hydro turbine-generators were originally installed in 1910 and 1936, and one unit is currently inoperable. Due to the likelihood of failure and potential for operator injury, the Boulder Canyon Hydro unit should be replaced with an appropriately sized hydro unit within the next five to 10 years. With the conversion of Barker Reservoir from hydropower generation to municipal water supply, the 20,000 kW capacity established in 1936 can no longer be supported. The current unit could be replaced with a new unit, but it is likely that the new unit would be smaller (5 MW or less) given the available water supply.

Over the next year, the city should continue efforts to obtain a conduit exemption from FERC licensing for the Barker System. The city should plan to extend or renegotiate the power sales contract with Xcel Energy, which is set to expire in 2009[23].

BOULDER FEEDER CANAL (11A, 11B, 11C, 11D) - Although the city has made progress in conveying stormwater over the Boulder Feeder Canal, there are still several outfalls that discharge to the canal. Within the next six years, the city should continue to construct stormwater diversions over the canal, giving priority to those outfalls with commercial, industrial, or agricultural land uses and where little vegetative buffer exists between land uses and the canal.

Recognizing mixed overall support to date and based on discussions with the CSG[24] and recommendations from the staff survey[25], the city should continue initial project evaluation for the Carter Lake Pipeline. Efforts include development of a CEAP, right-of-way acquisition, preliminary design and permitting activities. The CEAP will provide for a thorough analysis of the project merits, and the right-of-way acquisition and permitting activities will allow the project to proceed with limited delay should it ultimately be approved.

This approach is in accordance with the findings of the Boulder Reservoir WTF Integrated Source Water and Treatment Study[26]. The study recommended an alternative including full containment from Carter Lake to Boulder Reservoir WTF combined with chlorine dioxide pre-oxidation at the treatment facility, although this option was more expensive than some of the other alternatives evaluated.

The addition of the Carter Lake Pipeline would increase the city's flexibility in using this water source since it would allow water delivery via the canal to the Boulder Reservoir WTF year round. Currently, the Boulder Feeder Canal operates seasonally. In order to take advantage of opportunities to share costs and collaborate with other stakeholders, construction of the Carter Lake Pipeline should commence within the next six years.

Eventually, the city may want to consider the economic and environmental benefits of adding a hydro unit to the pipeline connecting Carter Lake and the Boulder Reservoir WTF. The addition of any new hydro facilities should be in accordance with guidance provided by City Council.

BOULDER RESERVOIR TO BOULDER CREEK EXCHANGE PIPELINE (12) - A low pressure pipeline from Boulder Reservoir to the mouth of Boulder Canyon, possibly running along the Farmer's Ditch alignment, could be used to improve the city's exchange potential. The pipeline length would be about 10.5 miles with an elevation gain of about 220 feet. Modeling of Boulder's current water supply system shows that at build-out, the city would meet its reliability criteria without the construction of an exchange pipeline. Therefore, this project is not recommended in the next 20 years, but it should be monitored for future feasibility and need.

WITTEMYER PONDS (13) - Use of Wittemyer Ponds for exchange is expected to be critical for Boulder's water supply under build-out water demand conditions. To maximize the storage available, the existing ponds should be expanded. A previous analysis suggested that storage volume could feasibly be increased to about 1,300 acre-feet[27]. In addition, the ponds would need to be lined on the sides. Additional water court approvals may be required for storage in the lined ponds of any new additions to the city's reusable supplies. The city should continue to evaluate changes in demand and its water supply portfolio prior to any construction or water court efforts regarding the use of Wittemyer Ponds. This project should be planned for the next 15 to 20 years, but might be undertaken sooner if determined to be an integral part of the South Boulder Creek instream flow efforts. Longer term, if climate change or other factors caused significant decline in the exchange potential on Boulder Creek, a low pressure pumped pipeline could be constructed from Wittemyer Ponds to Boulder Reservoir to return captured return flows to a point where they might be reused in the municipal water system.

FARMERS DITCH CAPACITY RESTORATION - One of the water rights the city conveyed to the CWCB for instream flow is for 13.52 cfs of the Farmers Ditch. Under the conveyance agreement, Boulder retained the right to divert this 13.52 cfs through the Farmers Ditch to Boulder Reservoir for municipal use (without storage) at Boulder Reservoir WTF whenever that right is not needed for instream flow (typically May through mid-July) and subject to certain annual and long-term volumetric limits on diversions. The potential yield to Boulder from such diversion is significant and was assumed to be available in the city's modeling studies. However, the delivery capacity of the Farmers Ditch has degraded over time and is currently insufficient to allow Boulder to divert the full 13.52 cfs when irrigation shareholders (principally OSMP) are taking water[28]. An evaluation should be conducted to determine the best way to restore needed delivery capacity and the associated costs and impacts. Capacity restoration should be planned for the next 10 to 15 years.

7.2.2 | Minor Projects

Other minor facilities improvement projects (each with a total cost less than $50,000) which could potentially be funded through an operating budget are summarized in Table 7-3. Top priority minor projects are shown in bold type.

TABLE 7-3. LIST OF MINOR IMPROVEMENT PROJECTS AND PRIORITY (CAPITAL COST LESS THAN $50,000)

Item #/ Funding Plan	Project	Priority	Project Description
North Boulder Creek Water Source			
1/FCP	**Green Lake #1 Outlet Repair**	**1**	**Repair non-functional outlet slide gate**
2/FCP	**Albion Dam Gage and Outlet Access**	**1**	**m) Install staff gage n) Install access to valve house patio**
3a/FCP	Silver Lake Dam generator	2	Portable generator to electrically actuate valves and power lighting
3b/FCP	Silver Lake Dam bypass repair	2	Repair non-functional bypass for low flows
4a/FCP	Silver Lake Residence SCADA	2	Tie into the SCADA monitoring system with internet capability via satellite
4b/FCP	**Silver Lake Residence and Bunk House roof replacement**	**1**	**Replace with metal roofs**
5/FCP	**Goose Dam control panel/actuator/ generator**	**1**	**Control panel on the top of the dam to actuate valves with portable generator**
6/FCP	Instream flow gage installation - North Boulder Creek	2	Gage installation on North Boulder Creek at Sherwood Creek
7/FCP	NBC instream flow recording upstream of Lakewood	2	Redesign of current system to measure low flows
Middle Boulder Creek Water Source			
8a/FCP	**Barker Dam floodgate conduit inspection**	**1**	**Video or manual inspection of floodgate conduits**
8b/FCP	**High water alarms upstream of Orodell**	**1**	**Alarms to warn of rapidly increasing flows**
9/FCP	Kossler inlet erosion	2	Armor Barker Gravity Line outlet to Kossler Reservoir to prevent further erosion
Other Minor Projects			
10/FCP	Raw water irrigation systems	2	Develop raw water irrigation systems for city properties where feasible

Priority Levels: 1 = next 6 years, 2 = next 7 to 20 years, 3 = long-term
Rows are shaded based on the Funding Plan: FCP = Fiscally Constrained Plan

The text below presents a brief narrative for each project listed in Table 7-3. The numbers in parenthesis following each facility name correspond to the numbers in Table 7-3.

GREEN LAKE #1 (1) - The city should repair or replace the non-functional slide gate in next five years. This will involve draining the reservoir by forcing the gate open in July or August. Due to the custom gate design, parts special fabrication may be needed for gate connections.

ALBION DAM GAGE AND OUTLET ACCESS (2) - Minor projects that should be completed within five years at Albion Dam include improving access to the valve house and installing a staff gage to measure reservoir storage.

SILVER LAKE DAM (3A, 3B) - In the next two years, the city should complete a video camera inspection of the Silver Lake valves to confirm their status. In the next 20 years, the bypass for low flows which is currently not functional should be repaired. Low flows are currently conveyed through the gate valve, which can cause cavitation. The valves are custom made, and correct sizing of connections will be important (or valve replacement could be considered). The city should purchase a portable generator that can be used to electrically actuate valves and provide lighting in the valve house.

SILVER LAKE RESIDENCE (4A, 4B) - In the next five years, the residence and bunk house roofs should be replaced. In the next 10 years, access to the city's SCADA system should be provided at the Silver Lake residence. Due to the remote location, a satellite connection is likely more feasible and cost effective for providing access to the SCADA system than extending the fiber optic cable from the Lakewood Residence. Stratos Global provided a quote for various levels of internet service[29]. Hardware costs would be minimal, and satellite service would include a monthly fee. Careful coordination with the city's IT department would be required to implement this project. The residence could either be connected directly to the city's SCADA system, or relevant data could be posted to a secured website that remote users could view. Access to the city's SCADA data would need to be provided in accordance with the city's security rules.

GOOSE DAM (5) - The city should add a control panel on the top of the dam to actuate valves with a portable generator. This would alleviate the need to dig through the snow to reach the valve house in winter.

INSTREAM FLOW GAGE INSTALLATION (6) - A gage is needed on North Boulder Creek at Sherwood Creek in connection with the CWCB instream flow agreement and the instream flow decree. Installation could be done in coordination with the State's Division of Water Resources or the USGS, which provide some technical support and cost sharing.

NORTH BOULDER CREEK DIVERSION TO LAKEWOOD (7) - It is difficult to measure flows less than 2 cfs in the Parshall flumes because they are intended for a higher flow rate range. The current design of diversion structures near Lakewood Reservoir should be evaluated to determine the best modifications to allow low flow measurement. Instrumentation at the constant head orifices downstream of the flumes could potentially be used to measure head differential and combined with the orifice gate setting, be used to record low flows.

BARKER DAM FLOODGATE CONDUIT INSPECTION (8A) - The condition of the lower seven outlets should be inspected in the next year at a time when the reservoir is drawn down.

HIGH WATER ALARMS (8B) - The FERC Part 12D inspection report recommended the installation of high water alarms by 2009 upstream of Orodell to "detect unexpected releases and provide advanced warning of rapidly increasing flows in Middle Boulder Creek"[30].

KOSSLER INLET EROSION (9) - The Barker Gravity Line outlet to Kossler Reservoir should be armored, particularly below the concrete slab and weir, to prevent further erosion and undercutting of the structure.

RAW WATER IRRIGATION SYSTEMS (10) - Using untreated water for irrigation reduces the demand on water treatment and distribution facilities. Along with reducing treatment and distribution costs, the reduction in summer peak demands that could be achieved by changing large city properties from treated water irrigation to raw water irrigation might delay or prevent the need to expand water system facilities such as pump stations, pipelines or treatment processes. Staff recommends that opportunities for raw water irrigation systems for city properties be identified and implemented if feasible. The majority of these opportunities will exist for properties managed by the Parks Department or Transportation Division, which will need to carry the majority of the cost. The water utility might assist these efforts with technical expertise or some level of funding.

7.3 | Programs

Programs include recommended studies, environmental enhancements and other staff efforts. Programs would probably be funded as part of the capital improvement program or through annual operating budgets. Recommended programs are listed by water source followed by recommendations that pertain to system-wide efforts. Each of the recommended programs is shown in Table 7-4. Top priority programs are shown in bold type.

TABLE 7-4. RECOMMENDED SOURCE WATER PROGRAMS AND STUDIES

Item #/ Funding Plan	Program/Study	Source	Issue(s) Addressed	Priority	Cost
North Boulder Creek Water Source					
1/FCP	**Evaluate Lakewood Dam and report on the longitudinal cracks observed in 2001**	**Staff**	**Facilities condition**	**1 (within the next year)**	**$15,000**
Middle Boulder Creek Water Source					
2/FCP	**FERC Part 12D Inspection Report recommendations**	**Staff**	**O&M (Operations/ Maintenance)**	**1**	**$30,000**
3/FCP	**Collaborate with other entities to prepare a community watershed wildland fire protection plan for the Middle Boulder Creek basin**	**CSG**	**Watershed management wildland fire**	**1 (ongoing)***	**$50,000**
South Boulder Creek					
4/FCP	**Assist the Open Space and Mountain Parks Department in developing an approach and organizational structure to provide instream flows in South Boulder Creek**	**CSG**	**Water use - instream flow protection**	**1**	**Staff Time**
5/FCP	**Explore options for use of Utilities assets within a comprehensive city program for improved instream flows on South Boulder Creek**	**CSG**	**Water use - instream flow protection**	**1 (ongoing)***	**Staff Time**

Item #/ Funding Plan	Program/Study	Source	Issue(s) Addressed	Priority	Cost
Colorado River Water Source					
6/AP	Continue to monitor developments on the Colorado River Compact. If the State study is inadequate, move ahead with other interested parties to conduct study of West Slope climate change impacts and mitigation option.	CSG	Water rights yields and protection	2	TBD
7/FCP	**Take immediate action to prevent or delay the introduction of zebra and quagga mussels to Boulder Reservoir by improving oversight on recreation and coordinating with NCWCD**	**Staff**	**Watershed management and invasive/non-native species**	**1**	**Staff Time**
8/FCP	**Continue involvement in Boulder Feeder Canal trail design to reduce potential impacts to the water supply**	**Staff**	**Source water protection**	**1 (ongoing)***	**Staff Time/FCP**
9/AP	**Work with the Parks and Recreation Department regarding planning for recreational uses on Boulder Reservoir**	**Staff**	**Source water protection**	**1 (ongoing)***	**Staff Time/AP**
10/FCP	**Take an active role in NCWCD's activities to proactively protect the quality of West Slope water supplies**	**Staff**	**Source water protection**	**1 (ongoing)***	**Staff Time/FCP**
System-Wide					
11/FCP	**Complete a source water emergency plan**	**CSG**	**Security, remote operation and monitoring**	**1**	**TBD/FCP**
12/FCP	**Update water demand projections based on BVCP and changes in demographic/water use projections**	**CSG**	**Water use - municipal use and conservation**	**1**	**$50,000**
13/FCP	**Complete modeling to define the level of reliability resulting from updated demand projections, water conservation savings and supply projections**	**CSG**	**Water use - municipal use and conservation**	**1**	**$100,000**
14/FCP	**Update water use conservation studies for water use in non-drought periods; update 2003 Drought Response Plan**[iii]	**CSG/WRAB**	**Water use - municipal use and conservation**	**1**	**$50,000/ $50,000**
15/AP	Explore the pros and cons of long-term commitments to non-municipal water uses	CSG	Water use - non-municipal uses	2	TBD
16/FCP	**Update aquatic habitat studies to assess effectiveness of current instream flow program and, if needed, evaluate options for providing enhanced habitat in sufficient detail to identify impacts, costs and benefits**	**CSG**	**Water use - instream flow protection**	**1**	**$100,000**
17/AP	Evaluate environmentally and economically feasible hydroelectric sites within the water transmission system	CSG	Water use - hydropower	2	TBD

[iii] The CSG recommended updating water use and conservation studies; WRAB recommended updating the Drought Response Plan.

Item #/ Funding Plan	Program/Study	Source	Issue(s) Addressed	Priority	Cost
18/FCP	**Develop a maintenance plan and corresponding maintenance logs for each water source to document daily and seasonal operations and maintenance needs.**	**Staff**	**Maintenance planning and execution**	**1 (ongoing)***	**TBD**
19/FCP	Evaluate the balance in reliance on East Slope and West Slope supplies and determine if a change in the balance would cause a need for new water supplies at build-out	CSG	Water rights yields and protection and balancing of water sources	2	TBD
TOTAL COSTS FOR PRIORITY 1 PROGRAMS					**$395,000**

Priority Levels: 1 = next 6 years, 2 = next 7 to 20 years, 3 = long term
Rows are shaded based on the Funding Plan: FCP = Fiscally Constrained Plan, AP = Action Plan
*As information and opportunities arise

LAKEWOOD DAM (1) - The longitudinal cracking of Lakewood Dam noted in 2001 should be rechecked to document that no significant changes in the dam condition have occurred[31].

FERC PART 12D INSPECTION REPORT RECOMMENDATIONS (2) - Several studies were recommended in the 2007 FERC Part 12D Inspection Report for the Boulder Canyon Hydroelectric Project[32]. These studies should generally all be completed by 2010. Recommendations and include the following:

- set action and threshold levels for piezometers at Kossler Dam (approximately $5,000);
- confirm hazard classification of Kossler Reservoir based on potential downstream damage (approximately $20,000);
- monitor seepage along the upper portion of Boulder Canyon Penstock to determine if there is a correlation with Kossler Reservoir levels (staff time);
- record reservoir levels at Barker Dam when the reservoir is above the spillway crest (staff time), and;
- update the maximum credible earthquake for Barker Dam for use in potential future project modifications (less than $5,000).

MIDDLE BOULDER CREEK WATERSHED WILDLAND FIRE PLAN (3) - The CSG recommended implementing fire risk identification and fire hazard mitigation measures as part of a watershed protection program with Boulder County, the Towns of Nederland and Eldora, the USFS and others[33]. Wildfire response should also be addressed in the Source Water Emergency Plan (see System-Wide Recommendations, below).

SOUTH BOULDER CREEK INSTREAM FLOWS (4, 5) - The goal of an improved instream flow program for South Boulder Creek was discussed at length in the CSG meetings. The CSG acknowledged that South Boulder Creek is not one of the sources for the city's drinking water, yet realized the potential for Utilities Division participation in implementation of an instream flow program. The CSG made a near term recommendation that the Utilities Division assist OSMP in developing an approach and organizational structure to provide instream flows in South Boulder

Creek in sufficient detail to identify costs and benefits[34]. Water Resources staff could provide insight on decisions related to water rights purchases, collaboration with South Boulder Creek water users and determining the need for a more reliable environmental pool in Gross Reservoir.

Senior water rights would need to be donated or purchased to create reliable instream flows in South Boulder Creek. A joint effort among Denver Water, Xcel Energy (in conjunction with Valmont Reservoir use for cooling), FRICO and the City of Lafayette would probably be the most effective way to obtain senior water rights for instream flow purposes. The city could independently pursue use of Wittemyer Ponds or Baseline Reservoir for exchange into the environmental pool at Gross Reservoir, but these actions may not provide instream flow water in every year. Any actions taken by the water utility would have to be done in accordance with enterprise fund requirements and restrictions.

COLORADO RIVER COMPACT STUDY (6) - The CSG recommended that the city continue to monitor developments on the Colorado River Compact. The State's "Colorado River Water Availability Study," which began in the fall of 2008, will attempt to estimate the future availability of water from the Colorado River to Colorado water users, and as currently scoped, will consider Compact issues and alternative hydrologic scenarios including paleo-hydrology and climate change. The city should track this study for findings that could help plan for water supply availability from the West Slope. If this study is inadequate, the city should collaborate with other interested parties to study West Slope climate change impacts and mitigation options[35].

INVASIVE SPECIES (7) - The city should take action to prevent the introduction of zebra and quagga mussels to Boulder Reservoir. Actions that delay introduction of these invasive species can delay considerable expenditures that could be necessary once the mussels colonize the reservoir.

The Colorado Department of Natural Resources through the Colorado Division of Wildlife and Colorado State Parks is making a concerted effort throughout the state to avoid the spread of zebra and quagga mussels to other Colorado waters. The Department's recommendations for recreational water users[36] include the following:

- clean boat hull after each use;
- drain the water from the boat, livewell and the lower unit of the engine;
- dry the boat, fishing gear, and equipment;
- inspect all exposed surfaces, and;
- remove all plant and animal material.

Colorado agencies and groups such as the Colorado Weed Management Association (CWMA) host aquatic nuisance species workshops that can include training on watercraft and equipment inspection as well as decontamination practices.

Municipal reservoir managers throughout Colorado are making changes to recreational programs to avoid introduction of these species via recreational equipment including the following:

- boat inspections and boater interviews prior to launch;
- banning of live bait;
- tagging of boats to identify if they have been used in other waters, and;
- drying and quarantine of boats used in other waters.

The city can leverage the efforts of other water suppliers to formulate a program that works for Boulder's needs. This program could be based on the established programs at Standley Lake. Most of the water supply in Boulder Reservoir is delivered via NCWCD's CBT Project. This water could potentially be stored in several reservoirs including Lake Granby, Grand Lake or Carter Lake. Recreation in these reservoirs is managed by the USFS or Larimer County. The city should work with NCWCD, the USFS and other state, county and entities that are stakeholders in the CBT system to evaluate the CBT system to understand which reservoirs are most at risk for mussel infestation, to understand the impact of mussels on operational and recreational practices, to identify responsive measures if mussels are found in the reservoirs, and to increase public participation in best practices to avoid the spread of mussels.

COORDINATION WITH OTHER STAKEHOLDERS (8, 9, 10) - A number of suggestions concerning coordination and communication with outside interests were received from city staff. The CSG also suggested that the city should more actively pursue collaboration with other water users. These efforts can involve continuing to work with other Boulder Reservoir stakeholders to reduce or mitigate water quality impacts and with other CBT users and NCWCD to evaluate operational concerns with the CBT Project.

SOURCE WATER EMERGENCY PLAN (11) - The CSG recommends that the city develop a source water emergency plan to evaluate risks to the water deliveries if there is a reduction in yield or quality of one or more of the city's water sources as a result of climate change, localized drought, compact call, wildfire, infrastructure failure or contamination event[37]. The plan should outline emergency response measures to be taken and define the city's ability to deliver water if a catastrophic event were to disable a portion of the source water system.

WATER DEMAND PROJECTIONS UPDATE (12, 13, 14) - The CSG considered a water demand projection update based on the most recent Boulder Valley Comprehensive Plan demographic projections to be an urgent need[38]. The update should include estimates of savings from federal mandates, advances in fixture manufacture, the city's water budget program and the water conservation plan. Water use factors and the current level of water conservation should be also be updated. The CSG further recommended that the city define the level of water supply reliability associated with the updated demand projections, water conservation savings and supply projections. WRAB suggested updating the 2003 Drought Plan, and staff concurs that this should be revisited.

LONG-TERM COMMITMENTS TO NON-MUNICIPAL WATER USES (15) - The CSG recommended that the city study the costs and benefits of long-term commitments of water to non-municipal uses such as instream flows and other environmental enhancements, recreation, and agricultural leasing[39].

EFFECTIVENESS OF THE CURRENT INSTREAM FLOW PROGRAM (16) - The CSG considered it urgent for the city to update aquatic habitat studies to assess the effectiveness of the existing instream flow program and to identify options for further habitat advancement[40]. In addition, the studies should identify impacts, costs and benefits of further enhancement of instream flows up to the desired minimum flows previously designated by the CWCB.

HYDROELECTRIC POWER GENERATION (17) - The CSG recommended that the city continue to develop the hydroelectric potential within the source water system where environmentally and economically feasible[41].

SYSTEM OPERATION AND MAINTENANCE (18) - The staff survey included numerous comments on operations and maintenance of the source water facilities. The source water system operations staff generally have been in their positions for a number of years and are very familiar with the facilities and features associated with the source water infrastructure. Operations and maintenance manuals exist for many, but not all, of the city's source water facilities. The city's current operations and maintenance program involves occasional exercising of valves, taking pipeline cathodic protection readings, inspecting the inside of pipelines, periodic visits to most active source water facilities, etc. In addition, source selection and water delivery requirements require reasonably frequent operation of gates and valves at various points of diversion within the city's system. The aforementioned activities which may be seasonal, monthly, weekly or daily create a reasonable staff presence within the city's source water system. As a result, the city has an active, hands-on operation and maintenance program, and repairs, replacements and rehabilitation activities are ongoing. Due to staff availability, training and other factors, the existing operations and maintenance program is for the most part fairly reactive and informal.

Opportunities to build on and formalize the existing operations and maintenance program within the source water system include the following:

- creating a systematic plan and schedule;
- improving documentation;
- building on preventive maintenance activities;
- clarifying which staff is responsible for "stranded facilities" such as air relief vaults and the raw water fire systems;
- creating operations and maintenance manuals/procedures for facilities for which no such documentation exists;
- developing a process to identify and provide required funding of maintenance activities, and;
- identifying activities requiring outside resources and contractors.

The periodic tasks should be documented in a maintenance plan for each of the three major sources in Boulder's system. Once the maintenance plans and schedules are developed, corresponding logs should be created. The logs should document when major or less frequent activities, such as exercising of particular watershed dam valves, are completed. They should also note any problems that may be developing in the system. They should be brief, user friendly, and developed with consideration of the operators' time and remote location constraints. Each year these logs should be scanned into an annual report. Annual reports can then be used to plan the following year's maintenance including budgeting and placing the projects on the monthly maintenance schedule. Utilities should also investigate the usefulness of a tracking database for watershed facilities, similar to the distribution and septic system maintenance database. Recommended minor projects (section 7.3) should also be added to the monthly maintenance calendar.

Due to staff availability and system features requiring specialty knowledge, contractors have been a vital component of the city's maintenance projects. Staff should continue to budget for contractors and consider developing continuing services agreements with contractors.

BALANCE BETWEEN EAST SLOPE AND WEST SLOPE WATER SOURCES (19) - The CSG expressed mixed opinions concerning whether the city has the appropriate balance between east slope and west slope water supplies to best meet future challenges, goals and objectives. An analysis of the costs and benefits of changing the current reliance on east slope and west slope supplies was recommended[42] as a necessary tool to reach informed decisions concerning:

- acquisition of interruptible agricultural leases;
- future use of groundwater supplies;
- acquisition of additional East Slope supplies and means of delivery to Boulder;
- sizing of future treatment processes at the Boulder Reservoir Water Treatment Facility;
- use of more CBT and Windy Gap water;
- West Slope replacement supplies;
- methods to increase stream recharge;
- keeping Windy Gap units and firming Windy Gap;
- repair and enhancement of storage capacity in the Boulder Creek basin;
- use of Boulder's exchange rights, and;
- new appropriations.

While current studies show that the city's water rights portfolio and facilities should be able to meet the city's water demands at build-out, a change in the current level of reliance on east slope and west slope water sources, changes in demand projections at build-out and/or changes in the current assessment of the effects of climate change could result in a need to acquire new water rights. It is not recommended that any acquisitions of new water rights be made solely to address this possibility at this time because the analysis of the appropriate balance between west slope and east slope supplies should be completed first.

As part of this analysis as well as part of routine ongoing water system modeling, the staff will continue to evaluate climate change effects on Boulder's water supply.

TABLE 7-5. 20-YEAR CIP

Project Name	Total	Assumed Inflation Rate																								
		Estimated 2008 Cost	Actual	Revised	Recommended	Projected																				
			2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
SOURCE WATER TRANSMISSION SYSTEM																										
Lakewood Pipeline	**$28,699,718**		$248,828	$113,124	$100,000	$100,000	$0	$1,238,060	$0	$119,405	$0	$126,677	$0	$8,063,498	$0	$142,576	$0	$151,259	$0	$9,347,804	$0	$170,243	$0	$8,778,243	$0	$0
Source Water Transmission Pipe Inspections	**$160,000**		$0	$0	$80,000	$0	$0	$80,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	***$28,859,718***		*$248,828*	*$113,124*	*$180,000*	*$100,000*	*$0*	*$1,318,060*	*$0*	*$119,405*	*$0*	*$126,677*	*$0*	*$8,063,498*	*$0*	*$142,576*	*$0*	*$151,259*	*$0*	*$9,347,804*	*$0*	*$170,243*	*$0*	*$8,778,243*	*$0*	*$0*
BARKER WATER SYSTEM																										
Barker Gravity Pipeline Repair	**$22,610,041**	$20,000,000	$907,699	$777,664	$360,500	$371,315	$382,454	$393,928	$405,746	$417,918	$922,405	$950,078	$978,580	$1,007,937	$1,038,175	$1,069,321	$1,101,400	$1,134,442	$1,168,476	$1,203,530	$1,239,636	$1,276,825	$1,315,130	$1,354,583	$1,395,221	$1,437,078
Barker-Kossler Penstock Repair	**$135,466**	$100,000	$4,989	$0	$0	$0	$0	$0	$0	$0	$0	$0	$130,477	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Dam Outlet	**$799,448**		$18,540	$0	$0	$0	$0	$0	$0	$780,908	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Dam Outlet - Bond Proceeds	**$7,809,084**	$7,055,000	$0	$0	$0	$0	$0	$0	$0	$0	$7,809,084	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Dam	**$430,456**	$350,000	$0	$0	$0	$0	$0	$0	$0	$0	$430,456	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Hydro System Integration	**$178,239**		$76,994	$101,245	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Relicensing	**$1,769,486**		$116,132	$400,000	$1,000,000	$0	$0	$0	$0	$0	$0	$253,354	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Instream Flow Release	**$58,824**		$58,824	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Betasso Penstock	**$3,361,383**		$272,671	$3,088,712	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Source Water Protection	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Kossler Reservoir	**$1,300,451**	1,200,000	$0	$0	$0	$360,706	$939,745	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	***$38,452,879***		*$1,455,849*	*$4,367,621*	*$1,360,500*	*$732,021*	*$1,322,200*	*$393,928*	*$405,746*	*$1,198,827*	*$9,161,945*	*$1,203,432*	*$1,109,057*	*$1,007,937*	*$1,038,175*	*$1,069,321*	*$1,101,400*	*$1,134,442*	*$1,168,476*	*$1,203,530*	*$1,239,636*	*$1,276,825*	*$1,315,130*	*$1,354,583*	*$1,395,221*	*$1,437,078*
RAW WATER STORAGE RESERVOIRS																										
Albion Dam	**$4,203,415**	$3,075,000	$0	$0	$0	$0	$0	$0	$0	$0	$92,241	$0	$0	$373,743	$3,737,431	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silver Lake Dam	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Island Lake Dam	**$108,150**	$105,000	$0	$0	$108,150	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Green Lake 1 Dam	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Green Lake 2 Dam	**$4,995,502**	$3,875,000	$0	$0	$0	$0	$0	$0	$86,946	$0	$0	$446,232	$4,462,324	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Green Lake 3 Dam	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Goose Lake Dam	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Boulder Reservoir	**$128,318**	$90,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$128,318	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lakewood Reservoir	**$137,751**	$102,500	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$137,751	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Skyscraper Dam	**$167,990**	125,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$167,990	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Wittemyer Ponds	**$6,032,736**	4,000,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$587,413	$5,445,323	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	***$15,773,863***		*$0*	*$0*	*$108,150*	*$0*	*$0*	*$0*	*$86,946*	*$0*	*$92,241*	*$446,232*	*$4,462,324*	*$679,484*	*$3,737,431*	*$128,318*	*$587,413*	*$5,445,323*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
OTHER RAW WATER FACILITIES																										
Farmer's Ditch	**$122,987**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$122,987	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Anderson Ditch	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Watershed Improvements	**$688,610**	$440,500	$0	$0	$0	$0	$317,437	$0	$0	$0	$92,241	$0	$0	$0	$0	$106,932	$0	$0	$0	$0	$172,000	$0	$0	$0	$0	$0
Nederland WWTF	**$300,000**		$0	$0	$300,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Instream Flow Structures and Gaging	**$50,000**		$0	$0	$0	$0	$50,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Como Creek Diversion Structure	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lakewood Diversion Structure	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silver Lake Diversion Structure	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
NCWCD Conveyance - Boulder Feeder Canal	**$739,623**	$283,000	$98,636	$340,752	$0	$300,235	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
NCWCD Conveyance - Carter Lake Pipeline	**$3,936,618**		$131,250	$1,118,750	$0	$0	$0	$0	$2,686,618	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
NCWCD Conveyance - Bond Proceeds	**$26,866,177**		$0	$0	$0	$0	$0	$0	$0	$26,866,177	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

Project Name	Total	Assumed Inflation Rate																								
		Estimated 2008 Cost	Actual	Revised	Recommended	Projected																				
			2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Subtotal	***$32,704,014***	*$25,000,000*	*$229,886*	*$1,459,502*	*$300,000*	*$300,235*	*$367,437*	*$0*	*$2,686,618*	*$26,866,177*	*$92,241*	*$0*	*$0*	*$0*	*$122,987*	*$106,932*	*$0*	*$0*	*$0*	*$0*	*$172,000*	*$0*	*$0*	*$0*	*$0*	*$0*
SOURCE WATER PRV, PUMPING AND HYDRO																										
Lakewood Hydroelectric	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Silver Lake Hydroelectric	**$0**		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Boulder Reservoir Intake and Pumping	**$100,000**		$0	$0	$100,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Betasso Hydro PRV Station	**$215,826**		$0	$215,826	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Barker Dam Hydro	**$3,652,725**		$0	$0	$0	$0	$0	$0	$0	$0	$3,652,725	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Boulder Canyon Hydro	**$7,766,278**	$3,300,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$7,766,278	$0	$0
Source Water Pressure Reducing, Pumping and Hydroelectric Facility Rehabilitation	**$4,402,900**	$4,300,000	$0	$0	$0	$0	$0	$0	$0	$0	$218,432	$224,985	$231,734	$238,686	$245,847	$253,222	$260,819	$268,643	$276,703	$285,004	$293,554	$302,360	$311,431	$320,774	$330,397	$340,309
Subtotal	***$11,734,830***		*$0*	*$215,826*	*$100,000*	*$0*	*$0*	*$0*	*$0*	*$0*	*$3,871,157*	*$224,985*	*$231,734*	*$238,686*	*$245,847*	*$253,222*	*$260,819*	*$268,643*	*$276,703*	*$285,004*	*$293,554*	*$302,360*	*$311,431*	*$8,087,052*	*$330,397*	*$340,309*

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