Chapter 1 - Environmental Setting and Hydrology of the Boulder Creek Watershed, Colorado

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Abstract

The Boulder Creek Watershed, Colorado, is 1160 square kilometers in area and ranges in elevation from 1480 to 4120 meters above sea level. The watershed consists of two regions that differ substantially in geology, climate, and land use. The upper basin consists primarily of Precambrian metamorphic and granitic bedrock with alpine, subalpine, montane, and foothills climatic/ecological zones. It is sparsely populated, and forest is the dominant land cover. The lower basin consists primarily of Paleozoic and Mesozoic sedimentary rocks with a plains climatic/ecological zone. The majority of the population in the watershed lives in the lower basin, where dominant land covers are grassland, agricultural land, and urbanized land.

Streamflow in the Boulder Creek Watershed originates primarily as snowmelt at and near the Continental Divide, and thus discharge shows great seasonal and annual variation. Most of the water in Boulder Creek is diverted for domestic, agricultural, and industrial use. Some diverted water is returned as wastewater effluent and groundwater contributions to baseflow. Non-native water is brought into the watershed by transbasin diversions. These diversions and returns lead to complex temporal and spatial variations in discharge.

The differing geology, climate, land use, and water use produce variations in water quality within the watershed. Boulder Creek can be further divided into five reaches based on hydrology and water quality: headwater, mountain, urban, wastewater-dominated, and wastewater/agricultural/aggregate-mining dominated reaches.

The issues affecting the Boulder Creek Watershed are typical for many river systems in the American West. Accordingly, the Boulder Creek Watershed offers an excellent opportunity to evaluate the potential effects of natural and anthropogenic processes on a small river system. Boulder Creek and its tributaries were sampled during high-flow and low-flow conditions in the year 2000. The study was a cooperative effort of the U.S. Geological Survey, the city of Boulder, and the University of Colorado, and included measurements of discharge, basic water quality variables, major ions, trace metals, wastewater-derived organic compounds, and pesticides. In addition, geographic information systems were used to delineate geology, land use, and watershed boundaries. This chapter briefly describes the physiography, climate, geology, vegetation, land use, and hydrology of the Boulder Creek Watershed and the natural and anthropogenic factors that can potentially affect water quantity and quality.

INTRODUCTION

Conditions such as climate and geology affect the natural water chemistry of a stream, while anthropogenic factors such as land and water use also can have considerable influence on water quality. In order to effectively evaluate water quality of a stream, the environmental setting and hydrology of its basin must be well characterized.

Purpose and Scope

This chapter briefly describes the physiography, climate, geology, vegetation, land

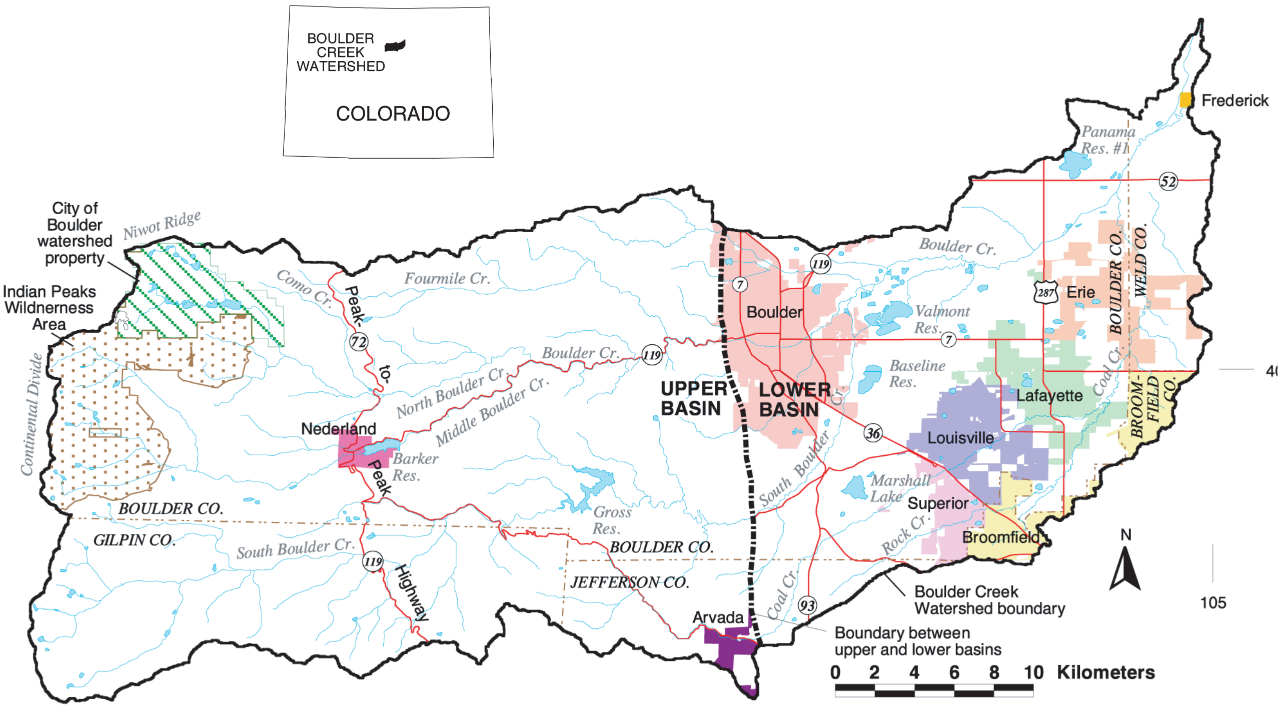

Figure 1.1. Map of the Boulder Creek Watershed showing location of study area, political boundaries, and major transportation routes. (County boundaries from National Weather Service, 2002; municipal boundaries from Colorado Department of Local Affairs, 2002; roads from Colorado Department of Transportation, 2002; surface waters from U.S. Geological Survey, 2002a; Indian Peaks Wilderness boundary from U.S. Department of Agriculture Forest Service, 2002; City of Boulder watershed property boundary courtesy City of Boulder)

use, and hydrology of the Boulder Creek Watershed and the potential solute sources that can affect water chemistry. A flow balance of the Middle Boulder Creek/Boulder Creek profile during high-flow and low-flow conditions is calculated. This chapter also provides background information about the U.S. Geological Survey/City of Boulder cooperative study.

The study was designed to capture a detailed profile of water quality during high-flow and low-flow conditions of Boulder Creek. Sampling occurred over three days in June 2000, which represented high-flow conditions, and over three days in October 2000, which represented low-flow conditions. The discharge of Boulder Creek downstream of the confluence of North Boulder Creek and Middle Boulder Creek reached its maximum value for the year 2000 two days before sampling began in June. While discharge in Boulder Creek dropped slightly after the October sampling, later sampling was not feasible due to short periods of daylight and limited accessibility to some sample sites.

Water-quality samples were collected from 29 sites along a 70-km reach, including 16 sites on the mainstem of Middle Boulder Creek/Boulder Creek, seven tributaries, wastewater effluent from the town of Nederland and the city of Boulder, the Silver Lake Pipeline, the Boulder Creek Supply Canal, and Saint Vrain Creek upstream of the confluence of Boulder Creek (figs. 1.1 and 1.2, table 1.1). A complete list of water quality variables evaluated is provided in the executive summary of this report.

SITE DESCRIPTION

Physiography

The Boulder Creek Watershed is approximately 1160 km^2 (447 mi^2) in area and is located in the Front Range of the Colorado Rocky

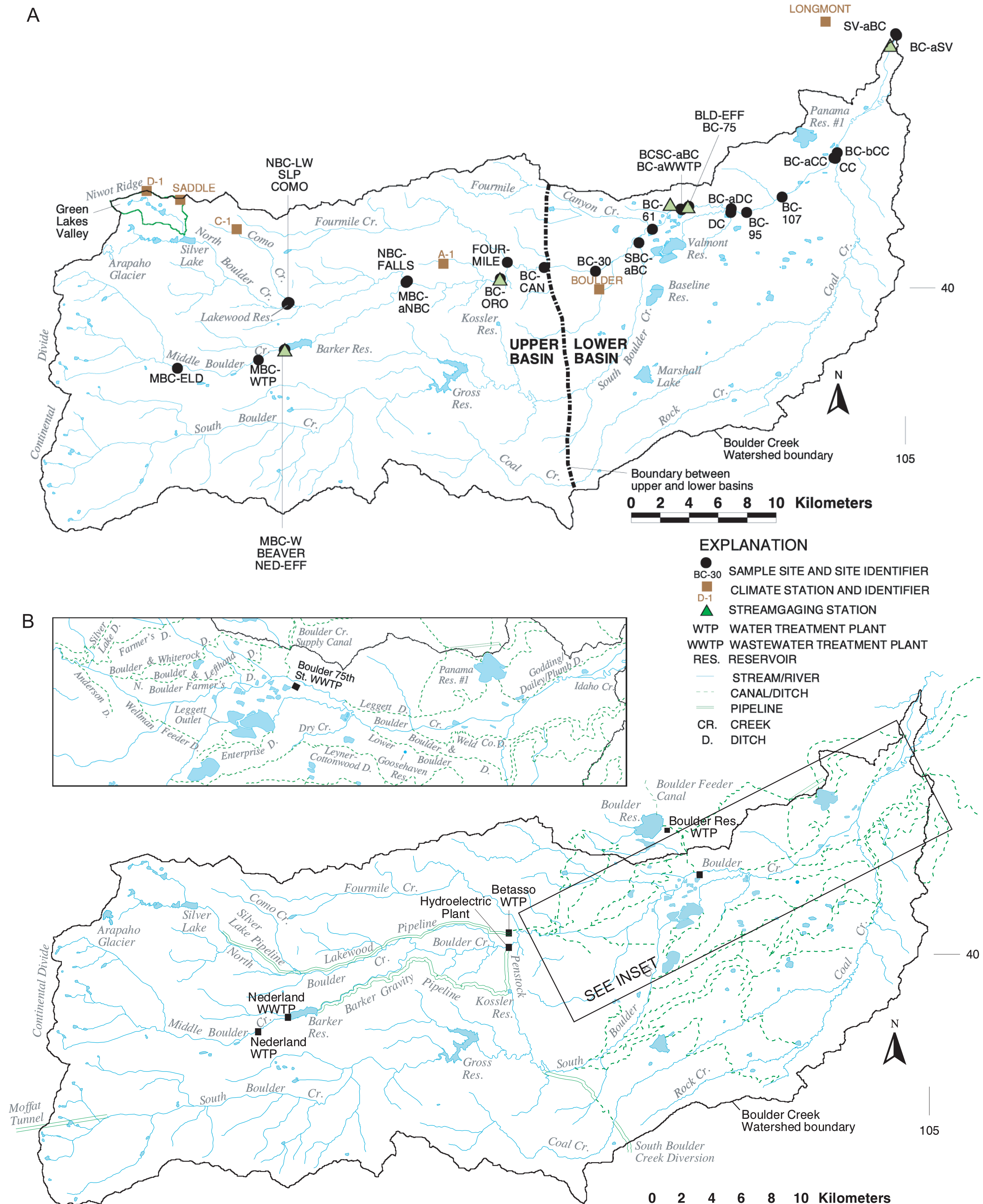

Figure 1.2. Maps of the Boulder Creek Watershed showing (A) sample sites and (B) major diversions. (Descriptions of sample sites provided in table 1.1; surface water data from U.S. Geological Survey, 2002a)

Table 1.1. Descriptions of sampling sites

[Distance, distance upstream from Saint Vrain Creek confluence; M., Middle; WTP, Water Treatment Plant; N., North; St., Street; WWTP, Wastewater Treatment Plant; S., South]

Site	Site description	Distance (meters)	Elevation (meters)	Latitude	Longitude
Middle Boulder Creek/Boulder Creek					
MBC-ELD	M. Boulder Creek upstream of town of Eldora	69590	2722	39.949722	-105.590833
MBC-WTP	M. Boulder Creek at Nederland WTP intake	62970	2560	39.955278	-105.525000
MBC-W	M. Boulder Creek at weir upstream of Barker Reservoir	60920	2496	39.961389	-105.504444
MBC-aNBC	M. Boulder Creek upstream of N. Boulder Creek	49440	2121	40.003889	-105.406389
BC-ORO	Boulder Creek at Orodell gaging station	41520	1775	40.006389	-105.330000
BC-CAN	Boulder Creek at Eben G. Fine Park (Boulder Canyon mouth)	36710	1646	40.013333	-105.294722
BC-30	Boulder Creek downstream of 30th St. bridge	32990	1603	40.011111	-105.252778
BC-61	Boulder Creek upstream of 61st St. bridge	27320	1567	40.037222	-105.206944
BC-aWWTP	Boulder Creek upstream of the Boulder 75th St. WWTP	24440	1562	40.050000	-105.183889
BC-75	Boulder Creek under 75th St. bridge	23850	1556	40.051667	-105.177778
BC-aDC	Boulder Creek upstream of Dry Creek	20180	1542	40.050278	-105.143333
BC-95	Boulder Creek downstream of 95th St. bridge	18790	1539	40.047778	-105.130833
BC-107	Boulder Creek upstream of 107th St. (Highway 287) bridge	16320	1530	40.058889	-105.101944
BC-aCC	Boulder Creek upstream of Coal Creek	10970	1513	40.081944	-105.059722
BC-bCC	Boulder Creek downstream of Coal Creek	10540	1512	40.085000	-105.057222
BC-aSV	Boulder Creek upstream of Saint Vrain Creek	110	1478	40.158056	-105.009444
Inflows/other flows					
COMO	Como Creek upstream of N. Boulder Creek	59340	2495	39.990833	-105.501111
NBC-LW	N. Boulder Creek upstream of Lakewood Reservoir	59370	2502	39.989722	-105.502500
SLP	Silver Lake Pipeline	59340	2495	39.991111	-105.500833
BEAVER	N. Beaver Creek upstream of M. Boulder Creek	60910	2495	39.961667	-105.504167
NED-EFF	Nederland WWTP effluent	60880	2497	39.961944	-105.503889
NBC-FALLS	N. Boulder Creek upstream of M. Boulder Creek	49420	2103	40.004722	-105.405556
FOURMILE	Fourmile Creek upstream of Boulder Creek	40120	1753	40.016389	-105.324444
SBC-aBC	S. Boulder Creek upstream of Boulder Creek	29070	1573	40.028889	-105.217778
BCSC-aBC	Boulder Creek Supply Canal upstream of Boulder Creek	24680	1567	40.500000	-105.190000
BLD-EFF	Boulder 75th St. WWTP effluent	24380	1559	40.049722	-105.183333
DC	Dry Creek upstream of Boulder Creek	20040	1542	40.047778	-105.143611
CC	Coal Creek upstream of Boulder Creek	10970	1512	40.081667	-105.058889
SV-aBC	Saint Vrain Creek upstream of Boulder Creek	90	1478	40.158889	-105.010000

Mountains, east of the Continental Divide (fig. 1.1). The watershed is located within two physiographic provinces (Worcester, 1960): the upper basin, defined on the west by the Continental Divide, is part of the Southern Rocky Mountain Province and is characterized by steeply sloping valleys; the lower basin, defined on the west by the foothills of the Rocky Mountains, is part of the Colorado Piedmont Section of the Great Plains Province, and slopes gently to the northeast.

Elevations in the watershed range from 4120 m at the Continental Divide to 1480 m at the confluence of Boulder Creek and Saint Vrain Creek. The most upstream site sampled for this study was located on Middle Boulder Creek upstream of the town of Eldora, at an elevation of approximately 2720 m (table 1.1). The elevations of sampling sites drop steeply as Middle Boulder Creek flows downstream through the town of Nederland and Boulder Canyon (fig. 1.3). The slope is much less steep when Boulder Creek reaches the plains at the mouth of Boulder Canyon. The most downstream site in the study was located on Boulder Creek approximately 110 m upstream from the confluence with Saint Vrain

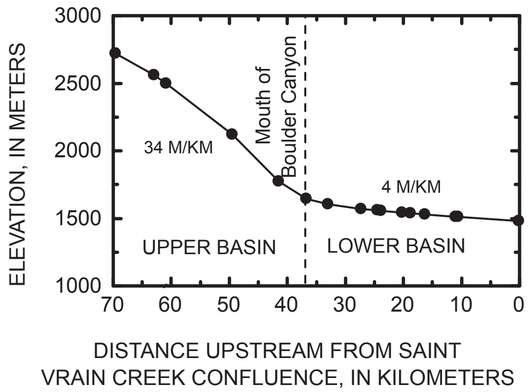

Figure 1.3. Graph showing elevation versus distance for Middle Boulder Creek/Boulder Creek sample sites.

Creek, at an elevation of 1478 m. Saint Vrain Creek discharges into the South Platte River a short distance downstream from the confluence.

Climate

The large variation in topography leads to different climatic zones in the watershed, including alpine, subalpine, montane, foothills, and plains (Rodeck, 1964; Weber, 1995). Temperatures vary widely across the climatic zones. In general, as elevation decreases, temperature increases, and the difference between daily minimum and maximum temperatures increases. In the year 2000, average daily minimum temperatures at three monitoring stations in the alpine (D-1 and Saddle) and subalpine (C-1) zones (fig. 1.2a) were -6°C, -5°C, and -3°C; average daily maximum temperatures were 1°C, 3°C, and 10°C (fig. 1.4). A monitoring station in the foothills zone (A-1) recorded average daily minimum and maximum temperatures of 3°C and 16°C, while stations in the plains zone recorded average daily minimum and maximum temperatures of 3°C and 19°C (Boulder) and 0°C and 20°C (Longmont). The majority of precipitation in the watershed falls as snow in the upper basin (fig. 1.5).

Geology

The upper basin of the watershed is composed primarily of Precambrian siliceous metamorphic and granitic rocks (fig. 1.6a). These rocks consist of gneisses and schists (1800 million years old) that were intruded by the Boulder Creek Granodiorite (1700 million years old) and the Silver Plume Granite (1400 million years old). In addition, early- and middle-Tertiary (30 to 60 million years old) deposits of metallic ores associated with intrusive dikes and sills are found in the upper basin. Deposits of gold, silver, tungsten, copper, lead, zinc, tin, and uranium were mined in the upper watershed beginning in 1859 (Lovering and Goddard, 1950; Bilodeau and others, 1987).

The lower basin is underlain by Paleozoic and Mesozoic sedimentary rocks that are progressively younger as they trend eastward. Shale, sandstone, limestone, and conglomerate formations that were deposited between 75 and 300 million years ago (Fountain, Lyons, Lykins, Ralston Creek, Morrison, Dakota, Benton, Niobrara, and Pierre formations, in order of oldest to youngest and west to east) were steeply tilted during mountain-building events, forming the easterly-dipping hogbacks, ridges, and valleys found at the edge of the mountain front just west of the city of Boulder (fig. 1.6a). Most of the city of Boulder is underlain by the Pierre Shale. Sandstone, shale, and coal-bearing formations that were deposited between 65 and 75 million years ago (Fox Hills and Laramie formations) overlay the Pierre Shale and dominate the geology east of the city of Boulder. Quaternary alluvium covers most of the flood plain of Boulder Creek and its tributaries (Runnells, 1976; Bilodeau and others, 1987).

Vegetation and Land Use

The upper and lower basins of the Boulder Creek Watershed differ markedly in vegetation and land use. The upper basin, which includes the

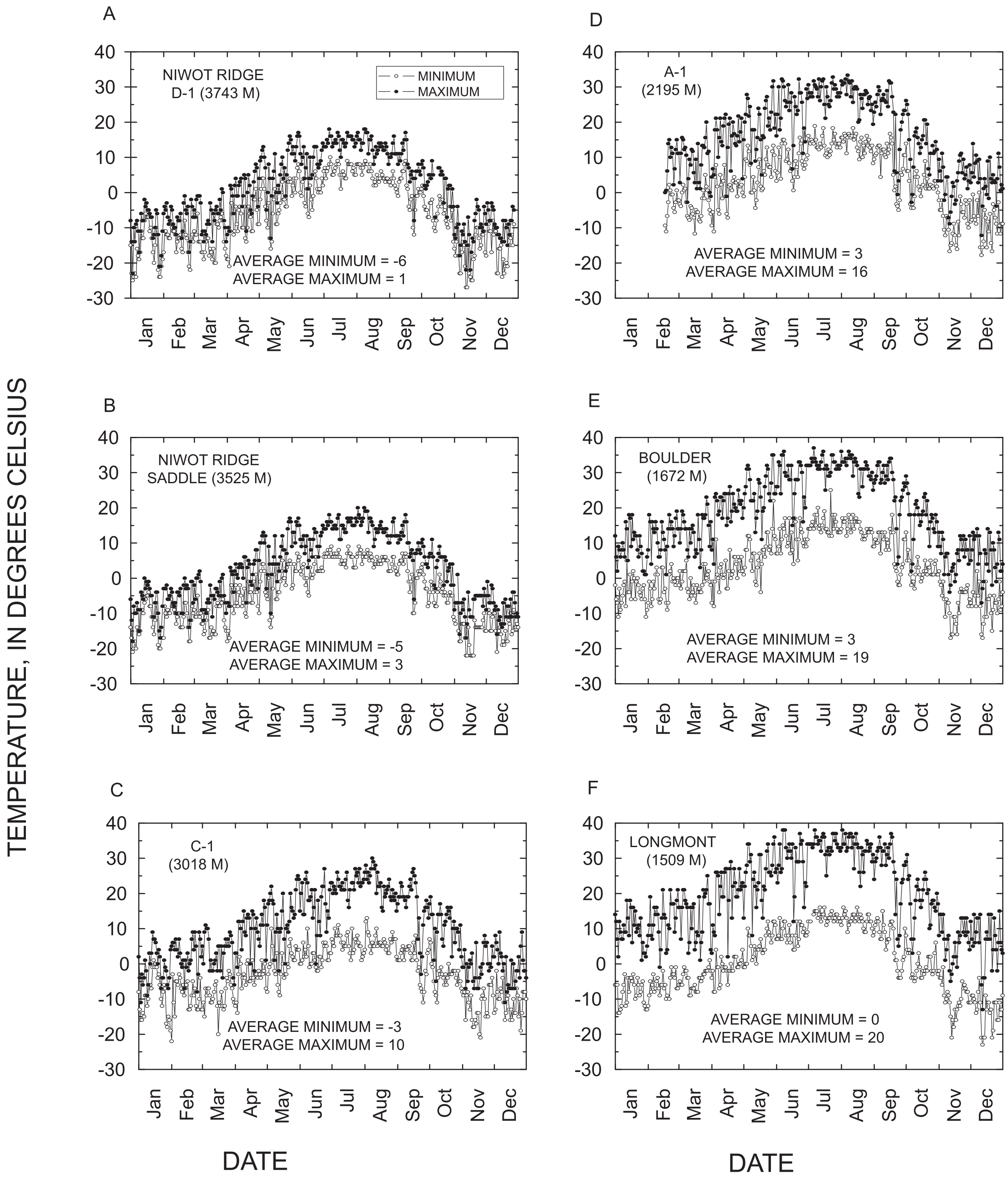

Figure 1.4. Graphs showing minimum and maximum daily air temperatures for sites in or near the Boulder Creek Watershed during 2000: (A) Niwot Ridge site D-1, (B) Niwot Ridge Saddle, (C) site C-1, (D) site A-1, (E) Boulder, (F) Longmont. (Site locations shown in fig. 1.2a. Data not available for site A-1 for January 1-February 17. Data for A-D obtained from Niwot Ridge Long-Term Ecological Research Program, 2002; data for E-F obtained from National Oceanic and Atmospheric Administration, 2002)

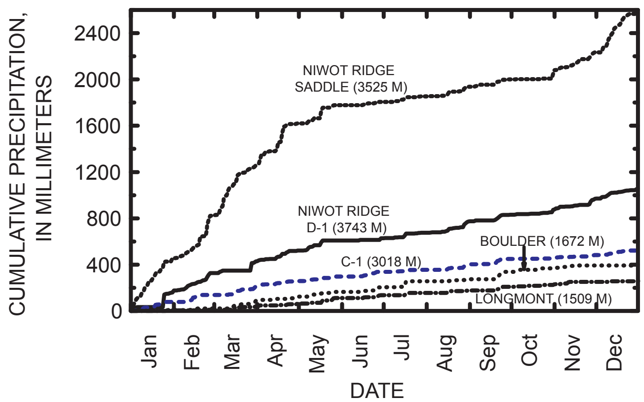

Figure 1.5. Graph showing cumulative precipitation for sites in the Boulder Creek Watershed for the year 2000. (Site locations shown in fig. 1.2a; data for Niwot Ridge sites obtained from Niwot Ridge Long-Term Ecological Research Program, 2002; data for Boulder and Longmont sites obtained from National Oceanic and Atmospheric Administration, 2002)

alpine, subalpine, montane, and foothills climatic zones, consists primarily of forests, shrubs, and ice (USGS, 2003; fig. 1.6b). The alpine tundra (elevations above 3500 m) is above tree line and is sparsely vegetated with lichen and low-growing herbaceous plants. The subalpine zone (3500 to 2700 m) primarily contains Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) forests, meadows, willow carrs, and peat fens. The montane zone (2700 to 2400 m) is dominated by lodgepole pine (*Pinus contorta*), quaking aspen (*Populus tremuloides*), and douglas-fir (*Pseudotsuga menziesii*). The foothills zone (2400 to 1800 m) contains ponderosa pine (*Pinus ponderosa*), douglas-fir, grasses, and flowering herbaceous plants (Rodeck, 1964; Weber, 1995). The upper basin is sparsely populated; the largest community is Nederland, with a year 2000 population of 1394 (U.S. Census Bureau, 2001).

The lower basin, which includes the plains climatic zone (1800 to 1500 m), consists of grassland, agricultural land, and residential/industrial/commercial land (fig. 1.6b). Grasslands consist of short-grass prairie, cactus, yucca (*Yucca glauca)*, and flowering herbs (Rodeck, 1964; Weber, 1995). Boulder County agricultural lands are primarily comprised of pasture, alfalfa, wheat, corn, and barley (U.S. Department of Agriculture, 1999). Urbanized areas in the Boulder Creek Watershed include the cities and towns of Boulder (population 94,673 in 2000; U.S. Census Bureau, 2001), Louisville (18,937), Lafayette (23,197), Erie (6,291), Superior (9,011), and part of Broomfield (total population 38,272; fig. 1.1).

REACHES OF BOULDER CREEK

As Boulder Creek and its tributaries flow from the mountains to the plains, they are subjected to a complex water management system. Differences in geology, climate, land use, and solute sources produce variations in water quality within the watershed. Boulder Creek can be divided into five reaches based on hydrology, geology, topography, and potential sources of pollution: (1) headwater region, (2) mountain corridor, (3) urban corridor, (4) wastewater-dominated reach, and (5) wastewater/agricultural/aggregate-mining region.

Headwater Region

The headwater region is considered the area upstream of population centers and most paved roads, and is defined here as the region from the Continental Divide to the Peak-to-Peak Highway (Highways 72 and 119; fig. 1.1). Streamflow primarily originates from snowpack stored within the watershed. In order to provide year-round water availabililty, water is stored and augmented. On North Boulder Creek, up to 8,600,000 cubic meters (m^3), or 7000 acre-feet of water can be stored in seven reservoirs owned by the city of Boulder (WBLA Inc., 1988). A pipeline diverts water from North Boulder Creek two kilometers downstream of Silver Lake Reservoir to Lakewood Reservoir (fig. 1.2b). Portions of Como Creek and North Boulder Creek are also diverted to Lakewood Reservoir during part of the year. Water in Lakewood

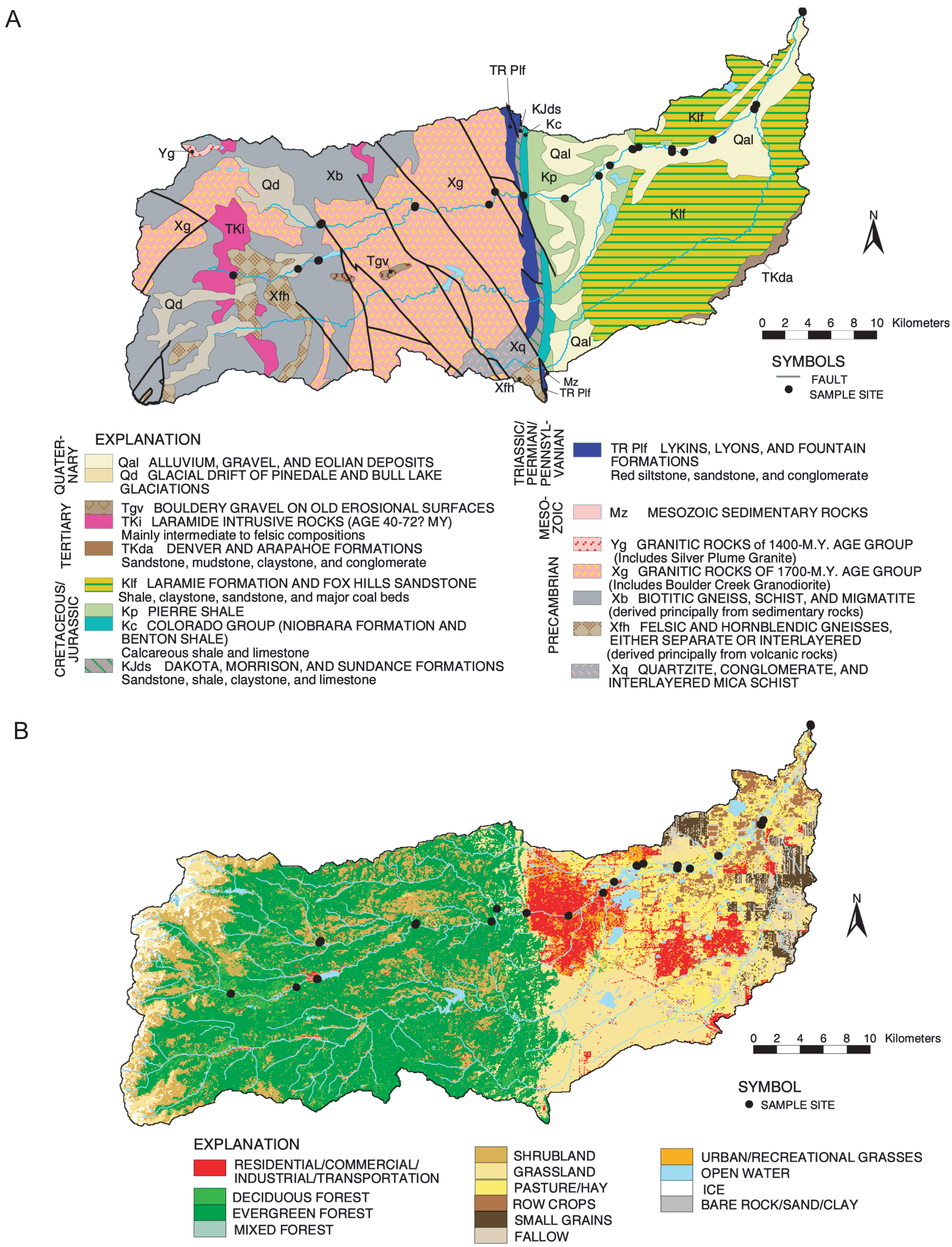

Figure 1.6. Maps showing (A) geology and (B) land cover in the Boulder Creek Watershed. (Geology modified from Tweto, 1979, and Green, 1992; land cover from U.S. Geological Survey, 2003).

Reservoir is diverted to the city of Boulder's Betasso Water Treatment Plant via the Lakewood Pipeline. The Silver Lake/Lakewood Reservoir watershed provides about 40 percent of the city of Boulder's water supply (City of Boulder, 2001). In contrast to North Boulder Creek, only a few small diversions, including the town of Nederland's water supply intake, affect the discharge of Middle Boulder Creek upstream of Barker Reservoir. South Boulder Creek receives transbasin water diverted from Denver Water's collection systems in the Fraser and Williams Fork basins via the Moffat Tunnel (fig. 1.2b). The headwater region is sparsely populated, but can be affected by recreation, air pollution, historical mining activity, road runoff, and mountain cabins. A 32-km^2 area of the North Boulder Creek watershed, including Arapaho Glacier and the Green Lakes Valley, is owned by the city of Boulder (fig. 1.1); public entry is prohibited. Most of the remaining headwater region lies within the Roosevelt National Forest; the headwaters of Middle Boulder Creek are located in the Indian Peaks Wilderness Area. While neither motorized vehicles nor mountain bikes are permitted, Indian Peaks is one of the most frequently visited wilderness areas in the state of Colorado (City of Boulder, 2002a). Numerous cabins, three developed U.S. Forest Service campgrounds, and the Eldora Mountain Ski Resort are located within the Middle Boulder Creek Watershed. The headwater region is represented in this study by sample sites on Middle Boulder Creek upstream of the town of Eldora (MBC-ELD) and at the Nederland Water Treatment Plant Intake (MBC-WTP), Como Creek (COMO), the Silver Lake Pipeline (SLP), and North Boulder Creek upstream of Lakewood Reservoir (NBC-LW; table 1.1 and fig. 1.2a).

Mountain Corridor

The Mountain Corridor is roughly considered the reaches of North Boulder Creek, Middle Boulder Creek, and the mainstem of Boulder Creek from the Peak-to-Peak Highway to the mountains/plains interface (fig. 1.1). Several paved roads traverse the region, including Highway 119, which runs alongside Middle Boulder Creek and Boulder Creek in Boulder Canyon. Road runoff can carry sediment, leaked automobile fluids, road salts, and debris. Population of the corridor has increased rapidly in recent years. Middle Boulder Creek flows through Nederland, a community whose population increased by 27 percent to 1394 from 1990 to 2000 (U.S. Census Bureau, 2001). Nederland's Wastewater Treatment Plant (WWTP) operates an aerated lagoon treatment process and discharges up to 0.008 m^3/s into Barker Reservoir when the reservoir is full, or into Middle Boulder Creek upstream of Barker Reservoir when the reservoir is low (City of Boulder, 2002a; U.S. Environmental Protection Agency, 2003). Barker Reservoir has a storage capacity of 14,426,000 m^3 (11,700 acre-feet) and provides up to 40 percent of the city of Boulder's drinking water supply (City of Boulder, 2002a). Water is released from the reservoir via the Barker Dam outlet works, which deliver water to the Barker Gravity Pipeline or to Middle Boulder Creek below the dam (fig. 1.2b). During times of high flow (as in June 2000), Barker Reservoir and the Barker Gravity Pipeline reach maximum capacity, and water spills over the dam into Middle Boulder Creek. During times of low flow (including October 2000), Middle Boulder Creek below Barker Dam has historically been virtually dry from October to April because all released water was diverted to the pipeline. Water in North Boulder Creek that is not diverted to Lakewood Reservoir flows 10 km, receiving some discharge from snowmelt and a few streams, before converging with Middle Boulder Creek below Boulder Falls (fig. 1.2b).

The Boulder Canyon Hydroelectric Plant, located 8 km downstream of the confluence of North and Middle Boulder Creeks, uses water diverted from Barker Reservoir via the Barker Gravity Pipeline, Kossler Reservoir, and the Boulder Canyon Hydroelectric Penstock (fig.

1.2b) to produce electricity, and discharges the water directly to Boulder Creek. The Orodell streamgaging station is located just downstream of the hydroelectric plant.

Boulder Creek receives flow from Fourmile Creek, minor tributaries, a small amount of treated wastewater from a restaurant, and possibly groundwater, and loses water to three diversion ditches before reaching the mouth of Boulder Canyon (fig. 1.2b). Fourmile Creek drains several historical mining districts and has the potential to contribute trace metals to Boulder Creek. Septic systems in the region have the potential to contribute bacteria, nutrients, and consumer products to groundwater.

The mountain corridor is represented by sample sites on Middle Boulder Creek in Nederland (MBC-W) and upstream of the confluence with North Boulder Creek (MBC-aNBC), North Beaver Creek in Nederland (BEAVER), North Boulder Creek upstream of the confluence with Middle Boulder Creek below Boulder Falls (NBC-FALLS), Boulder Creek at the Orodell streamgaging station (BC-ORO), Boulder Creek at the mouth of Boulder Canyon (BC-CAN), and Fourmile Creek (FOURMILE; table 1.1, fig. 1.2a). Nederland's wastewater effluent (NED-EFF) also was sampled.

Urban Corridor

At the mouth of Boulder Canyon, bedrock geology transitions from igneous and metamorphic rocks to much younger sedimentary rocks (fig. 1.6a), and Boulder Creek enters the main urban corridor of the city of Boulder (fig. 1.1). The population of Boulder was 94,673 in the year 2000, an increase of 13 percent since 1990 (U.S. Census Bureau, 2001). In the urban corridor, Boulder Creek gains water from minor tributaries, storm drains, treated wastewater from a mobile home park, and groundwater, but loses much of its water to irrigation ditches from May through September, and to off-channel reservoirs from October through April. South Boulder Creek enters Boulder Creek east of the city of Boulder; however, it usually contributes little discharge to the mainstem because most of the water in South Boulder Creek is diverted for domestic, industrial, and agricultural use.

Downstream from the South Boulder Creek confluence, Boulder Creek periodically receives water from the Colorado-Big Thompson Project. This water is conveyed from Lake Granby west of the Continental Divide via pipelines and canals to Carter Lake, and then via the Boulder Feeder Canal to Boulder Reservoir or the Boulder Creek Supply Canal (fig. 1.2b). Boulder Reservoir sources provide about 20 percent of the city of Boulder's water supply (City of Boulder, 2001). Water that is not diverted to the Boulder Reservoir Water Treatment Plant is conveyed to Boulder Creek via the Boulder Creek Supply Canal. Discharge in the canal varies depending on downstream delivery requests.

Human impact on Boulder Creek water quality increases in the urban corridor. Storm drains carry runoff from roads and lawns that may contain nutrients, pesticides, metals, and bacteria, particularly during storm events. Recreational activities, including swimming, wading, kayaking, and dog walking, can contribute suspended sediments, bacteria, and personal care products. The urban corridor is represented by sample sites on Boulder Creek at 30th Street (BC-30), at 61st Street (BC-61), and upstream of the Boulder 75th Street Wastewater Treatment Plant (BC-aWWTP), and South Boulder Creek upstream of Boulder Creek (SBC-aBC; table 1.1, fig. 1.2). The Boulder Creek Supply Canal (BCSC-aBC) also was sampled.

Wastewater-Dominated Reach

The Boulder 75th Street WWTP discharges to Boulder Creek downstream of the Boulder Creek Supply Canal (during the study, the discharge point was 300 m downstream of the canal; in March 2003, the discharge point was moved about 500 m downstream). The WWTP receives wastewater that originates from several sources (including Lakewood, Barker, and Boulder Reservoirs) and has undergone drinking-water treatment and residential, commercial, and industrial use. The wastewater is treated using a trickling filter/solids contact and nitrification process (City of Boulder, 2002b). The average discharge of raw sewage entering the WWTP, recorded with an ultrasonic meter, is about 0.74 m^3/s (26 ft^3/s). This rate varies diurnally depending on water usage within the city of Boulder.

The downstream impact of the WWTP is variable, depending on the baseflow of Boulder Creek, the volume of wastewater effluent, and depletion by agricultural diversions. In addition, Dry Creek, which carries water diverted from South Boulder Creek and released from Baseline Reservoir, discharges a varying amount of water to Boulder Creek about 4 km downstream from the WWTP (fig. 1.2b). The downstream boundary of the wastewater-dominated reach is therefore difficult to define. Boulder Creek at 75th Street (BC-75), upstream of Dry Creek (BC-aDC), at 95th Street (BC-95), and at 107th Street (BC-107; table 1.1, fig. 1.2a) are considered to be within the wastewater-dominated reach, with impact from the WWTP decreasing downstream (Murphy and others, 2003). Boulder 75th Street WWTP effluent (BLD-EFF) and Dry Creek (DC) also were sampled.

Wastewater/Agricultural/ Aggregate-Mining Region

Downstream of the Boulder 75th Street WWTP, Boulder Creek flows through agricultural fields, pastures, and open space. Panama Reservoir #1 and Goosehaven Reservoir (fig. 1.2b) release water to Boulder Creek during part of the year. Several aggregate mines operate along lower Boulder Creek, and small-scale oil wells are located in this area. Diversion ditches remove large amounts of water; some water is returned by agricultural return ditches and groundwater contributions to baseflow. Coal Creek discharges to Boulder Creek just upstream of the Boulder/Weld County line (fig. 1.1). Coal Creek receives effluent from the Erie, Lafayette, Louisville, and Superior WWTPs, which are permitted to discharge a total of 0.36 m^3/s (8.2 million gallons per day) into Coal Creek or its tributary Rock Creek (USEPA, 2003).

The water quality of the creek in the wastewater/agricultural/aggregate-mining region can be affected by agricultural runoff, road runoff, wastewater effluent, and interaction with groundwater. Due to less topographic variation and riparian vegetation than the mountain and urban reaches, Boulder Creek is much less shaded in this region than in the upper basin. Water temperatures approach 30°C in summer months, and the direct sunlight, shallow water, and high temperatures, along with nutrients provided by wastewater effluent and agricultural runoff, lead to extensive algal growth in the creek. This algal growth in turn causes dissolved oxygen and pH levels to oscillate from nighttime lows to daytime highs (TetraTech, Inc., 1993). The population of the lower Coal Creek watershed has grown substantially in recent years; the combined populations of Superior, Louisville, Lafayette, and Erie grew 102 percent to 57,436 from 1990 to 2000 (U.S. Census Bureau, 2001), increasing urban pressures on this tributary. The wastewater/agricultural/aggregate-mining region is represented by sampling sites on Boulder Creek above and below Coal Creek (BC-aCC and BC-bCC) and above Saint Vrain Creek (BC-aSV), Coal Creek (CC), and Saint Vrain Creek above Boulder Creek (SV-aBC; table 1.1, fig. 1.2a).

DISCHARGE OF BOULDER CREEK

Because the majority of precipitation in the Boulder Creek Watershed falls as snow (fig. 1.5), snowmelt controls discharge in Boulder Creek, leading to large seasonal fluctuations. Low-flow conditions occur from October through March, with discharge between 0.14 and 1.1 cubic

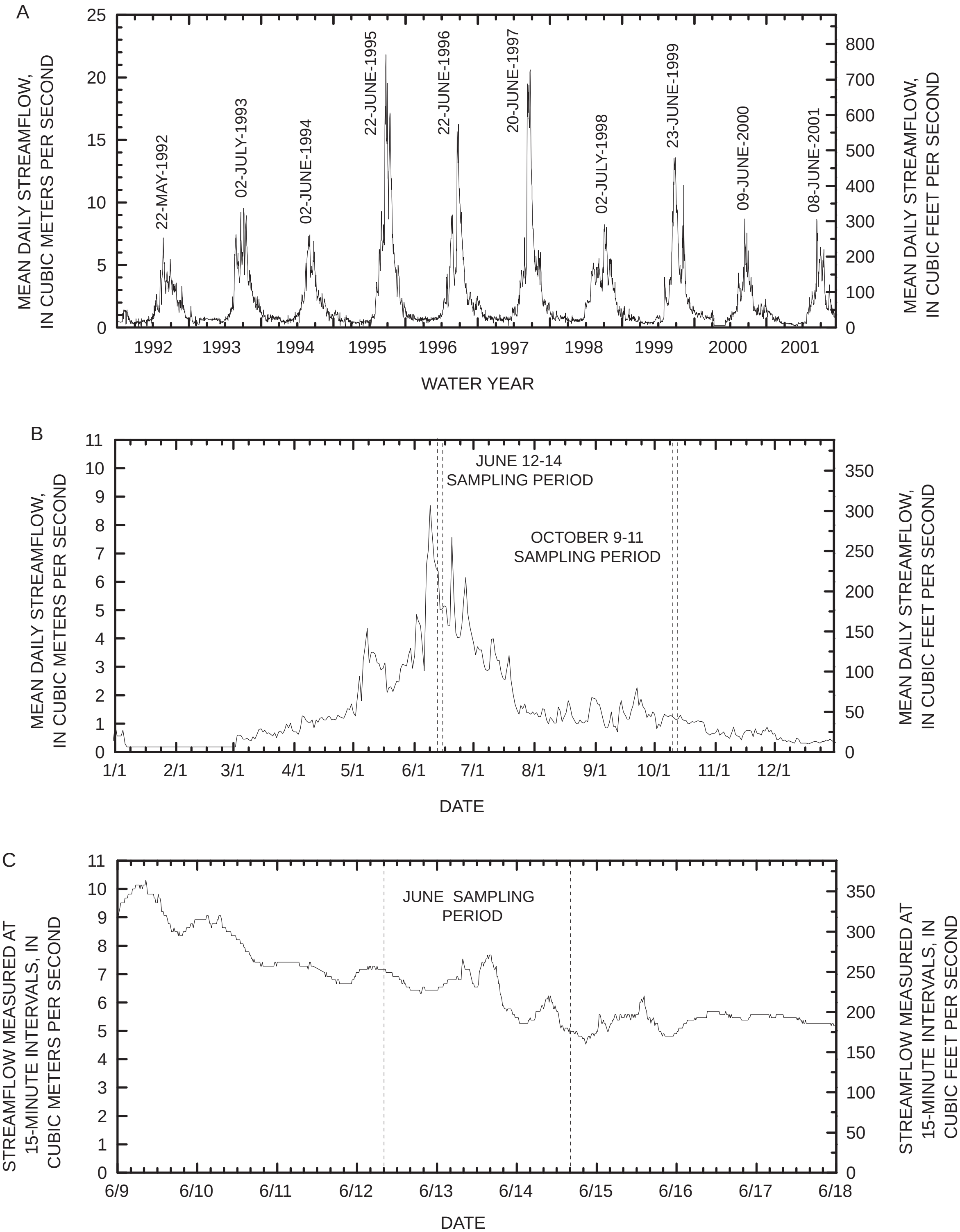

Figure 1.7. Hydrographs of Boulder Creek at the Orodell streamgaging station, (A) Water years 1992 to 2001 (water years begin October 1); dates of maximum annual discharge shown; (B) January 1 to December 31, 2000; (C) June 9 to June 18, 2000. (Data from U.S. Geological Survey, 2002b)

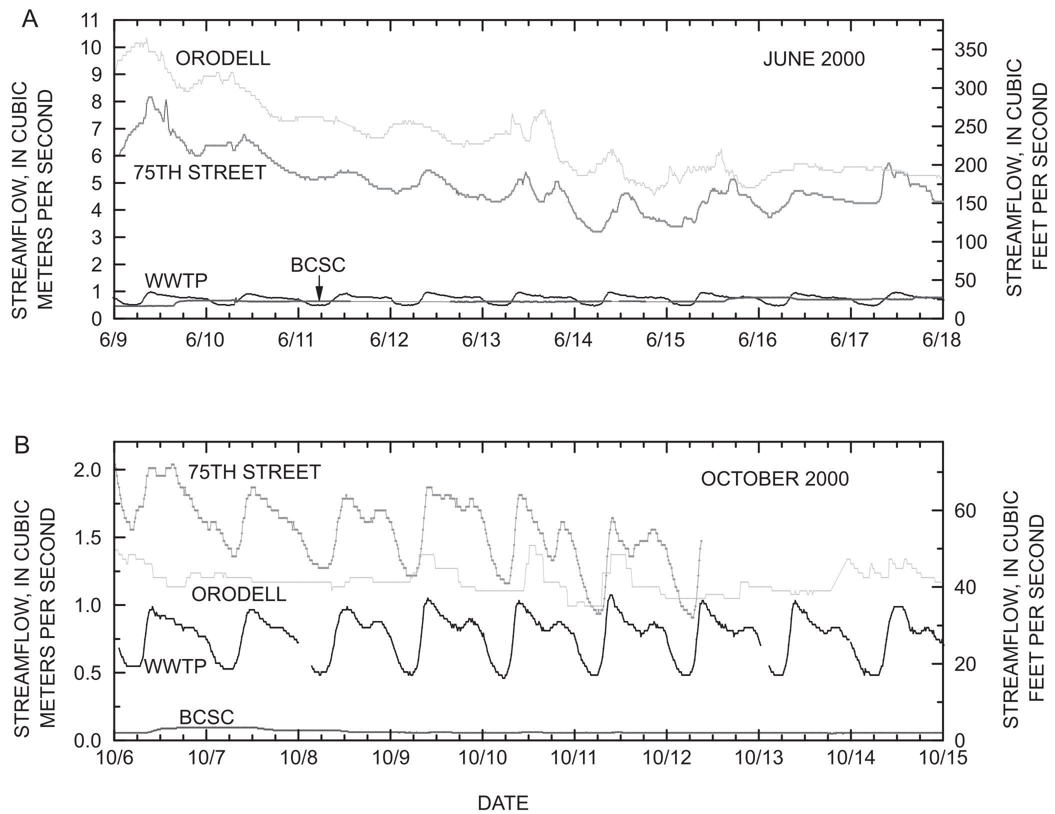

Figure 1.8. Hydrographs of Boulder Creek at the Orodell streamgaging station (Orodell), Boulder Creek at the 75th Street streamgaging station (75th Street), Boulder 75th Street Wastewater Treatment Plant inflow (WWTP), and Boulder Creek Supply Canal (BCSC) in (A) June 2000 and (B) October 2000. (Discharge measured at 15-minute intervals; data from U.S. Geological Survey, 2002b, Colorado Water Conservation Board and Colorado Division of Water Resources, 2002, and F. Bebler, City of Boulder, written commun., 2002)

meters per second (m^3/s), or 5 and 40 cubic feet per second (ft^3/s) measured at the Orodell streamgaging station from 1992 to 2001 (fig. 1.7a). High-flow conditions typically occur from May to July and peak in June, depending on snowpack depth and air temperature. Maximum average daily discharge between 1992 and 2001 ranged from 7 to 23 m^3/s (250 to 800 ft^3/s). During June 2000, the discharge at the Orodell streamgaging station reached its annual maximum average daily value of 9 m^3/s (307 ft^3/s) two days prior to the beginning of sampling (fig. 1.7b). The daily cycle of solar heating and subsequent snow melt produces a diurnal variation in discharge (fig. 1.7c; Caine, 1989).

The Boulder 75th Street WWTP also imparts a diurnal signal on the discharge of lower Boulder Creek. During the study, the rate of raw sewage entering the WWTP was lowest (0.45 to 0.51 m^3/s; 16 to 18 ft^3/s) between 3 and 7 AM, and then rose rapidly to maximum daily values (0.88 to 1.1 m^3/s; 31 to 38 ft^3/s) between 8 and 10 AM on weekdays and between 11 AM and 12 noon on Saturdays and Sundays (fig. 1.8). Discharge at the 75th Street streamgage, located about 500 m downstream of the WWTP discharge point in 2000, typically peaked within 0.5 to 1 hours of the WWTP influent peak, but the timing of the peak varies depending on the residence time in the WWTP and the discharge of the creek. This variation complicates the calculation of effluent contribution to discharge in Boulder Creek at the 75th Street streamgage; however, a range can be estimated by comparing discharge of raw sewage entering the Boulder 75th Street WWTP to discharge measured 0.5 to 1 hours later at the 75th

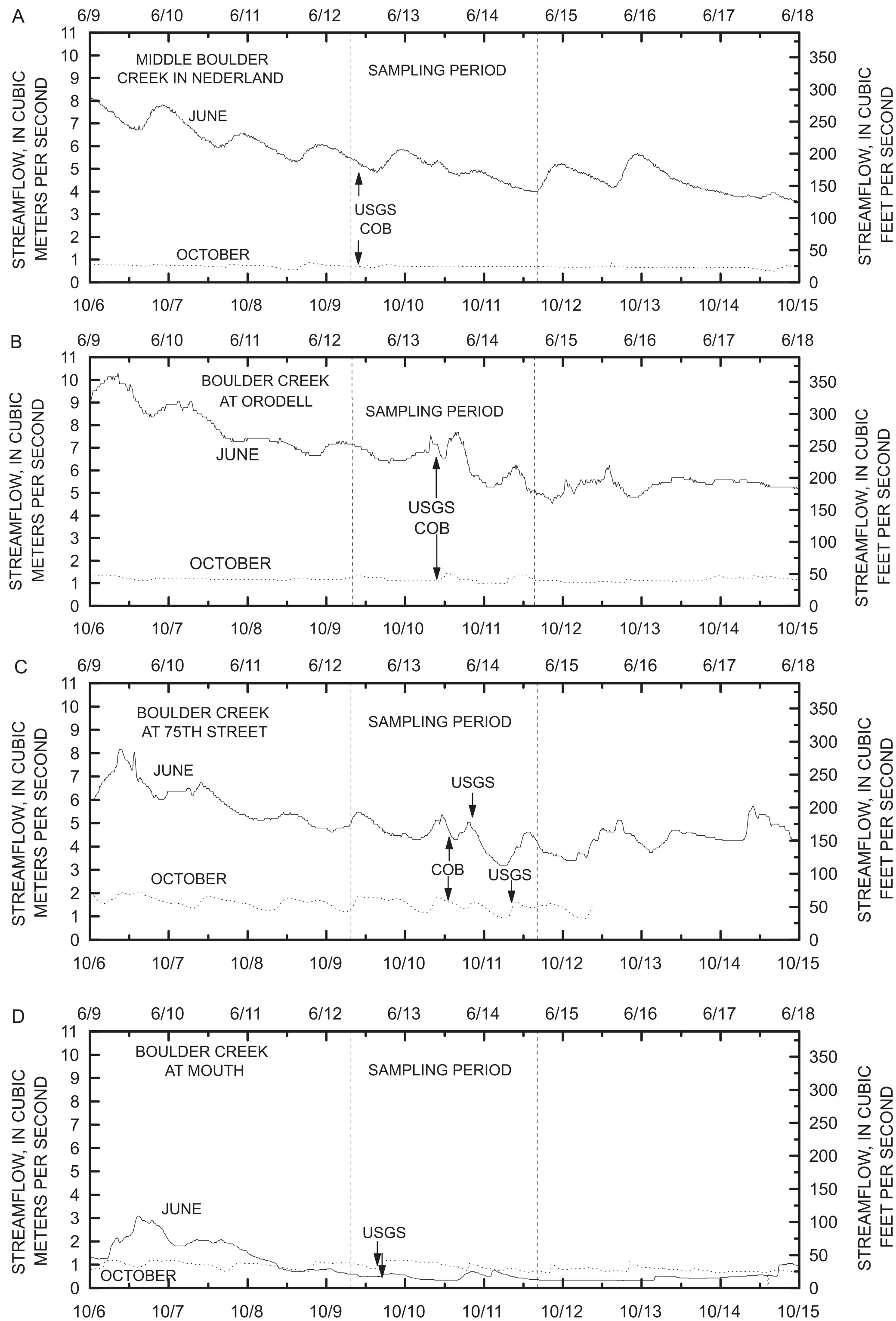

Figure 1.9. Hydrographs of streamgaging stations along Middle Boulder Creek and Boulder Creek, June and October 2000: (A) Middle Boulder Creek in Nederland, (B) Boulder Creek at Orodell, (C) Boulder Creek at 75th Street, and (D) Boulder Creek at mouth. (Arrows indicate times of sampling by U.S. Geological Survey (USGS) and City of Boulder (COB); discharge measured at 15-minute intervals; data from U.S. Geological Survey, 2002b)

Street streamgage. This calculation suggests that WWTP effluent contributed between 15 and 20 percent of the discharge measured at 75th Street during high-flow sampling and between 50 and 65 percent during low-flow sampling. Chemical mass-balance calculations imply that the effluent contributed between 37 and 49 percent to the discharge at 75th Street at the time of high-flow sampling, and between 69 and 77 percent at low flow (Barber and others, 2003; Murphy and others, 2003; Verplanck and others, 2003).

Because of the many diversions removing water during high flow, discharge at the mouth of Boulder Creek was substantially lower than at upstream streamgages (fig. 1.9). During the June sampling, discharge at the streamgage at the mouth of Boulder Creek was as little as 5 percent of that at the Orodell streamgage. Discharge at the mouth of Boulder Creek was actually higher in October than in June.

The velocity at which water travels down Boulder Creek varies depending on discharge and stream gradient. Previous studies on travel time in Boulder Creek have focused on the hydroelectric plant in the upper basin and WWTP releases in the lower basin. Prior to the year 2001, the Boulder Canyon Hydroelectric Plant released about 4.2 m^3/s (150 ft^3/s) of water to Boulder Creek for about three hours (between 6 and 9 pm) from November to March (City of Boulder, 2002a). This resulted in a wave of water estimated to have a speed of 1.1 m/s (J.A. Moody, USGS, written commun., 1999). At that speed, water would travel from the Orodell streamgage to the mouth of Boulder Creek in about 11 hours. Hydrosphere Resource Consultants (written commun., 1997) found that at a discharge of 1.7 m^3/s (60 ft^3/s), water traveled from 75th Street to 95th Street in 206 minutes, a speed of about 0.4 m/s. At this speed, water would travel from the 75th Street streamgage to the confluence of Boulder Creek and Saint Vrain Creek in about 17 hours. However, inputs and outputs along Boulder Creek would change the flow and thus the travel time. During the 2000 study, similar discharge peaks occurred on June 13 at 7:45 am at the Orodell streamgage, at 11:30 am at the 75th Street streamgage, and at 8:30 pm at the streamgage at the mouth of Boulder Creek (fig. 1.9). Discharge varies along the reach, complicating the calculation of speed.

A discharge profile along Middle Boulder Creek/Boulder Creek was estimated for one day in June and October based on discharge recorded at streamgages (fig. 1.9), measured by city of Boulder personnel (tables 1.2 and 1.3), and obtained from the Colorado Water Conservation Board and Colorado Division of Water Resources (2002; table 1.4), the town of Nederland, the city of Boulder, and the Public Service Company. The second day of sampling (Tuesday) was selected for the calculation because this was the day during which most discharge measurements were made. For sites with continuous discharge measurements (streamgaging stations and Boulder 75th Street WWTP influent), discharge recorded near the sampling times of nearby sites were used (table 1.5). The discharge passing through diversion structures were estimated by assuming constant discharge during the day (table 1.4).

The estimated discharge along the Middle Boulder Creek/Boulder Creek profile on June 13 and October 10, 2000 are shown in figure 1.10. In June, discharge of Middle Boulder Creek above Barker Reservoir increased downstream as it received snowmelt and tributary inflow. Water was flowing over Barker Dam into Middle Boulder Creek. Below the reservoir, the discharge of Middle Boulder Creek increased downstream, receiving inflows from snowmelt, leakage from the Barker Gravity Pipeline (which loses about 10 percent of the water it carries to leaks; City of Boulder, 2002a), and groundwater. Downstream of the confluence of Middle and North Boulder Creeks, the creek received water from the hydroelectric plant and Fourmile Creek and reached the maximum discharge along the Middle Boulder Creek/Boulder Creek profile, about 7.8 m^3/s (276 ft^3/s). Discharge was reduced by two-thirds over the next 4 km after diversions removed about 4.8 m^3/s (170 ft^3/s) from the

Table 1.2. Discharge measurements at sampling sites, June and October 2000

[COB group, city of Boulder group that measured discharge; ID, identification number; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; meter, Marsh-McBirney Flo-Mate 2000 portable flow meter, following USGS midsection methods (Rantz and others, 1982); Storm, Stormwater; --, not measured; Source, Sourcewater; WWTP, Wastewater Treatment Plant; data for gages 06725500, 06727000, and BCSCBCCO from Colorado Water Conservation Board and Colorado Division of Water Resources, 2002; data for gages 06730200 and 06730500 from U.S. Geological Survey (USGS), 2002b; when sampling times by USGS and city of Boulder differ, discharge at both times is given, if available; if discharge was determined by both meter and gage, both values are given]

Site	Method (COB group or station ID)	June				October			
		Date	Time	Discharge (m^3/s)	Discharge (ft^3/s)	Date	Time	Discharge (m^3/s)	Discharge (ft^3/s)
Middle Boulder Creek/Boulder Creek									
MBC-ELD	meter (Storm)	6/12/00	0820	3.7	130	10/9/00	0848	0.40	14
MBC-WTP	--	--	--	--	--	--	--	--	--
MBC-W	gage (06725500)	6/12/00	1315	5.0	176	10/9/00	1300	0.34	12
MBC-aNBC	--	--	--	--	--	--	--	--	--
BC-ORO	meter (Storm)	6/13/00	0900	6.5	231	10/10/00	1000	1.3	46
BC-ORO	gage (06727000)	6/13/00	1000	7.1	249	10/10/00	1000	1.1	39
BC-CAN	meter (Storm)	--	--	--	--	10/10/00	1045	1.0	35
BC-30	meter (Storm)	6/13/00	1445	2.3	81	10/11/00	--	0.37	13
BC-61	meter (Storm)	6/13/00	1110	3.2	113	10/10/00	1120	0.54	19
BC-aWWTP	meter (Storm)	--	--	--	--	10/10/00	1355	0.34	12
BC-75	gage (06730200)	6/13/00	1400	4.5	158	10/10/00	1330	1.6	57
BC-75	gage (06730200)	6/13/00	2000	4.9	172	10/11/00	0900	1.5	54
BC-aDC	meter (Storm)	6/13/00	1525	3.3	116	10/10/00	1355	1.1	37
BC-95	meter (Storm)	--	--	--	--	10/10/00	1435	0.99	35
BC-107	meter (Storm)	--	--	--	--	10/10/00	1510	0.68	24
BC-aCC	meter (Storm)	6/13/00	1645	1.1	38	10/10/00	1545	0.88	31
BC-bCC	meter (Storm)	6/13/00	1655	1.4	51	10/10/00	1610	1.2	43
BC-aSV	meter (Storm)	6/13/00	1740	0.45	16	10/9/00	1600	0.48	17
BC-aSV[1]	gage (06730500)	6/13/00	1800	0.57	20	10/9/00	1600	0.79	28
Inflows/other flows									
COMO	flume (Source)	6/12/00	1012	0.14	5.2	10/9/00	1023	0.03	1.0
NBC-LW	flume (Source)	6/12/00	1023	1.7	59	10/9/00	1040	0.17	6.0
SLP	Lakewood plant	--	--	--	--	10/9/00	1058	0.17	5.7
BEAVER	meter (Source)	6/12/00	1249	0.09	3.2	10/9/00	1230	0.01	0.48
NED-EFF	Nederland WWTP	6/12/00	1323	0.005	0.17	10/9/00	1317	0.003	0.10
NBC-FALLS	--	--	--	--	--	--	--	--	--
FOURMILE	meter (Storm)	6/13/00	0908	0.11	3.9	10/9/00	1005	0.02	0.66
SBC-aBC	[2]	6/13/00	ave.	0.02	0.72	10/9/00	ave.	0.01	0.5
BCSC-aBC	gage (BCSCBCCO)	6/11/00	1030	0.62	22	10/9/00	1740	0.06	1.9
BLD-EFF	Boulder WWTP	6/13/00	1345	0.86	30	10/10/00	1315	0.90	32
BLD-EFF	Boulder WWTP	6/13/00	2000	0.79	28	10/11/00	0830	1.0	34
DC	[3]	6/13/00	ave.	0.37	13	10/9/00	1344	0.03	0.9
CC	meter (Storm)	6/13/00	1650	0.31	11	10/10/00	1555	0.34	12
SV-aBC	meter (Storm)	6/13/00	1750	3.3	116	10/9/00	1545	1.9	68

[1]Gage located 1000 m upstream of sampling site.
[2]June discharge estimated from data for Leggett Outlet release (R. Rhodes, Xcel Energy, oral commun., 2003); October discharge visually estimated.
[3]June discharge estimated from Colorado Water Conservation Board and Colorado Division of Water Resources (2002) data for Baseline Reservoir replacement-to-river discharge minus Cottonwood Ditch #2 discharge; October discharge measured with meter by Stormwater group.

Table 1.3. Discharge measurements of ditches and minor tributaries of Boulder Creek, June and October 2000

[Discharge measured by city of Boulder Stormwater group; m^3/s, cubic meters per second; ft^3 /s, cubic feet per second; --, not measured; <, less than]

Tributary/Ditch	June					October				
	Method	Date	Time	Discharge (m^3/s)	Discharge (ft^3/s)	Method	Date	Time	Discharge (m^3/s)	Discharge (ft^6/s)
Tributaries										
Bear Canyon Creek	--	--	--	--	--	visual	10/9/00	1114	<0.1	<5
Goose Cr.	meter	6/13/00	1040	0.01	0.5	meter	10/9/00	1120	0.02	0.8
Fourmile Canyon Creek	meter	6/13/00	1130	0.14	5.0	visual	10/9/00	--	<0.06	<2
Ditches										
Silver Lake	--	--	--	--	--	visual	10/9/00	1034	0	0
Anderson	meter	6/13/00	0920	0.04	1.4	meter	10/9/00	1015	0.001	0.02
Farmers	meter	6/13/00	0938	0.68	24	visual	10/9/00	1027	0	0
12th Street Diversion[1]	meter	6/13/00	0955	3.0	107	meter	10/9/00	1043	0.96	34
Wellman Feeder	--	--	--	--	--	visual	10/9/00	1105	0	0
Butte Mill	meter	6/13/00	1050	0.06	2.1	visual	10/9/00	1130	0	0
Green	flume	6/13/00	1145	0.08	3	flume	10/9/00	1135	0.0003	0.01
Leggett	--	--	--	--	--	meter	10/9/00	1420	0.23	8.1
Lower Boulder	--	--	--	--	--	meter	10/9/00	1435	0.39	14
Boulder and Weld County	--	--	--	--	--	meter	10/9/00	1520	0.02	0.6

[1] Includes Boulder and White Rock, North Boulder Farmer's, Boulder and Left Hand, and McCarty Ditches.

Table 1.4. Discharge through major diversion structures on Boulder Creek, June and October 2000

[Data from Colorado Water Conservation Board and Colorado Division of Water Resources (2002) unless noted; distance, distance upstream from SaintVrain Creek confluence; m^3/s, cubic meters per second; ft^3/s, cubic feet per second; Co., County]

Diversion	Distance (meters)	Discharge[1]											
		6/12		6/13		6/14		10/9		10/10		10/11	
		(m^3/s)	(ft^3/s)	(m^3/s)	(ft^3/s)	(m^3/s)	(ft^3/s)	(m^3/s)	(ft^3/s)	(m^3/s)	(ft^3/s)	(m^3/s)	(ft^3/s)
Silver Lake	38660	0.14	4.9	0.14	5.1	0.13	4.6	0	0	0	0	0	0
Anderson	37300	0.13	4.5	0.12	4.3	0.13	4.5	0	0	0.08	2.9	0.11	3.8
Farmers	36860	0.76	27	0.79	28	0.74	26	0	0	0	0	0	0
12th Street[2]	35290	3.5	124	3.7	129	3.1	110	1.0	36	0.96	34	0.93	33
Smith-Goss	35290	0.11	4.0	0.11	4.0	0.11	4.0	0.11	4.0	0.11	4.0	0.11	4.0
Wellman Feeder[3]	33420	0	0	0	0	0	0	0	0	0	0	0	0
Butte Mill	29500	0.17	5.9	0.14	4.8	0.11	4.0	0	0	0	0	0	0
Green	27010	0.16	5.5	0.17	6.0	0.22	7.7	0	0	0	0	0	0
Leggett	21140	1.0	36	0.91	32	0.91	32	0.25	8.9	0.28	10	0.26	9.2
Lower Boulder	18550	2.3	81	2.3	80	2.5	87	0.51	18	0.48	17	0.48	17
Boulder and Weld Co.	16320	0.42	15	0.45	16	0.37	13	0	0	0	0	0	0
Howell	10320	0.06	2	0.06	2	0.06	2.0	0	0	0	0	0	0
Godding Dailey Plumb	9610	0.40	14	0.40	14	0.42	15	0.09	3.2	0.09	3.2	0.09	3.2
Idaho Creek[4]	6550	1.3	46	1.3	45	1.3	45	0.14	5.0	0.08	3.0	0.08	3.0
Rural	4560	0.74	26	0.54	19	0.54	19	0	0	0	0	0	0

[1]Estimated from cubic feet per second per day by assuming discharge was constant over 24 hours.
[2]Includes Boulder and Whiterock, Boulder and Lefthand, and North Boulder Farmer's Ditches.
[3]Data from R. Rhodes, Xcel Energy, oral commun., 2003.
[4]Includes Houck #2, Carr-Tyler, Highland South Side, Smith-Emmons, and Delehant Ditches.

Table 1.5. Estimated discharge of Middle Boulder Creek/Boulder Creek, June 13 and October 10, 2000

[Mainstem sites shown in bold; inflows and outflows indented; m^3/s, cubic meters per second; --, not applicable; WTP, water treatment plant; plant; PSCo, Public Service Company records obtained by the city of Boulder; NR, not recorded; USEPA, U.S. Environmental Protection Agency (2003);

Site	Discharge obtained from	June discharge (m^3/s)					
		Date	Time	Measured	Inflow	Outflow	Calculated[1]
MBC-ELD	meter	6/12/00	0820	3.7	--	--	--
Nederland WTP diversion	CWCB/CDWR	6/12/00	ave.	--	--	0.010	--
North Beaver Creek	meter	6/12/00	1249	--	0.09	--	--
MBC-W	gage	6/12/00	1300	5.0	--	--	3.8
Nederland WWTP effluent	Nederland WWTP	6/12/00	1323	--	0.005	--	--
MBC below Barker Reservoir	PSCo	6/13/00	NR	4.3	--	--	--
North Boulder Creek[2]	meter	6/12/00	1023	--	1.7	--	--
Hydroelectric plant discharge	PSCo	6/13/00	NR	--	0.51	--	--
BC-ORO	gage	6/13/00	1000	7.1	--	--	6.5
Red Lion Inn	USEPA	5/31/00	NR	--	0.0002	--	--
Fourmile Creek	meter	6/13/00	0908	--	0.11	--	--
Silver Lake Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.14	--
Anderson Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.12	--
Farmers Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.79	--
BC-CAN	meter	--	--	--	--	--	6.2
12th Street Diversion	CWCB/CDWR	6/13/00	ave.	--	--	3.7	--
Smith-Goss Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.11	--
Wellman Feeder Ditch	Xcel	6/13/00	--	--	--	0	--
BC-30	meter	6/13/00	1445	2.3	--	--	2.4
Bear Canyon Creek	visual	--	--	--	--	--	--
Butte Mill Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.14	--
San Lazaro WWTP	USEPA	5/31/00	NR	--	0.005	--	--
South Boulder Creek[3]		6/13/00	ave.	--	0.02	--	--
BC-61	meter	6/13/00	1110	3.2	--	--	2.2
Fourmile Canyon Creek	meter	6/13/00	1130	--	0.14	--	--
Green Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.17	--
Boulder Creek Supply Canal	gage	6/13/00	1310	--	0.62	--	--
BC-aWWTP	meter	--	--	--	--	--	3.8
Boulder WWTP effluent	Boulder WWTP	6/13/00	1245	--	0.86	--	--
BC-75	gage	6/13/00	1315	4.7	--	--	4.7
Leggett Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.91	--
BC-aDC	meter	6/13/00	1525	3.3	--	--	3.6
Dry Creek[4]		6/13/00	--	--	0.28	--	--
BC-95	meter	--	--	--	--	--	3.6
Lower Boulder Ditch	CWCB/CDWR	6/13/00	ave.	--	--	2.3	--
Boulder and Weld Co. Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.45	--
BC-107	meter	--	--	--	--	--	0.85
Goosehaven Reservoir release	CWCB/CDWR	6/13/00	ave.	--	0	--	--
BC-aCC	meter	6/13/00	1645	1.1	--	--	0.85
Coal Creek	meter	6/13/00	1650	--	0.31	--	--
BC-bCC	meter	6/13/00	1655	1.4	--	--	1.4
Howell Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.06	--
Panama Reservoir #1 release	CWCB/CDWR	6/13/00	ave.	--	0.59	--	--
Godding Dailey Plumb Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.40	--
Idaho Creek ditches	CWCB/CDWR	6/13/00	ave.	--	--	1.3	--
Rural Ditch	CWCB/CDWR	6/13/00	ave.	--	--	0.54	--
Boulder Creek above mouth	gage	6/13/00	1800	0.57	--	--	-0.31

[1] Estimated by adding inflows to and subtracting outflows from the last measured discharge of upstream site; negative values indicate additional source (such
[2] Measured at Lakewood Reservoir.
[3] Estimated in June from Valmont Reservoir release (R. Rhodes, Xcel Energy, oral commun., 2003); visually estimated in October.
[4] June discharge estimated from Colorado Water Conservation Board and Colorado Division of Water Resources (2002) data for Baseline Reservoir

CWCB/CDWR, Colorado Water Conservation Board and Colorado Division of Water Resources (2002); ave., daily average; WWTP, wastewater treatment
Xcel, oral commun. from R. Rhodes, Xcel Energy, 2003; Co., County]

Site	October discharge (m^3/s)						Other possible inflows and outflows
	Date	Time	Measured	Inflow	Outflow	Calculated[1]	
MBC-ELD	10/9/00	0848	0.40	--	--	--	
	10/9/00	ave.	--	--	0.007	--	
	10/9/00	1230	--	0.01	--	--	
MBC-W	10/9/00	1300	0.34	--	--	0.40	lakes, wetlands, snowmelt
	10/9/00	1317	--	0.003	--	--	
	10/10/00	NR	0	--	--	--	
	10/9/00	1040	--	0.17	--	--	
	10/10/00	NR	--	1.0	--	--	
BC-ORO	10/10/00	1000	1.1	--	--	1.2	pipeline leakage, snowmelt, gulches
	9/30/00	NR	--	0.0003	--	--	
	10/9/00	1005	--	0.02	--	--	
	10/10/00	ave.	--	--	0	--	
	10/10/00	ave.	--	--	0.08	--	
	10/10/00	ave.	--	--	0	--	
BC-CAN	10/10/00	1045	1.0	--	--	1.0	storm sewers, gulches
	10/10/00	ave.	--	--	0.96	--	
	10/10/00	ave.	--	--	0.11	--	
	10/10/00	NR	--	--	0	--	
BC-30	10/11/00	NR	0.37	--	--	-0.07	storm sewers, groundwater
	10/9/00	1114	--	0.03	--	--	
	10/10/00	ave.	--	--	0	--	
	9/31/00	NR	--	0.003	--	--	
	10/9/00	ave.	--	0.01	--	--	
BC-61	10/10/00	1120	0.54	--	--	0.41	storm sewers, ponds
	10/9/00	NR	--	0.03	--	--	
	10/10/00	ave.	--	--	0	--	
	10/10/00	1330	--	0.06	--	--	
BC-aWWTP	10/10/00	1355	0.34	--	--	0.63	ponds
	10/10/00	1230	--	0.94	--	--	
BC-75	10/10/00	1330	1.6	--	--	1.3	groundwater from WWTP, ditch returns
	10/10/00	ave.	--	--	0.28	--	
BC-aDC	10/10/00	1355	1.1	--	--	1.3	ditch return, ponds
	10/9/00	1344	--	0.03	--	--	
BC-95	10/10/00	1435	0.99	--	--	1.1	ponds
	10/10/00	ave.	--	--	0.48	--	
	10/10/00	ave.	--	--	0	--	
BC-107	10/10/00	1510	0.68	--	--	0.51	
	10/10/00	ave.	--	--	0	--	
BC-aCC	10/10/00	1545	0.88	--	--	0.68	ponds, ditch returns
	10/10/00	1555	--	0.34	--	--	
BC-bCC	10/10/00	1610	1.2	--	--	1.2	
	10/10/00	ave.	--	--	0	--	
	10/10/00	ave.	--	0	--	--	
	10/10/00	ave.	--	--	0.09	--	
	10/10/00	ave.	--	--	0.08	--	
	10/10/00	ave.	--	--	0	--	
BC-mouth	10/10/00	2100	1.0	--	--	1.0	ponds, groundwater, ditch returns

as ground water) required to produce measured discharge.

replacement-to-river discharge minus Cottonwood Ditch #2 discharge; October discharge measured with meter by Stormwater group.

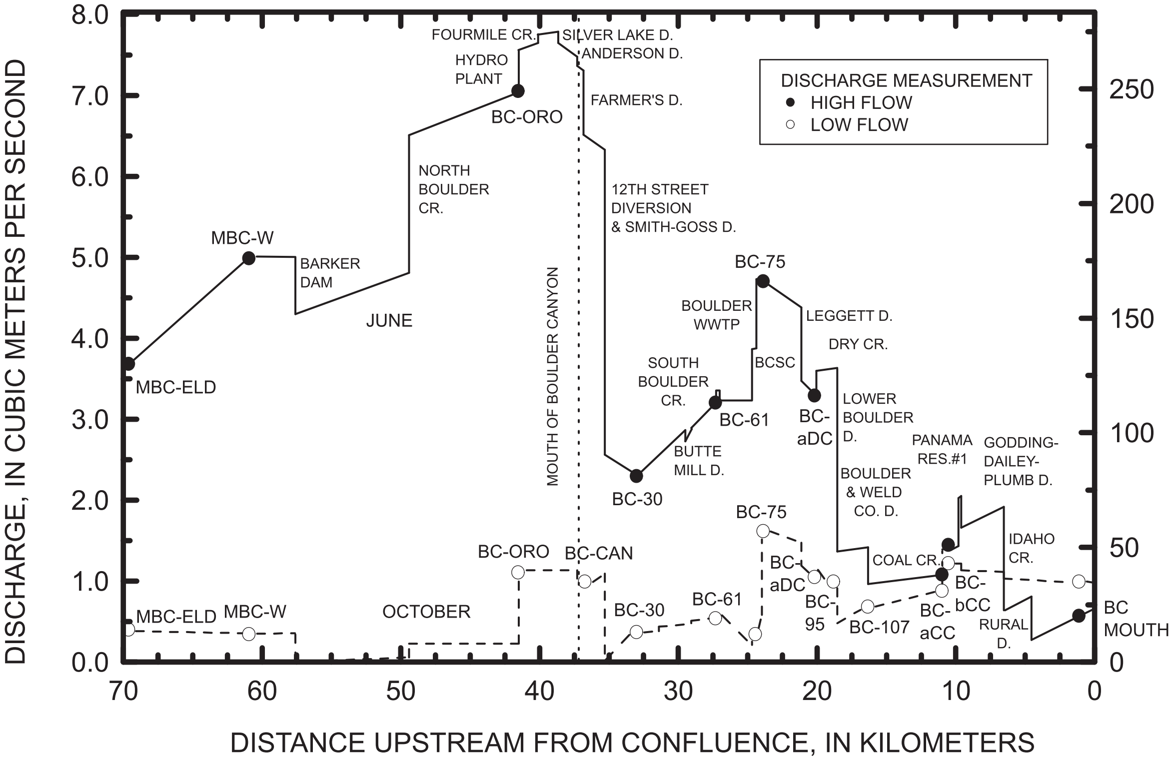

Figure 1.10. Estimated discharge along Middle Boulder Creek/Boulder Creek, June 12-13 and October 9-10, 2000. (Based on table 1.5; D., Ditch; Cr., Creek; WWTP, Wastewater Treatment Plant; BCSC, Boulder Creek Supply Canal)

creek. Boulder Creek regained about 1.8 m^3/s (62 ft^3/s) from South Boulder Creek, Fourmile Canyon Creek, the Boulder Creek Supply Canal, and Boulder 75th Street WWTP effluent, reaching a discharge of about 4.5 m^3/s (160 ft^3/s) at the 75th Street streamgage. From 75th Street to the mouth of Boulder Creek (a distance of approximately 25 km), a total of almost 5.9 m^3/s (210 ft^3/s) of water was diverted from the creek. The creek gained about 1.2 m^3/s (42 ft^3/s) from Dry Creek, Coal Creek, and Panama Reservoir #1, and some additional discharge from groundwater and agricultural returns. At the mouth of Boulder Creek, the discharge was 0.57 m^3/s (20 ft^3/s), less than 8 percent of the maximum discharge in Boulder Canyon.

In October 2000, discharge in most of Middle Boulder Creek and Boulder Creek was much lower than in June (fig. 1.10, table 1.5). The discharge was fairly constant from MBC-ELD to Barker Reservoir. Below Barker Dam, Middle Boulder Creek was dry for some distance, regaining a small amount of water from groundwater and the leaking pipeline. North Boulder Creek contributed some discharge, but a majority of the discharge recorded at the Orodell streamgaging station was due to releases from the hydroelectric plant. Downstream of the Orodell streamgage, fewer diversions were removing less water from Boulder Creek in October than in June (table 1.4), but the diversions in operation still removed a large fraction of the discharge. The 12th Street Diversion removed 0.96 m^3/s (34 ft^3/s), leaving less than 0.14 m^3/s (5 ft^3/s) in Boulder Creek. While the creek gained discharge from tributaries and groundwater inflow, the most significant contributor of water in the lower basin in October was the Boulder 75th Street WWTP. Discharge in Boulder Creek reached its maximum value of 1.6 m^3/s (57 ft^3/s), at the 75th Street streamgage. Downstream of 75th Street, Boulder Creek lost about 0.93 m^3/s (33 ft^3/s) to diversions, and gained about 0.37 m^3/s (13 ft^3/s) from Dry Creek and Coal Creek, with additional flow added by groundwater and agricultural returns. The discharge at the streamgage upstream of the mouth of Boulder Creek was 1.0 m^3/s (35 ft^3/s), roughly 90 percent of the discharge measured at the Orodell streamgaging station, and was higher in October than in June.

SUMMARY

The Boulder Creek Watershed is 1160 square kilometers in area and ranges in elevation from 1480 to 4120 meters above sea level. The upper and lower basins differ drastically in climate, geology, and land use. The upper basin consists primarily of metamorphic and granitic bedrock with alpine, subalpine, montane, and foothills climatic/ecological zones, with forest being the dominant land cover. The lower basin consists primarily of sedimentary bedrock with a plains climatic/ecological zone, with grassland, agricultural land, and urbanized land being the dominant land covers. The majority of the population lives in the lower basin.

Discharge varies annually and seasonally due to the snowmelt-dominated flow regime. Discharge also is affected by extensive water management. Boulder Creek gains water from wastewater effluent, transbasin diversions, and groundwater, and loses water to domestic, agricultural, and industrial diversions. Much of the diverted water is not returned immediately to the watershed, resulting in up to a 92 percent reduction in discharge from Boulder Canyon to the confluence with Saint Vrain Creek during high flow.

Variations in climate, geology, land cover, and hydrology affect water chemistry both spatially and temporally. Information presented in this chapter will assist in the evaluation of the effect of natural and anthropogenic factors on water quality of the Boulder Creek Watershed.

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