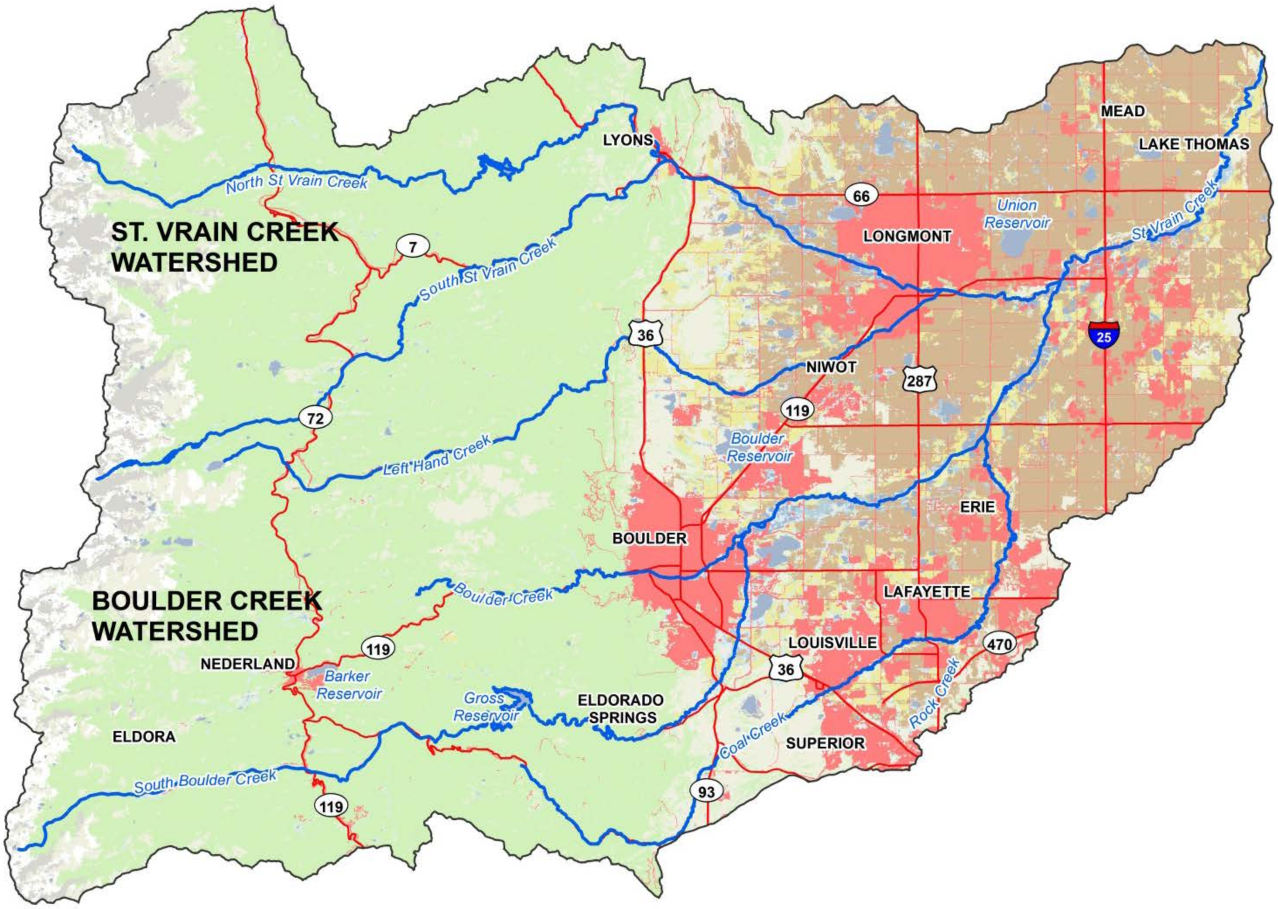
St. Vrain Basin Watershed-Based Plan: Boulder Creek, St. Vrain Creek and Tributaries



KEEP IT CLEAN PARTNERSHIP
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WRIGHT WATER ENGINEERS, INC.

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Report Preparation

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Minor revisions to Watershed Plan completed March 30, 2016.

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Watershed Overview

The 980-square-mile St. Vrain Basin includes two major subwatersheds: 1) Boulder Creek and 2) St. Vrain Creek. The two streams join to form the main stem of St. Vrain Creek, just east of the Boulder-Weld County line, and flow into the South Platte River downstream of Platteville, Colorado. Diverse land use characteristics are present in the watershed, with headwaters in pristine mountain settings flowing into the foothills and urbanized areas, and then through agricultural areas in the plains before joining the South Platte River. Colorado's 2012 303(d) List of Impaired Segments and Monitoring and Evaluation (M&E) List identifies 23 segments in the overall watershed that do not attain (or potentially do not attain) stream standards.

Plan

This Watershed-Based Plan (Watershed Plan), funded with State of Colorado Nonpoint Source grant monies, provides a framework for better understanding and addressing impaired stream segments. Because of the large watershed area, the primary focus of this Watershed Plan is the western edge of the urbanized areas in the foothills eastward to Interstate 25 (I-25); however, background information on the overall watershed is also provided. As part of this effort, a Monitoring Plan for the overall St. Vrain Basin has been developed to support coordinated watershed efforts into the future.

The Keep It Clean Partnership (KICP)[1] is a partnership of communities sharing, coordinating, and developing resources to reduce stormwater pollution within the Boulder Creek and St. Vrain Creek watersheds. KICP has led the effort to develop this Watershed Plan, incorporating the U.S. Environmental Protection Agency's "Nine Elements of a Watershed Plan," to meet the following objectives:

1. Develop a coordinated monitoring approach for the overall watershed, including identification of data gaps and data management needs.

2. Improve understanding of existing water quality issues in the watershed.

3. Identify steps necessary to improve water quality or otherwise resolve stream segments designated as impaired.

4. Develop a framework for implementing these measures.

[1] The KICP Partners includes the communities of Boulder, Boulder County, Erie, Lafayette, Longmont, Louisville and Superior.

In addition to meeting these objectives, the Watershed Plan serves as a broad reference (guide) for watershed stakeholders to obtain consolidated information on topics such as:

- Maps of land use, soils, mine locations, fire hazard areas, agricultural area, open space.
- Wastewater treatment plant and municipal stormwater discharge permits.
- Summaries of various planning efforts in the watershed.
- Stakeholders and monitoring data sources in the watershed.
- Stream standards and impairments, along with data analysis for selected pollutants.
- Strategies to reduce pollutant loading and to refine understanding of pollutant sources.

The primary water quality issues identified and explored in this Watershed Plan include**:**

- ***E. coli* (fecal indicator bacteria):** The most common water quality issue in the watershed is *E. coli* concentrations exceeding primary contact recreational standards. Impairments for *E. coli* are generally located in the urban and agricultural areas between the foothills and I-25. Although the City of Boulder is working to address elevated *E. coli* under a Total Maximum Daily Load (TMDL) for Boulder Creek from 13th Street to the confluence with South Boulder Creek, other streams also have elevated *E. coli* such as portions of Rock Creek, Coal Creek, Boulder Creek (additional segments), Dry Creek, Left Hand Creek and St. Vrain Creek. This Watershed Plan identifies portions of segments with elevated *E. coli* and identifies general reductions needed in various stream reaches to attain the stream standard.

  Additional monitoring is needed to better target the sources of *E. coli* in each segment. Source identification for *E. coli* is essential for identifying and implementing effective load reduction strategies, given the wide range of potential *E. coli* sources in a watershed. Typically, municipal wastewater treatment plant discharges are not the cause of elevated *E. coli*; however, leaking sanitary infrastructure may be a source in some areas. In urban areas, dogs, homeless or transient encampment areas, urban wildlife, waste management practices and urban runoff are representative sources potentially contributing to elevated *E. coli*. In agricultural areas, livestock, manure spreading, and failing septic systems are potential sources. This Watershed Plan includes recommendations for improved source identification and best management practices that can be implemented once sources of *E. coli* are better understood.

- **Nutrients:** In 2012, Colorado adopted new nutrient criteria for total phosphorus, total nitrogen and chlorophyll-*a*. Because these criteria are being adopted as stream standards in a phased approach, there are no current impairments for nutrients in the basin. Nonetheless, analysis in this Watershed Plan demonstrates that stream segments below municipal wastewater treatment plants are likely to exceed nutrient criteria for total phosphorus and total nitrogen, and possibly chlorophyll-*a*, if adopted as standards in the future.

- **Metals:** Although stream standards for metals are attained for most of the overall St. Vrain Basin, several types of metals issues are present in the watershed in various locations, with differing solutions. For example, portions of the watershed where historic mining occurred, such as in the Left Hand Creek subbasin, exceed standards for several metals and are the focus of a recent TMDL. The 2005 Left Hand Creek Watershed Plan recommended practices to reduce metals loading from abandoned mines in these areas, but remediation of these areas requires significant funding to complete and remains a need in the watershed. Selenium in Rock Creek and the portion of Coal Creek below Rock Creek presents a different impairment scenario. In this case, elevated selenium is expected to be due to naturally occurring conditions and exploration of an ambient-based, site-specific standard may be a more realistic solution. A third scenario for metals impairment may occur in the upper pristine portion of the watershed outside of the “mining belt” where extremely low hardness values result in very low hardness-based metals standards (e.g., copper). A similar situation occurs for arsenic on stream segments where extremely stringent “water plus fish” standards apply. (Most of these segments currently have a temporary modification for arsenic.) In these situations, even low-level metals detections may exceed stream standards.
- **Aquatic Life:** Attainment of aquatic life standards in Colorado is based on comparison of benthic macroinvertebrate data to a multi-metric index (MMI) established under Aquatic Life Policy 10-1. Local governments in the watershed sponsor aquatic life monitoring on Boulder Creek, South Boulder Creek, Rock Creek, St. Vrain Creek and Left Hand Creek. Based on biological monitoring results for 2014, portions of Coal Creek, Rock Creek, St. Vrain Creek and Left Hand Creek would be identified as impaired for aquatic life. One location on Boulder Creek above Coal Creek may also be impaired for aquatic life, depending on the biotype assumptions used in the analysis. As biological monitoring of these stream segments continues into the future, evaluation of the causes of poor MMI scores should continue to be evaluated to determine if these are due to water quality impacts, habitat limitations (e.g., flow), or biotype classification.

Future

Given the size of the watershed and the breadth of water quality issues that this Watershed Plan could potentially address, the primary focus of the implementation elements for this Watershed Plan is *E. coli*, since it is the most common water quality impairment in the overall watershed and is considered a high priority on the 303(d) List. Nonetheless, best management practices (BMPs) that reduce *E. coli* may also help to reduce nutrient loading and improve aquatic life conditions.

The on-going monitoring program adopted by the KICP as part of this Watershed Plan will be a key tool to refine the understanding of pollutant sources, trends and effectiveness of BMPs in the future. This information can be used to refine updates of this Watershed Plan. The KICP’s goal is to provide a forum to facilitate minor updates to this Watershed Plan on a five-year cycle, with major updates at ten-year intervals.

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1.0 Watershed Characterization and Regulatory Framework

1.1 Introduction

The 980-square-mile St. Vrain Basin includes two major subwatersheds: 1) Boulder Creek and 2) St. Vrain Creek. The 8-digit hydrologic unit code (HUC) for the St. Vrain Basin is 10190005. Boulder Creek and its tributaries flow through the southern portion of Boulder County, and St. Vrain Creek and its tributaries flow through the northern portion of Boulder County. The two streams join to form the main stem of St. Vrain Creek, just east of the Boulder-Weld County line, and flow into the South Platte River downstream of Platteville, Colorado. Colorado's 2012 303(d) List of Impaired Segments and Monitoring and Evaluation (M&E) List identifies 23 segments in the overall watershed that do not attain (or potentially do not attain) stream standards. This Watershed Plan has been developed to provide a framework for better understanding and addressing impairments for the flowing stream segments on this list. Because of the large watershed area, the primary focus of this Watershed Plan is the western edge of the urbanized areas in the foothills eastward to I-25; however, background information on the overall watershed is also provided. As part of this Watershed Plan, a Monitoring Plan for the St. Vrain Basin has been developed to support coordinated watershed efforts.

The Keep it Clean Partnership includes local governments in Boulder County that work together to promote improved water quality and stewardship of natural resources in the St. Vrain Basin. The Keep It Clean Partnership has led the effort to develop this Watershed Plan, with the primary objectives including:

1. Develop a coordinated monitoring approach for the overall watershed, including identification of data gaps and data management needs.
2. Improve understanding of existing water quality issues in the watershed.
3. Identify steps necessary to improve water quality or otherwise resolve stream segments designated as impaired.
4. Develop a framework for implementing these measures.

This Watershed Plan is generally organized according to the Colorado Uniform Watershed Plan Outline and addresses the U.S. Environmental Protection Agency's (EPA's) "Nine Elements of a Watershed Plan." This Watershed Plan should be viewed as a living, evolving document that will be updated periodically, based on the best available information. The remainder of this report addresses the topics listed in Table 1-1, cross-referencing the required chapters under Colorado's Uniform Watershed Plan Outline with EPA's required Nine Elements.

Appendix A provides a series of GIS maps that provide a variety of basic watershed information that is referenced throughout the remainder of this report. Monitoring locations are identified in figures in Appendix C.

Table 1-1. Nine Elements of EPA Watershed Plan Cross-Referenced to Colorado Uniform Watershed Plan Outline

Colorado Uniform Watershed Plan Outline and Chapter in St. Vrain Watershed Plan	EPA Watershed Plan Nine Required Elements
Chapter 1. Watershed Characterization	(*supports understanding of 1. Causes/Sources of Pollutants*)
Chapter 2. Watershed Partnerships	(*supports 6. Public Education/Outreach*)
Chapter 3. Scope of Watershed Efforts	(*supports 4. Financial/Technical Resources for Implementation*)
Chapter 4. Watershed Information Sources, Monitoring Plan and Data Inventories	(*supports 9. Monitoring Plan to Evaluate Effectiveness*)
Chapter 5. Data Analysis and Characteristics	1. Causes and Sources of Pollutants 2. Load Reduction Required
Chapter 6. Watershed Management Action Strategy, Policies and Programs	3. Management Measures to Support Load Reductions
Chapter 7. Implementation Plan Elements	4. Financial/Technical Resources for Implementation 5. Schedule for Implementation 6. Information and Education Component 7. Interim Measurable Milestones for Plan Implementation 8. Criteria to Assess Progress 9. Monitoring Plan to Evaluate Effectiveness
Chapter 8. Adaptive Watershed Management Plan	(*Builds upon evaluation of* *8. Criteria to Assess Progress* *9. Monitoring Plan to Evaluate Effectiveness*)

1.2 WATERSHED FEATURES

The overall St. Vrain Basin is located along the Front Range of the Colorado Rocky Mountains and can be divided into two subwatersheds: Boulder Creek and St. Vrain Creek, which converge to form the main stem of St. Vrain Creek, west of I-25. Each of these subwatersheds follows a similar progression of characteristics with mountains in the headwaters, urbanized communities in the foothills and plains, and predominantly agricultural land use in the lower watershed. St. Vrain Creek then flows into the South Platte River downstream of Platteville, which is part of the Mississippi River Basin. The NRCS classifies the watershed according to "Major Land Resource Areas" (MLRAs) and "Common Resource Areas" (CRAs), as shown in Figure 1-1 and described in Table 1-2. CRAs are geographical areas where resource concerns, problems, and treatment needs are similar. Landscape conditions, soil, climate, human considerations, and other natural resource information are used to determine the geographical boundaries of the common resource area (NRCS 2010).

Figure 1-1. NRCS Common Resource Areas
(Source: NRCS 2010)

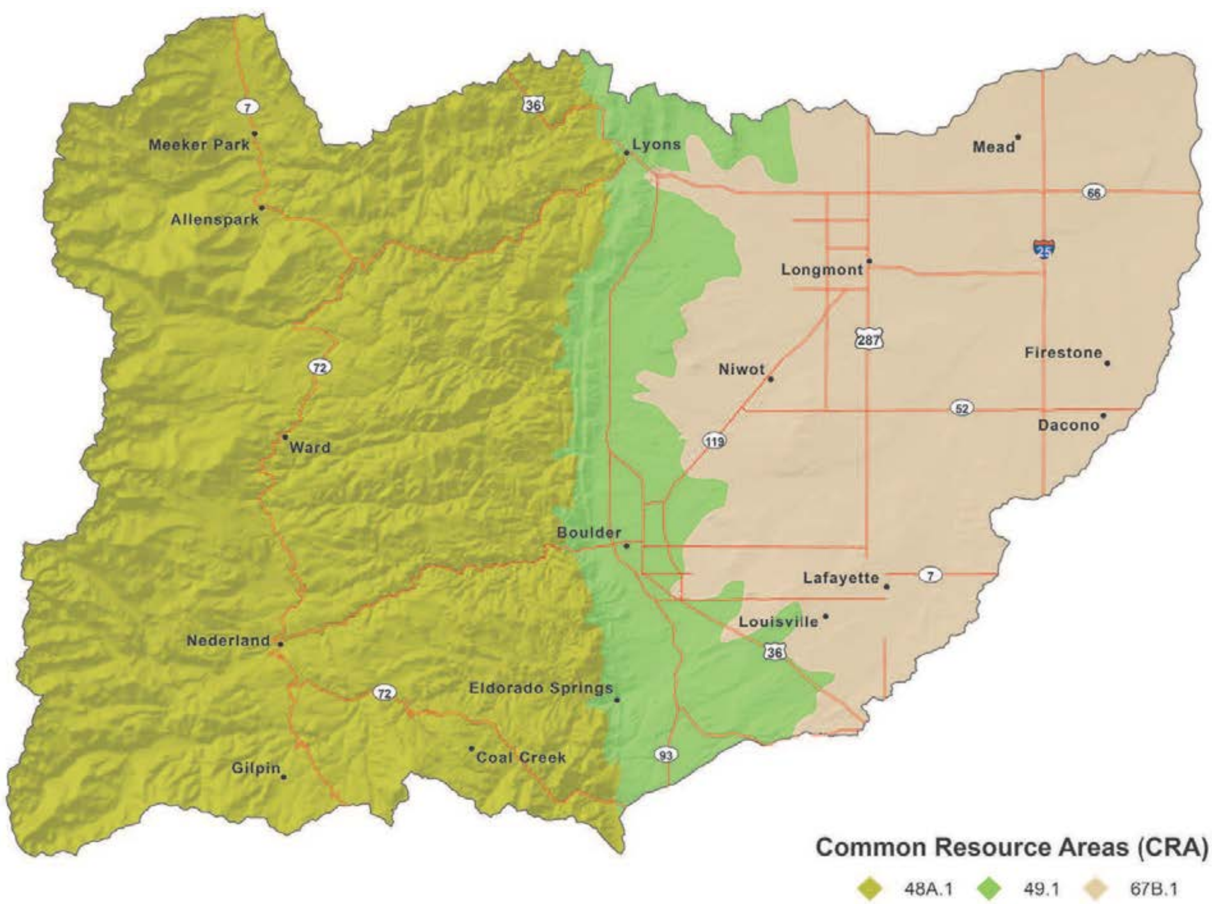


Table 1-2. Description of NRCS Common Resource Areas
(Source: NRCS 2010)

MLRA	CRA	CRA NAME	CRA Description
48A	48A.1	Southern Rocky Mountains - High Mountains and Valleys	This area is best characterized by steep, high mountain ranges and associated mountain valleys. The temperature regimes are mostly frigid and cryic; moisture regimes are mainly ustic and udic. Vegetation is sagebrush-grass at low elevations, and with increasing elevation ranges from coniferous forest to alpine tundra. Elevations range from 6,500 to 14,400 feet.
49	49.1	Southern Rocky Mountain Foothills	This area is generally a transition between the Great Plains and the Southern Rocky Mountains. The temperature regime is mesic or frigid, and moisture regime is ustic. Characteristic native vegetation ranges from grasslands and shrubs to ponderosa pine and Rocky Mountain Douglas fir forest.
67B	67B.1	Central Great Plains, Southern Part	The Central High Plains, Southern Part CRA is broad, undulating to rolling plains dissected by streams and rivers. Local relief is measured in tens of feet on the plains. Soils are deep and formed in eolian and alluvial materials. Pre-settlement vegetation was short grass prairies. Nearly all of this area is in fallow cropland rotations or rangeland. Some cropland areas are irrigated.

The Boulder Creek watershed covers approximately 450 square miles and includes the communities of Boulder, Nederland, Erie, Superior, Lafayette and Louisville. Elevations within the Boulder Creek watershed range from over 13,000 feet in the Upper Basin to approximately 5,000 feet at the confluence of Boulder Creek and St. Vrain Creek near Longmont, approximately 20 miles northeast of the City of Boulder. Primary tributaries of Boulder Creek include North, Middle, and South Boulder Creeks, Como Creek, Fourmile Creek, Coal Creek, and Rock Creek, along with several smaller streams such as Goose Creek, Bear Creek, and Skunk Creek.

The St. Vrain Creek watershed is larger than the Boulder Creek watershed, covering approximately 530 square miles.[2] The watershed begins just east of the Continental Divide and includes the communities of Lyons, Hygiene, Ward, Jamestown, and Longmont. It is bordered on the south by the Boulder Creek watershed and on the north by the Big Thompson River watershed. Elevations within the watershed range from over 12,000 feet above Wild Basin to approximately 5,000 feet. The primary tributaries of the St. Vrain Creek include North St. Vrain

[2] The overall St. Vrain Basin is approximately 980 square miles, with the Boulder Creek watershed totaling approximately 450 square miles. The USGS includes a portion of the Boulder Creek watershed in the St. Vrain watershed, which totals approximately 550 square miles. To avoid double counting, the "Boulder Creek Outlet" portion of the St. Vrain watershed has been subtracted to provide the estimate of 530 square miles to maintain the correct watershed total of 980 square miles.

Creek, South St. Vrain Creek, Middle St. Vrain Creek, and Left Hand Creek. Left Hand Creek's tributaries include James Creek and Little James Creek.

Both Boulder Creek and St. Vrain Creek are located in two physiographic provinces. The mountainous upper watersheds are part of the Southern Rocky Mountains Province and are characterized by deep, steeply sloping valleys. The flatter, lower watersheds are part of the Colorado Piedmont Section of the Great Plains Province and slope gently to the northeast. There are five distinct ecological zones represented including alpine, subalpine, montane, foothills, and plains (Murphy 2006).

Water quality varies naturally with location and elevation, so it is important to understand how these watershed characteristics affect water quality. For example, the headwaters region of both Boulder Creek and St. Vrain Creek are located at high elevation, and streams and reservoirs at this elevation tend to be cooler than at lower elevations. Other natural variations include: geology and soils, which can contribute particulates, metals, and nutrients; climate and weather, where solar radiation can influence temperature and algae growth and storms can deliver sediments to the surface waters; and vegetative cover, which provides shade and bank stability, impacting temperature, pH, and sediment delivery. Anthropogenic influences such as urban runoff, point source discharges, irrigation withdrawals or return flows, and groundwater inflows/recharge can influence stream and reservoir water quality (Murphy 2006).

1.3 Major Subwatersheds and Geographic Focus

The primary focus for this Watershed Plan is flowing streams in the Boulder Creek and St. Vrain Creek subwatersheds from the western edge of the urbanized areas in the foothills to I-25 (Figure A-1b). A decision to focus on this geographic area was primarily pragmatic, given the large size of the overall watershed. Additionally, due to complex dynamics associated with modeling and evaluation of reservoir conditions, lakes and reservoirs were excluded from the Watershed Plan, but could be added in future updates. For recent analysis of reservoir conditions in the Boulder watershed, see the *Boulder Watershed Baseline and Annual Water Quality Report for 2011* (City of Boulder and WWE 2013) and the 2012-2013 update (City of Boulder and WWE 2014). For additional information about reservoirs in the St. Vrain Creek watershed, see the *Windy Gap Firming Project Water Resources Technical Report* (U.S. Bureau of Reclamation 2007). The Boulder Creek and St. Vrain Creek watersheds are discussed separately below.

The USGS identifies streams by hydrologic unit codes (HUCs), ranging from 2 to 12 digits, with 12-digit HUCs representing the smallest watershed units. The St. Vrain Basin (8-digit HUC = 10190005) is a subwatershed of the Missouri River Basin (2-digt HUC = 10), South Platte River Basin (4-digit HUC = 1019), and South Platte River (6-digit HUC = 101900). Table 1-3 summarizes the 10-digit and 12-digit HUCs that comprise the subwatersheds of the St. Vrain Basin. Subwatersheds in the Boulder Creek subwatershed are highlighted in grey.

Table 1-3. 12-digit HUC Codes for the St. Vrain Basin

HUC-12	HUC -12 Name	HUC-12 Area (Acres)	HUC-10 Area (Acres)
South Saint Vrain Creek (1019000501)			57,165
101900050101	Headwaters South Saint Vrain Creek	21,848	
101900050102	Middle Saint Vrain Creek	20,953	
101900050103	Outlet South Saint Vrain Creek	14,364	
North Saint Vrain Creek (1019000502)			79,546
101900050201	Rock Creek	9,431	
101900050202	Headwaters North Saint Vrain Creek	24,248	
101900050203	Cabin Creek	14,504	
101900050204	Outlet North Saint Vrain Creek	31,363	
Left Hand Creek (1019000503)			46,548
101900050301	Little James Creek	11,921	
101900050302	Upper Left Hand Creek	14,845	
101900050303	Middle Left Hand Creek	10,294	
101900050304	Lower Left Hand Creek	9,488	
Headwaters Boulder Creek (1019000504)			107,354
101900050401	North Boulder Creek	28,624	
101900050402	Middle Boulder Creek	28,346	
101900050403	Fourmile Creek	15,535	
101900050404	Boulder Creek Canyon	9,787	
101900050405	Fourmile Canyon Creek	6,498	
101900050406	City of Boulder-Boulder Creek	18,564	
South Boulder Creek (1019000505)			85,759
101900050501	Headwaters South Boulder Creek	19,438	
101900050502	Upper South Boulder Creek	26,134	
101900050503	Middle South Boulder Creek	25,647	
101900050504	Lower South Boulder Creek	14,540	
Coal Creek-Boulder Creek (1019000506)			80,333
101900050601	Dry Creek-Boulder Creek	14,065	
101900050602	Upper Coal Creek	17,421	
101900050603	Middle Coal Creek	19,807	
101900050604	Lower Coal Creek	14,455	
101900050605	Bullhead Gulch-Boulder Creek	14,585	
Boulder Creek-St. Vrain (1019000507)			170,158
1.019E+11	Indian Mountain-Saint Vrain Creek	14,978	
1.019E+11	Dry Creek	8,962	
1.019E+11	McIntosh Lake-Saint Vrain Creek	28,629	
1.019E+11	Boulder Reservoir	21,491	
1.019E+11	Outlet Boulder Creek	12,859	
1.019E+11	Calkins Lake-Saint Vrain Creek	14,247	
1.019E+11	Firestone Lake-Saint Vrain Creek	44,437	
1.019E+11	Lake Thomas	11,470	
1.019E+11	Outlet Saint Vrain Creek	13,085	
Total Acres	**(979 sq. miles)**	**626,863**	**626,863**

1.3.1 Boulder Creek Subwatershed

To account for the variations in stream morphology, land use, and habitat (substrate, slope, and temperature), the City of Boulder divides the Boulder Creek subwatershed into the Upper, Middle, and Lower Basins, as illustrated in Figure 1-2. The Upper Basin of Boulder Creek is predominantly an alpine and mountain climatic and ecological zone with cold-water streams. The predominant land use is forest, alpine tundra, and development around the Town of Nederland. The upper reach of Boulder Creek has three tributaries: North Boulder Creek, Middle Boulder Creek and South Boulder Creek. The City of Boulder derives a significant portion of its drinking water supply from the Upper Basin, which includes Barker Reservoir and several smaller reservoirs at higher elevations.

The Middle Basin stream segments begin in the foothills at the confluence of Middle and North Boulder Creeks below Barker Reservoir and end near the confluence with South Boulder Creek at the eastern edge of the city's jurisdictional boundary. Here, Boulder Creek transitions from a cold-water stream to a warm-water plains stream, and the predominant land use is urban. Water chemistry in Boulder Creek changes from upstream to downstream due to a combination of natural and anthropogenic factors (Murphy et al. 2003). The stream transitions from steep terrain underlain by crystalline bedrock to the relatively flat plains underlain by sedimentary rock. Boulder Creek enters the City of Boulder at approximately the transition between the foothills and the plains.

The Lower Basin begins at the confluence of South Boulder Creek and Boulder Creek and flows to the confluence with St. Vrain Creek. Within and downstream of Boulder, multiple factors affect water quality in the creek, including stormwater runoff from urbanized areas, discharges to Boulder Creek and some of its tributaries from multiple wastewater treatment plants (WWTPs), water diversions, and runoff from agricultural land use in the lower watershed. Four general reaches of interest in the Lower Basin include:

- Boulder Creek above Coal Creek: This reach includes the portion of the stream from South Boulder Creek to Coal Creek and receives treated effluent discharges from the city's 75th Street WWTP and is dominated by agricultural and open space lands.

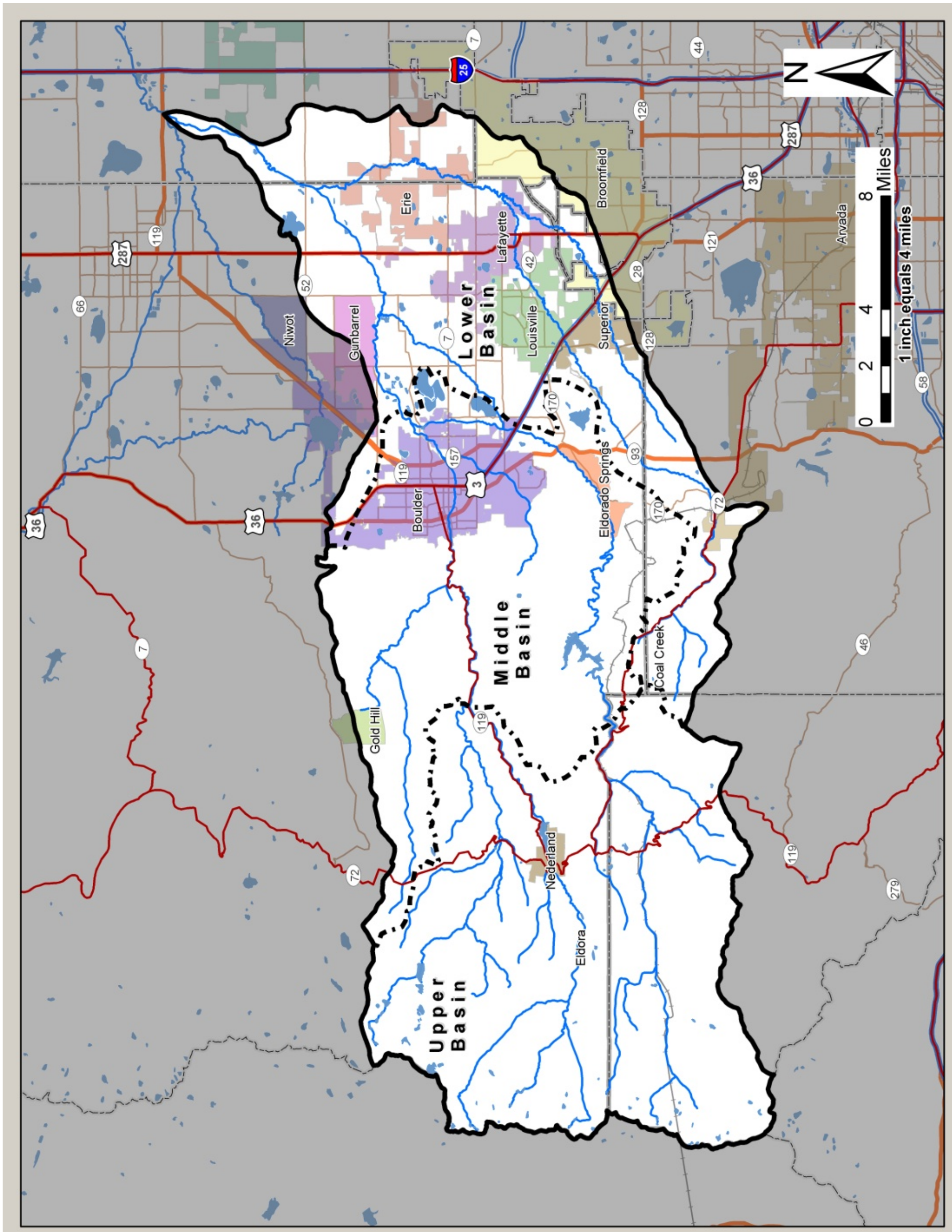
- Coal Creek: Coal Creek originates on the eastern flank of Thorodin Mountain and flows through Coal Creek Canyon, across the plains west of Rocky Flats and then through the communities of Superior, Louisville, Lafayette and Erie. Coal Creek flows 29 miles before joining Boulder Creek downstream of Erie. Above Highway 36, most of Coal Creek is forest or grassland. Below Highway 36, Coal Creek flows through a mixture of urbanized areas and agricultural land. For purposes of this Watershed Plan, the primary focus is the reach of Coal Creek downstream of Highway 36 to the confluence with Boulder Creek. Lafayette and Louisville operate WWTPs that discharge to Coal Creek in this reach.

- Rock Creek: Rock Creek forms in the grasslands just east of Highway 93 and flows through the town of Superior, then through grassland and crop areas prior to its confluence with Coal Creek southeast of Lafayette. Rock Creek is approximately 8 miles long. Superior's WWTP discharges to Rock Creek.

- Boulder Creek below Coal Creek: This primarily agricultural stream reach flows through Boulder County and is influenced by the cumulative WWTP discharges from Boulder, Erie, Superior, Lafayette and Louisville. Erie's new WWTP (North Plant) discharges directly to Boulder Creek in this reach. Boulder Creek joins St. Vrain Creek downstream of Longmont, west of I-25.

Table 1-3 provides 12-digit HUC codes for the smaller subwatersheds in the Boulder Creek subwatershed. Three 10-digit HUCs make up the Boulder Creek watershed as defined in this Watershed Plan, including Headwaters Boulder Creek (HUC 10190000504), South Boulder Creek (HUC 1019000506), and Coal Creek-Boulder Creek (HUC 1019000506). A portion of a fourth HUC identified as Boulder Creek-St. Vrain (1019000507) includes the outlet of Boulder Creek to St. Vrain Creek.

Figure 1-2. Boulder Creek Watershed
(Source: Murphy et al. 2003)



1.3.2 St. Vrain Creek Subwatershed

The upper portion of the St. Vrain Creek subwatershed is also principally an alpine and mountain climatic and ecological zone with cold-water streams. The headwaters of North St. Vrain Creek originate in the Wild Basin region of Rocky Mountain National Park. The headwaters of Left Hand Creek are located at the northern tip of the Colorado Mineral Belt, and the upper watershed terrain is primarily alpine and sub-alpine forest (Division 2015). Left Hand Creek serves as a key water supply (and the only winter water source) for the 18,000 residential customers of the Left Hand Water District (Left Hand Watershed Oversight Group [LWOG] 2005). This region of the upper watershed is of particular interest because of historical mining activity that has resulted in elevated instream metals concentrations, particularly in the vicinity of James Creek, Little James Creek and Left Hand Creek. Legacy mining features include draining mine adits, waste rock piles, and tailings.

As the St. Vrain Creek transitions from the foothills to the plains, its channel characteristics reflect the decrease in grade. This change is evident near the confluence of North and South St. Vrain Creeks in the town of Lyons. The land surrounding the creek just beyond the base of the foothills is primarily used for agriculture, and then transitions to urban use as the creek passes through the city of Longmont. Left Hand Creek joins St. Vrain Creek above Longmont's WWTP. Below the city of Longmont, the land use returns to primarily agricultural use to the confluence with the South Platte River. As noted in Section 1.3, Table 1-3 provides 12-digit HUC codes for the smaller subwatersheds in the St. Vrain Creek basin.

1.4 LAND USE

Characterizing land use in the basin is important in terms of identifying potential pollutant sources, as well as for identifying the types of control practices that may help to reduce pollutants loads. The majority of the St. Vrain Basin is located in Boulder County (Table 1-4), with the lower portion of the watershed located in Weld County. Although less than 5 percent of the watershed is urbanized, the urbanized area covers approximately 45 square miles. Approximately 40 percent of the watershed is forested and nearly 50 percent is rangeland, grassland or crops. Figure 1-3 illustrates the land uses in the watershed. Tables 1-4 and 1-5 provide a summary of county land areas in the St. Vrain Basin and a tabulation of land uses in the basin, respectively. Appendix A provides additional land use figures.

Table 1-4. St. Vrain Basin Land Use by County
(Source: NRCS 2010)

County	County Acres	County Acres in St. Vrain Basin	% of County in St. Vrain Basin	Percentage of St. Vrain Basin in the County
Boulder	473,815	460,864	97.3%	73.5%
Broomfield	21,454	5,529	25.8%	0.9%
Gilpin	96,045	44,896	46.7%	7.2%
Jefferson	494,626	17,287	3.5%	2.8%
Larimer	1,684,151	8,944	0.5%	1.4%
Weld	2,568,765	89,562	3.5%	14.3%

Table 1-5. Description of St. Vrain Basin Land Uses
(Source: NRCS 2010)

Land Area	Percentage
Forest	42%
Rangeland/Grassland	29%
Cropland: Irrigated	14%
Cropland: Dryland	4%
Commercial	2%
Residential	2%
Water	2%
Riparian	1%
Other	4%
Total	100%

Much of the Upper Boulder Creek watershed is managed by the U.S. Forest Service and/or protected as a source water area by the City of Boulder. The majority of the upper St. Vrain Creek subwatershed is undeveloped and consists primarily of evergreen forest. Most of the South St. Vrain Creek tributary is managed and owned by the U.S. Forest Service. The North St. Vrain Creek headwaters begin within Rocky Mountain National Park and most of the upper watershed below the park is owned by the City of Longmont and private owners. Boulder County Parks and Open Space also manages over 30,000 acres of forest in the basin.

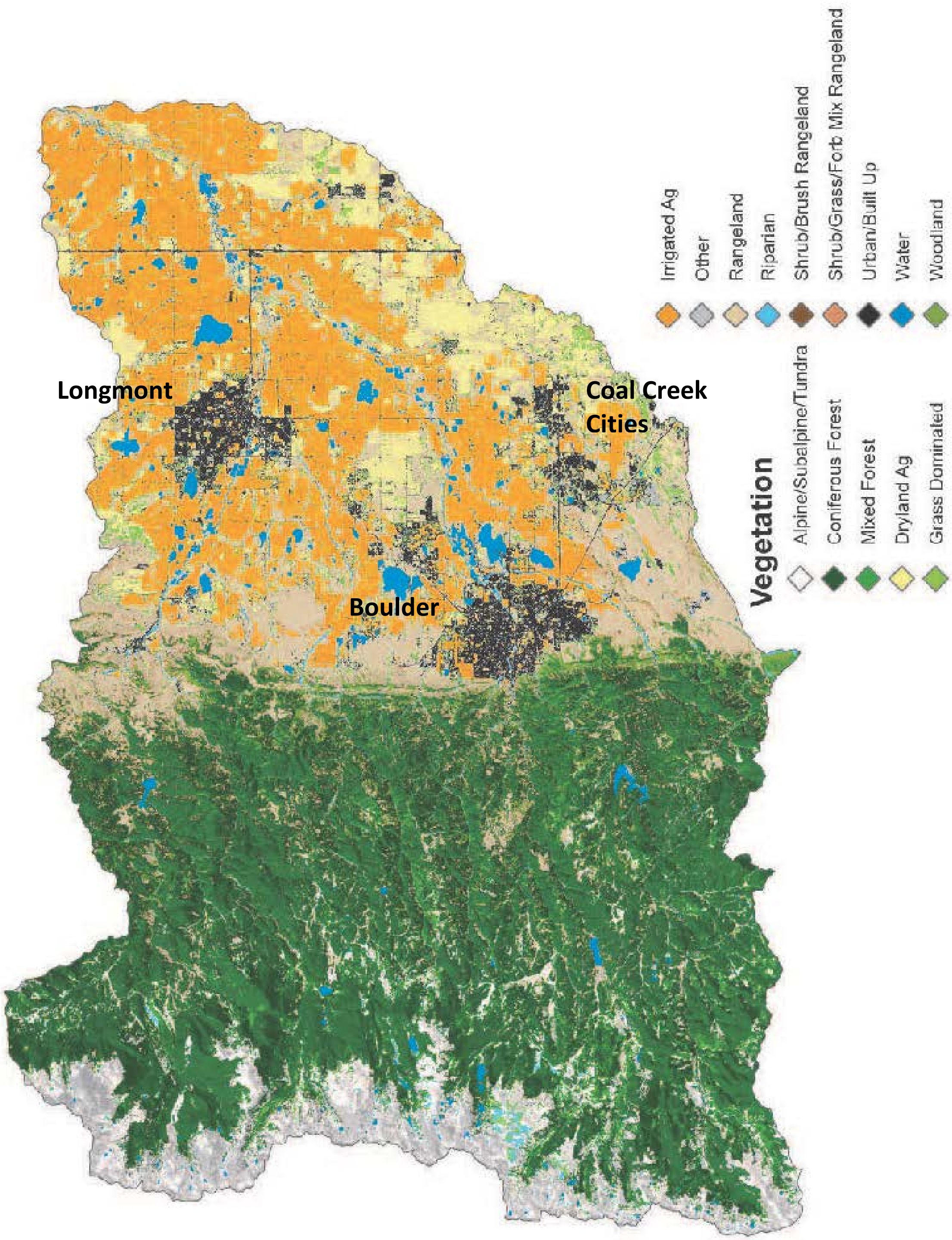
Farm-related characteristics are summarized in Table 1-6 (NRCS 2010), including both privately-owned and publically-owned land. Boulder County Parks and Open Space (BCPOS) leases approximately 20,880 acres of land to local farmers and ranchers. Additionally, the City of Boulder's Open Space and Mountain Parks (OSMP) Department leases almost 15,000 acres to local farmers and ranchers. Figure A-7 in Appendix A identifies publically-owned lands in agricultural production in Boulder County. Figure A-8 provides a map of all public open space properties in Boulder County.

Livestock production is the most widespread agricultural use of OSMP land, followed by hay and forage production. Due to soil types, slope, and access to irrigation water, most of the land owned by OSMP that is leased for agricultural purposes is best suited for livestock grazing. These lands include native grasslands and irrigated hay meadows. As of 2014, OSMP leases over 7,600 acres of land to four certified natural beef producers. Summer grazing occurs on grasslands with fall and winter aftermath grazing on hay fields (Source: https://bouldercolorado.gov/osmp/agriculture-program, accessed July 2014). The main irrigated crops in Boulder County are alfalfa, sugar beets, small grain, dry beans and pasture grasses. Vegetable crops are also grown on limited acreages. The main dryland crop is winter wheat (Boulder County 2014).

Table 1-6. Farm-Related Characteristics of St. Vrain Basin
(Source: NRCS 2010)

	County			
Farm Characteristic	**Boulder**	**Gilpin**	**Jefferson**	**Weld**
Farms (number)	736	26	457	3121
Land in Farms/Ranches (acres)	107,629	6,045	90,366	1,812,167
Average Farm size (acres)	146	233	198	581
Median Farm Size (acres)	38	154	35	158
Cattle and Calves (number)	11,000	NA	2,000	505,000

Figure 1-3. Land Use Characteristics in the St. Vrain Basin
(Source: NRCS 2010)



1.5 Population Characteristics

The Boulder Economic Council and City of Longmont Department of Economic Development released Demographic Profiles of each city in December 2011 and February 2012, respectively, which provide useful demographic information for Boulder County. Boulder County has an estimated 295,500 residents. Boulder and Longmont are the largest cities in Boulder County, comprising approximately two-thirds of the county's residents, with a combined population of over 184,300. Boulder's population is expected to grow by an average of 0.8% a year through 2035, while Longmont's population is expected to grow by an average of 0.6% during the same period.

Population estimates for other cities within the county are shown in Figure 1-4 and Table 1-7. Figure 1-5 shows the locations of the cities and towns in the watershed. Nederland and Ward are located in the upper Boulder Creek watershed. The City of Boulder is located in the middle and lower portions of the Boulder Creek watershed. Louisville, Lafayette and Erie are located in the Coal Creek subwatershed, and Superior is located in the Rock Creek subwatershed. Jamestown is located in the Upper St. Vrain Creek watershed. Lyons and Longmont are located in the middle portion of the St. Vrain Creek watershed. Unincorporated Boulder County includes areas in all of the subwatersheds, including a significant population of over 43,000 residents (BEC 2011). Unincorporated communities of Boulder County include Coal Creek Canyon (shared with Gilpin and Jefferson counties), Allenspark, Eldora, Eldorado Springs, Gold Hill, Gunbarrel, Hygiene and Niwot.

Figure 1-4. Boulder County Population by Municipality
(Source: Boulder Economic Council 2011, citing Colorado Demography Office)

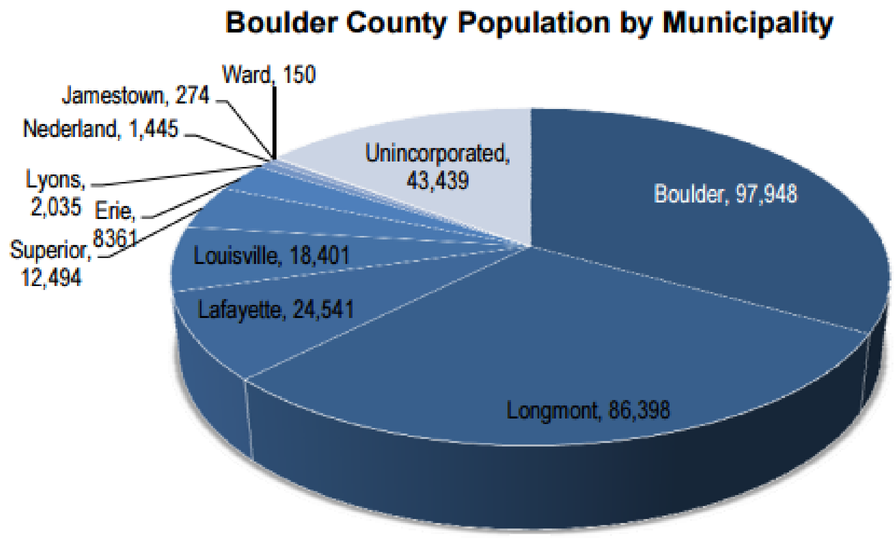


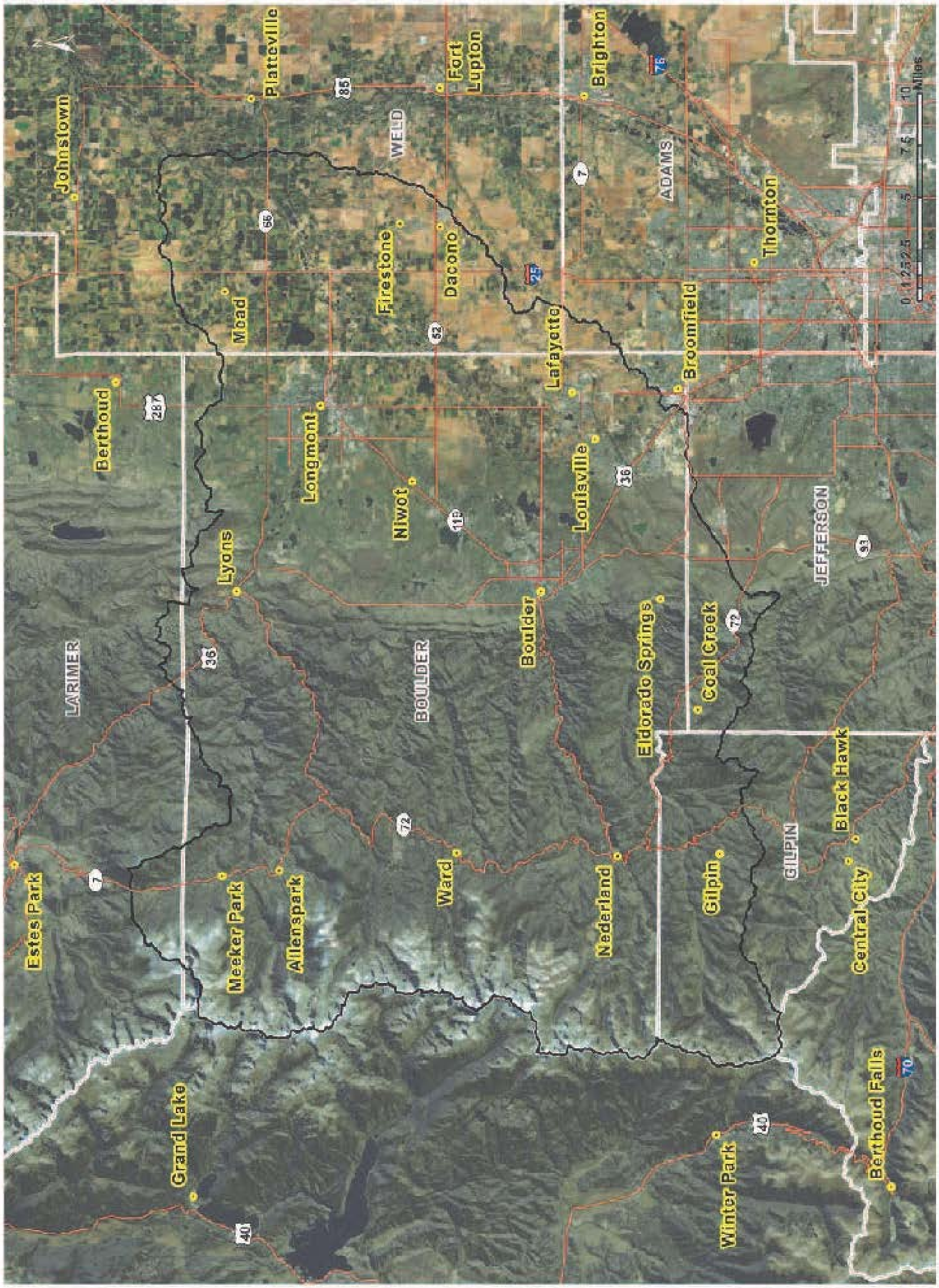
Table 1-7. Boulder County Population by Municipality
(Source: Boulder Economic Council 2011, citing Colorado Demography Office)

Boulder County Population by Municipality

	July 2000		July 2010		Change 2000 – 2010	
Boulder	98,747	35.7%	97,948	33.2%	-799	-.8%
Longmont*	72,372	26.2%	86,398	29.2%	14,026	19.4%
Lafayette	23,344	8.5%	24,541	8.3%	1,197	5.1%
Louisville	19,053	6.9%	18,401	6.2%	-652	-3.4%
Erie*	4,512	1.6%	12,494	4.2%	3,198	34.4%
Superior*	9,296	3.4%	8,361	2.8%	3,849	85.3%
Lyons	1,642	.6%	2,035	.7%	393	23.9%
Nederland	1,397	.5%	1,445	.5%	48	3.4%
Jamestown	291	.1%	274	.1%	-17	-11.2%
Ward	169	.1%	150	.1%	-19	-11.2%
Unincorporated	45,473	16.5%	43,439	14.7%	-2,034	-4.5%
Boulder County	276,296**	100.0%	295,486	100.0%	19,190	7.0%
Colorado	4,338,801		5,050,870		712,069	1.5%

Colorado State Demography Office; *Cities in more than one county (figures include Boulder County population only); **Includes Broomfield's 38,544 residents (the city became a separate county in 2001)

Figure 1-5. Cities and Towns in St. Vrain Basin
(St. Vrain Basin outlined in black. Source: NRCS 2010)



1.6 CDPS-Permitted Discharges

The National Pollution Discharge Elimination System (NPDES) was developed under the Clean Water Act to control pollutants from point sources, such as industrial dischargers, wastewater treatment facilities, and municipal stormwater dischargers in urbanized areas. In Colorado, the NPDES program is implemented by the Colorado Water Quality Control Division (Division) under the Colorado Discharge Permit System (CDPS). CDPS-permitted discharges to Boulder Creek and St. Vrain Creek and their tributaries include on-going and temporary discharges. Temporary discharge permits typically relate to subterranean dewatering and construction sites. On-going permitted discharges include sanitary wastewater, municipal separate storm sewer systems (MS4s), and industrial discharge permits. Numeric effluent limits are applied in sanitary wastewater and industrial discharge permits. Implementation of practice-based pollutant control programs is currently required for MS4s, as opposed to numeric discharge limits. Entities with stormwater and wastewater discharge permits are summarized in Tables 1-8 and 1-9. Industrial discharge permits also exist in the watershed and can be accessed from EPA's Enforcement and Compliance History Online (ECHO) database website (http://echo.epa.gov/).

Table 1-8. Summary of MS4 Permits in St. Vrain Basin

Name	MS4 Permit
Boulder Creek Watershed	
Boulder County	COR090020
Boulder, City of	COR090019
Erie, Town of	COR090021
Lafayette, City of	COR090030
Louisville, City of	COR090017
Superior, Town of	COR090022
St. Vrain Creek Watershed	
Longmont, City of	COR090018

Nonpoint Source funds can only be used to support projects outside of MS4 coverage areas. For example, CDPS permit requirements resulting from the Boulder Creek Segment 2b *E. coli* TMDL cannot be funded using Nonpoint Source funds. Figure A-1b identifies the MS4 coverage boundaries along with the existing Boulder Creek TMDL for *E. coli.*

Table 1-9. Summary of Municipal and Special District Wastewater Treatment Plant Discharges for Boulder Creek and St. Vrain Creek Watersheds

Watershed	Facility Name	City	Permit No.	Permit Type	Permitted Discharge (MGD)
Boulder Creek	SAN LAZARO MHP WWTP	BOULDER	CO0020184	Minor	0.11
Boulder Creek	RED LION INN	BOULDER	COG588118	Minor	0.007
Boulder Creek/ Fourmile Creek	BOULDER MOUNTAIN LODGE	BOULDER	COG650146	Minor	0.0045
Boulder Creek	LAKE ELDORA WSD WWTP	NEDERLAND	CO0020010	Minor	0.03
Boulder Creek/South Boulder Creek	SAN SOUCI MHP	LOUISVILLE	COG588101	Minor	0.018
Boulder Creek	NEDERLAND TOWN OF WWTP	NEDERLAND	CO0020222	Minor	0.189
Boulder Creek	75TH ST WWTP	BOULDER	CO0024147	**Major**	25.0
Boulder Creek	B&B MOBILE AND RV PARK	WELD	COG588107	Minor	0.015
Boulder Creek	ERIE WWTP (NORTH PLANT)	ERIE	CO0045926	**Major**	1.5
Coal Creek	LAFAYETTE WWTP	LAFAYETTE	CO0023124	**Major**	4.4
Coal Creek	LOUISVILLE WWTP	LOUISVILLE	CO0023078	**Major**	3.4
Coal Creek	ELDORADO SPRINGS WWTP	ELDORADO SPRINGS	CO0047651	Minor	0.032
Rock Creek	SUPERIOR METROPOLITAN DIST NO. 1	SUPERIOR	CO0043010	**Major**	2.2
St. Vrain Creek/ Dry Creek	NIWOT SANITATION DISTRICT	NIWOT	CO0021695	Minor	0.98
St. Vrain Creek	LONGMONT WWTP	LONGMONT	CO0026671	**Major**	17.0
St. Vrain Creek	ST VRAIN SANITATION DISTRICT	WELD COUNTY	CO0041700	**Major**	3.0
St. Vrain Creek	LAKE THOMAS SUBDIVISION WWTP	LONGMONT	CO0046868	Minor	0.012
St. Vrain Creek	LYONS, TOWN OF	LYONS	CO0020877	Minor	0.381
St. Vrain Creek	MEAD, TOWN OF	MEAD	CO0046876	Minor	0.499
St. Vrain Creek/South St. Vrain Creek	GLACIER VIEW RANCH	(*near Jamestown*)	CO0030112	Minor	0.040
St. Vrain Creek/Middle St. Vrain	PEACEFUL VALLEY RANCH WWTF	(*Peak to Peak Highway*)	CO0048828	Minor	0.013

1.7 Hydrology and Water Management (Water Rights)

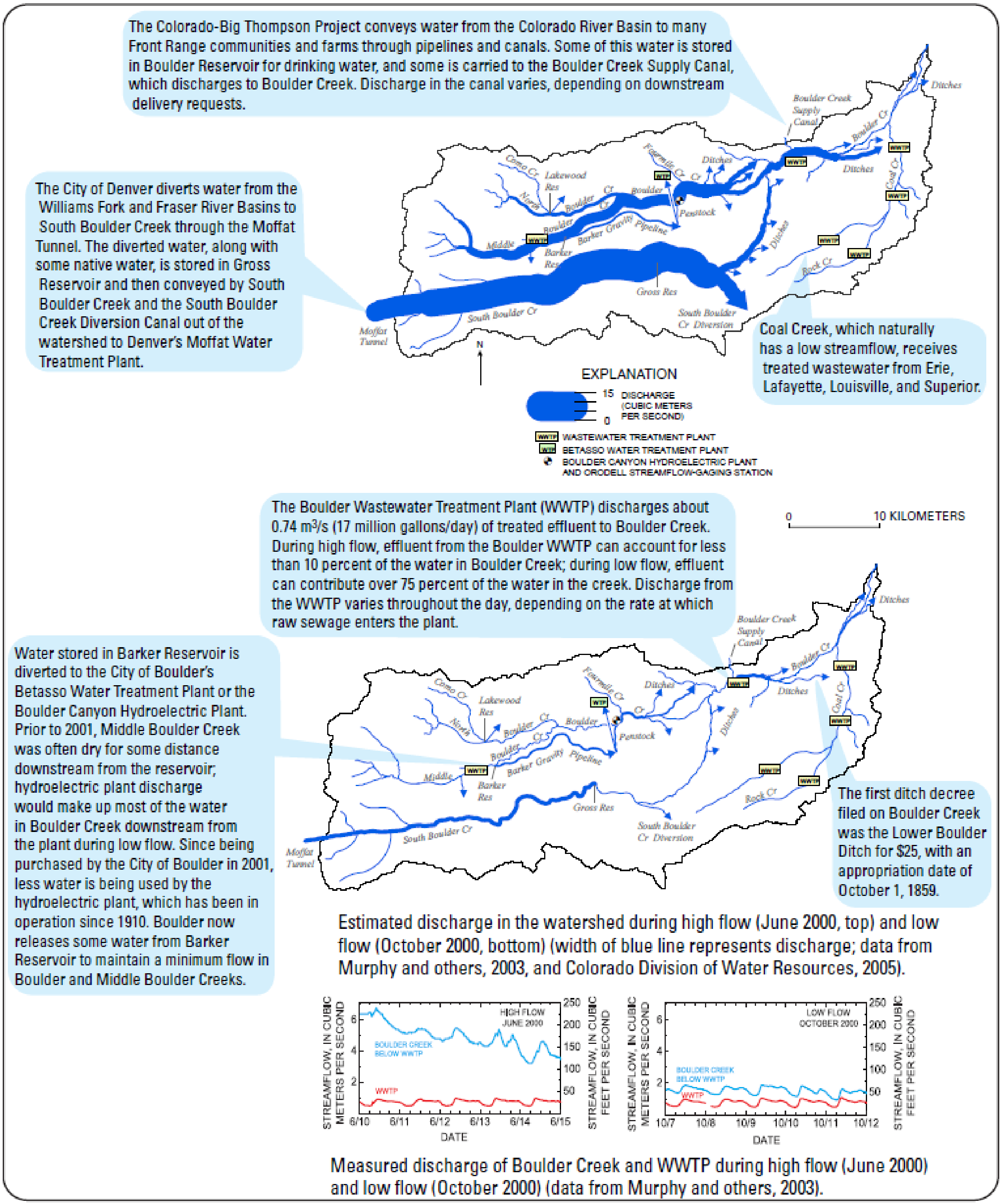
Streamflow in the St. Vrain Basin originates primarily as snowmelt near the Continental Divide. Stream discharge varies seasonally and annually depending on snowpack depth and air temperature. Low-flow conditions occur from October to March; high-flow conditions occur from May to July and usually peak in June (Murphy 2006). Representative factors affecting hydrology in the basin include natural precipitation, timing of spring runoff, WWTP discharges, ditch diversions, reservoir operations, water imported from other watersheds, irrigation runoff, and other factors. For some stream segments, treated wastewater flows dominate the stream during certain times of the year. This is particularly true in the urbanized portion of Coal Creek, Rock Creek and Lower Boulder Creek below the 75th Street WWTP.

Figure 1-6, developed by the U.S. Geological Survey (USGS), illustrates some of the major hydrologic influences in the Boulder Creek subwatershed at a conceptual level. Although a comparable figure has not been prepared for the St. Vrain Creek subwatershed, it also has complex hydrology. In the Left Hand Creek subbasin of St. Vrain Creek, the Left Hand Ditch Company (LHDC) owns the first 31 priorities for direct flow diversions from Left Hand Creek, and therefore effectively controls the entire flow of the creek in most years (LWOG 2005). Straight-line diagrams in Figures 1-7 through 1-9 identify inflows and diversions for Boulder Creek, Coal Creek, and St. Vrain Creek, further illustrating the complexity of the hydrology.

Identification of stream gauges and available flow data at locations throughout the watershed is a critical component of load estimation. Care should be taken to understand diversions or discharges to the stream between the gauge location and the water quality sampling location. Appendix B provides a summary of stream gauges present in the watershed, along with hydrographs for selected gauge locations. Some of the long-term gauges were damaged in the September 2013 flood and may require time to come back on-line. Others have been discontinued and have been replaced recently with new gauges. Table B-1 in Appendix B lists a summary of active gauges in the St. Vrain Basin and the operating entity. To obtain flow data, it may be necessary to access the USGS, Colorado Division of Water Resources, Northern Colorado Water Conservancy District and OneRain websites to download the most current data sets. Other gauge data may be available from private ditch companies. Manual instantaneous flow monitoring with handheld meters is also conducted by cities in the watershed at selected locations in conjunction with water quality sampling.

Figure 1-6. Characterization of Hydrologic Factors Affecting Boulder Creek

(Source: Murphy 2006, USGS Circular 1284)



Estimated discharge in the watershed during high flow (June 2000, top) and low flow (October 2000, bottom) (width of blue line represents discharge; data from Murphy and others, 2003, and Colorado Division of Water Resources, 2005).

Measured discharge of Boulder Creek and WWTP during high flow (June 2000) and low flow (October 2000) (data from Murphy and others, 2003).

Figure 1-7. Straight-Line Diagram of Water Inflows and Outflows for Boulder Creek
(Updated from work originally completed by Lewis and Saunders [2003] for Ammonia TMDL)

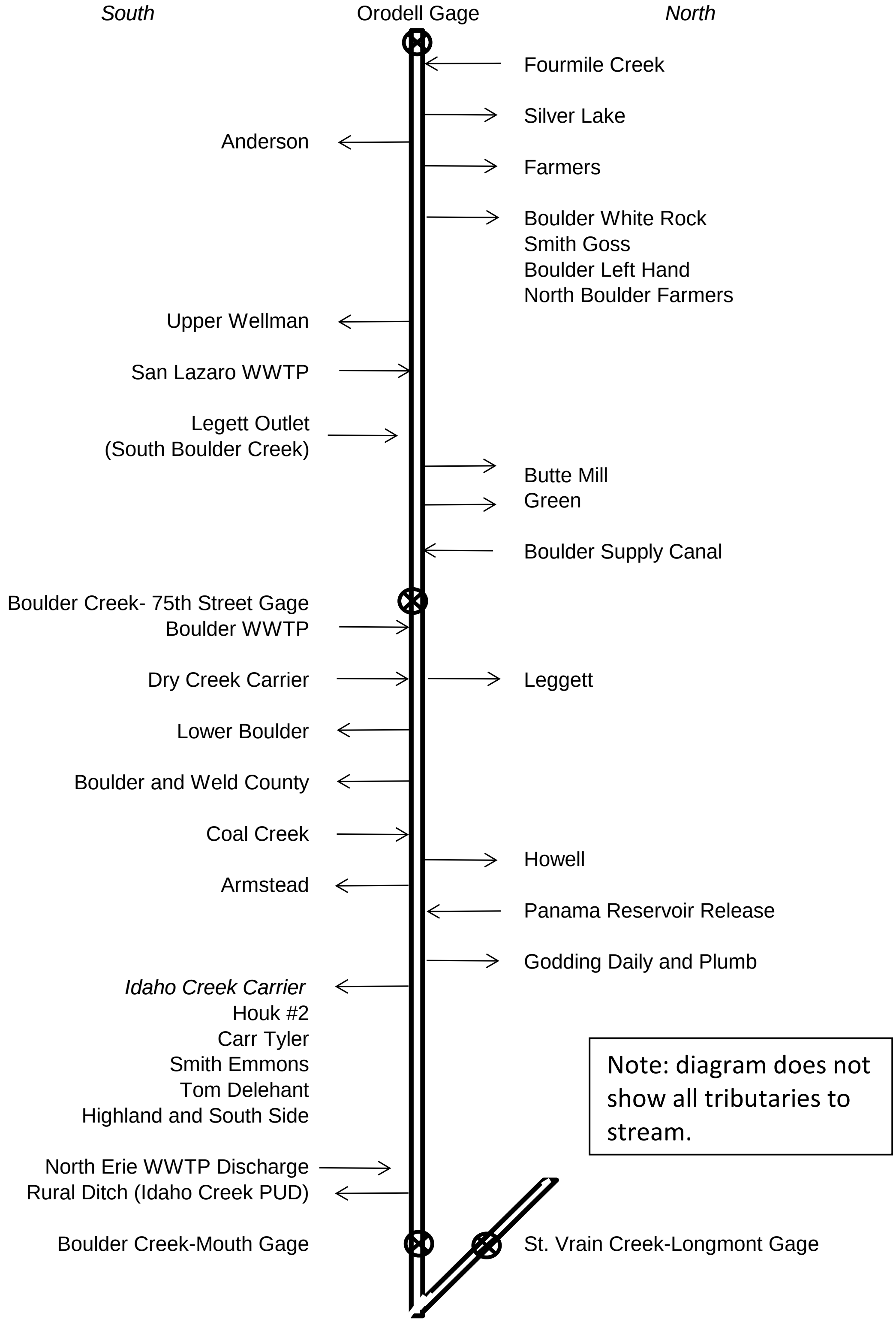


Figure 1-8. Straight-Line Diagram of Water Inflows and Outflows for Coal Creek
(Updated from work originally completed by Lewis and Saunders [2003] for Ammonia TMDL)

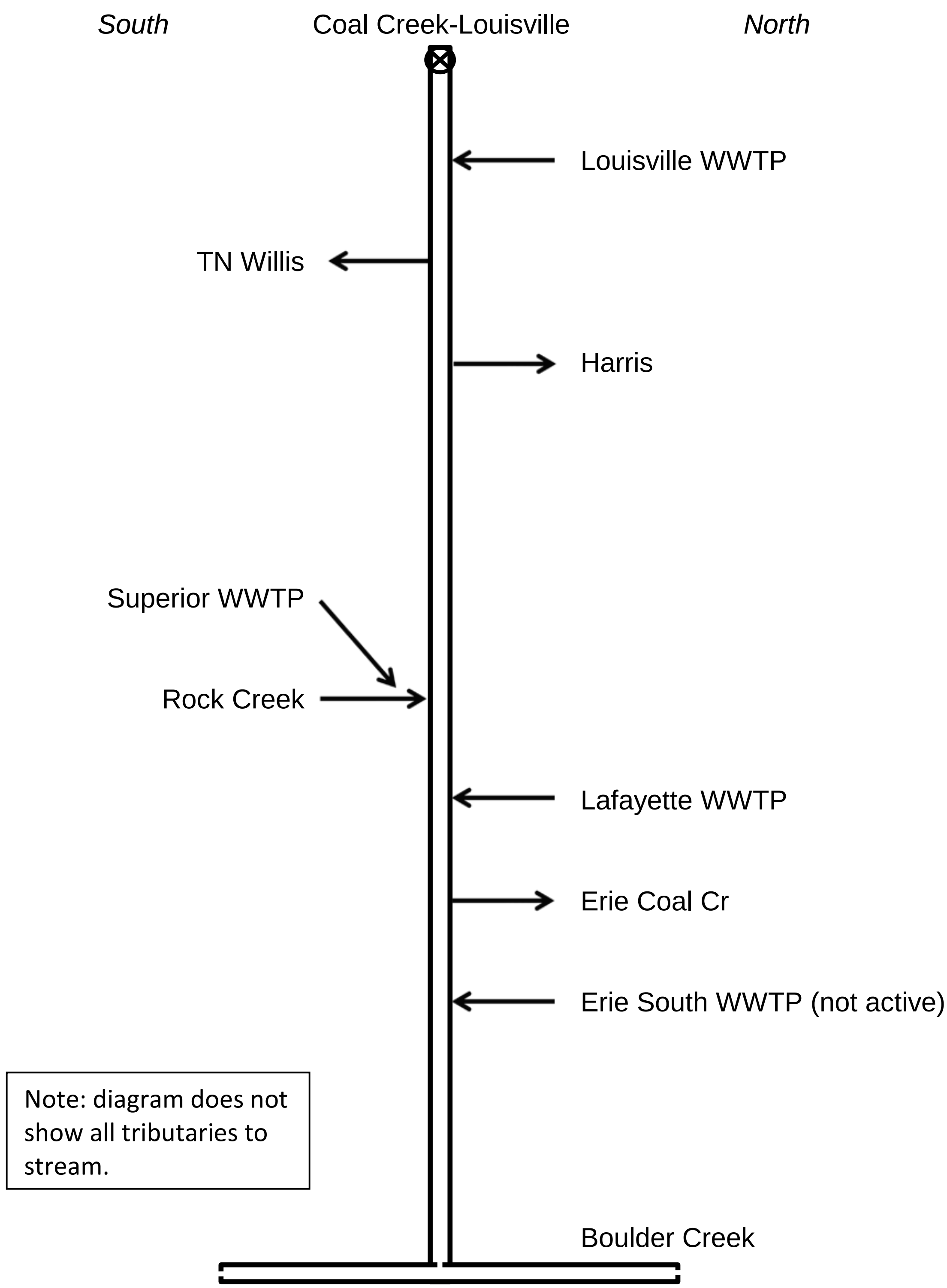
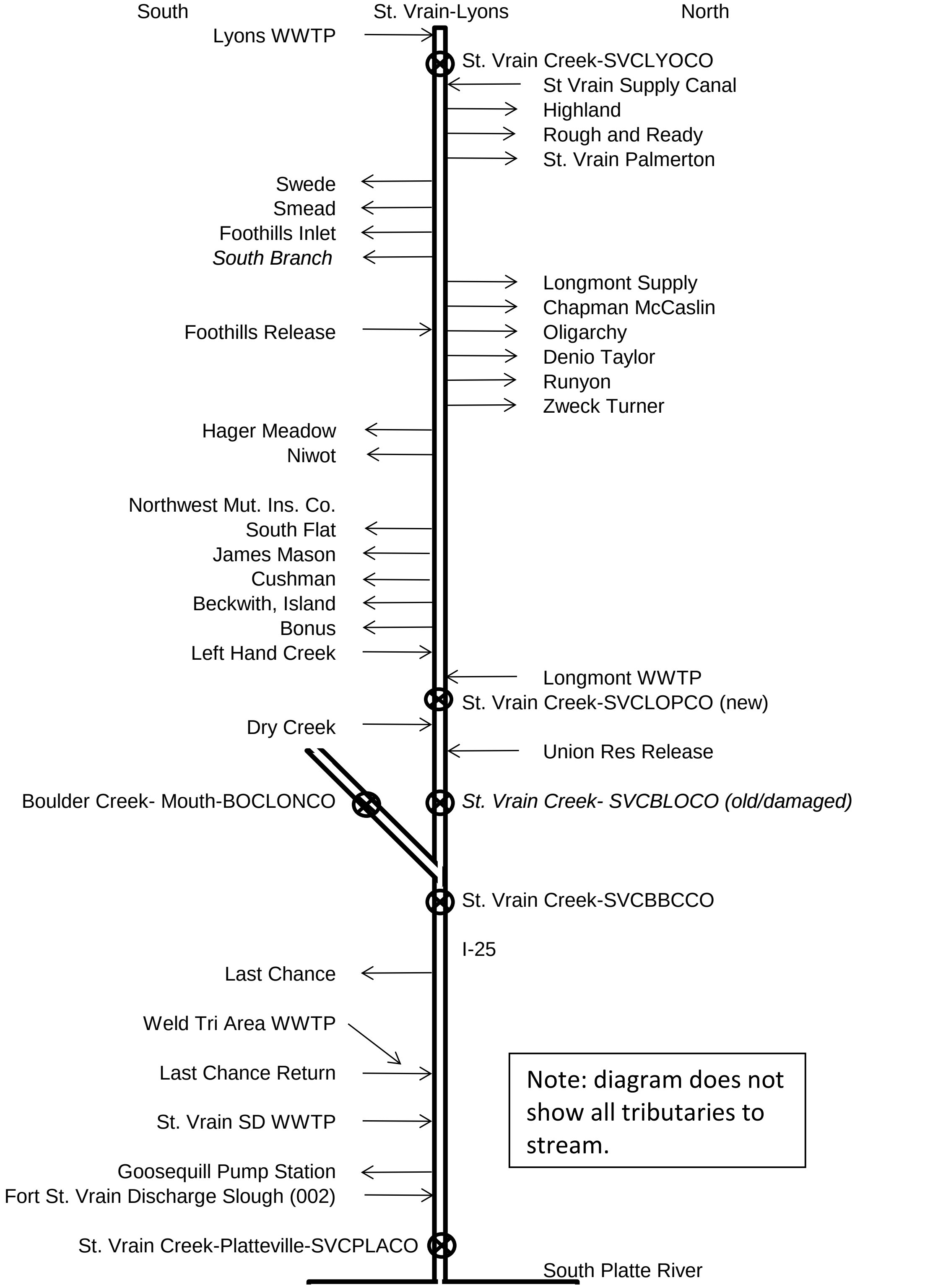


Figure 1-9. Straight-Line Diagram of Water Inflows and Outflows for St. Vrain Creek

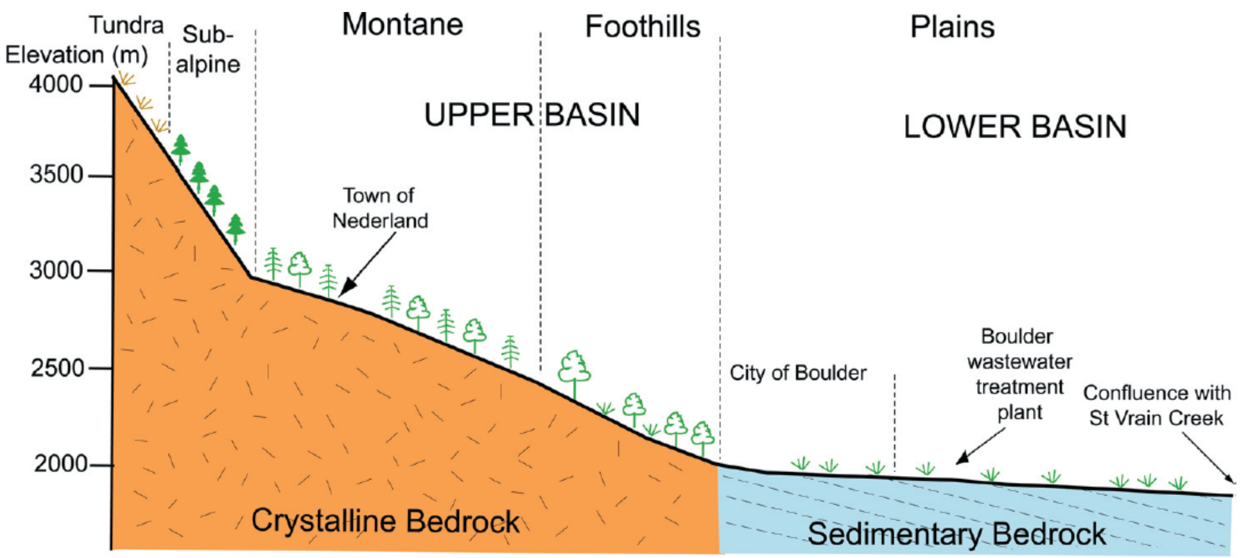
(Updated from work originally completed by Lewis and Saunders [2003] for Ammonia TMDL)



1.8 GEOLOGY AND MINING

The upper portion of the St. Vrain Basin is underlain by 1.4–1.8 billion-year-old metamorphic and granitic bedrock, with deposits of gold, silver, tungsten, and other metals that were emplaced 30–60 million years ago. The lower basin is underlain by 65–300 million-year-old sedimentary rocks, including shale, sandstone, limestone, and coal-bearing deposits. Mountain-building events that occurred about 70 million years ago caused steeply dipping rock layers at the edge of the mountain front. Ridges and valleys reflect subsequent erosional processes (Murphy et al., 2003). Figure 1-10 provides an illustration of these characteristics for the Boulder Creek portion of the basin, and a similar pattern is present in the St. Vrain Creek portion of the basin.

Figure 1-10. Geologic and Ecological Characteristics of Boulder Creek Watershed
(Source: Murphy et al. 2003)

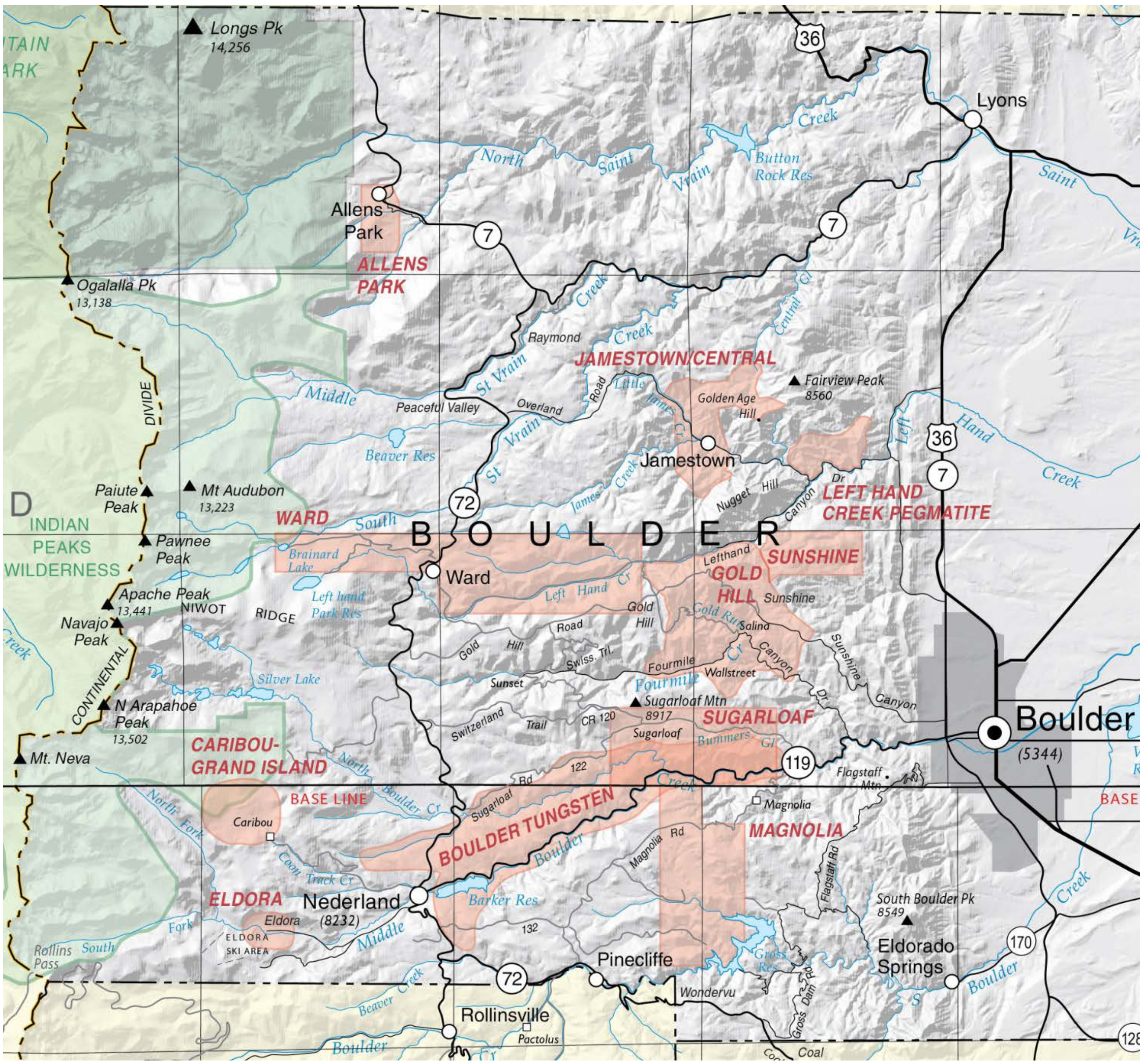


Mining has played a major role in the development of the Boulder County area. At least 300 hard rock mill sites, 500 hard rock mine sites and 80 coal mine sites existed over time in Boulder County. This has included historic coal mining in the Coal Creek and Rock Creek drainages and hard rock mines and mills along Middle Boulder Creek, Fourmile Creek, Left Hand Creek and James Creek (For more information see the BASIN website: http://bcn.boulder.co.us/basin/gallery/minesFigures.html). Fourmile Creek, which is a tributary to Boulder Creek, once had the highest level of gold-mining operations in the watershed (Murphy et al. 2003).

Figure 1-11 provides a general overview of the historic mining district areas of the watershed. Figure A-4 in Appendix A shows permitted mining activity in the watershed (dating back to 1974 only). Most active mining in the watershed is related to rock products such as sand and gravel; however, there is a “mining belt” that is located in the upper watershed. Metals mined in this area include gold, silver, copper and tungsten. Most of the hard-rock mine operations were shut down by approximately 1920, but small-scale mining still continues as shown in Figure A-4. Water quality effects from mining and associated mill sites may continue to occur after mining operations cease.

Figure 1-11. Boulder County Historic Mining District

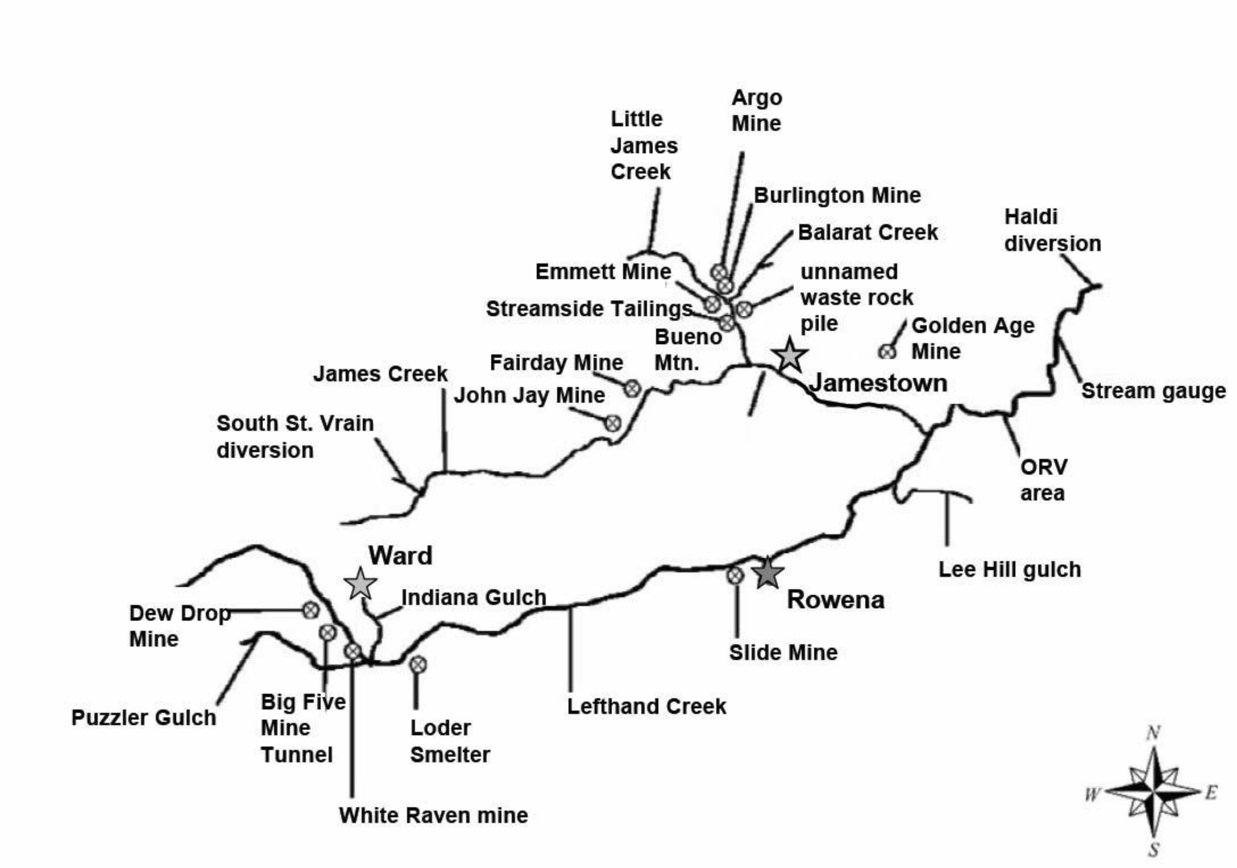
(Source: Colorado Geological Survey, http://coloradogeologicalsurvey.org/mineral-resources/historic-mining-districts/boulder-county/)



In the Boulder Creek subwatershed, the long-term effects of mining have been less pronounced due to low sulfide content in ores (Murphy 2006). Mining can affect water quality when sulfide minerals in waste rock and tailings interact with water and oxygen to produce sulfuric acid, which leaches metals from rock and increases metal toxicity to aquatic organisms. The ore deposits in the Boulder Creek subwatershed usually contain small amounts of sulfides, so runoff from old mines and tailings piles is typically not acidic or metal-rich. Metal concentrations in North Boulder and Middle Boulder Creeks are usually low (Murphy et al. 2003). Some tributaries of South Boulder Creek are acidic and have elevated metal concentrations, but flow in these tributaries is too small to have a substantial effect on the main stem of South Boulder Creek (Asher-Bolinder 1995; Colorado Riverwatch 2001).

In the St. Vrain Creek subwatershed, historic mining activities continue to impact streams, particularly in the Left Hand Creek subwatershed (including James Creek and Little James Creek) as shown in Figure 1-12. Metals loading and depressed pH within the Left Hand Creek Watershed result from both natural geologic conditions and historic (unpermitted) mining activities. Legacy mining features include draining mine adits, waste rock piles and tailings. Tailing materials were typically deposited adjacent to or directly down-gradient of milling operations. Although active mining ceased some time ago, the discharge of pollutants through the direct discharge of seepage from the mine workings and more diffuse transport via snowmelt or precipitation continue today (Division 2015). A total maximum daily load (TMDL) for several metals was originally completed for the Left Hand Creek and tributaries in 2002 and was recently updated by the Division in 2015, as discussed in Section 1.16.

Figure 1-12. Left Hand Creek Watershed Showing Significant Mining Features
(Source: Division 2015, originally from Bautts et al. 2007)



The Captain Jack Mill, which is a superfund site, is located at the headwaters of upper Left Hand Creek about 1.5 miles south of Ward in Boulder County, Colorado (generally located upstream [south] of the Big Five Mine Tunnel in Figure 1-12.) Mining for gold and silver in this area began in 1860 and ended in 1992. The Colorado Mined Land Reclamation Board received reports of dumping of mine and mill wastes into Left Hand Creek in October 1992. Subsequent sampling of the discharge to the creek showed high levels of zinc, cadmium, copper and lead. Because the Left Hand Water District uses water from Left Hand Creek as a drinking water source, contamination of the stream is a significant concern to water users.

Surface and subsurface remedies have been developed to address contamination from the Captain Jack Mill. The surface remedy was completed in 2012 and consisted of consolidating mine waste materials from various areas of the site into two consolidation cells. Vegetated soil cover systems with surface water diversion structures were established over each consolidation cell to prevent human contact with contaminated materials and to minimize rain and snow melt contact with the waste materials, to prevent leaching of metals into the surface water. The EPA reports that the surface remedy construction at the site fared very well in the September 2013 flood event. The Colorado Department of Public Health and Environment (CDPHE), as the site lead, has acquired a contractor to implement the subsurface remedy, which is slated to begin in September 2015. Above-ground monitoring systems will be installed the fall of 2015 and the in-tunnel treatment system and engineered flow-through bulkhead are scheduled to be installed in early summer 2016. For more information, see http://www2.epa.gov/region8/captain-jack-mill.

1.9 SOILS

Soil conditions are also an important factor affecting watershed health, particularly with regard to susceptibility to erosion. In 2012, a soil erodibility ranking was completed for much of the overall St. Vrain and Boulder Creek watersheds in support of a recent wildfire risk assessment (JW Associates 2012). Table 1-10 and Figure 1-13 illustrate portions of the watershed with high erodibility rankings.

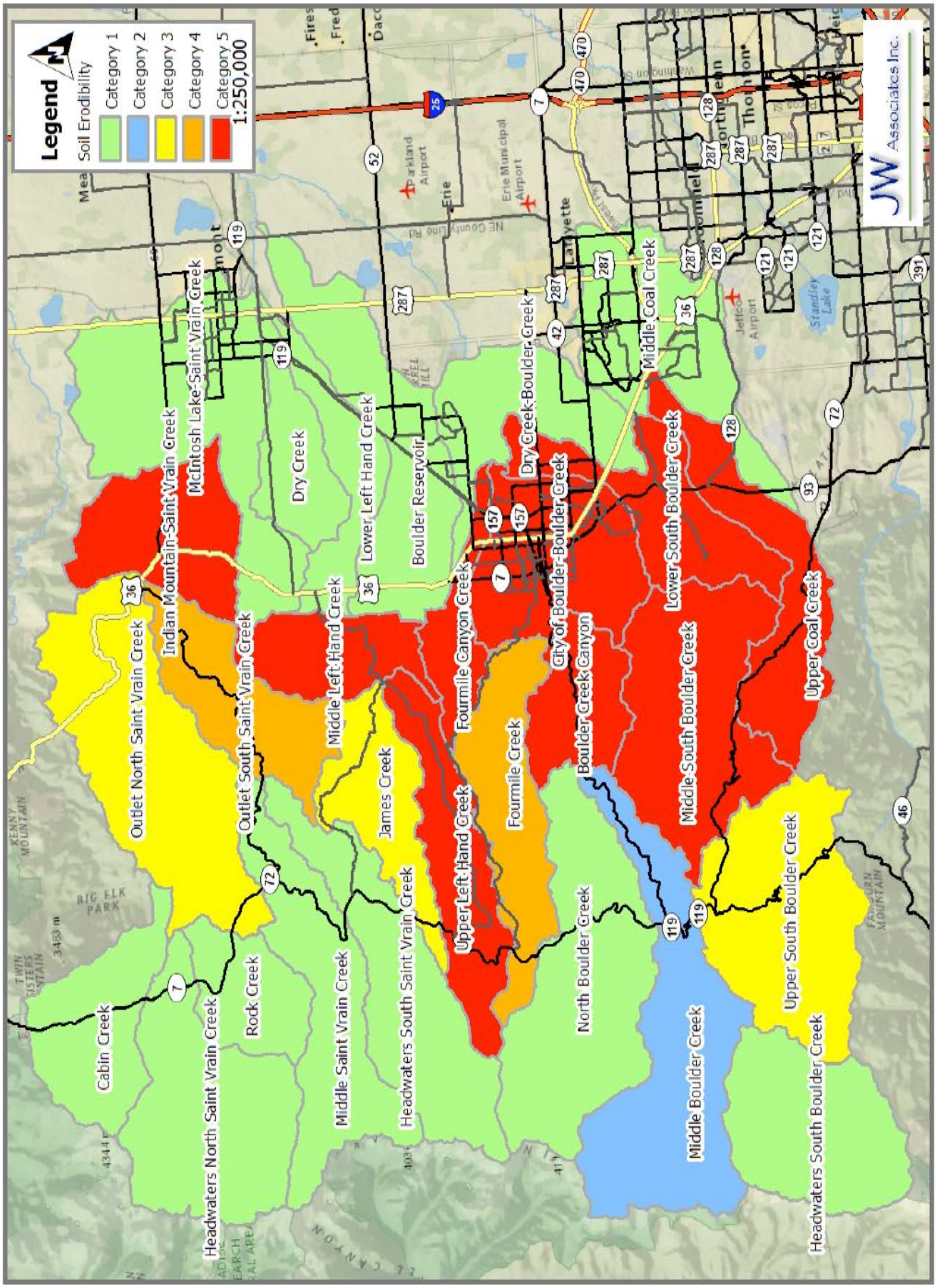
More detailed information on soil characteristics can be obtained from Soil Survey of the Boulder County Area (SCS 1975). The upper portion of the Boulder Creek watershed streams are in the Rock Outcrop-Juget-Baller association before entering the plains. Below an elevation of approximately 5,500 feet, different soil associations are present for various stream segments. For example, most of the main stem of Boulder Creek and South Boulder Creek is identified as the Niwot-Loveland-Calkins association, Rock Creek is identified in the Samsil-Shingle association, and Coal Creek is identified as the Nederland-Valmont association and the Nunn-Heldt association (SCS 1975). These differences in soil associations can affect the water quality characteristics of the streams, including conditions such as alkalinity, hardness, pH and other characteristics. Soil characteristics also affect the types of crops grown, irrigation practices, and other agronomic practices.

Information on hydrologic soil groups is also important with regard to urban developments and stormwater best management practice (BMP) selection. For example, Hydrologic Soil Group Type C and D soils are typically not well suited for infiltration of stormwater, whereas as sandy soils (Type A and B) can be ideal locations to manage frequently occurring storm events through infiltration.

Table 1-10. St. Vrain Basin Soil Erodibility Ranking
(Source: JW Associates 2012)

Sixth-level Watershed Name	Severe (%)	Very Severe (%)	Soil Erodibility Value	Soil Erodibility Rank
City of Boulder-Boulder Creek[5]	8.0%	71.1%	0.330	5.5
Indian Mountain-Saint Vrain Creek[5]	13.7%	66.5%	0.330	5.5
Upper Left Hand Creek[5]	66.1%	0.1%	0.330	5.5
Middle Left Hand Creek[5]	26.1%	10.6%	0.330	5.5
Boulder Creek Canyon[5]	49.6%	0.0%	0.330	5.5
Middle South Boulder Creek	17.0%	7.7%	0.325	5.4
Upper Coal Creek	16.4%	6.2%	0.288	4.9
Lower South Boulder Creek	16.2%	6.3%	0.287	4.9
Fourmile Canyon Creek	16.0%	5.7%	0.274	4.7
Fourmile Creek	25.2%	0.2%	0.257	4.4
Outlet South Saint Vrain Creek	22.4%	0.4%	0.233	4.0
Outlet North Saint Vrain Creek	13.9%	2.1%	0.181	3.2
James Creek (1)	15.8%	0.0%	0.158	2.9
Upper South Boulder Creek	8.4%	3.3%	0.151	2.8
Middle Boulder Creek	5.1%	2.8%	0.108	2.1
Lower Left Hand Creek	0.7%	2.6%	0.059	1.4
Boulder Reservoir	1.9%	1.7%	0.053	1.3
North Boulder Creek	2.4%	0.6%	0.036	1.0
McIntosh Lake-Saint Vrain Creek	1.4%	0.5%	0.023	0.9
Middle Coal Creek	1.5%	0.0%	0.015	0.7
Middle Saint Vrain Creek	1.3%	0.0%	0.013	0.7
Dry Creek	1.2%	0.0%	0.013	0.7
Headwaters South Saint Vrain Creek	0.6%	0.0%	0.006	0.6
Dry Creek-Boulder Creek	0.1%	0.0%	0.001	0.5
Rock Creek	0.0%	0.0%	0.000	0.5
Headwaters North Saint Vrain Creek	0.0%	0.0%	0.000	0.5
Cabin Creek	0.0%	0.0%	0.000	0.5
Headwaters South Boulder Creek	0.0%	0.0%	0.000	0.5

Figure 1-13. St. Vrain Basin Soil Erodibility Ranking

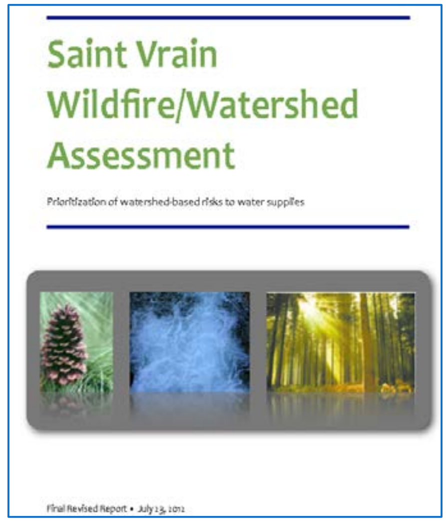


1.10 Oil and Gas Activity

Figure A-5 in Appendix A identifies oil and gas activity in the watershed. Most of the activity is concentrated in the lower watershed, including Weld County. The Colorado Oil and Gas Conservation Commission (COGCC) has rules and processes in place to help minimize and avoid water quality impacts associated with oil and gas development activities. For more information, see the COGCC website: http://cogcc.state.co.us/.

1.11 Wildfire Hazard

The Saint Vrain Wildfire/Watershed Assessment completed by JW Associates, Inc. (2012) assessed wildfire hazard in the St. Vrain Basin. The purpose of the watershed assessment was to identify and prioritize sixth-level watersheds based upon their hazards of generating flooding, debris flows and increased sediment yields following wildfires that could have impacts on water supplies (JW Associates 2012). The watershed assessment follows a procedure prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009). The watershed assessment included both the Boulder Creek and St. Vrain subwatersheds upstream of the plains portion of the watershed.



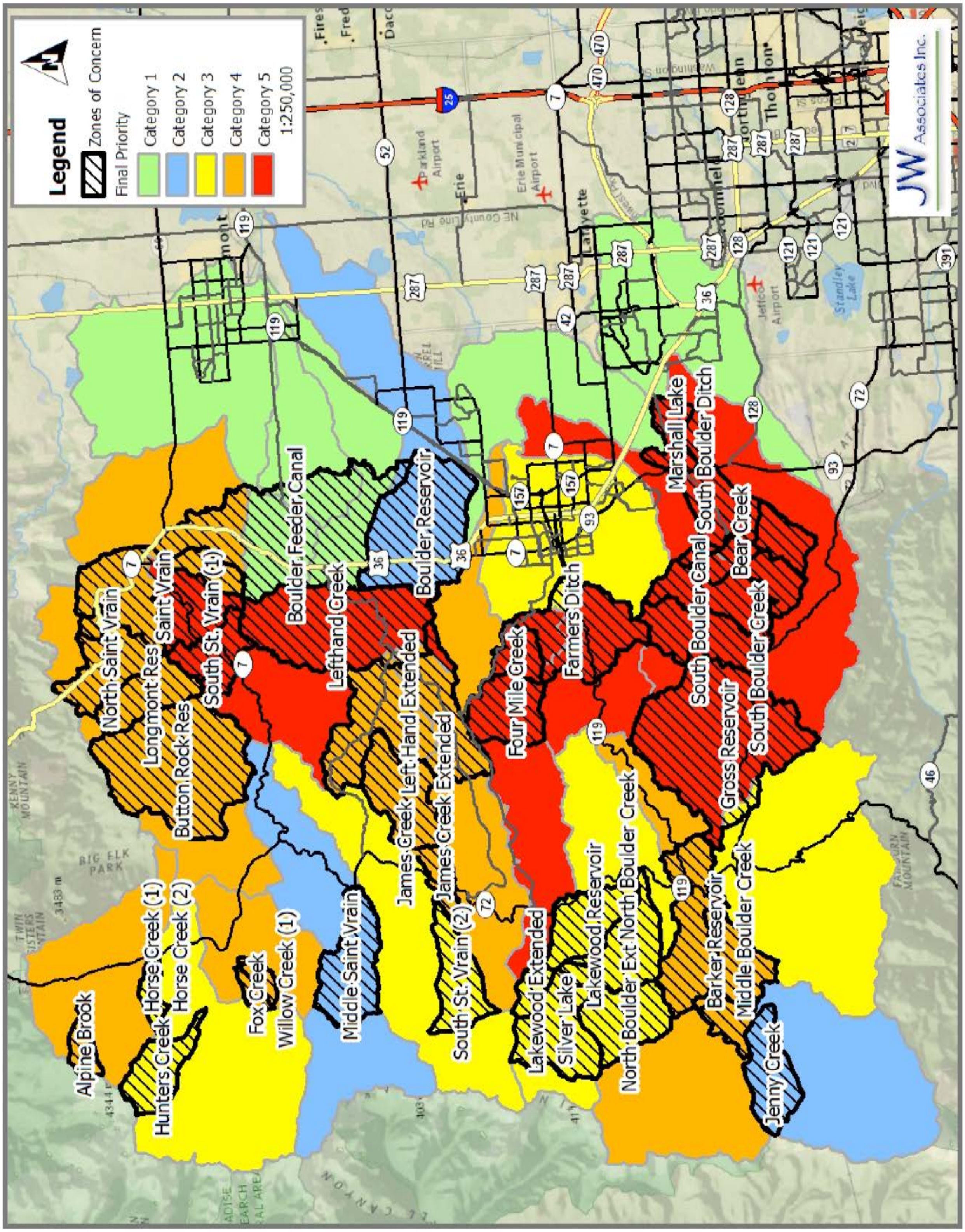
As described by JW Associates (2012), the potential of a watershed to deliver sediments following wildfire depends on forest and soil conditions, the configuration of the watersheds, and the sequence and magnitude of rain falling on the burned area. High-severity fires can cause changes in watershed conditions that can dramatically alter runoff and erosion processes in watersheds. Water and sediment yields may increase as more of the forest floor is affected by fire. The Saint Vrain Wildfire/Watershed Assessment considered four components that are integral in evaluating hazardous watershed conditions: wildfire hazard, flooding or debris flow hazard, soil erodibility and water supply.

As part of the assessment, inventories of ruggedness, road density, soil erodibility, land ownership, and vegetation were compiled for subwatersheds. These inventories are useful not only for assessing wildfire hazard, but also for assessing areas that may be subject to erosion and opportunities for BMP implementation as part of this Watershed Plan. The wildfire assessment incorporated Mountain Pine Beetle (MPB) mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey (ADS) Data from the years 2002-2007 (http://www.fs.fed.us/r2/resources/lm/aerialsurvey/). Table 1-11 provides wildfire hazard ranking for the St. Vrain Basin, excluding the plains portion of the basin. Figure 1-14 provides the final prioritized wildfire hazard ranking considering hazards of wildfires, flooding/debris flows, soil erodibility and the presence of water supply features. The stakeholder-determined “zones of concern” are also shown on this figure. The subwatersheds that ranked highest on the final priority figure are Boulder Creek Canyon, Fourmile Creek, Middle Left Hand Creek, Middle South Boulder Creek, Outlet South Saint Vrain Creek, and Upper Coal Creek. See the entire JW Associates (2012) report for more detail.

Table 1-11. St. Vrain Basin Wildfire Hazard Ranking
(Source: JW Associates 2012)

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Hazard Rank
Rock Creek	9,428	80.4%	5.5
Outlet North Saint Vrain Creek	31,351	78.5%	5.3
Outlet South Saint Vrain Creek	14,358	76.4%	5.1
Boulder Creek Canyon	9,783	75.6%	5.1
Upper Coal Creek	16,423	69.9%	4.5
Lower South Boulder Creek	14,534	68.8%	4.4
Middle Left Hand Creek	10,290	68.1%	4.4
Upper South Boulder Creek	26,124	67.5%	4.3
Middle South Boulder Creek	25,637	64.2%	4.0
Cabin Creek	14,498	63.8%	4.0
Fourmile Creek	15,528	63.1%	3.9
Headwaters South Boulder Creek	19,430	62.7%	3.9
Fourmile Canyon Creek	6,495	62.3%	3.8
Upper Left Hand Creek	14,839	61.2%	3.7
Headwaters South Saint Vrain Creek	21,839	61.2%	3.7
James Creek (1)	11,917	60.6%	3.7
North Boulder Creek	28,612	58.4%	3.5
Middle Saint Vrain Creek	20,944	58.3%	3.5
Indian Mountain-Saint Vrain Creek	14,972	58.0%	3.4
Middle Boulder Creek	28,334	56.4%	3.3
Headwaters North Saint Vrain Creek	24,238	52.3%	2.9
Dry Creek-Boulder Creek	14,059	40.7%	1.9
Middle Coal Creek	19,799	38.4%	1.6
Boulder Reservoir	21,482	35.6%	1.4
Dry Creek	8,958	34.3%	1.3
City of Boulder-Boulder Creek	18,556	34.2%	1.3
Lower Left Hand Creek	9,484	28.6%	0.8
McIntosh Lake-Saint Vrain Creek	28,617	25.8%	0.5
Totals	500,529		

Figure 1-14. St. Vrain Basin Final Priority Wildfire Hazard Ranking and Zones of Concern



1.12 September 2013 Flood Damage Inventory, Planning and Mitigation

The September 2013 flood event devastated large portions of Boulder County, including impacts to stream channels and riparian corridors. The flood occurred shortly after this watershed planning effort began; therefore, detailed flood damage planning and mitigation were not envisioned within the scope of this Watershed Plan. Flood-related planning is being conducted under a series of major watershed grants from the Colorado Water Conservation Board (>$700,000). These plans are being developed with strong emphasis on transportation, floodplain management and needed longer-term repairs, following the initial emergency response actions after the flood.

In the spring of 2014, Boulder County, in conjunction with partners and stakeholders throughout the county, created the Comprehensive Creek Planning Initiative (CCP) to develop post-flood, watershed-level master plans for creek corridors most impacted by the September 2013 flood. Master plans will assist in rebuilding efforts by providing post-flood analysis of flows, facilitating key decisions about creek alignment, and identifying actions for stream restoration and flood risk management. The master planning process is an open and collaborative effort among public agencies, property owners, ditch companies, stakeholders, and the public. This is an evolving process, with the latest information accessible at: http://www.bouldercounty.org/flood/creekrestoration/pages/default.aspx.

As of August 2015, post-flood master plans have now been completed for these Boulder County subwatersheds in the St. Vrain Basin:

- Fourmile Creek
- Left Hand Creek
- St. Vrain Creek
- Upper Coal Creek

There is also a planning process underway for Fourmile Canyon Creek and for Boulder Creek, from its confluence with Fourmile Creek to its confluence with St. Vrain Creek. Both projects will be completed by late summer 2015.

The watershed master plans identify recommended projects to restore and stabilize the watershed. Recommended projects are on private and public property and include measures such as bank stabilization, channel realignment, debris removal, revegetation, and restoration of the low-flow channel.

A complete inventory of flood damage, planning and mitigation activities is beyond the scope of this Plan; however, as such inventories become available, there may be opportunities to integrate features providing multi-purpose benefits as stream corridor improvements and repairs are implemented.

1.13 OTHER WATERSHED CHARACTERISTICS AND INVENTORIES

Critical wildlife and plants and threatened and endangered species are provided in Table 1-12, as summarized by the NRCS (2010). Threatened and endangered species information was gathered by the NRCS using data from the Colorado Division of Wildlife (CDOW) Natural Diversity Information Source (NDIS). For more information on the most current Colorado endangered and threatened species, as well as species of concern, visit http://mountainprairie.fws.gov/endspp/CountyLists/COLORADO.htm or http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/ThreatenedEndangeredList/ListOfThreatenedAndEndangeredSpecies.htm.

Maps of threatened and endangered species, critical wildlife habitat and migration corridors and Preble's Meadow Jumping Mouse habitat (and other information) can also be found on Boulder County's website:
http://www.bouldercounty.org/property/build/pages/bccpupdate.aspx.

Wildlife inventories can also be found in various open space and greenway master plans discussed in Section 1.14. For example, an evaluation of wildlife habitat conducted in the late 1990s in Lower Boulder Creek observed many mammals such as white-tailed deer, black-tailed prairie dogs, rock squirrels, raccoons, beavers, coyotes, black bears, gophers and yellow-bellied marmots and documented expected occurrence for other mammals such as foxes, bobcats and others (Meaney 1997). Bird species of special concern to Boulder County have also been documented, including peregrine falcons (federal endangered), double-crested cormorant, great blue herons and several others (Jones 1997).

Table 1-12. Threatened and Endangered Species in St. Vrain Basin
(Source: NRCS 2010)

Common Name	Scientific Name	Class	State Status	Federal Status
American Peregrine Falcon	*Falco peregrinus anatum*	Birds	Concern	None
Bald Eagle	*Haliaeetus leucocephalus*	Birds	Threatened	None
Black-tailed Prairie Dog	*Cynomys ludovicianus*	Mammals	Concern	None
Brassy Minnow	*Hybognathus hankinsoni*	Fish	Threatened	None
Burrowing Owl	*Athene cunicularia*	Birds	Threatened	None
Common Garter Snake	*Thamnophis sirtalis*	Reptiles	Concern	None
Common Shiner	*Luxilus cornutus*	Fish	Threatened	None
Greenback Cutthroat Trout	*Oncorhynchus clarki stomias*	Fish	Threatened	Threatened
Iowa Darter	*Etheostama exile*	Fish	Concern	None
Mountain Plover	*Charadrius montanus*	Birds	Concern	None
Northern Leopard Frog	*Rana pipiens*	Amphibians	Concern	None
Preble's Meadow Jumping Mouse	*Zapus hudsonius preblei*	Mammals	Threatened	Threatened
Swift Fox	*Vulpes velox*	Mammals	Concern	None
Stonecat	*Noturus flavus*	Fish	Concern	None
Townsend's Big-Eared Bat	*Corynorhinus townsendii pallescens*	Mammals	Concern	None

1.14 Integration with Other Planning Efforts

As an initial step in development of this Watershed Plan, other on-going planning efforts were inventoried.[3] Key plans with information pertinent to this Watershed Plan were provided by watershed stakeholders and are summarized in Table 1-13. Although this list is by no means all-inclusive, it identifies some of the key plans where there may be "opportunistic" benefits for improving water quality. Plans of particular interest include those that include stream restoration and stormwater quality BMPs. (*Some have already been mentioned in this Watershed Plan*.)

Table 1-13. Summary of Selected Planning Documents in St. Vrain Basin Pertinent to Water Quality and Stream Health

Document	Relationship to Water Quality/Stream Health in St. Vrain Basin by Stream Segment
Saint Vrain Wildfire/Watershed Assessment Prioritization of Watershed Based Risks to Water Supplies, Final Revised Report (JW Associates 2012)	Identifies areas at risk from wildfire and prioritizes actions to reduce risk, which can include water quality impacts in post-burn areas.
Rocky Mountain National Park Initiative (https://www.colorado.gov/pacific/cdphe/rocky-mountain-national-park-initiative)	Includes agricultural BMPs to reduce ammonia emissions to the air from agricultural operations during strategic time periods in order to reduce nitrogen deposition in Rocky Mountain National Park.
Boulder County's Comprehensive Creek Planning Initiative (http://www.bouldercounty.org/flood/property/pages/creeks.aspx)	Provides overall post-flood, long-term creek recovery effort focused on watershed-level master planning processes. Master plans will provide post-flood analysis of flows, facilitate key decisions about creek alignment, identify actions for stream restoration and flood risk management.
Boulder Creek E. coli TMDL Implementation Plan: 13th St. to South Boulder Creek (Tetra Tech 2011)	Includes schedule of actions related to E. coli reduction with a portion of MS4 boundary along Boulder Creek.
City of Boulder Comprehensive Flood and Stormwater Utility Master Plan (URS 2004)	Identifies need for stormwater quality features, with potential integration of flood control and water quality structures.

[3] Monitoring programs in the watershed are inventoried in the Monitoring Plan, available at http://www.keepitcleanpartnership.org/.

Document	Relationship to Water Quality/Stream Health in St. Vrain Basin by Stream Segment
City of Boulder Open Space and Mountain Parks, Grassland Ecosystem Management Plan (City of Boulder 2009)	Provides a framework for on-the-ground management actions, public policies, and land and water acquisition priorities to conserve the ecological values of Boulder's grasslands and ensure on-going agricultural production. Includes riparian corridor protection.
City of Boulder Source Water Master Plan (MWH and AMEC 2011)	Includes recommendations to protect and improve source water quality in the Upper Boulder Creek Basin and in tributaries to Boulder Reservoir.
Greenways Master Plan (City of Boulder 2011)	Identifies and prioritizes opportunities for environmental enhancement and restoration projects and areas for preservation. Includes riparian corridor preservation and practices on Boulder Creek and South Boulder Creek and other tributaries.
Open Space and Mountain Parks Agricultural Resources Management Plan (City of Boulder, in progress)	Includes measures to manage agricultural activities to minimize soil erosion and pollutant loading.
WERF Boulder Creek Nutrient Study (Bell et al. 2015)	Provides modeling assessment for nutrients in Boulder Creek.
Fourmile Creek Watershed Master Plan (Baker et al. 2014b)	Provides master plan to assist in post-flood recovery efforts by providing post-flood risk analysis, facilitating key decisions about creek alignment, and identifying actions for stream restoration and flood risk management.
Lower Boulder Creek and Coal Creek Open Space Master Plan (Anderson and Company 1998)	Includes riparian corridor preservation opportunities and practices in Lower Boulder Creek and Coal Creek. Topics addressed included restoring self-sustaining riparian ecosystems, restoring the floodplain, wetlands, native plant communities and wildlife habitat, aquatic life and other objectives. The plan advocates preservation of riparian buffers and grazing setbacks from streams, along with other management recommendations.
Upper Coal Creek Watershed Restoration Master Plan (Icon et al. 2014)	Evaluates flood, geomorphic, and ecological risk to drainageways and infrastructure within the Upper Coal Creek Watershed and provides recommendations, guidance, and prioritization for restoration and rebuilding efforts. Includes recommendations related to revegetation of riparian corridors to provide habitat and

Document	Relationship to Water Quality/Stream Health in St. Vrain Basin by Stream Segment
	help protect the physical integrity of the aquatic environment.
Coal Creek and Rock Creek Major Drainageway Plan (RESPEC 2013)	Provides master drainage plan from Highway 128 to the northern Erie city limit, just upstream of the confluence with Boulder Creek. Identifies needed stormwater conveyance, detention, stream stability, and stormwater quality improvement measures.
Watershed Management Plan for the Upper Left Hand Creek Watershed, Boulder, CO, Colorado (Left Hand Watershed Oversight Group 2005)	Prioritizes historic mining-related sources of metals contamination in Left Hand Creek watershed and identifies BMPs recommended to mitigate pollution.
Left Hand Creek Watershed Master Plan (AMEC et al. 2014)	Addresses and coordinates the response to key restoration issues in the planning area in the aftermath of the September 2013 floods. Includes measures to protect and enhance water quality, specifically addressing the impacts to the source water for Jamestown and Left Hand Water District's potable water systems.
St. Vrain Creek Watershed Master Plan (Baker et al. 2014a)	Provides long-term planning for St. Vrain Creek at the watershed scale to address flood control and stream restoration following the September 2013 flood.
City of Longmont St. Vrain Riparian Corridor Protection Plan (Biohabitats 2010)	Identifies recommended improvements to St. Vrain Creek and the creek corridor, including construction or preservation of wetlands, controlling invasive species, improving habitat, stabilizing the river bank, mitigating stormwater impacts, controlling and correcting nonpoint source pollution, and improving conditions for aquatic life and wildlife within the riparian corridor.
Focus on Longmont: Citywide Strategic Plan Update (Longmont 2012)	Includes enhancing the natural environment as part of its strategic direction and includes policies related to enhancing the St. Vrain Creek corridor and obtaining open space.
Open Space and Trails Master Plan (Longmont 2002)	Intended to incorporate citizen input into the use, management, and support of open space in Longmont. Includes riparian corridor protection.
St. Vrain Greenway Master Plan (Design Workshop 2001)	Seeks to demonstrate how the St. Vrain corridor can serve the dual purpose of environmental protection and

Document	Relationship to Water Quality/Stream Health in St. Vrain Basin by Stream Segment
	recreational opportunity. Includes riparian corridor protection.
Wildlife Management Plan, City of Longmont, Colorado (Longmont 2005)	Purpose of the plan is to assist the city in meeting the goals of wildlife protection and habitat preservation. Includes riparian corridor protection.

Other opportunities may also exist for integration with on-going efforts of the Colorado Division of Wildlife, Colorado Division of Reclamation Mining and Safety, U.S. Fish and Wildlife Service, USGS, NRCS, University of Colorado, and other local organizations and government agencies.

1.15 Stream Standards and designated Uses

Under Colorado Water Quality Control Commission regulations (e.g., Regulations 31 and 38), surface waters within a watershed are divided into segments, which are then assigned designated uses (Table 1-14) based on how the waters are currently used and what uses are desired for the future. There are 38 stream segments in the St. Vrain Basin. Appendix D provides the Regulation 38 tables (updated in June 2015) summarizing applicable stream standards and designated uses. General descriptions of applicable designated uses are also summarized below by subwatershed.

The Boulder Creek subwatershed has a total of 22 different segments, with 16 segments for streams and six segments for lakes. All of these segments have designated uses for “existing primary contact recreation” and agricultural use. Most of the segments also have water supply designated uses, with the exception of tributaries to South Boulder Creek and tributaries to Coal Creek (Segment 8). Aquatic-life classifications vary, depending on water temperature and discharge. The Boulder Creek segments include nine segments designated as aquatic life cold 1 (the most stringent), two designated as aquatic life cold 2, four designated as aquatic life warm 1, and seven designated as aquatic life warm 2 (the least stringent). Three of the segments containing lakes/reservoirs are also identified as Direct Use Water Supplies.

The St. Vrain Basin includes 16 stream segments, with seven of these segments assigned for lakes and reservoirs. All of these segments have designated uses for “existing primary contact recreation” and agricultural use. Most of the segments also have water supply designated uses, with the exception of Segment 3 (which includes the main stem of St. Vrain Creek from Hygiene Road to the confluence with the South Platte River) and Segment 6 (which includes certain tributaries to St. Vrain Creek from Hygiene Road to the confluence with the South Platte River). Aquatic-life classifications for the St. Vrain Basin segments include nine designated as aquatic life cold 1 (the most stringent), three designated as aquatic life warm 1, and four designated as aquatic life warm 2 (the least stringent). Three of the segments containing lakes/reservoirs are also identified as Direct Use Water Supplies.

Given the large watershed area and number of stream segments potentially requiring evaluation, the focus of this Watershed Plan has been narrowed to flowing waters with either impairments identified on the 2012 303(d) List or potential impairments based on the 2012 monitoring and evaluation (M&E) List, or within the vicinity of urbanized portions of the watershed (e.g., Segment 5 of South Boulder Creek). Table 1-15 summarizes these segments of interest. (*Note: the segments of interest have also been narrowed as a result of analysis completed later in this report in Section 5.2.2*.)

Table 1-14. Beneficial Use Classification Definitions[1]

Recreation: Class E - Existing Primary Contact: Waters are used for primary contact recreation or have been used since 1975. Class P - Potential Primary Contact: Waters have the potential to be used for primary contact recreation but there are no existing primary contact uses. Class N - Not Primary Contact: Waters are not suitable or intended to become suitable for primary contact recreation uses. Class U - Undetermined: Waters should be protected at the same level as existing primary contact use waters, but there has not been an inquiry about existing recreational uses.
Agriculture: Waters suitable for crop irrigation and for livestock drinking water.
Aquatic Life (Warm and Cold): Class 1: Waters capable of sustaining a wide variety of aquatic life, including sensitive species. There are two subcategories: cold water and warm water. Class 2: Waters not capable of sustaining a wide variety of cold-water or warm-water aquatic life, including sensitive species, due to physical habitat, water flows, or uncorrectable water quality conditions.
Domestic Water Supply: Surface waters suitable for drinking water supplies. After conventional treatment, these waters will meet Colorado drinking water regulations.
Direct Use Water Supply: Classification triggering application of nutrient criteria to lakes and reservoirs under Colorado's Nutrient regulations.

[1]More information on beneficial uses can be found in Commission Regulation #31 - *The Basic Standards and Methodologies for Surface Water*.

Table 1-15. Primary Stream Segments of Interest for Purposes of Watershed Plan

Stream Segment	Classification
Boulder Creek Basin	
2b. Mainstem of Boulder Creek, including all tributaries and wetlands, from the point immediately below the confluence with North Boulder Creek to a point immediately above the confluence with South Boulder Creek.	Aquatic Life Cold 1 Recreation E Water Supply Agriculture
7b. Coal Creek, Highway 36 to Boulder Creek.	Aquatic Life Warm 1 Recreation E Water Supply Agriculture
8. All tributaries to South Boulder Creek and all tributaries to Coal Creek. [*This Watershed Plan's focus is limited to Rock Creek.*]	Aquatic Life Warm 2 Recreation E Agriculture
9. Mainstem of Boulder Creek from a point immediately above the confluence with South Boulder Creek to the confluence with Coal Creek.	Aquatic Life Warm 2 Recreation E Water Supply Agriculture
10. Mainstem of Boulder Creek from the confluence with Coal Creek.	Aquatic Life Warm 1 Recreation E Water Supply Agriculture
St. Vrain Basin	
3. Mainstem of St. Vrain Creek from Hygiene Road to the confluence with the South Platte River. [*This Plan's focus extends to I-25.*]	Aquatic Life Warm 1 Recreation E Agriculture
4a. Mainstem of Left Hand Creek, including all tributaries and wetlands, from the source to a point immediately below the confluence w/ James Creek, except specific listings in Segment 4b.	Aq Life Cold 1 Recreation E Water Supply Agriculture
4b. Mainstem of James Creek, including all tributaries and wetlands, from the source to the confluence with Left Hand Creek.	
4c. Mainstem of Left Hand Creek, including all tributaries and wetlands, from point immediately below confluence w/ James Creek to HWY 36.	
5. Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confluence with St. Vrain Creek.	Aquatic Life Warm 2 Recreation E Water Supply Agriculture
6. All tributaries to St. Vrain Creek, including wetlands from Hygiene Road to the confluence with the South Platte River, except for specific listings in the Boulder Creek subbasin and in Segments 4a, 4b, 4c and 5. [*This Watershed Plan's focus is limited to Dry Creek.*]	Aq Life Warm 2 Recreation E Agriculture

1.16 Impaired Waters: 303(d) Listings and Existing TMDLs

Under the Clean Water Act, states are required to assess the quality of streams. When data from a stream or lake indicate that a standard is not met, the Commission places the stream segment on a list of impaired segments, called the 303(d) List. For impaired segments, the Division may require the development of a TMDL, which estimates pollutant load reductions necessary to meet stream standards.

The state's 303(d) List is typically revised and updated every two years (even years). Stream segments within the watershed are identified as impaired or placed on the Monitoring and Evaluation (M&E) list. Additional discussion on the state's methodology for identifying impaired stream segments can be obtained from *303(d) Listing Methodology: 2016 Listing Cycle* (Division 2014). This methodology is updated approximately every two years; however, Colorado's 2014 303(d) List was postponed to 2016. Table 1-16 identifies stream segments currently identified as impaired on the 2012 303(d) List. The draft 2016 303(d) List was released concurrent to the final draft of this Watershed Plan. Many changes to the 303(d) List are proposed in 2015 but were beyond the scope of this Watershed Plan due to timing of the release. However, in cases where the draft 2016 303(d) List proposes delisting, this is indicated by strikethrough in Table 1-16. Additional water quality issues are potentially present in the watershed, including constituents identified on the M&E list, assigned temporary modifications to standards (e.g., arsenic), and assigned interim values without adopted standards (e.g., nitrogen and phosphorus). These potential water quality issues are discussed in Chapter 5.

Table 1-16. 2012 303(d) List for Streams in the St. Vrain Basin

(Note: Completed TMDLs and Monitoring and Evaluation List Segments are <u>not</u> shown. If proposed for removal from 303[d] List in 2016, then shown in strikethrough. New 2016 proposed listings are <u>not</u> shown <u>unless pertinent to *E. coli*</u>.)

Segment ID	Segment Name	Impairment Causes	Priority for TMDL Development/Notes
Boulder Creek Watershed			
COSPBO07b	Coal Creek from Hwy 36 to Boulder Creek	*E. coli*	High
COSPBO08	Rock Creek	Selenium	Medium
COSPBO09	Boulder Creek from 107th St to Coal Creek Confl.	Aquatic Life (provisional)	Low
COSPBO10	Boulder Creek from Coal Creek to St. Vrain Confl.	*E. coli*	High
St. Vrain Creek Watershed			
~~COSPSV02a~~	~~St. Vrain Creek and tribs, RNMP to East NF boundary~~	~~Zinc~~	~~High~~ Note: removed from draft 2016 303(d) List.
COSPSV02b	St. Vrain Creek (RMNP to Hygiene Road)	Temperature~~, Copper~~	High Note: Cu removed from draft 2016 303(d) List.
COSPSV03	St. Vrain Creek (Hygiene Rd. to South Platte River for *E. coli*)	~~Aquatic Life (provisional, Left Hand Creek to confluence with Boulder Creek)~~	~~Low~~ Note: removed from draft 2016 303(d) List. (*E. coli* added as High)
COSPSV04a	Left Hand Creek (Hwy 72 to James Creek)	~~Zinc~~, Copper, Cadmium, Lead, ~~pH~~, ~~Arsenic~~ (various portions)	June 2015 TMDL addresses metals and pH for various portions of these segments
COSPSV04b	Little James Creek		
COSPSV04c	Left Hand Creek from James Creek to Hwy 36		
COSPSV05	Left Hand Creek Upstream Left Hand Feeder Canal	Manganese ~~(WS)~~ (*Note: elevated at Haldi Intake.*)	Low
COSPSV05	Left Hand Creek ~~downstream Feeder Canal~~	Copper	Medium
COSPSV06	Dry Creek	*E. coli*	High
COSPSV06	Tributaries to St. Vrain Creek	Selenium	Low

Notes: Grey-shaded segments addressed in Upper Left Hand Watershed Plan (LWOG 2005).

There are four TMDL documents that have been completed in the St. Vrain Basin (accessible at: https://www.colorado.gov/pacific/cdphe/tmdl-south-platte-river-basin), including:

- Boulder Creek Segment 2b *E. coli* TMDL: An *E. coli* TMDL has been developed for Boulder Creek from 13th St. to South Boulder Creek, which was finalized and approved by EPA in 2011 (Tetra Tech 2011).

- Gamble Gulch in Boulder Creek Segment 4a TMDL for Cadmium, Zinc and pH: In 2010, the Division completed the Gamble Gulch TMDL for pH, dissolved copper and dissolved zinc to address impaired aquatic life uses. The Tip Top Mine was mined for copper, lead, zinc and silver, which resulted in residual levels of elevated copper and zinc concentrations in Gamble Gulch. Currently, all of the mining features in Gamble Gulch are associated with abandoned mining operations. There are no permitted dischargers to Gamble Gulch (Division 2010).

- Boulder Creek and St. Vrain Creek Unionized Ammonia TMDL (multiple segments): In 2003, "Total Maximum Daily Load Assessment, Ammonia: Boulder Creek, South Boulder Creek to Coal Creek - Segment 9; Boulder Creek Coal Creek to St. Vrain Creek Segment 10; St. Vrain Creek, Hygiene Rd to S. Platte River - Segment 3, Boulder and Weld Counties, Colorado" was completed approved by EPA. The TMDL was driven by a lawsuit against EPA. The TMDL was based on application of the Colorado Ammonia Model by Lewis and Saunders (2003). The TMDL focused primarily on loads associated with WWTP discharges. Since that time, ammonia standards have changed from unionized to total ammonia (with another potential change on the horizon). All of the WWTP discharges currently meet CDPS permit limits for total ammonia under normal operating conditions.

- Left Hand Creek Watershed for Selected Metals and pH (multiple segments): This June 2015 TMDL updates the Little James Creek TMDL for cadmium, iron, manganese, zinc and pH that was originally completed in 2002. This TMDL includes: 1) mainstem of Left Hand Creek and tributaries, from the source to immediately below the confluence with James Creek (COSPSV04a); 2) mainstem of James Creek and tributaries (including Little James Creek) from the source to Left Hand Creek (COSPSV04b); and 3) mainstem of Left Hand Creek and tributaries, from immediately below the confluence with James Creek to Hwy 36 (COSPSV04c). Pollutants addressed include dissolved forms of cadmium, copper, lead, and zinc, as well as low pH.

No other TMDL efforts are known to be underway in the watershed. Figure 1b identifies the locations of the existing TMDLs. Activities supporting implementation of the Gamble Gulch and Left Hand Creek TMDLs would be eligible for Nonpoint Source funds; however, the Boulder Creek *E. coli* TMDL would not be, due to its location within MS4 permit boundaries.

1.17 Regulatory Issues and Processes

The primary regulatory issues related to current water quality impairments are CDPS wastewater and stormwater permits. Approved TMDLs in urbanized areas affect both types of CDPS permits. Non-point sources of pollution (e.g., agricultural, stormwater outside of MS4 boundaries) are addressed through implementation of BMPs on a voluntary basis.

1.18 Conclusion

The 980-square-mile St. Vrain Basin is a large, complex watershed with significant variations in land use, geology and ecology. The hydrology in the watershed is highly managed with many ditch diversions and regulated discharges to multiple stream segments. Additionally, 38 regulatory stream segments are present in the basin. This chapter provided a broad background of key watershed features that can be used to support pollutant source characterization. Because of the vast size of the watershed, subsequent chapters will focus on a more targeted portion of the basin, particularly the stream segments between the western boundary of the urbanized areas along the foothills eastward to I-25.

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2.0 Watershed Partnerships

The St. Vrain Basin is fortunate to have a well-established basic framework for cooperatively addressing water quality issues through the Keep It Clean Partnership that can be further expanded to include new partners in the future. This Watershed Plan will benefit from the existing Intergovernmental Agreement (IGA) (Appendix E) and long-term working relationships already established among member organizations.

2.1 Watershed Partners and Stakeholders

Most of the partners for development of this Watershed Plan are members of the Keep It Clean Partnership, which is a group of communities located along the Colorado Front Range dedicated to protecting water quality and reducing stormwater pollution. The partnership includes Boulder, Erie, Lafayette, Longmont, Louisville, Superior, and Boulder County. Other watershed groups active in the St. Vrain portion of the watershed include the James Creek Watershed Initiative (JCWI) and the Left Hand Watershed Oversight Group (LWOG). Additionally, potential state and federal partners and stakeholders include the U.S. Geological Survey (USGS), the U.S. Forest Service, the National Park Service (upper watershed reaches), the Natural Resources Conservation Service (NRCS), Colorado State University Extension, Colorado Parks and Wildlife, and others. The Colorado Data Sharing Network (CDSN) is also a source of water quality data pertinent to the Watershed Plan. The partners also reached out to the Left Hand Ditch Company, Denver Water (due to Gross Reservoir) and Xcel Energy (discharges to St. Vrain Creek near the confluence with the South Platte).

The Keep It Clean Partnership functions under an IGA, and decisions are made based on a two-thirds vote of a quorum of the partners, as represented on a steering committee. Leadership and coordination is provided by the Keep It Clean Partnership coordinator. Each partner contributes financially to baseline operations of Keep It Clean Partnership, as well as for special projects. The partners develop an annual budget plan and assess dues, based on the planned activities and available funding. Boulder County Public Health functions as the fiscal agent for Keep It Clean Partnership. A copy of the IGA is provided in Appendix E.

The Left Hand Watershed Oversight Group is a citizen-based nonprofit group working with residents and partners to improve water quality, watershed health, and watershed awareness along Left Hand, James, and Little James Creeks in Boulder County, Colorado. Key funding sources include the Left Hand Water District and Boulder County.

In the future, Keep It Clean Partnership may want to consider formation of a 501(c)(3) non-profit organization, based on recommendations provided in *Keep it Clean Partnership 2011 Evaluation of Shared Programs* (FHU 2011).

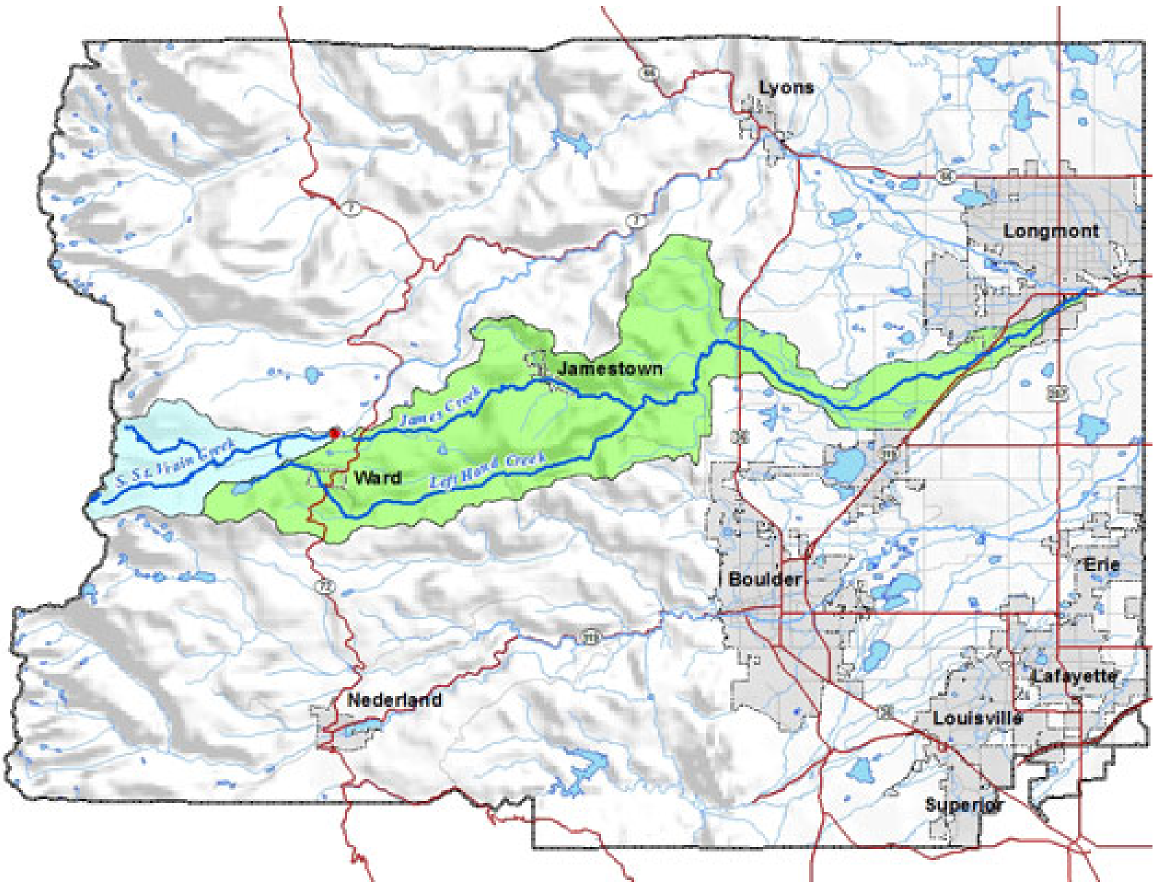
2.2 Outreach Activities and Technical Assistance

The Keep It Clean Partnership already has an outreach framework in place, including a maintained website (http://www.keepitcleanpartnership.org/). Although Keep It Clean Partnership messages have been targeted to stormwater-related pollution sources within the participating MS4s, many of these messages also apply to non-point sources. Non-point source messaging can also be integrated into the Keep It Clean Partnership website, with links to agricultural planning resources. The Implementation Plan developed in Chapter 7 will be reviewed by the partners for potential integration into the Keep It Clean Partnership annual work plan and 2016 strategy documents, within the constraints of available funding.

Figure 2-1. Keep It Clean Partnership St. Vrain Watershed Webpage

Left Hand Watershed Oversight Group also maintains a website (http://lwog.org/). Due to the devastation experienced in the Left Hand Creek watershed during the September 2013 flood, outreach is currently focused on flood mitigation and creek restoration projects that could be implemented as funding allows. Some of these projects have a watershed-wide scope, and others are specific to certain stream reaches. The area of focus for the Left Hand Watershed Oversight Group is shown in Figure 2-2.

Figure 2-2. Left Hand Watershed Oversight Group Area of Focus



During development of this Watershed Plan, primary outreach activities have focused on intergovernmental communication and cooperation to develop the plan through a series of meetings, supplemented by small group meetings on specific topics. Table 2-1 summarizes meetings supporting development of this Watershed Plan. Other outreach activities have included increasing interdepartmental communication within local governments (e.g., parks and open space, wastewater, stormwater). In January 2015, the Boulder County Consortium of Cities Water Stewardship Initiative hosted a workshop where progress on the Watershed Plan was shared with a larger group of stakeholders. Watershed-related information is also being shared through a new watershed page on the Keep It Clean Partnership website shown in Figure 2-1 (see http://www.keepitcleanpartnership.org/watershed/).

Table 2-1. Major Meetings Supporting Development of Watershed Plan

Date	Topic	Location
11/21/2013	Kick-off Boulder Creek Portion of Watershed Plan	75th Street WWTP, Boulder, CO
7/8/2014	Review of Draft Monitoring Plan with Keep It Clean Partners	75th Street WWTP, Boulder, CO
7/22/2014	Agricultural Stakeholder Input and Information Sharing on BMPs/Stream Protection	75th Street WWTP, Boulder, CO
8/12/2014	Monitoring Plan Wrap Up and Watershed Plan Progress (Boulder Creek)	75th Street WWTP, Boulder, CO
1/21/2015	Overview of Watershed Plan Effort: Boulder County Consortium of Cities Water Stewardship Initiative (attendance >150 people)	Conference Center, Longmont, CO
2/12/2015	Kick-off St. Vrain Portion of Watershed Plan	Training Center, Longmont, CO
5/28/2015	2014 Data Analysis from Monitoring Plan Developed under Watershed Plan (in-kind) and Update on Watershed Plan Progress	Training Center, Longmont, CO
8/4/2015	Review of Draft Watershed Plan	75th Street WWTP, Boulder, CO

Note: additional small group meetings have also been held, but Table 2-1 summarizes the primary outreach meetings.

In addition to intergovernmental outreach for jurisdictions with the watershed, several key organizations with technical expertise in the Boulder Creek watershed have been contacted for input on this Watershed Plan including:

- **USGS**: The USGS has played a key role in supporting characterization of the St. Vrain Basin, as well as in conducting cutting-edge studies such as microbial source tracking in Boulder Creek.

- **Colorado State University Extension - Boulder County**: The Extension office provides assistance and programs for citizens in five main areas: Agriculture, Horticulture, Family and Consumer Science, Natural Resources and 4-H Youth Programs. The office provides information and education, and encourages the application of research-based knowledge in response to local, state, and national issues. Of particular interest is the small acreage management program, which provides guidance on grazing management, weed control and other topics. Boulder County has more than 5,000 properties from 1 to 100 acres, totaling over 37,000 acres considered "small acreage" sites. See http://www.coopext.colostate.edu/boulder/.

- **USDA NRCS (Longmont Field Office - Boulder County)**: The NRCS provides a variety of technical and financial assistance for agricultural landowners and managers. In particular, the Colorado Field Office Technical Guide (FOTG) provides access to: 1) general information pertinent to the service area; 2) soil and site information; 3) conservation management systems, 4) conservation practice standards, and 5) conservation effects (expected performance of conservation practices). These resources are discussed further in Chapters 6 and 7.

Other organizations that were not involved in development of this Watershed Plan but that may provide technical expertise or guidance in support of this Watershed Plan are discussed in Chapter 8. Notable examples include Urban Drainage and Flood Control District and the CLEAN Center at Colorado State University.

2.3 Conclusion

The St. Vrain Basin stakeholders have an established outreach program in place through the Keep It Clean Partnership. Information and education efforts identified in this Watershed Plan will be carried forward under the umbrella of the Keep It Clean Partnership, rather than developing an independent outreach program. This Watershed Plan will provide partners with the underlying science needed to prioritize education and outreach activities in the future.

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3.0 Scope of Watershed Efforts

For pragmatic reasons related to the vast size of the St. Vrain Basin, the primary focus of this Watershed Plan is existing 303(d) Listings in the watershed for flowing streams, particularly impairments that have not been addressed in previous planning efforts. Other water quality issues may be present or arise in the future. As a result, the scope of the plan may change over time.

3.1 Pollutants of Concern

Pollutants in watersheds can originate from many different sources, including point sources such as municipal and industrial discharges, municipal stormwater sewer systems (MS4s), non-point sources such as agriculture, and natural environmental conditions (e.g., selenium-bearing geologic formations). The primary purpose of a Watershed Plan is to address non-point sources of pollution; however, it is necessary to first develop an understanding of the significant sources of a pollutant in order to properly target control strategies.

As a first step in developing this Watershed Plan, monitoring data in the watershed were broadly inventoried and compiled into a master water quality database in Microsoft Access. This database drew upon over 260,000 records from the City of Boulder and over 100,000 records from other entities conducting monitoring in the watershed. The data sets were screened and narrowed to focus primarily on data for constituents of interest collected over the past 5 to 10 years. Based on the 303(d) and M&E listings described in Chapter 5, data sets were reviewed to narrow the focus of this Watershed Plan to the highest priority pollutants. As a result, the pollutants of concern for purposes of this Watershed Plan include:

- *E. coli* (fecal indicator bacteria, present for multiple stream segments)
- Nutrients (generally limited to stream segments downstream of municipal WWTP discharges; considered a future regulatory issue)
- Aquatic life (selected locations)
- Selected metals
    - Selenium in Rock Creek and Coal Creek (believed to be naturally occurring)
    - Legacy mining impacts in the Left Hand Creek Subwatershed (addressed under 2015 TMDL and LWOG (2005) Watershed Plan)
- pH (limited to lower Boulder Creek)

Of these, *E. coli* is the primary focus for these reasons: 1) it is considered a high priority from a human health perspective, 2) it is an existing impairment common to each of the subwatersheds addressed in this Watershed Plan, and 3) it has not yet been addressed in other planning documents (as opposed to metals associated with legacy mining impacts). (Note: The existing Boulder Creek *E. coli* TMDL is limited to a specific portion of stream Boulder Creek Segment 2b.)

3.2 Indicators to Measure Environmental Conditions

A key objective of this Watershed Plan has been development of a coordinated monitoring framework (Monitoring Plan) for the watershed. This monitoring framework summarizes the key indicators to measure environmental conditions in the watershed, including flow, water chemistry and biological indicators (benthic macroinvertebrates). Selected tables and figures from the Monitoring Plan are provided in Appendix C, with the complete Monitoring Plan available from the Keep It Clean Partnership website. Monthly routine instream monitoring at key locations will be used to refine understanding of pollutant sources so that controls can be more effectively targeted.

3.3 Mission and/or Vision of Watershed Organization

The Keep It Clean Partnership is a group of communities located in Boulder County and portions of Jefferson and Weld Counties dedicated to protecting water quality and reducing stormwater pollution. The partnership communities of Boulder, Boulder County, Erie, Lafayette, Longmont, Louisville, and Superior are mandated by the EPA (under the Clean Water Act) to address stormwater pollution issues. The Keep It Clean Partnership has developed programs to meet requirements established by the EPA and the Division regarding stormwater regulations.

Although the Keep It Clean Partnership's primary directive focuses on stormwater, as a result of this Watershed Plan, the focus of the group is expanding to include increased characterization of instream water quality conditions and an understanding of the broader sources of pollutants in the St. Vrain Basin.

In addition to the collaborative efforts of the Keep It Clean Partnership, individual cities in the watershed also have their own independent water quality objectives related to source water protection of drinking water supplies and compliance with CDPS permits for WWTP discharges.

3.4 Goals and Objectives of Watershed Plan

The goals and objectives of the overall St. Vrain Creek Basin Watershed Plan are summarized below.

3.4.1 Goals

The long-term environmental goal of this Watershed Plan is restoration of stream health in the overall St. Vrain Basin. As part of this effort, a strong baseline data inventory and long-term, coordinated Monitoring Plan for the overall St. Vrain Basin have been completed.

Goals of Watershed Plan

Environmental Goal 1: Restore beneficial uses for the overall St. Vrain Basin. Impaired beneficial uses include aquatic life, domestic water supply and recreation.

Programmatic Goal 1: Involve stakeholders throughout the overall St. Vrain Basin to develop a watershed plan that properly inventories and integrates existing watershed efforts and resources.

Programmatic Goal 2: Develop a long-term monitoring, assessment and data management plan that is consistently followed in the overall St. Vrain Creek watershed to support scientifically sound decision-making.

Programmatic Goal 3: Complete an implementation-ready, holistic watershed plan that is practical and readily usable by watershed stakeholders.

3.4.2 Objectives

Four objectives were developed to support the project goals and comply with EPA's Nine Elements of a Watershed Plan. These objectives are defined below, along with tasks completed to achieve these objectives, as part of this Watershed Plan effort.

Objective 1: Stakeholder and Public Involvement and Education. In order to effectively address non-point sources of pollution, stakeholder and public involvement is essential. Building upon the existing stakeholder framework of the Keep It Clean Partnership, the project co-sponsors reached out to other stakeholders and used existing communications pathways to involve and educate the public regarding non-point source issues. To support this objective, a project webpage was developed, eight stakeholder meetings were held, and a public education and outreach plan was developed as part of the Implementation Plan in Chapter 7.

Objective 2: Watershed Characterization and Assessment and Priority Identification. One of the primary obstacles to moving forward with solutions to stream impairments in the watershed is inadequate characterization of the sources and extent of impairments, due to piecemeal monitoring and independent assessment efforts in the watershed. Thus, a primary objective of this Watershed Plan is to properly characterize and assess causes and sources of pollutants and identify the relative priorities for restoration, building upon the priorities developed on Colorado's 2012 303(d) List. Key tasks completed to support this objective include:

a. Identify the causes and sources of pollutants. The first step in watershed characterization included inventorying existing data in the watershed and compiling a master database for available electronic data. These data were then combined with existing GIS land use coverages available from the cities and counties to develop a general understanding of likely causes and sources of pollution in the watershed. For *E. coli*, some significant data gaps were identified and are included in recommendations for future monitoring.

b. Estimate pollutant load reductions needed. Based on available data, best estimates of load reductions needed to meet water quality standards that protect beneficial uses or restore impaired beneficial uses were made for selected pollutants in Chapter 5, within the constraints of available water quality and hydrologic data. (Note: advanced modeling was beyond the scope/budget of this Watershed Plan. However, such modeling could be conducted in the future to refine load estimates in subsequent efforts.)

c. Identify nonpoint source management measures to achieve load reductions. Based on identified and anticipated sources of pollutants, nonpoint source management measures expected to be useful in reducing pollutant loads were inventoried in Chapters 6 and 7 and integrated into the Implementation Plan in Chapter 8. (Note: Because sources of *E. coli* are not currently well defined in the watershed, a "menu" of BMPs has been provided that can be used to select appropriate practices once the sources are better defined.)

<u>Objective 3</u>: Watershed Plan Development and Implementation and Evaluation Approaches. In order to effectively move forward with nonpoint source pollution control measures, an Implementation Plan was developed in Chapter 8 of this Watershed Plan. Development of the Implementation Plan included these tasks:

a. Estimate technical and financial resources needed to implement the Watershed Plan. As part of the plan, a tabular summary was prepared with estimates of technical and financial resources necessary to implement recommended load reduction measures.

b. Develop implementation schedule for management measures. A schedule for implementation of management measures was developed for the initial release of the Watershed Plan, along with recommendations to update the schedule as a refined understanding of pollutant sources is developed.

c. Develop measurable milestones for measures identified in the Watershed Plan. Interim measureable milestones were developed for each key component of the Watershed Plan.

d. Develop criteria to assess load reductions and measurable progress. Through stakeholder input, criteria to assess the success of nonpoint source control measures and measurable progress were defined. Ultimately, these criteria are based on compliance with stream standards; however, measureable milestones also include concepts such as a decrease in the number of standards exceedance days.

Objective 4: Monitoring and Data Management. Project co-sponsors identified an integrated, watershed-scale monitoring and data management approach as a high-priority objective for meeting environmental goals in the overall St. Vrain Creek watershed. Essentially, if watershed conditions have not been effectively measured, they are unlikely to be effectively managed. Additionally, due to the size of the watershed, an integrated data management approach was identified as a key need, both for baseline data and for future monitoring to assess effectiveness of control measures implemented in the watershed.

The St. Vrain Basin Coordinated Monitoring Program (excerpts in Appendix C) was developed with significant stakeholder input to meet this objective. Stakeholders provided information on existing monitoring programs in the watershed so that a master watershed monitoring plan could be developed and adopted by stakeholders. In 2015, the monitoring plan was followed to enable preparation of the Keep It Clean Partnership's first annual water quality report (KICP and WWE 2015).

3.5 Organizational Concerns

During development of this Watershed Plan, several "tiers" of pollutants of interest and stream-related conditions in the Watershed Plan were identified. These include:

1. Addressing 303(d)-listed segments. Boulder County has a goal of having all stream segments removed from the 303(d) List. Ideally, this would be accomplished through attainment of applicable stream standards through reducing pollutant loading to streams. In some cases, development of a site-specific standard may be appropriate where natural or irreversible human-induced ambient water quality levels are higher than specific numeric levels in Regulation 38, but are determined to be adequate to protect classified stream uses.

2. Planning for future regulatory issues, such as nutrients. In 2015, standards for total nitrogen, total phosphorus and chlorophyll-a were adopted in Regulation 38 for certain stream segments upstream of WWTP discharges, in accordance with "interim nutrient values" adopted in Regulation 31. These interim values for nutrients may be adopted as stream standards within the next 10 years downstream of WWTP discharges. Considerable challenges are anticipated regarding attainment of these standards downstream of WWTP discharges and in agricultural areas.

3. Planning for aquatic life, particularly segments that do not attain standards in Aquatic Life Policy 10-1. Aquatic life impairments may be habitat driven, water quality driven, or a combination of both. Repair of riparian habitat damaged during the September 2013 flood is addressed in various watershed master plans completed during 2014 in response to the flood.

4. Improving understanding of the current metals “mass balance” in the Left Hand Creek subwatershed and addressing elevated metals due to legacy mining impairments, in accordance with the LWOG (2005) implementation plan (Appendix F). Additionally, stakeholders would like to verify that measures implemented as part of the Voluntary Clean Up (VCUP) at the Burlington Mine are still functioning properly.

5. Considering emerging contaminants. Emerging contaminants are beyond the scope of this Watershed Plan, but are an area of on-going interest to the stakeholders. Two existing programs in place that monitor emerging contaminants include the Northern Colorado Water Conservancy District and the USGS (in cooperation with the City of Boulder).

4.0 Watershed Information Sources, Monitoring Plan and Data Inventories

As an initial step in development of this Watershed Plan, an extensive effort was undertaken to compile watershed-wide water quality monitoring data and identify parties actively monitoring various portions of the watershed. The data resulting from this effort are compiled in an Access Database. A subset of this broad data set has been evaluated to support this Watershed Plan. A primary objective of this Watershed Plan was to develop a coordinated monitoring plan. Because the Monitoring Plan is provided in its entirety on the Keep It Clean Partnership website (http://www.keepitcleanpartnership.org/), this chapter provides only brief highlights from the Monitoring Plan, with a summary of monitoring locations included in Appendix C.

4.1 Information Sources

As a first step in developing this Watershed Plan and the Monitoring Plan, data from multiple organizations conducting monitoring in the watershed were inventoried. This required a substantial effort and was conducted for the overall St. Vrain Basin. Table 4-1 summarizes these data sources.

Table 4-1. Monitoring Data Sources in St. Vrain Basin

Water Quality Data
Keep It Clean Partnership Partner Water Quality Data Sources
City of Boulder
City of Longmont
Town of Superior
City of Louisville
City of Lafayette
Town of Erie
Other Water Quality Data Sources
Denver Water
Colorado Water Quality Control Division (via Colorado Data Sharing Network and/or STORET)
Riverwatch (via Colorado Data Sharing Network)
Northern Colorado Water Conservancy District
Biological Monitoring (Timberline Aquatics for local governments)
Boulder, Longmont, Superior, Louisville, Lafayette, Erie
Stream Gauge Flow Data
U.S. Geological Survey (and some water quality data)
Colorado Division of Water Resources
OneRain Gauge Network
City of Louisville Gauge (COC-1, operated by municipality)

4.2 DATA INVENTORIES

Data obtained from the sources identified in Section 4.1 were uploaded into a common database (in Microsoft Access 2010). Over 100 different stream locations have been monitored over time in the watershed by various entities. Although all of these monitoring locations are included in the database, the primary locations of interest for the purpose of analysis in this report are long-term monitoring locations that are consistently and routinely monitored and that include recent data for the past 5 to 10 years. Figures C-1 through C-5 in Appendix C provide an overview of the primary monitoring location of interest for purposes of this Watershed Plan and identify sites incorporated into the Monitoring Plan.

A significant challenge in developing the water quality database related to changes in monitoring station nomenclature over time and various names assigned to the same location by different entities collecting data. For this reason, the database includes a table of water quality monitoring data and a separate table that provides information on the monitoring locations, including common nomenclature ("Plot IDs") assigned to a common physical location that may be named several different ways (i.e., a lookup table).

4.3 MONITORING PROGRAM

After reviewing the various monitoring programs in place in the St. Vrain Basin, the Keep It Clean Partners chose to develop a targeted Monitoring Plan (monitoring locations provided in Appendix C) for these purposes:

- Provide better coordination of existing multi-jurisdictional monitoring efforts.
- Provide consolidated documentation of the monitoring that is occurring in the watershed.
- Provide guidance for standardized field procedures and analytical methods.
- Identify and recommend additional monitoring to fill data gaps to support progress toward attainment of stream standards.

The intended use of data collected, shared and interpreted under the Monitoring Plan is to provide a sound scientific understanding of baseline water quality conditions, identify reaches of streams in need of water quality and aquatic life improvements, and to support prioritization of improvements expected to improve water quality and aquatic life. Due to the size of the watershed, the remote nature of the upper basin locations, and varying levels of participation among governmental jurisdictions, the partners recognized that the Monitoring Plan could not practically address all stream reaches; however, the partners agreed that a Monitoring Plan could be designed to address water quality, flow and biological conditions at key locations in the watershed where supported by local jurisdictions. The scope of the Monitoring Plan is limited to flowing streams. Additionally, biological monitoring is conducted for Boulder Creek, South Boulder Creek, Coal Creek, Rock Creek, Left Hand Creek and St. Vrain Creek in accordance with sampling and analysis procedures developed by Timberline Aquatics.

Individual local governments in the watershed are now sharing and analyzing their data using comparable statistical analysis methods to assess and characterize existing impairments, fill data gaps, and assess progress towards meeting environmental goals.

4.4 Data Management and Reporting

A primary objective of the Monitoring Plan is to provide guidance for coordinated watershed-scale data management and analysis. Under the direction of the KICP, a centralized watershed database in Microsoft Access 2010 has been developed to store data for the overall St. Vrain and Boulder Creek watersheds. The database is structured in a format compatible with the Colorado Data Sharing Network (CDSN) schema for physical and chemical data. The database structure provides for efficient data storage and queries that can be exported to Excel, CSV files and other commonly used formats. The basic structure includes these three tables:

- Project Information
- Monitoring Location Information
- Monitoring Results

The data uploaded to the master database will be analyzed and reviewed by the Keep It Clean Partners, with analysis results provided in an annual report that is posted to the Keep It Clean website.

Because the monitoring program is voluntary, reporting is not “required”; however, Keep It Clean Partners have mutually agreed to conduct monitoring at locations described in Appendix C and to provide data for inclusion in the Keep It Clean Partners database on an annual basis. The partners have also committed to a coordinated annual data analysis report, sponsored by the Keep It Clean Partnership. The first such report was completed in July 2015 and focused on monitoring data collected during 2014 (WWE 2015).

4.5 SUMMARY OF RECOMMENDATIONS FOR MONITORING

In summary, it is recommended that the Keep It Clean Partners implement the Monitoring Plan developed under this Nonpoint Source grant in 2014. Additionally, two special supplemental monitoring efforts are recommended as a result of analysis conducted in Chapter 5 of this Watershed Plan:

- In order to address controllable *E. coli* sources to the streams, a more refined monitoring program (both temporally and spatially) is needed for *E. coli* for certain stream reaches.

- Additional metals monitoring is needed in the Left Hand Creek basin to further refine understanding of metals loading. This monitoring would be conducted by Colorado State University and include a metals "mass balance" to further prioritize mine reclamation efforts to control metals in the Left Hand Creek Watershed

5.0 Data Analysis and Characteristics

5.1 Data Management and Analysis Methodologies

As an initial task supporting development of this Watershed Plan, water quality data collected by multiple entities were collected and entered into a Microsoft Access database to facilitate analysis and assessment of constituents listed on the 303(d) and Monitoring and Evaluation (M&E) lists, as well as other selected constituents of interest. Statistical analysis procedures in the 2016 303(d) Listing Methodology (Division 2014) were followed for purposes of data analysis in this Watershed Plan. Because of the phased funding cycles for the Boulder Creek and St. Vrain Creek portions of this Watershed Plan, the time period used in the analyses may vary, depending on the stream segment and pollutant. Additionally, the availability of data varies for each stream reach, which also affects the time period presented in the analyses.

For *E. coli*, where initial analysis indicated that standards were exceeded, then additional characterization using load duration curves (LDCs) was completed using flow analysis tools accessible at www.erams.com (Section 5.6.2). More advanced modeling was beyond the scope of this Watershed Plan, but could be considered in the future for selected constituents.

5.2 Review of Potential Water quality Issues

5.2.1 Primary Pollutants of Interest

Table 5-1 summarizes 2012 303(d) and M&E listings in the St. Vrain Basin and identifies whether the listing is addressed in this Watershed Plan. The draft 2016 303(d) List was released concurrent to the final draft of this Watershed Plan. Segments no longer included on the draft 2016 303(d) List are shown in strikethrough in Table 5-1. (New proposed listings for 2016 are not shown in Table 5-1.)

Table 5-1. Summary of 2012 St. Vrain Basin 303(d) and M&E Listings Considered in Plan[1]

Address in Plan?	Segment ID	Description	Portion	2012 M&E	2012 303(d)	Priority
Boulder Creek Segments						
No	COSPBO01	All tribs to Boulder Creek within the Indian Peaks Wilderness Area	all	pH, Zn		
No	COSPBO02a	Mainstem of Boulder Creek, from the boundary of the Indian Peaks Wilderness Area to a point immediately below the confluence with North Boulder Creek	all	Cd, Cu		
No	COSPBO02b	Boulder Creek, from below the confluence with North Boulder Creek to above the confluence with South Boulder Creek	all	~~Cd, Cu~~		
No	COSPBO03	Mainstem of Middle Boulder Creek from source to the outlet of Barker Reservoir	all	~~Cd, Cu~~		
Yes	COSPBO07b	Coal Creek, HWY 36 to Boulder Creek	all	Aquatic Life	*E. coli*	H
Yes	COSPBO08	All tribs to South Boulder Creek and all tribs to Coal Creek	Rock Creek	*E. coli*	Se	M
No	COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	all	Cd, As		
Yes	COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	107th Street to confl. w/ Coal Creek		Aquatic Life (provisional)	L
Yes	COSPBO10	Boulder Creek, Coal Creek to St. Vrain Creek	all	~~Aquatic Life~~, Cd	*E. coli*	H
No	COSPBO14	Lakes and reservoirs tributary to Boulder Creek from source to South Boulder Creek.	Barker Reservoir	Cd, Cu		
No	COSPBO~~15~~ 18	~~South Boulder Creek and tributaries from source to outlet of~~ Gross Reservoir	Gross Reservoir	Aquatic Life Use (Hg Fish Tissue)		

Address in Plan?	Segment ID	Description	Portion	2012 M&E	2012 303(d)	Pri-ority
St. Vrain Creek Segments						
No	COSPSV02a	Mainstem of St. Vrain from Indian Peaks Wilderness Area and RMNP to eastern boundary of Roosevelt Ntl Forest	all		Zn	H
No	COSPSV02b	St. Vrain Creek, RMNP to Hygiene Road	all		Cu, Temperature	H
Yes	COSPSV03	St. Vrain Creek, Hygiene Rd. to S. Platte River	~~From confl.w/ Left Hand Creek to confl. w/ Boulder Creek~~		~~Aquatic Life Use (provisional~~)	~~L~~
Yes	COSPSV03	St. Vrain Creek, Hygiene Rd. to S. Platte River	~~From Hover Road to the confl. w/ Left Hand Creek~~	~~Aquatic Life Use~~		
Ref. to TMDL & LWOG 2005	COSPSV04a	Left Hand Creek, from source to blw confl. w/ James Creek	Hwy 72 to James Ck		pH, Cu, Zn	M
	COSPSV04b	James Creek, Little James Creek	Little James Creek		Cu, Pb	M
	COSPSV04c	Left Hand Creek from James Creek to HWY 36	all		~~Cu, As~~	H
Ref. to LWOG 2005	COSPSV05	Mainstem of Left Hand Creek, including all tributaries and wetlands from HWY 36 to confl. w/ St. Vrain Creek	*To Below Left Hand Feeder Canal*		Mn (~~WS~~)	L
No	COSPSV05	Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confl. w/ St. Vrain Creek	Downstream Left Hand Feeder Canal		Cu	M
Yes	COSPSV06	Tributaries to the St Vrain River	Dry Creek		*E. coli*	H
No	COSPSV06	Tributaries to the St Vrain River	all		Se	L
No	COSPSV13	All lakes and reservoirs tributary to Left Hand Creek from Hwy 36 to St. Vrain Creek.	~~Lake Thomas~~	~~D.O.~~		

[1]Text in strikethrough indicates that the pollutant is not included on the draft 2016 303(d) List.

Table 5-2 identifies the subset of pollutants addressed in this Watershed Plan, as summarized from Table 5-1 (i.e., segments with a "yes" in column 1) and adds several additional pollutants of interest for certain stream segments that are being addressed proactively, even if they are not currently listed on the 303(d) List. For example, nutrient criteria for total phosphorus and total nitrogen are not yet adopted for most stream segments in Colorado downstream of WWTP discharges; therefore, they are not considered to be current regulatory water quality concerns. However, based on review of available data, elevated total nitrogen and total phosphorus are present in each stream segment below municipal WWTP discharges based on comparison to the "interim values" in Regulation 31. These segments include portions of Boulder Creek Segments 7b, 8, 9 and 10 and St. Vrain Creek Segment 3. Upstream of WWTP discharges to these segments, the nutrient criteria are expected to be attained, so those segments (or segment portions) are not discussed with regard to nutrients.

As summarized in Table 5-2, the constituents of interest for purposes of this Watershed Plan are focused on flowing streams in the middle to lower portions of the Boulder Creek and St. Vrain Creek watersheds and are focused on *E. coli*, nutrients, aquatic life, and selected metals for certain segments. Elevated pH is of interest for Segment 10 of Boulder Creek, although it is not considered an impairment on the 303(d) List.

Table 5-2. Summary of St. Vrain Basin 2012 303(d) and M&E Listings Addressed in Plan

Segment ID	Description	Portion	2012 M&E	2012 303(d)	Other Reason
Boulder Creek Segments					
COSPBO02b	Boulder Creek, from below the confluence with North Boulder Creek to above the confluence with South Boulder Creek	13th St. to South Boulder Creek			*E. coli* TMDL
COSPBO07b	Coal Creek, HWY 36 to Boulder Creek	all	Aquatic Life	*E. coli*	TP, TN (future) Se proposed on 2016 303(d) List
COSPBO08	All tribs to South Boulder Creek and all tribs to Coal Creek	Rock Creek	*E. coli*	Se[1]	TP, TN (future)
COSPBO09	Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek	All, except as noted[2]		Aquatic Life (provisional)[2]	*E. coli* TP, TN (future)
COSPBO10	Boulder Creek, Coal Creek to St. Vrain Creek	all		*E. coli*	TP, TN (future) pH
St. Vrain Creek Segments					
COSPSV03	St. Vrain Creek, Hygiene Rd. to S. Platte River [3]	all	~~Aquatic Life Use (Hover Road to the confl. w/ Left Hand Creek)~~	~~Aquatic Life Use (provisional) (From confl.w/ Left Hand Creek to confl. w/ Boulder Creek)~~	*E. coli* proposed on 2016 303(d) List TP, TN (future)
COSPSV-04a,b,c	Left Hand Creek, James Creek, Little James Creek	Various Portions[4]		Metals in TMDL[4]	Included in TMDL
COSPSV06	Tributaries to the St Vrain River	Dry Creek		*E. coli*	

[1]Selenium is discussed further in this Watershed Plan, but a site-specific standard is recommended due to natural conditions.
[2]Aquatic life (provisional) portion was limited to the portion from 107th Street to confluence w/ Coal Creek in 2012; however, on the draft 2016 List, the entire segment was proposed for listing due to aquatic life impairment.
[3] COSPSV03 does not include aquatic life listings on the draft 2016 303(d) List.
[4]See Left Hand Creek TMDL (Division 2015) for specific segments and metals listings.

5.2.2 Pollutants Excluded from Further Analysis

As identified in Table 5-1, a number of segments have been excluded from further analysis and planning in this Watershed Plan. The rationale for exclusion of these segment pollutants is described below. As previously noted, lakes and reservoirs are not being addressed in this Watershed Plan in an effort to manage the project scope.

Boulder Creek Stream Segments

- Segment COSPBO01 "All tribs to Boulder Creek within the Indian Peaks Wilderness Area" was listed on the M&E list for lead and zinc. Based on review of data with stakeholders and watershed experts, a decision was made to exclude these constituents from further focus in this Watershed Plan based on the following:

    - The data evaluation forming the basis for the 2012 303(d) List was based on samples collected from 2000-2003 at the Middle Boulder Creek @ Hessie (WQCD Site 5547). For dissolved zinc, eight of nine samples were below detection limits, with only one detection at 55 ug/L. For dissolved lead, seven out of eight samples were below detection limits, with only one detect at 2 ug/L.

    - Since that time, the WQCD collected six additional samples at this location in 2011-2012. All results for dissolved lead and zinc were non-detect, verifying that a 303(d) listing is not necessary.

    - These stream segments are located outside of the mining belt for the watershed. USGS representatives indicated that the potential listing is inconsistent with scientific knowledge of geology and mining activity in this portion of the watershed. Additionally, the tributary area included in this segment is beyond the jurisdictional boundary of the cities and counties developing this Watershed Plan.

- COSPBO02a, COSPBO02b, COSPBO03, and COSPBO14 were all listed on the M&E List for dissolved copper and dissolved cadmium. See Appendix D for segment descriptions. These are all segments in the Upper Watershed through Barker Reservoir. Each segment has very low hardness values; as a result, the hardness-based metals standards are extremely stringent. The segments were placed on the M&E list in 2012 due to copper and cadmium concentrations above the stream standard. However, there were inconsistencies in copper and cadmium results from the City of Boulder and the Division, which were due to questionable data analyzed by the City of Boulder in the 2004-2008 timeframe. Specifically, the City of Boulder's data showed elevated concentrations relative to the calculated stream standards, but the Division's data set did not. Further review of the Boulder data in that time period indicated some potential data quality issues that appear to have been resolved. The current data set shows attainment of the cadmium standard for all three segments and shows copper results near practical quantitation limits for copper. As a result of this recent analysis, copper and cadmium will not be addressed in this Watershed Plan for these four segments, given the very low concentrations of both constituents. Additional specific information includes:

- Segment 2a:

  - For dissolved cadmium, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved cadmium 85th percentile of 0.0128 ug/L and a maximum value of 0.03 ug/L, both of which are below calculated stream standards.

  - For dissolved copper, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved copper 85th percentile of 2.2 ug/L and a maximum value of 3.86 ug/L. These values result in exceedance of hardness-based stream standards; however, both the results and the calculated standards are near practical quantitation limits. Technically, this is still an exceedance of a water quality standard; however, reduction of copper beyond this extremely low concentration is not practical and is not addressed further in this Watershed Plan.

- Segment 2b:

  - For dissolved cadmium, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved cadmium 85th percentile of 0.012 ug/L and a maximum value of 0.248 ug/L, both of which are below calculated stream standards. *(Note: 2009 data are available and continue to show some isolated high values, but the 2010-2013 period is considered more reliable.)* This listing has been removed from the draft 2016 303(d) List.

  - For dissolved copper, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved copper 85th percentile of 0.95 ug/L and a maximum value of 4.5 ug/L. These results attain hardness-based stream standards. (*If evaluated using 2009-2013, this data set also attains standards*.) This listing has been removed from the draft 2016 303(d) List.

  - During 2011-2012, Division staff collected dissolved cadmium and dissolved copper at three locations on Segment 2b, totaling 14 samples. These locations included: 5577 Boulder Creek @ Valmont Rd., Upstream of South Boulder Creek, 5579 Boulder Creek Downstream of

Hydroelectric Plant @ Orodell Gauge, and 5597 Fourmile Creek at Mouth. All results for dissolved cadmium and copper were non-detect.

- Segment 3:
    - For dissolved cadmium, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved cadmium 85th percentile of 0.052 ug/L and a maximum value of 0.069 ug/L, both of which are below calculated stream standards. This listing has been removed from the draft 2016 303(d) List.
    - For dissolved copper, data collected by the City of Boulder from 2010 through March 2013 showed a dissolved copper 85th percentile of 2.84 ug/L and a maximum value of 3.60 ug/L. These values attain chronic and acute hardness-based stream standards for Segment 3. This listing has been removed from the draft 2016 303(d) List.

- COSPBO09 “Mainstem of Boulder Creek, from South Boulder Creek to Coal Creek” is listed for cadmium and arsenic.
    - For total recoverable arsenic, detection limits prior to 2011 limit comparisons between instream data and the extremely stringent “water + fish” stream standard (0.02 µg/L). The Division has assigned a temporary modification to the standard as of May 2013, which also allows the 75th Street WWTP to discharge arsenic at “current conditions” to this segment through 2021. Data collected from 2011 through March 2013 show that the 0.02 µg/L arsenic standard is not attainable at any location on Boulder Creek (including the upstream and downstream segments, not just COSPBO09). The 85th percentile value for Segment 9 is 1.02 ug/L. Because arsenic is a statewide issue and temporary modifications are in place until this issue can be resolved, it will not be discussed further in this Watershed Plan for any segment. (Note: the arsenic concentrations present on Boulder Creek attain aquatic life standards for arsenic and are below the drinking water MCL of 10 ug/L.)

- COSPBO10 “Boulder Creek, Coal Creek to St. Vrain Creek” is listed on the M&E List for cadmium. For dissolved cadmium, data collected by the City of Boulder from 2009 through March 2013 showed a dissolved cadmium 85th percentile of 0.048 ug/L and a maximum value of 1.48 ug/L, both of which are below calculated stream standards.

- COSPBO10 “Boulder Creek, Coal Creek to St. Vrain Creek” was listed on the M&E list for aquatic life prior to 2010. The basis for inclusion on the M&E list was not clear at the time that this Watershed Plan was being prepared and the segment has subsequently been removed from the draft 2016 303(d) List for aquatic life impairment.

St. Vrain Creek Segments

- COSPSV02a "Mainstem of St. Vrain from Indian Peaks Wilderness Area and Rocky Mountain National Park to eastern boundary of Roosevelt National Forest." This segment has been removed from the draft 2016 303(d) List and is not addressed further in this Watershed Plan.

- COSPSV02b "St. Vrain Creek, RMNP to Hygiene Road" is on the 2012 303(d) List for copper and temperature, but is not addressed in this Plan because it is located in area not actively monitored or managed by the watershed stakeholders. (*This decision was a pragmatic decision to manage the scope of the Watershed Plan*.) The copper listing has been removed from the draft 2016 303(d) List.

- COSPSV03 "St. Vrain Creek, Hygiene Rd. to S. Platte River" was listed as impaired and on the M&E list for aquatic life impairment for two portions of the segment, but these listings are no longer listed in the draft 2016 303(d) List. Nonetheless, aquatic life is discussed for informational purposes in Section 5.3.4.3.

- COSPSV4a, 4b and 4c of Left Hand Creek includes impairments for multiple metals associated with historic mining activities. New analysis of data for these segments has not be completed in this Watershed Plan, given the recently updated metals TMDL completed by the Division in 2015, as well as the Left Hand Creek Watershed Plan completed in 2005 (LWOG 2005). A plan to mitigate metals pollution for unpermitted mines in the watershed has been developed, but has not been fully implemented due to funding limitations. Selected elements from these plans are summarized in Appendix F.

- COSPSV05 "Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confluence with St. Vrain Creek." The portion Upstream Left Hand Feeder Canal was identified as low priority for elevated manganese with regard to the water supply standard. This listing was low priority and appears to be limited to the area in the vicinity of the Haldi Intake and sampling locations in the vicinity of the Boulder Feeder Canal. This listing is only addressed at a cursory level in this Watershed Plan because metals in this stream segment are addressed in the Left Hand Creek Watershed Plan (LWOG 2005).

- COSPSV05 "Mainstem of Left Hand Creek, including all tributaries and wetlands from Highway 36 to the confluence with St. Vrain Creek," including the portion "Downstream of the Left Hand Feeder Canal" is listed as a medium priority for copper on the 2012 303(d) List. Review of the draft 2015 Division assessment of this segment, the listing appears to be due to three exceedances of the acute dissolved copper standard at the Haldi Intake, based on data provided by Riverwatch in the 2009-2013 timeframe. This listing is not addressed further in this Watershed Plan because metals in this stream segment are addressed in the Left Hand Creek Watershed Plan (LWOG 2005).

- COSPSV06 "Tributaries to the St Vrain River" was on the 2012 303(d) List for selenium, as a low priority listing. Initial assessment of this segment by the Division in January 2015 indicated that this segment was likely to be removed from the draft 2016 303(d) List, so a decision was made not to address this segment further in this Watershed Plan. However, the draft 2016 303(d) List retained the selenium listing based on new data considered by the Division for this segment, specifically for elevated selenium at monitoring locations on Dry Creek. Due to the timing of this change, additional analysis of selenium data has not been completed for purposes of this Watershed Plan, but may be appropriate to consider in future updates.

5.3 IDENTIFIED WATER QUALITY ISSUES

This section discusses E. coli, nutrients, aquatic life, selected metals for certain stream segments, and pH in lower Boulder Creek. Sampling locations are identified on maps in the Monitoring Plan, as provided in Appendix C.

5.3.1 *E. coli*

Elevated *E. coli* is common to multiple stream segments in middle and lower portion of the St. Vrain Basin. *E. coli* was the focus of a TMDL on Boulder Creek between 13th Street and South Boulder Creek (Tetra Tech 2011), but additional stream reaches also show evidence of elevated *E. coli*. South Boulder Creek and upper watershed segments typically attain *E. coli* standards. This may be in part due to lower stream temperatures, lower organic matter and higher stream gradient, in addition to fewer anthropogenic impacts. A discussion of available *E. coli* data for each stream segment of interest follows. Figure A-9 in Appendix A provides a map of the monitoring locations discussed in this section, with locations color-coded according to whether the recreational season geometric mean attains the stream standard or exceeds the standard to varying degrees.

5.3.1.1 Boulder Creek

Table 5-3 and Figure 5-1 summarize instream *E. coli* data for Boulder Creek. Key observations include:

- *E. coli* standards are attained for all bimonthly assessment periods in upstream reaches of Boulder Creek down through Canyon Road.

- All segments attain standards during the winter assessment periods (Jan-Feb, Nov-Dec), whether reviewed for the period of record or since 2008. Most segments also attain the standards during March-April, with the exception of Boulder Creek below Coal Creek (Segment 10), which slightly exceeded the standard during March-April.

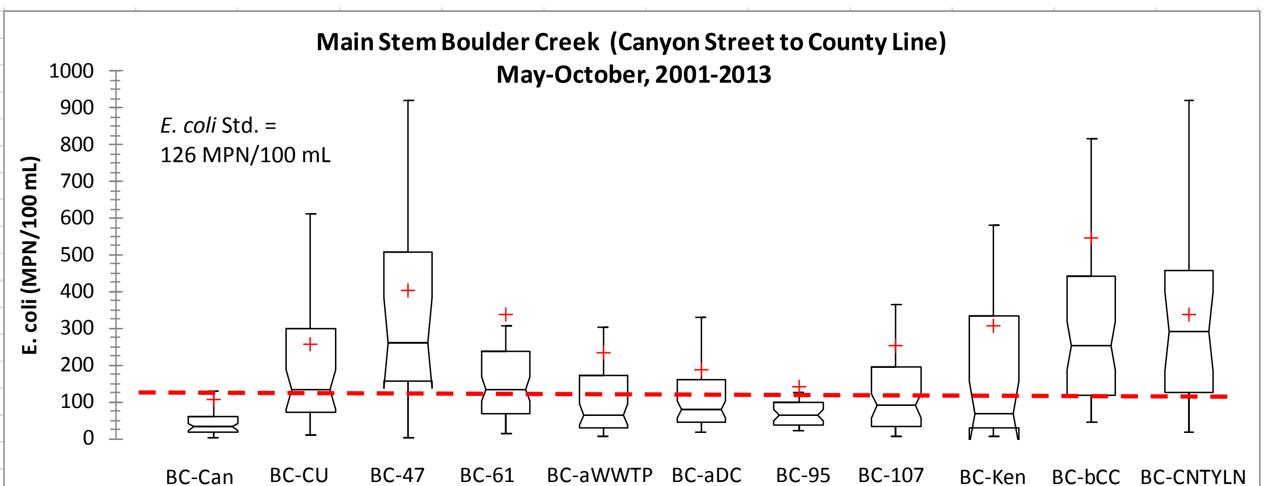
- At BC-CU, BC-47 and BC-61 (Boulder Creek from University of Colorado through 61st Street), standards are exceeded during July to October. The approved *E. coli* TMDL includes BC-CU and BC-47, but BC-61 is downstream of the confluence with South Boulder Creek and is not part of the TMDL. Additionally, BC-61 is located in Segment 9 of Boulder Creek, whereas the upstream stations are in Segment 2b. (Note: Segment 9 as a whole is not listed as impaired for *E. coli,* since five of the six monitoring locations attain the *E. coli* standard during the recreation season. *E. coli* concentrations at Site BC-61 are only slightly elevated relative to the stream standard.)

- The stream then generally attains the stream standard in the reach just above the Boulder WWTP discharge (BC-aWWTP) down through 95th Ave (BC-95). (Note: there is some sensitivity to averaging period for this reach.)

- From 107th Avenue to Coal Creek (portion of Segment 9), the stream exceeds standards during May and June for both the period of record and 2008-2013. Again, this segment is sensitive to averaging period. As shown in Figure 5-1, the overall recreation season is attained if bimonthly averaging is not used.

- Below Coal Creek (Segment 10), Boulder Creek exceeds standards in the March through October assessment periods based on data collected below Coal Creek (BC-bcc) and at the Weld County line.

Figure 5-1. Main Stem Boulder Creek *E. coli*



	BC-Can	BC-CU	BC-47	BC-61	BC-aWWTP	BC-aDC	BC-95	BC-107	BC-Ken	BC-bCC	BC-CNTYLN
No. Samples	64	43	20	65	66	62	36	64	31	60	24
Geometric Mean	35	135	218	145	74	95	76	96	91	277	241

Table 5-3. Boulder Creek Bimonthly Geometric Mean *E. coli* (2001-2013)

		2001-2013		2008-2013	
Period	Location	# Samples	Geometric Mean	# Samples	Geometric Mean
Jan-Feb	BC-Oro	2	1	1	1
Mar-Apr	BC-Oro	16	1	8	1
May-Jun	BC-Oro	18	9	8	9
Jul-Aug	BC-Oro	18	16	8	18
Sept-Oct	BC-Oro	17	4	8	2
Nov-Dec	BC-Oro	11	1	5	1
Jan-Feb	BC-Lib	6	19	4	27
Mar-Apr	BC-Lib	6	22	4	20
May-Jun	BC-Lib	7	62	5	62
Jul-Aug	BC-Lib	6	98	4	64
Sept-Oct	BC-Lib	8	71	4	56
Nov-Dec	BC-Lib	7	32	3	54
Jan-Feb	BC-Can	17	4	11	3
Mar-Apr	BC-Can	20	8	12	10
May-Jun	BC-Can	21	20	11	31
Jul-Aug	BC-Can	22	36	12	42
Sept-Oct	BC-Can	21	61	12	61
Nov-Dec	BC-Can	16	11	9	12
Jan-Feb	BC-CU	14	57	12	59
Mar-Apr	BC-CU	14	51	12	46
May-Jun	BC-CU	13	57	11	58
Jul-Aug	BC-CU	14	143	12	139
Sept-Oct	BC-CU	16	258	12	258
Nov-Dec	BC-CU	12	72	9	78
Jan-Feb	BC-47	6	104	4	107
Mar-Apr	BC-47	6	110	4	116
May-Jun	BC-47	6	121	4	87
Jul-Aug	BC-47	6	374	4	351
Sept-Oct	BC-47	8	228	4	365
Nov-Dec	BC-47	7	85	3	116
Jan-Feb	BC-61	19	31	12	30
Mar-Apr	BC-61	20	39	12	23
May-Jun	BC-61	22	89	12	128
Jul-Aug	BC-61	22	183	12	210
Sept-Oct	BC-61	21	191	12	161
Nov-Dec	BC-61	17	48	9	54

		2001-2013		2008-2013	
Period	**Location**	**# Samples**	**Geometric Mean**	**# Samples**	**Geometric Mean**
Jan-Feb	BC-aWWTP	18	10	11	13
Mar-Apr	BC-aWWTP	20	17	12	12
May-Jun	BC-aWWTP	22	65	12	78
Jul-Aug	BC-aWWTP	22	58	12	69
Sept-Oct	BC-aWWTP	22	108	12	97
Nov-Dec	BC-aWWTP	19	37	10	45
Jan-Feb	BC-aDC	17	45	12	62
Mar-Apr	BC-aDC	18	32	12	36
May-Jun	BC-aDC	21	74	12	80
Jul-Aug	BC-aDC	19	98	11	106
Sept-Oct	BC-aDC	22	117	12	150
Nov-Dec	BC-aDC	19	73	10	113
Jan-Feb	BC-95	11	31	4	52
Mar-Apr	BC-95	10	31	2	28
May-Jun	BC-95	12	79	2	132
Jul-Aug	BC-95	12	59	2	60
Sept-Oct	BC-95	12	92	2	62
Nov-Dec	BC-95	10	59	2	123
Jan-Feb	BC-107	19	13	12	16
Mar-Apr	BC-107	20	38	12	46
May-Jun	BC-107	22	136	12	178
Jul-Aug	BC-107	22	99	12	140
Sept-Oct	BC-107	20	63	12	89
Nov-Dec	BC-107	19	49	10	64
Jan-Feb	BC-Ken	8	16	4	25
Mar-Apr	BC-Ken	8	22	3	19
May-Jun	BC-Ken	10	198	2	553
Jul-Aug	BC-Ken	11	62	2	18
Sept-Oct	BC-Ken	10	64	2	46
Nov-Dec	BC-Ken	9	32	2	58
Jan-Feb	BC-bCC	19	58	12	67
Mar-Apr	BC-bCC	20	133	12	150
May-Jun	BC-bCC	19	234	12	244
Jul-Aug	BC-bCC	20	325	12	293
Sept-Oct	BC-bCC	21	276	12	211
Nov-Dec	BC-bCC	18	98	9	93
Jan-Feb	BC-CNTYLN	7	50		
Mar-Apr	BC-CNTYLN	7	169		
May-Jun	BC-CNTYLN	10	303		
Jul-Aug	BC-CNTYLN	8	170		
Sept-Oct	BC-CNTYLN	6	261		
Nov-Dec	BC-CNTYLN	8	74		

5.3.1.2 Coal Creek Routine Sampling

Table 5-4 and Figures 5-2 and 5-3 contain the results of routine sampling on Coal Creek and Rock Creek for the period of record (2003-2013). Key findings include:

- All monitoring locations exceed the bimonthly stream standards for May through October. Additionally, January-February is also slightly exceeded at several locations (2-CC, 6-CC and 7-CC) and November-December at CC-Ken. A clear seasonal pattern is evident at most sites, with summer samples higher than winter samples.

- Based on results of the Kruskal-Wallace hypothesis test to assess significant differences among monitoring locations, no statistically significant differences among monitoring locations were identified ($p = 0.40$).

- Figure 5-4 illustrates the annual geometric means at each monitoring location over time. At most of the sites, the data sets are limited to 2008-2011, without a trend over time suggested. CC-1 and CC-Ken have longer periods of record. The years 2003 and 2004 are not shown because winter months are missing, biasing the annual geometric means on the high side. Trends over time were not formally evaluated, other than to observe that conditions do not appear to be worsening or limited to a certain year.

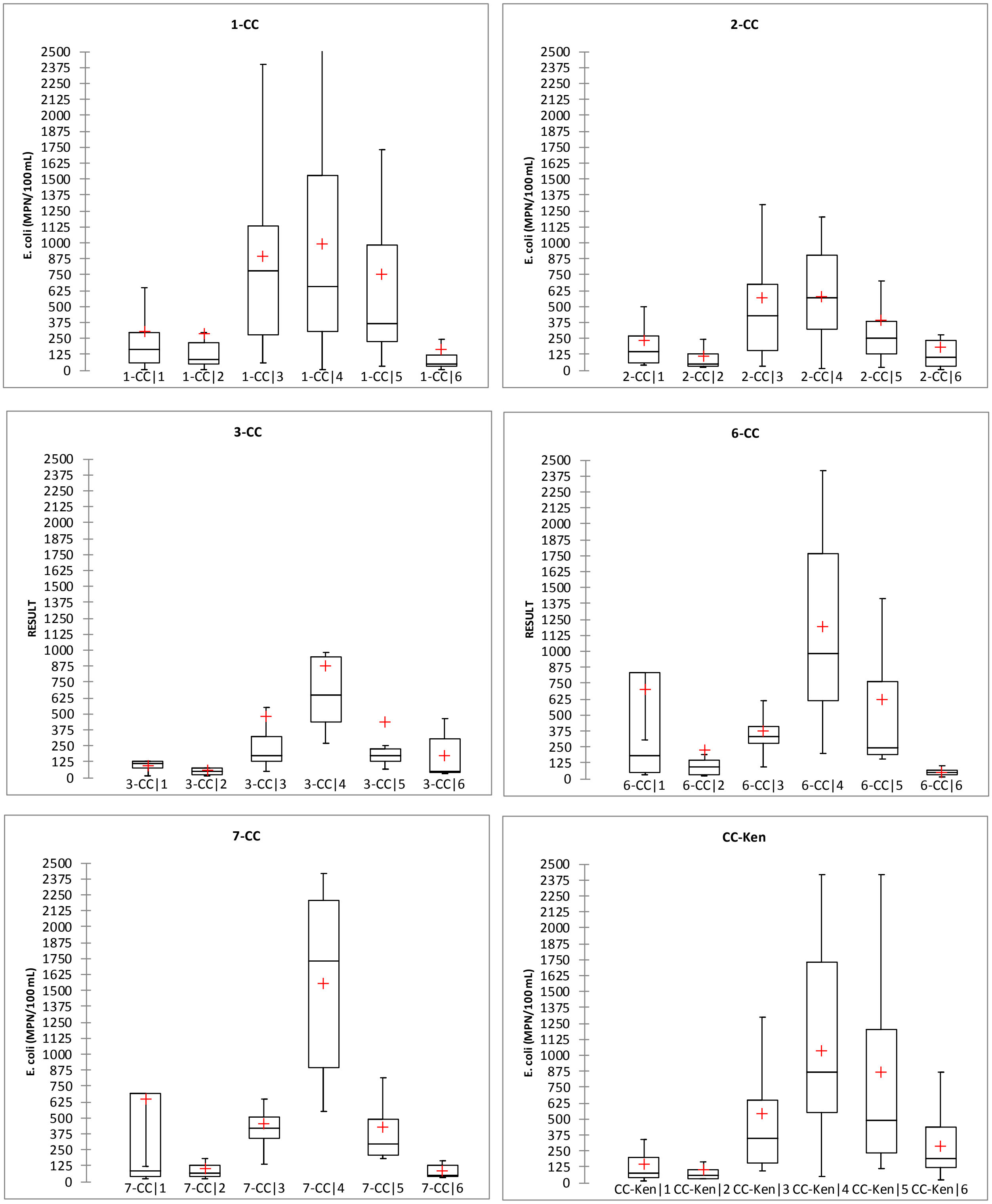
In addition to routine long-term sampling at these locations, two special studies have been conducted on Coal Creek and Rock Creek, as discussed further in Sections 5.3.1.3 and 5.3.1.4.

Table 5-4. Coal Creek and Rock Creek Bimonthly Sample Results (2003-2013)

Location/ Bimonthly Interval	No. Samples	Geometric Mean
1-CC| Jan-Feb	23	115
1-CC| Mar-Apr	22	92
1-CC| May-Jun	20	546
1-CC| Jul-Aug	18	570
1-CC| Sept-Oct	21	449
1-CC| Nov-Dec	22	64
2-CC| Jan-Feb	16	143
2-CC| Mar-Apr	15	67
2-CC| May-Jun	14	327
2-CC| Jul-Aug	16	415
2-CC| Sept-Oct	16	229
2-CC| Nov-Dec	16	91
3-CC| Jan-Feb	4	70
3-CC| Mar-Apr	7	42
3-CC| May-Jun	8	211
3-CC| Jul-Aug	7	688
3-CC| Sept-Oct	8	205
3-CC| Nov-Dec	6	91
6-CC| Jan-Feb	4	186
6-CC| Mar-Apr	7	94
6-CC| May-Jun	8	315
6-CC| Jul-Aug	7	899
6-CC| Sept-Oct	8	386
6-CC| Nov-Dec	7	45
7-CC| Jan-Feb	4	134
7-CC| Mar-Apr	7	74
7-CC| May-Jun	8	393
7-CC| Jul-Aug	7	1338
7-CC| Sept-Oct	8	347
7-CC| Nov-Dec	7	70

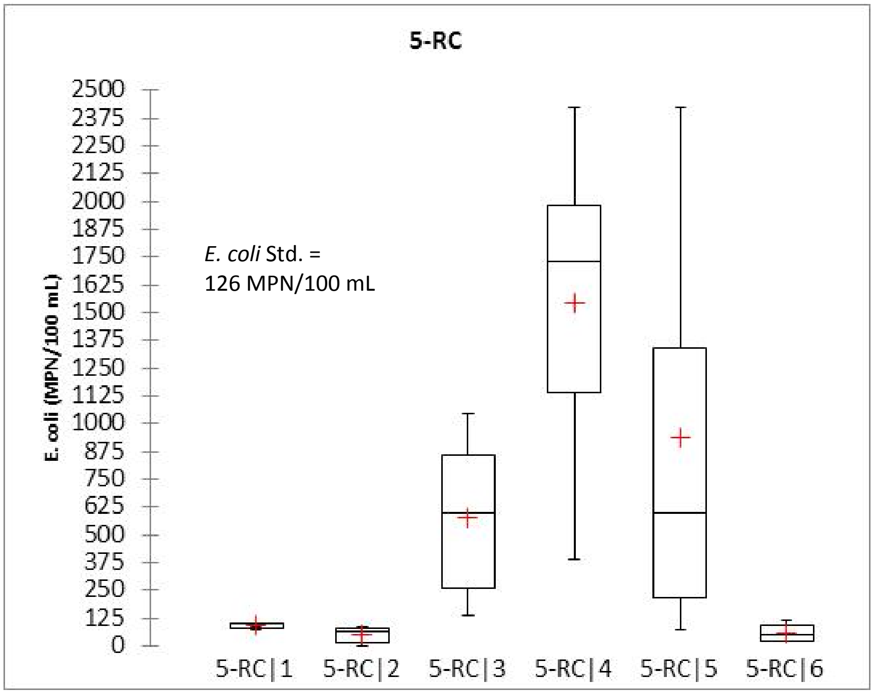
Location/ Bimonthly Interval	No. Samples	Geometric Mean
CC-Ken| Jan-Feb	16	89
CC-Ken| Mar-Apr	16	70
CC-Ken| May-Jun	20	362
CC-Ken| Jul-Aug	21	738
CC-Ken| Sept-Oct	19	525
CC-Ken| Nov-Dec	17	200
5-RC| Jan-Feb	4	91
5-RC| Mar-Apr	7	30
5-RC| May-Jun	8	459
5-RC| Jul-Aug	7	1342
5-RC| Sept-Oct	8	511
5-RC| Nov-Dec	6	49

Figure 5-2. Coal Creek Routine Sampling Locations by Bimonthly Assessment Period[1]



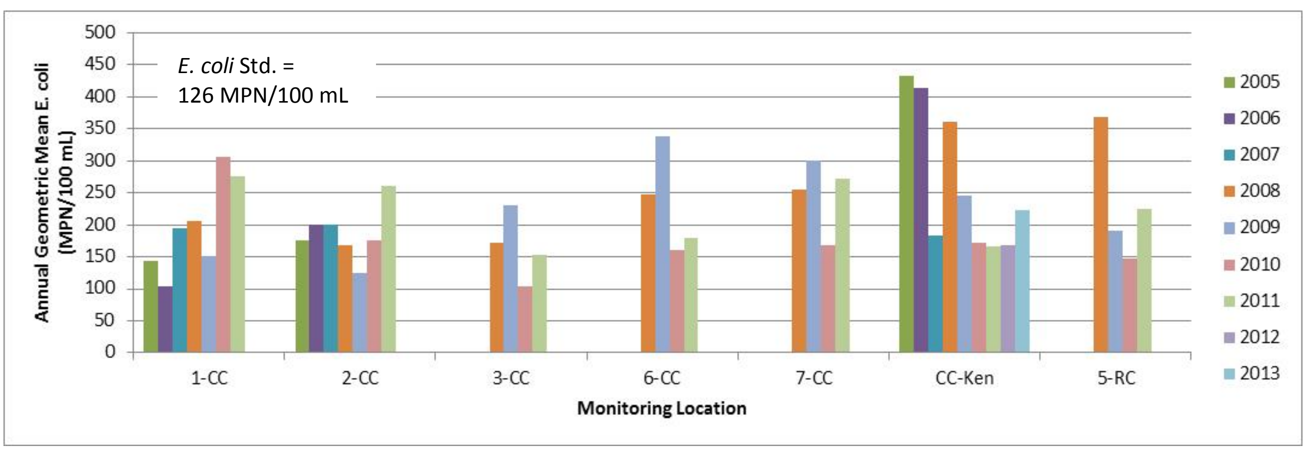
[1]Note: Six bimonthly monitoring periods are shown for each location: 1 = Jan/Feb; 2 = Mar/April; 3 = May/June; 4 = July/August; 5 = Sept/Oct; 6 = Nov/Dec. *E. coli* Std. = 126 most probable number (MPN)/100 mL.

Figure 5-3. Rock Creek Routine Sampling Locations by Bimonthly Assessment Period[1]



[1]Note: Six bimonthly monitoring periods are shown: 1 = Jan/Feb; 2 = Mar/April; 3 = May/June; 4 = July/August; 5 = Sept/Oct; 6 = Nov/Dec

Figure 5-4. Annual Geometric Mean *E. coli* by Sample Location over Time at Coal Creek and Rock Creek (2005-2013)



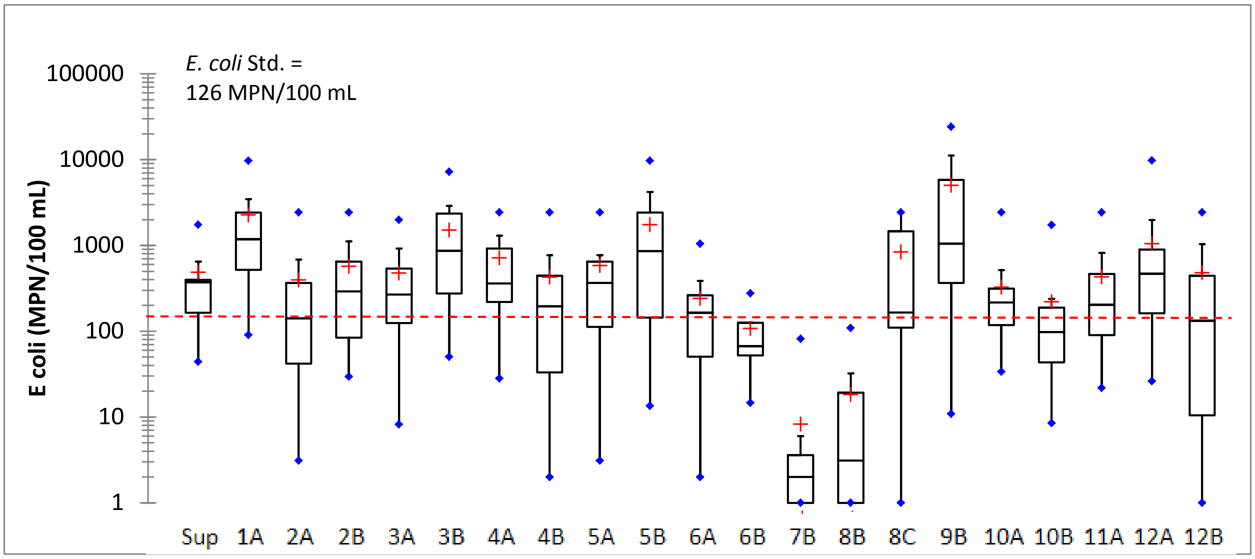
5.3.1.3 Coal Creek Special Study (2007-2014)

A long-term special study of *E. coli* was conducted from 2007 through 2014 on Coal Creek by the City of Louisville, building upon some initial sampling conducted by the City of Boulder in 2007-2008. Table 5-5 and Figure 5-5 summarize data for the recreational season. Figure 5-7 shows the approximate monitoring locations for these special samples. Sites identified by “A” are instream samples and sites identified by “B” are samples from drainage to the stream. Additional bimonthly boxplots and summary statistics are also available for these sites in Appendix G of the Keep It Clean Partnership Annual Water Quality Report for 2014 (KICP and WWE 2015), which showed that most sites attained the stream standards during the non-recreation/winter season, but multiple locations exceeded the standard during the recreation season.

Table 5-5. Recreation Season *E. coli* for Louisville’s *E. coli* Sampling on Coal Creek (2007-2014)

Sample ID	Sample Type	Sample Location Description	Rec. Season Geometric Mean (2007-2014)
Superior	Stream	HW 36 SOUTH OF BRIDGE	309
1A	Stream	HW 36 NORTH OF BRIDGE CREEK SAMPLE	1146
2A	Stream	DILLON RD AT FOOT BRIDGE CREEK SAMPLE	122
2B	Drainage	DILLON RD. AT FOOT BRIDGE DRAINAGE SAMPLE	263
3A	Stream	ANDREWS ST. CREEK SAMPLE	240
3B	Drainage	ANDREWS ST. DRAINAGE	845
4A	Stream	FOOT BRIDGE GOLF COURSE CREEK SAMPLE	430
4B	Drainage	GOODHUE DITCH (DAM DOWNSTREAM AT FOOT BRIDGE)	119
5A	Stream	CREEK SAMPLE (AUGUSTA LN.)	258
5B	Drainage	DRAINAGE (AUGUSTA LN.)	610
6A	Stream	NEAR DUTCH CREEK COAL CREEK SAMPLE	96
6B	Drainage	DRAINAGE NEAR DUTCH CREEK	71
7B	Drainage	DRAINAGE (GREEN PIPE 10 INCH) (JEFFERSON LN.)	3
8B	Drainage	DRAINAGE (WHITE PIPE 6 INCH) (JEFFERSON LN.)	5
8C	Drainage	DRAINAGE ON SOUTH OF 8B	145
9B	Drainage	DRAINAGE (ASPEN WAY)	1133
10A	Stream	COAL CREEK UPSTREAM (96TH STREET)	195
10B	Drainage	DRAINAGE (96TH STREET)	90
11A	Stream	FOOT BRIGDE HW 42 CREEK SAMPLE	215
12A	Stream	UPSTREAM OF DRAINAGE (BEFORE MAY HOFFER SPRING)	426
12B	Drainage	DRAINAGE FROM MAY HOFFER SPRING	75

Figure 5-5. Recreation Season *E. coli* for Louisville's Sampling on Coal Creek (2007-2014)



Based on these results presented in Table 5-5 and Figure 5-5, elevated *E. coli* is present at multiple monitoring locations, both instream and in drainages to the stream. The highest priority locations for additional source investigation based on this monitoring includes sites 1A (Highway 36 north of bridge), 3B (Andrews St. Drainage), 5B (Augusta Lane), and 9B (Aspen Way). Elevated *E. coli* was present at high concentrations in several storm drains; however, lack of flow estimates for these outfalls limits interpretation regarding the effect on instream concentrations. In some locations, very high concentrations were present at the outfalls, but there did not appear to be a significant instream influence at the next instream sampling location.

5.3.1.4 Coal Creek Special Study (2007-2008)

In addition to the long-term sampling sites on Coal Creek and Rock Creek and the long-term special study through the Louisville reach of Coal Creek, a short-term exploratory special study was completed in 2007-2008. Three data sets were collected, as shown by the green, blue and yellow pins in Figure 5-6. The Louisville reach is not discussed in this section because a longer term sampling program continued, as described above in Section 5.3.1.3. Although the time periods were similar for the samples collected in these reaches, the samples were not collected in a synoptic manner, so they are discussed in two groups: Lafayette reach and Erie reach. The Erie samples include a combination of instream and outfall samples, whereas the Lafayette samples include instream samples only. Flow estimates from outfalls were not completed at the time of sampling, so it is unclear whether outfalls with significantly elevated *E. coli* contribute to exceedances of instream standards. For the Coal Creek samples in Erie, weekly spring plus summer samples were collected in 2007 and summer plus fall samples twice a month were collected in 2008. Thus, the samples were condensed to monthly geometric means and limited to the recreation season before plotting results on the figures.

Summary statistics are provided in Table 5-6 and Figures 5-7 and 5-8. Although the data set is limited, it is clear that all monitoring locations exceed the instream standard of 126 cfu/100 mL. An upstream to downstream trend is not apparent. For the Erie segment, two drainages (drn sites) had elevated *E. coli* relative to primary contact standards; however, the concentrations were lower than upstream samples collected instream.

Figure 5-6. General Sample Locations for Coal Creek *E. coli* Special Study (2007-2008)

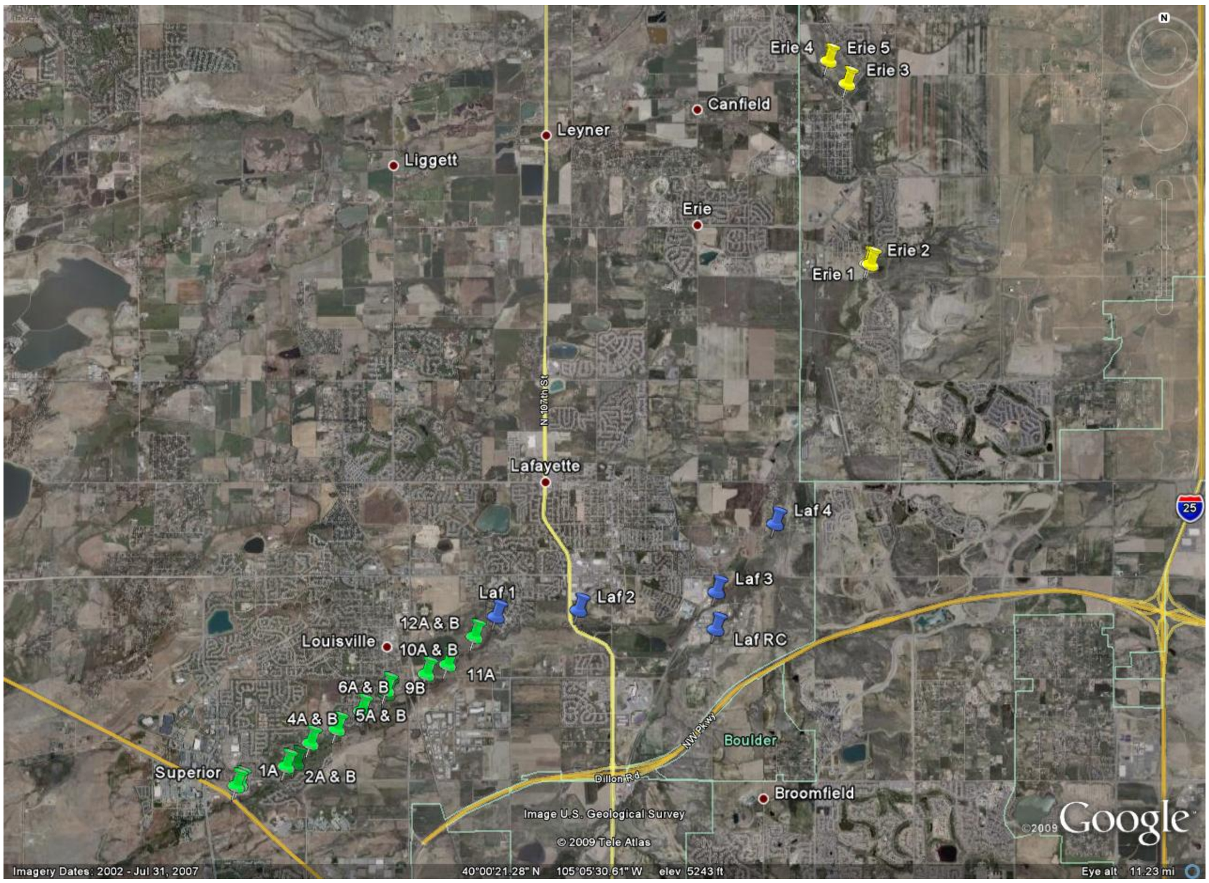


Table 5-6. Instream and Drainage Outfalls to Coal Creek for Recreation Season

Figure 5-6 Map ID	Location	No.	Geometric Mean
	Lafayette Segment		
Laf 1	Bike_Centaur	7	357
Laf 2	Hwy287	7	505
Laf 3	CC_119th	7	373
Laf RC	RC_119th	7	485
Laf 4	Flagg Park	7	498
	Erie Segment		
Erie 1	1-Crk	10	425
Erie 2	*2-Drn-Rivera*	7	212
Erie 3	3 Crk Abv WWTP	10	322
Erie 4	3 Crk Blw WWTP	10	472
Erie 5	*5-Drn*	10	167

Figure 5-7. Boxplots of Instream and Drainage Outfalls to Coal Creek for Recreation Season (August -September 2007) for the Lafayette Reach

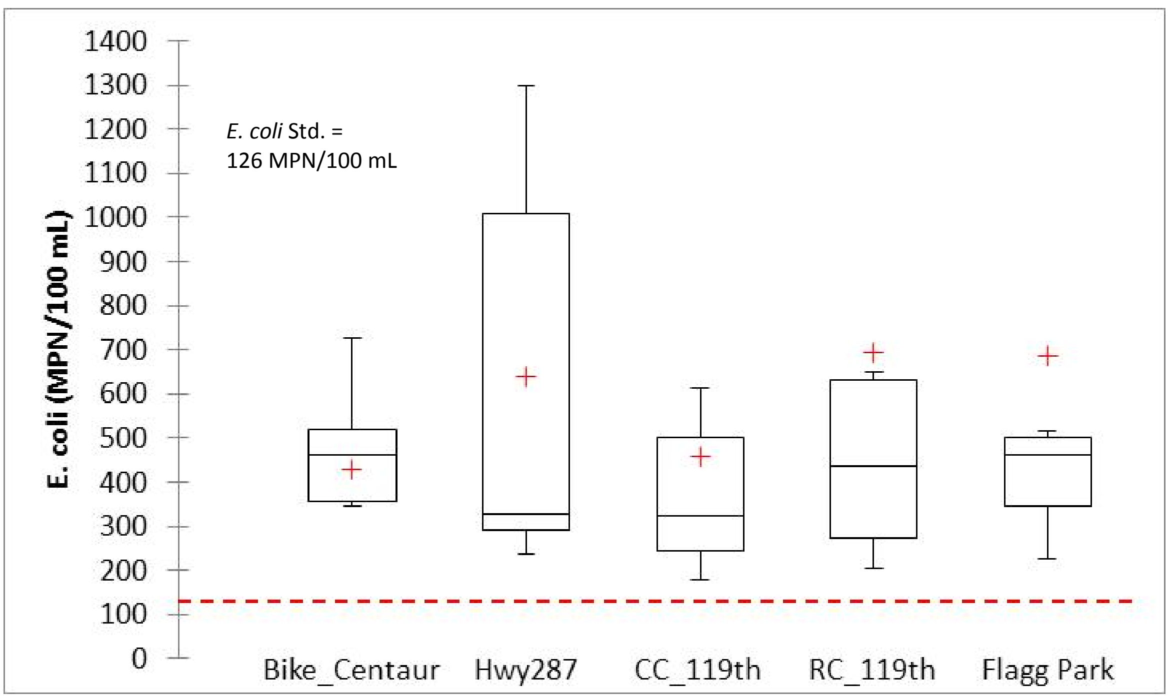
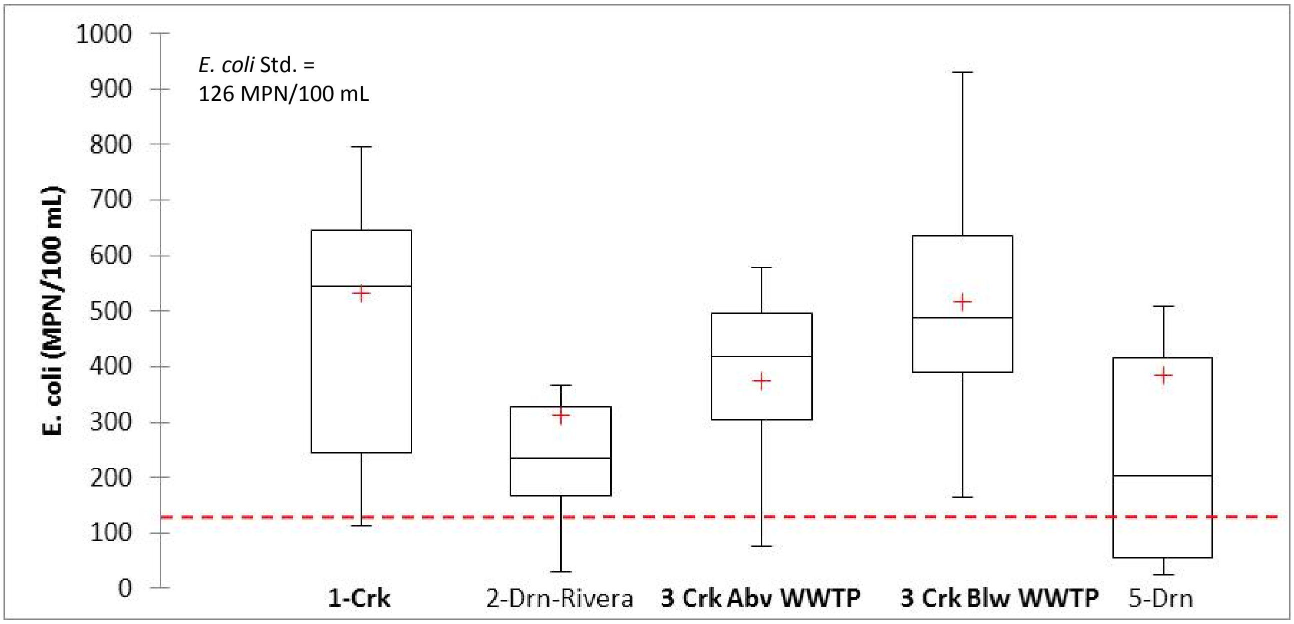


Figure 5-8. Boxplots of Instream and Drainage Outfalls to Coal Creek for Recreation Season (May-Oct, 2007-2008) for the Erie Reach



Note: Bold = instream sample; Drn = drainage sample

5.3.1.5 St. Vrain Creek/Left Hand Creek/Dry Creek

E. coli data collected from 2008 through 2014 were evaluated for St. Vrain Creek and Left Hand Creek and are summarized in Tables 5-7 and 5-8 and Figures 5-9 through 5-11. Key observations include:

- During November-April (non-recreational season), geometric mean *E. coli* concentrations were below the stream standard of 126/100 mL, with the exception of M7-SV, which had inadequate data to draw conclusions (n = 2). During May through October (recreational season), the geometric mean *E. coli* concentration exceeded the stream standard at all instream monitoring locations.
- An upstream to downstream trend is not apparent.
- Discharges from the Longmont WWTP, as represented by location T-Eff, which contains combined roadside ditch drainage and WWTP effluent, are consistently low and well below the stream standard.
- The locations with the three highest geometric mean concentrations were M8.9-SV, Left Hand Creek (T11-LH), and M4-SV.

In summary, the pattern of exceedances of the *E. coli* standard for St. Vrain Creek and Left Hand Creek do not indicate a specific hot spot or upstream to downstream trend; therefore, identification of the causes of elevated *E. coli* would require additional monitoring at a finer spatial resolution and for a longer period of record to draw conclusions or form and evaluate hypotheses about sources.

Table 5-7. Seasonal *E. coli* in St. Vrain Creek and Left Hand Creek (2008-2014)

Sample	Season	No.	Minimum	Maximum	Geometric mean
M9.5-SV	N	2	21	52	33
M8.9-SV	N	17	4	272	35
M8.4-SV	N	5	21	185	47
M8.2-SV	N	5	41	135	63
M8-SV	N	28	9	387	59
T11-LH	N	33	6	1730	47
T-EFF	N	26	1	81	11
M7-SV	N	2	84	326	166
M6-SV	N	25	11	488	52
M4-SV	N	10	23	173	55
M9.5-SV	R	4	42	980	170
M8.9-SV	R	22	46	2420	315
M8.4-SV	R	18	52	1410	161
M8.2-SV	R	18	63	2420	234
M8-SV	R	34	32	1300	204
T11-LH	R	28	39	2420	269
T-EFF	R	33	3	1550	26
M7-SV	R	6	83	206	150
M6-SV	R	30	48	1990	229
M4-SV	R	17	127	1730	386

R = Recreational Season (May-Oct.) and N = Non-recreational Season (Nov.-Apr.)

Table 5-8. Bimonthly *E. coli* in St. Vrain Creek and Left Hand Creek (2008-2014)

Sample	Season	No.	Geometric mean
M9.5-SV	Jan-Feb	0	NA
M9.5-SV	Mar-Apr	0	NA
M9.5-SV	May-Jun	0	NA
M9.5-SV	Jul-Aug	2	340
M9.5-SV	Sep-Oct	2	85
M9.5-SV	Nov-Dec	2	33
M8.9-SV	Jan-Feb	2	8
M8.9-SV	Mar-Apr	9	48
M8.9-SV	May-Jun	6	222
M8.9-SV	Jul-Aug	7	545
M8.9-SV	Sep-Oct	9	260
M8.9-SV	Nov-Dec	6	36
M8-SV	Jan-Feb	7	42
M8-SV	Mar-Apr	13	51
M8-SV	May-Jun	10	143
M8-SV	Jul-Aug	11	179
M8-SV	Sep-Oct	13	299
M8-SV	Nov-Dec	8	104
T11-LH	Jan-Feb	7	16
T11-LH	Mar-Apr	12	34
T11-LH	May-Jun	9	194
T11-LH	Jul-Aug	12	322
T11-LH	Sep-Oct	13	304
T11-LH	Nov-Dec	8	47
T-EFF	Jan-Feb	7	29
T-EFF	Mar-Apr	11	5
T-EFF	May-Jun	9	31
T-EFF	Jul-Aug	11	40
T-EFF	Sep-Oct	13	17
T-EFF	Nov-Dec	8	13

Sample	Season	No.	Geometric mean
M8.4-SV	Jan-Feb	0	NA
M8.4-SV	Mar-Apr	2	110
M8.4-SV	May-Jun	5	113
M8.4-SV	Jul-Aug	6	294
M8.4-SV	Sep-Oct	7	124
M8.4-SV	Nov-Dec	3	26
M8.2-SV	Jan-Feb	0	NA
M8.2-SV	Mar-Apr	2	107
M8.2-SV	May-Jun	5	122
M8.2-SV	Jul-Aug	6	309
M8.2-SV	Sep-Oct	7	292
M8.2-SV	Nov-Dec	3	44
M7-SV	Jan-Feb	0	NA
M7-SV	Mar-Apr	0	NA
M7-SV	May-Jun	2	95
M7-SV	Jul-Aug	2	200
M7-SV	Sep-Oct	2	178
M7-SV	Nov-Dec	2	166
M6-SV	Jan-Feb	7	67
M6-SV	Mar-Apr	12	39
M6-SV	May-Jun	8	143
M6-SV	Jul-Aug	10	244
M6-SV	Sep-Oct	12	296
M6-SV	Nov-Dec	6	66
M4-SV	Jan-Feb	0	NA
M4-SV	Mar-Apr	8	64
M4-SV	May-Jun	6	301
M4-SV	Jul-Aug	5	464
M4-SV	Sep-Oct	5	328
M4-SV	Nov-Dec	2	30

Figure 5-9. St. Vrain Creek/Left Hand Creek Recreational Season *E. coli* (2008-2014)

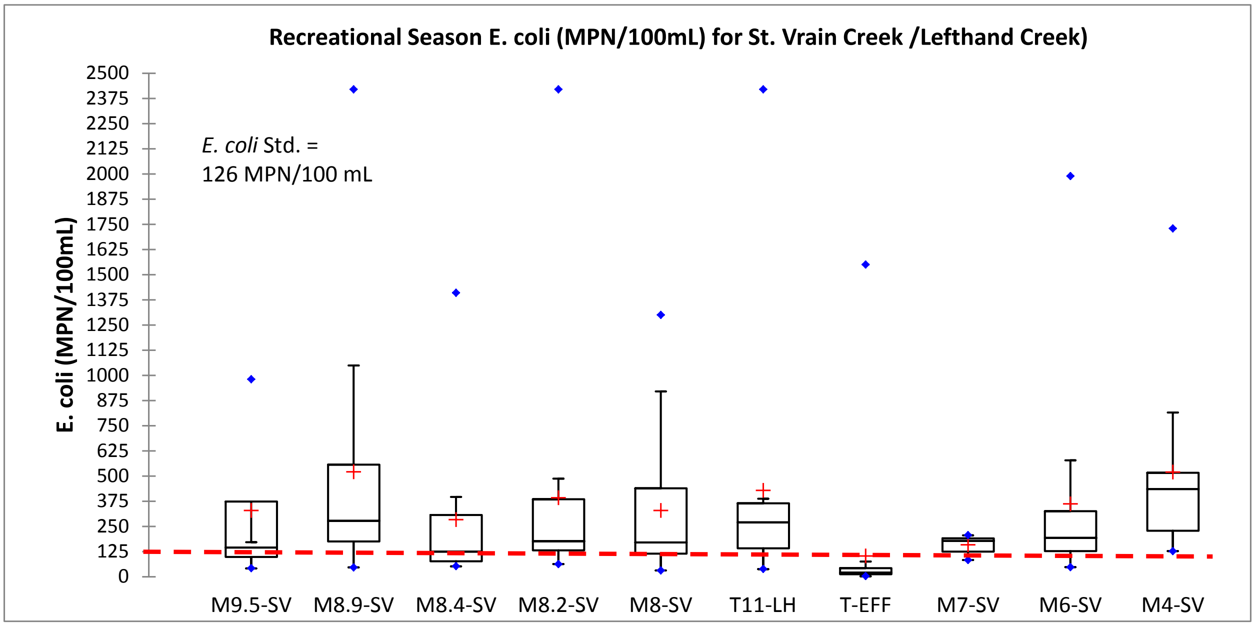
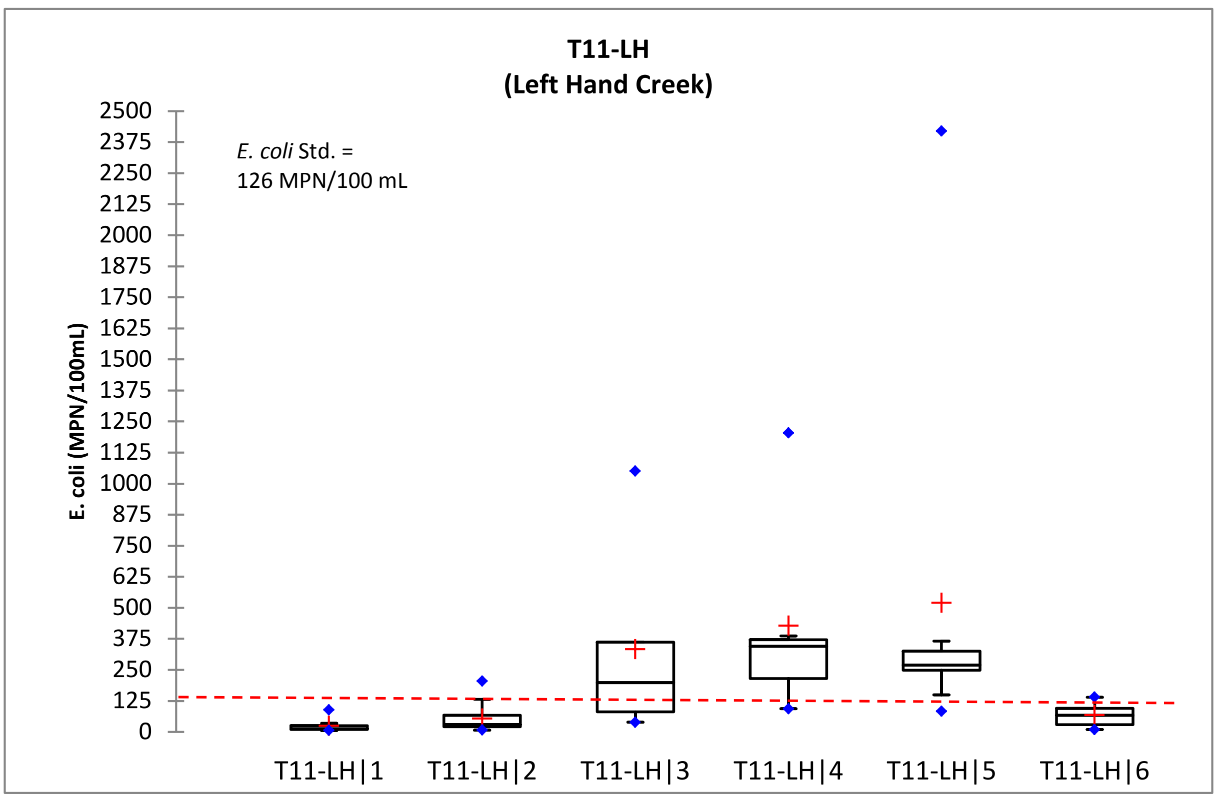
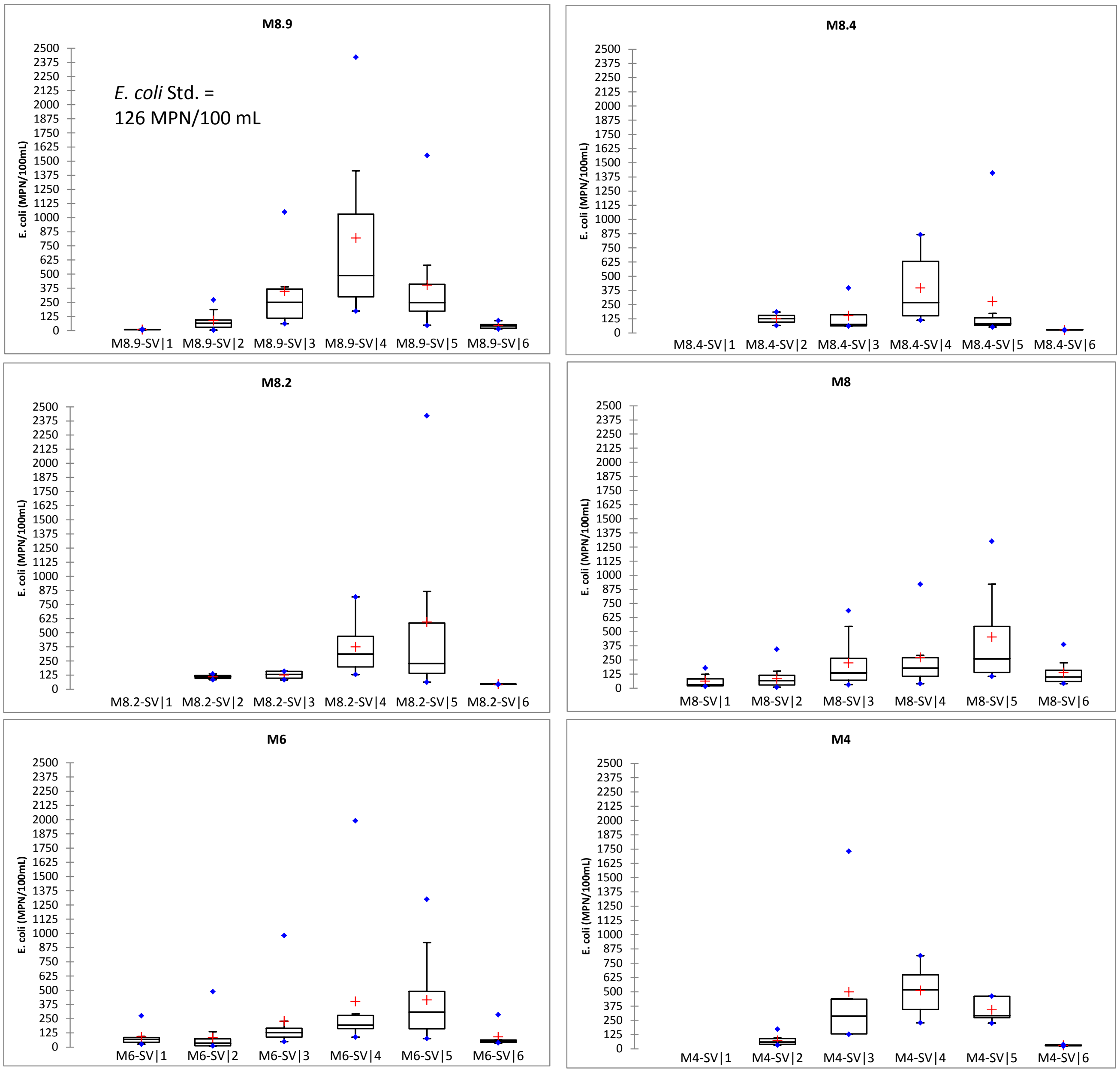


Figure 5-10. Left Hand Creek *E. coli* by Bimonthly Assessment Period (2008-2014)



Note: Six bimonthly monitoring periods are shown for each location: 1 = Jan/Feb; 2 = Mar/April; 3 = May/June; 4 = July/August; 5 = Sept/Oct; 6 = Nov/Dec.

Figure 5-11. St. Vrain Creek *E. coli* by Bimonthly Assessment Period (2008-2014)



Note: Six bimonthly monitoring periods are shown for each location: 1 = Jan/Feb; 2 = Mar/April; 3 = May/June; 4 = July/August; 5 = Sept/Oct; 6 = Nov/Dec.

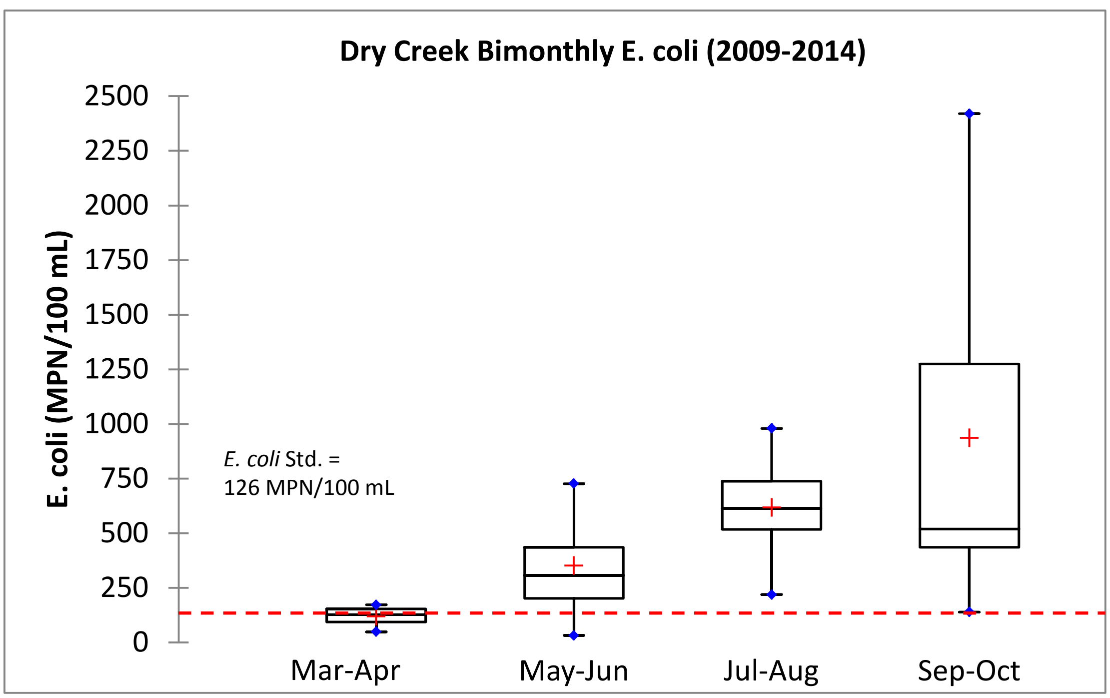
5.3.1.6 Dry Creek

Dry Creek (tributary to the St. Vrain River in Longmont) is identified as impaired for *E. coli*. Table 5-9 and Figure 5-12 provide a bimonthly summary of *E. coli* data for data collected by the City of Longmont from 2009 through 2014. Although a year-round data set is not available, the recreational season geometric mean of 475 most probable number (MPN)/100 mL exceeds the instream standard of 126 MPN/100 mL, with all recreational season bimonthly assessment intervals exceeding the instream standard.

Table 5-9. Dry Creek *E. coli* by Bimonthly Assessment Period (2009-2014)

Bimonthly Assessment Period	n =	Geometric mean (MPN/100 mL)
Jan-Feb	0	NA
Mar-Apr	4	108
May-Jun	9	272
Jul-Aug	12	569
Sep-Oct	10	632
Nov-Dec	0	NA

Figure 5-12. Dry Creek *E. coli* by Bimonthly Assessment Period (2009-2014)



5.3.2 Metals

5.3.2.1 Selenium

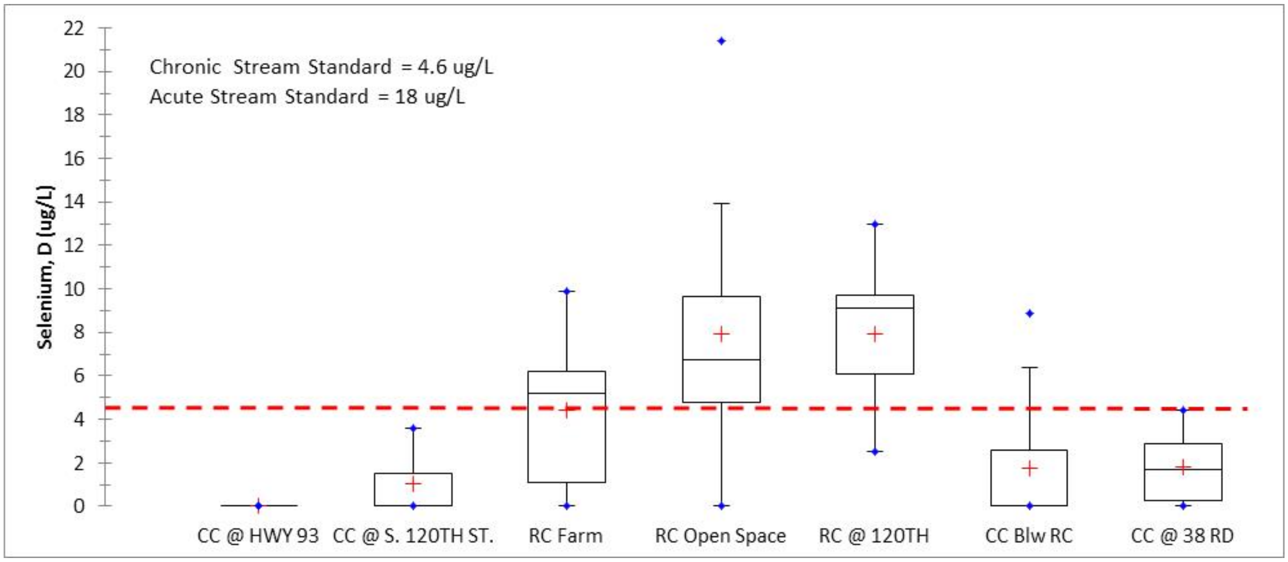
Selenium exceedances in the Boulder Creek watershed have only been documented in the Rock Creek watershed and in Coal Creek directly below the confluence with Rock Creek (Table 5-10 and Figure 5-13). Available data for "Coal Creek below the confluence with Rock Creek" were collected by the RiverWatch program from 2010 to 2012. The 85th percentile value was 5.8 ug/L, which exceeds the chronic stream standard of 4.6 ug/L. This segment is proposed for listing as impaired on the 2016 303(d) List.

In June 2015, a temporary modification for selenium (chronic) was established at current condition for Segment 8, which included Rock Creek, with an expiration date of 12/31/2020. The source of the elevated selenium is expected to be due to naturally occurring geologic sources. Rather than developing a TMDL and recommending an approach to reduce selenium concentrations in Rock Creek, it is recommended that a site-specific, ambient-based standard be pursued at the next Regulation 38 triennial review. A similar issue is present in the adjacent Big Dry Creek Watershed and special studies determined that naturally-occurring geologic sources were indeed the source of the elevated selenium in Big Dry Creek, particularly during low-flow periods when Big Dry Creek was dominated by groundwater inflows (WWE 2007). Given that portions of Rock Creek are known to be spring-fed (Timberline Associates 2013), a similar dynamic may be occurring on Rock Creek. Additional monitoring data for selenium will likely be needed to support a site-specific standard.

Table 5-10. Summary of Rock Creek and Coal Creek Dissolved Selenium Data (2001-2012)

Station ID	Location	85th	Maximum	Count	Years
5596 (Division)	Coal Creek @ HWY 93	0.0	0.0	6	2001, 2003, 2008
5594 (Division)	Coal Creek @ S. 120TH ST.	2.3	3.6	5	2001, 2007, 2008
4002 (Riverwatch)	Rock Creek Farm	**7.2**	9.9	6	2005, 2007
4001 (Riverwatch)	Rock Creek Open Space	**13.6**	21.4	8	2005, 2007
5592 (Division)	Rock Creek @ S. 120TH ST.	**10.3**	13.0	9	2001, 2007-2010
2600 (Riverwatch)	Coal Creek Below Confluence with Rock Creek	**5.8**	8.9	15	2010-2012
5590 (Division)	Coal Creek @ 38 RD	3.4	4.4	14	2001, 2003, 2007, 2008

Figure 5-13. Summary of Rock Creek and Coal Creek Dissolved Selenium Data (2001-2012)



5.3.2.2 <u>Mining-Related Metals in Left Hand Creek Subwatershed</u>

The water quality in Left Hand Creek, James Creek, and Little James Creek is affected by discharges from various mines, waste rock and mine tailings in the area. The drainage area encompasses the historical Captain Jack and Golden Age mining districts and receives runoff from a number of rock dumps, mill tailings, and abandoned mining sites (Division 2015).

In June 2015, the Division released an updated TMDL for public notice for three impaired segments (COSPSV04a, COSPSV04b, and COSPSV04c) of the Left Hand Creek Watershed near Jamestown, Colorado. TMDLs for cadmium, iron, manganese, zinc and pH were originally completed for Little James Creek in 2002. However, the standards for cadmium and zinc have been modified since 2002, therefore, TMDLs to address new cadmium and zinc standards for Little James Creek are included in the Division's TMDL. Although not identified on the 2010 or 2012 List, the portion of James Creek above its confluence with Little James Creek exceeds dissolved copper chronic standards. This portion also exceeds acute standards for dissolved copper, dissolved lead and dissolved zinc. Exceedances of cadmium, copper and zinc chronic standards and copper and zinc acute standards are documented in the Division's 2015 analysis for James Creek within the reach from Little James Creek to Left Hand Creek.

5.3.3 pH in Lower Boulder Creek

No streams in the St. Vrain Basin are currently identified as impaired on the 303(d) List due to pH; however, recent analysis of the City of Boulder's data along Segments 9 and 10 of Boulder Creek indicate elevated pH. As shown in Table 5-11 and Figure 5-14, the pH in Boulder Creek generally increases from upstream to downstream, with some reductions in pH below the Boulder WWTP discharge and below the confluence with Coal Creek. Locations with 85th

percentile values greater than 9.0 S.U. occur at 95th Street (BC-95), 107th Street (BC-107), and downstream of Coal Creek (BC-bCC). The pH at these locations may be increasing over time (City of Boulder and WWE 2013); however, this potential trend may also be influenced by flow conditions in the stream. Additional monitoring and research is needed to determine the cause of the elevated pH. A potential explanation that may be considered is naturally alkaline geologies and lithologies, based on the known presence of lime and alkaline conditions in soil associations along the stream. For example, a representative profile of the Loveland soil series along Boulder Creek includes a surface layer that is calcareous, with a strongly calcareous underlying layer. In the surface layer and underlying material, the soils are moderately alkaline. In most areas, gypsum crystals and soft lime segregations are present in some layers (SCS 1975). These soil factors may influence high pH in portions of the watershed.

Another commonly posed explanation of elevated pH in some watersheds is increased photosynthesis (e.g., algae) associated with elevated nutrient concentrations. In the reach with elevated pH, Boulder Creek has been channelized and experiences prolonged low-flow periods, has significant sunlight exposures, and has adequate nutrients to facilitate photosynthesis. However, seasonal patterns of pH show that the highest pH conditions tend to occur during the winter, instead of during the summer when highest algal productivity typically occurs. The seasonal pattern is more consistent with a geologic cause of elevated pH, as opposed to a photosynthesis-driven pattern. Additionally, relatively high pH is also present above the WWTP, where nutrients are below interim values established under Regulation 31, so the elevated pH does not appear to be a solely nutrient-driven phenomenon.

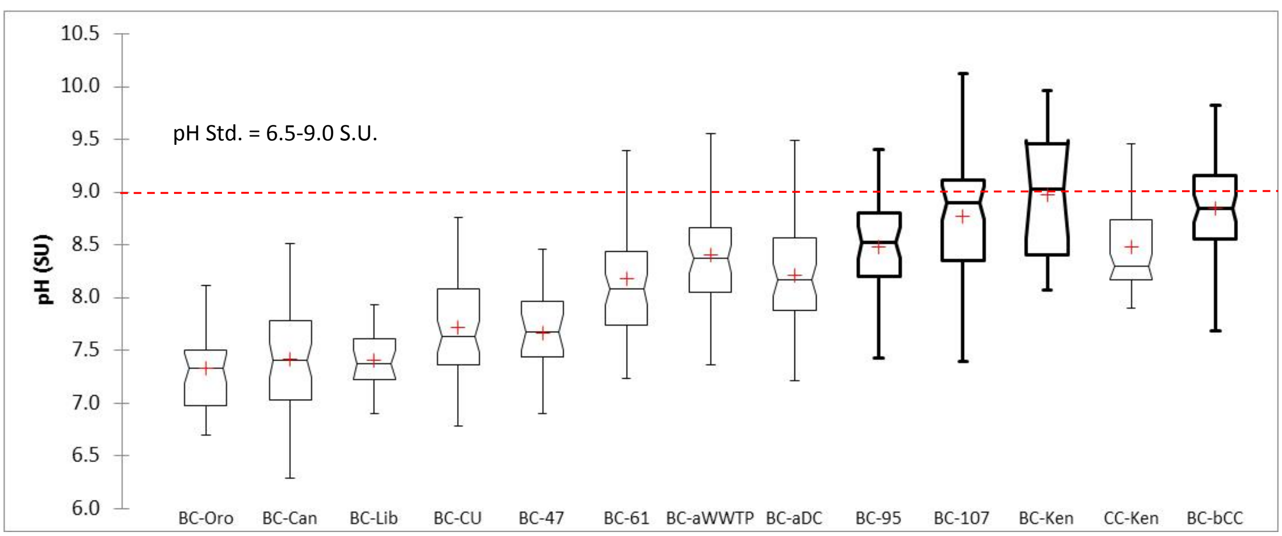
The City of Boulder conducted a diel temperature and pH study to support ammonia modeling for Boulder Creek during 2012 and 2013, which may be a helpful source of information if pH is addressed in future revisions to this Watershed Plan. During 2014, pH in this portion of Boulder Creek attained standards (Keep It Clean Partnership and WWE 2015). However, it may be appropriate to address pH in future revisions to this Watershed Plan, if the periodically elevated pH persists in this segment.

Table 5-11. 85th Percentile Values for pH at Selected Monitoring Locations on Boulder Creek and Coal Creek (2008-2012)

Stream Segment	Location	85th Percentile	# Samples
2b	BC-Oro	7.9	36
2b	BC-Can	8.0	54
2b	BC-Lib	7.8	23
2b	BC-CU	8.3	55
2b	BC-47	8.0	22
9	BC-61	9.0	56
9	BC-aWWTP	8.9	54
9	BC-aDC	8.6	55
9	BC-95	9.1	42
9	BC-107	9.3	*56*
9	BC-Ken[1]	9.6	13
7b (Coal Creek)	CC-Ken	8.9	55
10	BC-bCC	9.4	55

[1]Due to the smaller sample size at BC-Ken, it may not be appropriate to directly compare pH at BC-Ken to differing periods of record at the other monitoring locations where four to five times the number of samples collected at BC-Ken have been collected.

Figure 5-14. pH at Selected Locations on Boulder Creek and Coal Creek (2008-2012)



5.3.4 Aquatic Life

On behalf of local governments in the watershed, Timberline Aquatics conducts biological monitoring of Boulder Creek and South Boulder Creek, Coal Creek and Rock Creek and St. Vrain Creek and Left Hand Creek. The monitoring is conducted using comparable methods for all of the streams, which are described in the individual biological monitoring reports for each basin. Monitoring locations are shown on maps in Appendix C. The summary below highlights key findings from the latest report for each stream, focusing primarily on comparison of the multi-metric index (MMI) scores to thresholds for various biotypes defined in *Policy 10-1, Aquatic Life Use Attainment, Methodology to Determine Use Attainment for Rivers and Streams* (WQCD 2010). Policy 10-1 should be referenced for more detailed guidance on the interpretation of MMI scores.

As a brief overview, the location of macroinvertebrate sample sites results in assignment of one of three biotypes for the MMI assessments, as summarized in Table 5-12. Biotype site class is a function of three environmental variables: EPA Level IV ecoregion, site elevation, and stream slope (Policy 10-1, Appendix A). The thresholds that determine attainment or impairment are different for each biotype. Higher MMI scores are better than low scores. When an MMI score falls between the attainment and impairment thresholds identified in Table 5-12, additional evaluation using supplemental thresholds using the Hilsenhoff Biotic Index (HBI) and the Shannon Diversity Index (SDI) (Table 5-13) are required for "Class 1" aquatic life, as described in Regulation 38 (see Appendix E). For the Hilsenhoff Biotic Index (HBI), lower values are better. For the Shannon Diversity Index (SDI), higher values are better. If a Class 1 site fails to meet the criteria shown in Table 5-13 for either auxiliary metric, the site will be considered impaired. Auxiliary metrics are not applicable to Class 2 waters (CDPHE 2010). The only Class 1 streams evaluated in this report are Boulder Creek, South Boulder Creek and St. Vrain Creek. (Auxiliary metrics do not apply to Coal Creek and Rock Creek.)

Table 5-12. Policy 10-1 MMI Thresholds

Biotype	Description	Attainment Threshold	Impairment Threshold
1	Transition	>52	42
2	Mountains	>50	42
3	Plains & Xeric	>37	22

Table 5-13. Policy 10-1 Supplemental Evaluation Thresholds

Biotype	Description	Hilsenhoff Biotic Index	Shannon Diversity Index
1	Transition	<5.4	>2.4
2	Mountains	<5.1	>3.0
3	Plains & Xeric	<7.7	>2.5

All locations discussed in this report are located in either Biotype 1 or Biotype 3. Biotype 1 (Transition Zone) includes lower mountain areas of the Colorado Front Range downstream to the lower boundary of the "Front Range Fans". Biotype 3 (Plains) ranges from the eastern border of the "Front Range Fans" to the eastern border of Colorado. Both ecoregion and stream elevation are used to determine which biotype is appropriate, with the elevation of 5085 feet serving as the dividing threshold between Biotype 1 and Biotype 3. The Division has acknowledged that where uncertainty exists regarding the transitional boundaries between biotypes, the MMI for the adjacent biotype may be used to help determine the status of the aquatic life use. This additional analysis may be conducted under two circumstances:

1. At sites in Level IV Ecoregion 21c where the biotype assignment along a waterbody varies between Biotypes 1 and 2 because the stream slope fluctuates above and below 0.04. This situation typically occurs when stream slopes are slightly greater than or less than 0.04 along the gradient of a waterbody resulting in varying site classifications or biotypes.

2. At sites that encompass the physical border between two different Level IV Ecoregions or elevation zone boundaries used in the biotype classification. This results in a predicted site classification in one biotype, but is narrowly adjacent to another biotype. In such cases, sites may be represented by characteristics shared by more than one biotype.

For these circumstances, the Division states that "MMIs for each of the adjacent biotypes shall be investigated and used in the assessment." This new procedure has not yet been applied to 303(d) listings to date, but is expected to be taken into consideration in development of the 2016 303(d) List.

For in-depth discussion of biological findings for each stream segment, the Timberline Aquatics annual reports for each basin should be reviewed. The remainder of this chapter provides MMI, HBI and SDI summaries, as well as EPT[4]scores, which are provided for general reference, but not discussed in this report.

5.3.4.1 Boulder Creek and South Boulder Creek

For Boulder Creek and South Boulder Creek, sites were strategically established at specific locations to assist in the evaluation of aquatic conditions. These sites include:

[4] The EPT index an index of water quality based on the abundance of three pollution-sensitive orders of macroinvertebrates relative to the abundance of a hardy species of macroinvertebrate. It is calculated as the sum of the number of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* divided by the total number of midges (*Diptera: Chironomid*).

- BC-CAN: the furthest upstream site on Boulder Creek upstream of most urban development, serving as a reference site with relatively low anthropogenic influences.
- SBC-OS: located on South Boulder Creek upstream of most urban development, serving as a reference site with relatively low anthropogenic influences. Within the City of Boulder, site BC-28 was used to monitor possible impacts from urban runoff.
- BC-55: located further downstream on Boulder Creek and used to assess recovery that may occur downstream from the City of Boulder, but upstream of the 75th Street WWTP.
- BC-aWWTP: located immediately upstream of Boulder's 75th Street WWTP to evaluate changes in habitat that have been observed at that location. Four sites downstream of the WWTP provide information on the influence of WWTP effluent and potential recovery.
- BC-aDC: located on Boulder Creek 2.4 river miles (RM) (3.9 km) downstream of the WWTP.
- BC-95: located on Boulder Creek 3.2 RM (5.1 km) below the WWTP.
- BC-107 located on Boulder Creek approximately 4.7 RM (7.5 km) downstream of the WWTP.
- BC-aCC: established on Boulder Creek in 2012, farther downstream in a stream reach with possible impacts from nutrients.

Based on review of the 2014 MMI scores (Tables 5-14 & 5-15 and Figure 5-15), all monitoring locations attain Biotype 1 aquatic life thresholds, with the exception of site BC-aCC. BC-aCC's MMI scores are in the "grey zone" and require assessment of auxiliary metrics in Table 5-15. The HBI auxiliary metric is not attained for 2014 at this location. Sites BC-aDC, BC-95, BC-107, and BC-aCC are located within the Biotype 3 elevation range, but in the Biotype 1 ecoregion. These lower elevation locations coincide with the portion of the stream below Boulder's 75th Street WWTP, which is a confounding factor in data analysis, given that these sites were selected to provide information on the influence of WWTP effluent and potential recovery. At the time of this report, Timberline Aquatics has suggested that for BC-aCC, a Biotype 3 classification is expected to be more appropriate than Biotype 1. Timberline Aquatics recalculated the MMI score for this location as Biotype 3, with a resulting MMI score of 46.2 which attains the Biotype 3 threshold (Personal Communication with Dave Rees, June 2015). Using these assumptions, the 2014 MMI scores show attainment of aquatic life use for all monitoring locations. Significant recovery of aquatic life following the 2013 flood impacts is evident at most of the sites.

Table 5-14. Boulder Creek and South Boulder Creek MMI Scores

Date	BC-CAN	BC-28	BC-55	BC-aWWTP	BC-aDC	BC-95	BC-107	BC-aCC[2]	SBC-OS
23-Sep-10	76.2	78.0	50.7	67.3	57.7	52.2	NA	NA	76.0
29-Sep-11	73.6	84.8	79.5	74.7	52.8	61.8	53.8	NA	72.6
28-Sep-12	73.5	63.5	70.4	62.8	42.4	43.3	37.0	40.2	78.8
25-Oct-13	68.3	75.5	0[1]	45.5	40.2	40.0	35.2	35.4	71.0
26-Oct-14	73.2	67.6	84.4	79.4	53.3	62.5	58.4	44 (Biotype 1) or 46.2 (Biotype 3)	80.6

Pink-shaded cells indicate impairments. Grey-shaded cells are MMI scores between attainment and impairment thresholds.

[1]The substrate at BC-55 was completely covered with sand in October 2013, providing no colonizable substrate after the flood. No invertebrates were present at this site during 2013 sampling.

[2]BC-aCC may be more appropriately classified as Biotype 3.

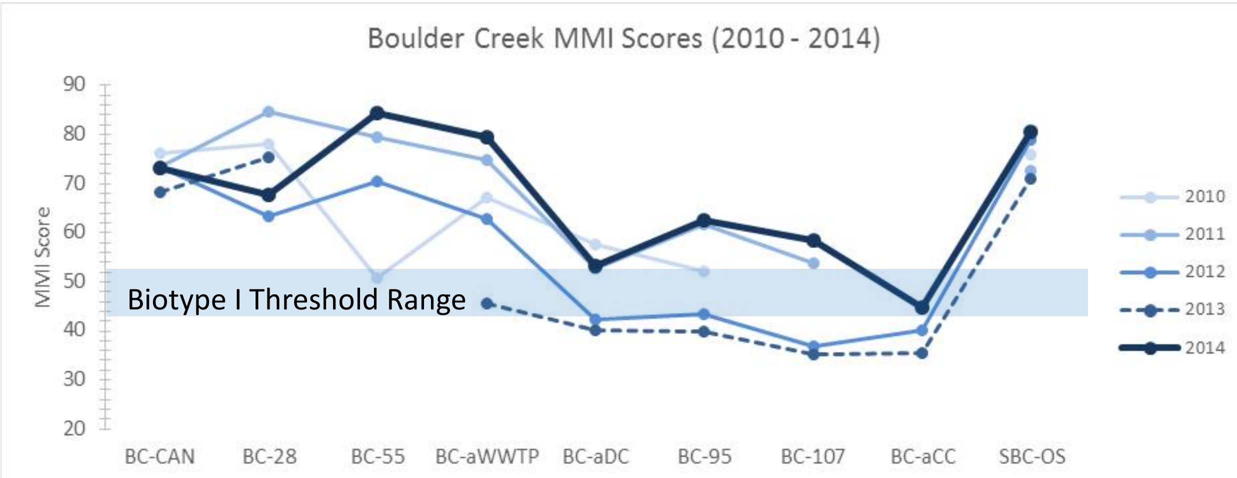
Table 5-15. Boulder Creek and South Boulder Creek EPT, Diversity Index and HBI Scores

Date	BC-CAN*	BC-28	BC-55	BC-aWWTP*	BC-aDC*	BC-95*	BC-107*	BC-aCC	SBC-OS
EPT Scores									
23-Sep-10	23	14	12	14	10	10	NA	NA	22
29-Sep-11	17	19	14	13	8	8	6	NA	21
28-Sep-12	18	10	14	13	6	9	6	4	20
25-Oct-13	12	14	NA	8	6	5	7	7	18
26-Oct-14	18		18	19	17	8	10	8	8
Shannon Diversity Index Scores									
23-Sep-10	3.40	3.07	2.70	2.72	2.86	2.67	NA	NA	3.99
29-Sep-11	3.19	3.23	2.39	2.90	2.83	2.78	2.80	NA	3.01
28-Sep-12	2.80	3.15	3.46	2.50	3.12	2.82	2.35	2.52	3.77
25-Oct-13	2.61	2.96	NA	2.48	2.54	2.82	2.66	2.47	2.47
26-Oct-14	3.17	4.29	2.62	3.16	3.16	3.19	2.72	2.57	3.56
HBI Scores									
23-Sep-10	3.22	3.80	5.96	5.97	4.64	4.74	NA	NA	3.43
29-Sep-11	2.09	3.66	3.91	4.61	4.81	5.06	5.02	NA	4.60
28-Sep-12	3.60	4.22	5.22	6.01	4.93	5.64	7.41	6.51	2.69
25-Oct-13	3.56	3.64	NA	4.79	4.11	5.86	4.23	5.53	3.38
26-Oct-14	2.01	4.22	4.23	4.70	4.70	5.33	5.83	5.70	3.33

*Also an active water quality monitoring location.

Pink-shaded cells do not attain target thresholds for Biotype 1.

Figure 5-15. Boulder Creek and South Boulder Creek MMI Scores (2010-2014)



*Does not show the "0" MMI score for BC-55 following the September 2013 flood.

5.3.4.2 <u>Coal Creek and Rock Creek</u>

Five biological monitoring locations are included for Coal Creek and Rock Creek. These sites are located in Aquatic Life Class 2 segments and include these monitoring locations:

- CC-EMP, which is the "reference site" upstream of the effluent discharge from the WWTP for the City of Louisville.
- CC-OSB, which is 0.4 km downstream of site CC-EMP, intended to evaluate the potential influence of the Louisville WWTP.
- RC-120, which is on Rock Creek, approximately 1 km upstream of its confluence with Coal Creek, downstream of Superior WWTP.
- CC-AP, located on Coal Creek: downstream of the confluence with Rock Creek, influenced by effluent from Lafayette WWTP and Rock Creek.
- CC-CLR, located on Coal Creek, downstream of Erie WWTP, influenced by effluent from all four municipalities (although Erie has been discharging from the North Erie WWTP to Boulder Creek instead of Coal Creek).

Each of these locations is classified as Biotype 1. Sites CC-OSB on Coal Creek and RC-120 on Rock Creek would be considered impaired based on comparison of the 2014 MMI scores to the MMI thresholds (Tables 5-16 and 5-17 and Figure 5-16). Most of the sites showed decreases in MMI scores following the September 2013 flood; however, 2014 MMI scores showed significant recovery of the aquatic life at most of these sites, with the exception of CC-OSB. Interestingly, the downstream-most site has the highest (best) MMI score for the stream.

Timberline Aquatics (2013) noted that the low MMI scores are likely influenced by the spring-fed nature of Coal Creek and Rock Creek that may have inadvertently influenced components of the MMI that are intended to represent responses to changes in water quality. The unique physical parameters (temperature, dissolved oxygen, etc.) that are typically found near the origin of spring-fed streams may contribute to the structure and function of macroinvertebrate communities in a way that negatively influences the MMI. These types of physical environmental changes may partially explain the relatively low MMI scores at the upstream sites (e.g., CC-EMP) on Coal Creek and gradual improvement in a downstream direction (Timberline Aquatics 2013).

The intermittent, spring-fed nature of these two effluent-dominated streams requires consideration when evaluating the status of aquatic life in Coal Creek and Rock Creek. The macroinvertebrate communities present in these streams depend on effluent discharge to provide stable aquatic habitat. The reference site in this study (CC-EMP) was selected because it was upstream of most potential perturbations and maintained enough groundwater to achieve permanent flow. At other locations, these streams rely on effluent discharge to maintain permanent flows through stream reaches that coincide with areas of urban development. Because of the intermittent nature of these streams, there is little opportunity for colonization from upstream macroinvertebrate populations in Coal Creek or Rock Creek. Aquatic life communities in these unique streams are substantially limited by the natural, intermittent, pre-existing conditions (Timberline Aquatics 2013).

Table 5-16. Coal Creek and Rock Creek MMI Scores

Date	CC-EMP	CC-OSB	RC-120	CC-AP	CC-CLR
22-Sep-10	38.1	42.2	38.6	44.1	50.1
28-Sep-11	39.8	37.4	36.0	51.4	49.7
27-Sep-12	43.7	33.6	22.5	42.2	53.6
26-Oct-13	24.5	32.3	24.1	38.1	36.6
28-Sep-14	47.8	31.5	36.0	51.3	53.4

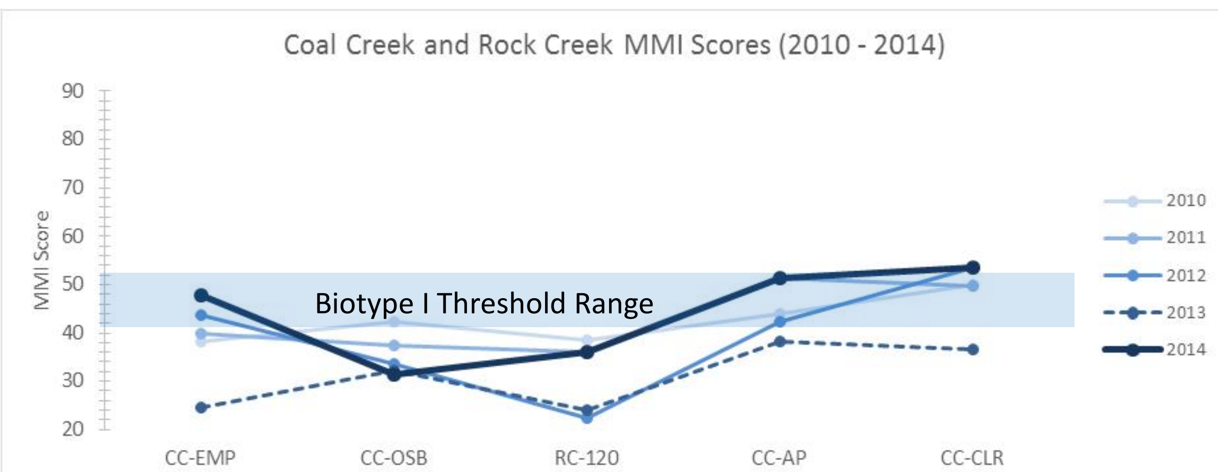
Grey-shaded cells are scores between the attainment and impairment threshold. Scores in pink are considered impaired.

Table 5-17. Coal Creek and Rock Creek EPT, Diversity Index and HBI Scores

Date	CC-EMP	CC-OSB	RC-120	CC-AP	CC-CLR
EPT Scores					
22-Sep-10	6	7	8	9	8
28-Sep-11	6	4	8	9	8
27-Sep-12	6	2	6	6	10
26-Oct-13	4	6	4	7	10
28-Sep-14	9	5	7	10	9
Shannon Diversity Index Scores					
22-Sep-10	2.23	2.02	3.42	3.11	2.56
28-Sep-11	1.97	1.76	3.35	3.35	2.79
27-Sep-12	2.32	1.30	2.59	2.68	2.58
26-Oct-13	2.76	2.91	1.99	2.70	2.46
28-Sep-14	2.70	2.71	2.48	2.82	2.61
HBI Scores					
22-Sep-10	6.29	6.48	5.92	5.12	4.64
28-Sep-11	6.27	6.86	5.77	5.66	4.77
27-Sep-12	6.65	6.69	6.79	5.97	5.24
26-Oct-13	6.73	6.51	6.37	6.47	5.95
28-Sep-14	6.08	5.97	5.73	5.53	4.86

Note: Diversity and HBI scores are not required to be evaluated to assess aquatic life use attainment for Class 2 streams.

Figure 5-16. Coal Creek and Rock Creek MMI Scores (2010-2014)



5.3.4.3 St. Vrain Creek and Left Hand Creek

Biological monitoring is conducted at six monitoring locations on St. Vrain Creek, and Left Hand Creek.[5] These sites, which are all classified as Aquatic Life Class 1 segments, include:

- SVC-75: farthest upstream site was added in 2013 to serve as a new reference site on St. Vrain Creek upstream of urban influences.
- SVC-M9: upstream site on St. Vrain Creek is used to provide reference information upstream of urban influences.
- SVC-M8: site within the city of Longmont is used to assess potential impacts from urban runoff.
- LHC-1: site on Left Hand Creek is located approximately 300 m upstream of its confluence with St. Vrain Creek and is used to evaluate the contributions and influence of Left Hand Creek on St. Vrain Creek.
- SVC-M6: site is located on St. Vrain Creek downstream of the Longmont WWTP and is used to measure the influence of treated effluent in combination with urban runoff
- SVC-M4: site is the farthest downstream site on St. Vrain Creek and was established to evaluate potential recovery downstream of the city.

During 2014, no MMI scores for St. Vrain Creek or Left Hand Creek were poorer than the impairment threshold (Table 5-18 and Figure 5-17); however, four sites fell within the “grey” zone, requiring additional evaluation of supplementary metrics (Table 5-19). Sites SVC-M8 on St. Vrain Creek and LHC-1 on Left Hand Creek were identified as impaired after review of the supplementary metrics. The downstream-most sites showed significant improvements in MMI scores relative to several previous years that showed impairment based on MMI scores. Although the St. Vrain Creek and Left Hand Creek sites are evaluated as Biotype 1, it is noteworthy that all of these sites are located in Biotype 3 elevation range (below 5085 feet) with the exception of SVC-75.

[5] A special study location on Spring Gulch (SG-2) is also monitored, but it is not included in this report since it is not part of the long-term monitoring program.

Table 5-18. St. Vrain and Left Hand Creek MMI Scores

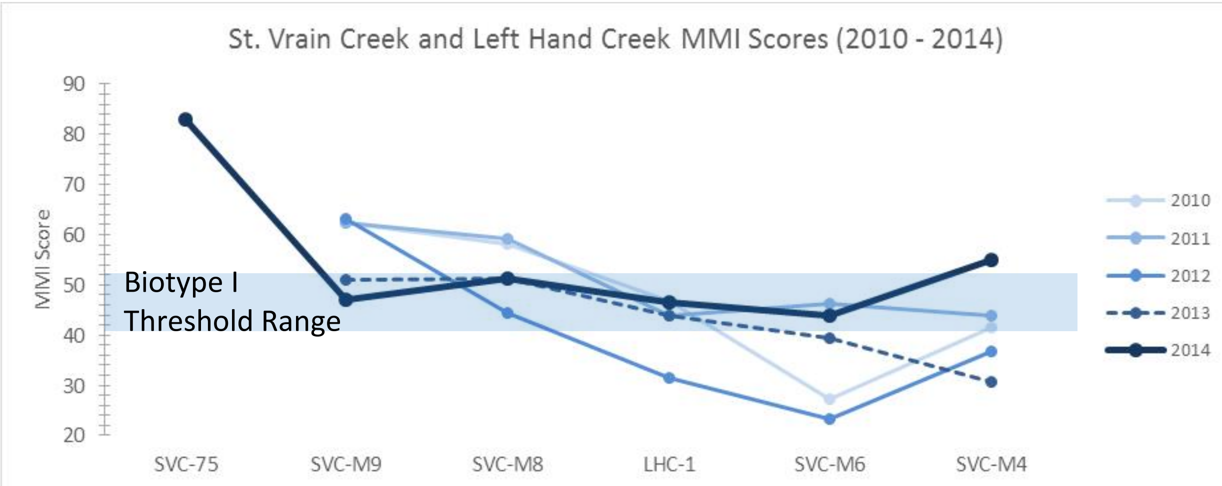
Date	SVC-75	SVC-M9	SVC-M8	LHC-1	SVC-M6	SVC-M4
WQ Cross-Ref	M9.5-SV	M8.9-SV	M8-SV	T11-SV	M6-SV	M4-SV
22-Sep-10	NA	62.5	58.2	46.9	27.2	41.5
28-Sep-11	NA	62.3	59.1	43.8	46.2	44.0
27-Sep-12	NA	63.2	44.5	31.6	23.3	36.9
28-Oct-13	NA	51.0	51.4	43.8	39.4	30.6
2-Oct-14	82.9	47.1	51.4	46.6	43.9	54.9

Note: all sites on St. Vrain and Left Hand Creek are below elevation 5085 ft, with the exception of SVC-75. Grey-shaded cells are scores between the attainment and impairment threshold. Scores in pink are considered impaired.

Table 5-19. St. Vrain and Left Hand Creek EPT, Diversity Index and HBI Scores

Date	SVC-75	SVC-M9	SVC-M8	LHC-1	SVC-M6	SVC-M4
EPT Scores						
22-Sep-10	NA	14	14	8	10	7
28-Sep-11	NA	11	8	8	7	7
27-Sep-12	NA	10	8	3	9	7
28-Oct-13	NA	9	13	6	8	6
2-Oct-14	20	9	10	7	10	8
Shannon Diversity Index Scores						
22-Sep-10	NA	2.65	2.81	3.50	2.43	3.05
28-Sep-11	NA	2.19	2.25	2.59	2.95	2.16
27-Sep-12	NA	1.99	1.70	2.65	2.63	2.84
28-Oct-13	NA	2.23	3.08	3.11	2.69	2.00
2-Oct-14	2.74	2.81	2.58	1.31	2.71	3.30
HBI Scores						
22-Sep-10	NA	3.90	5.15	6.49	5.49	5.12
28-Sep-11	NA	4.90	4.73	6.83	4.37	4.95
27-Sep-12	NA	5.36	6.56	7.41	5.93	5.68
28-Oct-13	NA	4.58	5.42	5.11	4.96	4.13
2-Oct-14	3.67	4.41	5.72	3.54	4.19	4.88

Figure 5-17. St. Vrain and Left Hand Creek MMI Scores (2010-2014)



5.3.4.4 <u>Summary of Findings for Biological Data</u>

Based on biological monitoring results for 2014, portions of Coal Creek, Rock Creek, St. Vrain Creek and Left Hand Creek would be identified as impaired for aquatic life. One location on Boulder Creek above Coal Creek (BC-aCC) would be considered impaired for aquatic life when evaluated as Biotype 1, but not when evaluated as Biotype 3. It may be worth further evaluating whether other monitoring locations, particularly those within the Biotype 3 elevation range, are more appropriately evaluated as Biotype 1 or Biotype 3, given new provisions in the 2016 303(d) Listing Methodology.

5.3.5 Nutrients

In 2012, Colorado adopted interim nutrient values for total nitrogen, total phosphorus, and chlorophyll-a in Regulation 31, as summarized in Table 5-20. These values have been adopted as standards in Regulation 38 for stream segments (or portions of stream segments above WWTP discharges and may be adopted as standards after May 2022 for segments below WWTP discharges.

Table 5-20. "Interim Values" for Total Nitrogen, Total Phosphorus and Chlorophyll-a

Analyte	Cold Water "Interim Value"	Warm Water "Interim Value"
Total Phosphorus	0.11 mg/L	0.17 mg/L
Total Nitrogen	1.25 mg/L	2.01 mg/L
Chlorophyll-*a*	150 mg/m^2	150 mg/m^2
Streams: Interim values for phosphorus and nitrogen are assessed based on comparison of annual median to standard. Allowable exceedance frequency is once every five years. Chlorophyll-*a* is measured as maximum attached algae and is assessed during July 1-September 30 as a "not to exceed" value.		

5.3.5.1 Boulder Creek (Segments 9 and 10)

Nutrients are of interest for the main stem of Boulder Creek due to current and future water quality regulations and the city's desire to maintain healthy aquatic life and aesthetically pleasing conditions on Boulder Creek. Excessive nutrient concentrations can lead to undesirable algae and other vegetative growth in streams, adversely affecting aquatic life and aesthetics. Weaker or inconsistent nutrient and flow-related relationships exist in the portion of Boulder Creek upstream of the WWTP discharge. Downstream of the WWTP discharge, an inverse relationship with flow is present for several nutrients, indicating that dilution from spring runoff generally decreases nutrient concentrations downstream of the WWTP, which is also consistent with previous findings by the USGS (Murphy 2006).

Currently, Boulder Creek has stream standards in place for ammonia, nitrate and nitrite for the entire segment. Total phosphorus and chlorophyll-a standards are also now in place for portions of segments above WWTP discharges, as of June 2015. Additional nutrient standards for total nitrogen, total phosphorus and chlorophyll-a are expected to apply within the next 10 years in accordance with Regulation 31. Boulder's 75th Street WWTP will require additional upgrades in order to meet Colorado's interim nutrient criteria for instream total phosphorus and total nitrogen (discharge permit limits are based on total inorganic nitrogen). These upgrades will be necessary despite the significant reductions in WWTP effluent ammonia concentrations resulting from the 2008 WWTP upgrades.

<u>Ammonia</u>

An ammonia TMDL for Segment 9 of Boulder Creek was completed in 2003 (Lewis and Saunders 2003). Since that time, an upgrade to the WWTP was completed in 2008. Statistically significant reductions in total ammonia are evident downstream of the WWTP following completion of the facility upgrade in 2008. Due to changes in the ammonia standard and instream improvements, the stream is no longer considered impaired for ammonia. Additionally, the stream currently attains Aquatic Life Criteria downstream of the WWTP based on the MMI thresholds established in Commission Policy 10-1, which suggests that current ammonia concentrations are not adversely affecting aquatic life in the stream.

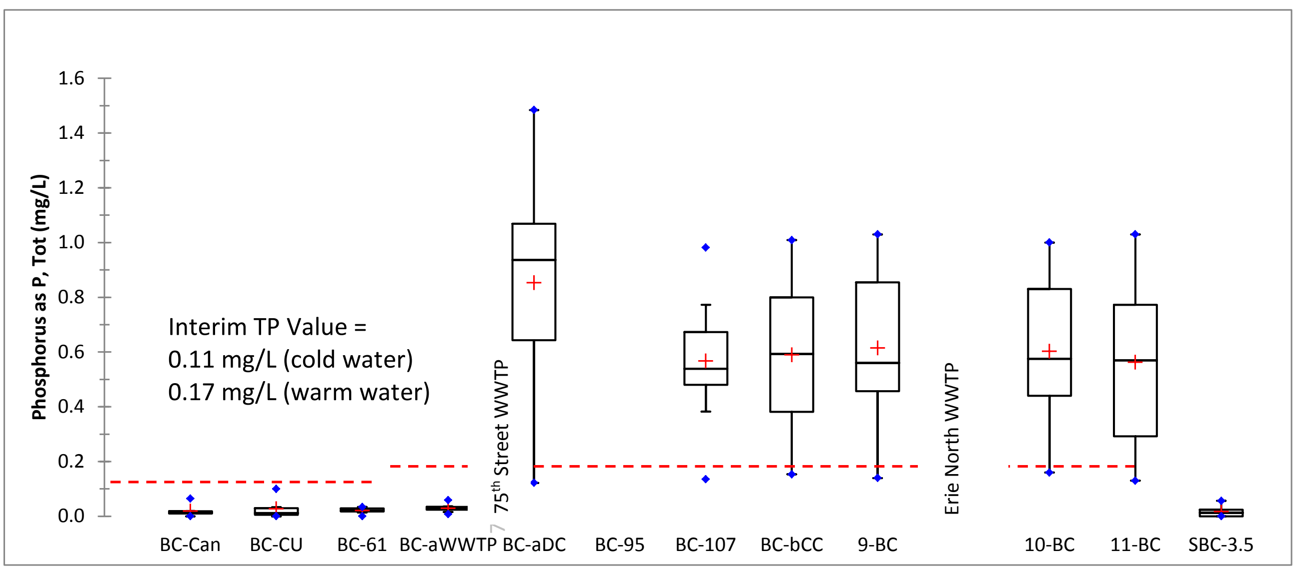
<u>Total Phosphorus</u>

Total phosphorus standards vary for cold water and warm water streams, and total phosphorus standards in the upper portion of Boulder Creek are more stringent than in middle and lower Boulder Creek. Nonetheless, phosphorus upstream of the WWTP discharge is below stream standards. Phosphorus standards do not yet apply below the 75th Street WWTP, but are expected to apply in less than 10 years. As shown in Table 5-21 and Figure 5-18, phosphorus concentrations downstream of the WWTP are significantly higher than upstream of the WWTP and gradually decrease through the lower watershed, although they remain well-above stream standards. Phosphorus concentrations from Coal Creek are also above the stream standard; however, Coal Creek concentrations are significantly lower than the instream total phosphorus concentrations in Boulder Creek upstream of the confluence. Similar concentrations are present when considering the 2009-2013 time period. Given that the primary influence on total phosphorus concentrations is the WWTP, annual boxplots of BC-aDC are also provided (Figure 5-19). Concentrations tend to be higher in the winter when less dilution from spring runoff is present, as shown in the monthly boxplots in Figure 5-20.

Table 5-21. Boulder Creek Total Phosphorus (2014)

	Total Phosphorus (mg/L)							
Boulder Creek	No.	Min	Max	25th%	**Median**	75th%	Mean	St. Dev.
BC-Can	11	ND	0.06	0.01	**0.01**	0.02	0.02	0.02
BC-CU	11	ND	0.10	0.01	**0.01**	0.03	0.03	0.03
BC-61	11	ND	0.03	0.02	**0.02**	0.03	0.02	0.01
BC-aWWTP	12	0.01	0.06	0.02	**0.03**	0.03	0.03	0.01
BC-aDC	11	0.12	1.48	0.64	**0.94**	1.07	0.85	0.37
BC-107	11	0.14	0.98	0.48	**0.54**	0.67	0.57	0.21
BC-bCC	11	0.15	1.01	0.38	**0.59**	0.80	0.59	0.26
9-BC	12	0.14	1.03	0.46	**0.56**	0.86	0.62	0.28
10-BC	12	0.16	1.00	0.44	**0.58**	0.83	0.60	0.26
11-BC	12	0.13	1.03	0.29	**0.57**	0.77	0.56	0.27
South Boulder Creek	No.	Min	Max	25th%	**Median**	75th%	Mean	St. Dev.
SBC-3.5/4.0	11	ND	0.06	ND	0.01	0.02	0.02	0.02

Figure 5-18. Boulder Creek Total Phosphorus (2014)



Note: two municipal WWTPs discharge to Boulder Creek at locations, as shown on Figure 5-18 for general reference. These include Boulder's 75th Street WWTP and Erie's North WWTP.

Figure 5-19. Annual Total Phosphorus below the 75th Street WWTP (2009-2013)

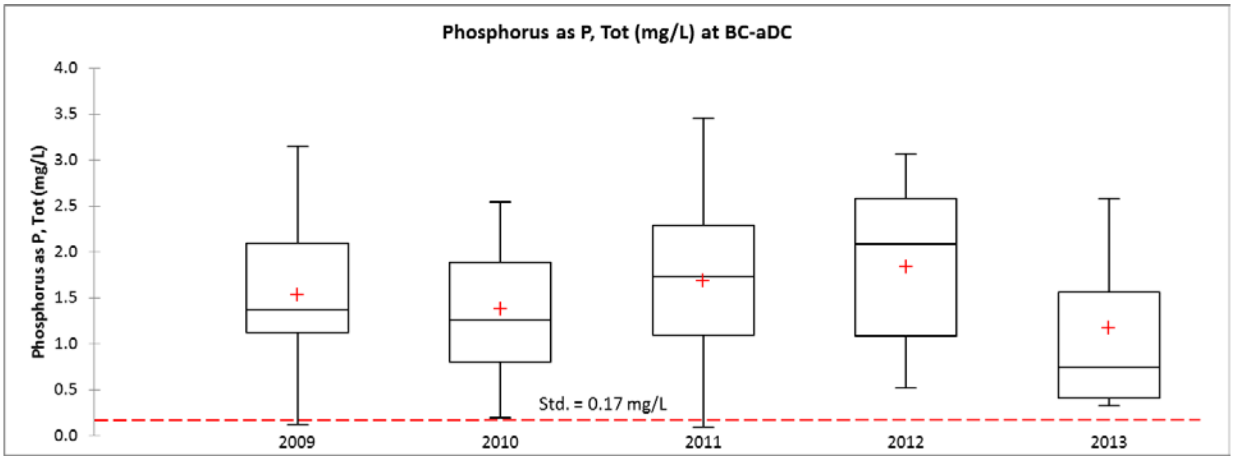
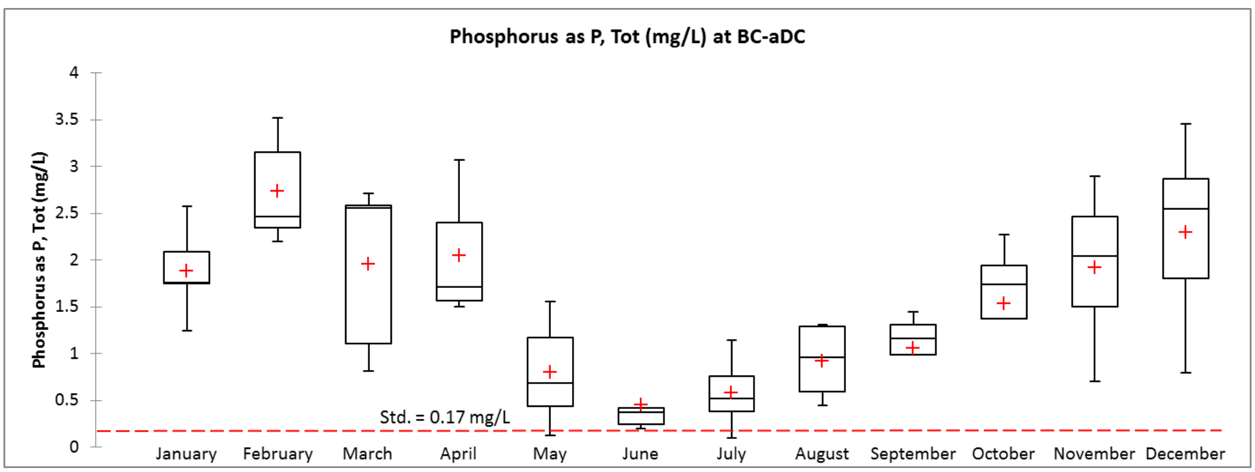


Figure 5-20. Monthly Total Phosphorus Downstream of the 75th Street WWTP (2009-2013)



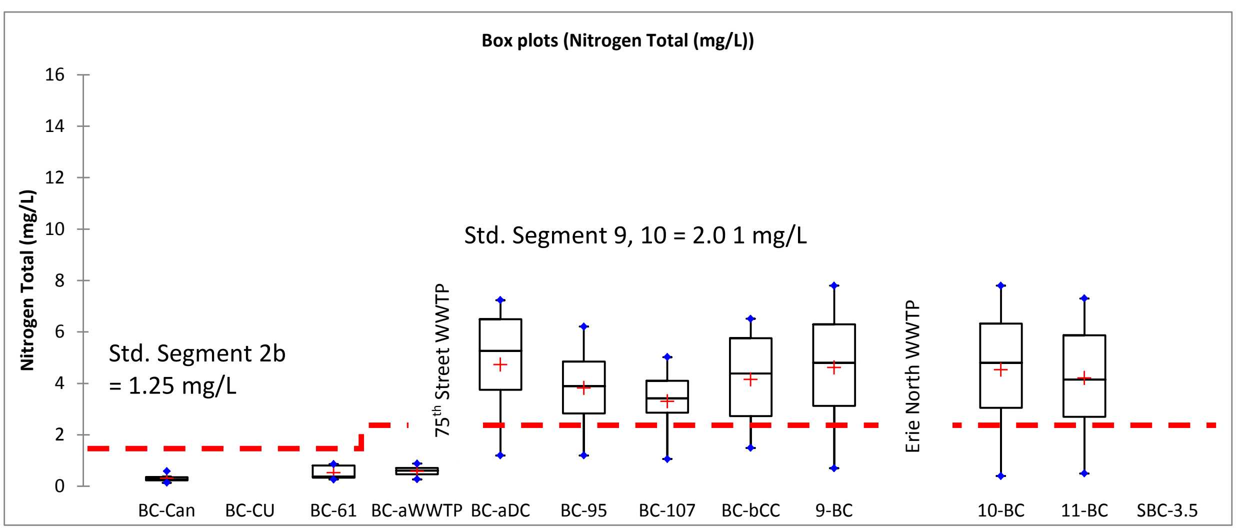
Total Nitrogen

Total nitrogen in Boulder Creek is expected to attain the interim Colorado total nitrogen criteria for Segment 9 upstream of the WWTP discharge based on data at BC-61, but exceeds interim total nitrogen standards downstream of the discharge (Table 5-22 and Figure 5-21). Total nitrogen concentrations have decreased since the WWTP upgrade was completed in 2008; however, instream concentrations downstream of the WWTP remain well above the interim total nitrogen concentration of 2.01 mg/L (Figure 5-21). Figure 5-22 illustrates the seasonal variation of total nitrogen, with winter months having the most elevated concentrations.

Table 5-22. Boulder Creek Total Nitrogen (2014)

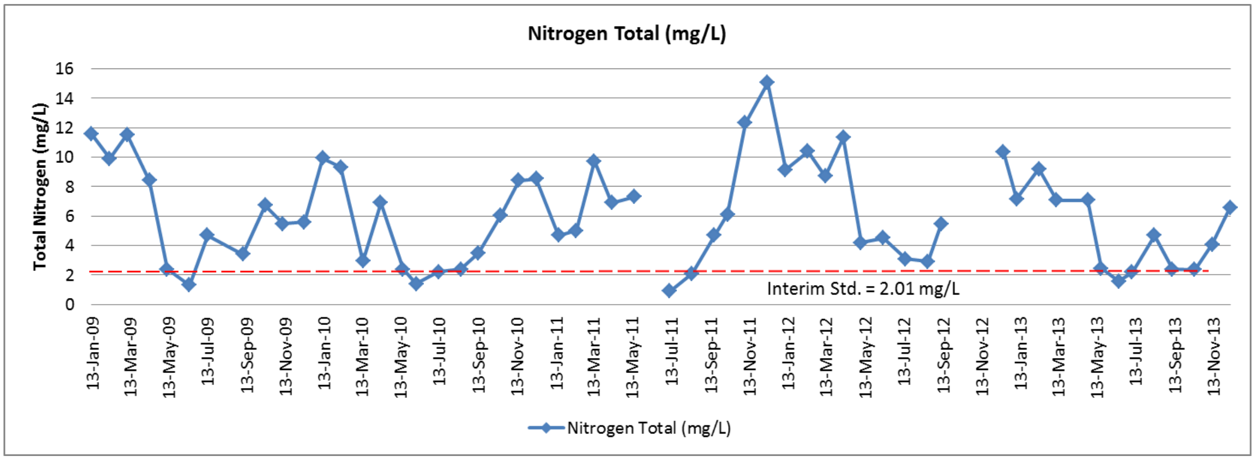
	Total Nitrogen (mg/L)							
Boulder Creek	No.	Min	Max	25th%	**Median**	75th%	Mean	St. Dev.
BC-Can	12	0.14	0.59	0.23	**0.27**	0.35	0.31	0.13
BC-61	12	0.26	0.86	0.34	**0.38**	0.81	0.53	0.24
BC-aWWTP	12	0.27	0.88	0.47	**0.61**	0.71	0.59	0.17
BC-aDC	12	1.20	7.24	3.75	**5.27**	6.49	4.73	2.03
BC-95	12	1.20	6.21	2.84	**3.89**	4.85	3.82	1.61
BC-107	12	1.06	5.02	2.86	**3.42**	4.10	3.30	1.16
BC-bCC	12	1.49	6.51	2.73	**4.39**	5.76	4.15	1.74
9-BC	12	0.70	7.80	3.13	**4.80**	6.30	4.62	2.11
10-BC	12	0.40	7.80	3.05	**4.80**	6.33	4.53	2.20
11-BC	12	0.50	7.30	2.70	**4.15**	5.88	4.21	2.06

Figure 5-21. Boulder Creek Total Nitrogen (2014)



Note: two municipal WWTPs discharge to Boulder Creek at locations, as shown on Figure 5-18 for general reference. These include Boulder's 75th Street WWTP and Erie's North WWTP.

Figure 5-22. Boulder Creek Total Nitrogen below the 75th Street WWTP (2009-2013)



5.3.5.2 Coal Creek and Rock Creek

Table 5-23 and Figure 5-23 show instream concentrations of total phosphorus and limited WWTP total phosphorus concentrations for 2009-2013. Similar to Boulder Creek, the Coal Creek and Rock Creek instream sample locations above the WWTP discharges meet the instream value and below the discharges they do not, with the exception of the Coal Creek location downstream of the Louisville WWTP.

Table 5-24 and Figure 5-24 show instream concentrations of total nitrogen and limited WWTP total nitrogen concentrations for 2009-2013. Similar to Boulder Creek, the Coal Creek and Rock Creek instream sample locations above the WWTP discharges meet the instream value and below the discharges they do not. Rock Creek above the Superior WWTP discharge slightly exceeds the standard; additional data would be needed to further evaluate this situation.

Table 5-23. Coal Creek and Rock Creek Total Phosphorus (2009-2013)

Location	1-CC	A-CC	2-CC	3-CC	4-RC	B-RC	5-RC	6-CC	C-CC	7-CC
		Louis. WWTP				Sup. WWTP			Laf. WWTP	
No. of obs.	7	7	7	54	5	6	54	54	8	56
Minimum	0.01	0.04	0.04	0.01	0.01	1.69	0.03	0.03	1.90	0.20
Maximum	0.03	0.84	0.24	17.90	0.08	3.81	9.34	7.50	4.20	8.20
1st Quartile	0.01	0.17	0.10	0.13	0.03	2.21	0.29	0.19	2.15	0.57
Median	0.01	0.26	0.13	0.30	0.03	2.80	0.64	0.37	2.85	0.71
3rd Quartile	0.02	0.34	0.22	1.00	0.04	3.45	1.62	1.03	3.08	1.22
Mean	0.01	0.31	0.15	1.41	0.04	2.80	1.44	1.01	2.79	1.21
CV	0.60	0.79	0.47	2.13	0.61	0.28	1.33	1.54	0.26	1.23

Note: Trend comparisons between sites with 7 and 54 samples are not appropriate.

Figure 5-23. Coal Creek and Rock Creek Total Phosphorus (2009-2013)

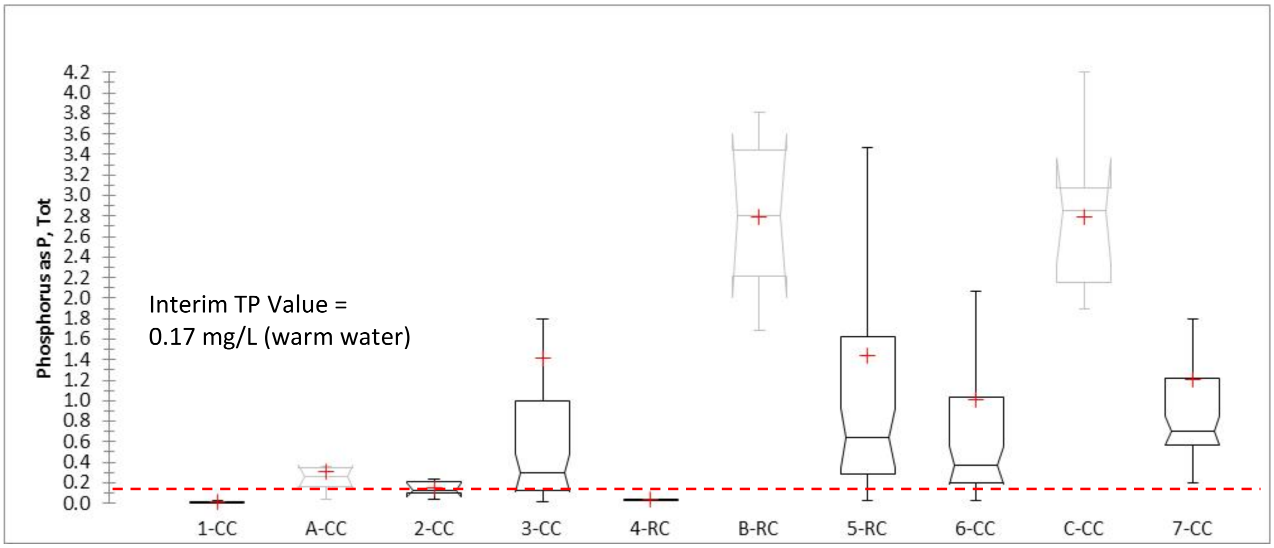
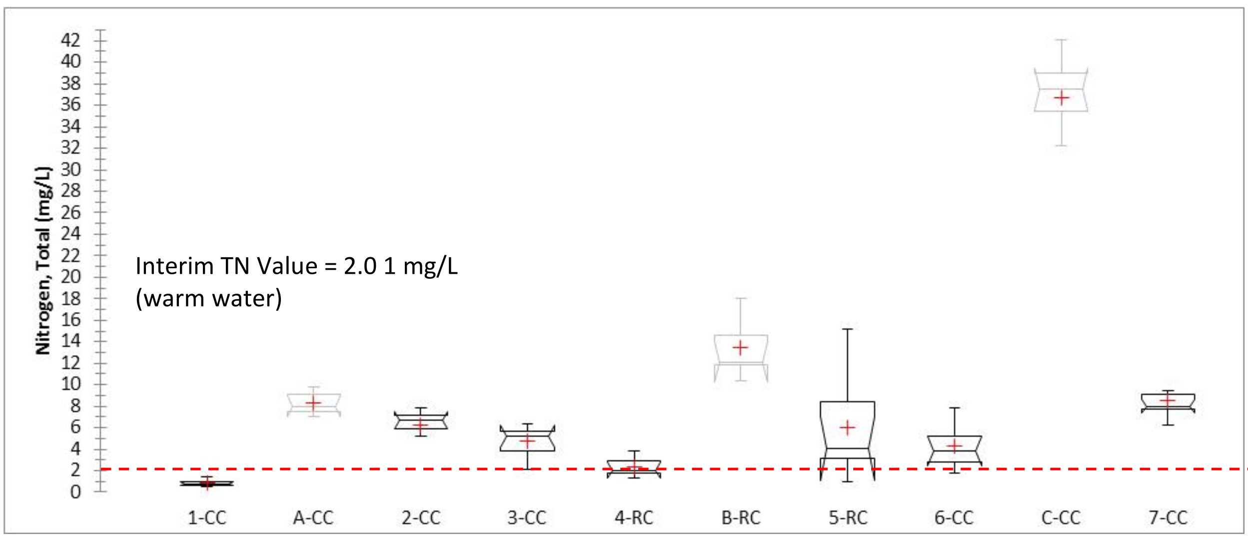


Table 5-24. Coal Creek and Rock Creek Total Nitrogen (2013)

Location	1-CC	A-CC	2-CC	3-CC	4-RC	B-RC	5-RC	6-CC	C-CC	7-CC
		Louis. WWTP				Sup. WWTP			Laf. WWTP	
No. of obs.	7	7	7	8	5	5	8	8	8	11
Minimum	0.46	7.00	2.90	2.17	1.37	10.42	0.94	1.83	28.80	6.22
Maximum	1.39	9.80	7.80	6.40	3.79	18.05	15.21	7.90	42.10	11.90
1st Quartile	0.67	7.45	5.90	3.83	1.82	11.87	3.10	2.78	35.49	7.77
Median	0.77	8.00	6.70	5.25	2.06	12.12	4.05	3.85	37.50	8.00
3rd Quartile	0.98	9.10	7.15	5.70	2.88	14.55	8.43	5.20	38.98	9.05
Mean	0.84	8.27	6.21	4.80	2.38	13.40	6.02	4.27	36.67	8.58
CV	0.34	0.12	0.25	0.29	0.36	0.20	0.74	0.46	0.11	0.18

Figure 5-24. Coal Creek and Rock Creek Total Nitrogen (2013)



5.3.5.3 St. Vrain Creek and Left Hand Creek

Table 5-25 and Figure 5-25 show instream concentrations of total phosphorus in St. Vrain Creek and Left Hand Creek. Similar to Boulder Creek, Coal Creek and Rock Creek, St. Vrain Creek and Left Hand Creek instream sample locations above the WWTP discharges meet the instream values for total phosphorus and below the discharges they do not. Figure 5-26 shows the range of annual phosphorus concentrations from 2008 through 2014 at M6-SV downstream of Longmont's WWTP discharge.

Table 5-26 and Figure 5-27 show instream concentrations of total nitrogen in St. Vrain Creek and Left Hand Creek. The data set is more limited than for total phosphorus due to inconsistency in availability of total nitrogen data at various sampling locations over time.

Similar to Boulder Creek, Coal Creek and Rock Creek, the total nitrogen instream sample locations above the Longmont WWTP discharge meet the instream value and below the discharges they do not.

Table 5-25. Total Phosphorus in St. Vrain Creek and Left Hand Creek (2008-2014)

Location	No.	Median (2008-2014)
M9.5-SV	6	0.01
M8.9-SV	39	0.01
M8.4-SV	23	0.03
M8.2-SV	23	0.03
M8-SV	66	0.03
T11-LH	66	0.03
T-EFF (Combined ditch & WWTP)	60	1.92
M7-SV	13	0.33
M6-SV	55	0.29
M4-SV	27	0.26

Figure 5-25. Total Phosphorus in St. Vrain Creek and Left Hand Creek (2008-2014)

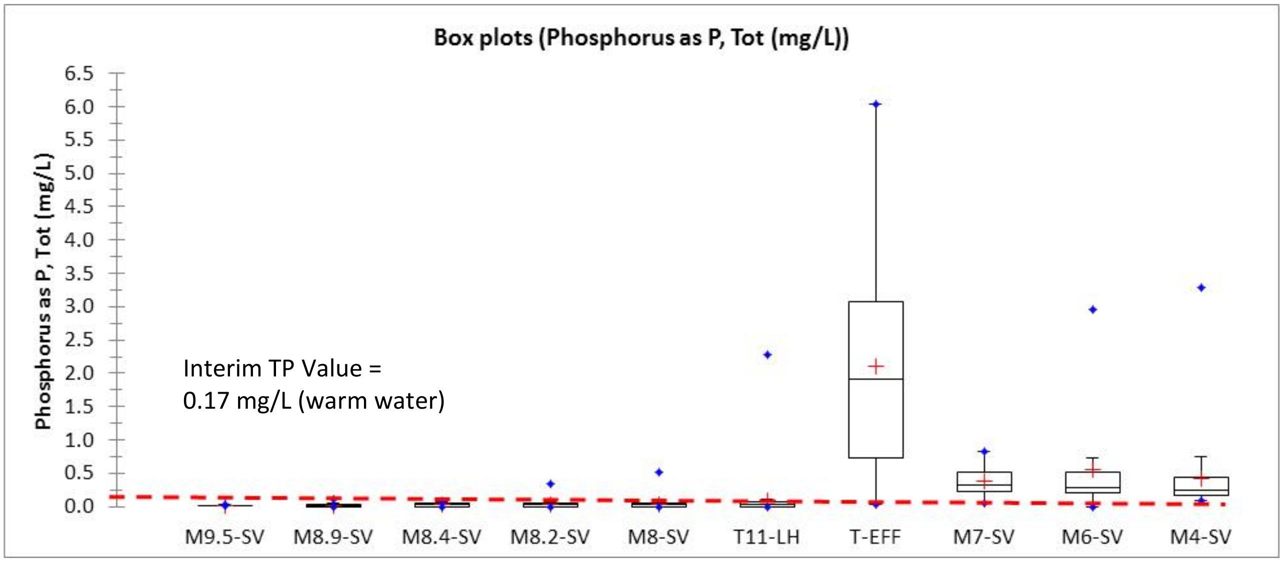


Figure 5-26. Annual Total Phosphorus in St. Vrain Creek at M6-SV (2008-2014)

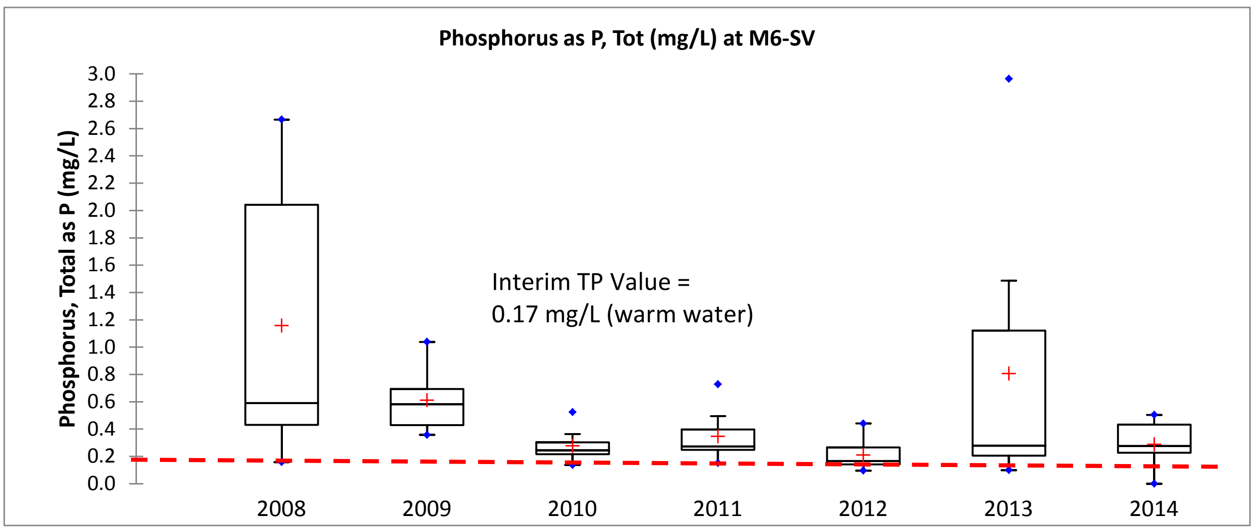
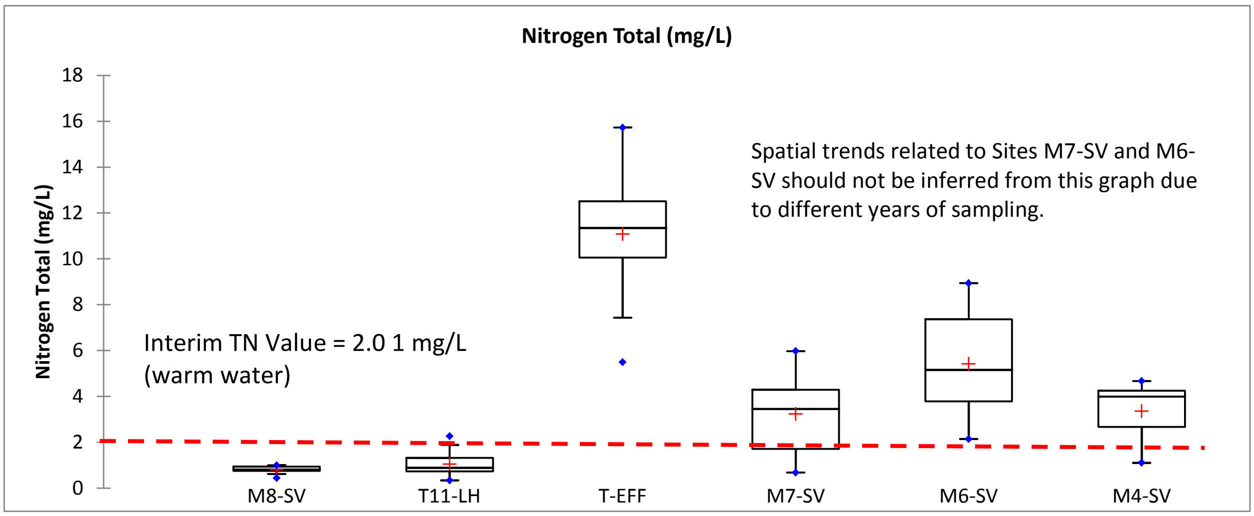


Table 5-26. Total Nitrogen in St. Vrain Creek and Left Hand Creek (2008-2014)

Location	No.	Median	Minimum	Maximum
M8-SV*	9	0.81	0.44	1.00
T11-LH	36	0.88	0.34	2.27
T-EFF (Combined ditch & WWTP)	19	11.34	5.49	15.72
M7-SV*	13	3.46	0.68	5.97
M6-SV	17	5.16	2.14	8.94
M4-SV	11	3.99	1.10	4.67

*Period of record limited to approximately 2014 for these two sites.

Figure 5-27. Total Nitrogen in St. Vrain Creek and Left Hand Creek (2008-2014)



5.3.6 Conclusions Regarding Water Quality Issues in the St. Vrain Basin

Based on the analysis presented herein, as well as the City of Boulder Water Quality Monitoring Report: 2011 and Baseline (City of Boulder and WWE 2013), the following water quality issues are considered further in this report:

1. *E. coli* in Boulder Creek between BC-CU and 61st Street and between 107th Street and the confluence with St. Vrain Creek.

2. *E. coli* in Coal Creek from Highway 36 to the confluence with Boulder Creek and in Rock Creek above the confluence with Coal Creek.

3. *E. coli* in St. Vrain Creek from North 75th Street (M9.5-SV) to the confluence with Boulder Creek. Additionally, Left Hand Creek and Dry Creek near their confluences with St. Vrain Creek.

Additional evaluation of aquatic life data is needed prior to concluding aquatic life impairments are due to water quality issues. The following two factors need to be further evaluated before further steps are taken:

1. A determination of the appropriateness of Biotype 1 versus Biotype 3 for portions of stream segments below 5,085 ft.
2. A determination of appropriate site-specific aquatic life objectives in spring-fed, intermittently flowing stream reaches.

Based on findings in the adjacent Big Dry Creek watershed related to naturally-occurring sources of selenium, development of a site-specific standard is considered to be the most realistic approach to addressing elevated selenium on Rock Creek (and Coal Creek below the confluence with Rock Creek).

Currently available data (particularly collected 2010-2013) for metals in the Boulder Creek Watershed indicate that most segments attain the majority of assigned metals standards (with the exception of arsenic). In the uppermost segments of the watershed, hardness-based standards are so low that they approach practical quantitation limits for metals; therefore, metals are not addressed further in this Watershed Plan. In the St. Vrain Creek watershed, metals are of concern in the Left Hand Creek subwatershed, as described in the 2015 TMDL (Division 2015).

The driving factor for nutrients in the watershed is WWTP discharges. Attainment of the interim nutrient values will be driven by nutrient concentrations from the WWTPs. Given that this is an evolving area of policy and permitting, nutrient BMPs will be encouraged in this Watershed Plan, but are not expected to reduce loading to the extent that the interim values could be achieved in lieu of dramatic reductions in nutrient discharges from WWTPs

5.4 Water Quality and Environmental Models and Modeling

When adequate supporting data are present and adequate budget is provided, water quality models can be used to develop a better understanding of existing pollutant loading and to facilitate and optimize selection of treatment. There are many water quality models that could be applied to the watershed in the future. Given that the primary water quality issue throughout the watershed in *E. coli*, modeling has not been conducted for purposes of this Watershed Plan, other than load duration curves. Currently, there is significant uncertainty associated with using watershed models for *E. coli*.

5.5 Recommended TMDL Strategy

Currently, no new TMDLs are recommended for Boulder Creek stream segments until additional information is compiled regarding sources of bacteria loading. Such additional information will be evaluated by the Division as it prepares to develop other *E. coli* TMDLs in the watershed by the year 2021. The approach for addressing existing water quality issues is discussed below and in Chapter 7. The highest priority is *E. coli*, with highest priority load reductions focused on human and agricultural sources. Implementation plans developed for existing TMDLs for Boulder Creek Segment 2b (*E. coli*) and Left Hand Creek (metals) should continue to be implemented.

5.6 Quantify Pollutant Loads and Load Reductions for *E. coli*

As discussed in Section 5.5, *E. coli* has been selected as the primary focus for the first release of this Watershed Plan. This section describes preliminary load estimates and load reductions needed for *E. coli*.

5.6.1 Concerns and Observations

As summarized in Section 5.3.1, *E. coli* is elevated at multiple locations in the watershed. Concentrations are typically highest in the late summer, when temperatures are warm. Nonpoint sources of *E. coli* are suspected as contributing to elevated *E. coli* instream; however, additional dry weather screening of stormwater outfalls is also recommended in the urbanized portion of the watershed.

5.6.2 Pollutant Load Estimates for *E. coli* Using Load Duration Curves

Pollutant load estimates for *E. coli* were calculated for four stream segments where suitable flow data were available to be paired with *E. coli* data to complete flow duration curves and calculate loads. Load duration curves were generated using Colorado State University's "eRAMS" tool, accessible at www.erams.com. The instream concentration target was defined as 126 MPN/100 mL *E. coli* and each water quality sample point was color-coded to represent whether the sample occurred during the recreation season (May-Oct, shown in black) or during the non-recreation season (Nov-Apr, shown in green). The standard of 126 MPN/100 mL applies during both seasons, but exposure to stream water is more likely during the recreational season. The load duration curves from the eRAMS tool are shown in the remainder of this section. The eRAMS tool provides this description of the load duration curve methodology:

> A flow duration curve (FDC) is the ranked graphing of river flows on a scale of percent exceedance. For example a flow value associated with the flow interval of 15% means that particular flow value is met or exceeded only 15% of the time. This graph is meant to give a quick overview of the flow ranges, variability, and probability of flows of a river segment during the different flow periods of a river; which are High Flows from 0 to 10 percent flow interval, Moist Conditions 10-40, Mid-Range Flows 40-60, Dry Conditions 60-90, and Low Flows 90-100 (Cleland 2003).

> A load duration curve (LDC) is a flow duration curve multiplied by the user's chosen target pollutant concentration that is wished not to be exceeded. This LDC for the selected river segment is graphed along with points of observed pollution concentrations and box plots of the observed points within their respective flow intervals. The interpretation of this graph is if the observed points are below the LDC line, there is no excess problem for that particular pollutant. If, however, the observed points lie above the LDC line this is indicative that there are observations which exceed the maximum specified target pollution concentration. A more in depth study of the particular watershed should be done to completely identify the proper pollution sources and remediation solutions.

Based on the load duration curve plots, general inferences can potentially be made regarding potential sources of pollution, as described by Cleland (2003) in Table 5-27. Depending on which flow interval(s) contain the exceeded observations, different pollution sources are expected to be the likely the cause. For the four load duration curves completed for this Watershed Plan, eRams returned “multiple sources” as the likely source of *E. coli*; therefore, the load duration curves were essentially inconclusive, emphasizing the need for additional source characterization in the watershed before determining the types of strategies needed to reduce loading to the streams. Additional discussion of the load duration curve calculations for each stream segment follows.

Table 5-27. Flow Interval and Probable Contributing Source

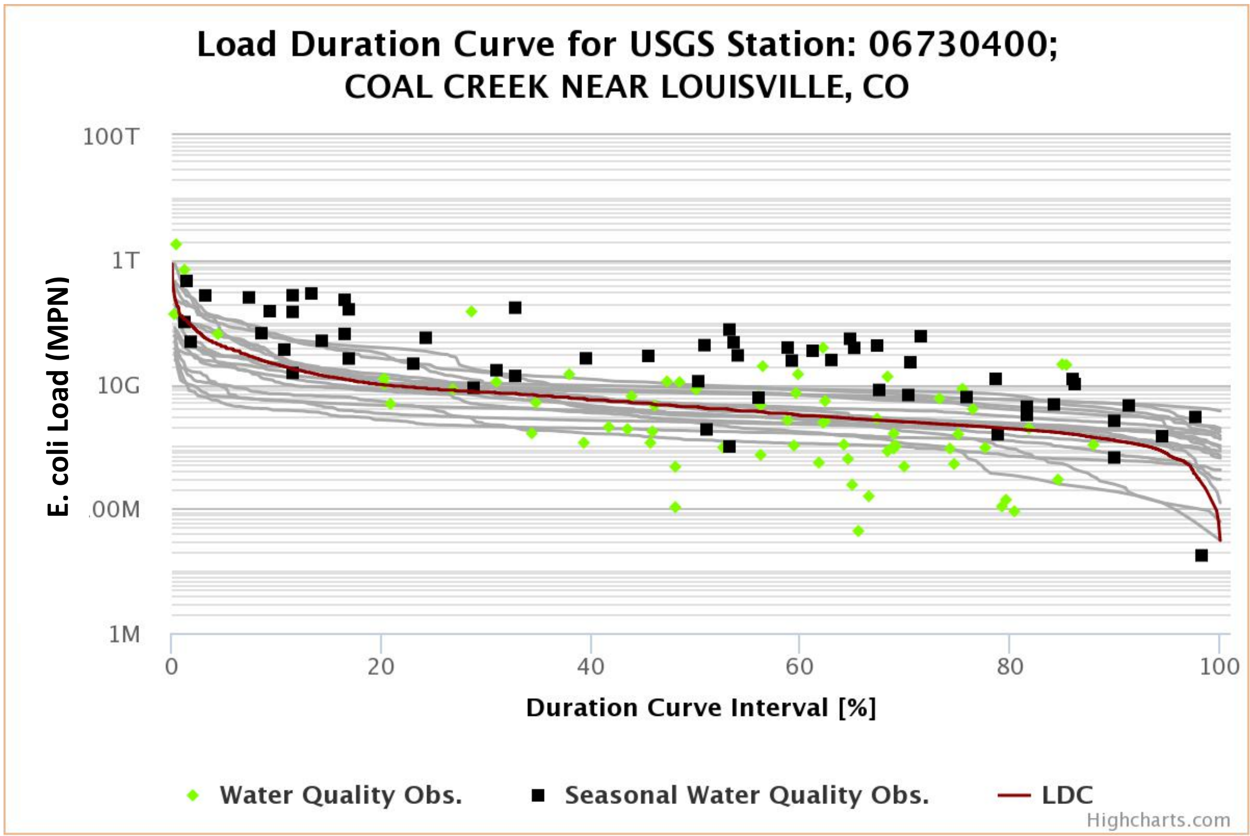
(Source: www.erams.com, as adapted from Cleland 2003)

	Duration Curve Zone				
Contributing Source Area	**High Flow**	**Moist**	**Mid-range**	**Dry**	**Low Flow**
Point Source	-	-	-	Med.	High
On-site wastewater systems	-	-	High	Med.	-
Riparian Areas	-	High	High	High	-
Stormwater: Developed Areas		High	High	High	-
Combined sewer overflows (*not applicable in Boulder County*)	High	High	High	-	-
Stormwater: Upland	High	High	Med.	-	-
Bank erosion	High	Med.	-	-	-

5.6.2.1 Coal Creek

Load Duration Curves were generated for Coal Creek near the Louisville WWTP, as shown in Figure 5-28. The analysis showed that most of the flow intervals contain many points which exceed the target and no single pollution source is likely.

Figure 5-28. Load Duration Curve for *E. coli* at CC-1



Note: Y axis units: M = million (mega), G = billion (giga), T = trillion (tera). LDC = Load Duration Curve. Observations in green are winter samples.

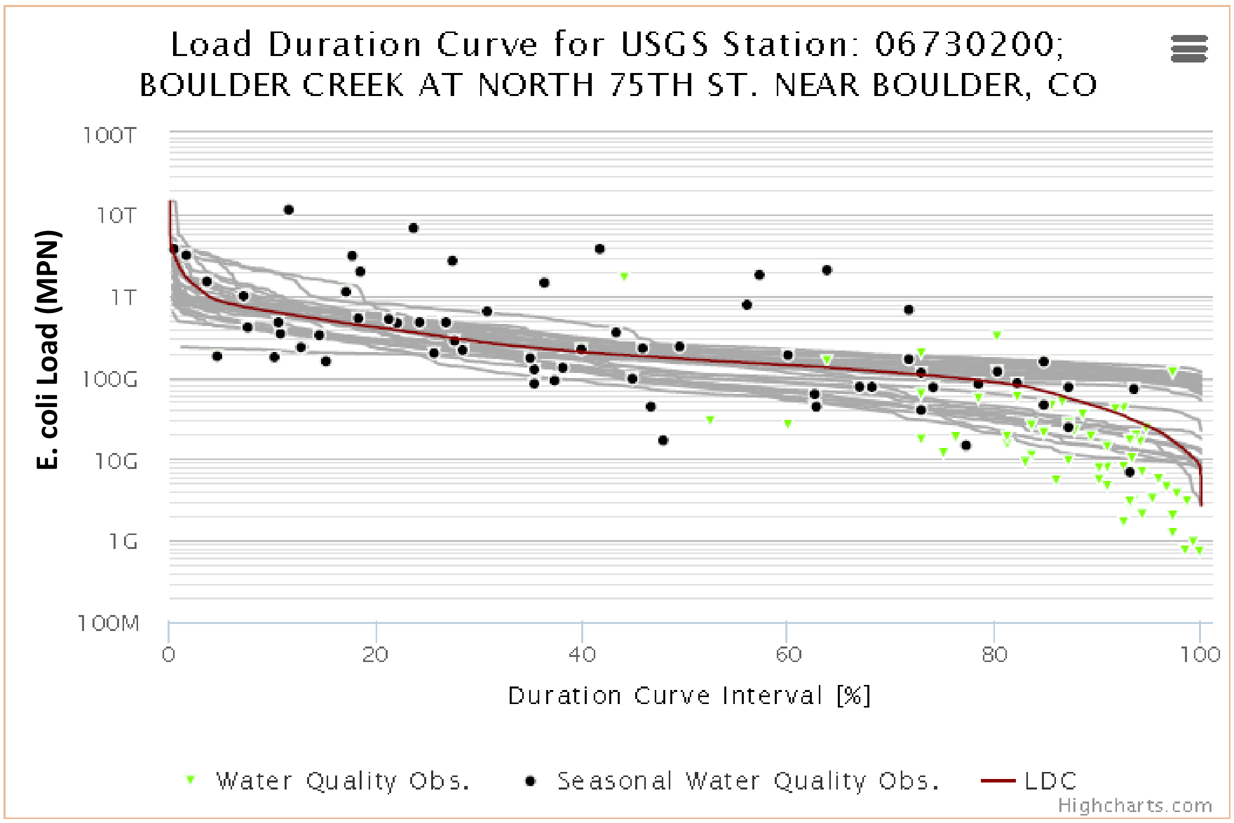
5.6.2.2 Rock Creek

A load duration curve was not generated for Rock Creek due to lack of suitable flow data. Either installation of a flow gauge or instream flow monitoring at the time of sampling is needed in order to better understand conditions present in Rock Creek. In lieu of flow data, conditions present for Rock Creek will be assumed to be similar to those on Coal Creek.

5.6.2.3 Boulder Creek

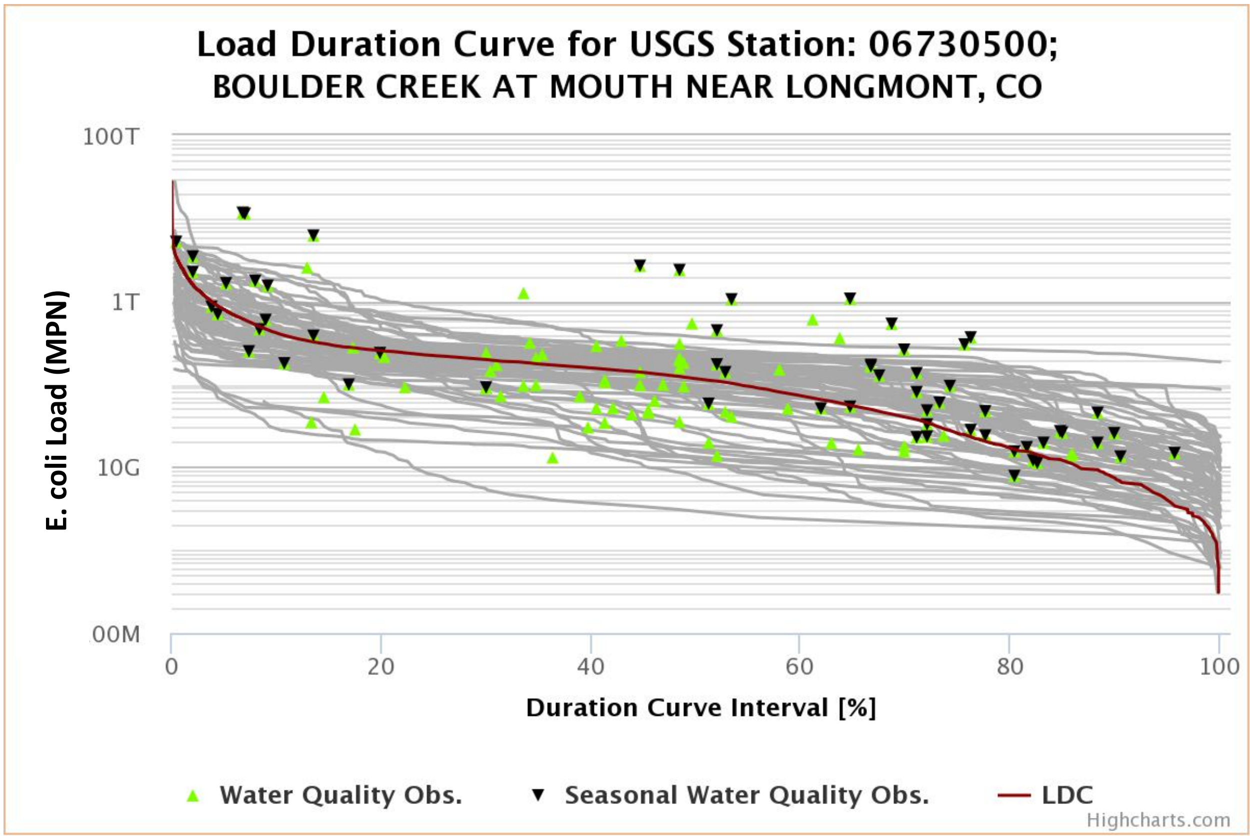
Two load duration curves were generated for Boulder Creek. The first paired *E. coli* data from BC-61 with the USGS Gauge at Boulder Creek at North 75th Street above the 75th Street WWTP discharge (Figures 5-29 and 5-30, respectively). This load duration curve represents the upper portion of Segment 9. The second paired data collected at BC-bCC with the USGS Gauge on Boulder Creek near the Mouth in Longmont, representing Segment 10 of Boulder Creek. The analysis showed that most of the flow intervals contain many points which exceed the target and no single pollution source is likely.

Figure 5-29. Load Duration Curve for *E. coli* at BC-61



Note: Y axis units: M = million (mega), G = billion (giga), T = trillion (tera). LDC = Load Duration Curve. Observations in green are winter samples.

Figure 5-30. Load Duration Curve for *E. coli* at Boulder Creek below Coal Creek (BC-bCC)



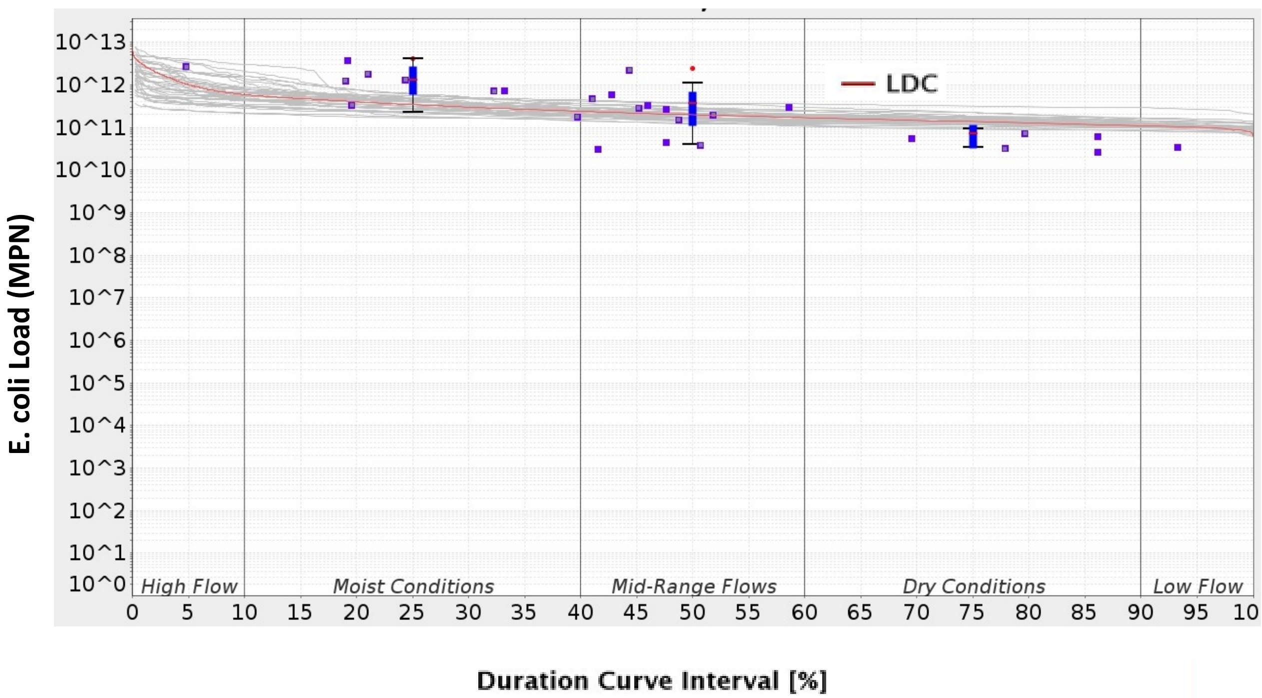
Note: Y axis units: M = million (mega), G = billion (giga), T = trillion (tera). LDC = Load Duration Curve. Observations in green are winter samples.

5.6.2.4 St. Vrain Creek and Left Hand Creek

A load duration curve was generated for St. Vrain Creek below Longmont paired with data for M4-SV (Figure 5-31). As was the case for Boulder Creek and Coal Creek, the eRAMS analysis report stated that no single pollution source is likely. The St. Vrain data set is significantly smaller than the analysis conducted for Boulder Creek and is less useful for that reason. Although fewer exceedances in the "dry" flow interval are shown for St. Vrain Creek than are shown for Boulder Creek, these are expected to be due to low flows coinciding with colder winter water temperatures.

Inadequate data were available to conduct a meaningful flow duration curve for Left Hand Creek.

Figure 5-31. Load Duration Curve for *E. coli* for St. Vrain Creek below Longmont (USGS 06725450) and Water Quality Sampling Location SV-M4



Note: eRams formatting options changed in 2015; therefore, this figure's appearance differs from other load duration curves in this chapter. LDC = Load Duration Curve. Data points are shown in purple, with boxplots aggregating data in each duration curve interval shown in blue.

5.6.3 Estimate Needed *E. coli* Load Reductions by Source and Type

Because *E. coli* originates from many sources, it can be challenging to identify the source and type without relatively in-depth special sampling. Following the Load Duration Curve methodology developed by Cleland and often used by EPA in TMDLs, multiple sources of *E. coli* are suspected in the various stream segments, with the load duration curve method generally being inconclusive (which is not unexpected for a highly variable parameter such as *E. coli*). Given the complex water rights administration for the streams in this watershed, it was not feasible to reliably pair flow and water quality at the level of analysis being used for this Watershed Plan for multiple monitoring locations. For this reason, concentration-based reductions were calculated for sampling locations on the stream, as summarized in Tables 5-28 and 5-29 for the past five years of data. See Figure A-9 for spatial distribution of recreation season *E. coli* data throughout the watershed. (*Note: statistical summaries earlier in this chapter may have characterized a longer period of record for purposes of general characterization and data exploration, but this load reduction table is limited to data in the five year period*.)

Table 5-28. Estimated Instream *E. coli* Reductions Needed to Meet Primary Contact Recreation Standard for Boulder Creek Watershed Segments

Sample Location	n =	Rec. Geomean (2010-2014)	% Reduction Needed During Rec. Season	Location and Data Notes
Boulder Creek				
BC-Can	29	44	NA	Canyon Road
BC-Lib	21	74	NA	Library; 2004-2014 (above TMDL)
BC-CU	29	132	5%	University of Colorado (in TMDL)
BC-47	20	218	42%	47th Ave.; 2004-2014 (in TMDL)
BC-61	30	169	25%	61st Ave. (below TMDL & below S. Boulder Creek)
BC-aWWTP	30	94	NA	Above Boulder 75th St. WWTP
BC-aDC	30	114	NA	Below Boulder 75th St. WWTP
BC-95	30	79	NA	95th Street
BC-107	30	114	NA	107th Street
BC-Ken	27	89	NA	Kenosha Rd.
BC-bCC	30	230	45%	Below Coal Creek
BC-CNTYLN	8	233	46%	At County Line (Division); 2004-2014
Coal Creek				
Superior	15	163	23%	Hwy 36 South of Bridge
1A	15	413	70%	Hwy 36 North of Bridge
2A	16	66	NA	Dillon Rd. at Foot Bridge
3A	16	112	NA	Andrews St.
4A	16	221	43%	Foot Bridge-Golf Course
5A	15	188	33%	Augusta Ln
6A	11	26	NA	Near Dutch Creek
10A	16	149	16%	96th Street
11A	15	107	NA	Footbridge Hwy 42
12A	16	232	46%	Above May Hoffer Spring
1-CC	7	898	86%	Above Louisville WWTP; (If 2004-014, 75% Reduction).
2-CC	7	435	71%	Below Louisville WWTP; (If 2004-2014, 62% Reduction)
3-CC	17	213	41%	Above Confl. with Rock Creek
6-CC	17	395	68%	Above Lafayette WWTP
7-CC	17	443	72%	Below Lafayette WWTP
CC-Ken	30	380	67%	Coal Creek above Confl. with Boulder Creek (at Kenosha Rd.)
Rock Creek				
5-RC	17	486	74%	Above Confl. with Coal Creek

Note: For South Boulder Creek, no load reductions are needed. For Coal Creek, drainage/outfall sample locations are not shown. Site 1-CC is also elevated during the winter (Geometric mean = 167 MPN/100 mL).

Table 5-29. Estimated Instream *E. coli* Reductions Needed to Meet Primary Contact Recreation Standard for St. Vrain Watershed Segments

Sample Location	n =	Rec. Geomean (2010-2014)	% Reduction Needed During Rec. Season	Note
St. Vrain				
M9.5-SV	4	170	26%	Western edge of urban area
M8.9-SV	22	378	67%	Near Golden Ponds
M8.4-SV	21	189	33%	Boston Ave.
M8.2-SV	21	276	54%	Pratt Parkway
M8-SV	29	161	22%	Above Left Hand Creek & WWTP Effluent
M7-SV	6	150	16%	Below Longmont WWTP
M6-SV	25	191	34%	@ 119
M4-SV	18	385	67%	Above Confluence with Boulder Creek
Left Hand Creek				
T11-LH	28	242	48%	Enters St. Vrain Creek between M8-SV and Longmont WWTP
Dry Crk				
Dry Crk	28	517	75%	Enters St. Vrain Creek between M8.2-SV and M8-SV

6.0 Watershed Management Action Strategy, Policies and Programs

Management strategies for the watershed include a range of source controls and structural BMPs. These are described further below, following a brief discussion of the importance of source identification for *E. coli*.

6.1 Source Identification for *E. coli*[6]

This section discusses the human health risk associated with exposure to *E. coli* as well as potential *E. coli* sources and recommendations for source identification strategies.

6.1.1 Human Health Risk and Sources of *E. coli*

The primary concern related to elevated *E. coli* (as an indicator of potential fecal contamination) is human illness caused by pathogens in the stream. Actual human health risk is a function of exposure to pathogens and the source of the fecal contamination. This is important because highest-risk sources of contamination should be addressed first. Recent research supported by EPA has shown that human health risk from various sources of fecal contamination likely varies; thus, it is important to develop an understanding of the *E. coli* source. As an example, EPA sponsored quantitative microbial risk assessment (QMRA) associated with the update to the 2012 Recreational Water Quality Criteria (EPA 2012). As part of a key QMRA study, Soller et al. (2010) estimated the likelihood of pathogen-induced effects by various sources. This work was conducted to determine whether estimated risks following exposure to recreational waters impacted by gull, chicken, pig, or cattle fecal contamination are substantially different than those associated with waters impacted by human sources such as treated wastewater. As shown in Figure 6-1, the primary findings, which may affect recreational water management in areas not affected by human contamination, included:

1. gastrointestinal illness risks associated with exposure to recreational waters impacted by fresh cattle feces may not be substantially different from waters impacted by human sources; and

2. the risks associated with exposure to recreational waters impacted by fresh gull, chicken, or pig feces appear substantially lower than waters impacted by human sources (approximately two orders of magnitude lower than the human-based benchmark).

Other QMRA work by Schoen and Ashbolt (2010) also showed a lower predicted illness risk from seagull impacted waters relative to primary sewage at the same fecal indicator bacteria density. These findings are consistent with the World Health Organization (WHO 2003) policies

[6] Discussion in this section is developed or directly integrated from *Pathogens in Urban Stormwater Systems*, Prepared by Urban Water Resources Research Council (2014), eds. J. Clary, R. Pitt and B. Steets.

that assume that in general, sources other than human fecal contamination are less of a risk to human health. WHO (1999) states that "due to the species barrier, the density of pathogens of public health importance is generally assumed to be less in aggregate in animal excreta than in human excreta and may therefore represent a significantly lower risk to human health."

Figure 6-1. QMRA-based Probability of Gastrointestinal Illness from Ingestion of Water Containing Fresh Fecal Contamination from Various Sources
(Soller et al. 2010)

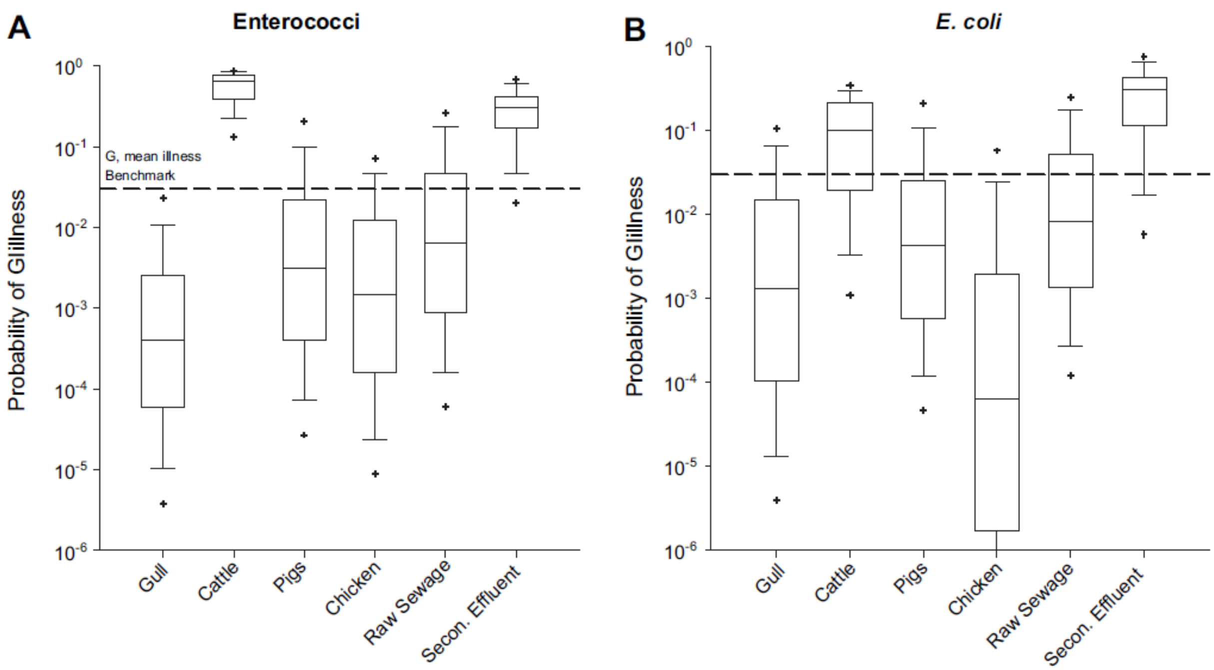


Figure 6-1 Notes (Soller et al. 2010): QMRA Run 1 probability of GI illness from ingestion of water containing fresh fecal pollution at densities of 35 cfu/100 mL ENT (1A) and 126 cfu/100 mL E. coli (1B). Predicted risk for fresh gull, cattle and pig feces, and chicken litter. Human impacts are presented for primary sewage (Human 1) and secondary disinfected effluent (Human 2). The illness benchmark represents a geometric mean probability of illness of 0.03. The higher risk from disinfected wastewater results from a higher proportion of fecal indicator bacteria being removed relative to viral and parasitic protozoan pathogens by wastewater treatment and disinfection (Metcalf and Eddy 2003) at the same indicator level.

6.1.2 *E. coli* Sources

In order to develop an effective plan for managing and reducing *E. coli*, it is first necessary to identify the likely sources and associated transport pathways to receiving waters. Effectively targeting source controls requires substantial information about the land uses and activities within the watershed.

Sources of pathogens and fecal indicator bacteria in MS4s and receiving waters vary widely, originating from both animal and human sources. Representative sources of fecal indicator bacteria in urbanized areas in Colorado may include sanitary sewer overflows (SSOs), wet weather (stormwater) discharges from MS4s, illicit connections to storm sewer systems (dry weather discharges), illicit discharges to storm sewer systems (e.g., household automobile washing or power washing), failing or improperly located onsite wastewater treatment systems (septic systems), WWTPs, urban wildlife, domestic pets, agriculture (e.g., ranchettes) and other sources (Table 6-1). Allowed discharges to MS4s such as irrigation runoff and uncontaminated groundwater discharges may also transport fecal indicator bacteria originating from other sources.

In agricultural areas, both livestock and manure management can be agricultural sources of *E. coli*. Secondary sources of persistent fecal indicator bacteria include sediments in receiving waters, biofilms in storm sewers and waterbody substrate/sediments, and naturalized fecal indicator bacteria associated with plants (e.g., kelp) and soil (Francy et al. 2003, Ran et al. 2013, Byappanahalli and Fujioka 2004, McCarthy 2009, Ellis et al. 1998, Ishii and Sadowsky 2008, among others). Table 6-1 provides a summary of potential fecal indicator bacteria sources that communities should consider, depending on the conditions potentially present in a specific watershed.

Although some of these sources can be controlled to an appreciable extent (e.g., wastewater discharges, illicit connections), other sources are much more difficult to control. These diffuse and often mobile sources include wildlife such as raccoons, beavers, birds, etc. and environmental sources, such as the biofilms and sediments which provide a stable habitat for these organisms to reproduce. Properly accounting for and identifying potential sources is the first step in working toward minimizing fecal indicator bacteria contributions from controllable sources.

Currently, in the St. Vrain Basin, a clear understanding of *E. coli* sources has not been developed, although initial hypotheses can be formulated and further explored so that targeting of solutions is cost-effective.

Table 6-1. Potential Sources of Fecal Indicator Bacteria in Urban and Agricultural Areas

General Category	Source/Activity
Municipal Sanitary Infrastructure (piped)	Sanitary sewer overflows (SSOs)
	Leaky sewer pipes (Exfiltration) (see Sercu et al. 2011)
	Illicit Sanitary Connections to MS4
	WWTPs (if inadequate treatment or upsets); regulated under NPDES
Other Human Sanitary Sources (some also attract urban wildlife)	Leaky or failing septic systems
	Homeless encampments
	Porta-Potties
	Dumpsters (e.g., diapers, pet waste, urban wildlife)
	Trash cans
	Garbage trucks
Domestic Pets	Dogs, cats, etc.
Urban Wildlife (naturally-occurring and human attracted)	Rodents/vectors (rats, raccoons, squirrels, opossums)
	Birds (gulls, pigeons, swallows, etc.)
	Open space (coyotes, foxes, beavers, feral cats, etc.)
Other Urban Sources (including areas that attract vectors)	Landfills
	Food processing facilities
	Outdoor dining and Bars/stairwells (washdown areas)
	Restaurant grease bins
	Piers/docks
Urban Non-stormwater Discharges (Potentially mobilizing surface-deposited fecal indicator bacteria)	Power washing
	Excessive irrigation/overspray
	Car washing
	Pools/hot tubs
	Reclaimed water/graywater (if not properly managed)
MS4 Infrastructure	Illegal dumping
	Illicit sanitary connections to MS4 (*also listed above*)
	Leaky sewer pipes (exfiltration) (*also listed above*)
	Biofilms/regrowth
	Decaying plant matter, litter and sediment in the storm drain system
Recreational Sources	Bathers and/or boaters
	RVs (mobile)
Agricultural Sources (potentially including ranchettes within MS4 boundaries)	Livestock, manure storage
	Livestock, pasture
	Livestock, corrals
	Livestock, confined animal feeding operations (CAFO) (NPDES-regulated)
	Manure spreading, pastures/crops
	Municipal biosolids re-use
	Reclaimed water
	Irrigation tailwater
	Slaughterhouses (NPDES-regulated)
Natural Open Space/Forested Areas	Wildlife populations
	Grazing
Other Naturalized Sources	Decaying plants/algae, sand, soil (naturalized fecal indicator bacteria)

Note: this table builds upon previous work by San Diego County (Armand Ruby Consulting 2011), as summarized in UWRRC (2014).

6.1.3 General Recommendation for Source Identification

E. coli is used as an indicator of fecal contamination and associated potential human health risk due to the presence of pathogens in waterbodies. Because *E. coli* originates from humans, agricultural sources, and wildlife and can persist outside of a host in the natural environment in soils and sediments, interpretation of the causes of elevated *E. coli* in a watershed can be very complicated. Typically, large data sets are needed in order to begin to draw meaningful conclusions about *E. coli* sources and potential strategies to reduce loading. *E. coli* data are well documented to be highly variable, even at the same location within relatively short time periods.

Sampling programs should consider the following:

- Sample during a representative range of seasons and flow conditions and be sure to document flow conditions at the time of sampling.
- Field notations during sampling events should record factors such as irrigation activities, antecedent conditions (e.g., recent storms), presence of cattle adjacent to stream, manure spreading practices in adjacent fields, wildlife observed and presence of animal tracks and fecal waste adjacent to or in the stream. Field measurements such as pH, temperature, dissolved oxygen, specific conductivity and turbidity should also be recorded.
- CDPHE recommends a minimum of five samples to calculate a geometric mean during the 60-day assessment period associated with the standard. (EPA currently recommends a 30-day assessment period.) In practice, many communities sample monthly, but the more samples collected, the better. Generally, it would be better to collect more samples at fewer locations than a few samples at many locations.
- Sample locations should be selected to “bracket” potential contributing source areas. For example, above a field with cattle grazing and below the field, above a tributary and below a tributary, suspected source area, etc.
- Initially, sampling should occur at least on a monthly basis year-round. Although the recreation seasons may be the primary time period of interest in terms of protection of human health, winter samples can be useful in terms of formulating hypotheses regarding sources. (For example, a location that has elevated *E. coli* even during winter months would generally be of higher priority than one that has elevated *E. coli* only during August because the data suggest an on-going year-round source.)
- Time of day of sample collection can also affect *E. coli* results. For example, samples collected in the morning tend to be higher than those in the afternoon (likely due to sunlight/UV exposure).

- When collecting samples, be sure not to disturb stream sediment during sample collection. For example, collect the water sample first and then perform flow measurements.

- If initial samples exceed the upper quantitation limit for the selected method (e.g., IDEXX upper limit is 2,419 MPN/100 mL), then additional analysis using dilution techniques should be used. Generally, warm summer months tend to have higher *E. coli* than winter months, so additional dilutions are often needed in the summer.

- For purposes of source identification, it may be most helpful to focus on dry weather conditions, since temporarily elevated *E. coli* following storm events is a common occurrence ("a given") in many watersheds. Elevated *E. coli* following storm events can occur both from runoff from land surfaces, as well as due to resuspension of sediments in the stream bottom.

Once a representative data set has enabled focusing on portions of the stream segment with elevated *E. coli*, then there are many techniques that communities can use to explore and identify sources of *E. coli*. The selection of techniques should be based on initial hypotheses formed from basic *E. coli* monitoring and in most urban areas should include basic dry weather screening of outfalls in stream reaches with elevated fecal indicator bacteria. Some of these methods have been available for 20 years or more (e.g., Pitt 1994, CWP et al. 2004), whereas others include recently published methods that integrate significant advances in microbial source tracking (e.g., Griffith et al. 2013). There are strengths and limitations of both the older and more recent approaches, and source tracking objectives must be balanced with available budget and technical resources. These budget-related decisions also need to consider the benefits that a well formulated source tracking program may provide relative to the projected costs of the actions specified in TMDL Implementation Plans.

Table 6-2 provides a summary or toolbox of potential source tracking methods, ranging from simple to complex. This table integrates findings from earlier EPA-sponsored work by the Center for Water Protection et al. (2004) titled *Illicit Discharge Detection and Elimination Manual* and two recently developed key references on source identification approaches that incorporate use of molecular methods. The two latter references include *The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches* (Griffith et al. 2012) and *Tools for Tracking Human Fecal Pollution in Urban Storm Drains, Creeks, and Beaches* (City of Santa Barbara 2012a&b). The primary purpose of the tools in Table 6-2 is to identify signals of human waste in creeks, beaches, and storm drains and track these signals to their sources.

Table 6-2. Fecal Contamination Source Tracking Tools

(Modeled after *Tools for Tracking Human Fecal Pollution in Urban Storm Drains, Creeks, and Beaches*, City of Santa Barbara 2012a&b; supplemented by Pitt 1994, CWP et al. 2004, as provided in UWRRC [2014])

Tool	Best Use	Caveats and Challenges	Relative Cost
Visual Surveys of Potential Sources	Homeless encampments, sites with frequent daytime use, under bridges, obvious contamination associated with inappropriate discharges.	Feces often contained in newspaper or plastic bags.	$
GIS	Essential for planning and analyzing data in relation to infrastructure. Useful prior to initial field investigations, as well as for targeting areas for more detailed investigations.	Requires accurate data for both storm drains and sanitary sewers, including pipe elevations and inverts, where available.	$$
Dry Weather Outfall Screening	Identification of flowing outfalls for water quality sampling, along with physical observations (odor, color floatables, deposits, stains).	Dry weather flows can originate from both contaminated and uncontaminated sources.	$$
Fecal Indicator Bacteria (*E. coli*, enterococci)	Basic indicator of potential fecal contamination tied to regulatory receiving water limits.	Recommended in conjunction with additional chemical or molecular tests. Urban wildlife and pets may be responsible for high values observed. Biofilms and sediment sources may also contribute to elevated fecal indicator bacteria. (May be elevated in the absence of human sources.)	$
Chemical Indicators (Basic Flow Fingerprinting/ Non-human Chemistry)	Finding illicit connections. Good for understanding nutrient inputs from any type of illicit connection. Example indicators include: detergents, fluorides, ammonia, and potassium. Others may also be useful.	May not identify direct human deposition (e.g., homeless) and small sewage leaks that are significantly diluted by other flows. Background signal of urban runoff can make fingerprinting sewage difficult in some urban areas.	$$
Chemical Indicators (Advanced Markers of Human Waste)	Finding sewage leaks. Advanced analyses may include: sucralose, caffeine, and cotinine.	Some advanced chemical indicators may be present in the environment from surface deposition, rather than sewage sources (e.g., dumping coffee down storm drains).	$$

Tool	Best Use	Caveats and Challenges	Relative Cost
Canine Scent Tracking	Best for use when real time results are desired, such as working up storm drain networks with many branches. Also when broad spatial coverage is sought.	Canines may respond to non-human illicit connections, due to training with detergents. Requires specially trained canines with trained staff.	$$
CCTV (Closed Circuit Television) of Storm Drains	Best for use where sampling data suggests sustained input of sewage.	Most operators are trained for sanitary sewer pipe inspection, and may seek to clean the lines first. Plan to guide operators to slow down, look carefully at leaks, and do not clean the lines first (in order to see solids on bottom of storm drain).	$$
Electric Current Flow Method	The method uses the variation of electric current flow through the pipe wall to locate defects that are potential water leakage paths either into or out of the pipe.	See ASTM F2550 – 13. Applies only to electrically non-conducting pipes w/ diameters of diameters of 3 to 60 in.	ND
Basic Dye Test	Best for testing laterals or fixtures feeding a single illicit connection that has been observed by CCTV.	Use bright green dye and a UV light to look for dye in storm drains.	$
Smoke Test	Best for limited geographic areas with strong evidence for direct connections (e.g., toilet paper).	Difficult in large pipes and densely populated areas.	$$
Dye with Rhodamine Probe	Best for testing suspected sewage infiltration to storm drains when persistent human-waste markers are found w/out observing solids such as toilet paper.	Difficult to know how long to leave probe in storm drain. Rain events may create a false positive signal.	$$
Automated continuous flow gauges and autosamplers	Best for drains with evidence of higher flows (wet walls, signs of water shooting into creek channel). Supports load estimation.	Check specs carefully to find flow gauges suitable for dry weather flows. Requires confined space entry in most cases.	$$$ (initial)
Temperature Probes	Can be placed in storm drain outfalls to further verify certain types of suspected illegal connections (e.g., flushing/showering patterns).	Does not identify where the illegal connection is located. More useful in smaller drainage areas.	$

Tool	Best Use	Caveats and Challenges	Relative Cost
Human-specific waste markers (Advanced Technique)	Best tool for quantifying inputs of human waste. Best for sampling in creeks, beaches, storm drain outfalls or major nodes in storm drain network.	Plan repeated sampling to account for variable results. Requires more expertise and cost. (See Section 6.1.4)	$$$
Community approach, e.g., Phylochip (Emerging Advanced Technique)	Best for sampling along a gradient of suspected inputs, (e.g., to test if septage is entering a creek). May be advantageous in storm drains diluted with clean ground water, due to low detection thresholds.	At this point, results are not conducive to simple interpretation suitable for a nontechnical audience. Requires more expertise and cost.	$$$$

Notes: Cost—increasing $ indicates more expensive techniques. ND = not determined.

6.1.4 Considerations for Advanced Microbial Source Tracking

Because of the cost of molecular methods (e.g., human-specific waste markers), these would only be recommended in targeted locations after routine *E. coli* sampling has identified a problem portion of a stream segment. Additional "desktop review" of potential sources should also be conducted prior to embarking on molecular methods. For example, a more detailed review of septic systems in proximity to streams could be conducted. This could include septic system permit review, maintenance records review, aerial photography to identify potentially problematic systems, and/or dye testing the septic system if system failure is suspected. Monitoring for human-related chemical markers is also an option if septic systems are suspected. Examples include sucralose, cotinine, caffeine, detergents and other chemicals.

Molecular source tracking methods have improved in recent years and are now available through commercial laboratories, typically at a price of several hundred dollars per sample per marker tested (e.g., $275-375), with declining costs per sample depending on the number of markers tested, the number of samples analyzed, and the type of quantification of results. For an example of a commercial laboratory offering such analyses, see: http://www.sourcemolecular.com/microbial-source-tracking/microbialsourcetracking.html. Molecular methods can be applied in a manner that reports either presence/absence or that provides relative quantification among several sources (e.g., results could be reported as high likelihood of bovine sources, low likelihood of human sources).

An example of a qualitative report from Source Molecular includes:

SM #	Client #	Analysis Requested	DNA Analytical Results
SM 16294	01012011A	Cow Bacteroidetes ID	Negative
SM 16295	01012011B	Cow Bacteroidetes ID	Negative
SM 16296	01012011C	Cow Bacteroidetes ID	**Positive**
SM 16297	01012011D	Cow Bacteroidetes ID	**Positive**
SM 16298	01012011E	Cow Bacteroidetes ID	**Positive**
SM 16302	01012011F	Cow Bacteroidetes ID	**Positive**

An example of a quantitative report from Source Molecular includes:

SM #	Client #	Approximate Contribution of Bird Fecal Pollution in Water Sample	Comment
SM 16298	01012011E	**Major Contributor**	High levels of bird biomarker detected
SM 16300	01012011A	Negative	Negative for the bird biomarker

When applying molecular methods, the first priority is typically to determine if human sources of waste are present. In agricultural settings, cattle sources are also high priority since pathogens in cattle manure are well documented to cause illness in humans. Based on experience, Source Molecular recommends testing for two or more hosts (such as cattle and human) simultaneously in order to achieve greater sensitivity and reliability with the results, and to make sure that human sources are not underestimated. Table 6-3 provides a summary of representative commercially available molecular methods.

When reviewing microbial source tracking literature, it is important to note that the current preference is for use of "library independent" methods such as the methods described in Tables 6-3 and 6-4, rather than library-dependent methods that involve developing a site-specific DNA library. When reviewing literature and guidance on microbial source tracking methods, preference should be given to recent publications. For example, a recent summary of the latest microbial source tracking methods is provided in *The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches* (Griffith et al. 2013). Although this publication is geared toward beaches, the discussion of molecular methods is up-to-date, unlike guidance produced even 5 to 10 years ago. Griffith et al. (2013) provide recommendations and standard operating procedures for various MST markers, as summarized in Table 6-4.

Table 6-3. Representative Summary of Commercially Available Molecular Methods for Microbial Source Tracking

(Source: Source Molecular Laboratories, http://www.sourcemolecular.com/complete-list.html)

Tests	Target
Human	
Human Bacteroidetes ID™ (4 tests available)	Human Fecal Bacteria: Bacteroides dorei Human Fecal Bacteria: Bacteroides stercoris Human Fecal Bacteria: Bacteroides spp. Human Fecal Bacteria: Bacteroides fragilis
Human Urine Virus ID™	Human Fecal Virus: Polyomavirus
Cattle	
Cow Bacteroidetes ID™	Cattle Fecal Bacteria: Bacteroidetes
Cow Fecal Virus ID™	Cattle Fecal Virus: Enterovirus
Pig	
Pig Bacteroidetes ID™	Swine Fecal Bacteria: Bacteroidetes
Bird	
Bird Fecal ID™	Bird Fecal Bacteria: Helicobacter
Gull	
Gull Fecal ID™	Gull Fecal Bacteria: Catellicoccus
Goose	
Goose Bacteroidetes ID™	Goose Fecal Bacteria: Bacteroidetes
Chicken	
Chicken Bacteroidetes ID™	Chicken Fecal Bacteria: Bacteroidetes
Dog	
Dog Bacteroidetes ID™	Dog Fecal Bacteria: Bacteroidetes
Deer/Elk	
Deer (Elk) Enteroccocus ID™	Deer Fecal Bacteria: Enterococcus
(Elk) Bacteroidetes ID™	Elk Fecal Bacteria: Bacteroidetes
Ruminant	
Ruminant Fecal ID™	Ruminant Fecal Bacteria: Bacteroidetes
Horse	
Horse Bacteroidetes ID™	Horse Fecal Bacteroidetes

Table 6-4. Summary of Recommended MST Marker Methods
(Table developed based on information in Griffith et al. [2013])

MST Marker Method[1]	Description
Human Markers with SOPs	
HF183 Taqman qPCR	Targets *Bacteroides* bacteria in human fecal material. Performed best in method evaluation studies. Recommended by Griffith et al. (2013) as best starting point for detecting human fecal material. However, it has been shown to occasionally cross-react with chicken or dog feces. If those sources are of concern, then it is recommended that HF183 be paired with HumM2.
HumM2 qPCR	Targets *Bacteroides* bacteria in human fecal material. Slightly less sensitive than HF183.
Human Adenovirus qPCR	Targets human adenovirus. Can be used on an as-needed basis to supplement and verify bacterial marker results. More costly and requires more specialized laboratory expertise than the bacterial qPCR methods.
Human Polyomavirus qPCR	Targets human Polyomavirus. Can be used on an as-needed basis to supplement and verify bacterial marker results. More costly and requires more specialized laboratory expertise than the bacterial qPCR methods.
Non-Human Markers with SOPs	
BacCan-UCD qPCR and DogBact qPCR	Targets dog-related fecal sources. Both methods were found to be highly sensitive and specific, though occasional cross reactivity with other species has been observed. Equally recommended by Griffith et al. (2013).
CowM2 qPCR	CowM2 is the recommended marker for cattle because it is expected to become an EPA-approved method.
Rum2Bac qPCR	Recommended for non-bovine ruminants. When both cattle and other ruminants are present in the watershed, then both CowM2 and Rum2Bac are recommended. Rum2Bac occasionally had false positive results with septage, so users should conclusively rule out septage before employing Rum2Bac.
Pig2Bac qPCR	Pig2Bac is the recommended method for detection of pig feces. It may cross-react with human/septage and dog feces, so it is best applied when those sources have been ruled out.
Horse Conventional PCR	This method is recommended when horses are present and other sources have been ruled out. It is not as sensitive as most other host associated assays. This method is not quantitative.
Gull2 Taqman qPCR and Lee Seagull qPCR	Four gull markers were evaluated, with Gull2 Taqman and Lee Seagull markers recommended due to sensitivity and specificity. Bird markers will amplify pigeon and sometimes goose feces, as well as gull. Considered general bird assays and not necessarily specific to gulls. Other new assays may also be available.

[1]SOPs are also provided for procedures including membrane filtration for molecular analysis, DNA EZ ST1 Extraction (GeneRite, LLC), Sketa (Sample Processing Control) qPCR.
Before embarking on microbial source tracking, it is important to have a realistic estimate of number of samples and marker tests needed to meet study objectives so that adequate budget is allocated and to avoid false negatives with results. Additionally, false positives may also occur with molecular methods, such as in cases where DNA from "dead" organisms is detected in disinfected WWTP discharges, but the method still reports the marker. (Molecular methods detect both viable and non-viable DNA.)

Depending on the findings of additional sampling, it may also be worthwhile to determine the frequencies with which *E. coli* standards are exceeded in reference stream conditions (e.g., those without human or known agricultural sources). Examples of such studies conducted under dry weather and wet weather conditions include work in Southern California (e.g., Tiefenthaler et al. 2008; Griffith et al. 2005, Schiff et al. 2005). This information may be useful in determining a natural baseline condition, useful for setting realistic expectations for TMDLs.

Finally, a consideration regarding *E. coli* monitoring in agricultural areas is that the contributions of *E. coli* from wildlife should not be underestimated. As one example, Harmel et al. (2010) studied the effects of agricultural management, land use and watershed scale on *E. coli* concentrations in runoff and streamflow in rural watersheds in Texas. The study found no significant differences in *E. coli* concentrations in "impacted" and "unimpacted" rural streams. In another study in Riesel, Texas, Harmel et al. (2013) also found that mean and median *E. coli* concentrations generally occurred in the following order: cultivated < hayed pasture < native prairie < mixed agricultural land use < grazed pasture. The median *E. coli* concentration for native prairie was 2,000 cfu/100 mL for 22 storm events. The increase in *E. coli* runoff from native prairie relative the hayed pasture was expected to be due to a more abundant wildlife population resulting from the diverse vegetation and habitat on the native prairie. Both studies concluded the likelihood of substantial inputs of fecal indicator bacteria by wildlife should be carefully considered when drawing conclusions regarding management options and when evaluating the contribution of agricultural practices to fecal indicator bacteria impairments.

6.2 BMPs and Policies to Reduce Pollutant Loading by Source Type

BMPs and policies to reduce *E. coli* loading by source type can generally be categorized as urban source controls, constructed urban stormwater BMPs, agricultural practices (on public and private lands), and channel restoration practices. These practices also typically help to reduce nutrient loading and may improve aquatic life health.

6.2.1 Urban Source Controls (Including Public Education)

The Keep It Clean Partnership website (http://www.keepitcleanpartnership.org/) already provides information on many pollutant source control practices that can be implemented by citizens, business owners and municipal operations. The Keep It Clean Partnership program contracts with the Partners for a Clean Environment (PACE) Program to implement a stormwater compliance assistance program for municipal operations within the Keep It Clean Partnership communities. The PACE Program ensures that the Keep It Clean Partnership communities are advised if they are meeting the intent of their stormwater permits. PACE has a BMP library with information on the following BMPs:

- Concrete Pouring And Finishing
- Contracts, Contractors & Property Leasing
- Dewatering Of Secondary Containment Structures
- Employee And Contractor Training
- Facilities And Building Maintenance
- Firefighting Activities
- Food Service Facilities & Waste Handling
- Good Housekeeping & Spill Prevention
- Illegal Connection & Discharge Reporting
- Landscaping And Lawn Maintenance
- Liquid Bulk Material Loading & Unloading
- Materials Loading And Unloading
- New Construction
- Outdoor Container Storage
- Parking Lot Maintenance
- Potable Water Line Discharges
- Salt Storage & Snow Disposal
- Sanitary Sewer Back Up
- Spill Clean-Up
- Storm Drain System Maintenance
- Street Sweeping & Road Maintenance
- Swimming Pool Maintenance
- Utility Installation In Roadway
- Vehicle And Equipment Fueling
- Vehicle And Equipment Washing
- Vehicle Maintenance And Storage
- Waste Management And Disposal

Table 6-5 summarizes specific urban source controls that may help to reduce *E. coli* in urban areas.

Table 6-5. Urban Source Control Practices for *E. coli* (Source: UWRRC 2014)

Bacteria Source	Stormwater Control/Management Strategy
Domestic Pets (dogs and cats)	Provide signage to pick up dog waste, providing pet waste bags and disposal containers. Adopt and enforce pet waste ordinances. Place dog parks away from environmentally sensitive areas. Protect riparian buffers and provide unmanicured vegetative buffers along streams to dissuade stream access.
Urban Wildlife (rats, bats, raccoons)	Reduce food sources accessible to urban wildlife (e.g., manage restaurant dumpsters/grease traps, residential garbage, feed pets indoors).
Illicit Connections to MS4s	Implement an IDDE program to identify and remove illicit connections.
Leaking Sanitary Sewer Lines/Aging Sanitary Infrastructure	Conduct investigations to identify leaking sanitary sewer line sources and implement repairs.
Onsite Septic Systems and Package Plants	Implement a program to identify potentially failing septic systems. Enforce discharge permit requirements for small package plants.
Illegal Dumping	Implement a reporting hotline for illegal dumping and educate the public/industries that dumping to storm sewer system is illegal.
Storm Sewer System and Stormwater Quality BMPs	Proper maintenance of the storm sewer system and water quality BMPs is needed for proper functioning of the system. For example, sediment, organic deposits and biofilms in stormwater facilities can be sources of elevated fecal indicator bacteria.
Storm Runoff from Urban Areas	Encourage site designs that minimize directly connected impervious areas.
Dry Weather Urban Flows (irrigation, carwashing, powerwashing, etc.)	Implement public education programs to reduce dry weather flows from storm sewers related to lawn/park irrigation practices, carwashing, powerwashing and other non-stormwater flows. Provide irrigation controller rebates. Implement and enforce ordinances related to outdoor water waste. Inspection of commercial trash areas, grease traps, washdown practices, along with enforcement of ordinances.
Birds (e.g., Canada geese, gulls, pigeons)	Identify areas with high bird populations and evaluate deterrents, population controls, habitat modifications and other measures that may reduce bird-associated fecal indicator bacteria loading.
Wildlife: (raccoons, beavers, deer, coyotes, field rats, mice)	Consult with state wildlife offices on strategies to reduce food, shelter and habitat for overpopulated urban wildlife. Implement and enforce urban trash management practices.
Homeless Populations	Support of city shelters and services to reduce homelessness. Periodic cleanup of homeless camps near streams. Police enforcement. Providing public restrooms. Partnering with non-governmental organizations to address homelessness.

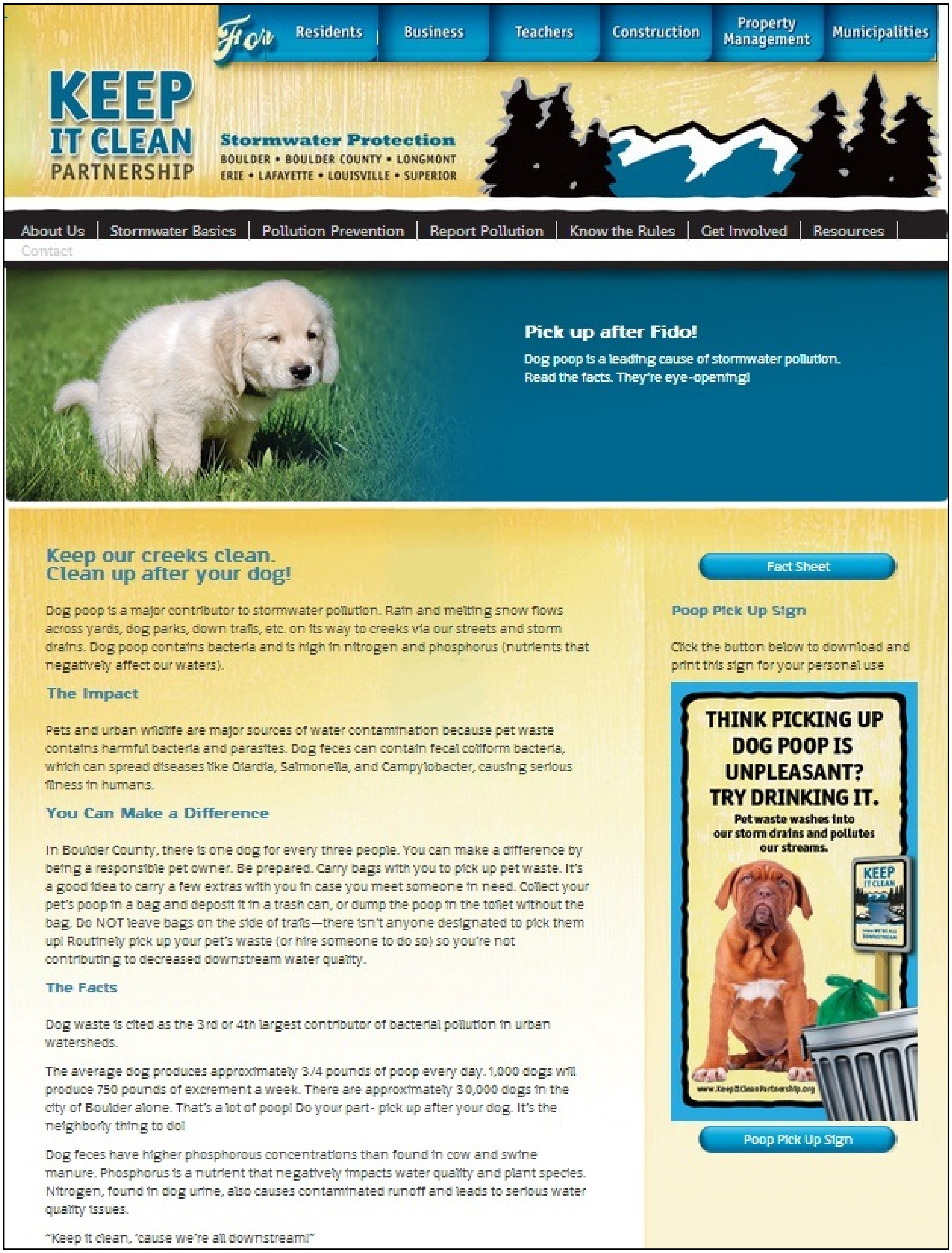
The most obvious source control for citizens with regard to *E. coli* involves pet waste management. The Keep It Clean Partnership website (Figure 6-2) encourages pet guardians to be a "Doo Gooder" by remembering these five practices:

- Be prepared: carry poop bags with you.
- Take extra bags so you don't run out (and you can help someone in need).
- Make sure the bag ends up in a trash can.
- When you hike, never leave a bag on the trail – there's nobody designated to pick them up!
- Pick it up at home (or hire someone to do it) to keep your yard healthy and to protect streams.

At dog parks in Boulder County, signage is provided regarding pet waste disposal and is also directly addressed on its website (http://user.govoutreach.com/boulder/faq.php?cid=23384).

Pet waste ordinances are in place in all communities in the St. Vrain Basin and require removal and proper disposal of animal excrement. These ordinances provide the ability to levy fines and other penalties if the ordinances are not followed.

Figure 6-2. Keep It Clean Partnership Website with Pet Waste Information



6.2.2 Urban Stormwater Quality Management—Constructed Measures

Urban stormwater quality management is based on implementation of both source controls and structural BMPs. The Urban Drainage and Flood Control District's *Urban Storm Drainage Criteria Manual, Volume 3 Best Management Practices* (UDFCD 2010) includes design criteria for permanent structural stormwater BMPs, construction BMPs, source control practices, and maintenance requirements. Table 6-6 summarizes BMPs included in Volume 3, which should be referenced directly for design and maintenance recommendations. When selecting a BMP to address a specific pollutant, it is important to understand whether the BMP provides unit treatment processes expected to be effective for that pollutant. Additionally, load reduction can be achieved by reducing the volume of runoff, so it is important to consider both volume reduction and concentration reduction when evaluating BMP performance. Unfortunately, bacteria are not easily removed by stormwater BMPs to concentrations meeting stream standards. However, pollutant load reductions can be achieved by practices that include volume reduction either through infiltration or evapotranspiration. (See UDFCD Volume 3 for a description of commonly used BMPs).

Table 6-6. Common Urban Stormwater BMPs and Primary Unit Treatment Processes
(Source: UDFCD 2010, Volume 3 Urban Storm Drainage Criteria Manual)

	Hydrologic Processes			Treatment Processes				
	Peak	Volume		Physical			Chemical	Biological
UDFCD BMP	Flow Attenuation	Infiltration	Evapo-transpiration	Sedimentation	Filtration	Straining	Adsorption/ Absorption	Biological Uptake
Grass Swale	I	S	I	S	S	P	S	S
Grass Buffer	I	S	I	S	S	P	S	S
Constructed Wetland Channel	I	N/A	P	P	S	P	S	P
Green Roof	P	S	P	N/A	P	N/A	I	P
Permeable Pavement Systems	P	P	N/A	S	P	N/A	N/A	N/A
Bioretention	P	P	S	P	P	S	S[1]	P
Extended Detention Basin	P	I	I	P	N/A	S	S	I
Sand Filter	P	P	I	P	P	N/A	S[1]	N/A
Constructed Wetland Pond	P	I	P	P	S	S	P	P
Retention Pond	P	I	P	P	N/A	N/A	P	S
Underground BMPs	Variable	N/A	N/A	Variable	Variable	Variable	Variable	N/A

Notes:
P = Primary; S = Secondary, I = Incidental; N/A = Not Applicable
[1] Depending on media

In terms of BMP performance, the International Stormwater BMP Database (www.bmpdatabase.org)[7] is the largest known repository of BMP performance information. As of January 2014, the BMP Database contained over 5,800 sample results for fecal indicator bacteria, including fecal coliform, *E. coli*, fecal streptococcus and total coliform. Performance summary reports for fecal indicator bacteria were completed in 2010, 2012 and 2014 as part of the BMP Database project and are accessible at www.bmpdatabase.org, along with the underlying data sets used for analysis (Wright Water Engineers and Geosyntec 2010, 2012, 2014). Since publication of these reports, additional data submissions have resulted in

[7] Discussion related to analysis from the International Stormwater BMP Database was taken directly from *Pathogens in Urban Stormwater Systems* (UWRRC 2014). Text, tables and figures were prepared by Wright Water Engineers for use in the UWRRC report.

significant growth of the fecal indicator bacteria data set; nonetheless, the majority of available data are for fecal coliform and the data sets remain relatively limited for some stormwater control categories. Data available in the BMP Database as of 2014 were queried to prepare updated performance information.

Tables 6-7 and 6-8 provide selected summary statistics for data sets included in this analysis, followed by boxplots corresponding to these summary statistics in Figures 6-3 and 6-4. To graphically illustrate the central tendencies and ranges of fecal indicator bacteria concentrations observed for the inflow and outflow for each control practice category, boxplots were completed for fecal coliform (Figures 6-3a and 6-3b) and *E. coli* (Figure 6-4). In the boxplots, the inflow is provided in the first box and the outflow is provided in the second box (in bold) above each treatment category. Concentrations of fecal indicator bacteria are shown on a logarithmic scale.

Conclusions that can be drawn regarding stormwater BMP performance for fecal indicator bacteria based on this analysis are generally consistent with previous analyses completed for the BMP Database (WWE and Geosyntec 2010, 2012). These findings are important in terms of setting realistic expectations for BMP performance. Key findings and observations based on the data set analyzed include:

- Regardless of fecal indicator bacteria type, the available data set shows that concentrations in urban runoff typically exceed primary contact recreation standards, often by one or more orders of magnitude.

- Regardless of stormwater control type or fecal indicator bacteria type, both inflow and outflow concentrations are highly variable, typically spanning an order of magnitude or more for the interquartile range.

- Currently available data suggest that it is unlikely that conventional structural stormwater controls using passive treatment can consistently reduce fecal indicator bacteria concentrations in runoff to primary contact recreation standards. Sand filters are the only stormwater control category evaluated with effluent concentrations approaching primary contact stream standards for *E. coli*, and retention (wet) ponds approached the primary contact standard for enterococcus. Although the bioretention data set achieved *E. coli* concentrations below stream standards, this data set had low *E. coli* in the influent relative to other BMP categories; therefore, these findings are inconclusive for bioretention. Active treatment devices using UV-disinfection were able to reduce effluent concentrations to stream standards.

- Bioretention, sand filters, retention (wet) ponds, extended detention basins (dry) and composite (treatment train) stormwater controls appear to be able to reduce fecal indicator bacteria concentrations to some extent, based on hypothesis testing. Unit processes such as sorption and filtration are present in bioretention and media filters, whereas wet ponds may provide long holding times that enable sedimentation, solar irradiation and habitat conducive to natural predation. Detention basins rely primarily on sedimentation; however, scouring and resuspension of sediment deposited in detention basins may be a potential on-going source of fecal indicator bacteria loading in the effluent. Review of individual detention basin studies shows that some detention basins export fecal indicator bacteria, whereas others reduce fecal indicator bacteria concentrations.

- Grass strips and swales do not appear to reduce fecal indicator bacteria concentrations in their effluent. Instead, increases in effluent concentrations for fecal coliform are shown for grass strips and some grass swales studies. These stormwater control types may be exporting fecal indicator bacteria, either from entrainment of previously deposited fecal indicator bacteria or from new sources (e.g., animal excrement). (Note: reductions in fecal indicator bacteria loading due to infiltration and evapotranspiration are not evaluated in this analysis.)

- Inadequate data sets are available to evaluate the performance of permeable pavements and green roofs. Previous review of the green roof data in the BMP Database has shown that even though roofs have relatively few sources of fecal indicator bacteria (i.e., birds), sample results an order of magnitude above primary contact stream standards are not uncommon (WWE and Geosyntec 2010).

- The manufactured device category includes a range of proprietary devices that rely on various unit treatment processes; therefore, performance should be evaluated on a unit treatment process basis for purposes of stormwater BMP selection. Nonetheless, the manufactured device studies currently included in the BMP Database did not result in fecal indicator bacteria effluent concentrations attaining stream standards. Significant overlap of interquartile ranges for inflows and outflows is present for the majority of the manufactured devices, with nearly statistically significant increases (export) of fecal indicator bacteria for this overall stormwater treatment device category. Due to ongoing innovation regarding unit processes provided in manufactured devices, general conclusions about manufactured devices should be used with caution.

- The concentration-based analysis does not account for load reductions that may result from reduced surface volumes discharged from the various stormwater control types. For more information on volume reduction benefits of BMPs, see *International Stormwater Best Management Practices (BMP) Database Technical Summary: Volume Reduction* (Geosyntec and Wright Water Engineers 2011) and *Addendum 1 Expanded Analysis of Volume Reduction in Bioretention BMPs* (Geosyntec and Wright Water Engineers 2012) for a discussion of volume reduction analyses for the BMP Database.

- Several stormwater control types that communities may consider using to reduce fecal indicator bacteria loading are not currently well represented in the BMP Database.

These include subsurface flow wetlands with upstream detention, permeable pavement, and emerging manufactured device products.

Table 6-7. Selected Summary Statistics for Fecal Coliform for BMP Database Studies
(Accessed January 2014; Table Source: UWRRC 2014)

BMP Category	BMP-Flow Type[1]	No. of Events	Geometric Mean	Min	Max	1st Quartile	Median	3rd Quartile	Mean	COV
	Fecal Coliform (#/100 mL); Primary Recreational Contact Geometric Mean Criteria = 200/100 mL									
Biofilter, Grass Strip	BI-In	79	**5,497**	1	2,200,000	1,000	9,889	100,000	115,256	2.6
	BI-Out	100	**26,003**	240	1,890,000	4,100	19,600	181,748	202,790	1.9
Bioretention	BR-In	27	**3,355**	1	160,000	460	5,000	27,000	22,705	1.6
	BR-Out	30	**886**	19	160,000	100	750	4,500	11,390	2.7
Biofilter, Grass Swale	BS-In	71	**3,755**	4	2,000,000	1,255	4,200	24,000	58,397	4.2
	BS-Out	71	**4,777**	19	1,100,000	1,453	5,397	21,000	37,523	3.6
Composite, Treatment Train	CO-In	75	**8,046**	1	282,019	2,530	11,850	28,664	24,302	1.6
	CO-Out	73	**3,738**	9	60,768	973	6,980	18,657	11,547	1.1
Detention Basin (grass, dry)	DB-In	162	**2,218**	1	330,600	505	2,497	18,219	18,860	2.2
	DB-Out	165	**639**	1	138,000	70	700	5,750	8,021	2.3
Detention Basin (other, concrete)	DO-In	36	**8,570**	106	324,893	1,890	11,051	51,224	35,701	1.7
	DO-Out	22	**5,057**	2	551,558	1,123	10,407	45,449	46,491	2.4
Filter, Other Media	FO-In	31	**618**	8	13,000	200	350	4,300	2,635	1.4
	FO-Out	30	**350**	2	3,000	170	515	1,318	884	1.1
Filter, Sand	FS-In	157	**1,463**	2	430,000	200	1,600	11,600	16,533	3.0
	FS-Out	150	**632**	2	98,224	110	593	7,819	7,174	2.0
Infiltration Basin	IB-In	8	**36,257**	800	2,400,000	12,750	37,000	142,500	360,475	2.2
	IB-Out	8	**13,723**	80	280,000	18,033	40,000	97,500	84,276	1.2
Disinfection System	Dis-In	80	**1,158**	80	90,000	450	1,050	2,550	4,318	3.2
	Dis-Out	64	**17**	10	220	10	10	20	28	1.5
Manufactured Device	MD-In	104	**1,478**	13	160,000	200	1,300	5,000	9,706	2.6
	MD-Out	110	**2,504**	80	160,000	325	2,300	10,250	19,368	2.1
Retention Pond (Wet)	RP-In	152	**2,930**	1	964,860	775	3,200	23,224	32,978	3.1
	RP-Out	162	**637**	1	1,770,741	64	1,500	6,570	21,964	6.5
Wetland Basin	WB-In	24	**3,673**	10	41,424	2,125	6,930	15,570	11,096	1.0
	WB-Out	23	**1,115**	10	44,845	105	1,900	15,373	9,209	1.4
Wetland Channel	WC-In	80	**357**	1	2,400	110	933	2,400	1,154	0.9
	WC-Out	53	**247**	2	2,400	33	540	1,600	937	1.0

[1]Abbreviations correspond to BMP type in column 1.

Table 6-8. Selected Summary Statistics for *E. coli* for BMP Database Studies
(Accessed January 2014; Table Source: UWRRC 2014)

BMP Category	BMP-Flow Type[1]	No. of Events	Geometric Mean	Min	Max	1st Quartile	Median	3rd Quartile	Mean	COV
	E. coli (#/100 mL); Primary Recreational Contact Geometric Mean Criteria = 126/100 mL									
Bioretention	BR-In	54	145	1	7,701	42	135	1,821	1,121	1.6
	BR-Out	54	60	1	19,863	5	30	965	1,539	2.5
Biofilter, Grass Swale	BS-In	39	1,440	4	41,000	295	3,500	11,000	9,270	1.4
	BS-Out	39	2,365	11	40,000	1,200	4,100	10,000	8,993	1.4
Detention Basin (grass, dry)	DB-In	42	1,011	1	198,600	333	850	4,500	14,184	2.6
	DB-Out	42	283	1	22,800	63	370	1,700	2,167	2.2
Filter, Sand	FS-In	5	2,099	105	15,500	830	2,600	11,605	6,128	1.0
	FS-Out	5	79	10	280	72	98	160	124	0.7
Retention Pond (Wet)	RP-In	87	6,580	10	16,621,000	686	3,466	29,028	799,060	3.2
	RP-Out	84	726	1	12,400,000	23	393	5,225	352,426	4.0
Wetland Basin	WB-In	42	681	5	14,136	257	714	2,509	2,516	1.5
	WB-Out	42	539	6	36,540	65	622	3,577	3,822	2.0

[1]Abbreviations correspond to BMP type in column 1.

Figure 6-3a. Boxplots of Fecal Coliform Data from the Stormwater BMP Database (part 1)
(Source: UWRRC 2014)

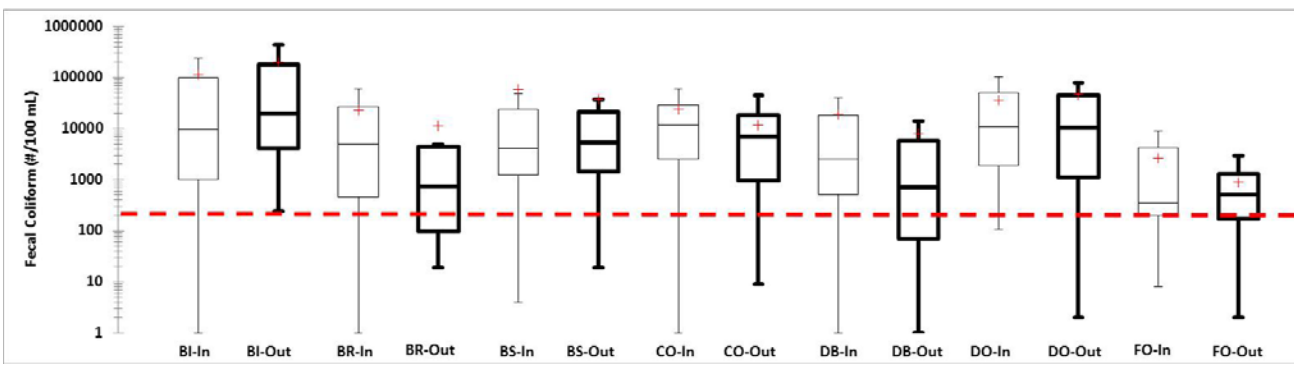
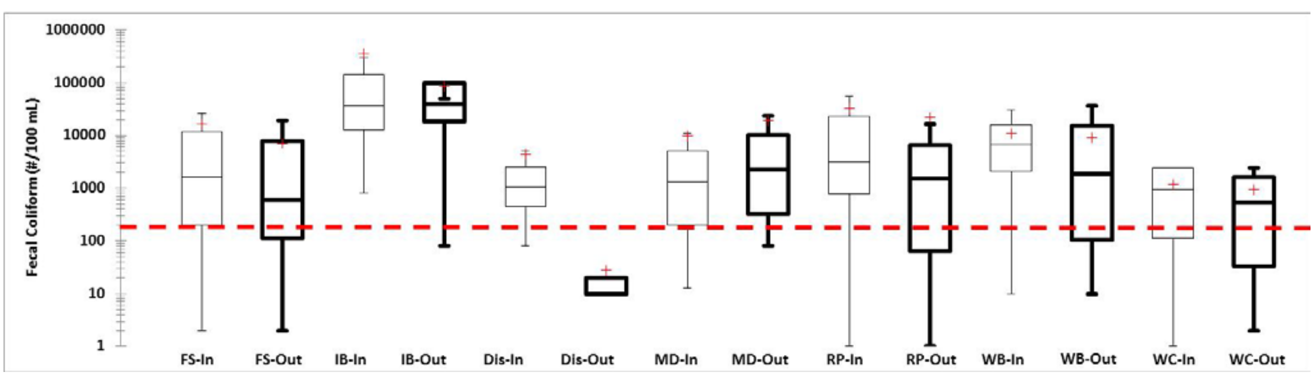
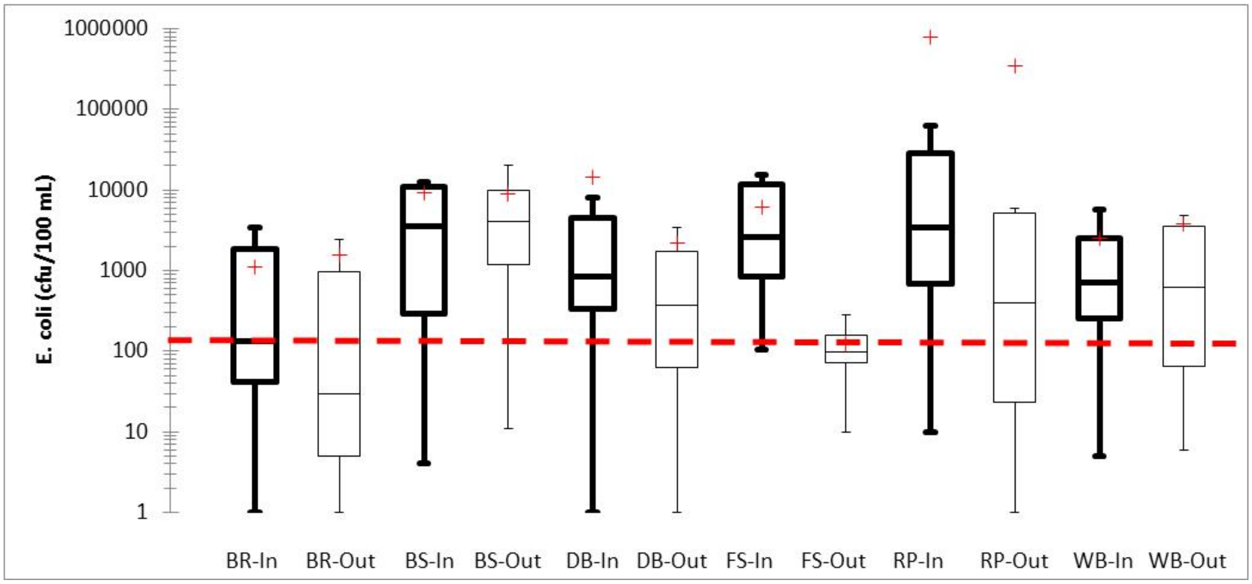


Figure 6-3b. Boxplots of Fecal Coliform Data from the Stormwater BMP Database (part 2)



See Tables 6-3 and 6-4 for abbreviations and corresponding data. Red dashed lines correspond to historically recommended geometric mean primary contact recreational criterion of 200 cfu/100 mL for fecal coliform.

Figure 6-4. Boxplots of *E. coli* Data from the Stormwater BMP Database
(Source: UWRRC 2014)



Note: See Table 6-8 for abbreviations and corresponding data. Red dashed line corresponds to geometric mean primary contact recreational water quality criteria recommended by EPA for *E. coli* of 126 cfu/100 mL.

6.2.3 Agricultural BMPs—General Practices

6.2.3.1 Overview of Practices

Agricultural conservation practices require site-specific knowledge that balances operations and production objectives with water quality protection. Effectiveness of these practices depends on-site specific characteristics and implementation practices. The NRCS Electronic Field Office Technical Guide (eFOTG) provides descriptions and specifications for many practices that could be implemented in the St. Vrain Basin (see http://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/technical/?cid=nrcs144p2_062771). Brief descriptions of general practices that should be considered when trying to reduce nutrient and bacteria loading on agricultural lands follow.

- Irrigation Management: The NRCS defines irrigation management as the process of determining and controlling the volume, frequency and application rate of irrigation water in a planned, efficient manner. Flood/furrow irrigation remain common practices in Boulder County. Conversion of flood irrigation to center pivot irrigation practices in encouraged by the NRCS field office.

- Nutrient Management Plans: Nutrient management plans manage the amount, source, placement, form and timing of the application of plant nutrients and soil amendments. These plans are designed to: 1) budget and supply nutrients for plant production, 2) properly utilize manure or organic byproducts as a plant nutrient source, 3) minimize agricultural nonpoint source pollution of surface and ground water resources, 4) protect air quality by reducing nitrogen emissions (ammonia and NOx compounds) and the formation of atmospheric particulates, and 5) maintain or improve the physical, chemical and biological condition of soil (NRCS 2006, Practice 590).

- Grazing Management: A grazing management plan is a site-specific conservation plan developed to address one or more resource concerns on land where grazing related activities or practices are planned and applied. These plans consider forage-animal demand balance to ensure the forage produced and available meets forage demand of livestock and/or wildlife. A grazing schedule that considers animal units and grazing periods is also included. The following resources are recommended for additional information pertinent to grazing management in Colorado:

    - National Range and Pasture Handbook, NRCS GLTI 2003 Chapter 4: Inventorying and Monitoring Grazing Land Resources, Chapter 11: Conservation Planning on Grazing Lands. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=STELPRDB1043084

    - Grazing Management Plan Practices Activity Code (110) (NRCS 2012). eFOTG Section III. Conservation Activity Plans. http://efotg.sc.egov.usda.gov/references/public/CO/CO110_CAP_GM.pdf

    - National Standard and State Specification for Prescribed Grazing Code 528. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025729.pdf

    - NRCS National Planning Procedures Handbook. January 2013. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=33237.wba

    - National and State Resource Concerns and Planning Criteria. Colorado eFOTG. Section III. http://efotg.sc.egov.usda.gov/references/public/CO/CO_ResourceConcerns&PlanningCriteria.pdf

    - Passey, H.B 1969. The Art of Communication: Grazing Land Conservation and Application. ftp://ftpfc.sc.egov.usda.gov/NEDC/consplan/communication.pdf

- Filter Strips: Filter strips are vegetated areas that separate agricultural land and surface waters. They are designed to filter sediment, organic matter, nutrients, and contaminants from runoff. Vegetation in the filter strip slows down runoff and enhances infiltration, allowing sediment to drop out. Filter strips, also known as buffer strips, are most effective on evenly distributed runoff that enters as sheet flow. Design parameters including width and vegetation type depend on site characteristics such as contributing area, soil type, and climate. Proper maintenance is important to preserve effectiveness of the filter strip. Maintenance activities include sediment removal, mowing and weeding, and repair of rills or channelized flow areas.

- Grassed Waterways: Grassed Waterways are vegetated channels that transport runoff in a manner that minimizes erosion. Concentrated flow can be slowed down and vegetation removes nutrients and sediment from field runoff. Grassed waterways may be a good option for conveying runoff from steeper slopes or terraces where channel or gully erosion is a concern. Design of grassed waterways is site-specific. Cross sections may be trapezoidal or parabolic but should be designed to decrease flow velocity to enhance pollutant removal. Care of vegetation and regular maintenance of grassed waterways are important considerations.

- Riparian Buffers: Riparian buffers are areas of vegetation surrounding receiving waters which function to reduce pollutant and sediment loading and maintain healthy ecosystems. Riparian buffers may have multiple vegetation zones between waterbodies and agricultural land such as native vegetation, managed forest, and grass zones. In addition to providing water quality benefits, riparian vegetation also can help stabilize streambanks and provide wildlife habitat. Climate, terrain and soil type are among the factors that need to be accounted for when implementing a riparian buffer. Exclusion of livestock from riparian zones may allow for regeneration of native vegetation and establishment of a riparian buffer which can provide filtering benefits.

- Conservation Tillage: Conservation tillage is principally a way of reducing erosion from agricultural fields but can also help reduce nutrient losses in runoff. Conservation tillage is a practice that involves crop and plant residue left on the soil surface. No-till and strip-till are types of conservation tillage wherein crops are planted on fields where residue has not been tilled or has only been tilled in narrow strips. Various different types of conservation tillage may be implemented depending on equipment and site-specific conditions. Conservation tillage practices increase organic matter and moisture to soil and are very effective in reducing sheet, wind and rill erosion.

- Cover Crops: Cover crops include grasses, legumes, forbs, or other herbaceous plants established for seasonal cover and conservation purposes. Representative benefits include: reducing erosion from wind and water; increasing soil organic matter; capturing and recycling or redistributing excess nutrients in the soil profile; promoting biological nitrogen fixation and reducing energy use; increasing biodiversity; weed suppression; soil moisture management; minimizing and reducing soil compaction; protecting growing crops from damage by wind-borne soil particles; and providing supplemental forage.

- Grade Stabilization and Channel Protection: Grade stabilization involves structures installed to control natural stream gradients and reduce erosion potential and sediment transport. Grade stabilization structures may be constructed out of a variety of materials such as concrete, rock, earth or steel. Channel protection measures to stabilize channel beds also help control stream gradients and manage sediment transport.

6.2.3.2 Effectiveness of Agricultural BMPs in Reducing *E. coli*

Many studies have been conducted to evaluate the effectiveness of various agricultural BMPs for reducing *E. coli*. Although multiple practices appear to provide bacteria reduction benefits, the removal efficiencies vary widely based on site-specific conditions and there is uncertainty regarding achievable runoff concentrations. Table 6-9 provides a summary of some of the ranges of bacteria reductions reported in the literature. When evaluating expected effectiveness of agricultural BMPs, it is recommended that effluent concentrations (and loads) be reported due to the significant limitations associated with percent removal as a performance metric. Table 6-9 is useful for developing a general sense of whether a practice may be beneficial, but is not directly transferable in terms of absolute percent reductions for a specific site. An excellent resource on grazing-related BMPs is the Texas Water Resource Institute's website: http://lshs.tamu.edu/.

Despite the uncertainties related to achievable runoff concentrations, the following recommendations by Osmond et al. (2007) are good general guidance to consider for creek-side pastures:

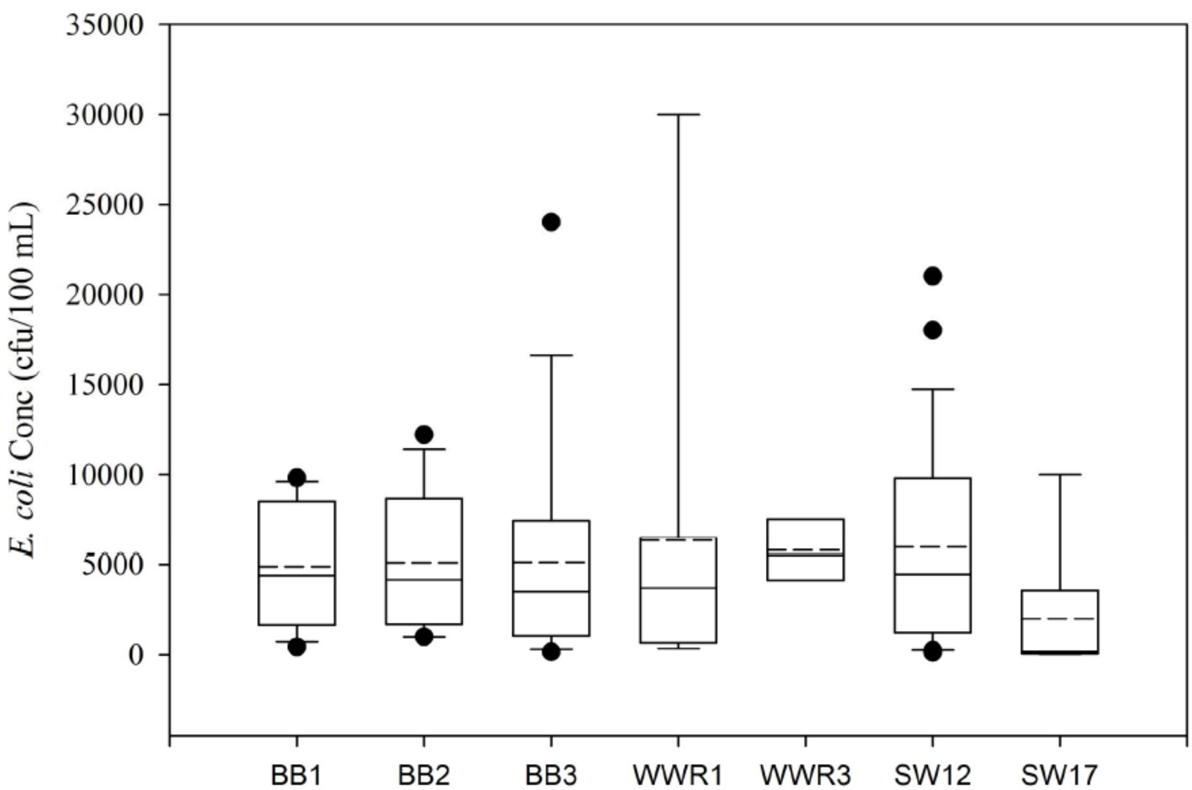
1. *Practices should be used that encourage more uniform livestock distribution over the pasture.*
2. *Riparian areas should not be used as shade paddocks, holding areas, or feeding areas. In addition, because riparian areas are very important in maintaining water quality, rotational stocking systems should be encouraged that limit the duration of grazing in riparian areas to a maximum of 3 days and that provide an adequate nongrazing recovery period of 3 weeks.*
3. *Access to the riparian area should not occur (a) when soils are wet or boggy, and (b) when acceptable forage is available on riparian sites within the same grazing unit.*
4. *Consider using goats or sheep to graze riparian areas in preference to cattle or horses.*
5. *Fencing is the most reliable way to minimize the impacts of livestock on riparian areas. If, however, this is not possible, at least fence the most vulnerable streamside corridors for complete habitat preservation, while providing strategic access to drinking water for grazing animals.*

Table 6-9. Example Ranges of Livestock-related Agricultural BMP Performance

BMP Type	Reduction of Bacteria Reported by Researcher	Source
Filter Strip	16% (FC) for 0.5% slope, 91 m buffer, feedlot runoff	Dickey & Vanderholm 1981 in Wagner et al. 2008
	74% (FC) for 9% slope, 9m buffer, poultry litter, no-till cropland	Coyne et al. 1995 in Wagner et al. 2008
	43% (FC) for 9% slope, 9m buffer, poultry litter, conv. till cropland	Coyne et al. 1995 in Wagner et al. 2008
	70% (FC) for 4% slope, 36 m buffer, feedlot runoff	Young et al. 1980 in Wagner et al. 2008
	59% (FC) (for contour buffer strips)	Minnesota Department of Agriculture (2012)
Alternative Water Source	85-95% (EC)	Byers at al. 2005, cited in Wagner et al. 2008
	51% (FC)	Sheffield 1997, cited in Wagner et al. 2008
	NSD (EC)	Wagner et al. 2011
Exclusionary Fencing	30% (FC)	Brenner et al. 1994, cited in Wagner et al. 2008
	41% (FC)	Brenner 1996, cited in Wagner et al. 2008
	66% (FC)	Line 2003, cited in Wagner et al. 2008
	99% (FC)	Minnesota Department of Agriculture (2012)
	22% - 35% (modeling estimate)	Collins et al., 2004
Rotational Stocking/Grazing	88 to 99% (EC) (potential expected effectiveness)	Wagner (2011) (If utilize rotational grazing and graze creek pastures when runoff less likely)
EC = *E. coli*; FC = Fecal coliform; NSD = no significant difference		

A significant constraint in estimating the effectiveness of agricultural BMPs (or the effluent concentrations that can be achieved) is background concentrations of bacteria that may persist, despite implementation of agricultural background *E. coli* concentrations. For example, Wagner (2011) identified significant and highly variable median concentrations of *E. coli* ranging from 1,000 to 10,000 and no significant difference between *E. coli* concentrations observed in runoff from destocked sites and ungrazed sites based on research in Texas. Figure 6-5 summarizes "background" *E. coli* concentration at various Texas agricultural research sites (Wagner 2008).

Figure 6-5. "Background" *E. coli* Concentrations at Texas Agricultural Research Sites
(Source: Wagner et al. 2008)



6.2.3.3 <u>NRCS Conservation Activity Plans in Colorado</u>

Farm Bill legislation provides NRCS the authority to use financial assistance through the Environmental Quality Incentives Program (EQIP) for conservation practice payments to develop plans appropriate for the eligible land of a program participant. The conservation practice associated with plan development under this authority is known as a "Conservation Activity Plan", or CAP. These priorities can change from year to year, with the 2014 priorities summarized in Table 6-10. Because agricultural conservation plan needs and objectives are site-specific, development of an individualized plan is important. Many activities that help to reduce pollutant loading from agricultural practices are in-field operational practices that can be identified and developed in such plans.

The conservation activity plan practices most directly relevant to the objectives of this Watershed Plan include:

- Comprehensive Nutrient Management Plan (102) and Nutrient Management Plan (104)
- Grazing Management Plan (110)
- Irrigation Water Management Plan (118)
- Drainage Water Management Plan (130)

Table 6-10. 2014 Conservation Activity Plans in Colorado
(Source: NRCS 2014; accessible at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/programs/financial/eqip/?cid=stelprdb1240806)

NRCS Code	Conservation Activity Plan Name	General Description
102	Comprehensive Nutrient Management Plan	A comprehensive nutrient management plan (CNMP) is a conservation plan for an animal feeding operation (AFO) that documents how nutrients and contaminants will be managed in the production and land treatment areas of the farm to protect animal & human health, and the environment.
104	Nutrient Management Plan	Nutrient management plans are documents of record of how nutrients will be managed for plant production and to address the environmental concerns related to the offsite movement of nutrients from agricultural fields.
106	Forest Management Plan	A forest management plan is a site specific plan developed for a client, which addresses one or more resource concerns on land where forestry-related conservation activities or practices will be planned and applied.
108	Feed Management Plan	A feed management plan is a farm-specific documented plan developed for a client who addresses manipulation and control of the quantity and quality of available nutrients, feedstuffs, and/or additives fed to livestock and poultry.
110	Grazing Management Plan	A grazing management plan is a site-specific plan, developed with a client to address one or more resource concerns on land where grazing related activities or practices will be applied.
112	Prescribed Burning Plan	A prescribed burning plan is a site-specific plan developed with a client that addresses one or more resource concerns on land through the use of fire.
114	Integrated Pest Management	Integrated pest management (IPM) is an ecosystem-based strategy that is a sustainable approach to manage pests using a combination of techniques such as chemical tools biological control, habitat manipulation, and modification of cultural practices and use of resistant varieties.
118	Irrigation Water Management Plan	The objective of irrigation water management (IWM) is to control the volume, frequency, and rate of water for efficient irrigation. Measurements of soil moisture, plant water use, and climate provide feedback to decide when to irrigate, and how much water to apply.

NRCS Code	Conservation Activity Plan Name	General Description
122	Agricultural Energy Management Plan – Headquarters	An agricultural energy management plan – headquarters (AgEMP) is a detailed documentation of energy-consuming components and practices of the current operation, the previous year's on-farm energy consumption, and the strategy by which the producer will explore and address their on-farm energy conservation concerns, objectives, and opportunities.
124	Agricultural Energy Management Plan – Landscape	A landscape energy plan is a detailed report/audit documenting the energy consuming components and practices of the current operation's on-farm field energy consumption involved in the cropland, pasture/hayland, range, and woodland activities with recommended strategies to conserve energy resources.
126	Comprehensive Air Quality Management Plan	Comprehensive air quality management plans (CAQMPs) may be part of conservation plans applicable to many agricultural operations. These plans assess practices and strategies adopted by agricultural operations to address environmental concerns directly related to air quality and atmospheric change.
130	Drainage Water Management Plan	The objective of drainage water management (DWM) is to control soil water table elevations and the timing of water discharges from subsurface or surface agricultural drainage systems, allowing the opportunity for crop use of the subsurface water and nutrients.
134	Conservation Plan Supporting Transition from Irrigation to Dryland Plan	A transition from irrigated to dryland farming and ranching conservation activity plan is a conservation system that focuses on crop yield sustainability and water conservation/water harvesting techniques.
138	Conservation Plan Supporting Organic Transition	A "Conservation Plan Supporting Organic Transition" is a conservation activity plan documenting decisions by producers/growers who agree to implement a system of conservation practices which assist the producer to transition from conventional farming or ranching systems to an organic production system.
142	Fish and Wildlife Habitat Plan	A fish and wildlife habitat plan is a site-specific plan developed with a client who is ready to plan and implement conservation activities or practices with consideration for fish and wildlife habitat.

NRCS Code	Conservation Activity Plan Name	General Description
146	Pollinator Habitat Plan	A pollinator habitat enhancement plan is a site-specific conservation plan developed for a client that addresses the improvement, restoration, enhancement, expansion of flower-rich habitat that supports native and/or managed pollinators.
154	IPM Herbicide Resistant Weed Conservation Plan	Integrated pest management herbicide resistance weed conservation plan is a plan with emphasis on modifying herbicide use for suppressing weeds.

6.2.4 Agricultural BMPs—Public Lands

Boulder County has developed policies related to agricultural production and grassland on county open space properties that include elements likely to decrease loading of bacteria, nutrients and other pollutants. These policies are described below.

6.2.4.1 Boulder County Grassland Policy

Boulder County is developing an overarching policy for the management of grasslands and shrublands on properties owned and managed by the Parks and Open Space Department. The policy will provide a framework for consistent grassland and shrubland management and improve management efficiency.

The policy is part of a larger effort to create management policies for certain land covers (i.e. grassland, shrubland, and forest), land uses and designations (i.e. visitor use, cropland, conservation easements), and particular resources (i.e. cultural resources, water, wildlife). Each policy will serve as an essential link between the overarching management guidance provided in the Boulder County Comprehensive Plan and property-specific management plans.

The county currently owns and manages 14,223 acres of grasslands, which includes over 9,000 acres of native grasslands and slightly less than 2,000 acres of restored grasslands, and 4,867 acres of shrublands. These lands are currently managed for:

- Plant and wildlife habitat
- Livestock production
- Recreation
- Education and outreach
- Community buffers
- Scientific investigation

A number of tools and practices are also utilized to sustainably manage these areas such as revegetation, weed control, prescribed fire, livestock grazing, mowing, rest, and wildlife management (Figure 6-6). The policy will guide the future management of these ecosystems. For more information, see http://www.bouldercounty.org/os/openspace/pages/grasspland.aspx.

Figure 6-6. Summary of Grassland Management Tools Implemented by Boulder County

6.2.4.2 Boulder County Agricultural Lands Policy

Boulder County manages approximately 25,000 acres of agricultural land and leases it to qualified operators, with acreages shown in Table 6-11. Crops grown on this land include alfalfa and grass, wheat, barley, corn, sugar beets, pinto beans and sunflowers. The Parks and Open Space Agricultural Resources Division oversees the land, manages the leases, and tracks rent and crop production. The county has a written cropland policy (Boulder County 2011), which can be accessed at: http://www.bouldercounty.org/doc/parks/croppolicy.pdf.

Table 6-11. Summary of Agricultural Lands Managed by Boulder County

Land Type	Acres
Irrigated Cropland	16,000
Dryland Cropland	4,000
Range	7,000
Out of Production (Roads, ditches, buildings, wildlife habitat, other)	-2,000
Total Active County Agricultural Land	**25,000**

Ongoing management practices implemented by Boulder County for these lands include:

- Evaluating and exercising water rights, lining and maintaining irrigation ditches and reservoirs.
- Installing center-pivot irrigation systems to cut water use in half and reduce soil erosion by 95%.
- Fencing cropland and riparian areas to help achieve our livestock management goals.
- Re-vegetating lands taken out of production and converting marginal cropland back to grassland.
- Mapping properties using GIS to track and compare farm yields and efficiencies.
- Combating noxious weeds.

6.2.4.3 City of Boulder Open Space and Mountain Parks

The City of Boulder's Open Space and Mountain Parks (OSMP) Department currently leases almost 15,000 acres to local farmers and ranchers for the production of livestock, fruits, vegetables and forage. Nearly 80 percent of this acreage is used exclusively for cattle grazing because of water availability, slopes, and compatibility with ecological conservation. Currently, 470 acres of agricultural land are used for the production of locally-marketed food products, including natural beef, lamb and honey, as well as fruits and vegetables. Several written policies are in place, key examples include the 2009 Grasslands Policy and a new Agricultural Management Plan, which began being developed in 2014.

The Grasslands Policy (2009) included recommendations for conservation practices pertinent to this Watershed Plan. Enhanced prescribed grazing is one of these practices, which includes improvements to fencing, livestock watering facilities, stocking rate and seasonal use adjustments, and the establishment of one or more grass banks. Grazing is an important process structuring Grassland Plan targets. Increasing flexibility of livestock grazing gives OSMP greater ability to manage grasslands toward acceptable conditions of vegetative structure and composition. This strategy includes:

- Evaluating fencing alignments to allow OSMP to use rotational, deferred (rest rotation) and seasonal stocking systems in response to management needs.
- Developing water sources to improve OSMP's flexibility in distributing livestock.
- Evaluating the potential to manage selected OSMP lands as grass banks (grazing reserves).

- Adjusting stocking rates, timing and duration to achieve acceptable conditions.

Implementation of changes to grazing management will be integrated with other grassland plan strategies, especially fire management and IPM to develop specific treatments for specific areas.

In July of 2014, OSMP staff began the planning process for an Agricultural Resources Management Plan (Agricultural Plan). The purpose of the Agriculture Plan is to ensure the long-term sustainability of agricultural operations and the ecological health of OSMP lands as well as to foster connections between the community and agricultural operations. The Agriculture Plan will begin where OSMP's Grassland Ecosystem Management Plan left off and provides specific direction and commitments about how the city will manage and monitor sustainable agricultural operations.

The Agriculture Plan, as proposed, will provide direction and objectives for specific topics related to agricultural operations on OSMP, including:

- Managing agricultural activities to minimize soil erosion and protect soil fertility.
- Enhancing prescribed grazing program through improvements to fencing, livestock watering facilities, stocking rate and seasonal use adjustment, and the establishment of one of more grass banks (areas under lease that are not grazed - leaving them available to shift grazing there if conditions elsewhere determine such a shift would be beneficial).
- Improving the irrigation delivery system.
- Identifying and obtaining water rights needed to support irrigated agriculture.
- Analyzing methods to establish connections between producers and local consumers/community.
- Evaluating the suitability of OSMP lands for diversified vegetable farming and local food production.
- Conserving populations of native plants and animals through the use of traditional and innovative agricultural practices.
- Managing Ute ladies'-tresses orchid habitat with compatible grazing, haying and irrigation practices.
- Developing an IPM policy specific to OSMP agricultural lands.

6.2.5 Agricultural BMPs—Barnyards/CAFO/AFO

Most of the general agricultural BMP practices discussed in Section 6.2 are oriented toward crops or grazing; however, barnyards and some animal feeding operations are present in the watershed, warranting a different types of agricultural BMPs. CDPHE recommends implementation of BMPs for animal feeding operations (see https://www.colorado.gov/pacific/cdphe/protecting-environment). Brief descriptions of representative practices include:

1. Divert runoff away from animal confinement areas, manure stockpiles and wastewater control facilities by:
    - Constructing ditches, terraces or other waterways.
    - Installing gutters and downspouts to divert roof drainage.
    - Building roofs over animal confinement areas, where practical.
2. Reduce wastewater discharges to watercourses by:
    - Collecting and allowing wastewater to evaporate.
    - Collecting and evenly applying wastewater to land application sites at agronomic rates.
    - Locating animal waste away from stormwater runoff, streams, ditches or other channels that can carry waste.
3. Protect groundwater by:
    - Maintaining a buffer area around water wells when applying manure and wastewater to land.
    - Locating manure and wastewater facilities downhill and at least 150 feet away from all water supply wells.
    - Installing liners in wastewater impoundments to reduce seepage if a significant risk of groundwater contamination exists.

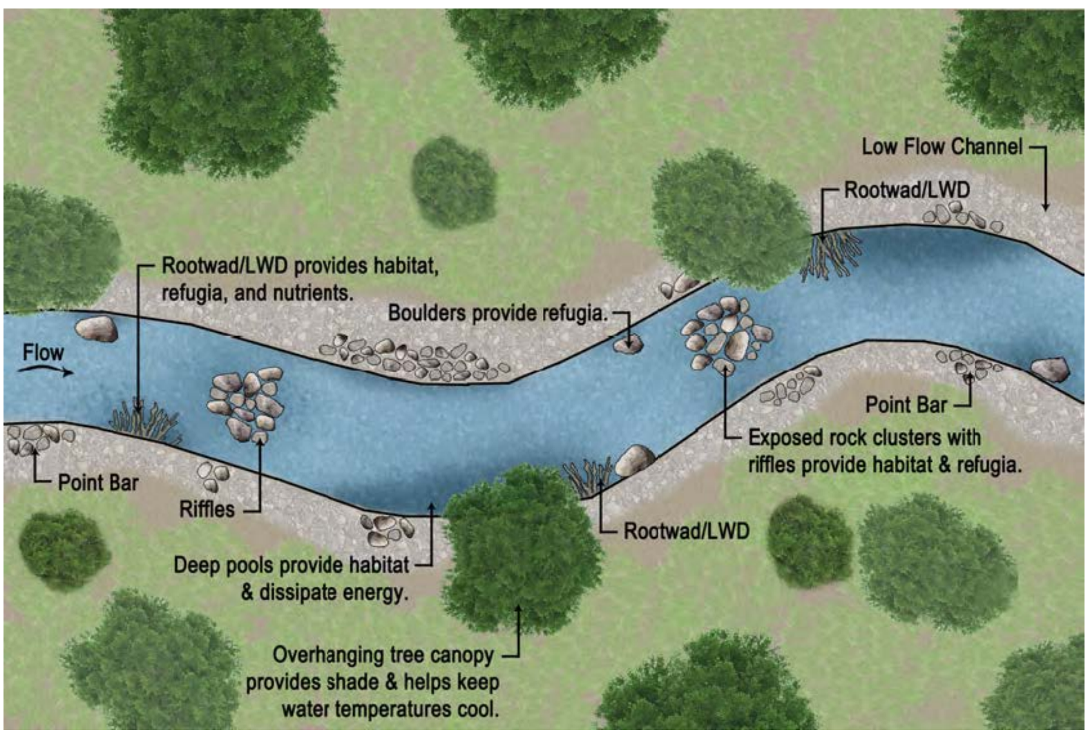
6.2.6 Channel Restoration Practices Benefiting Aquatic Life

For major channel improvements, master planning results in identification of potential solutions in an orderly and comprehensive manner. From a water quality and aquatic life perspective, there may be opportunities to provide water quality enhancements for planned projects. For example, master drainage planning was recently completed for Rock Creek and

Coal Creek (RESPEC 2015). Because channel and floodplain improvements are often already supported under existing capital improvement programs, these represent opportunities for water quality staff to encourage implementation.

Additionally, as a result of channel restoration efforts planned in response the 2013 flood, channel improvements are planned for some stream segments to increase in-stream habitat complexity, which is anticipated to benefit aquatic life (Figure 6-7). In-stream features typically consist of natural materials, predominantly large rock and wood. Examples of in-stream features that can be used to increase habitat complexity include: constructed riffles, pools, step pools, step pools, root wads and large woody debris and instream boulders (Baker et al. 2014a.) Although a reach-by-reach discussion of such practices is far beyond the scope of this Watershed Plan, watershed stakeholders should be aware that these planned channel restoration practices may provide significant aquatic life benefits that align well with this Watershed Plan.

Figure 6-7. In-Stream Stability and Habitat Examples
(Source: St. Vrain Creek Watershed Master Plan, Baker et al. 2014a)



6.3 Watershed Management Action Strategy by Pollutant Type

Once sources of pollutants are identified, then management strategies can be selected and scheduled for implementation. These strategies will vary depending on property ownership (public vs. private), and whether development is new or existing. When prioritizing strategies and programs, it is recommended that multiple factors be considered and weighed so that practices expected to be most effective and that provide multiple benefits receive highest priority. As an example, the City of Boulder (2011) considers the following factors related to Greenways Projects:

- Benefits (active threat abatement rank, leverage, and overall benefits)
- Feasibility (lead individual/institution, ease of implementation, overall feasibility)
- Cost
- Habitat quality
- Overlap or conflict with other projects or entities
- Objectives within the area/reach
- Property ownership
- Risk of failure

6.3.1 *E. coli*

Based on review and analysis of available data, the recommended strategy for reducing *E. coli* loading in urban portions of the watershed includes the following steps:

1. Monitor to refine understanding of sources of *E. coli*. The monitoring program should include compilation and systematic storage of data pertinent to characterizing *E. coli* sources and loads.

2. Focus first on dry weather and human-related sources of *E. coli*.

3. Correct sanitary sources contributing to storm sewers and/or poorly functioning septic systems.

4. After dry weather sources are addressed, then determine whether realistic opportunities exist for implementation of wet-weather controls.

5. Continue to implement pet waste controls.

Based on review and analysis of available data, the recommended strategy for reducing *E. coli* loading in agricultural portions of the watershed includes the following steps:

1. Monitor to refine understanding of sources of *E. coli*. The monitoring program should include compilation and systematic storage of data pertinent to characterizing *E. coli* sources and loads.

2. Assess potential septic system contributions of *E. coli*.

3. Assess agricultural animal related contribution of *E. coli*, such as from cattle grazing, barnyards, and confined animal feeding operations.

4. Assess potential *E. coli* contribution from fertilizer application, irrigation water and other agricultural operational sources.

This strategy is refined into an Implementation Plan in Chapter 7.

6.3.2 Metals

6.3.2.1 Selenium in Rock Creek/Coal Creek Subwatershed

The recommended strategy for addressing selenium standard exceedances in the watershed is to first characterize the extent to which natural geologic sources in the watershed contribute to these exceedances. Based on experiences in adjacent watersheds, it is expected that a proposal for an ambient-based site-specific standard based on "natural or irreversible human-induced conditions" should be prepared and submitted as part of the Regulation 38 triennial review. Information contained in the monitoring program described in Appendix C and the geologic information provided in Figure A-6 can be used to support this request. Similar concentrations of selenium were identified in the Big Dry Creek Watershed, just south of the Rock Creek watershed and were determined to be due to natural geologic sources, particularly seasonally at certain locations with low flows dominated by groundwater (Wright Water Engineers 2007). An ambient-based site-specific standard was developed and agreed upon by the Division, Commission and EPA, as documented in Regulation 38.

It is recommended that the local governments on Rock Creek and upper Coal Creek meet with the Division to determine what type of additional sampling would be needed to form the basis of a site-specific standard. With ambient based standards, it is important that concentrations under a range of hydrologic conditions are represented; otherwise, the ambient-based standard may underestimate concentrations (which can result in listing/delisting cycles, depending on the stream hydrology). As part of data collection, it is important that the hydrologic conditions at the time of sampling be well represented. Because there is some irrigated agriculture in a portion of the Rock Creek drainage, it may be necessary to characterize its potential influence on selenium concentrations. A full characterization of selenium conditions to support a site-specific standard is beyond the scope of this Watershed Plan.

6.3.2.2 Metals in Left Hand Creek Subwatershed

The June 2015 Final Draft TMDL for Left Hand Creek, James Creek and Little James Creek include these targeted load reductions for various metals:

- For COSPSV04a: the TMDLs require 67%-77% reduction in cadmium, 81%-98% reduction in copper, and 40%-88% reduction in zinc.
- COSPSV04b: TMDLs were developed for three reaches in COSPSV04b: James Creek above Little James Creek (James Creek above Little James Creek), Little James Creek (Little James Creek) and James Creek below Little James Creek
  - For James Creek above Little James Creek, the TMDLs require 14%-50% reduction in cadmium, 35% to 41% reduction in copper, 62%-95% reduction in lead and 45%-89% reduction in zinc
  - For Little James Creek, the TMDLs require 72%-98% reduction in cadmium, 57%-99% reduction in copper, 54%-96% reduction in lead and 66%-99% reduction in zinc.
  - For James Creek below Little James Creek, the TMDLs require 21%-80% reduction in cadmium, 17%-90% reduction in copper, 37%-95% reduction in lead, and 46-88% reduction in zinc.

Because there are no active mines or mills currently operating in the Left Hand Creek Watershed, reductions in loads cannot be achieved through controls required under discharge permits. The Captain Jack Mine and Mill site within the Left Hand Creek Watershed is listed on the EPA's National Priorities List (NPL) for environmental clean-up.

The 2005 Left Hand Creek Watershed Plan (LWOG 2005) remains the best overall strategy for reducing loads of these metals. The recommended BMPs for prioritized reclamation efforts are provided in Appendix F to this Watershed Plan. Table 6-12 lists the prioritized mine sites. Reclamation and treatment methods presented in the Left Hand Creek Watershed Plan (LWOG 2005) generally include:

1. Surface and Subsurface Hydrologic Controls: These are generally preventative measures intended to inhibit the processes or acid formation or toxic metal dissolution by minimizing or eliminating the contact of water with mine wastes, particularly sulfide minerals. Surface hydrologic controls include surface and groundwater diversion features, mine waste removal, consolidation, and stabilization, capping, and revegetation.

2. Passive Treatment: Passive treatment techniques refer to a range of low maintenance drainage treatment strategies. Passive treatment BMPs include anoxic limestone drains,

settling ponds, sulfate reducing wetlands, oxidation wetlands, aeration, and neutralization systems.

Table 6-12. Left Hand Creek Watershed Prioritized Mine Sites
(Source: LWOG 2005)

Priority Ranking of Mine Sites	Mine Name
High Priority Mine Sites	• Bueno Mountain (James Creek and Little James Creek) • Burlington Mine Pond (Little James Creek) • Roadside Tailings (Little James Creek) • Streamside Tailings (Little James Creek)
Medium Priority Mine Sites	• Loder Smelter (Left Hand Creek) • Slide Mine (Left Hand Creek) • Castle Gulch (James Creek) • Evening Star Mine (Little James Creek)
Low Priority Mine Sites	• Indiana Gulch (Left Hand Creek) • Nugget Gulch (Left Hand Creek) • Lee Hill Gulch (Left Hand Creek) • Carnage Canyon Gulch (Left Hand Creek) • Sixmile Creek (Left Hand Creek) • John Jay Mine (James Creek)
Under-characterized Mine Sites	• See LWOG (2005)
Active and Post-Reclamation Mine Sites	• All sites within the Captain Jack Mine and Mill Superfund site on Left Hand Creek, from the Peak-to-Peak Highway to approximately 2.5 km downstream from the site. • Fairday Mine (James Creek). • Burlington Mine (Little James Creek).

6.3.2.3 Mining-Related Metals in Gamble Gulch (Tributary to South Boulder Creek)

From 1994 through 1999, River Watch, in conjunction with the Logan School for Creative Learning constructed a wetland in Gamble Gulch. This project was funded with Nonpoint Source funds. Experiments were performed using phytoremediation to mitigate the effects of heavy metal waste from the abandoned mine site. Because of limited funding and ongoing operation and maintenance requirements, as well as liability issues, the remediation efforts were conducted as a demonstration project. As such, the phytoremediation demonstration was not continued. Cadmium and zinc levels continue to exceed the current water quality standards. A substantial reduction of metals from Tip Top mine would be necessary to meet the TMDL load target (Division 2010). Planning and design for cadmium and zinc remediation at the Tip Top mine have been undertaken, but remediation has not yet been implemented (Communication with Division 2016). Addressing elevated metals in Gamble Gulch is beyond the scope of this Watershed Plan at this time.

6.3.3 Nutrients

Development of TMDLs for potential future nutrient impairments is premature, given that no stream standards for nutrients have yet been adopted downstream of WWTP discharges, which is where concentrations of nutrients are elevated above interim values for the locations evaluated in the St. Vrain Basin. Recognizing the dominant influence of municipal WWTP discharges, the recommended strategy for purposes of this Watershed Plan is that urban and agricultural BMPs that reduce nutrient loading should be encouraged; however, given the controlling influence of the WWTP discharges, it is unlikely that nonpoint source load reductions would be sufficient to meet instream “values” below WWTP discharges in the basin. Nonetheless, nutrient load reduction is an area where “Integrated Planning” concepts may be applicable, in accordance with guidelines provided by EPA (2011).

6.3.4 Aquatic Life

TMDL development for aquatic life impairment is not recommended at this time due to additional research needed to 1) verify whether impairment exists and 2) determine the cause of the impairment, which would be the basis for determining the types of load reductions needed if the impairment is due to pollutant loading. The on-going biological monitoring program (including locations in Appendix C) can be used to further support this process. One outstanding issue regarding potential aquatic life impairments is whether the particular reach of stream is truly impaired and whether the Policy 10-1 metrics are accurately capturing aquatic life conditions expected or attainable at these particular sites. For example, portions of the St. Vrain Basin segments are located on the boundary of Biotypes 1 and 3. In at least one case (BC-bcc), initial analysis suggests that the segment would be more appropriately classified as Biotype 3, in which case, the segment would not be considered impaired for aquatic life. Factors such as elevation, stream gradient and hydrologic limitations (e.g., lack of flow) may all affect the types of aquatic life present for a particular segment, prior to considering the impacts of pollutant loading. It is recommended that the current biological monitoring program be continued for each stream segment that local governments continue to work with their biological consultant to further evaluate aquatic life conditions, coordinating as appropriate with the Division.

6.4 Watershed Management Action Strategy by Source Type

The overall watershed management action strategy includes these general strategies, which are further outlined in the Implementation Plan in Chapter 7.

- **Source Characterization:** Regardless of the pollutant type, source characterization through monitoring, desktop records review and field investigations is recommended as a first step to refine understanding of pollutant sources so that BMPs can be most effectively targeted to control pollutant loading and so that finite financial resources can be allocated to maximize pollutant reduction benefits.

- **Source Controls/Public Education:** Source controls are typically the best first step in reducing pollutant loading, and this is particularly true for bacteria. The Keep It Clean Partnership's educational campaigns are a key component in educating the public about actions that they can take to reduce pollution at its source.

- **Stormwater Quality BMPs**: Construction and post-construction stormwater quality BMPs should continue to be implemented following the recommendations of Volume 3 of the Urban Drainage and Flood Control District *Urban Storm Drainage Criteria Manual*, particularly in MS4 permit-covered areas. Because of the general nature of this Watershed Plan, more detailed recommendations regarding specific locations for BMP installation are not appropriate at this time. As a general recommendation for bacteria, practices that provide runoff volume reduction through infiltration and/or filtration (e.g., sand filter, bioretention) are expected to be most beneficial for bacteria reduction. Subsurface wetlands and wet ponds with permanent pools may also help to reduce bacteria concentrations; however, water rights and space constraints may preclude their use for new developments and redevelopments in some locations.

- **Agricultural Sources on Public Lands**: To identify and control agricultural sources on public lands, it is important to work with entities such as Boulder County Parks and Open Space, City of Boulder Open Space and Mountain Parks, and others to identify opportunities for implementation of agricultural BMPs in accordance with established policies. For agricultural areas, potential reductions in pollutant loading will be determined by the extent to which practices are already in place on specific parcels. For example, some parcels may have significant opportunity for improvements, whereas others may already be implementing agricultural BMPs such as fencing, rotational grazing and irrigation management. Keep It Clean Partnership is also coordinating with Boulder County Parks and Open Space with regard to a water quality monitoring program that is being developed to assess the effectiveness of various practices implemented on County lands.

- **Agricultural Sources on Private Lands**: On private lands, it is recommended that local governments support existing efforts through the NRCS and Extension to encourage implementation of BMPs on private lands.

- **Legacy Mining Impacts in Left Hand Creek Watershed**: Support refinement of mine prioritized reclamation activities described in Appendix F through an enhanced monitoring program.
- **Stream Restoration**: Basin master plans developed in response to the September 2013 flood provide a prioritized framework for stream reaches in need of channel restoration. As these plans enter final design phase and are implemented, there may be opportunities for watershed stakeholders to encourage design features that provide multi-objective benefits, including water quality and aquatic life, as part of repairs are made to the stream channel.
- **WWTP Upgrades to Meet Regulation 85 Requirements**: Nutrient load reductions from WWTPs are being addressed under Regulation 85 requirements. Plant upgrades to meet these requirements will be costly and will be implemented over time, typically through use of compliance plans outlined in discharge permits.

6.5 Cost Benefit Analysis

A formal cost-benefit analysis has not been conducted for this Watershed Plan due to the "framework" nature of the initial plan. Additional data are needed to determine specific projects that need to be undertaken to reduce pollutant loading; otherwise, expensive structural improvements may be implemented that do not result in the desired outcomes related to pollutant load reduction. Appendix G contains cost data for urban and agricultural BMPs (based on EQIP) that can be referenced in future releases of this Watershed Plan for implementation of specific BMPs. As a general strategy, this Watershed Plan recommends source controls first, then structural controls.

6.6 Coordination with Other Efforts

The local governments within the watershed have many on-going activities and plans that benefit water quality and aquatic life. There are opportunities to support existing plans that further the water quality objectives identified in this Watershed Plan. A list of some of these plans was previously provided in Table 1-13 and is not repeated in this section. However, it is worthwhile to recognize that coordination with other efforts is a key tool in stretching limited budgets. When riparian buffer features, stream restoration projects and other infrastructure improvements are being planned and implemented, it may be possible to incorporate water quality and aquatic life enhancements that would have otherwise been infeasible as stand-alone projects. Interdepartmental communication within and among local governments is important to take advantage of these opportunities.

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7.0 Implementation Plan Elements

This chapter integrates the findings of Chapters 1 through 6, culminating in a coordinated Implementation Plan that addresses EPA's Nine Elements of a Watershed Plan. Because of the 980-square-mile size of the St. Vrain Basin and data gaps regarding sources of pollutants, the plan is presented as a general framework. As actions are planned and implemented on a smaller scale, then more refined plans and cost estimates can be developed. Section 7.1 provides the Implementation Plan elements, Section 7.2 identifies technical and financial resources that can be helpful in executing this Watershed Plan, and Section 7.3 addresses how this Watershed Plan fits into the TMDL process, which may be considered in the future for certain stream segments in the St. Vrain Basin.

7.1 Implementation Plan Elements (Actions, Milestones and Costs)

The Implementation Plan for the initial release of the Watershed Plan is focused on these efforts: 1) monitoring and assessment to refine understanding of sources of pollutants, 2) public information and education, and 3) identification of BMPs effective in reducing pollutant loading for targeted pollutants. The following series of tables has been developed to support the Implementation Plan:

- Table 7-1 provides a broad, overall Implementation Plan framework for multiple issues identified in this Watershed Plan. Because *E. coli* impairments are a primary focus of this Watershed Plan, more specific Implementation Plan elements for *E. coli* are further developed in a series of supporting tables.

- Table 7-2 provides an Information and Education Plan that targets a wide range of urban pollutants through the existing framework of the Keep It Clean Partnership, as well as adds a few recommended educational efforts related to agricultural sources. The overall Information and Education Plan for this Watershed Plan will be coordinated by the Keep It Clean Partnership, building upon the existing communication pathways and processes developed over the past 13 years. For agriculture-related outreach, the Keep It Clean Partnership recognizes and defers to the existing leadership and communication framework in place in the watershed through the Colorado State University Extension and the NRCS. Although the Keep It Clean Partnership was formed to focus on stormwater MS4 issues, the group is exploring widening its focus to include non-point source efforts, which can also be supported through communication pathways established through the existing Keep It Clean program. The Keep It Clean Partnership will seek to coordinate and support efforts in the agricultural portion of the watershed, particularly with regard to opportunities on public lands.

- Table 7-3 provides a summary of near-term and long-term activities and milestones and an estimated cost table for the *E. coli* portion of the watershed plan. Implementation will depend on availability of funding, balancing multiple priorities in the watershed.

Because sources of *E. coli* have not yet been fully identified, Appendix G provides general cost data for various BMPs that can be further refined into more specific cost estimates once sources are more clearly identified and appropriate BMPs are selected in relation to the sources of *E. coli* being targeted.

- Table 7-4 provides a menu of BMPs for *E. coli* (developed from the information presented in Chapter 6) that provides relative cost and expected effectiveness information for BMPs to reduce *E. coli*. (As previously noted, additional cost information can be found in Appendix G.)

- Tables 7-5 and 7-6 provide the Boulder Creek Segment 2b *E. coli* TMDL action plan and timeline because the Boulder Creek TMDL approach is transferable to *E. coli*-related issues in other portions of the watershed, particularly in urban areas.

- Appendix F provides the Implementation Plan elements previously developed to address metals in the Left Hand Creek watershed, which remain the best currently available framework for addressing metals in the Left Hand Creek watershed.

From the information provided in these tables, a summary of key elements and associated costs based on this Watershed Plan include:

<u>Near Term (Beginning year 1 and on-going)</u>:

- Baseline Annual Funding for Outreach and Education: $100,000
- Baseline Annual Water Quality Report: $20,000 to 30,000

<u>Mid-Term (2-5 years)</u>:

- Enhanced Monitoring for Metals in Left Hand Watershed: $61,300
- Enhanced Monitoring for *E. coli*: $10,000 to 50,000 per targeted segment, depending on type and extent of effort
- 5-year Review and Update Watershed Plan: $20,000 to 30,000

<u>Long-Term BMP implementation</u> (Extending 20 years or longer)

- Estimated Cost Range per Square Mile of *E. coli* Reduction in Urban Areas: $1 to 8 million/square mile of targeted area, with improvements phased at $500,000 to $1,000,000/year
- Estimated Cost Range Per Square Mile of *E. coli* Reduction in Agricultural Areas: Cost varies per square mile of targeted area, with improvements phased at $25,000 to $100,000/year

Monitoring is a key component of this Watershed Plan at all stages of the plan. Monitoring components include:

- Baseline coordinated monitoring program (for locations described in Appendix C).
- Enhanced monitoring to refine understanding of pollutant sources (described above).
- Monitoring to evaluate success of implemented BMPs—although the baseline monitoring program can be used to evaluate success in terms of attainment of stream standards, which is the ultimate metric to determine whether designated beneficial uses are being attained, additional monitoring of specific practices will also be useful for determining which practices provide the greatest benefit per cost. The Boulder County Parks and Open Space program is currently developing a monitoring plan that can be used to evaluate effectiveness of targeted agricultural BMPs. This plan was not yet available at the time that this Watershed Plan was completed, but as a result of the Watershed Plan stakeholder process, increased coordination between the Boulder County Parks and Open Space monitoring plan and this Watershed Plan has occurred.

Although basic GIS mapping was developed to support this Watershed Plan, there are significant benefits to continuing to develop high quality GIS mapping and associated geodatabases for the watershed to support more robust spatially-based water quality analysis. Such analysis can be useful in refining understanding of pollutant sources, as well as for prioritization of BMPs. Given the multiple jurisdictions in the watershed, coordinating GIS coverages can be a significant, but worthwhile, undertaking as this Watershed Plan is updated in the future.

Table 7-1. Overall Watershed Plan Implementation Plan Framework

Water Quality Issue	Pollutant Sources	Watershed Locations/Segment Portions	Watershed Management Actions	Schedule/Costs	Measures of Success	Included in Education Program (Table 7-2)	Included in Another Existing Plan
E. coli							
Urban/MS4	Possible Sources (not confirmed): Sanitary Sewer Leakage Sanitary Sewer Illicit Connection Urban Wildlife (birds/raccoons) Pets Restaurants/Garbage Bins Transient/Homeless	Urbanized areas (e.g., City of Boulder, Longmont, Coal Creek Cities)	1. Determine sources. 2. Reduce loading from controllable identified human sources under dry weather conditions (e.g., sanitary sewer-related, septic systems). 3. Reduce loading from controllable animal sources (e.g., pets). 4. Reduce loading from urban wildlife through deterrents, food source controls, etc. 5. Determine background/uncontrollable sources, if standard not attained.	See Table 7-3.	Reduce number of bimonthly exceedance periods (fewer exceedance days) (mid-term). Attainment of stream standard (long-term). OR Determination of alternative site-specific standard (long-term).	Yes	Portion: Boulder Creek TMDL from Canyon to 13th Street. See Tables 7-5 and 7-6 for Boulder Creek Segment 2b TMDL implementation plan for elements transferable to other stream segments. Also see Table 7-3.
Non-point Source	Possible Sources (not confirmed): Septic Systems Wildlife Pets/Trails/Ranchettes Cattle/Livestock	Agricultural areas on stream segments from western urbanized boundary to I-25	1. Determine sources. 2. Reduce loading from controllable identified human sources under dry weather conditions (e.g., septic systems). 3. Reduce loading from grazing areas (if identified as source). 4. Reduce loading from barnyard/concentrated livestock areas (if identified as source). 5. Reduce loading from irrigation return flows (if identified as source). 6. Determine background/uncontrollable sources, if standard not attained.	See Table 7-3.		Yes	See Table 7-3.
Nutrients							
Portion of Stream Segments Below WWTP discharges	WWTP Discharges (dominant) Urban Stormwater Agricultural Runoff	Stream segments below WWTP discharges	1. Continued instream monitoring for TP and TN under Regulation 85. 2. Consider periphyton monitoring in reaches below WWTPs. 3. Implementation of nutrient limits in WWTP discharge permits. 4. Implementation of structural and non-structural BMPs in urban areas. 5. Implementation of agricultural BMPs in agricultural areas.	Schedule/Costs Not Addressed in this Plan; See Table 7-2 for Educational Outreach	Attainment of interim nutrient values under Regulation 31. OR Determination of best achievable condition using advanced modeling.	Yes	Regulation 85 Discharge Permit Limits for WWTPs. Implementation of stormwater BMPs for new development and redevelopment in accordance with MS4 permit requirements.
Metals							
Left Hand Creek, James Creek, Little James Creek	Legacy Mining	Left Hand Creek & Tribs	1. Develop enhanced metals monitoring program to refine metals mass balance. 2. Review and revise priority projects based on findings from revised monitoring. 3. Secure grant funding for highest priority legacy mine areas.	See Appendix F.	Attainment of metals stream standards.	No	Left Hand Creek, James Creek TMDLs and Left Hand Creek Watershed Plan (LWOG 2005); Left Hand Creek stakeholders have identified updated monitoring data as a need to prioritize additional reclamation activities, given 10-year old watershed plan for Left Hand Creek.
Gamble Gulch	Legacy Mining	Gamble Gulch	Not addressed in this Plan.	Not Addressed in this Plan.	Attainment of metals stream standards.	No	Gamble Gulch TMDL
Rock Creek/Coal Creek	Selenium (expected to be due to natural sources)	Rock Creek and Coal Creek below Rock Creek	1. Review water quality data and geology to determine whether nautral conditions warrant a site-specific ambient based standard. 2. Conduct additional water quality monitoring for selenium to support a site-specific standard. 3. Determine whether agricultural irrigation and/or industrial discharges influence instream selenium concentrations.	Not Addressed in this Plan (in terms of BMPs).	Determination of appropriate stream standard.	No	No
Aquatic Life							
Flood Damaged Channel Segments	Flood damage	Portions of Most Subwatersheds	1. Implement stream restoration measures identified in master plans to improve habitat conditions.	See post-flood watershed plans and UDFCD master plans.	Attainment of MMI threshold or other appropriate metric.	No	August 2015 post-flood master plans for: Fourmile Creek, Left Hand Creek, St. Vrain Creek, Upper Coal Creek. UDFCD 2014 master plan for Coal Creek/Rock Creek.
Coal Creek/ Rock Creek	Natural flow limitations Other Point and Nonpoint Sources	Coal Creek/Rock Creek	1. Continued monitoring. 2. Determine appropriate aquatic life metric, given flow limitations.	Not Addressed in this Plan.	Urban stormwater BMPs implemented on new development and redevelopment > or = 1 acre. (on-going) Agricultural BMPs implemented on publically-owned lands in accordance with Open Space policies. (on-going) Agricultural BMPs implemented on privately-owned lands (voluntary, with potential grant support and/or cost-sharing). (mid-term) Attainment of MMI threshold or other appropriate metric (long-term).	No	See annual biological monitoring reports for analysis and progress toward attaining aquatic life objectives.
Boulder Creek	Note: 2014 MMI scores attain Policy 10-1 thresholds for most locations.	To Be Determined (limited to one possible reach below 75th Street WWTP)	1. Continued monitoring. 2. Determine appropriate MMI Biotype for lower monitoring locations.	Not Addressed in this Plan.			
Left Hand Creek & St. Vrain Creek	Point and Nonpoint Sources (not identified)	St. Vrain Creek through Longmont and Left Hand Creek above confluence with St. Vrain Creek	1. Continued monitoring. 2. Determine appropriate MMI biotype for elevations <5085 ft. 3. Determine probable causes of impairment, if applicable (habitat and/or water quality). 4. Identify point and non-point source pollutant reduction measures.	Not Addressed in this Plan.			

Table 7-2. Information and Education Plan

	Educational/Outreach Activity	Objective	Est. Annual Cost	Funding Source
	Near Term (Years 1-5)			
1	Develop webpage with Watershed Plan and Monitoring Plan information.	Provide public information on watershed planning efforts.	$1,000 (one-time)	Nonpoint Source Grant
2	Urban community outreach through school programs, hosting event booths, distributing collateral, placing advertisements and maintaining KICP website.	Enhance existing program to focus on priority pollutants *E. coli*, TN and TP through mini–campaigns. Examples: "Doo Good" and "Green is the New Pink."	$80,000	KICP Annual Budget
3	Education/outreach on stormwater pollution prevention to the business community.	Reach businesses such as restaurants, vehicle service, retail and contract service providers regarding BMPs for priority pollutants.	$10,000	KICP Annual Budget
4	Low Impact Develop/Green Infrastructure workshop.	Encourage development practices that reduce pollutant loading, with emphasis on runoff volume reduction.	$1,500	KICP Annual Budget
5	Permanent BMP operation and maintenance trainings.	Ensure long-term performance of stormwater BMPs.	$2,500	KICP Annual Budget
6	Erosion control trainings for the construction industry.	Reduce sediment loading to streams, which can protect aquatic habitat and also reduce loading of phosphorus-adsorbed to sediment.	$3,000	KICP Annual Budget
7	KICP website maintenance.	Maintain up-to-date links to key watershed planning efforts, including source water protection plans.	$1,000	KICP Annual Budget
8	Co-publicize agricultural field days demonstrating agricultural BMPs.	Encourage implementation of agricultural BMPs that reduce pollutant loading.	$1,000	KICP Annual Budget, CSU Extension, NRCS
Estimated Total Annual Cost			**$100,000**	
	Long-Term (> 5 years; implemented at 5-year increments)			
9	Review and update Watershed Plan.	Update management plan based on new information, particularly with regard to identified *E. coli* sources.	$20,000-$30,000 (5-year)	KICP Special Project

Table 7-3. E. coli Load Reduction Implementation Plan

ID	Activity	Measure of Success/Product	Estimated Cost	Comment	Year/Milestone Date																			
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Near Term (Years 1-5)				*Year 1 assumed to be 2016.*																			
	Additional Monitoring																							
1	Implement Coordinated Monitoring Framework and Annual Analysis (Note: cost of monitoring programs is not included since this is funded through existing programs.)	Coordinated data analysis and first annual report. (complete)	$20,000-30,000	Coordinated data analysis and annual report. Revisions to monitoring plan, as needed. Primary issues addressed: E. coli, nutrients, aquatic life.																				
2	Identify stream segments warranting additional E. coli monitoring and develop monitoring plan.		See subtasks.																					
2a	Initial desktop review of potential sources areas in targeted segments to develop enhanced monitoring plan.	Implemented monitoring plan that further refines understanding of E. coli sources so that BMPs can be better targeted.	$5,000-10,000/target reach	Desktop review includes an inventory of existing data and identification of data gaps. Target timeframe: March prior to summer sampling.																				
2b	Dry weather screening of storm drain outfalls, ditch inflows and irrigation return flows, tributaries for segments of interest for E. coli. Increased instream "bracketing" of potential sources.		$10,000-25,000/target reach	Cost depends on number of flowing outfalls, number of samples collected, duration of sampling program and staffing source. Various reaches have differing levels of baseline knowledge regarding sources.																				
3	Implement additional E. coli monitoring in targeted reaches and interpret findings.	Refined understanding of E. coli sources in watershed so that BMPs can be better targeted.	$5,000-10,000/target reach	Target dates recommended to be April-October.																				
4	Evaluate whether molecular methods are needed for refined source identification and develop monitoring plan for appropriate reaches.	Refined understanding of E. coli sources in watershed so that BMPs can be better targeted.	$5,000-7,500/target reach	Develop plan in early spring. Make sure that plan is suitable to support immediate questions as well as potential longer term needs such as QMRA for site-specific standards.																				
5	Implement targeted advanced monitoring using molecular source ID methods.	Refined understanding of E. coli sources in watershed so that BMPs can be better targeted.	$5,000-25,000/target reach	Implement April-Oct. Prior to implementing costly structural BMPs, it is expected to be worthwhile to confirm whether the source has been correctly targeted.																				
	Education and Outreach																							
6	Implement information/education plan (See Table 7-2).	Increased public awareness of BMPs to reduce E. coli and nutrient loading. (Measure of success could be attendance at workshops, website hits, number of materials distributed, etc.)	$100,000/year	See Table 7-2 Public Education and Outreach Plan. Primary issues addressed: E. coli, nutrients, aquatic life.																				
	BMP Implementation																							
	Sanitary Sources																							
7	Complete at-risk septic system prioritization following 2013 flood and evaluate.	Identification of systems in need of repair, particularly those in proximity to stream corrdidors.	TBD	Effort led by Boulder County.																				
8	Identify and prioritize sanitary repairs needed to reduce E. coli and nutrient loading to the stream.	IDDE is an MS4 permit requirement.	TBD	Effort led by MS4s.																				
	Mid to Long-Term (Years 6-20)																							
	Sanitary Sources																							
9	Complete permitting of all unpermitted septic systems in Boulder County	This is a target established by Boulder County. In areas where unpermitted septic systems exist, this may help to reduce bacteria and nutrient loading to the streams.	TBD	County target is 12/31/2023.																				
	Agricultural Sources																							
10	Develop structural BMP Implementation Plan for targeted reaches.	Based on refined data collected through year 3, develop a more refined BMP implementation plan	$25,000-50,000/Reach	Recommended practices should provide benefits for multiple pollutants--nutrients and E. coli reductions may be achieved using similar practices.																				
11	Implement agricultural structural BMP program.	Based on refined data collected during through year 3, develop a more refined BMP implementation plan	$50,000-150,000/Reach or Project																					
	Urban Stormwater Sources																							
12	Urban Sources (Addressed under MS4 Permit)	See representative urban BMPs and phased schedule in Tables 7-6 and Table 7-7.	$500,000-$1,000,000 per year	Urban MS4 sources are outside the scope of the 319 planning.																				

Table 7-4. Menu of BMPs with Expected Costs and Benefits for *E. coli* Load Reduction

BMP Menu	Relative Cost and Expected Effectiveness for *E. coli* Load Reduction			
	Expected Effectiveness for Bacteria Reduction	Relative Cost	Existing Programs/ Partners	Potential Funding Sources
Urban Areas				
IDDE and Preventive Maintenance/Cleaning (Sanitary-Storm)	H	$$	MS4, KICP, PACE	MS4, Utilities
Pet Waste Education and Outreach	L-M	$	MS4, KICP, PACE	KICP
Pet Ordinance Enforcement	L-M	$	BCOS, OSMP, Animal Control	Local Government
Residential Education and Outreach	M	$	MS4, KICP, PACE	KICP
Restaurant Education and Outreach	M	$	MS4, KICP, PACE	KICP
Wildlife Management	M	$	MS4, KICP, PACE	KICP
Recreational and Transient Users	M	$-$$$	MS4, BCOS, OSMP, Police, Social Services	Local Govern-ment
Open Space Opportunities	M	$$-$$$	BCOS, OSMP, MS4	Multi-party
Urban Retrofits	M	$$$	MS4	MS4
BMP Implementation (new development)	M	$$$	Engineering, MS4	Private
Low Flow Diversions to Sanitary	H	$$$	MS4	MS4
Disinfection (only as last resort)	H	$$$	MS4	MS4
Non-point/Agricultural BMPs				
Center Pivot Irrigation	M	$$$	NRCS, BCOS, OSMP	EQIP, CRP, other NRCS Programs
Grazing Management	H	$-$$		
Off-stream Stock Water	M	$$$		
Fencing	M-H	$$		
Barnyard Management	H	$-$$		
Revegetation/Restoration	M	$-$$		
Riparian Buffers	M	$-$$		
Septic System Maintenance/Repairs	H	$-$$	Boulder County	Private, Boulder County
Connect Septic to Sanitary	H	$$$	Boulder County	

Tables 7-5 and 7-6 provide excerpted tables from the TMDL Implementation Plan for Boulder Creek Segment 2b from 13th Street to the confluence with South Boulder Creek (Tetra Tech 2011). The Boulder Creek TMDL plan is within the MS4 boundary of the City of Boulder and also includes the MS4 permits for the University of Colorado, the Boulder Valley School District and Boulder County. The implementation elements and general phasing of the approach are transferable to the general strategy for addressing *E. coli* nonpoint sources in this broader St. Vrain Basin Watershed Plan, with the possible exception of the Phase 3 elements because disinfection and use of proprietary devices are not well-suited to agricultural and non-point source load reductions. Phase 1 of implementation begins with source controls and includes monitoring to refine understanding of sources, followed by more costly structural implementation strategies in Phase 2. The Boulder Creek TMDL is based on a 10-year implementation schedule, but a longer schedule is expected to be needed for non-point sources, perhaps 20 years or longer.

Table 7-5. Boulder Creek *E. coli* TMDL Implementation Plan for 13th Street to the Confluence with South Boulder Creek

(Source: Boulder Creek Segment 2b, TMDL Implementation Plan, Prepared for the City of Boulder by Tetra Tech, 2011)

Phase	Activity	Recommendation	Notes
Phase 1	Illicit Discharge Detection and Elimination and Preventive Maintenance	Inspection of MS4 and Sanitary	Evaluation and refinement of existing program.
		Cleaning sanitary and MS4 lines	Evaluation and refinement of existing program.
	Pet Waste Education and Outreach	Review number, location and use of pet waste stations	Coordinate with OSMP to identify additional locations and effective signage.
		Publicize City code penalties	Coordinate with OSMP to identify effective signage.
		Increase pet waste and Education	Evaluation and refinement of existing program.
		Develop recognizable “Scoop the Poop” campaign	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Enforcement Codes	Evaluate the enforcement need and effectiveness. Coordinate efforts with OSMP.

(table continued on next two pages)

(***Boulder Creek TMDL Implementation Plan, continued***)

Phase	Activity	Recommendation	Notes
	Residential Education and Outreach	Pet waste education	Evaluation and refinement of existing program.
		Reducing irrigation overspray	Evaluation and refinement of existing program; review and revised regulations as necessary to prevent overspray.
		Downspout disconnection	Evaluation and refinement of existing codes, ordinances and education programs.
	Restaurant Education and Outreach	Education focused on proper housekeeping of trash storage areas	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Fats, oil and grease management	Evaluation and refinement of existing education program. Partner with KICP and PACE.
		Guidance on washing of areas surrounding restaurants	Evaluation and refinement of existing education program. Partner with KICP and PACE.
	Wildlife Management	Develop wildlife management plan to include raccoons	Coordinate with Urban Wildlife Conservation Coordinator to develop.
		Wildlife relocation	Conduct relocation as necessary and in compliance with established City codes.
		Inlet protection	Coordinate with Utilities Maintenance and Transportation staff to minimize entry points for wildlife.
		Monitoring	Coordinate monitoring with Utilities Maintenance staff to monitor the effectiveness of wildlife management.
	Recreation and Transient Population Outreach	Targeted outreach	Evaluation and refinement of existing education program.
		Improved facilities	Coordinate with other City departments to evaluate needs and opportunities of facilities surrounding high use areas.
	Riparian Enhancements	Continued maintenance and enhancement of riparian zone	Collaborate with the City's Greenways program to evaluate needs and opportunities for riparian enhancements.
		Monitoring water quality associated with capital improvement projects	Work with other City departments to coordinate monitoring studies to measure and document improvements related to CIPs.
	Continued Monitoring	Continued weekly monitoring	Dedicate City staff and resources to continued weekly monitoring. In addition to the four weekly sites established, begin sampling near the Foothills Parkway to evaluate/narrow the downstream impairment.
		Continued outfall Inventories	Dedicate City staff and resources to continued outfall inventories. May require temporary staffing. In addition to the four weekly sites established, begin sampling near the Foothills Parkway to evaluate/narrow the downstream impairment.
		Land use assessment	Coordinate existing and future monitoring studies to evaluate land use generation and the identification of bacteria 'hot spot' locations.

(***Boulder Creek TMDL Implementation Plan, continued***)

Phase	Activity	Recommendation	Notes
		In-system monitoring	Continue in-system sampling. Efforts should be made to establish a monitoring cycle and document conducted monitoring with analysis of results in annual report.
Phase 2	Private Retrofits	Needs and feasibility study	Evaluate existing programs/partnerships to determine feasibility of private retrofits
		Continued monitoring	Characterize baseline conditions and evaluate effectiveness of private retrofits (include an evaluation of reduction in runoff volume and pollutant loads).
	Open Space Opportunities	Needs and feasibility study	Coordinate with OSMP, Parks and Recreation, and Greenways to evaluate needs and opportunities for BMP implementation of Open Space and public parks.
		Conceptual design	Work with engineers to develop conceptual designs.
		Pilot study	Monitor pre- and post- BMP implementation to evaluate implementation effectiveness.
	Urban Retrofits	Needs and feasibility study	Coordinate with Transportation and other City departments to evaluate needs and opportunities for the incorporation of BMPs in City right-of-ways.
		Conceptual design	Work with engineers to develop conceptual designs.
		Pilot study	Monitor pre- and post- BMP implementation to evaluate implementation effectiveness.
	Proprietary BMP	Needs and feasibility study	Coordinate with Transportation, Utilities and other City departments to evaluate needs and opportunities for the incorporation of proprietary BMPs in City right-of-ways and/or end-of-pipe.
		Conceptual design	Work with engineers to develop conceptual designs.
		Pilot study	Monitor pre- and post- BMP implementation to evaluate implementation effectiveness.
Phase 3	Low Flow Diversions	Needs and feasibility study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.
	Ultraviolet Treatment	Needs and feasibility study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.
	Ozone Treatment	Needs and feasibility study	Evaluate needs and opportunities after other stormwater BMPs have been implemented to their full capacity.

Table 7-6. Boulder Creek *E. coli* TMDL Implementation Plan Schedule 13th Street to the Confluence with South Boulder Creek

(Source: Boulder Creek Segment 2b, TMDL Implementation Plan, Prepared for the City of Boulder by Tetra Tech, 2011)

		Implementation Year									
	Pre-Permit*	1	2	3	4	5	6	7	8	9	10
Milestone	☆			☆		☆			☆		☆
Phase 1: Nonstructural BMP Implementation											
IDDE and Preventive Maintenance	High emphasis	High emphasis	High emphasis	Moderate emphasis	Moderate emphasis	High emphasis	High emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis
Pet Waste Education and Outreach	High emphasis	High emphasis	High emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Residential Education and Outreach	High emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Restaurant Education and Outreach	High emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Wildlife Management	High emphasis	High emphasis	Moderate emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Recreational and Transient Users Education and Outreach	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Moderate emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Riparian Enhancements	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Continued Monitoring	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Phase 2: Structural BMP Implementation											
Private Retrofits		Explore needs and feasibility	Explore needs and feasibility	Explore needs and feasibility	High emphasis	High emphasis	High emphasis	High emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Open Space Opportunities			Explore needs and feasibility	Explore needs and feasibility	High emphasis	High emphasis	High emphasis	High emphasis	Continued emphasis	Continued emphasis	Continued emphasis
Urban Retrofits			Explore needs and feasibility	Explore needs and feasibility	Explore needs and feasibility	High emphasis	High emphasis	High emphasis	High emphasis	High emphasis	Moderate emphasis
Proprietary BMPs					Explore needs and feasibility	Explore needs and feasibility	Explore needs and feasibility	High emphasis	High emphasis	High emphasis	Moderate emphasis
Phase 3: Active Treatment											
Low Flow Diversions									Explore needs and feasibility	Explore needs and feasibility	Explore needs and feasibility
Ultraviolet Treatment											Explore needs and feasibility
Ozone Treatment											Explore needs and feasibility

* **Pre-permit implies period prior to next permit renewal**

☆ **Identifies milestone**

High emphasis

Moderate emphasis

Continued emphasis

Explore needs and feasibility

The City of Boulder has undertaken a variety of activities to better understand sources of *E. coli* in accordance with its TMDL Implementation Plan, including:

- The city reinstated a raccoon-proofing pilot study on Marine St. and has observed drastic reductions in bacteria levels at the outfall from the system. The study involves securing a small storm sewer from raccoon intrusion.
- The city conducted a dry weather screening of all outfalls to Boulder Creek which included bacteria sampling and snapshots of optical brightener levels from the outfalls.
- The city has initiated an inspection, cleaning and rehabilitation program for the oldest parts of its system. Cleaning of the lines is followed by inspections to identify pipe condition and identify any illicit connections. This is followed by pipe lining and replacing damaged sections of the system as necessary.

7.2 Technical and Financial Assistance

In order to implement the actions described in Section 7.1, significant technical and financial resources are needed. Sources of technical and financial assistance are described below.

7.2.1 Technical Assistance

The primary sources of technical assistance for this Watershed Plan include:

Stormwater Resources

- Keep It Clean Partnership Website (http://www.keepitcleanpartnership.org/)
- Boulder County Public Health Partners for a Clean Environment (PACE) resources (http://pacepartners.com/water)
- Volume 3 Urban Stormwater BMPs, Urban Storm Drainage Criteria Manual (UDFCD 2010) (www.udfcd.org)
- International Stormwater BMP Database (www.bmpdatabase.org)
- CLEAN Center (https://erams.com/clean/)

Agricultural Resources/Nonpoint Source Resources

- NRCS Conservation Practices Standards Field Office Technical Guide (eFOTG) (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/technical/?cid=nrcs144p2_062771)
- Colorado State University Extension (http://www.extension.colostate.edu/boulder/)
- Boulder County Parks and Open Space (portion of website related to management plans and policies, http://www.bouldercounty.org/os/openspace/pages/posplans.aspx)
- City of Boulder Open Space and Mountain Parks (https://bouldercolorado.gov/osmp)
- CLEAN Center (portion of website focused on agricultural resources, including irrigation scheduling tools, https://erams.com/clean/)

- Boulder County SepticSmart (http://www.bouldercounty.org/env/water/pages/septicsmartindex.aspx)

7.2.2 Financial Assistance and Planning

The financial plan for improvements for the St. Vrain Basin includes three general components:

1) City and county funding for stream segments within local jurisdictions that are covered in existing programs (e.g., stormwater, wastewater, transportation, parks and open space),
2) Keep It Clean Partnership-coordinated activities (e.g., database development, annual water quality report), and
3) Grant funded activities through programs sponsored by entities such as the Colorado Nonpoint Source Program, Colorado Healthy Rivers Fund, Colorado Water Conservation Board, Great Outdoors Colorado, the NRCS and other sources (including federal flood-related funding). The Colorado Healthy Rivers fund may be a good source of funds to support advanced monitoring for *E. coli* and additional metals characterization in the Left Hand Creek watershed.

NRCS programs can be particularly helpful for funding improvements on private property in agricultural areas, with current cost-share and grant programs, accessible at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/co/programs/financial/. Representative programs include:

- Conservation Innovation Grants (CIG): CIG is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging federal investment in environmental enhancement and protection, in conjunction with agricultural production.

- Conservation Stewardship Program (CSP): CSP is a voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities, while improving, maintaining, and managing any existing conservation activities.

- Environmental Quality Incentives Program (EQIP): EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length.

- Emergency Watershed Protection Program (EWP): EWP was established by Congress to respond to emergencies created by natural disasters. The EWP Program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, drought, windstorms, and other natural occurrences.

- Agricultural Conservation Easement Program (ACEP): ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands and their related benefits. Under the Agricultural Land Easements component, NRCS helps Indian tribes, state and local governments and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. Under the Wetlands Reserve Easements component, NRCS helps to restore, protect and enhance enrolled wetlands.

Depending on Farm Bill funding, other programs such as the Wetlands Reserve Program (WRP), Grassland Reserve Program (GRP), and the Healthy Forest Reserve Program (HFRP) may also be available. The NRCS webpage should be referenced for active programs, enrollment dates and application data requirements, which may vary by program and year.

7.3 TMDL Implementation Process

A TMDL implementation process is premature for the first release of this Watershed Plan, particularly given the framework nature of this Watershed Plan and the data gaps identified for *E. coli*, which warrant improved information prior to developing a TMDL that allocates wasteloads and loads among point and nonpoint sources, respectively. Identification of sources is also important for BMP selection. (Note: As summarized in Tables 7-5 and 7-6, the *E. coli* TMDL within MS4 boundaries in Boulder already has an Implementation Plan in place.)

Coordination with the Urban Drainage and Flood Control District, the Left Hand Watershed Oversight Group, and other agencies will be a key aspect of future implementation efforts. As a result of the September 2013 Flood, multiple projects are planned or underway by various entities in the watershed.

8.0 Adaptive Watershed Management Plan

Adaptive management is a fundamental premise of the St. Vrain Basin Watershed Plan. The first release of this Watershed Plan is primarily a framework document that provides a path forward for collaboration and coordination of water quality protection and improvement at a watershed scale, including coordinated monitoring to fill data gaps. As more refined information becomes available for specific stream reaches, then targeted projects may be added to this Watershed Plan, which will be maintained over time by the Keep It Clean Partnership and remain accessible on the Keep It Clean Partnership website. The Keep It Clean Partnership's goal is to provide a forum to facilitate minor updates to this Watershed Plan on a five-year cycle, with major updates at ten-year intervals.

The review process for adaptive management should be data-driven, both in the pollutant source identification phase and the implementation phase. For example, in the case of *E. coli*, correction strategies should be driven by a clear understanding of sources of *E. coli*. Once management strategies and BMPs are implemented, then monitoring should be conducted to assess effectiveness of the implemented practices so that fiscally-responsible decision-making occurs as the practices are considered in other locations. Systematic record-keeping to document actions that have been implemented, together with water quality monitoring results, are critically important to assessing progress toward load reductions.

Several stream segments in the watershed may be affected by TMDLs in the future. These TMDLs should either be integrated into the Watershed Plan or added as addenda. As new concerns are identified by the partners, this information should be added to the Watershed Plan.

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