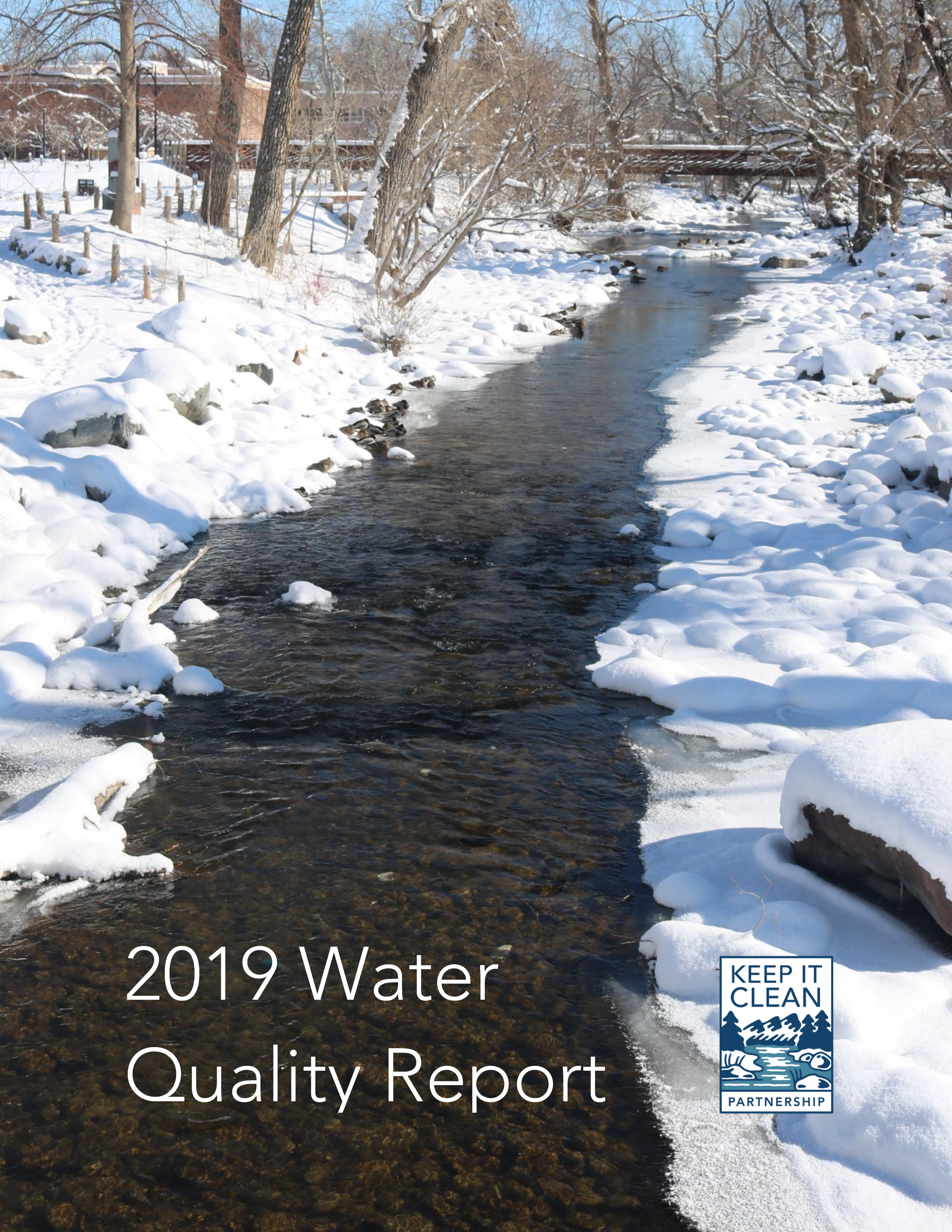

2019 Water Quality Report

KEEP IT CLEAN PARTNERSHIP

Report Preparation

This report was prepared by the Keep it Clean Partnership. The following individuals supported this effort by providing water quality data and/or review of the report:

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KEEP IT CLEAN PARTNERSHIP

Boulder
Boulder County
Erie
Lafayette
Longmont
Louisville
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Table of Contents

Tables

Figures

Executive Summary

In 2014 the Keep it Clean Partnership (KICP) developed a shared monitoring plan to improve coordination between multiple independent monitoring efforts being conducted by various parties in the watershed. The annual development of this report furthers the KICP's work on monitoring and improving water quality throughout the watershed and aligns with the goals of the 319 non-point source management plan developed by the KICP in 2015. Key findings from analysis of 2019 data include:

General water quality

- Boulder Creek does not have any current issues with pH and this previous impairment has been removed.
- Conductivity has increased slightly in Boulder Creek since the early 2000s, but has not increased or decreased over the last 5 years.
- Dissolved oxygen remains low in Rock Creek, potentially due to low stream flow, and has decreased over the last 5 years.

Nutrients

- Nitrogen and phosphorus are elevated below major wastewater facilities, which may contribute to exceedances of future instream nutrient standards. While wastewater facilities are primary contributors to nutrient levels, reductions from stormwater, agriculture, and other sources could also have a significant impact.
- Nitrogen has decreased at most sites over time, especially below major wastewater facilities, which can likely be attributed to facility upgrades.
- Phosphorus does not have a clear long-term trend, with some upstream sites decreasing and some downstream sites increasing.
- While ammonia has increased slightly over the last 5 years, it has decreased at many sites long-term and does not indicate any current issues.

Bacteria

- *E. coli* levels are highest near urban areas and tend to decrease in non-urban areas, suggesting that agriculture, open space, and rural areas are lesser contributors than urban runoff.
- *E. coli* levels were low in spring but peaked in May and remained elevated through early fall. While the timing of peaks varied from previous years, this follows the general trend that bacteria concentrations are highest from late spring through early fall.
- *E. coli* levels have remained relatively stable at all instream sites over the last 5 years.

Metals

- Most metals increased further downstream, although dissolved silver did not show a clear trend.
- Despite some slight long-term increases, total arsenic has decreased at most sites over the last 5 years.

- Dissolved copper has increased slightly in Boulder Creek over the last 5 years but does not indicate any current issues.

Recommendations

The following recommendations were developed in collaboration with stakeholders from KICP communities and prioritized through a brief survey. Collectively the KICP partners intend to focus on making progress on these recommendations and annual updates to this report may be scaled back to allow more capacity for these efforts. More detail on these recommendations is included in the Conclusions section of this report.

1. **Develop updated fact sheets for priority pollutants**

2. **Identify specific new steps for *E. coli* based on studies that have been conducted**

3. **Update the Keep it Clean Partnership shared monitoring plan and St. Vrain Basin Watershed-Based Plan**

4. **Evaluate nutrient levels and feasibility of nutrient reductions throughout the watershed**

Introduction

Monitoring program overview

The Keep it Clean Partnership (KICP) coordinated monitoring program was initiated in 2014 in tandem with the St. Vrain Basin Watershed-Based Plan (KICP and WWE 2015). The original objectives for this plan were to leverage data to target impaired stream reaches for improvement, identify changes in water quality, and evaluate the return on investment for capital improvements (WWE 2017). Over the last 6 years the KICP has continued to pursue these objectives and enhanced communication and integration of data with the public and other organizations.

Data for this report is collected by the cities of Boulder, Longmont, Louisville, and Lafayette, and the towns of Erie and Superior. Maps of regularly monitored sites are presented in Figures 1.1-3 and a summary of these sites is presented in Table 1.2. The 2019 annual data report includes data from the last 5 years (2015 – 2019) in accordance with the period of record considered by the Colorado Department of Public Health and Environment (CDPHE), with a focus on the most recent year of data.

Table 1.1 provides a summary of the analytes considered as part of the KICP monitoring program with units, minimum detection limits (MDL), and sampling frequency. MDLs provided here are the baseline agreed upon by the participating entities, and some analyses utilize more sensitive sampling methods with lower MDLs.

Analyte	Units	MDL	Frequency
Temperature	°C	-15 °C	Monthly
Hardness	mg/L	1 mg/L	Monthly
Alkalinity	mg/L	1 mg/L	Monthly
Conductivity	µS/cm	0.1 µS/cm	Monthly
Total suspended solids	mg/L	2 mg/L	Monthly
Dissolved oxygen	mg/L	0.1 mg/L	Monthly
pH	Standard units	1 S.U.	Monthly
Total nitrogen	mg/L	0.1 mg/L	Monthly
Total Kjedahl nitrogen	mg/L	0.1 mg/L	Monthly
Total inorganic nitrogen	mg/L	N/A	Monthly
Nitrites and nitrates	mg/L	0.02 mg/L	Monthly
Total ammonia	mg/L	0.05 mg/L	Monthly
Total phosphorus	mg/L	0.01 mg/L	Monthly
E. coli	MPN or CFU /100 mL	1 MPN or CFU /100 mL	Monthly
Total arsenic	µg/L	Varies	Monthly
Dissolved copper	µg/L	Varies	Monthly
Dissolved selenium	µg/L	Varies	Monthly

Table 1.1 Summary of KICP shared monitoring program analytes

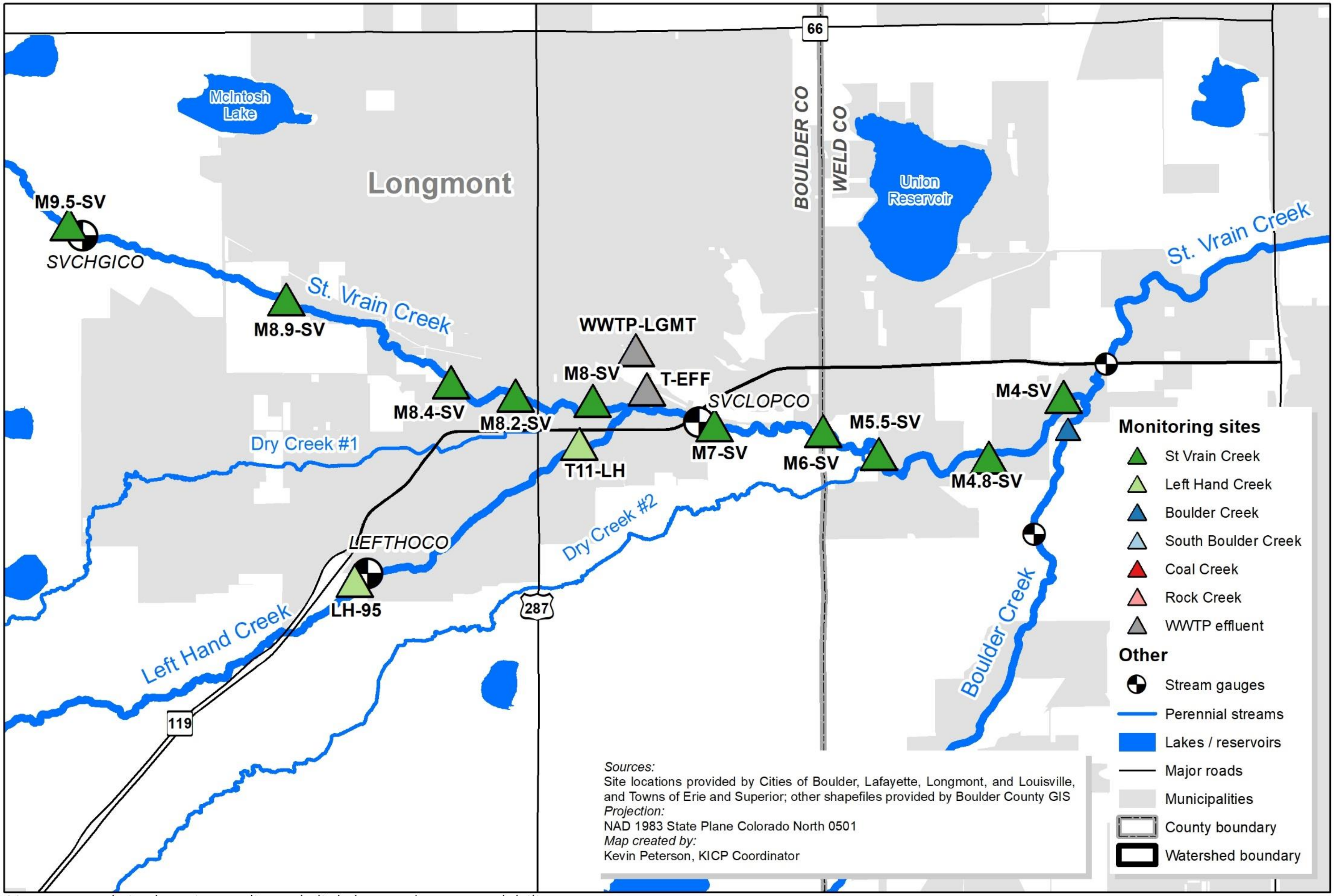
Changes to the 2019 report

This is the second year that the KICP Annual Water Quality Report was directly developed by in-house staff rather than a consultant. In accordance with this transition numerous changes have been made to the format of this report to improve readability and focus on the most important observations. Future versions of this report will continue to be modified based on feedback received from stakeholders and the priorities of the Keep it Clean Partnership and its participating communities.

Summary of 2019 changes:

- Added description of low flow events in addition to high flow events to *Precipitation and Stream Flow* section.
- Expanded description of updates to the 303(d) list of impairments at KICP monitoring sites in *Stream Standards* section.
- Expanded summary of long-term trends to include both 5 year trends and full dataset trends and presented in new tables.
- Changed methodology of correlation summary presented in *Data Attributes* section.
- Moved overview of stream standard evaluation process to Appendix A.
- Adjusted boxplot graphs to synchronize scale of y-axis for each analyte.
- Added time series graphs of all parameters to Appendix C.

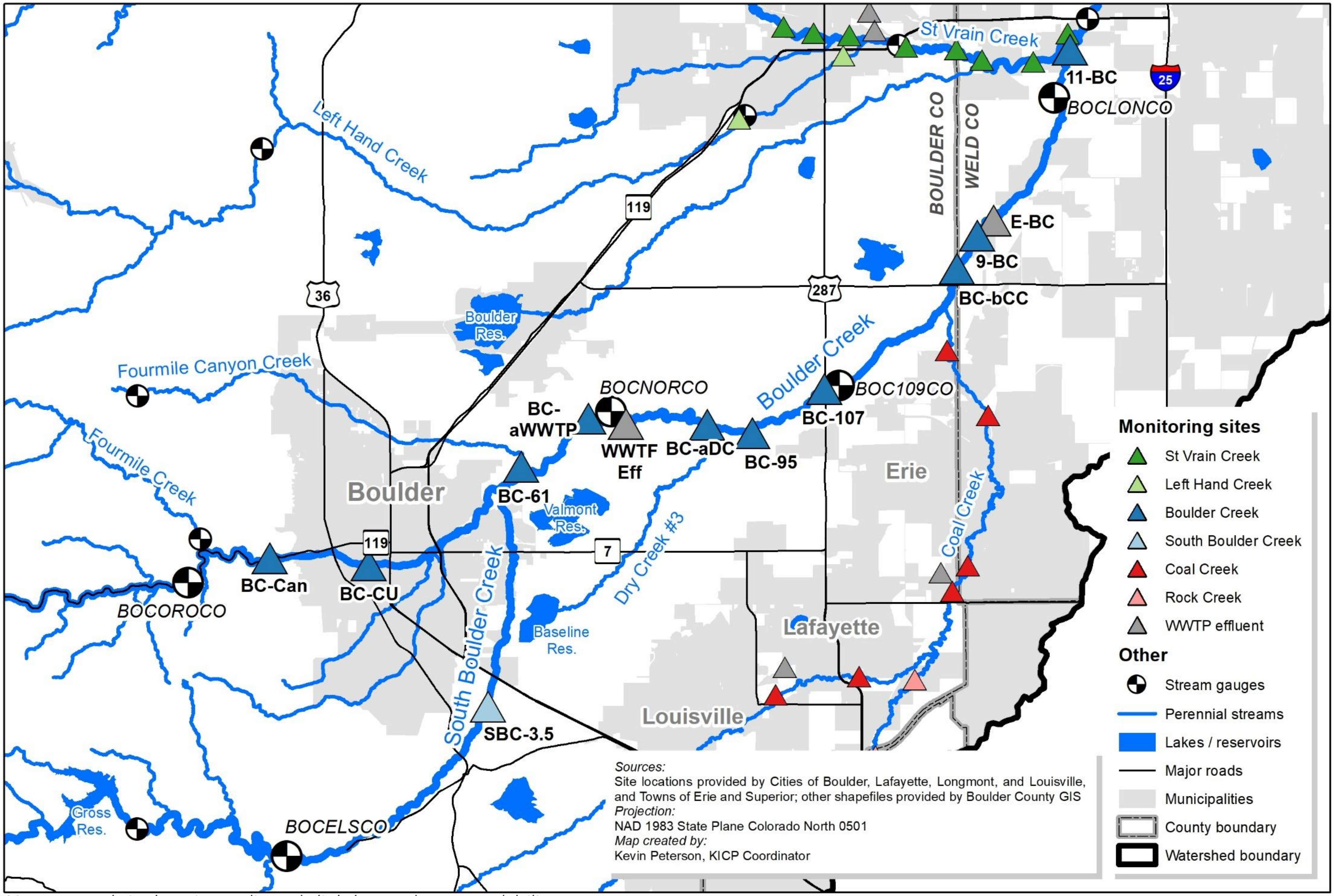
ST VRAIN CREEK MONITORING SITES



Note: several site locations adjusted slightly to enhance readability

Figure 1.1 2019 St. Vrain Creek and Left Hand Creek monitoring sites

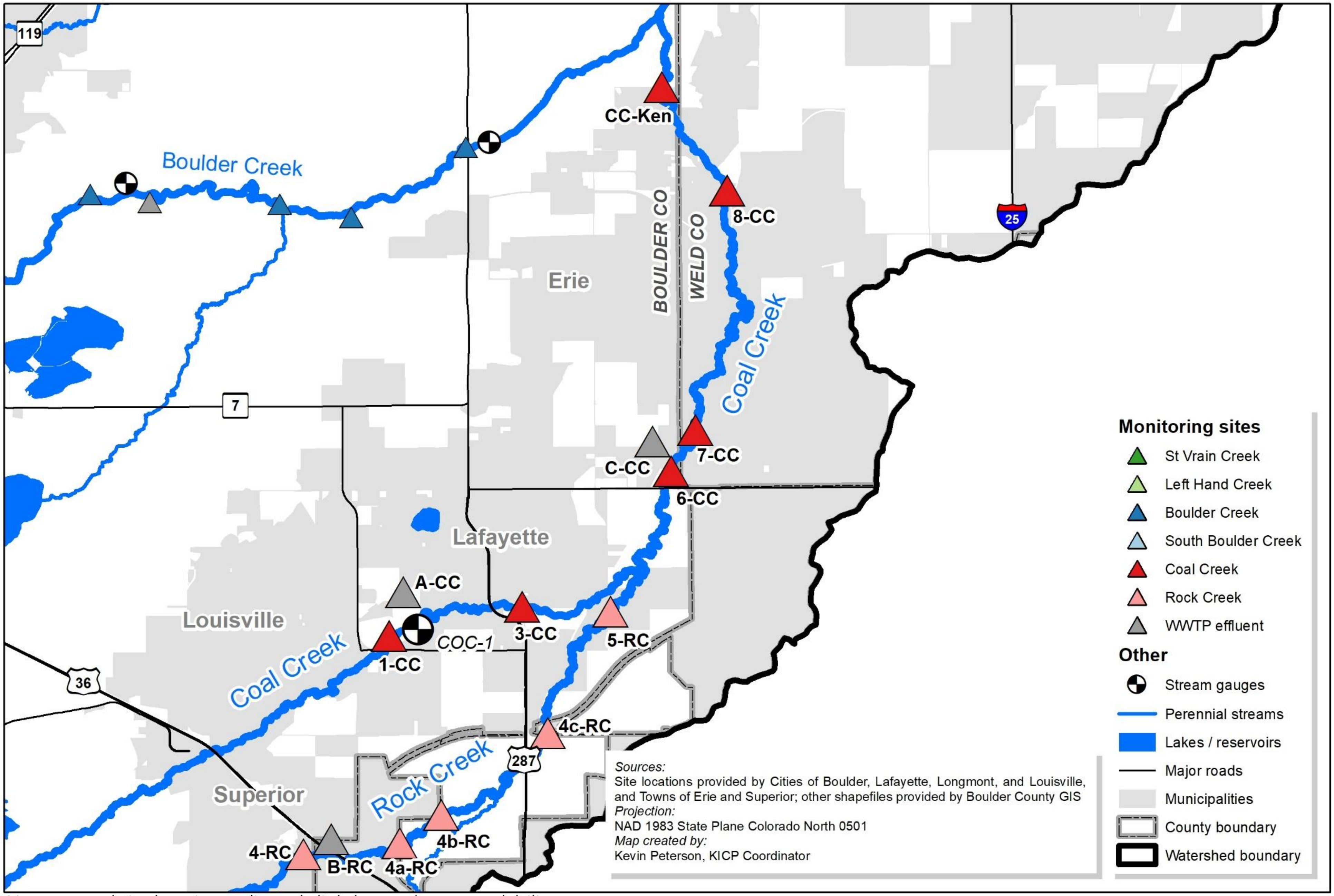
BOULDER CREEK MONITORING SITES



Note: several site locations adjusted slightly to enhance readability

Figure 1.2 2019 Boulder Creek and South Boulder Creek monitoring sites

COAL CREEK MONITORING SITES



Note: several site locations adjusted slightly to enhance readability

Figure 1.3 2019 Coal Creek and Rock Creek monitoring sites

Site	Description	Latitude	Longitude	Data provider	Stream Segment
M9.5-SV	St. Vrain Creek at North 75th St	40.1775	-105.1784	City of Longmont	COSPSV03
M8.9-SV	St. Vrain Creek at Golden Ponds	40.1693	-105.1442	City of Longmont	COSPSV03
M8.4-SV	St. Vrain Creek downstream of Boston Ave	40.1586	-105.1169	City of Longmont	COSPSV03
M8.2-SV	St. Vrain Creek at Pratt Parkway	40.1569	-105.1062	City of Longmont	COSPSV03
M8-SV	St. Vrain Creek upstream of the Longmont WWTP discharge	40.1553	-105.0878	City of Longmont	COSPSV03
LH-95	Left Hand Creek at 95th St	40.13391	-105.1318	City of Longmont	COSPSV05
T11-LH	Left Hand Creek at St. Vrain Creek	40.1551	-105.087	City of Longmont	COSPSV05
WWTP-LGMT	Discharge from Longmont WWTP	40.1574	-105.0862	City of Longmont	N/A
T-EFF	Ditch carrying combined WWTP effluent and roadside flow to St. Vrain Creek	40.1557	-105.0862	City of Longmont	N/A
M7-SV	St. Vrain Creek at CO-119	40.153	-105.0741	City of Longmont	COSPSV03
M6-SV	St. Vrain Creek at County Line Rd	40.1522	-105.0551	City of Longmont	COSPSV03
M5.5-SV	St. Vrain Creek at Peschel Rd	40.14944	-105.048	City of Longmont	COSPSV03
M4.8-SV	St. Vrain Creek below Spring Gulch #2	40.14889	-105.028	City of Longmont	COSPSV03
M4-SV	St. Vrain Creek upstream of the confluence with Boulder Creek	40.1582	-105.0108	City of Longmont	COSPSV03
BC-Can	Boulder Creek at the pool area at the Anderson Ditch head gate	40.01318	-105.3015	City of Boulder	COSPBO02b
BC-CU	Boulder Creek at foot bridge connecting Folsom Field with the parking lot to the north	40.011112	-105.2661	City of Boulder	COSPBO02b
SBC-3.5	South Boulder Creek at McGinn Ditch Gate	39.97215	-105.2236	City of Boulder	COSPBO04b
BC-61	Boulder Creek just west of the 61st St bridge	40.03809	-105.2116	City of Boulder	COSPBO09
BC-aWWTP	Boulder Creek under bridge at 75th St upstream of the Boulder WWTP discharge	40.05152	-105.1786	City of Boulder	COSPBO09
WWTF Eff	Discharge from Boulder WWTP	40.05137	-105.1775	City of Boulder	N/A
BC-aDC	Boulder Creek upstream of Dry Creek	40.04948	-105.1449	City of Boulder	COSPBO09
BC-95	Boulder Creek downstream of the Lower Boulder Ditch headgate	40.04716	-105.1288	City of Boulder	COSPBO09
BC-107	Boulder Creek at the 107th St bridge	40.05922	-105.103	City of Boulder	COSPBO09
BC-bCC	Boulder Creek at the East County Line Rd bridge	40.09211	-105.0553	City of Boulder	COSPBO10
9-BC	Boulder Creek upstream of the North Erie WWTP discharge	40.1012	-105.048	Town of Erie	COSPBO10
E-BC	Discharge from the North Erie WWTP	40.1021	-105.0474	Town of Erie	N/A
11-BC	Boulder Creek at mouth near Longmont at USGS gage 06730500	40.1522	-105.0144	Town of Erie	COSPBO10
1-CC	Coal Creek upstream of the Louisville WWTP discharge	39.9761	-105.1164	City of Louisville	COSPBO07b
A-CC	Discharge from the Louisville WWTP	39.9801	-105.1221	City of Louisville	N/A
3-CC	Coal Creek upstream of the confluence with Rock Creek	39.9799	-105.0909	City of Lafayette	COSPBO07b
4-RC	Rock Creek upstream of the Superior WWTP discharge	39.93738	-105.1402	Town of Superior	COSPBO08
B-RC	Discharge from the Superior WWTP	39.9368	-105.1403	Town of Superior	N/A
4a-RC	Rock Creek at Brainard Dr	39.9392	-105.1186	Town of Superior	COSPBO08
4b-RC	Rock Creek at South 104th St	39.94409	-105.1093	Town of Superior	COSPBO08
4c-RC	Rock Creek at West Dillon Rd near Ruth Roberts Park	39.95806	-105.0853	Town of Superior	COSPBO08
5-RC	Rock Creek upstream of the confluence with Coal Creek	39.979	-105.0711	City of Lafayette	COSPBO08
6-CC	Coal Creek upstream of the Lafayette WWTP discharge	40.0032	-105.0574	City of Lafayette	COSPBO07b
7-CC	Coal Creek downstream of the Lafayette WWTP discharge	40.0103	-105.0519	City of Lafayette	COSPBO07b
C-CC	Discharge from the Lafayette WWTP	40.0038	-105.0579	City of Lafayette	N/A
8-CC	*Coal Creek at Cheesman St (not monitored in 2019)*	*40.05157*	*-105.0444*	*City of Louisville*	*COSPBO07b*
CC-Ken	Coal Creek at the Kenosha Rd bridge upstream of Boulder Creek	40.06949	-105.059	City of Boulder	COSPBO07b

Table 1.2 Summary of 2019 KICP shared monitoring program sites

Precipitation and Stream Flow

Water quality in streams is dependent on precipitation patterns, which in turn influence stream flows. Diversions for municipal and agricultural uses also have a strong influence on stream flows. High precipitation events can flush pollutants into streams and lead to high concentrations of nutrients, bacteria, and other analytes. Periods of low flow can help illuminate background concentrations that aren't associated with storm events. A thorough analysis of precipitation and stream flow is not provided, but the following graphs should be used as context for interpreting results through this report.

Precipitation

Precipitation data was summarized for two sites within the basin in line with previous analysis reports; Station US1COBO0352 in Longmont, CO (Lat. 40.1848, Long. -105.082) and Station USC00050848 in Boulder, CO (Lat. 39.9919, Long. -105.2667). Data was obtained from the National Oceanic and Atmospheric Administration National Centers for Environmental Information database. Precipitation is highly variable throughout the watershed and these summaries are not representative of precipitation throughout the entire basin.

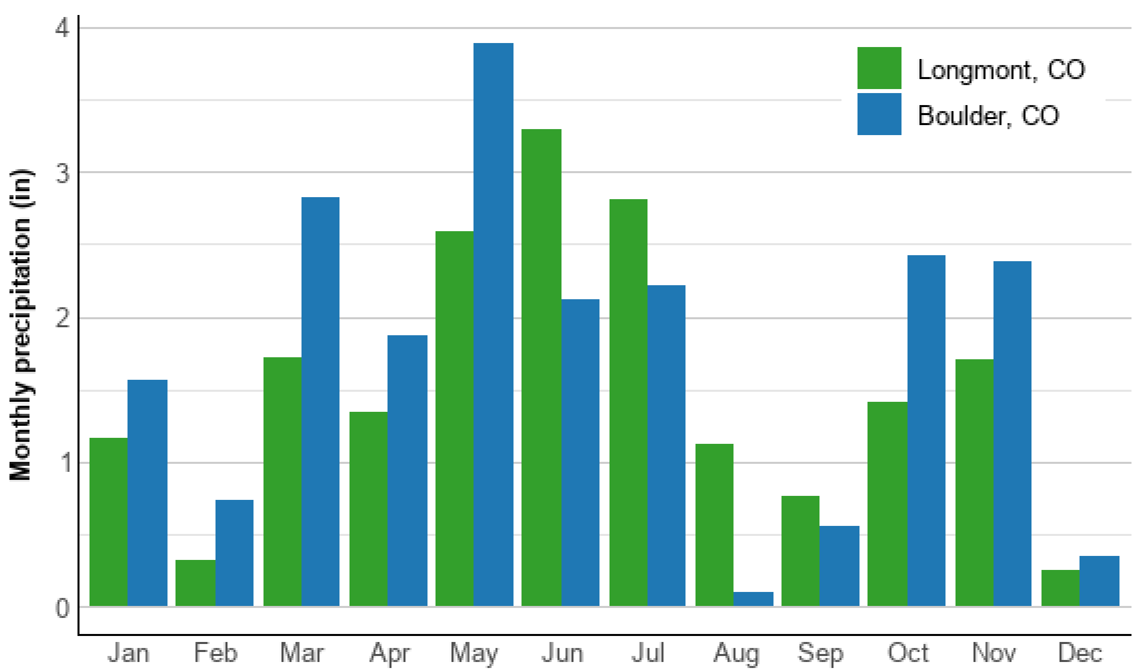
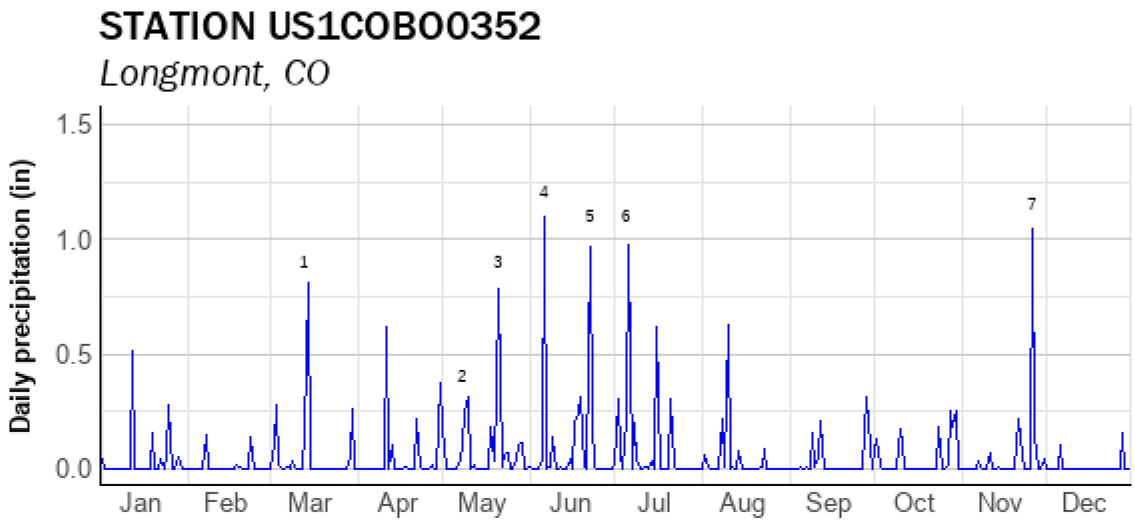


Figure 2.1 2019 monthly precipitation totals in Boulder and Longmont

A monthly summary of precipitation totals is presented in Figure 2.1. Precipitation events that exceeded a total of 1 inch at either station were recorded in Table 2.1 and annotated in Figure 2.2 to compare the same events at each station. A single precipitation event was identified as a period with consecutive days of measurable precipitation. There were a total of 5 precipitation events at each station, occuring on slightly different dates. Both stations had large precipitation events in mid-March and late November, with more frequent events from May to July.



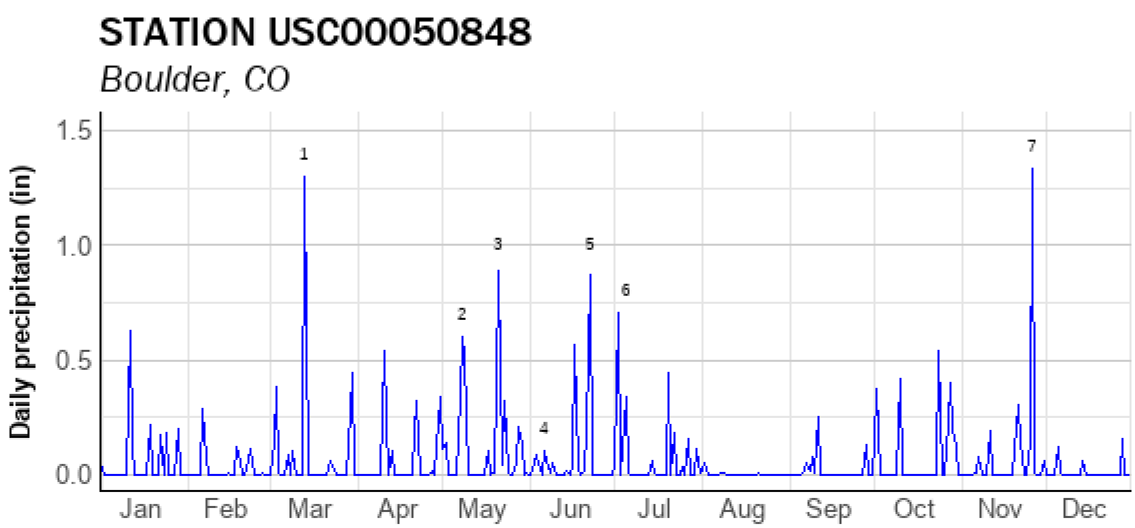


Figure 2.2 2019 daily precipitation at Boulder and Longmont gages, numbers on the graph correspond to event annotations described in Table 2.1

Event #	Event dates *Longmont, CO*	Total precipitation *Longmont, CO*	Event dates *Boulder, CO*	Total precipitation *Boulder, CO*
1	Mar 13-14	0.97 in	Mar 13	1.30 in
2	May 7-10	0.69 in	May 7-9	1.46 in
3	May 18-24	1.46 in	May 19-24	1.67 in
4	Jun 5-6	1.13 in	Jun 6-9	0.22 in
5	Jun 22-24	1.20 in	Jun 20-22	1.08 in
6	Jul 5-6	1.20 in	Jul 4-6	0.46 in
7	Nov 26-27	1.20 in	Nov 25-27	1.48 in

Table 2.1 Major 2019 precipitation events at Boulder and Longmont gages

Stream flow

Data was obtained from the Colorado Division of Water Resources (DWR) and U.S. Geological Survey (USGS) for stream gages. The City of Louisville provided data for gage COC-1. Table 2.2 provides a basic summary of 2019 flow conditions at each gage and Figures 2.3-2.11 depict 2019 hydrographs of each gaging station with reference medians for the last 5 years overall.

At most gages, stream flows were higher in June and July and lower in May relative to the last 5 years overall (2015-2019). This was less evident in Left Hand Creek and South Boulder Creek, where flows are heavily dependent on trans-basin diversions through Left Hand Ditch and Moffat Tunnel respectively (Figures 2.4 and 2.7). Low flow periods are defined as dates where the flow is less than the 10th percentile flow for the last 5 years, high flow periods are dates where the flow is greater than the 90th percentile flow for the last 5 years.

Stream gage	Latitude	Longitude	10th percentile (2015-19)	Total low flow days	90th percentile (2015-2019)	Total high flow days
SVCHGICO	40.1774	-105.1781	5.4 cfs	13 (Apr)	198.9 cfs	27 (Jun, Jul)
LEFTHOCO	40.1343	-105.1308	2.0 cfs	23 (Jan, Feb)	64.9 cfs	19 (Jun, Jul)
SVCLOPCO	40.1533	-105.0757	28.9 cfs	49 (Jan, Feb, Mar, Apr)	211.0 cfs	28 (Jun, Jul)
BOCOROCO	40.0065	-105.3305	12.6 cfs	80 (Jan, Oct, Nov, Dec)	227.3 cfs	34 (Jun, Jul)
BOCELSCO	39.9316	-105.3050	8.8 cfs	25 (Jan, Feb, Oct, Dec)	124.0 cfs	49 (May, Jun, Jul)
BOCNORCO	40.0517	-105.1789	11.8 cfs	66 (Jan, Feb, Mar, Apr, Oct)	255.6 cfs	30 (Jun, Jul)
BOC109CO	40.0598	-105.0979	10.3 cfs	7 (Aug, Sep)	202.3 cfs	33 (Jun, Jul)
BOCLONCO	40.1388	-105.0202	6.2 cfs	36 (Aug, Sep, Nov)	297.0 cfs	20 (Jun, Jul)
COC-1	39.5834	-105.0659	0.1 cfs	204 (Jan, Feb, Mar, Apr, May, Aug, Sep, Oct, Nov, Dec)	10.0 cfs	37 (May, Jun, Jul)

Table 2.2 Summary of 2019 flow conditions at nearby gages, months in which low flow and high flow days occur listed in parentheses

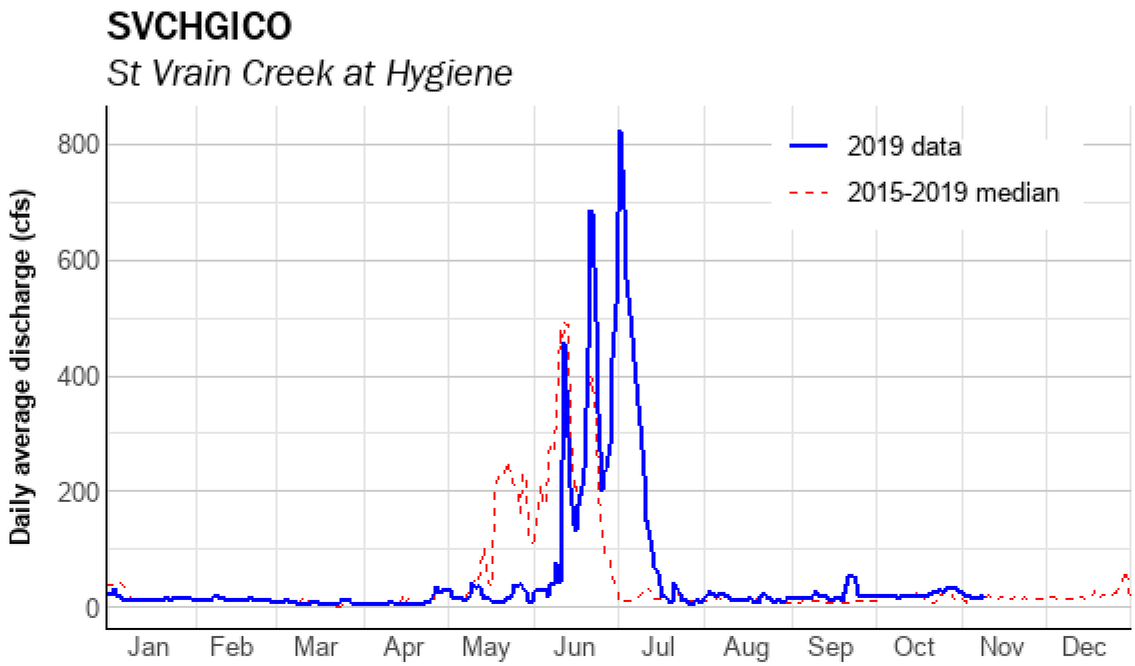


Figure 2.3 Stream flow at gage SVCHGICO

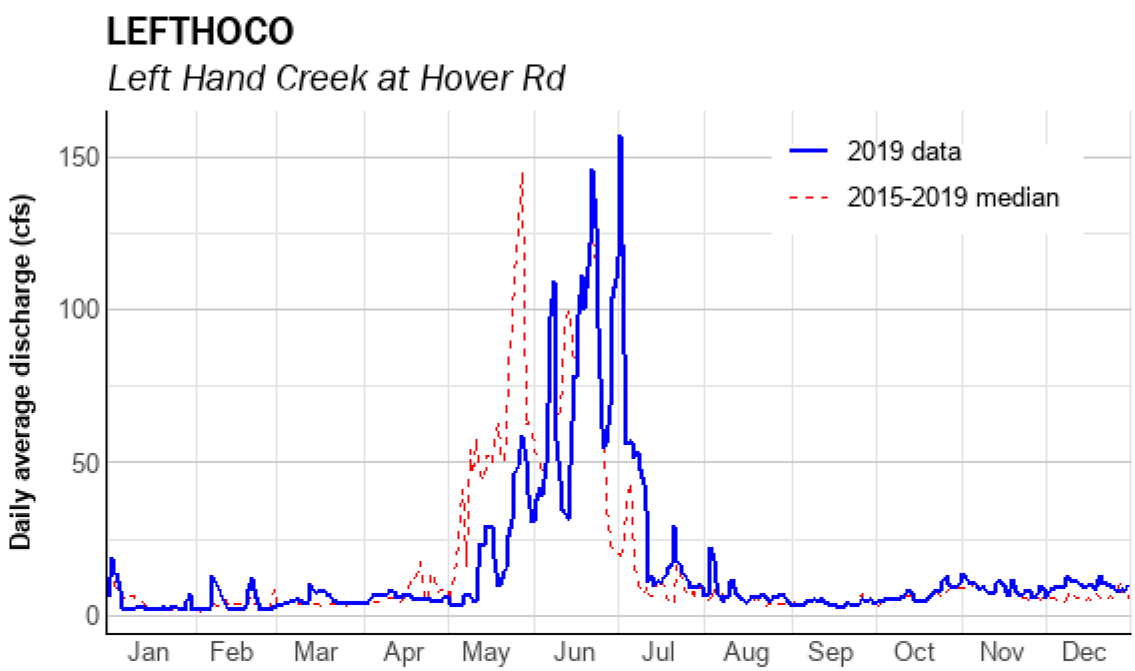


Figure 2.4 Stream flow at gage LEFTHOCO

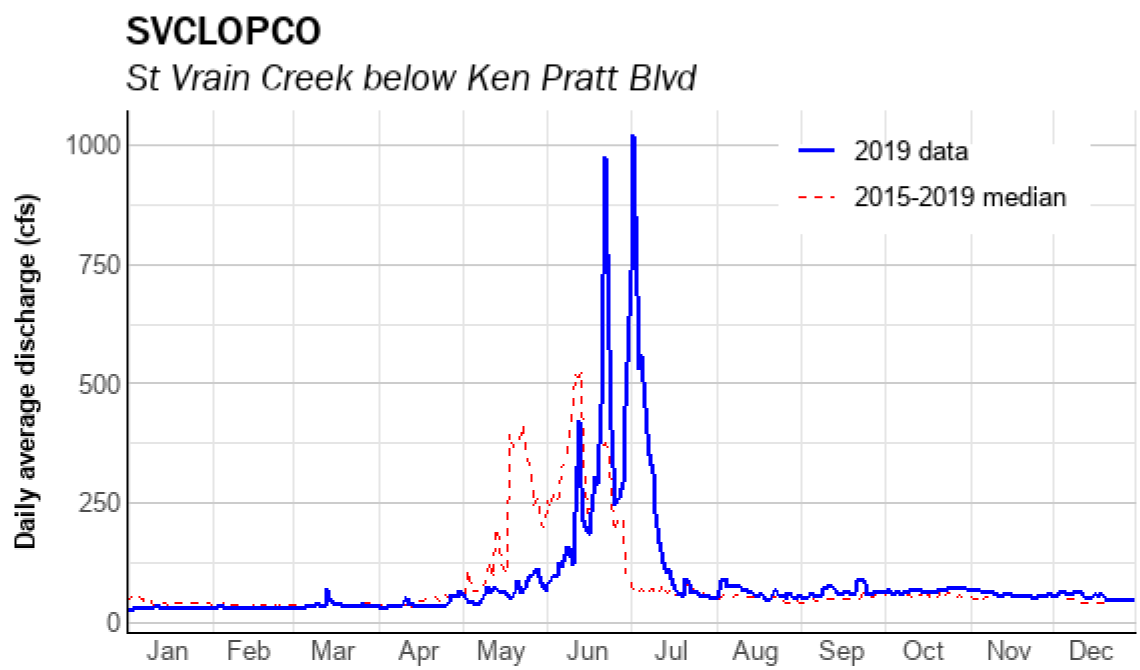


Figure 2.5 Stream flow at gage SVCLOPCO

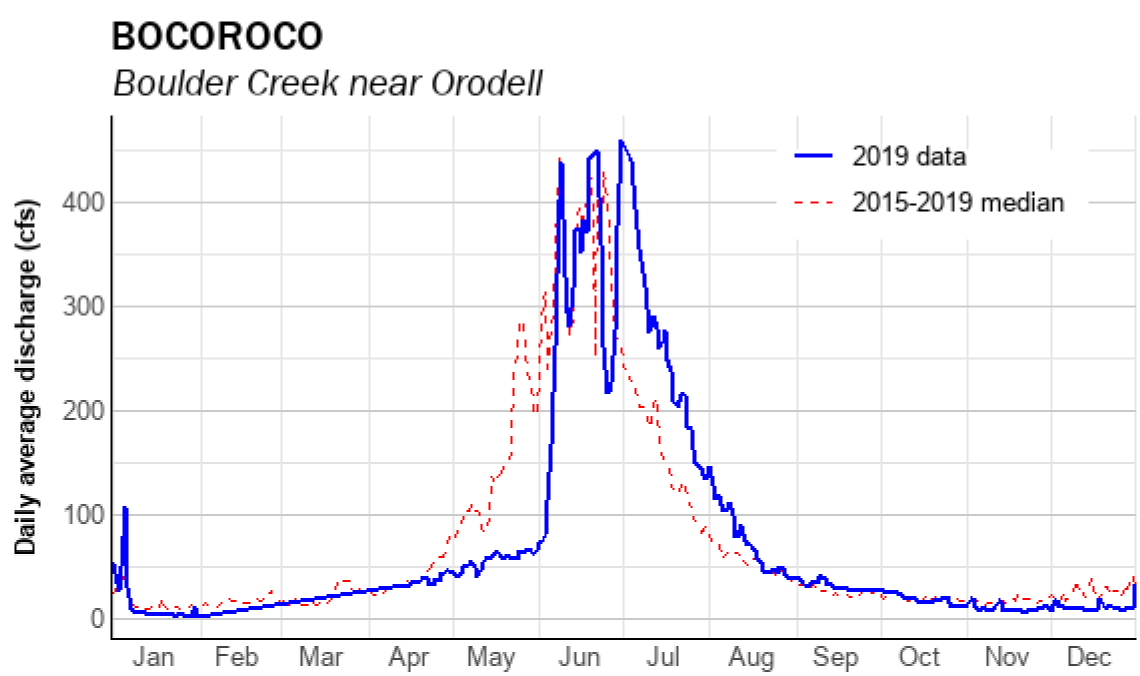


Figure 2.6 Stream flow at gage BOCOROCO

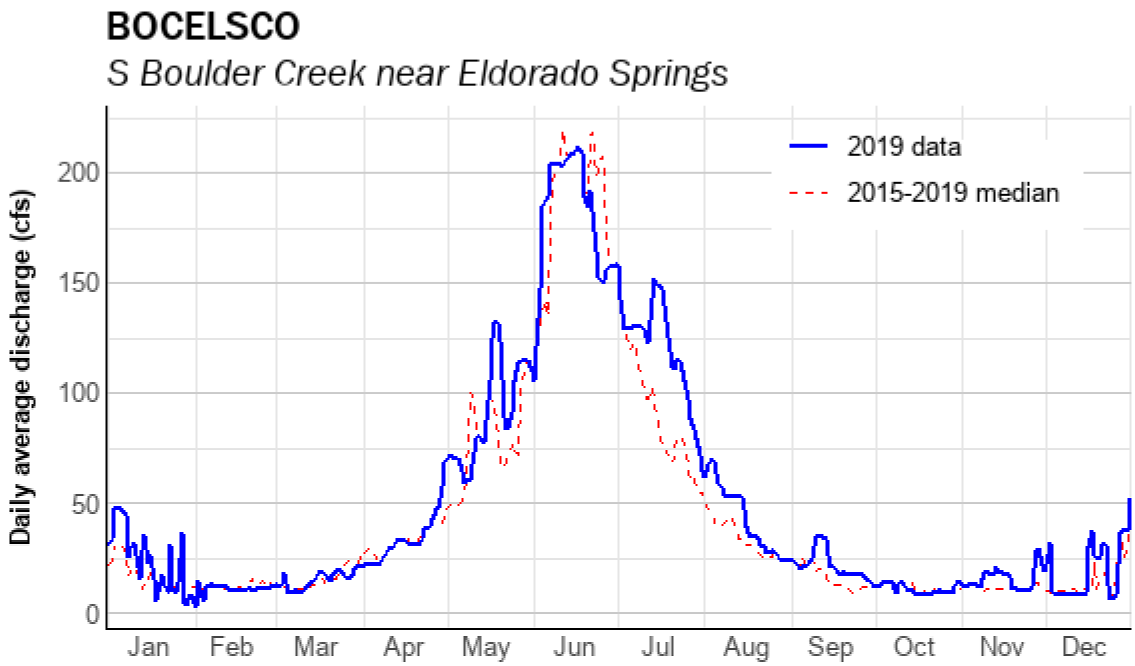


Figure 2.7 Stream flow at gage BOCELSCO

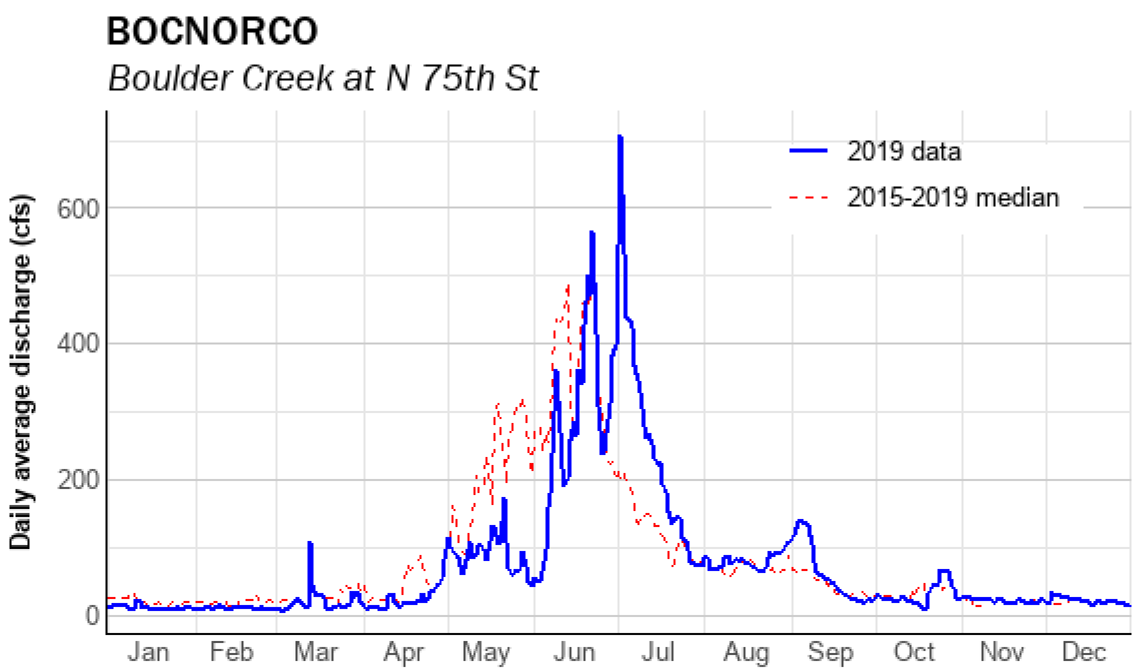


Figure 2.8 Stream flow at gage BOCNORCO

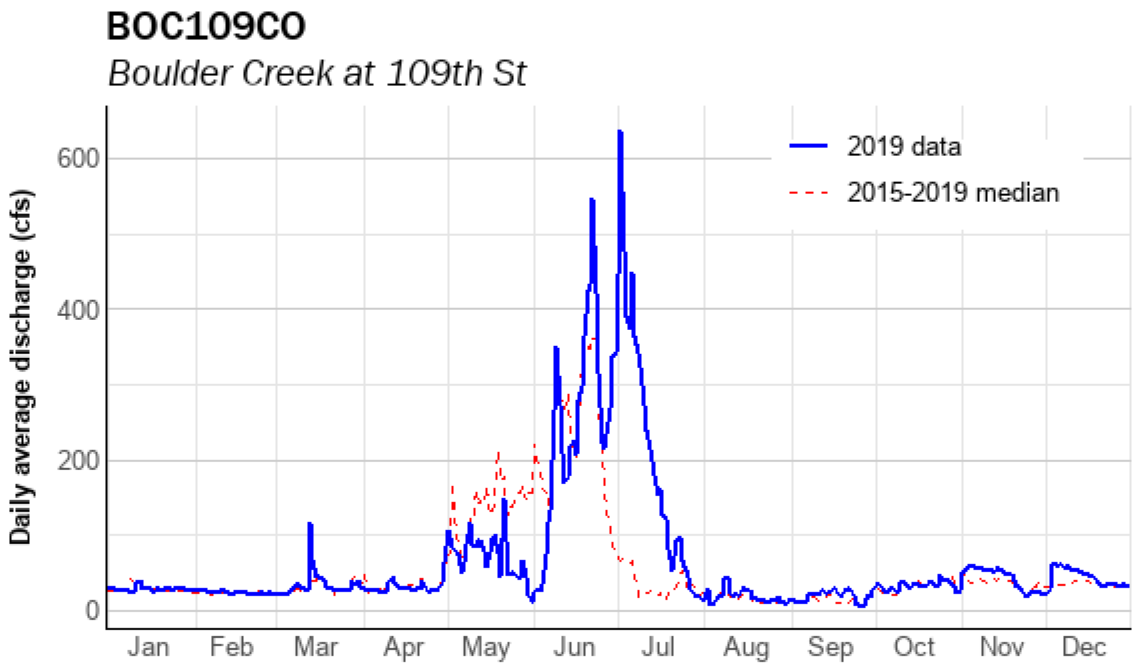


Figure 2.9 Stream flow at gage BOC109CO

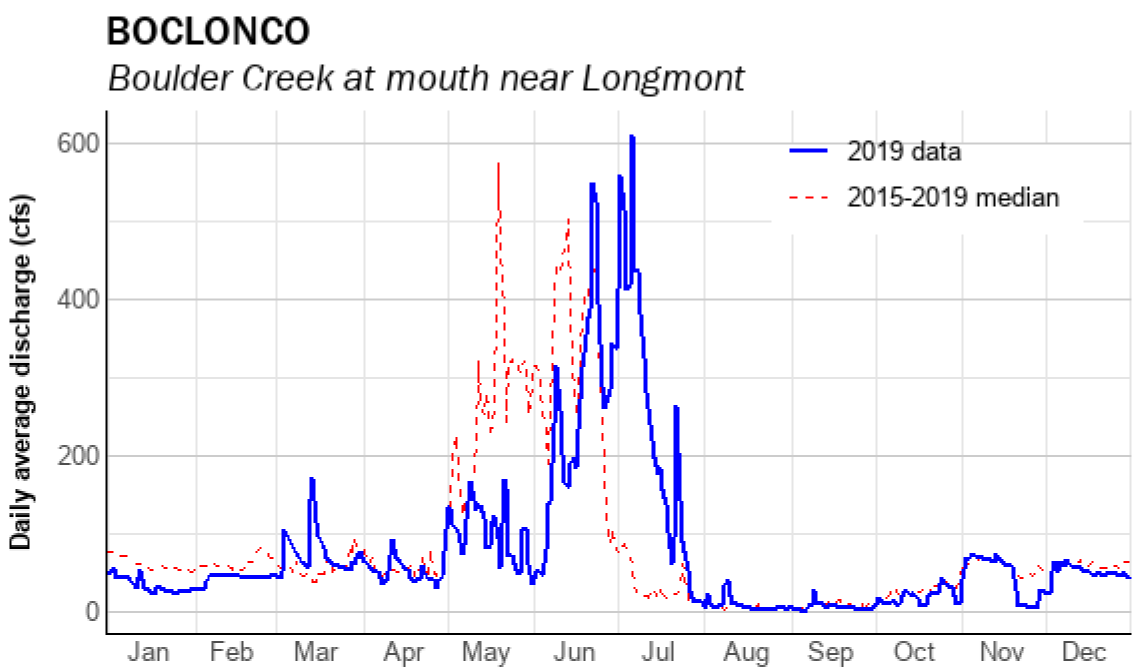


Figure 2.10 Stream flow at gage BOCLONCO

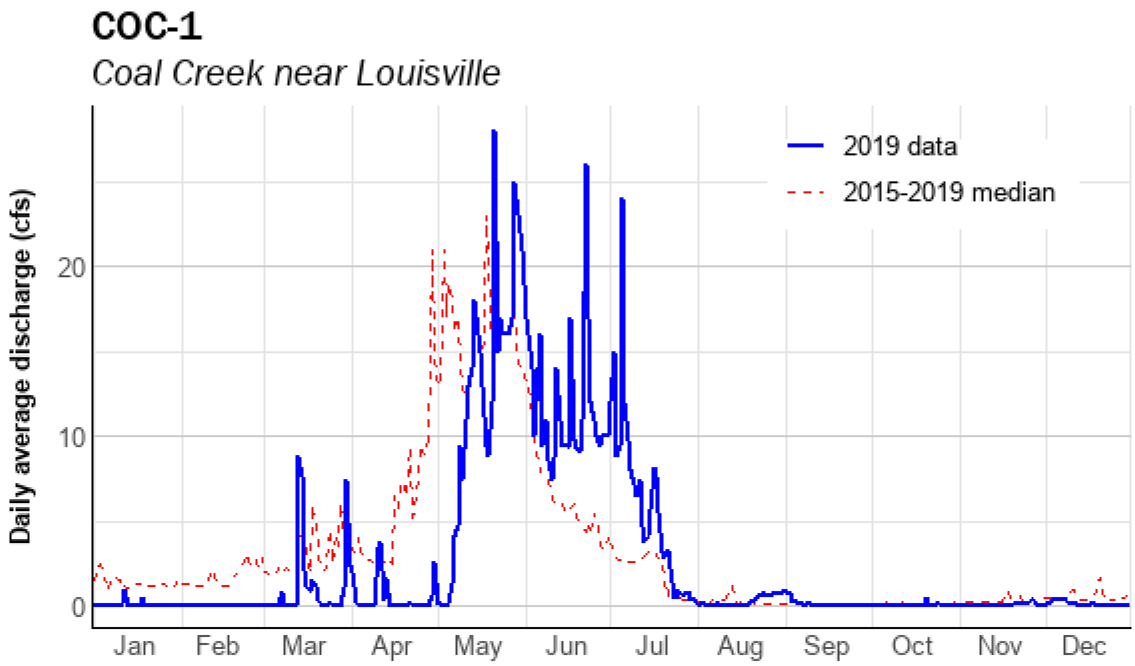


Figure 2.11 Stream flow at gage COC-1

Stream Standards

One of the primary ways that we assess water quality is by comparing observed concentrations with the standards set by the Colorado Department of Public Health and Environment (CDPHE). These standards are developed by experts with the goal of protecting aquatic life, recreation, and water supply and can differ by stream based on how the water is used, species that are present, and other conditions.

An overview of the CDPHE methodology for determining stream impairments is provided in Appendix A. Changes made to the 2020 303(d) list of impairments from the 2018 version in stream segments with KICP monitoring sites are summarized below in Table 3.1. A full summary of current impairments in these stream segments is provided in Table 3.2.

Analyte	Areas with impairments added	Areas with impairments removed
pH		Boulder Creek from Coal Creek to St. Vrain Creek
E. coli	Boulder Creek from North Boulder Creek to 13th St	
	South Boulder Creek from Community Ditch diversion to South Boulder Rd (monitoring and evaluation list)	
Macroinvertebrates	South Boulder Creek from Community Ditch diversion to South Boulder Rd	Boulder Creek from 107th St to Coal Creek (provisional)
Copper (dissolved)		South Boulder Creek from Community Ditch diversion to South Boulder Rd
Silver (dissolved)	Boulder Creek from North Boulder Creek to 13th St	
	South Boulder Creek from Community Ditch diversion to South Boulder Rd	
Manganese (dissolved)	Coal Creek from Rock Creek to Boulder Creek	
	Left Hand Creek from Boulder Feeder Canal to St. Vrain Creek	

Table 3.1 List of areas with impairments added or removed from 2018 to 2020 version of CDPHE 303(d) list

Boulder Creek from N Boulder Creek to 13th St (COSPBO02B) BC-Can

Affected use	Analyte	Category	Status
Water supply use	Arsenic (total)	303(d)	
Aquatic life use	Silver (dissolved)	303(d)	New in 2020
Recreational use	*E. coli*	303(d)	New in 2020

Boulder Creek from 13th St to S Boulder Creek (COSPBO02B) BC-CU

Affected use	Analyte	Category	Status
Water supply use	Arsenic (total)	303(d)	
Aquatic life use	Silver (dissolved)	303(d)	New in 2020

South Boulder Creek from Community Ditch to South Boulder Rd (COSPBO04B) SBC-3.5

Affected use	Analyte	Category	Status
Recreational use	*E. coli*	M&E list	New in 2020
Water supply use	Arsenic (total)	303(d)	
Aquatic life use	Silver (dissolved)	303(d)	New in 2020
Aquatic life use	Macroinvertebrates	303(d)	New in 2020

Coal Creek from Highway 36 to Rock Creek (COSPBO07B) 1-CC, 3-CC

Affected use	Analyte	Category	Status
Aquatic life use	Macroinvertebrates	M&E list	
Recreational use	*E. coli*	303(d)	

Coal Creek from Rock Creek to Boulder Creek (COSPBO07B) 6-CC, 7-CC, 8-CC, CC-Ken

Affected use	Analyte	Category	Status
Aquatic life use	Macroinvertebrates	M&E list	
Recreational use	*E. coli*	303(d)	
Aquatic life use	Selenium (dissolved)	303(d)	
Water supply use	Manganese (dissolved)	303(d)	New in 2020

Rock Creek (COSPBO08) 4-RC, 4a-RC, 4b-RC, 4c-RC, 5-RC

Affected use	Analyte	Category	Status
Recreational use	*E. coli*	M&E list	
Aquatic life use	Selenium (dissolved)	303(d)	

Boulder Creek from South Boulder Creek to 107th St (COSPBO09) BC-61, BC-aWWTP, BC-aDC, BC-95, BC-107

Affected use	Analyte	Category	Status
Recreational use	*E. coli* (Jul – Oct)	303(d)	
Water supply use	Arsenic (total)	303(d)	

Boulder Creek from Coal Creek to St. Vrain Creek (COSPBO10) BC-bCC, 9-BC, 11-BC

Affected use	Analyte	Category	Status
Recreational use	*E. coli*	303(d)	
Water supply use	Arsenic (total)	303(d)	

St. Vrain Creek from Hygiene Rd to Boulder Creek (COSPSV03) M9.5-SV, M8.9-SV, M8.4-SV, M8.2-SV, M8-SV, M7-SV, M6-SV, M5.5-SV, M4.8-SV, M4-SV

Affected use	Analyte	Category	Status
Recreational use	*E. coli*	303(d)	

Left Hand Creek from Boulder Feeder Canal to St. Vrain Creek (COSPSV05) LH-95, T11-LH

Affected use	Analyte	Category	Status
Aquatic life use	Copper (dissolved)	303(d)	
Water supply use	Manganese (dissolved)	303(d)	New in 2020

Table 3.2 Summary of local stream impairments from 2020 303(d) list of impairments

Future regulations

In 2017 the Water Quality Control Division developed the 10-Year Water Quality Roadmap to adopt new water quality standards through evidence development, stakeholder outreach, and rulemaking hearings. A timeline of standard adoption statewide is provided in Table 3.1.

Year	Analyte	Status
2021	Temperature (excursions removed)	Adopt
2022	Chlorophyll-a	Adopt
2023	Ammonia, arsenic	Draft
2024	Selenium	Draft
	Arsenic	Adopt
2025	Total nitrogen, total phosphorus	Draft
2027	Ammonia, selenium, total nitrogen, total phosphorus	Adopt

Table 3.3 Upcoming regulations for Colorado streams based on CDPHE 10-Year Water Quality Roadmap

While the development of each of these updated standards is an important process, the Keep it Clean Partnership (KICP) is most invested in the 2025 drafting and 2027 adoption of standards for total nitrogen and total phosphorus. Similar to many other urbanized streams throughout the State, it is anticipated that our local streams will not meet the proposed standards once they are implemented. The 10-Year Water Quality Roadmap allows KICP and other organizations to prioritize efforts on upcoming regulations and engage in the regulatory process as needed.

Methods

Detailed sampling and analysis methods are described in the Keep it Clean Partnership coordinated monitoring plan. Provided below is a brief description of primary analysis steps conducted for this report.

Preprocessing steps

Samples designated as field duplicates were removed from analysis and considered solely for quality control, with accidental duplicates also being removed. Values below detection limit (flagged variously as ND, BDL, U, or <) were set to one half of the provided minimum detection limit, except for *E. coli* values which were set to 1, based on the most recent assessment methodology used by the Colorado Department of Public Health and Environment (CDPHE 2019c). Values reported as estimates (flagged as J) were removed if a non-estimated value was also available for the same sample. Except for when evaluating five year trends (see method below), if multiple samples remained for the same date they were averaged together. Units were converted if necessary to align with shared monitoring procedures (see Table 1.1). A thorough analysis of outliers was not conducted for this report and outliers were not removed from analysis, but data providers were contacted to clarify and/or correct any values suspected to be inaccurate.

Upstream to downstream trends

Upstream to downstream trends plots include all sites along the mainstems of St. Vrain Creek, Boulder Creek, and Coal Creek for ease of representation. A GIS analysis was used to measure stream miles between each site and sites were plotted according to their distance from the furthest upstream site (M9.5-SV, BC-Can, or 1-CC). The median of all 2019 samples was calculated and plotted against this distance.

Long term trends

Significant trends over the last five years were evaluated for each analyte at instream sites using a Seasonal Kendall test with a significance level of $p < 0.05$. A seasonal Sen's slope was calculated for significant trends to provide an estimated yearly rate of change. Seasons were defined as individual months and a single sample was used for each month and year combination. If more than one valid sample existed for a given month and year a random sample was taken of these values according to accepted practice for this method. Longer term trends were evaluated in the same way when sufficient data was available, and all significant trends are summarized in tables. Five year trends are also plotted on maps for select analytes with the estimated yearly rate of change annotated.

Boxplots

Data for several analytes in the main report and all analytes in Appendix B are plotted as boxplots including the median value, 25th and 75th percentiles, and lower and upper outlier limits (Figure 4.1). Outliers are values that exceed the 75th percentile by greater than the interquartile range (75th – 25th percentile), or that are lower than the interquartile range subtracted from the 25th percentile. Where applicable, stream standards are also depicted with a solid red line for acute standards and a dashed red line for chronic standards.

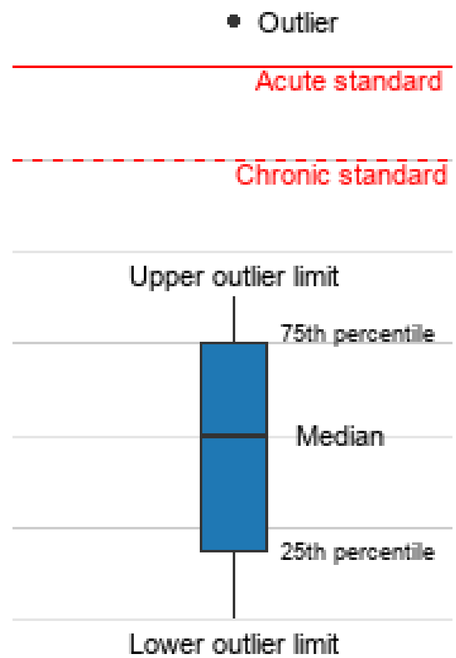


Figure 4.1 Boxplot key

Time series

As a new addition to this year's report, time series plots for each analyte broken down by site were added to Appendix C. Each site was assigned a symbol and color combination to differentiate individual trends. Where applicable, stream standards are also depicted with a solid red line for acute standards and a dashed red line for chronic standards.

Quality control

With the 2015 shared Keep it Clean Partnership (KICP) monitoring plan, a certain frequency of field replicates and field blanks were recommended for participating entities. Table 4.1 depicts recommended frequencies, acceptance criteria, and corrective actions. Field blanks and field replicates are not currently reported by all participating entities, but thorough quality control procedures are highly encouraged. See Appendix D for more details on 2019 quality control samples.

QC sample	Recommended frequency	Acceptance criteria	Corrective action
Field blank	5% of samples	< reporting limit	Flag suspect data and eliminate source of contamination
Field replicate	5% of samples	< 25% relative percent difference (if > reporting limit)	Flag sample, request re-analysis, and investigate cause

Table 4.1 Recommended field quality control samples

Results

Overview

Results for this report are separated into four main sections: general water quality, nutrients, bacteria, and nutrients. Each section is laid out in the same way, starting with a summary of upstream to downstream trends and a series of supporting graphs. Additional graphs and trends are highlighted where applicable and long-term trends are summarized with a table and map. Boxplots and time series plots are provided in Appendix B and Appendix C respectively.

General water quality

Water temperature, conductivity, total suspended solids, alkalinity, hardness, and pH generally increased from upstream to downstream in 2019 (Figure 5.1). These trends can primarily be attributed to changes in land use and geology and are less evident in Coal Creek, which does not have its headwaters high in the mountains. Temperature and pH values in St. Vrain Creek were lower near the Longmont wastewater treatment plant before increasing further downstream, but did not indicate any issues. Most temperature readings are based on grab samples and results may be affected by sampling time or holding time.

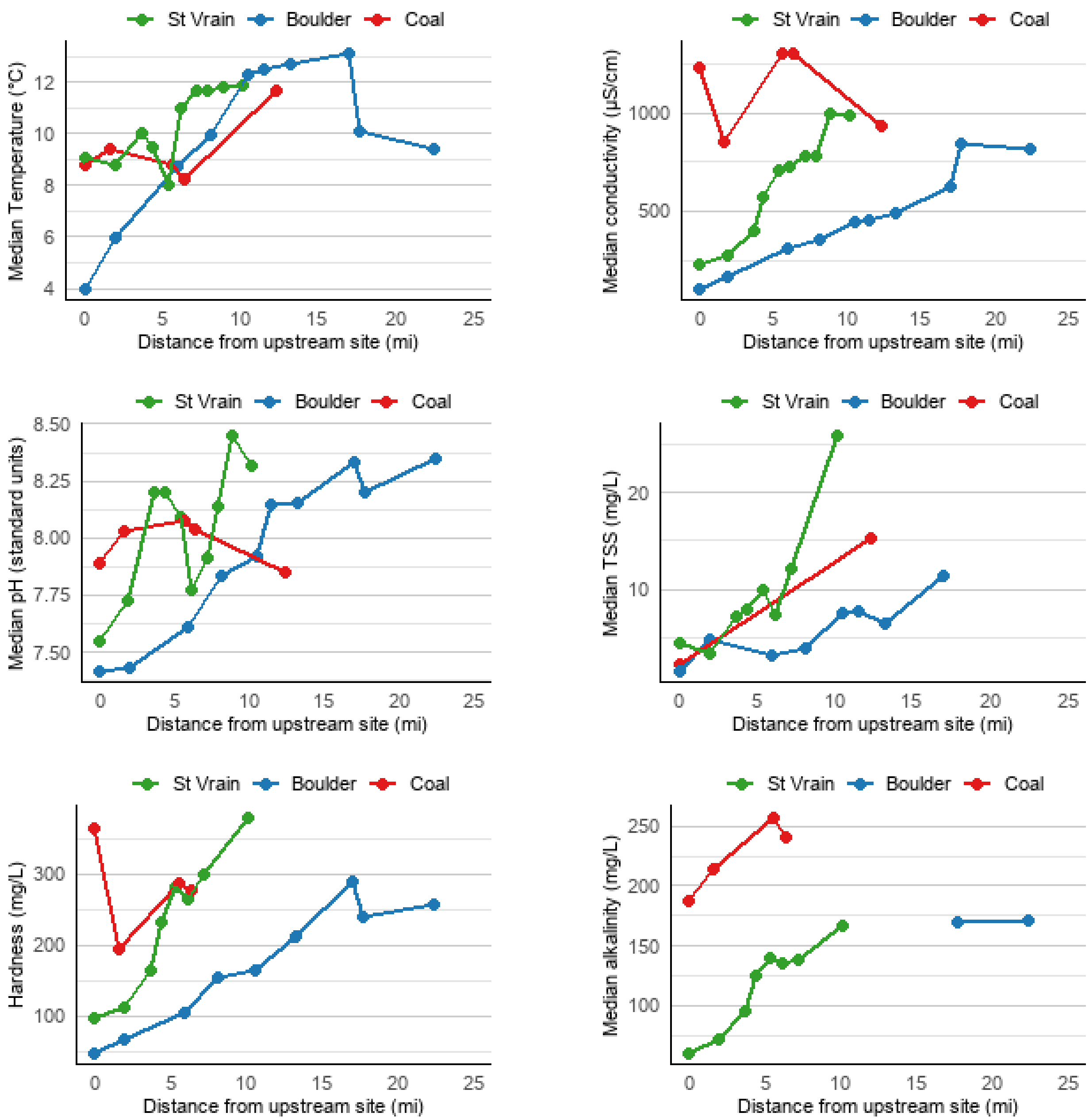


Figure 5.1 2019 median general water quality values by distance from furthest upstream site

Dissolved oxygen remained below the 5.0 mg/L stream standard in portions of Rock Creek for the 5 year period of record from 2015 – 2019 (Figure 5.2). The majority of these low values occurred in 2018 and 2019, suggesting a more recent issue that merits further investigation.

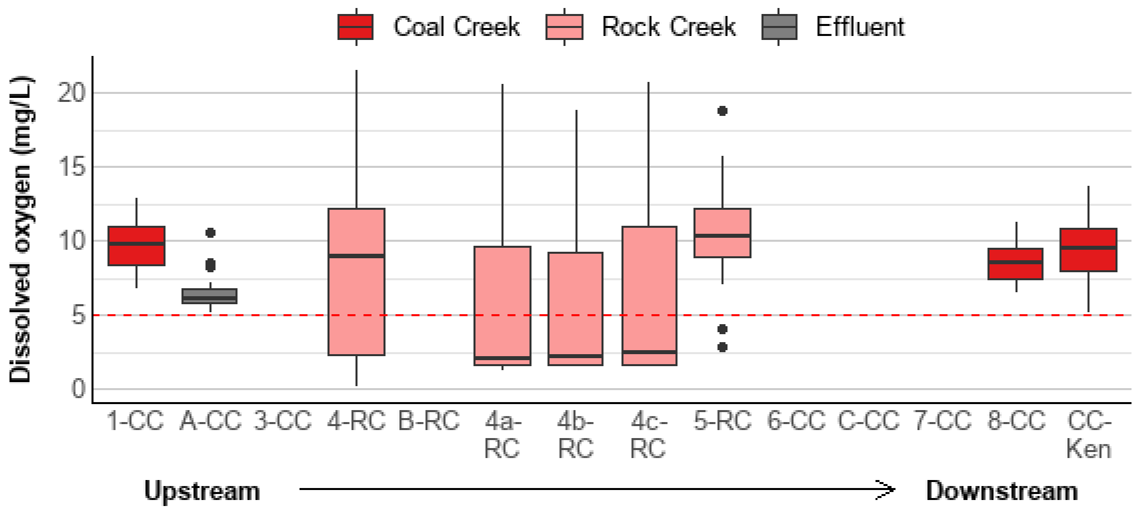


Figure 5.2 Dissolved oxygen in Coal Creek and Rock Creek from 2015 – 2019, red dashed line depicts the chronic stream standard

As depicted in Figure 5.3, all monitoring sites met the pH stream standard (majority of values above 6.5 and below 9.0, see previous section for more details). In previous years some high values were observed at downstream sites on Boulder Creek and low values observed at upstream sites, but more recent data suggests that pH is less of an issue and does not violate any chronic stream standards at KICP monitoring sites.

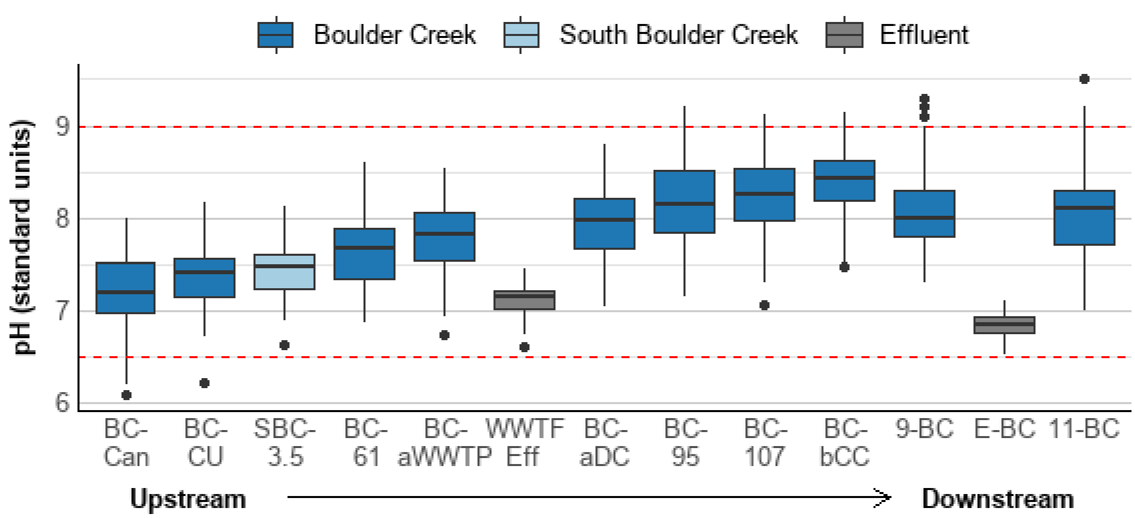


Figure 5.3 pH in Boulder Creek and South Boulder Creek from 2015 – 2019, red dashed line depicts chronic stream standards

Table 5.1 depicts the median annual change for significant long term trends for general water quality (Sen's slope estimator, Seasonal Mann Kendall test with significance level of $p < 0.05$). Cells are labeled *N/A* where insufficient data was available to calculate a trend. This summary does not account for more complex trends, but simply describes whether a variable has generally increased or decreased more often than would be expected by chance (see *Methods* section for more details on analysis). Since this is only the second year of this analysis, any trends listed may represent further understanding of trends rather than emerging issues. A few key observations from this analysis are listed below:

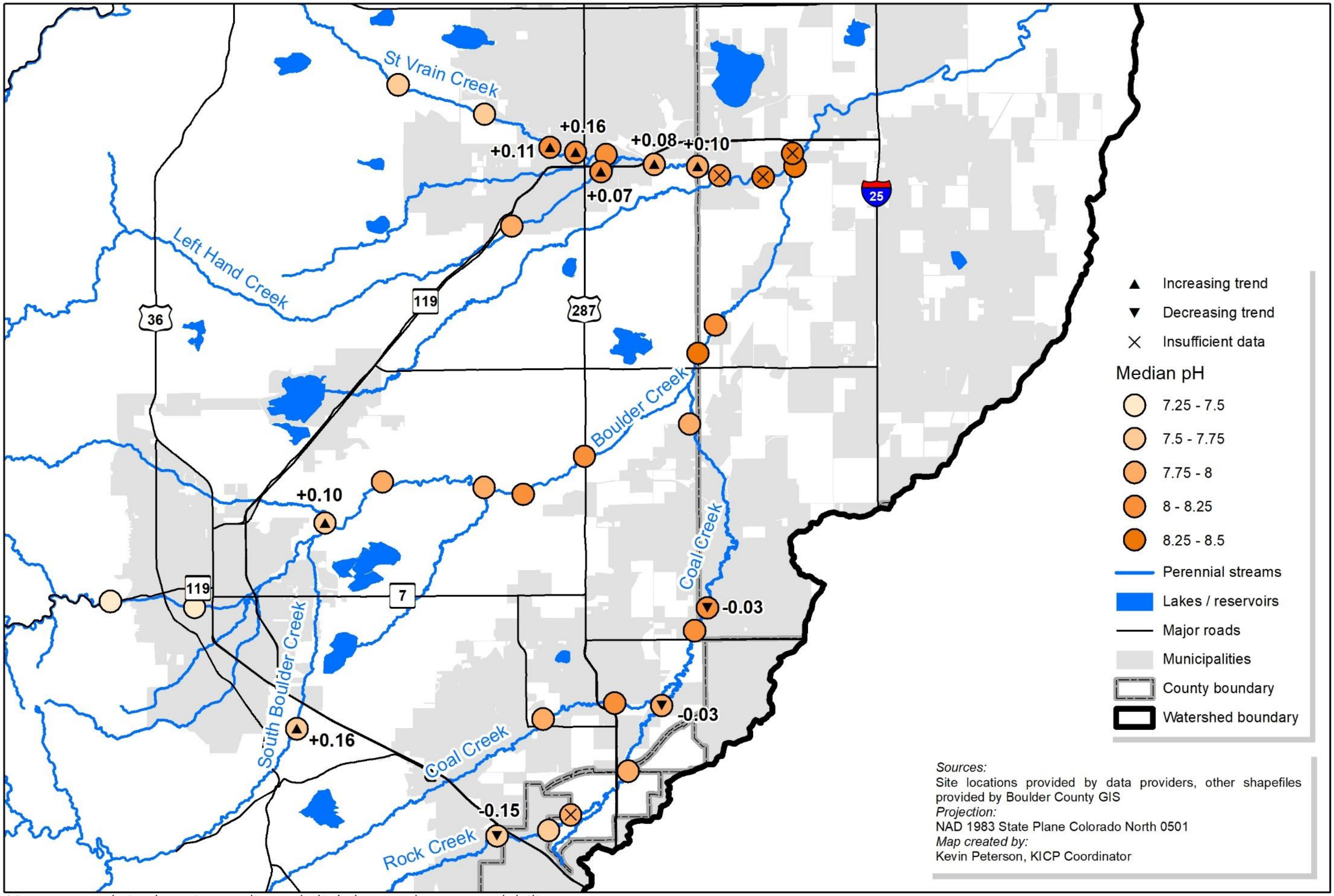
- Hardness decreased at several sites in Coal Creek over the last 5 years, but increased at several sites in Rock Creek and Coal Creek from 2001-2019.
- Conductivity increased at sites 1-CC and CC-Ken over the last 5 years, and increased slightly in several Boulder Creek sites from around 2004-2019.
- There was a large decrease in dissolved oxygen at site 4-RC over the last 5 years, while dissolved oxygen increased slightly over the last 10-15 years at several sites in St. Vrain Creek and Boulder Creek.
- pH did not show any clear overall trends, with some sites increasing slightly and others decreasing slightly over both the last 5 years and longer time frames.

Figure 5.4 is a map of 2019 median pH values at each monitoring site with significant 5 year trends. pH increases moving downstream and has increased slightly at several sites over the last 5 years, particularly in St. Vrain Creek. None of these trends have indicated any issues, with all monitoring sites meeting existing stream standards. Hardness, alkalinity, conductivity, and dissolved oxygen did not exhibit significant 5 year trends and most sites and thus are not depicted in a similar figure.

Site	Hardness (mg/L)		Alkalinity (mg/L)		Conductivity (µS/cm)		DO (mg/L)		pH (S. U.)	
	5 yr	Overall	5 yr	Overall	5 yr	Overall	5 yr	Overall	5 yr	Overall
M9.5-SV										
M8.9-SV								+0.09 *2008-2019*		
M8.4-SV									+0.11	+0.04 *2011-2019*
M8.2-SV									+0.16	
M8-SV								+0.15 *2008-2019*		+0.03 *2008-2019*
LH-95		N/A		N/A		N/A		N/A		N/A
T11-LH				-3.32 *2008-2019*				+0.12 *2008-2019*	+0.07	
WWTP-LGMT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T-EFF		+3.3 *2008-2019*	+4.2	+2.2 *2008-2019*	-15.1			-0.24 *2008-2019*		-0.04 *2008-2019*
M7-SV									+0.08	+0.09 *2014-2019*
M6-SV				-1.7 *2008-2019*				+0.11 *2008-2019*	+0.10	
M4-SV	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BC-Can	-2.4			+0.5 *2004-2018*		+1.8 *2004-2019*				-0.03 *2004-2019*
BC-CU				+0.8 *2006-2018*		+2.6 *2006-2019*				-0.03 *2006-2019*
SBC-3.5			N/A	+0.7 *2008-2018*		+1.5 *2008-2019*		+0.07 *2008-2019*	+0.16	-0.06 *2008-2019*
BC-61									+0.10	-0.02 *2004-2019*
BC-aWWTP										-0.03 *2004-2019*
WWTF Eff		N/A		N/A		N/A		N/A	-0.05	N/A
BC-aDC		+1.9 *2007-2019*						+0.09 *2004-2019*		
BC-95	N/A	N/A	N/A	N/A				+0.07 *2004-2019*		
BC-107				-0.9 *2004-2018*			+0.37			
BC-bCC		+4.3 *2004-2019*				+9.4 *2004-2019*				-0.02 *2004-2019*
9-BC		N/A		N/A		N/A		N/A		N/A
E-BC		N/A		N/A	N/A	N/A	N/A	N/A		N/A
11-BC		N/A		N/A		N/A		N/A		N/A
1-CC				-5.0 *2000-2019*	+94.3			N/A		
A-CC	N/A	N/A		N/A		N/A		N/A	-0.09	
3-CC	-23.6						N/A	N/A		
4-RC		N/A		N/A		N/A	-2.02	N/A	-0.15	N/A
B-RC	N/A	N/A	N/A	N/A		N/A	N/A	N/A		N/A
4a-RC	N/A	N/A	N/A	N/A		N/A				N/A
4b-RC	N/A	N/A	N/A	N/A		N/A			N/A	N/A
4c-RC	N/A	N/A	N/A	N/A		N/A				N/A
5-RC		+2.3 *2001-2019*					N/A	N/A	-0.03	+0.01 *2001-2019*
6-CC	-14.7	+2.4 *2001-2019*					N/A	N/A		+0.01 *2001-2019*
7-CC	-8.5	+3.2 2001-2019					N/A	N/A	-0.03	+0.02 *2001-2019*
C-CC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
CC-Ken	N/A	N/A		+2.9 *2004-2018*	+60.8	+26.6 *2004-2019*		+0.09 *2004-2019*		

Table 5.1 Median annual change for significant 5 year and overall trends for general water quality parameters (Seasonal Mann-Kendall with significance $p < 0.05$), year range listed for overall trends

PH TRENDS



Note: several site locations adjusted slightly to enhance readability

Figure 5.4 2019 pH values and significant 5 year trends (median change in standard units per year)

Nutrients

As seen in Figure 5.5, large increases in total nitrogen and total phosphorus are associated with inflows of treated wastewater from major wastewater treatment plants (WWTPs). There is a clear increase in nitrogen and phosphorus concentrations below the Longmont WWTP, which then decreases further downstream in St. Vrain Creek. Nitrogen in Boulder Creek increases slightly below the Boulder WWTP and there was a large increase between sites BC-bCC and 9-BC without a clear explanation. For phosphorus, there was a large increase below the Boulder WWTP and a smaller increase between these same two sites. In Coal Creek, there was a large increase in nitrogen and phosphorus below the Lafayette WWTP and a similar increase in nitrogen only downstream of the Louisville WWTP.

Total ammonia did not show a clear trend overall; increasing steadily downstream in St. Vrain Creek, appearing to remain consistent in Boulder Creek, and decreasing downstream in Coal Creek. While elevated ammonia due to WWTPs was once an issue, there are no indications that this is a current problem at KICP monitoring sites. Collectively, these trends suggest that WWTPs are a primary contributor to excess nutrient levels and that inputs from urban stormwater and agriculture may be lesser factors in these basins. However, nutrient reductions from these sources can be significant and will be needed to meet anticipated stream standards. Further investigation could help further clarify the role of land use in nutrient trends.

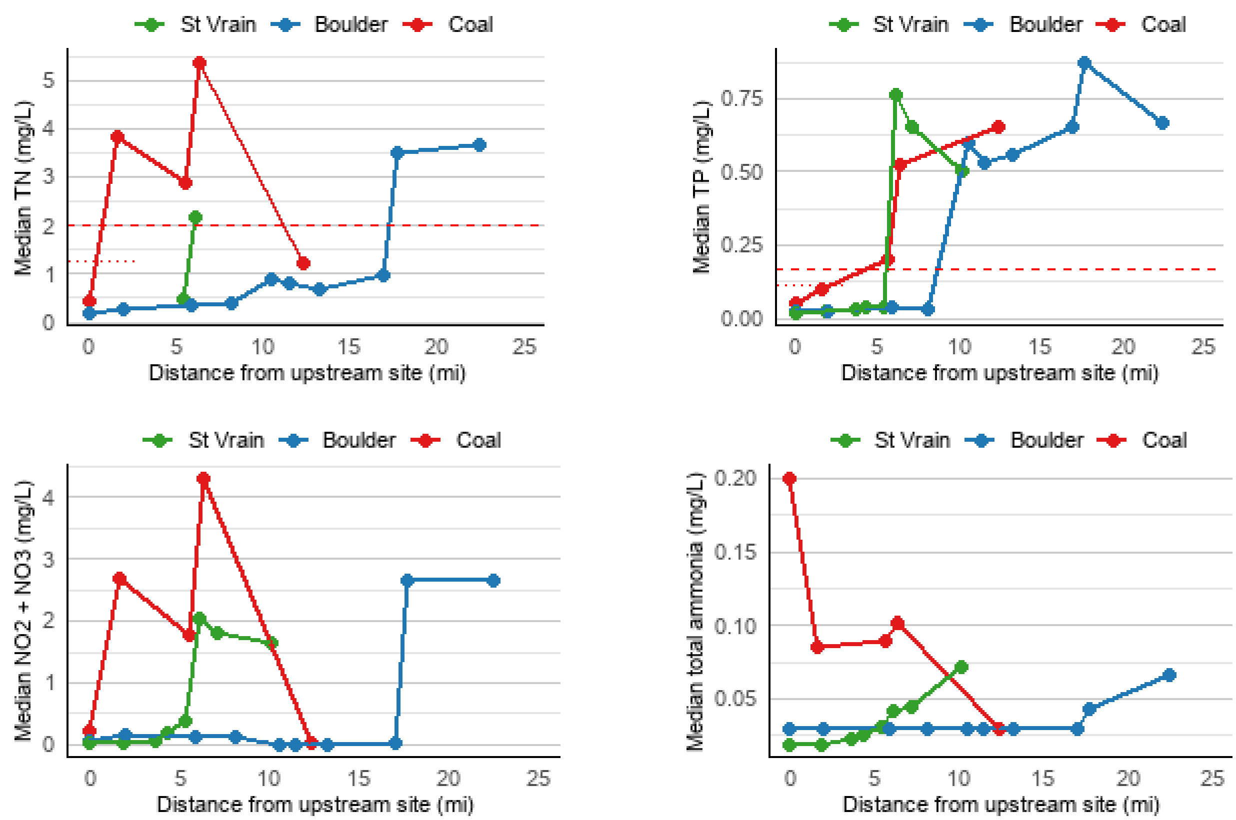


Figure 5.5 2019 median nutrient values by distance from furthest upstream site, dashed line is interim chronic standard (except two most upstream Boulder Creek sites where standard is marked with dotted line) which does not apply to effluent sites and has not yet been implemented for instream sites downstream of major WWTPs

Table 5.3 depicts the median annual change for significant long term trends for nutrients and bacteria (Sen's slope estimator, Seasonal Mann Kendall test with significance level of $p < 0.05$). Cells are labeled *N/A* where insufficient data was available to calculate a trend. This summary does not account for more complex trends, but simply describes whether a variable has generally increased or decreased more often than would be expected by chance (see *Methods* section for more details on analysis). Since this is only the second year of this analysis, any trends listed may represent further understanding of trends rather than emerging issues. Nutrient trends may also be impacted by changing minimum detection levels (MDL), which have decreased over time due to changing analysis methods. Long-term decreasing trends in particular may be influenced by changes to MDLs and may need further investigation.

Analyte	Highest MDL	Lowest MDL
Nitrates/nitrites (NO_x)	0.150 mg/L	0.0013 mg/L
Total ammonia (NH_3)	0.100 mg/L	0.0058 mg/L
Total phosphorus (TP)	0.129 mg/L	0.00277 mg/L

Table 5.2 Summary of changing minimum detection limits for nutrients at instream sites

A few key observations from this analysis are listed below:

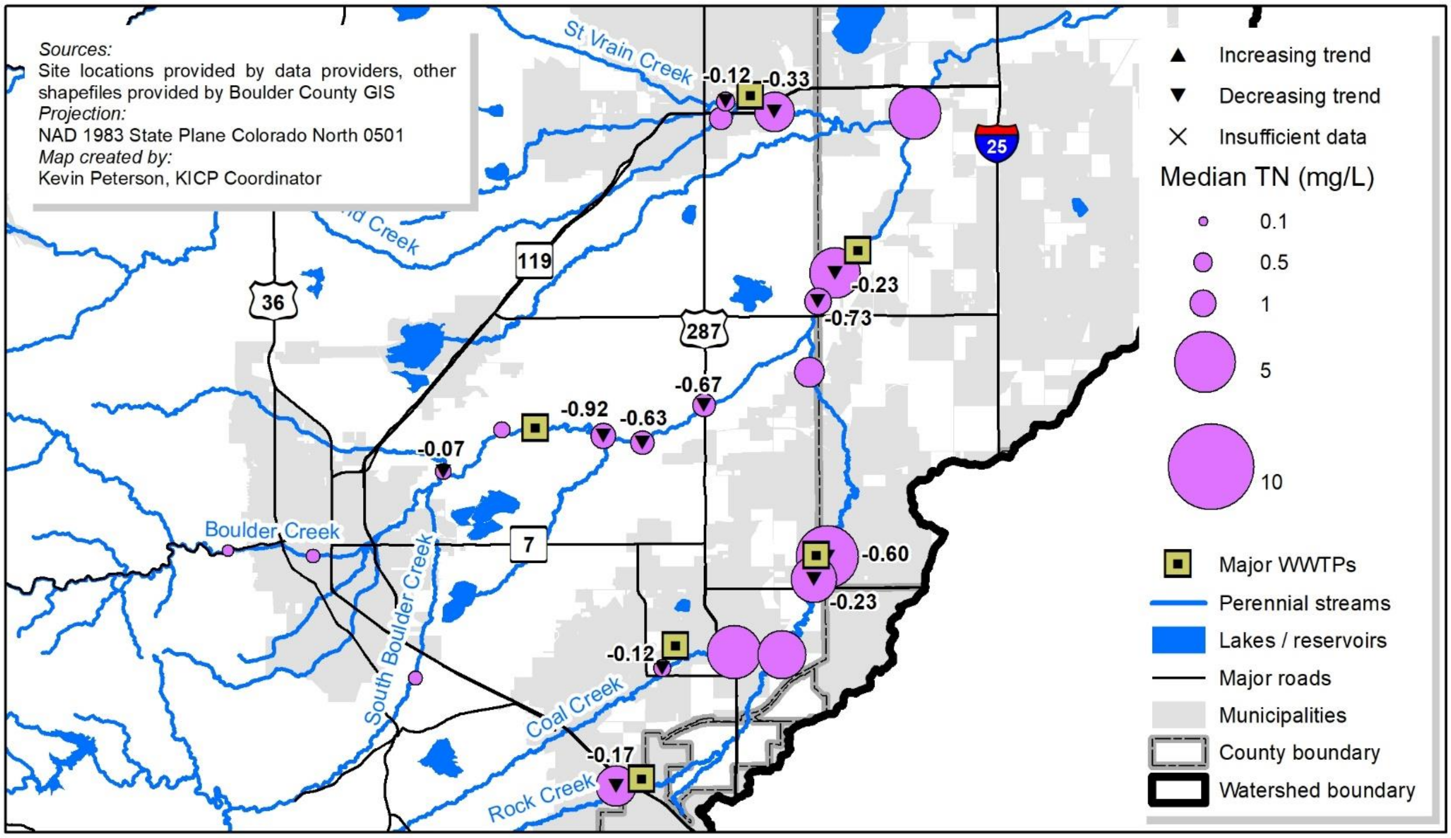
- Total nitrogen and nitrates/nitrites decreased somewhat at most sites over both the last 5 years and longer timeframes. Nitrogen in effluent flows decreased by large amounts at several facilities due to wastewater treatment plant upgrades or operating procedures. Instream reductions appeared slightly greater downstream of wastewater plants, but further analysis would be needed to clarify this trend.
- While total ammonia has generally decreased over the last 10-15 years, a slight increasing trend was observed at several sites in Boulder Creek over the most recent 5 years. Since ammonia levels remain well below instream standards, this is not a priority issue for investigation.
- Total phosphorus has decreased slightly in most sites in Boulder Creek and Coal Creek over the last 10-20 years, but an increasing trend was observed at sites M7-SV, 11-BC, 4-RC, and 1-CC. An increase in phosphorus was also observed in effluent flows above M7-SV that may contribute to this trend, but further analysis would be need to clarify this trend at other sites.

Figure 5.6 is a map of 2019 median total nitrogen and total phosphorus values at each monitoring site with significant 5 year trends. Total nitrogen decreased at most sites over the last 5 years, with larger decreases generally downstream of major wastewater treatment plants. Instream nitrogen has experience significant decreases due to various improvements at wastewater treatment plants. Despite any improvements instream nitrogen levels remain above proposed instream standards downstream of these facilities, as is commonly seen in other streams around the state and country.

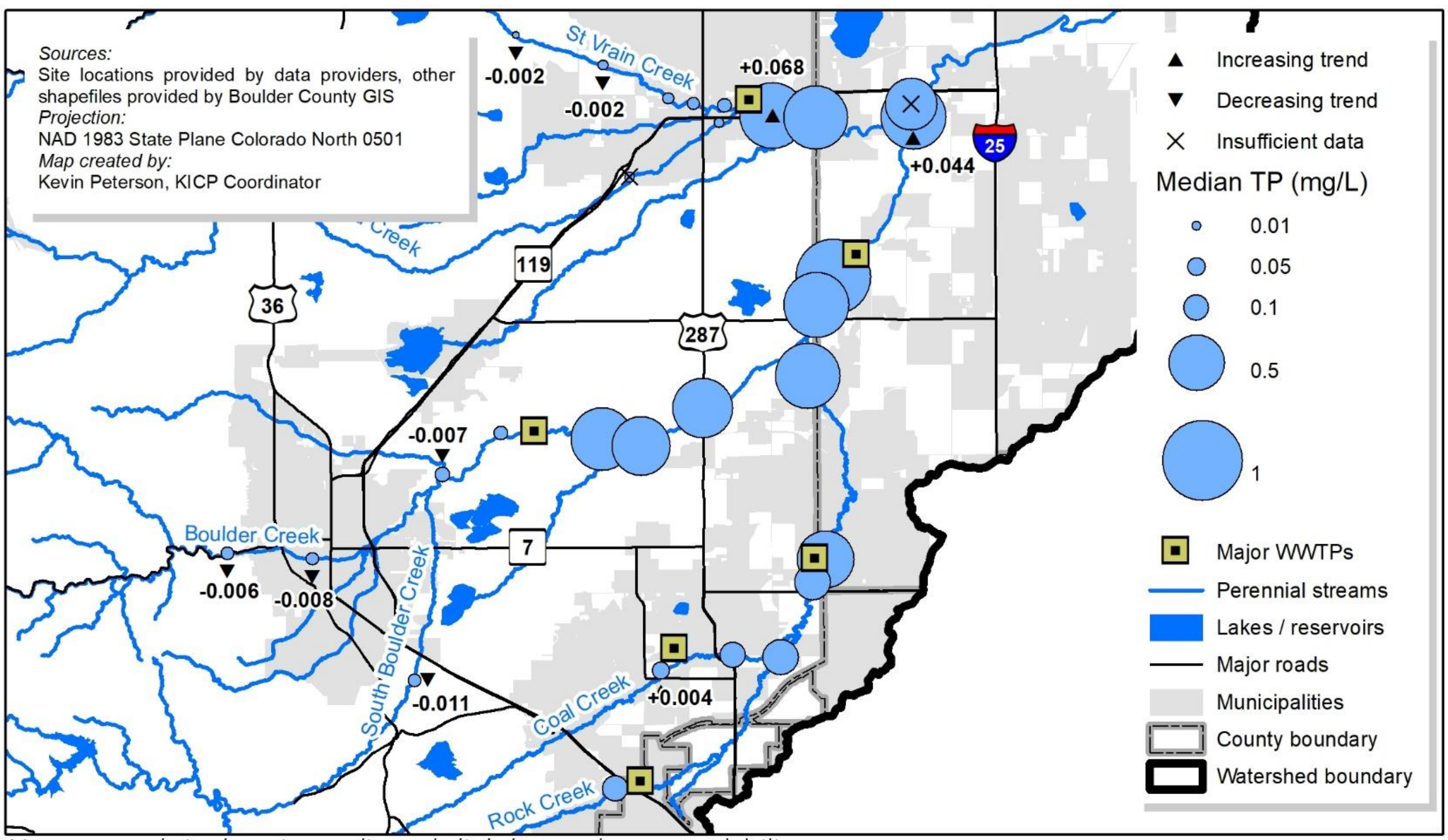
Site	**Total N** (mg/L)		**NO_x** (mg/L)		**Total NH_3** (mg/L)		**Total P** (mg/L)		***E. coli*** (cfu/100mL)	
	5 yr	**Overall**	**5 yr**	**Overall**	**5 yr**	**Overall**	**5 yr**	**Overall**	**5 yr**	**Overall**
M9.5-SV	*N/A*	*N/A*		-0.01 2014-2019	-0.003	-0.003 2014-2019	-0.002	-0.001 2014-2019		
M8.9-SV	*N/A*	*N/A*	-0.01				-0.002			
M8.4-SV	*N/A*	*N/A*	-0.03	-0.01 2011-2019						
M8.2-SV	*N/A*	*N/A*	-0.04		-0.005					
M8-SV	-0.12	-0.09 2013-2019	-0.02	-0.01 2008-2019	-0.002					
LH-95	*N/A*	*N/A*	-0.03	*N/A*		*N/A*		*N/A*		*N/A*
T11-LH		-0.06 2013-2019		-0.03 2008-2019	-0.003		-0.005			-2.91 2008-2019
WWTP-LGMT	-1.79	*N/A*	-1.53	*N/A*	-0.036	*N/A*	+0.457	*N/A*	*N/A*	*N/A*
T-EFF	*N/A*	*N/A*	-1.52	-0.21 2008-2019			+0.385	+0.113 2008-2019		+3.76 2008-2019
M7-SV	-0.33	-0.14 2013-2019				-0.007 2013-2019	+0.068	+0.074 2013-2019		
M6-SV	*N/A*	*N/A*		-0.08 2008-2019	-0.009					
M4-SV	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
BC-Can			*N/A*	*N/A*	+0.001	-0.003 2004-2019	-0.006			
BC-CU			*N/A*	*N/A*	+0.004	-0.003 2006-2019	-0.008			
SBC-3.5			*N/A*	*N/A*	+0.005	+0.001 2008-2019	-0.011	-0.009 2008-2019		
BC-61	-0.07		*N/A*	*N/A*			-0.007			
BC-aWWTP			*N/A*	*N/A*				-0.001 2004-2019		
WWTF Eff	-2.95	*N/A*	*N/A*	*N/A*		*N/A*		*N/A*		*N/A*
BC-aDC	-0.92	-0.43 2004-2019	*N/A*	*N/A*				-0.140 2004-2019		
BC-95	-0.63	-0.33 2004-2019	*N/A*	*N/A*	+0.005	-0.005 2004-2019		-0.096 2004-2019	*N/A*	
BC-107	-0.67	-0.22 2004-2019	*N/A*	*N/A*	+0.004	-0.004 2004-2019		-0.050 2004-2019		
BC-bCC	-0.73	-0.19 2004-2019	*N/A*	*N/A*		-0.002 2004-2019		-0.070 2004-2019		-6.17 2004-2019
9-BC	-0.23	-0.25 2013-2019	-0.20	-0.25 2013-2019				+0.047 2013-2019		*N/A*
E-BC										*N/A*
11-BC		-0.22 2013-2019		-0.14 2013-2019			+0.044	+0.038 2013-2019		*N/A*
1-CC	-0.12	-0.11 2013-2019	-0.04	-0.02 1999-2019	+0.005		+0.004	+0.003 2013-2019		
A-CC		-0.47 2013-2019				-0.065 2013-2019	-0.148		-2.15	*N/A*
3-CC		-0.26 2013-2019				-0.001 2001-2019		-0.012 2001-2019		
4-RC	-0.17			-0.06 2013-2019				+0.013 2013-2019		*N/A*
B-RC	-5.32		-4.55		*N/A*	-0.083 2013-2019	-0.745		*N/A*	*N/A*
5-RC		-0.30 2013-2019						-0.012 2001-2019		
6-CC	-0.23	-0.22 2013-2019				-0.003 2001-2019		-0.006 2001-2019		
7-CC	-0.60	-0.61 2013-2019	-0.31	-0.33 2013-2019		-0.003 2001-2019		-0.016 2001-2019		
C-CC		-2.03 2013-2018		-1.67 2013-2018	*N/A*		+0.217	+0.117 2013-2018	*N/A*	*N/A*
CC-Ken			*N/A*	*N/A*				-0.101 2004-2019		-7.88 2004-2019

Table 5.3 Median annual change for significant 5 year and long term trends for nutrients and bacteria (Seasonal Mann-Kendall with significance $p < 0.05$), year range listed for overall trends

TOTAL NITROGEN TRENDS



TOTAL PHOSPHORUS TRENDS



Note: several site locations adjusted slightly to enhance readability

Figure 5.6 2019 nutrient values and significant 5 year trends (median change in mg/L per year)

Bacteria

As shown in Figure 5.7, *E. coli* values were generally higher during the recreation season (May – October) than during the non-recreation season (November – April). While *E. coli* values can be highly variable, there is a well-established connection between urbanized area and increased bacteria concentrations. In St. Vrain Creek the geometric mean of *E. coli* increased somewhat inconsistently moving downstream. In Boulder Creek *E. coli* increased for the first 5-6 miles through the City of Boulder, decreased downstream of the city limits, and started increasing again downstream of the confluence with Coal Creek. *E. coli* increased consistently in Coal Creek downstream of the confluence with Rock Creek.

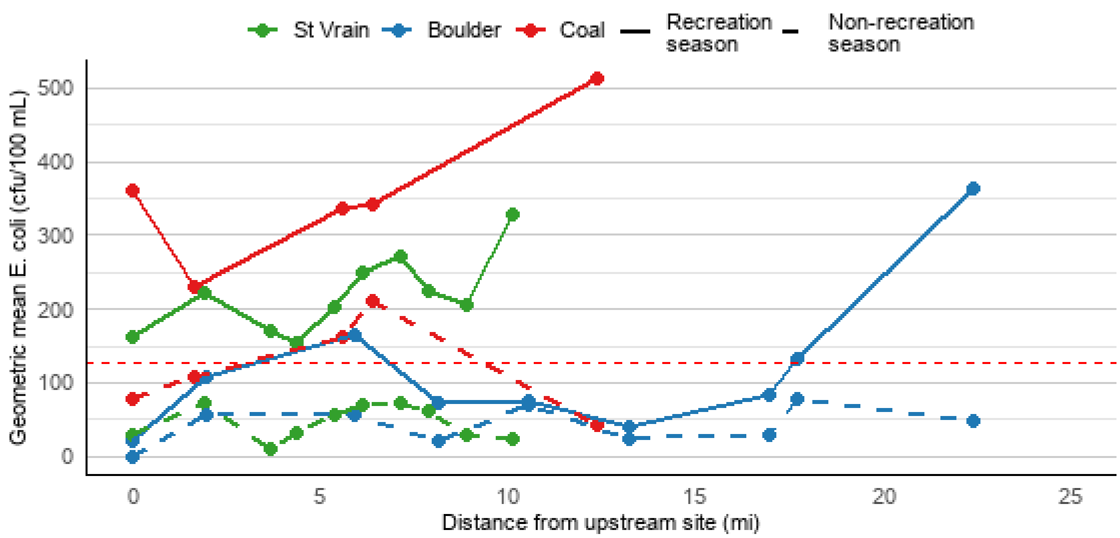


Figure 5.7 2019 geometric mean *E. coli* values by distance from furthest upstream site, solid lines depict recreation season values and thick dashed lines depict non-recreation season values with thin dashed red line depicting chronic *E. coli* standard

As seen in Figure 5.8 and similar to previous years, *E. coli* concentrations remained low in St. Vrain Creek, Boulder Creek, and Coal Creek through April. The geometric mean of sites in each of St. Vrain Creek, Boulder Creek, and Coal Creek had an initial peak in May. This was followed by relatively low values in Boulder Creek, while the geometric mean remained somewhat elevated in St. Vrain Creek and Coal Creek through at least October.

As can be seen in Table 5.3 and Figure 5.9, there were no significant trends in *E. coli* at instream sites over the last 5 years. While some long term trends were observed, they may not be describing important changes due to the high variability of bacteria measurements. It appears that *E. coli* has neither increased nor decreased over the last 5 years, but more in-depth analysis or higher frequency sampling could provide more insight into any existing trends.

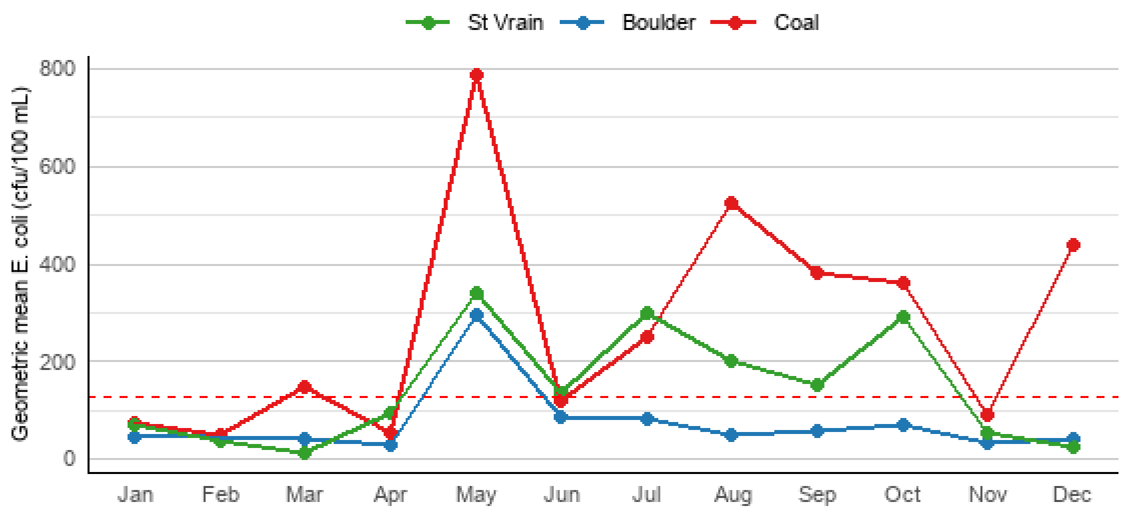
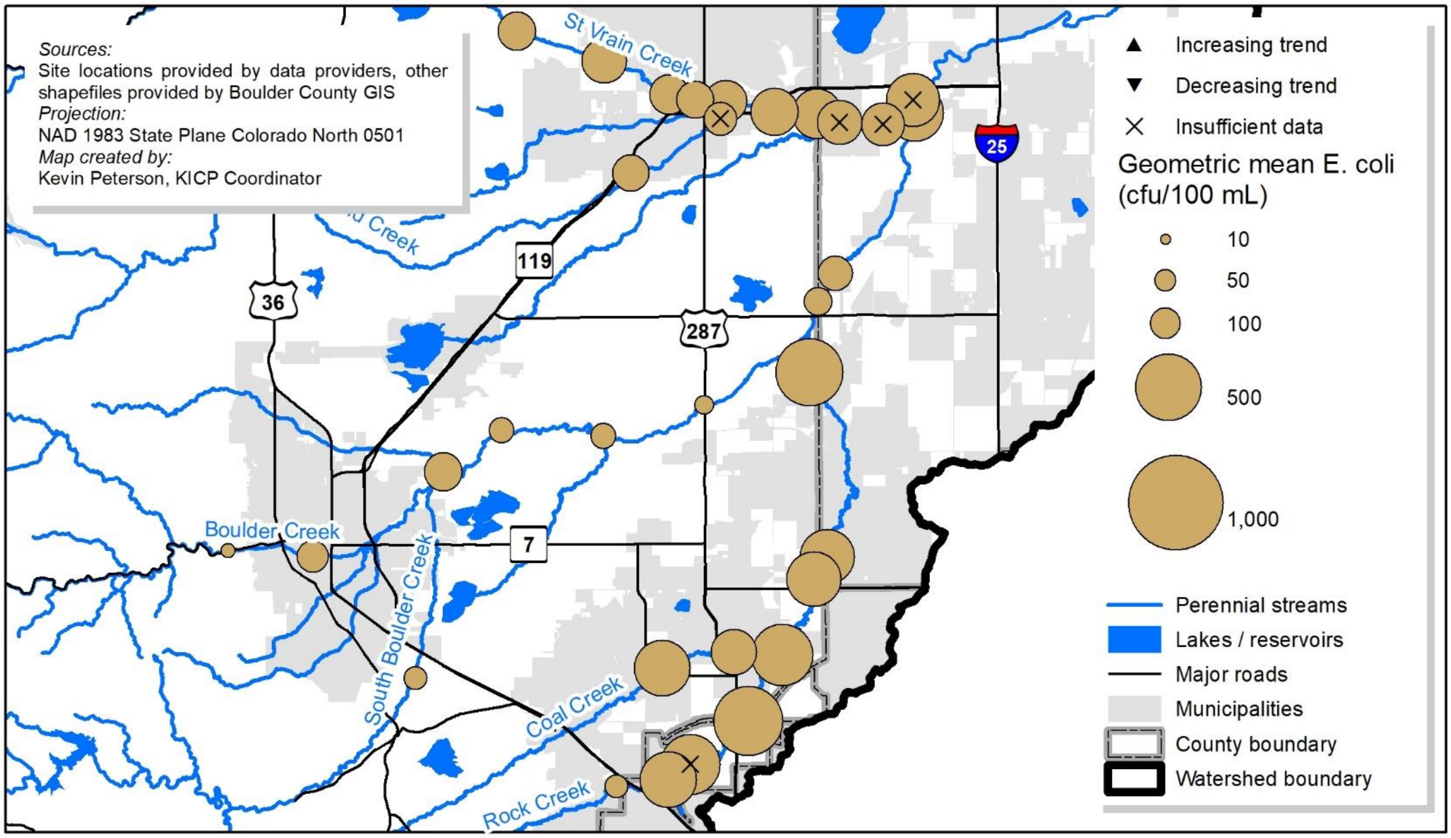
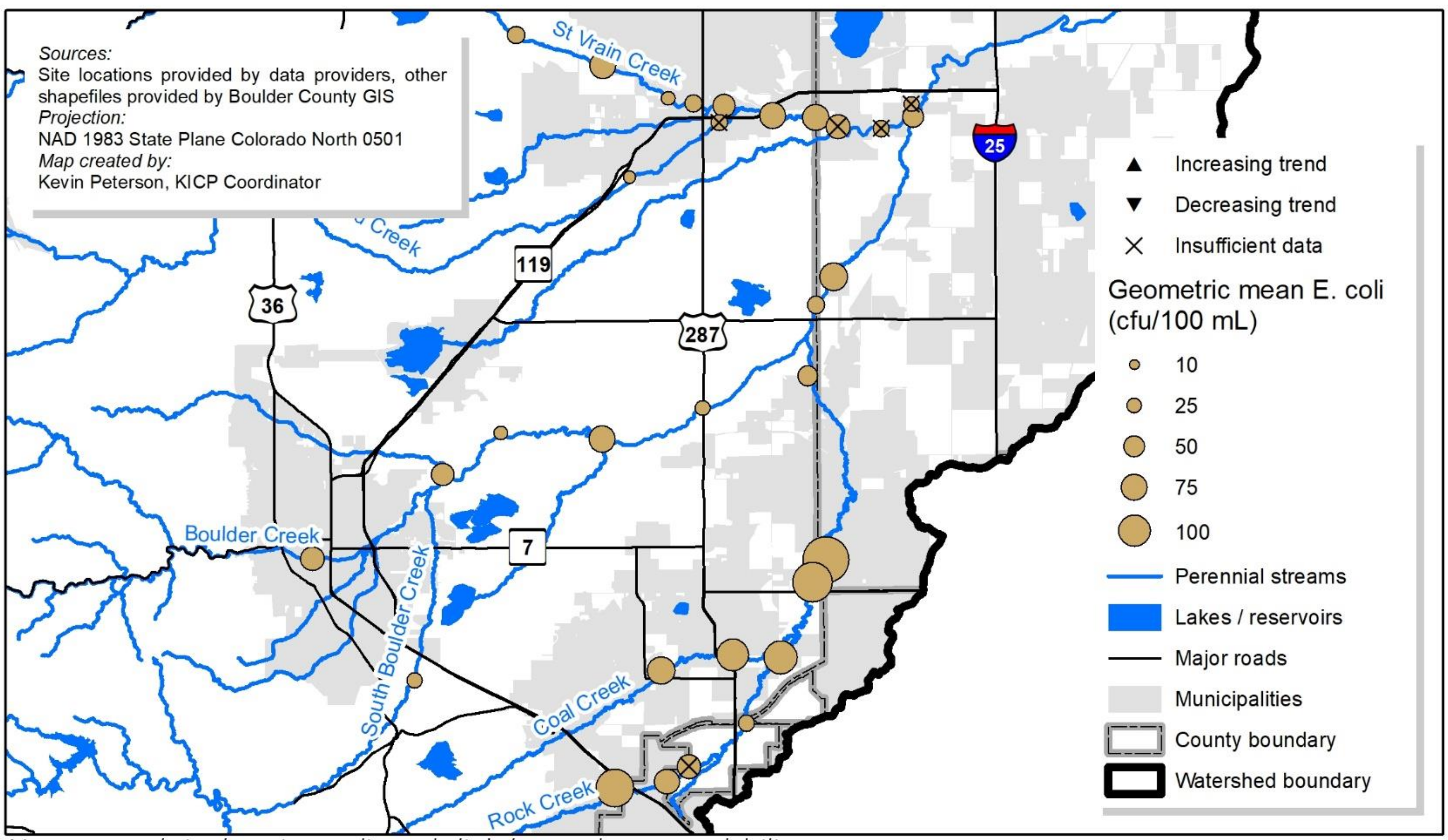


Figure 5.8 2019 geometric mean *E. coli* values by month (all mainstem sites compiled), dashed red line depicts chronic *E. coli* standard

E. COLI TRENDS (RECREATION SEASON)



E. COLI TRENDS (NON-RECREATION SEASON)



Note: several site locations adjusted slightly to enhance readability

Figure 5.9 2019 *E. coli* values and significant 5 year trends (median change in cfu/100 mL per year)

Metals

As seen in Figure 5.10, total arsenic increased moving from upstream to downstream in St. Vrain Creek and Boulder Creek, while this trend was less clear in the limited sites in Coal Creek. Dissolved selenium increased downstream in Boulder Creek, while dissolved copper increased dramatically below the Boulder wastewater treatment plant. Dissolved silver did not follow a clear trend moving downstream, but remained relatively low and was highest at some of the furthest downstream sites.

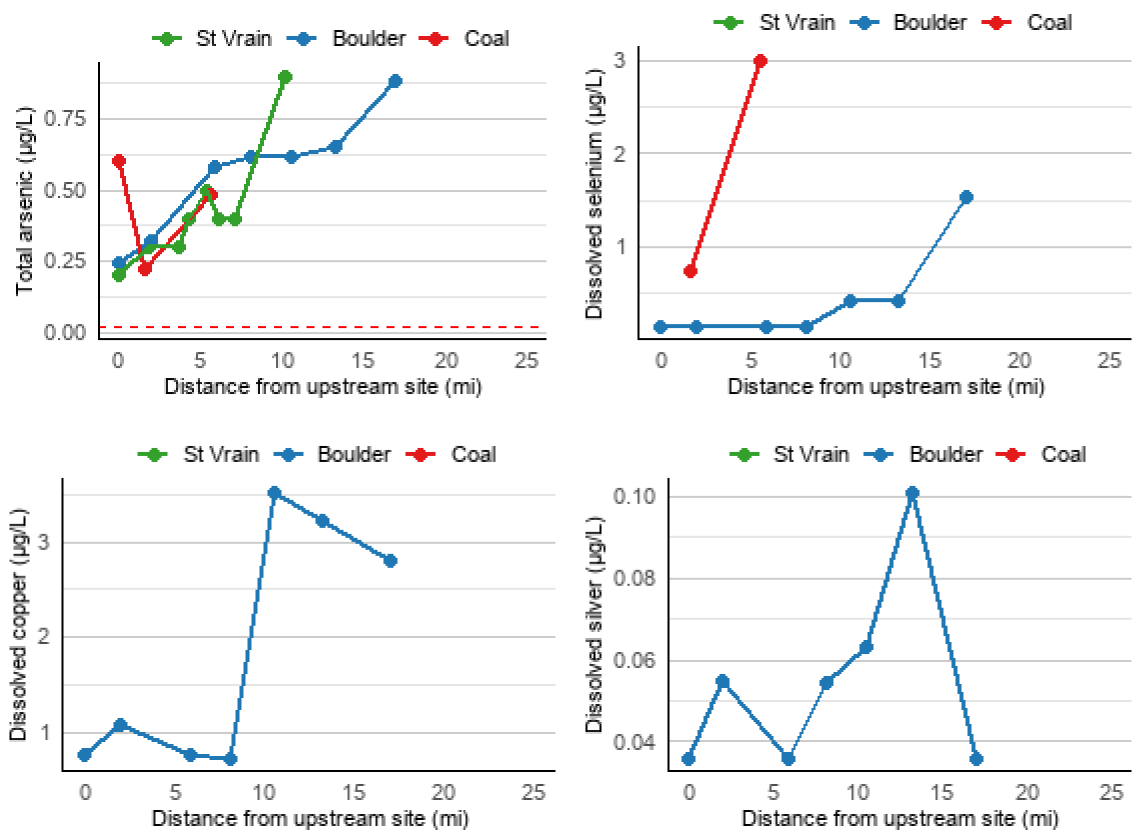


Figure 5.10 2019 median metals values by distance from upstream site, red dashed line depicts chronic standard (arsenic standard only applies in Boulder Creek)

Sites in Boulder Creek are impaired for total arsenic due to significantly lower standards—due to the aquatic life life and water supply use classifications—than other local streams. Sites BC-Can, BC-CU, and SBC-3.5 are impaired for dissolved silver associated with low levels of hardness that result in a more stringent standard. Coal Creek and Rock Creek are impaired for dissolved selenium and Left Hand Creek is impaired for dissolved copper. Coal Creek and Left Hand Creek are also impaired for dissolved manganese, which is not evaluated within this report. See Appendix A for more information on how stream standards are calculated and Appendix B for summary boxplots of these parameters.

Table 5.5 depicts the median annual change for significant long term trends for metals (Sen's slope estimator, Seasonal Mann Kendall test with significance level of $p < 0.05$). Cells are labeled *N/A* where insufficient data was available to calculate a trend. This summary does not account for more complex trends, but simply describes whether a variable has generally increased or decreased more often than would be expected by chance (see *Methods* section for more details on analysis). Since this is only the second year of this analysis, any trends listed may represent further understanding of trends rather than emerging issues. Trends in metals may also be impacted by changing minimum detection levels (MDL), which have decreased over time due to changing analysis methods. Long-term decreasing trends in particular may be influenced by changes to MDLs and may need further investigation.

Analyte	Highest MDL	Lowest MDL
Total arsenic	7.69 µg/L	0.00082 µg/L
Dissolved selenium	4.77 µg/L	0.00080 µg/L
Dissolved copper	3.16 µg/L	0.00076 µg/L
Dissolved silver	2.48 µg/L	0.00056 µg/L

Table 5.4 Summary of changing minimum detection limits for metals at instream sites

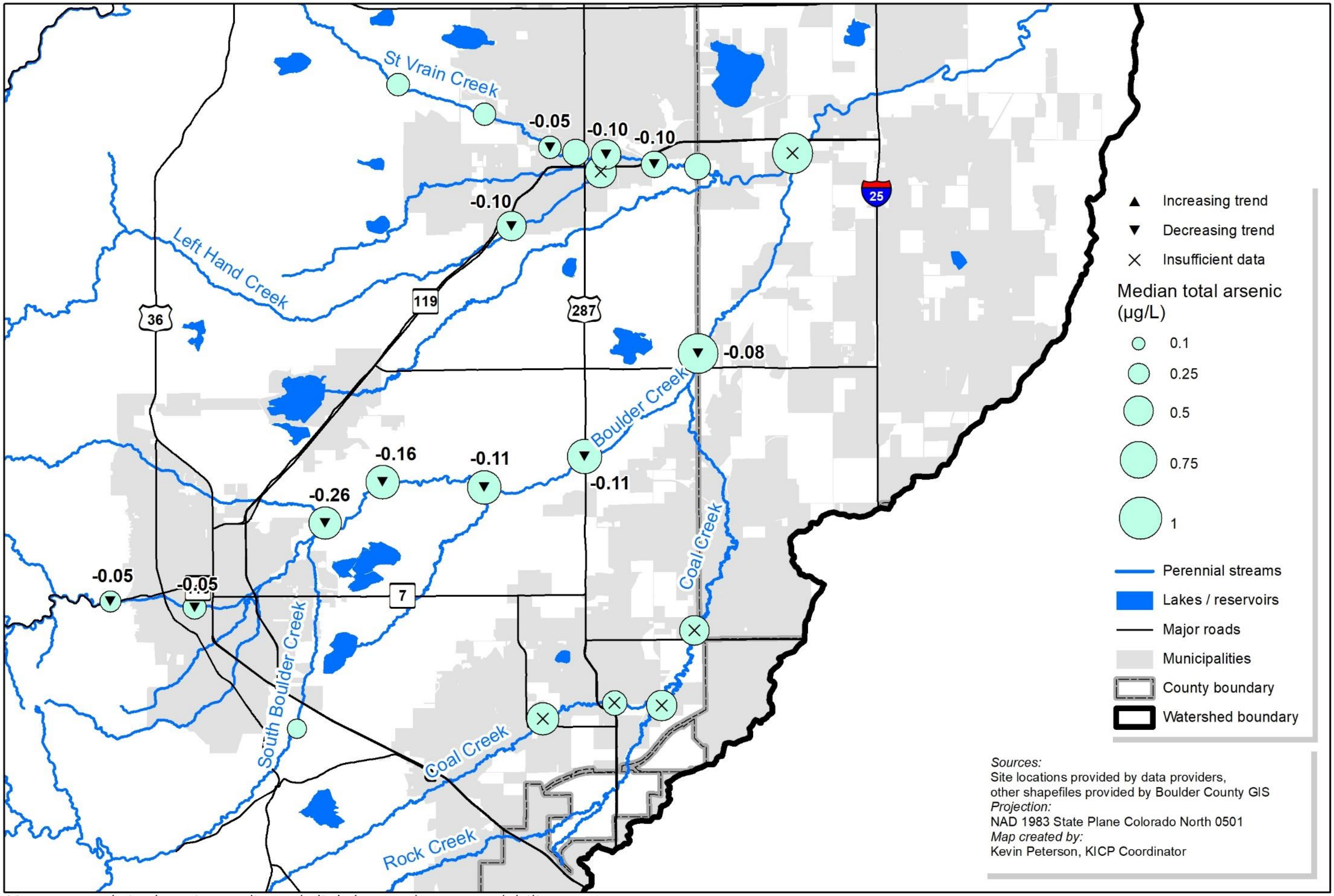
A few key observations from this analysis are listed below:

- Total arsenic has decreased at most sites over the last 5 years, but has increased slightly over the last 10-15 years.
- Dissolved selenium decreased at several sites in Boulder Creek over the last 5 years and decreased slightly at most sites over the last 10-15 years, although concentrations increased slightly at BC-aDC and BC-107, two of the more downstream sites. Total selenium decreased somewhat at M8-SV over the last 5 years, but dissolved selenium data was not available for comparison.
- Dissolved copper has increased somewhat over the last 5 years at most sites in Boulder Creek, although some of these sites have also shown a decreasing trend over the last 10-15 years overall. All of the sites currently meet stream standards and do not indicate any pressing water quality issues. Total copper in St. Vrain Creek has decreased at sites T-EFF and M7-SV over the last 5 years, but the trends over the last 10-15 years are less clear, with some sites increasing and others decreasing.
- Dissolved silver has not shown any tends over the last 5 years, but has increased slightly at sites SBC-3.5 and BC-aWWTP over the last 10-15 years.

Site	Tot. arsenic (µg/L)		Dis. selenium (µg/L)		Dis. copper (µg/L)		Dis. silver (µg/L)	
	5 yr	Overall	5 yr	Overall	5 yr	Overall	5 yr	Overall
M9.5-SV			*	N/A	*	N/A	N/A	N/A
M8.9-SV		+0.04 2008-2019	*	*	*	+0.10* 2008-2019	N/A	N/A
M8.4-SV	-0.05	+0.05 2011-2019	*	-0.025* 2011-2019	*	+0.13* 2011-2019	N/A	N/A
M8.2-SV		+0.05 2011-2019	*	*	*	+0.11* 2011-2019	N/A	N/A
M8-SV	-0.10	+0.05 2008-2019	-0.250*	*	*	+0.11* 2008-2019	N/A	N/A
LH-95		N/A	*	N/A	*	N/A	N/A	N/A
T11-LH	-0.10	+0.06 2008-2019	*	*	*	+0.13* 2008-2019	N/A	N/A
WWTP-LGMT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T-EFF		+0.03 2008-2019	*	+0.017* 2008-2019	-0.90*	-0.11* 2008-2019	N/A	N/A
M7-SV	-0.10	N/A	*	*	-0.35*		N/A	N/A
M6-SV		+0.05 2008-2019	*	*	*	+0.19* 2008-2019	N/A	N/A
M4-SV	N/A	+0.10 2008-2019	N/A	*	N/A	*	N/A	N/A
BC-Can	-0.05	-0.01 2004-2019		-0.003 2004-2019	+0.10	-0.05 2004-2019		+0.001 2006-2019
BC-CU	-0.05			-0.004 2006-2019	+0.14	-0.04 2006-2019		
SBC-3.5		+0.01 2008-2019			+0.14	+0.07 2008-2019		+0.004 2008-2019
BC-61	-0.26	+0.03 2004-2019		-0.003 2004-2019	+0.09	-0.04 2004-2019		
BC-aWWTP	-0.16	-0.07 2012-2019	-0.038	-0.010 2012-2019	+0.14			
WWTF Eff	-0.02	N/A	-0.072	N/A		N/A		N/A
BC-aDC	-0.11	+0.03 2007-2019		+0.016 2007-2019		-0.24 2007-2019		
BC-95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
BC-107	-0.11	+0.03 2004-2019	-0.044	+0.007 2004-2019	+0.16	+0.05 2004-2019		
BC-bCC	-0.07	+0.02 2004-2019		+0.039 2004-2019	+0.12			

Table 5.5 Median annual change for significant 5 year and long term trends for metals (Seasonal Mann-Kendall with significance $p < 0.05$), year range for long-term trends listed in parentheses, asterisks mark where total fraction was sampled instead of dissolved fraction.

TOTAL ARSENIC TRENDS



Note: several site locations adjusted slightly to enhance readability

Figure 5.11 2019 total arsenic values and significant 5 year trends (median change in µg/L per year)

Correlations

Table 5.12 depicts significant correlations at KICP instream monitoring sites from 2015 – 2019. The values listed in the table below are measures of association from a 2-sided Kendall correlation at significance level $p < 0.05$. Blank cells did not have a significant correlation in this analysis. Hardness, conductivity, and alkalinity were all highly correlated and TN, NOx, and TP were also closely correlated. *E. coli* had a relatively weak positive correlation with temperature and negative correlation with dissolved oxygen.

Stream flow is an important variable for instream water quality, but correlations with flow were not evaluated within this report. An in-depth analysis or explanation of correlations between water quality parameters is also outside the scope of this report. The values presented in Table 5.12 can be used to support a fuller understanding of the dataset analyzed within this report.

	Temp	Hardness	Alkalinity	Conductivity	TSS	DO	pH	TN	NOx	NH3	TP	*E. coli*	Arsenic (T)	Copper	Selenium
Hardness	-.04														
Alkalinity		.71													
Conductivity	-.05	.74	.74												
TSS	.23	.07		.09											
DO	-.47	.07		.04	-.18										
pH	.04	.35	.36	.33	.05	.08									
TN		.44	.38	.43	.25	-.06	.29								
NOx	-.05	.42	.41	.46	.19		.17	.82							
NH3		.28	.21	.30	.23	-.08	.08	.27	.29						
TP	.05	.21	.18	.24	.31	-.06	.18	.57	.52	.22					
E. coli	.27		.05	.07	.24	-.24	-.05	.05	.05	.15	.06				
Arsenic (T)	.27	.18	.10	.17	.32	-.21	.16	.19	.14	.16	.25	.08			
Copper	.19	.31	.30	.32	.33	-.06	.29	.46	.19	.23	.48	.07	.20		
Selenium	.13	.66	.68	.64	.30		.40	.51	.50	.35	.38	.14	.18	.40	
Silver		-.14	-.16	-.12		-.15			-.30		.08				-.16

Table 5.6 2015-2019 significant correlations ($p < 0.05$) between analytes at instream monitoring sites, Kendall's tau estimate is reported

Conclusions

General water quality

- Dissolved oxygen remains very low in Rock Creek from March through October. While flow data is not available at these sites, typically low flows may contribute to this issue. The site upstream of the Superior wastewater facility (4-RC) had a large decrease in dissolved oxygen over the last 5 years, while other sites did not have enough data for trend analysis.
- All Boulder Creek sites meet the required standard for pH, with most values falling between 6.5 and 9.0. Sites downstream of Coal Creek were removed from the list of impairments by the State and there no current pH impairments at any KICP monitoring sites.
- Conductivity has increased slightly at several sites in Boulder Creek since 2004, but no trends were observed over the last 5 years. This is in contrast to the increasing trend observed from 2014-2018 in last year's report.

Nutrients

- Nitrogen and phosphorus remain high downstream of major wastewater facilities and are not expected to meet future instream nutrient standards. While non-urban land uses are lesser contributors to nutrient levels, reductions from all sources will be needed to meet anticipated stream standards.
- Nitrogen has decreased at most sites over the last 5 years and beyond, with the largest decreases downstream of major wastewater facilities. Since nitrogen has also decreased in the effluent of most of these facilities, it seems that some of these decreases can be attributed to wastewater facility upgrades or changes in procedures.
- Phosphorus trends over the last 5 years were unclear, with some areas further upstream decreasing and other areas further downstream increasing.
- Ammonia has increased slightly at several sites over the last 5 years but has decreased overall during the last 10-15 years at most sites. These changes are minor and ammonia remains below required standards at all sites.

Bacteria

- *E. coli* concentrations were highest in and immediately downstream of urbanized areas. Concentrations tend to decrease through non-urban areas, suggesting that urbanized areas should be the largest focus for mitigation although non-urban areas should also be addressed.
- *E. coli* concentrations were low during the spring, initially peaked in May, and remained elevated at several sites through early to mid-autumn.
- *E. coli* is highly variable in stream environments, but based on the data available there were no increases or decreases in concentrations over the last 5 years.

Metals

- Arsenic and selenium generally increased moving downstream, while copper increased downstream of the Boulder wastewater facility and silver did not show a clear trend.

- Arsenic has decreased at most sites over the last 5 years, but there have been slight increases at some sites over the last 10-15 years.
- Dissolved copper has increased slightly in Boulder Creek over the last 5 years but continues to meet required standards and does not indicate any pressing water quality issues.

Recommendations

The following recommendations were developed in collaboration with stakeholders from KICP communities and prioritized through a brief survey. Collectively the KICP partners intend to focus on making progress on these recommendations and annual updates to this report may be scaled back to allow more capacity for these efforts.

1. **Develop updated fact sheets for priority pollutants**
   KICP has developed several fact sheets previously to summarize priority pollutants, but these documents are somewhat outdated and should be updated based on findings from recent water quality reports and with improved visuals according to new KICP branding guidelines.

2. **Identify specific new steps for *E. coli* based on studies that have been conducted**
   Numerous studies have been conducted locally and across the nation on *E. coli* to better understand sources and management tools. In addition, existing resources such as the Colorado *E. coli* toolbox and St. Vrain Basin Watershed-Based Plan provide a framework for managing *E. coli*. KICP should collectively review findings from studies done by the City of Boulder and others and work with the KICP partners to help develop specific next steps to address instream bacteria impairments.

3. **Update the Keep it Clean Partnership shared monitoring plan and St. Vrain Basin Watershed-Based Plan**
   Since these plans were developed in 2015, they have been utilized to improve watershed collaboration and lay the groundwork for this annual report, but they have not been utilized to their full potential. The shared monitoring plan should be updated according with most recent watershed recommendations, including those listed in this document, and in an effort to address data gaps. The St. Vrain Basin Watershed-Based Plan is due for a 5-year minor update which should focus on updating implementation tables, improving communication of key components, and increasing utilization of resources and tools included in this plan.

4. **Evaluate nutrient levels and feasibility of nutrient reductions throughout the watershed**
   With total nitrogen and phosphorus standards to be drafted in 2025 and adopted in 2027, nutrient reductions will be a key topic over at least the next several years. Several KICP monitoring sites do not meet interim nutrient standards and will not be expected to meet future standards when adopted. Efforts should focus on finding ways to collaborate on nutrient studies and reductions throughout the watershed, as well as engaging in rulemaking sessions for new standards.

5. **Other recommendations**
   Other important recommendations were identified by the KICP partners that will be addressed as time allows. These recommendations include the following: 1) determine approach to PFAS, harmful algal blooms, and other emerging contaminants, 2) determine the Keep it Clean Partnership's role in future regulatory developments, and 3) develop a visual executive summary for the annual water quality report. Some progress has been made on these efforts individually and collectively and they will be revisited while developing future work plans.

Appendix A

Standard assessment

Stream standards in Colorado are assessed according to the most recent regulations and listing methodology distributed by the Colorado Department of Public Health and Environment (CDPHE). A brief overview is presented of the current listing methodology used by the Water Quality Control Division to list streams for impairment.

Step 1: Evaluate the most recent five years of data at each sample site

For acute standards:
Impaired if more than 1 sample exceeds standard in a 3-year period

For pH, 15th percentile may not be less than lower end of standard and 85th percentile may not be greater than higher end of standard

For chronic standards:
Impaired if percentile value exceeds (< or >) standard

Percentile	Analytes
15th (<)	Dissolved oxygen
50th (>)	Total metals
85th (>)	Dissolved metals and all others

Step 2: Combine all sites in a stream segment and assess together

If segment exceeds standard or limited samples available:
Full stream segment may be listed

If some sites exceed standard, but entire segment does not:
Portion of segment may be listed

Step 3: Assess sample size for chronic standards (stream chemistry only)

If percentile value exceeds standard by more than 50%:

Sample size	List
1	No action
2 – 3	M&E list
4+	303(d) list

Otherwise:

Sample size	List
1	No action
2 – 9	M&E list
10+	303(d) list

Figure A.1 Stream standard assessment method overview

Temperature

Temperature standards are based on the time of year and the classification of streams into warm water and cold water tiers based on expected fish species. Table A.1 depicts stream standards that apply to KICP monitoring sites. Continuous temperature data is typically used to compare to stream standards, but single samples can be used in place of daily maximum temperatures if needed. There are several exceptions for periods between seasons and extreme air temperatures.

Temperature tier	KICP monitoring sites	Applicable months	Max weekly average temperature (MWAT)	Daily maximum temperature (DM)
Cold Stream Tier II (CS-II)	BC-Can, BC-CU, SBC-3.5	Apr – Oct	18.3 °C	23.9 °C
		Nov – Mar	9.0 °C	13.0 °C
Warm Stream Tier I (WS-I)	All St. Vrain Creek and Left Hand Creek sites	Mar – Nov	24.2 °C	29.0 °C
		Dec – Feb	12.1 °C	14.5 °C
Warm Stream Tier II (WS-II)	All other sites	Mar – Nov	27.5 °C	28.6 °C
		Dec – Feb	13.8 °C	14.3 °C

Table A.1 Local water temperature stream standards

pH

The 15th percentile of pH for samples at a given site may not be below 6.5 and the 85th percentile may not exceed 9.0.

Dissolved Oxygen

Dissolved oxygen standards are based on the aquatic life classification of the stream (warm water or cold water) and whether certain fish species are expected to be spawning. The 15th percentile of dissolved oxygen may not be lower than the standard value or the spawning standard, when applicable. Table A.2 depicts dissolved oxygen standards at KICP monitoring sites.

Aquatic life classification	KICP monitoring sites	DO standard	Spawning standard
Cold 1	BC-Can, BC-CU, SBC-3.5	6.0 mg/L	7.0 mg/L
Warm 1	All other sites	5.0 mg/L	N/A
Warm 2	Coal Creek, Rock Creek, and Left Hand Creek sites	5.0 mg/L	N/A

Table A.2 Local dissolved oxygen stream standards

Ammonia

Total ammonia standards are based on pH and water temperature and the aquatic life classification of the stream (warm water or cold water). Individual samples may not exceed the acute standard more than once in every 3 years, while the 85th percentile may not exceed the chronic standard as calculated by mean pH and temperature (Figure A.2). If calculated for individual events, less than 15% of values may exceed the paired standard.

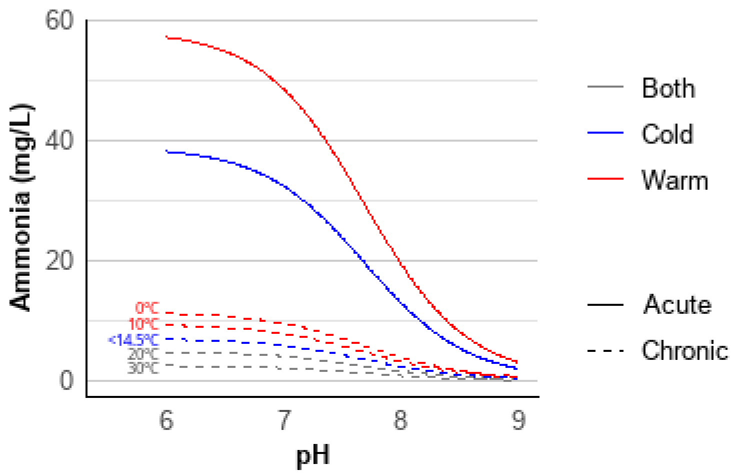


Figure A.2 Graph of total ammonia standards based on pH, temperature, and aquatic life classification

Nutrients

Interim standards are in place for total phosphorus (TP), total nitrogen (TN), and chlorophyll-a. TP and chlorophyll standards only apply upstream of designated wastewater treatment facilities and TN standards have not yet been adopted. Where adopted, annual median values may not exceed the standard more than once in every 5 years. Table A.3 provides a summary of current interim standards and Table 3.6 provides a schedule of adoption for future regulations.

Analyte	Cold water	Warm water
Total phosphorus (TP)	0.11 mg/L	0.17 mg/L
Total nitrogen (TN)	1.25 mg/L	2.01 mg/L
Chlorophyll-a	150 mg/m^2	

Table A.3 Interim value nutrient standards

E. coli

E. coli standards are assessed by calculating the geometric mean for rolling 61-day intervals for the entire period of record, with each new sample starting a new window. This is a significant revision to the previous methods and existing impairments should be reassessed. The current method is generally more stringent, and it should be anticipated that additional segments may now be considered impaired. Placement on the M&E list or 303(d) list is dependent on the maximum number of samples in a window. For delisting, a minimum of 5 samples must be collected within one window and all windows must indicate attainment, including during the months originally exceeding the standard when placed on the M&E or 303(d) list.

Geometric mean exceeds standard by > 50%:

Sample size	List
1	No action
2 – 3	M&E list
4+	303(d) list

Otherwise:

Sample size	List
1	No action
2 – 4	M&E list
5+	303(d) list

Arsenic

Arsenic standards are based on the aquatic life and water supply classifications of a stream segment as summarized in Table A.4. Individual samples may not exceed the acute standard for dissolved arsenic more than once in every 3 years, while the 85th percentile may not exceed the chronic standard for total arsenic. When a range of standards is listed, the first number is a health-based value that serves as a water quality target and the second number is the maximum contaminant level under the federal Safe Drinking Water Act. Water bodies are considered in attainment of this standard as long as the existing quality does not exceed the second number.

Aquatic life classification	Water supply classification	KICP monitoring sites	Acute dissolved arsenic standard	Chronic total arsenic standard
Cold 1 / Warm 1	Water Supply	All Boulder Creek and South Boulder Creek sites	340 µg/L	0.02 µg/L
Warm 2	Water Supply	All Left Hand Creek and Coal Creek sites	340 µg/L	0.02-10 µg/L
Warm 1	N/A	All St. Vrain Creek sites	340 µg/L	7.6 µg/L
Warm 2	N/A	Rock Creek	340 µg/L	100 µg/L

Table A.4 Local total arsenic standards

Selenium

Dissolved selenium standards are established for the protection of aquatic life. Individual samples may not exceed the acute standard of 18.4 µg/L more than once in every three years, while the 85th percentile of values may not exceed the chronic standard of 4.6 µg/L.

Copper

Dissolved copper standards are based on hardness as depicted in Figure A.3. Individual samples may not exceed the acute standard more than once in every 3 years, while the 85th percentile may not exceed the chronic standard as calculated by mean hardness. If calculated for individual events, less than 15% of values may exceed the paired standard.

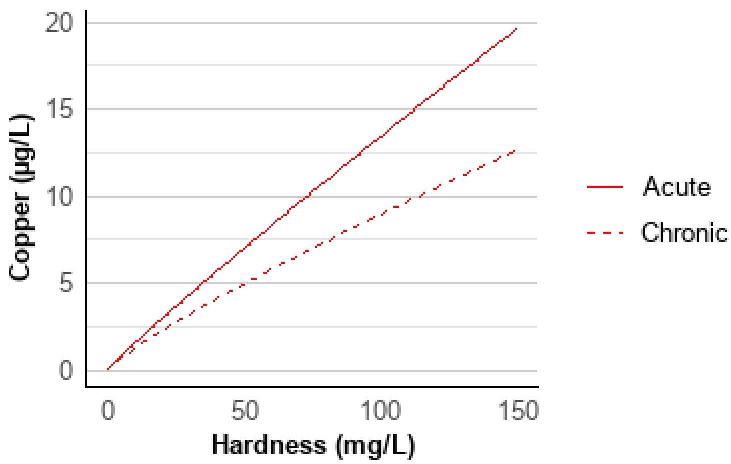


Figure A.3 Graph of dissolved copper standards based on hardness

Silver

Dissolved silver standards are based on hardness and whether sensitive trout species are thought to be present as depicted in Figure A.4. Individual samples may not exceed the acute standard more than once in every 3 years, while the 85th percentile may not exceed the chronic standard as calculated by mean hardness. If calculated for individual events, less than 15% of values may exceed the paired standard.

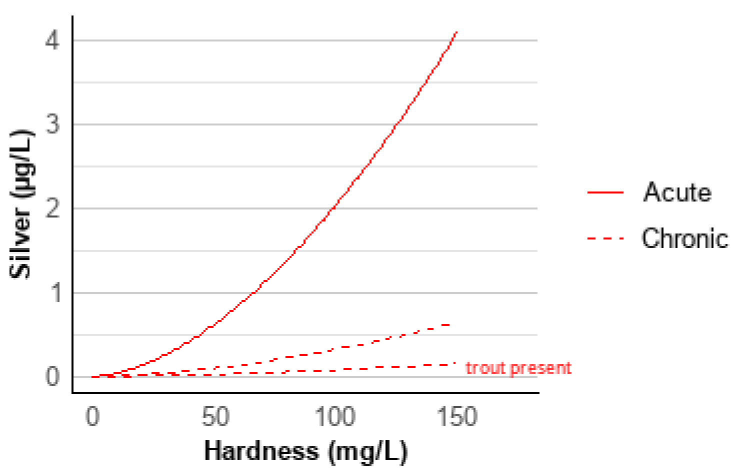


Figure A.4 Graph of dissolved silver standards based on hardness

Manganese

Dissolved manganese standards are based on hardness as depicted in Figure A.5. Individual samples may not exceed the acute standard more than once in every 3 years, while the 85th percentile may not exceed the chronic standard as calculated by mean hardness. If calculated for individual events, less than 15% of values may exceed the paired standard.

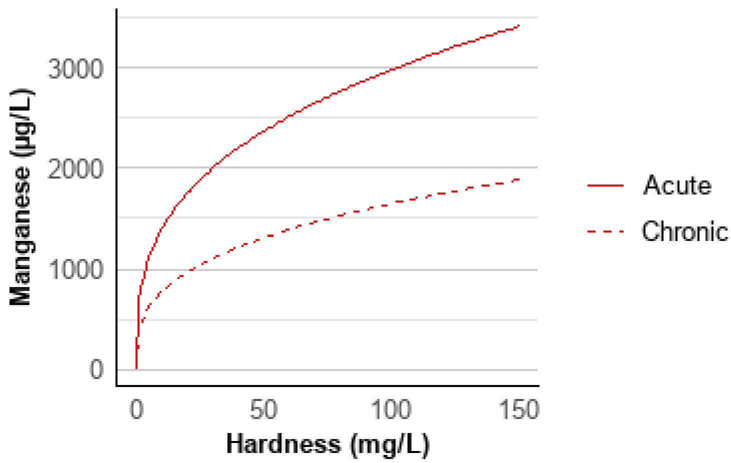


Figure A.5 Graph of dissolved manganese standards based on hardness

Appendix B

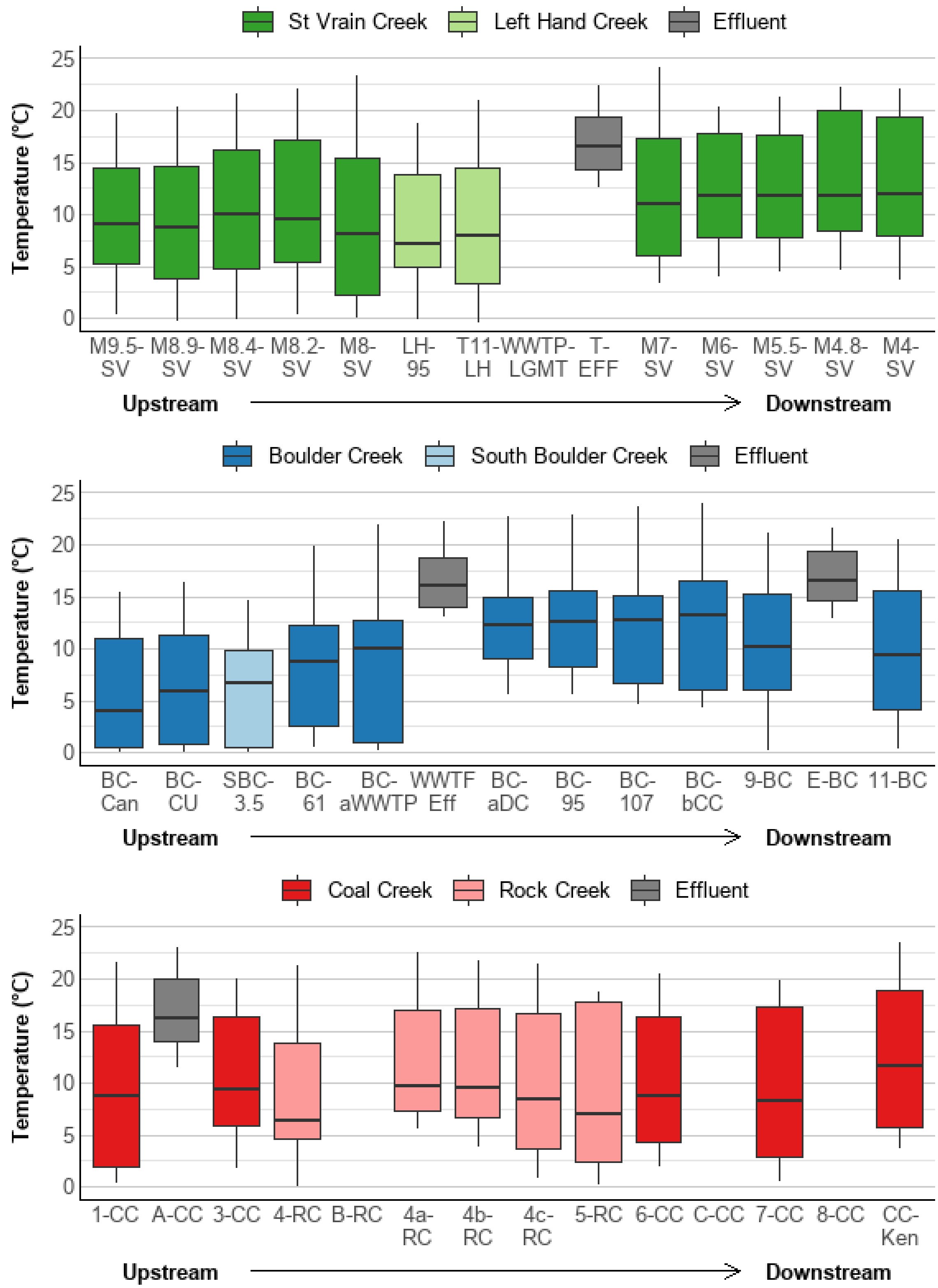


Figure B.1 2019 temperature boxplot summary

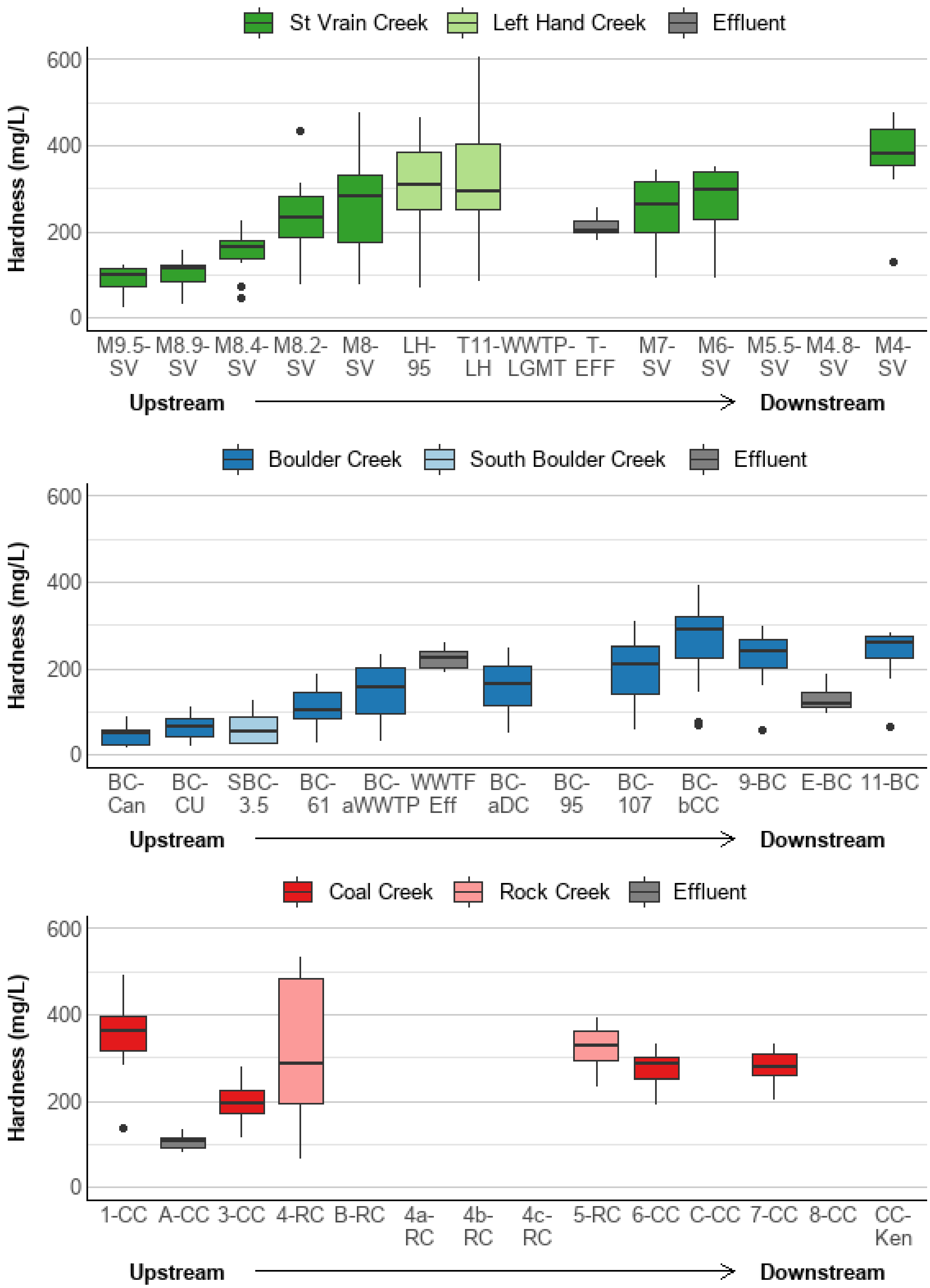


Figure B.2 2019 hardness boxplot summary

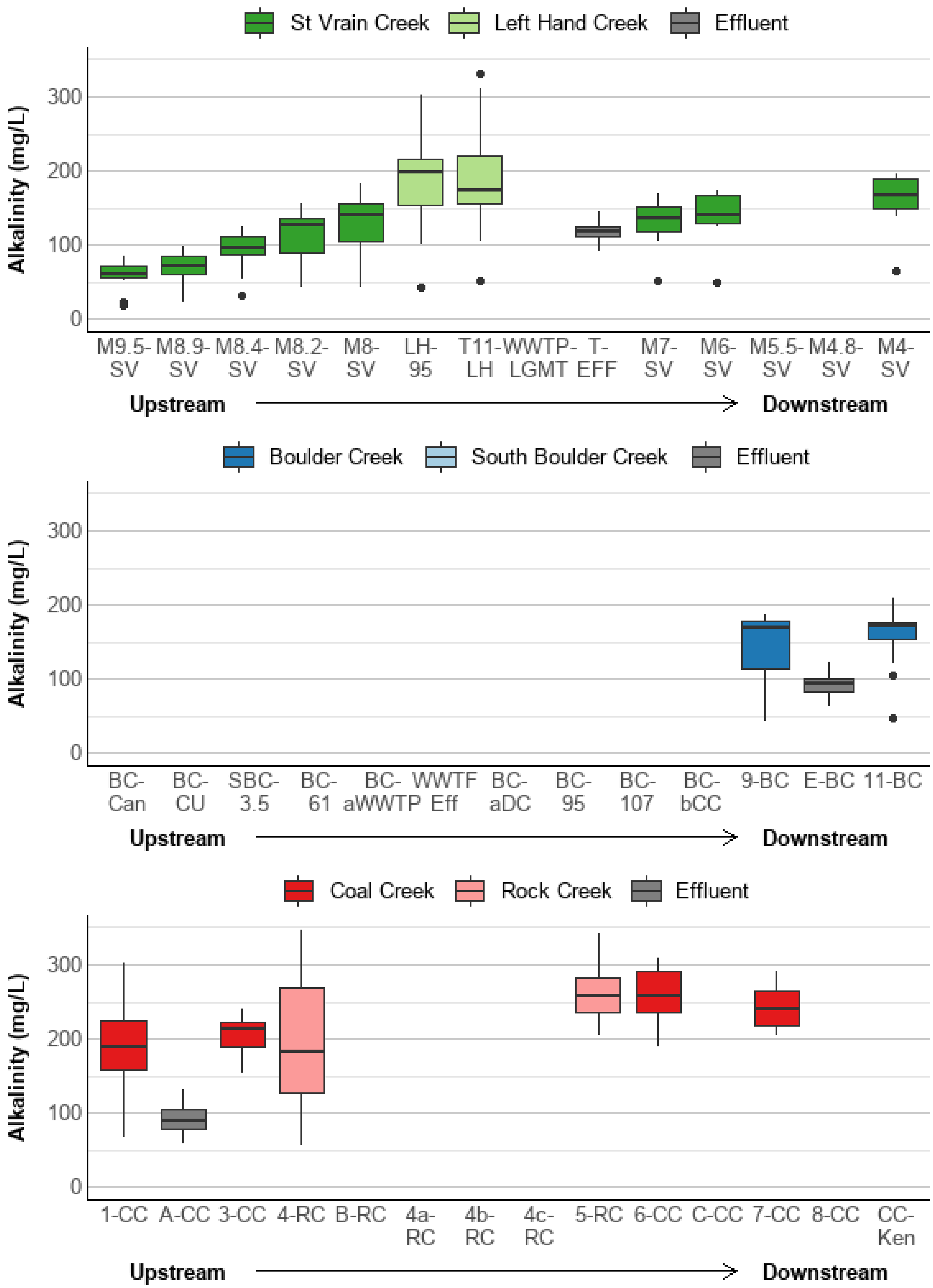


Figure B.3 2019 alkalinity boxplot summary

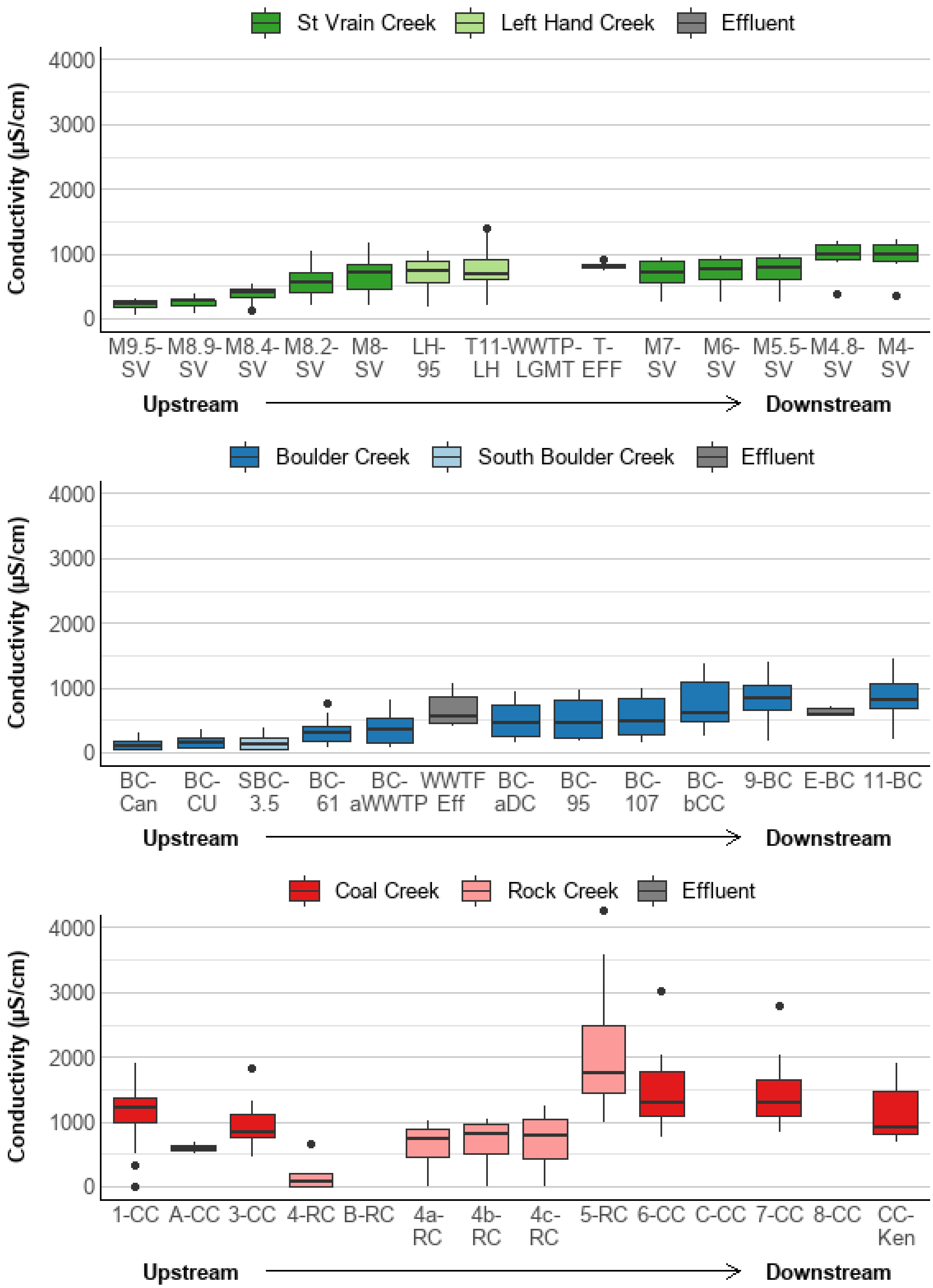


Figure B.4 2019 conductivity boxplot summary

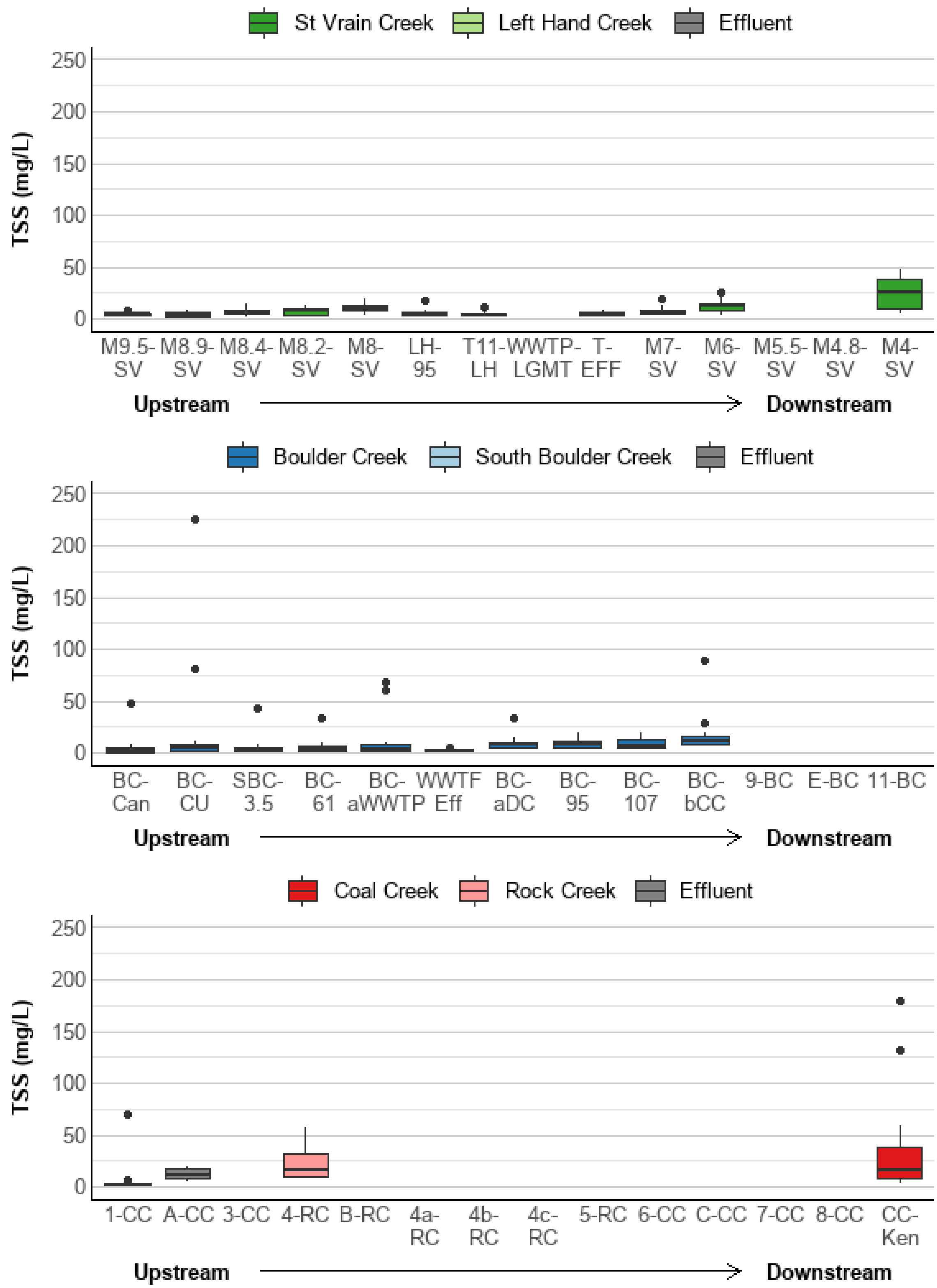


Figure B.5 2019 total suspended solids boxplot summary

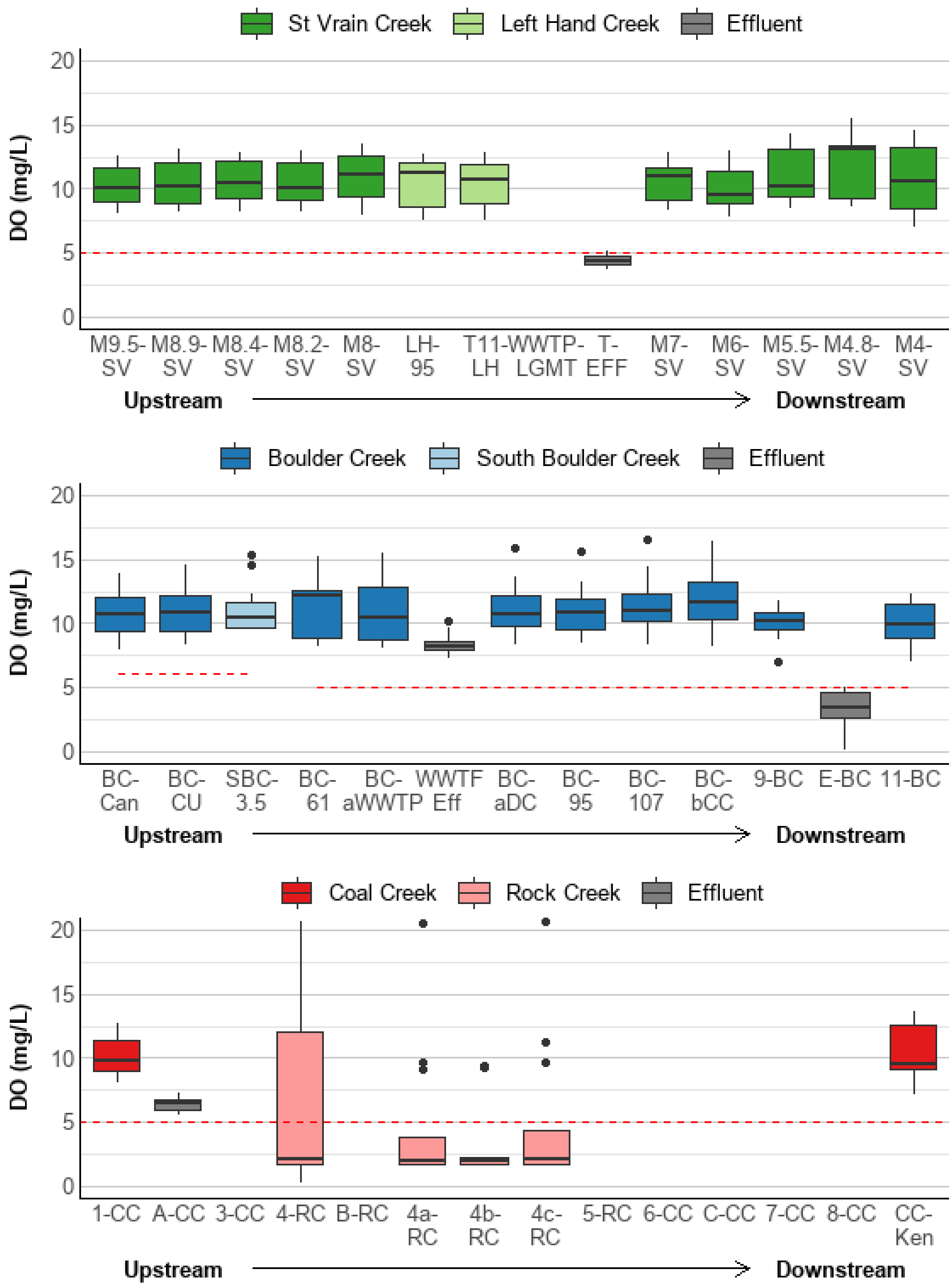


Figure B.6 2019 dissolved boxplot summary, red dashed line depicts chronic standard and does not apply to effluent sites

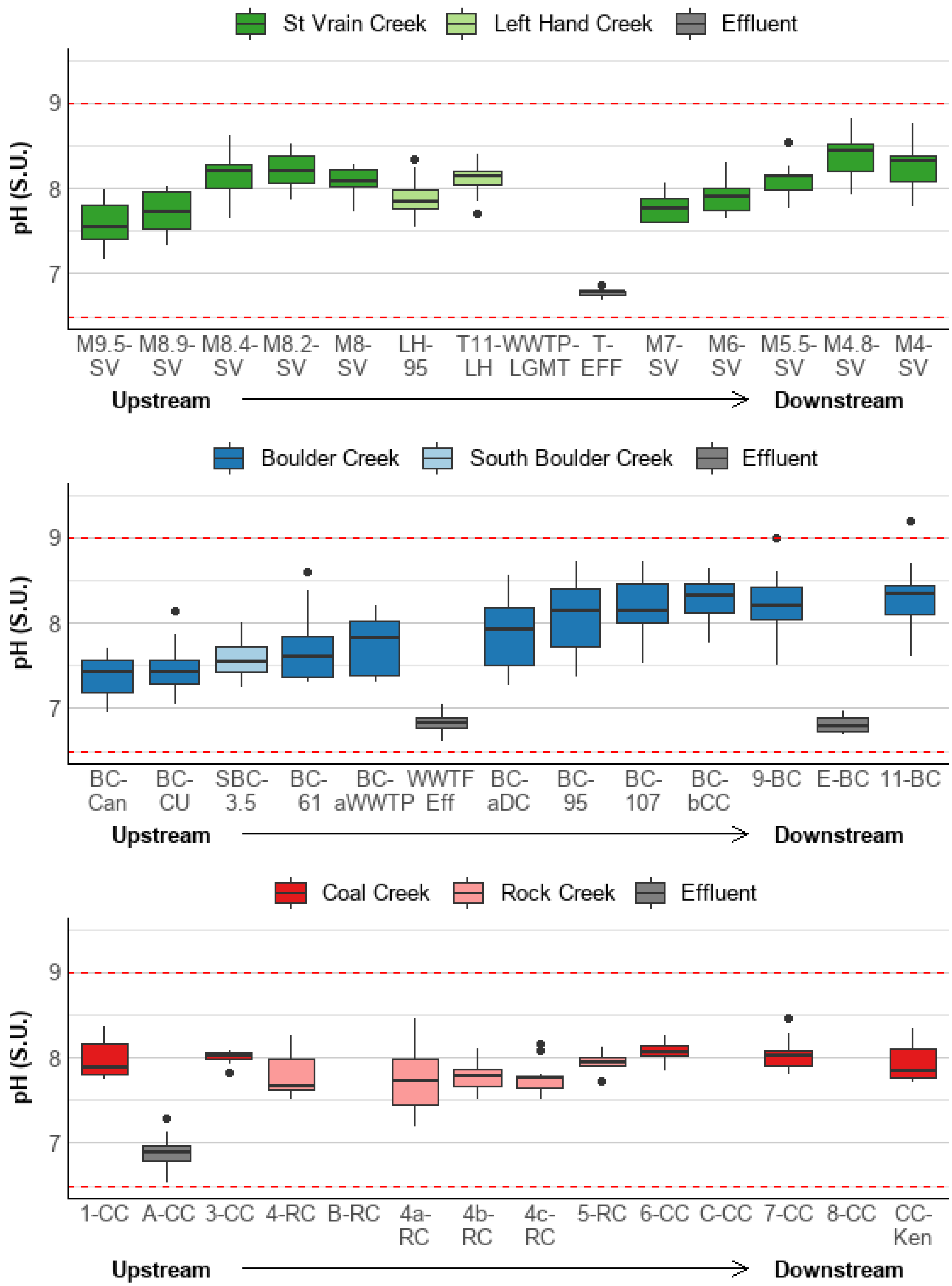


Figure B.7 2019 pH boxplot summary, red dashed line depicts chronic standard and does not apply to effluent sites

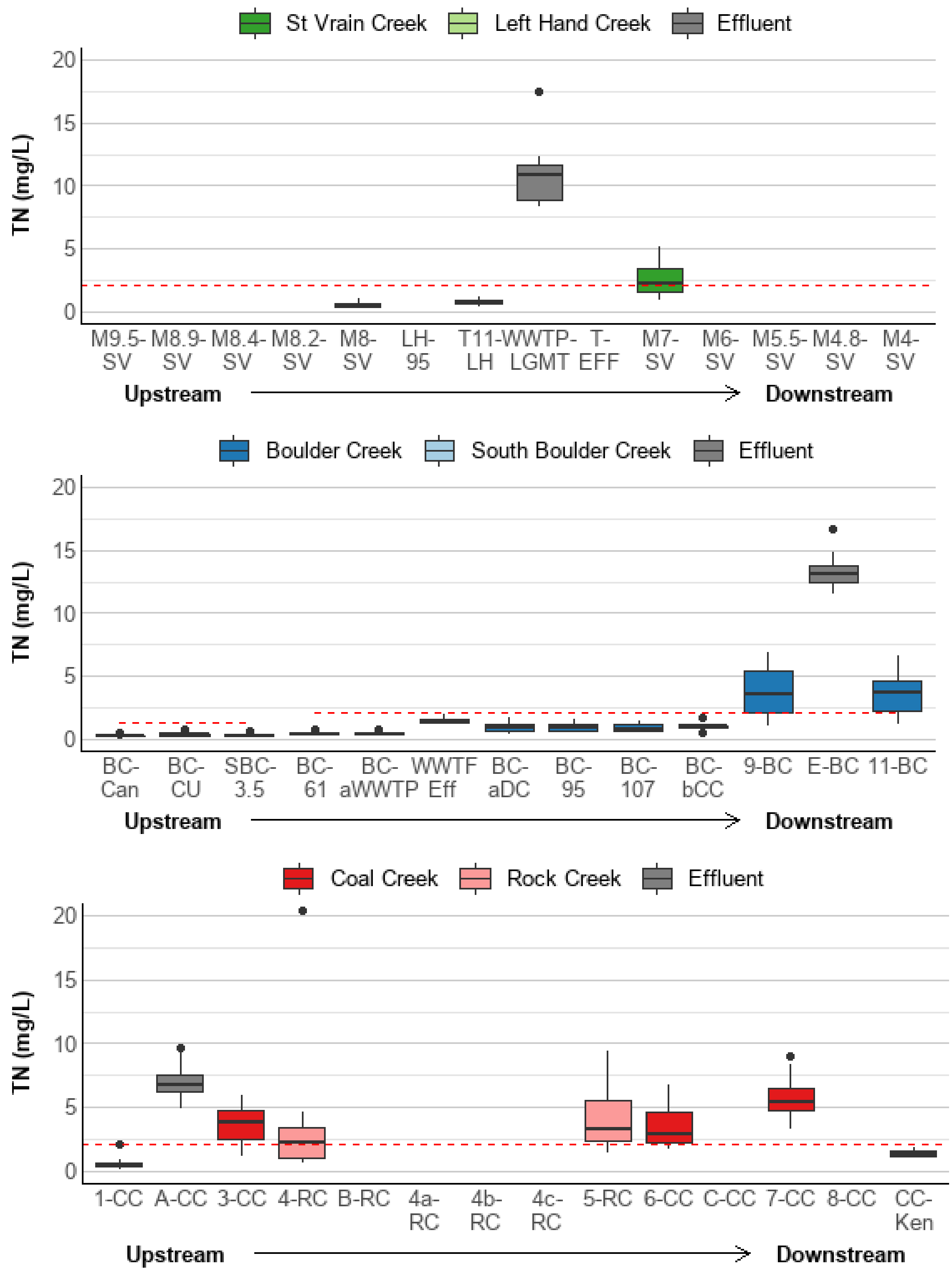


Figure B.8 2019 total nitrogen boxplot summary, red dashed line depicts interim chronic standard which does not apply to effluent sites and has not yet been implemented for instream sites downstream of major WWTPs

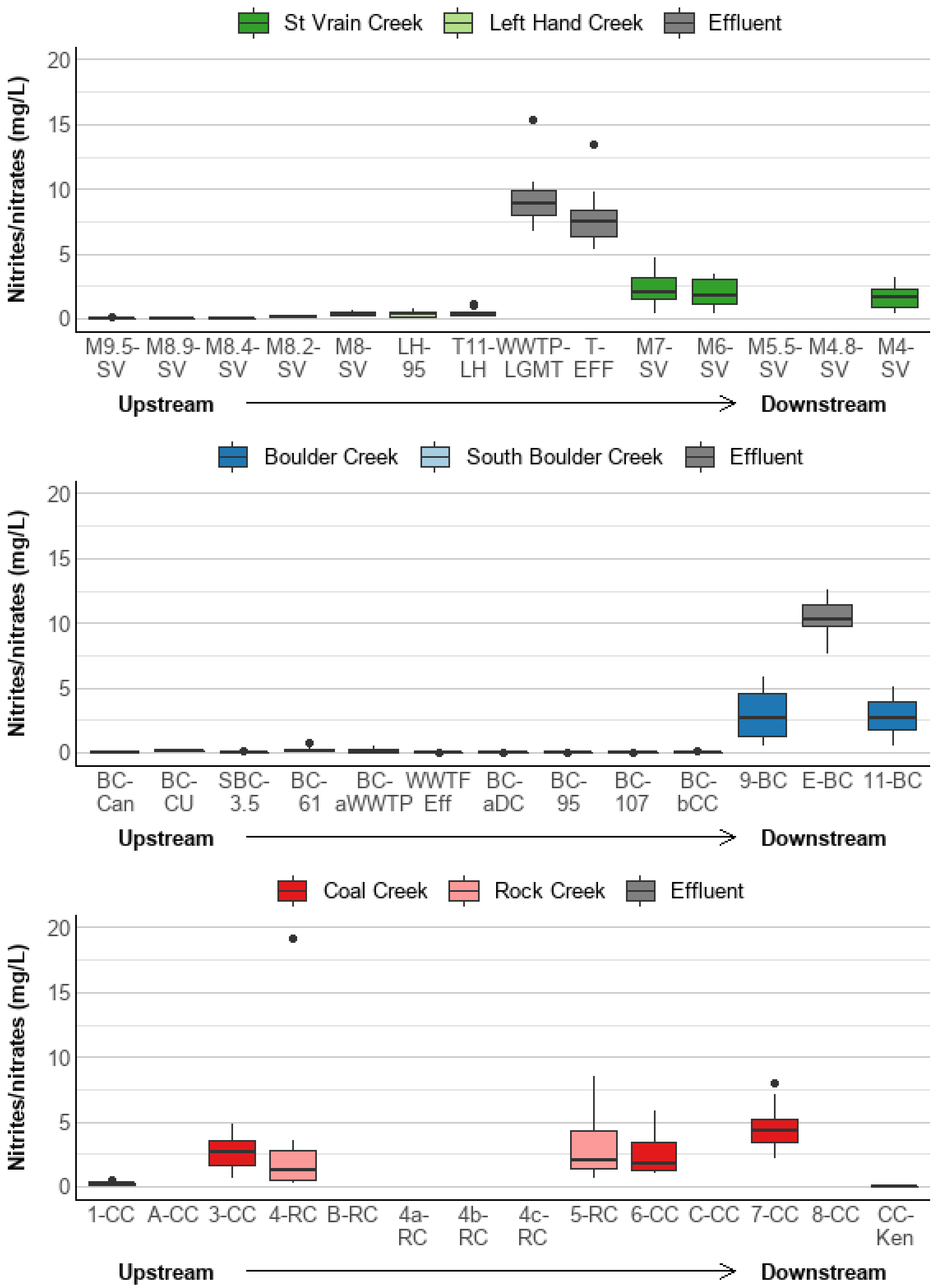


Figure B.9 2019 nitrites and nitrates boxplot summary

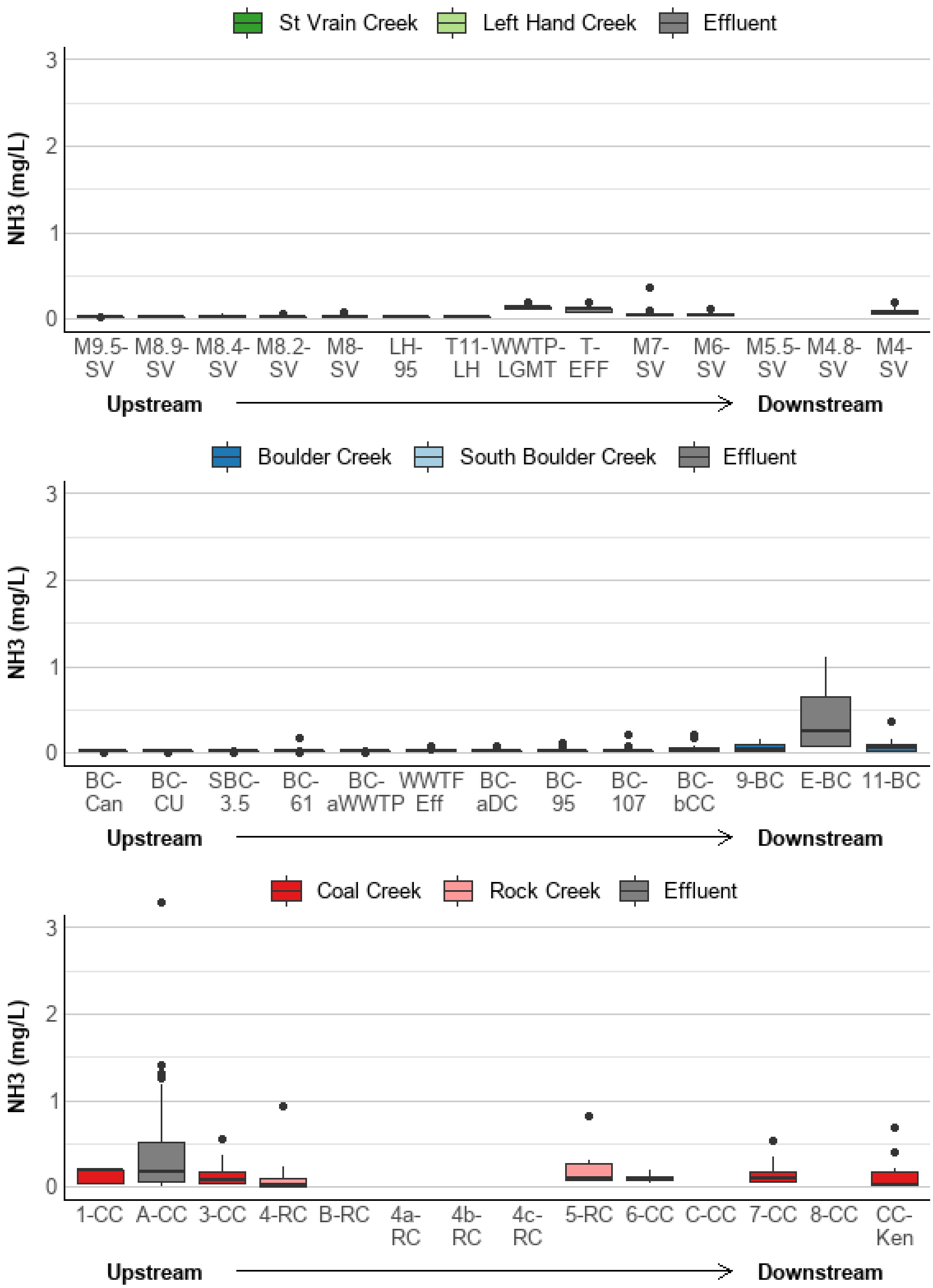


Figure B.10 2019 total ammonia boxplot summary (single outlier > 6.0 mg/L at E-BC not pictured)

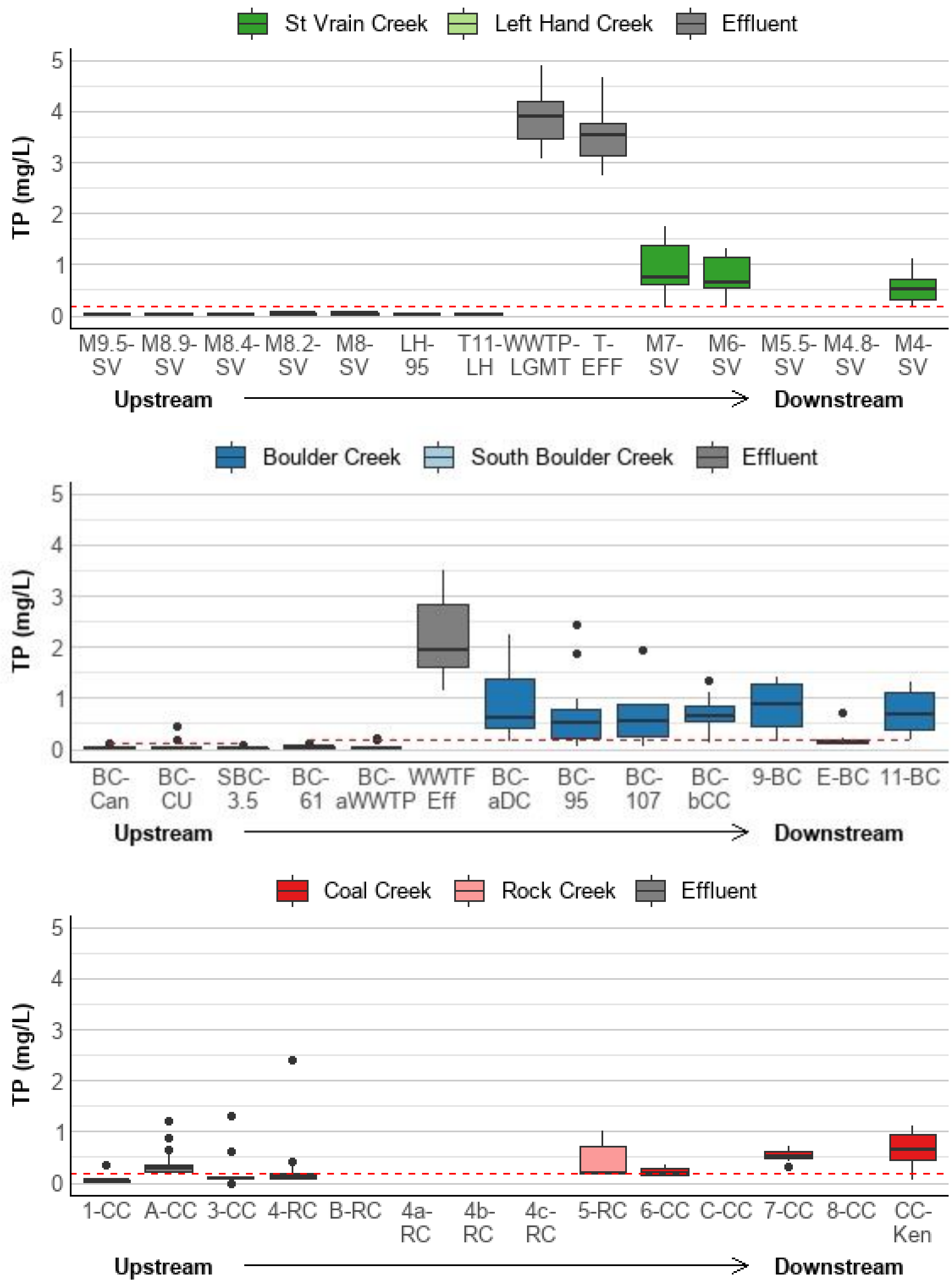


Figure B.11 2019 total phosphorus boxplot summary, red dashed line depicts interim chronic standard which does not apply to effluent sites and has not yet been implemented for instream sites downstream of major WWTPs

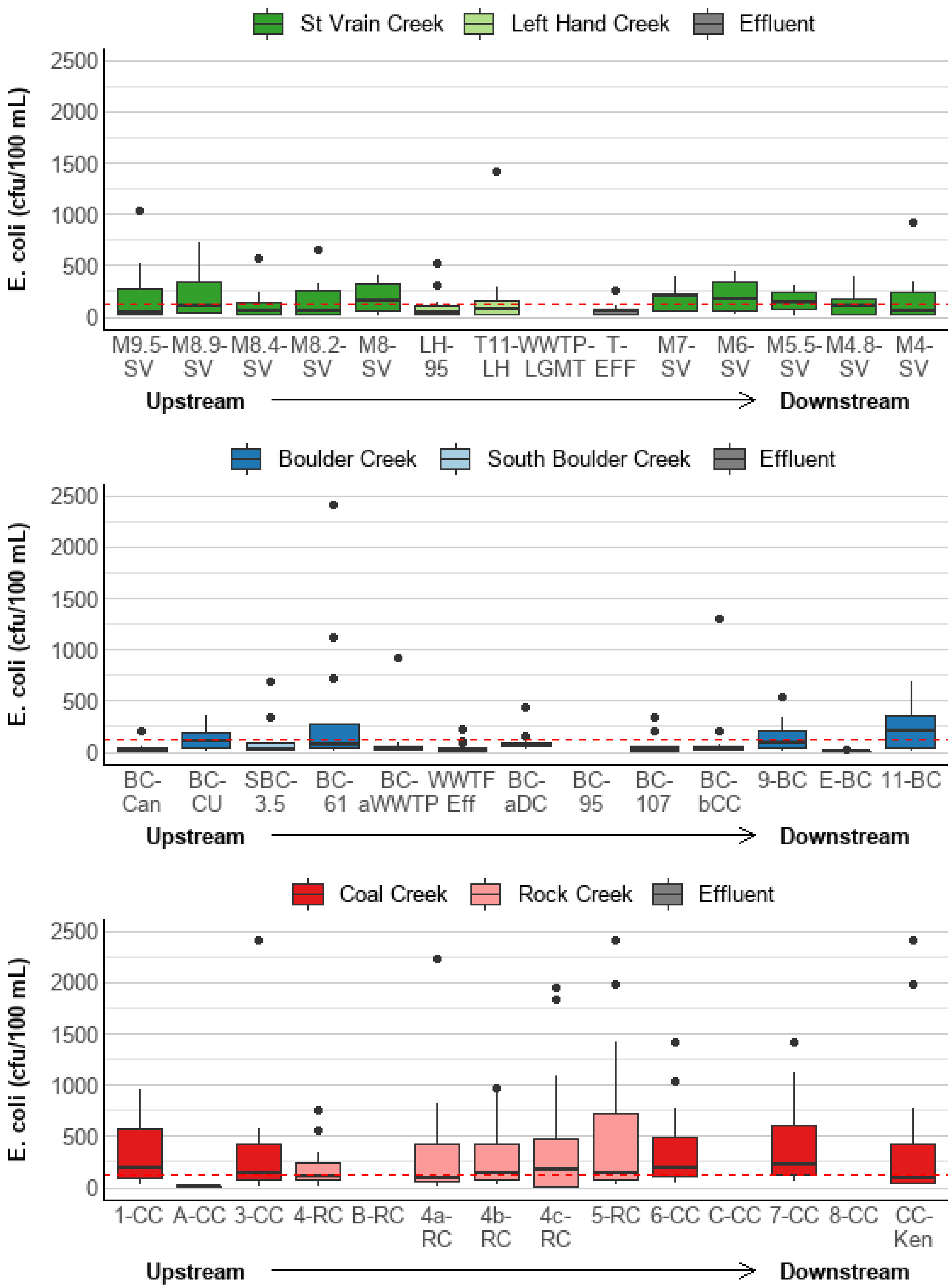


Figure B.12 2019 *E. coli* boxplot summary, red dashed line depicts chronic standard and does not apply to effluent sites

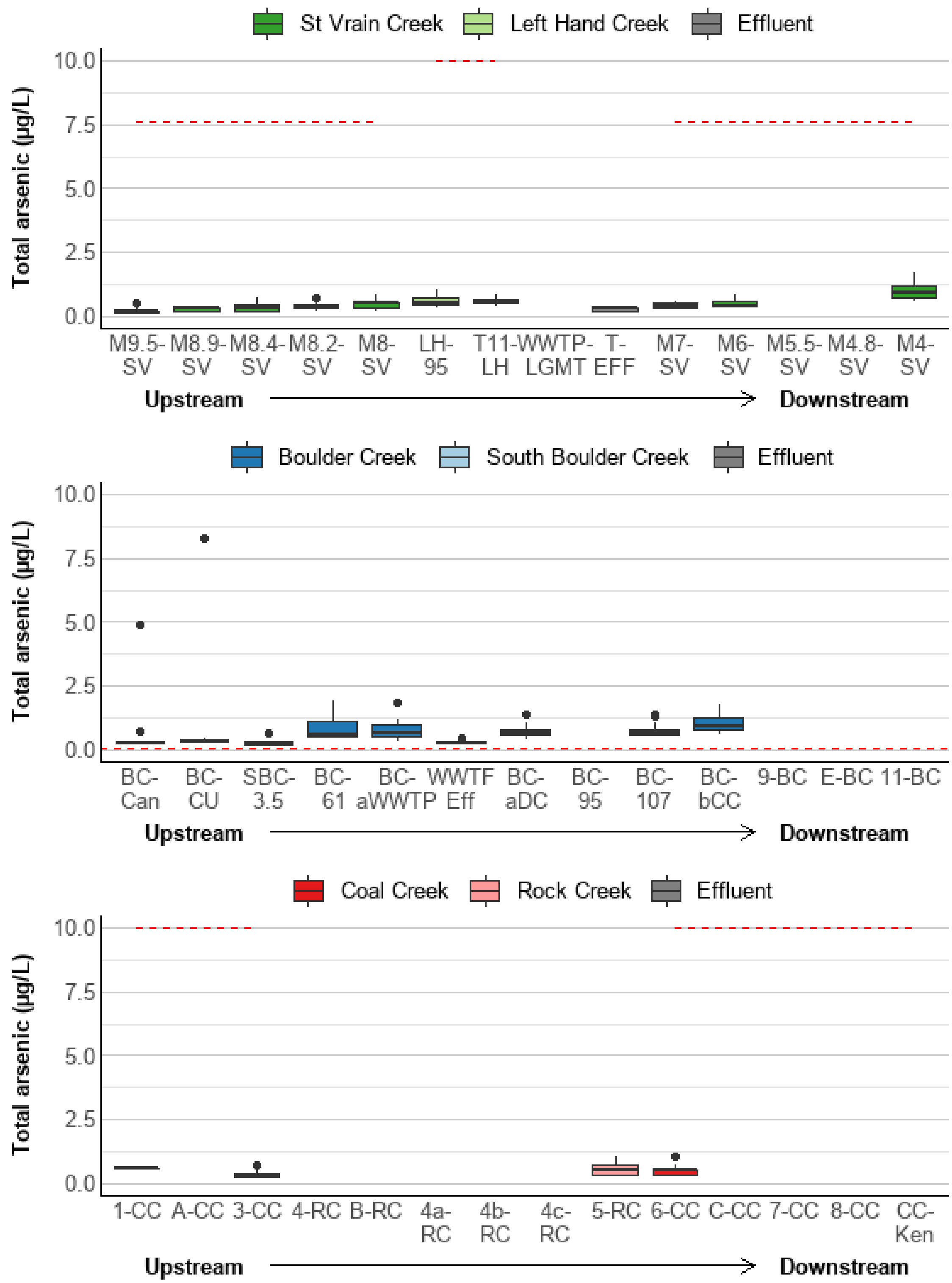


Figure B.13 2019 total arsenic boxplot summary, red dashed line depicts chronic standard and does not apply to effluent sites

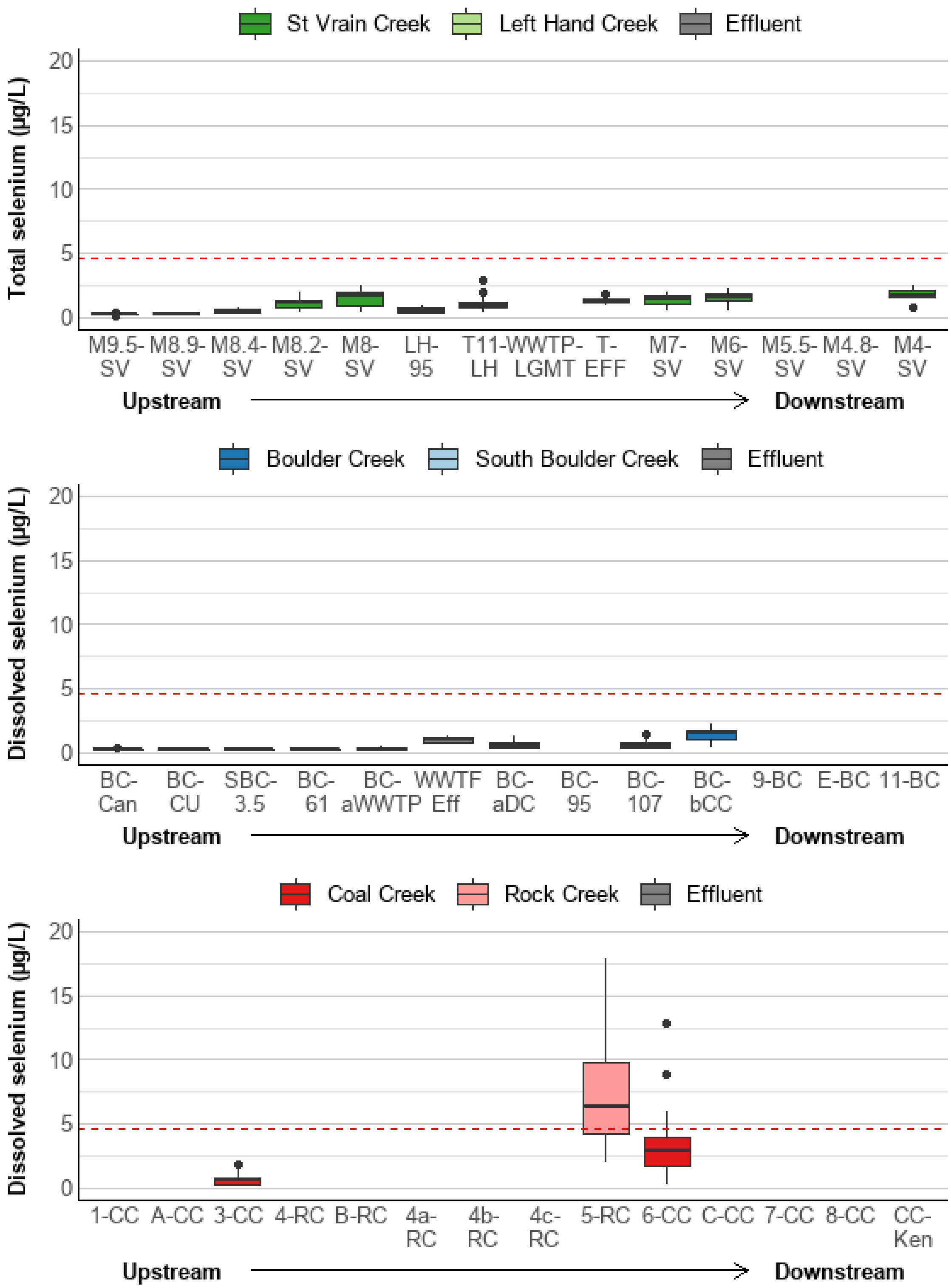


Figure B.14 2019 selenium boxplot summaries, red dashed line depicts chronic standard for dissolved selenium and does not apply to effluent sites (note total selenium is depicted for St. Vrain and Left Hand Creek sites)

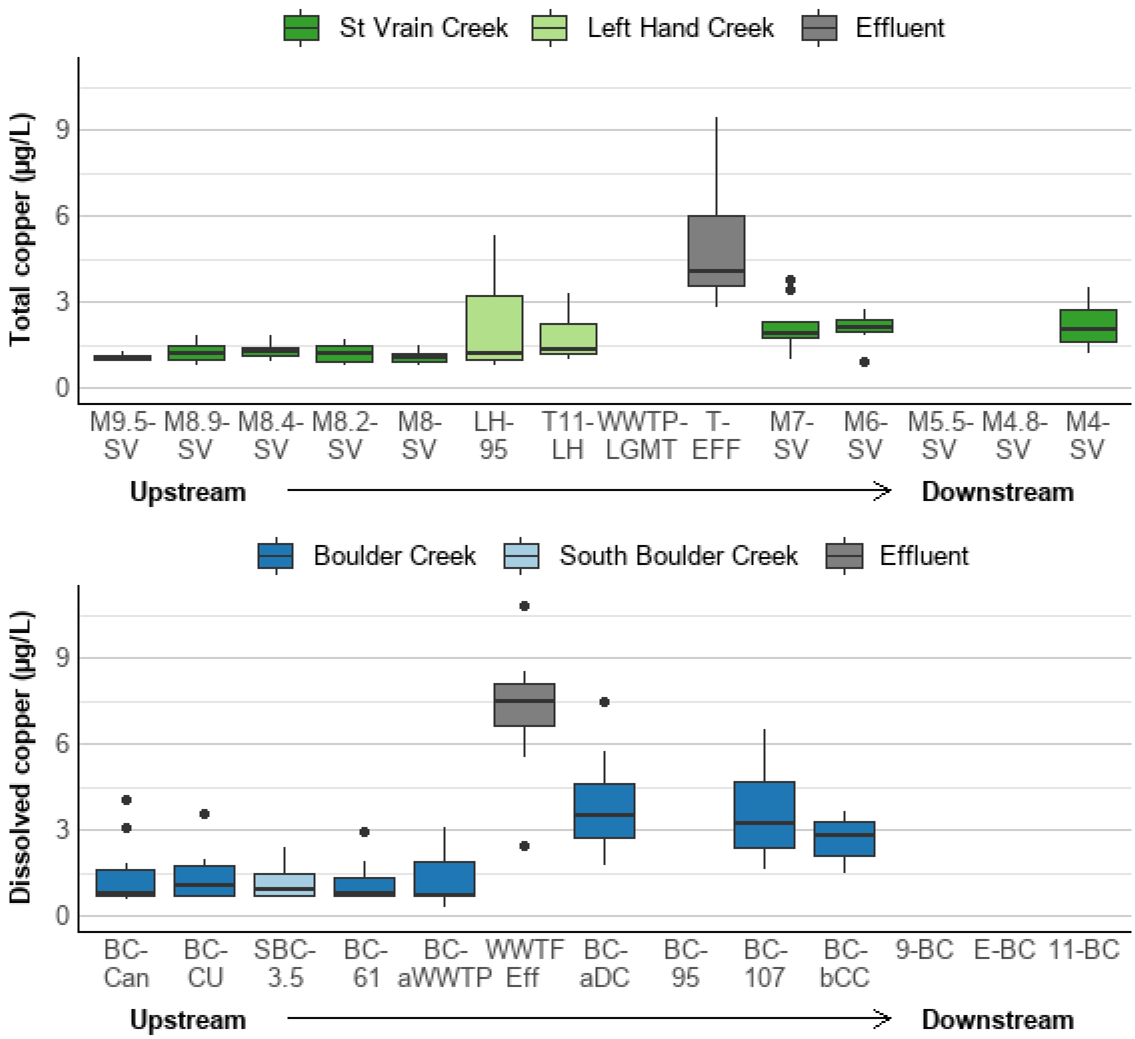


Figure B.15 2019 copper boxplot summaries (note total copper is depicted for St. Vrain and Left Hand Creek sites)

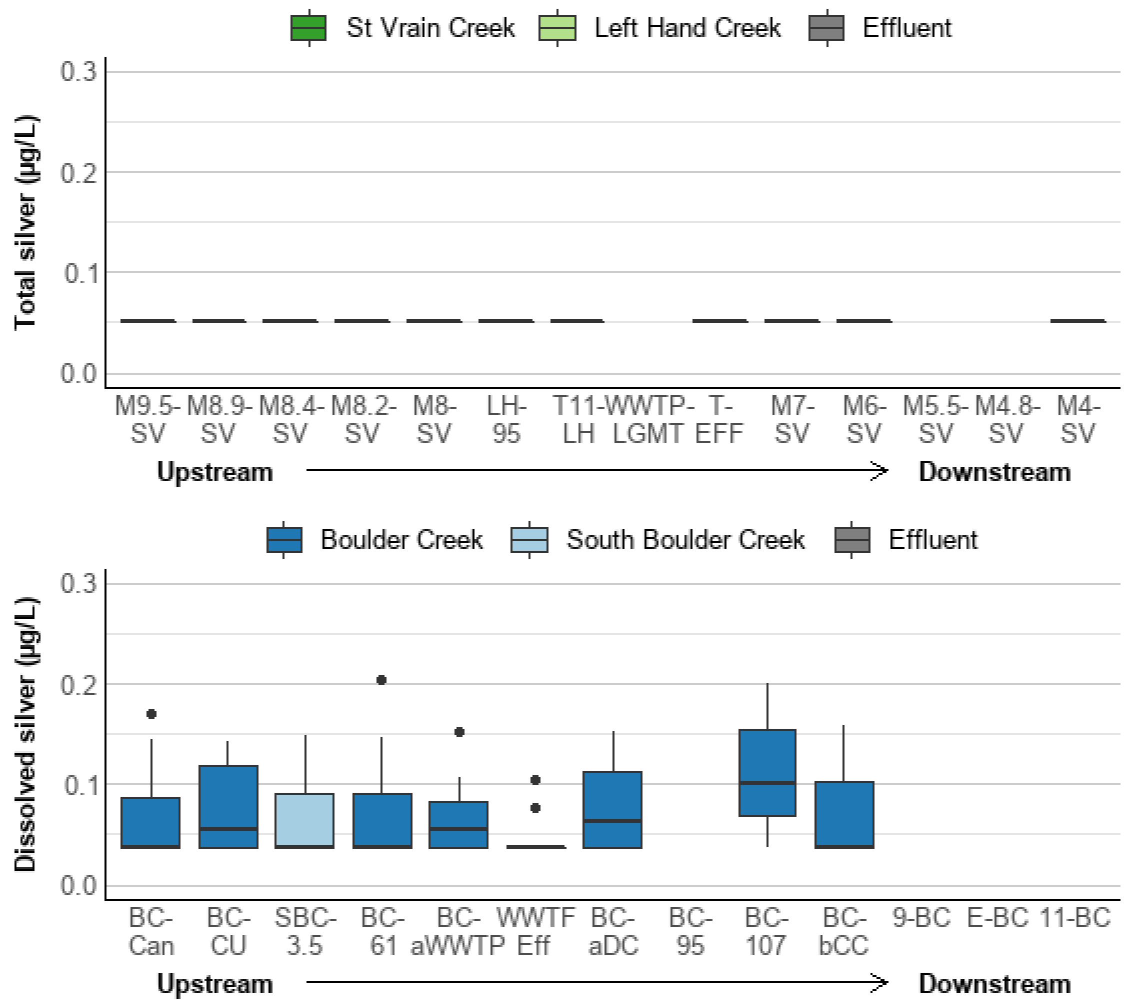


Figure B.16 2019 dissolved silver boxplot summary (note total silver is depicted for St. Vrain and Left Hand Creek sites)

Appendix C

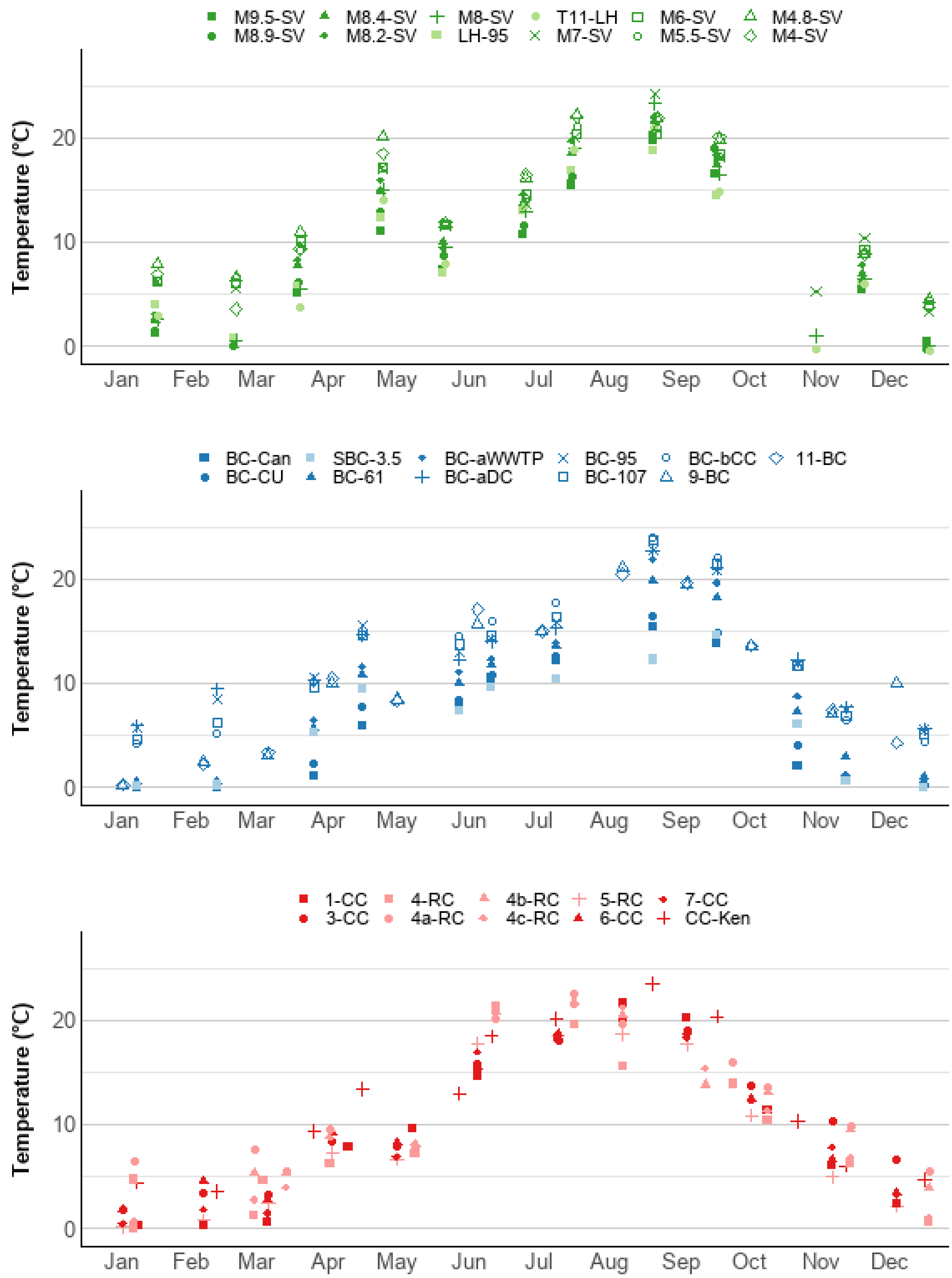


Figure C.1 2019 temperature time series plots

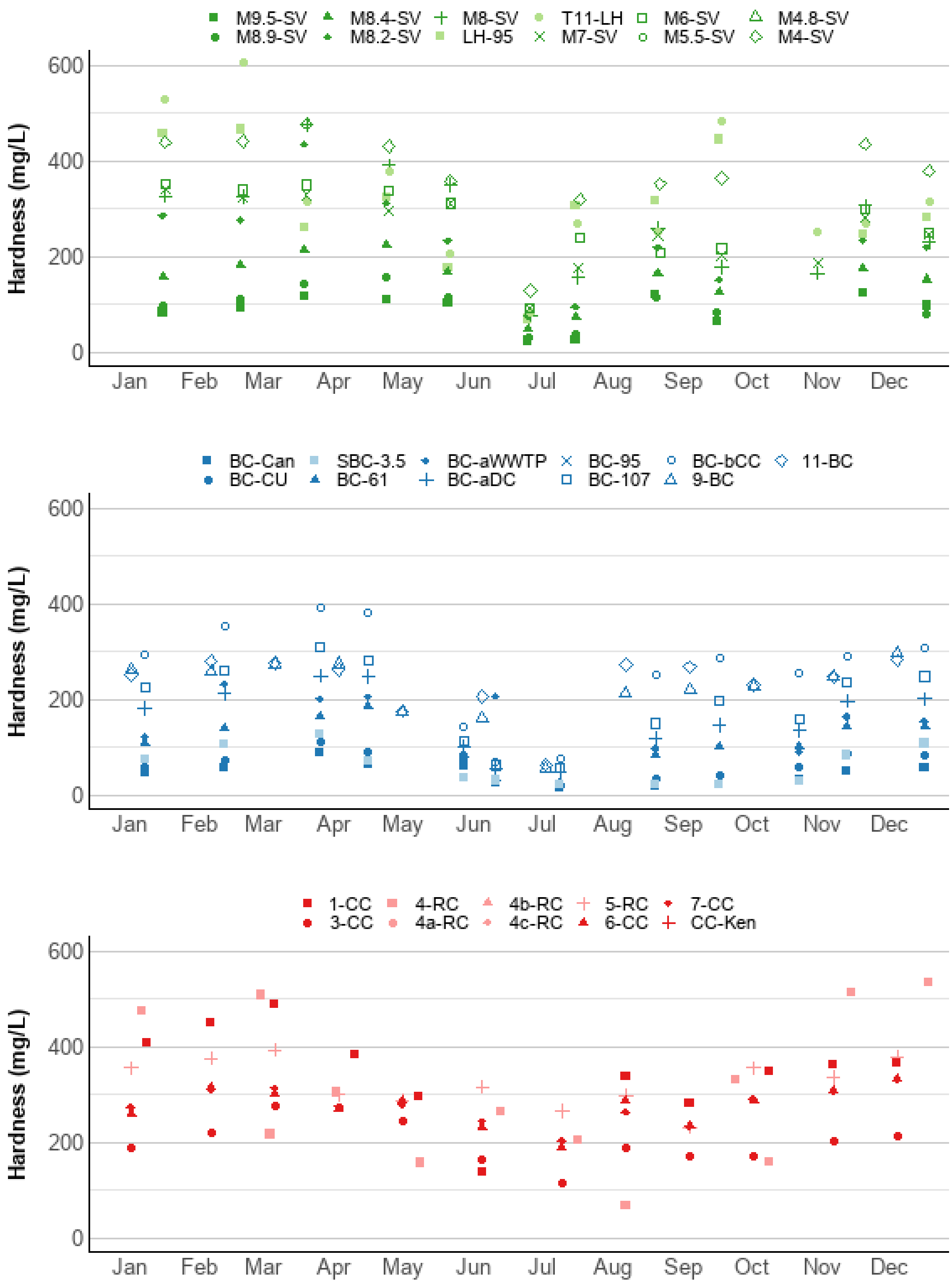


Figure C.2 2019 hardness time series plots

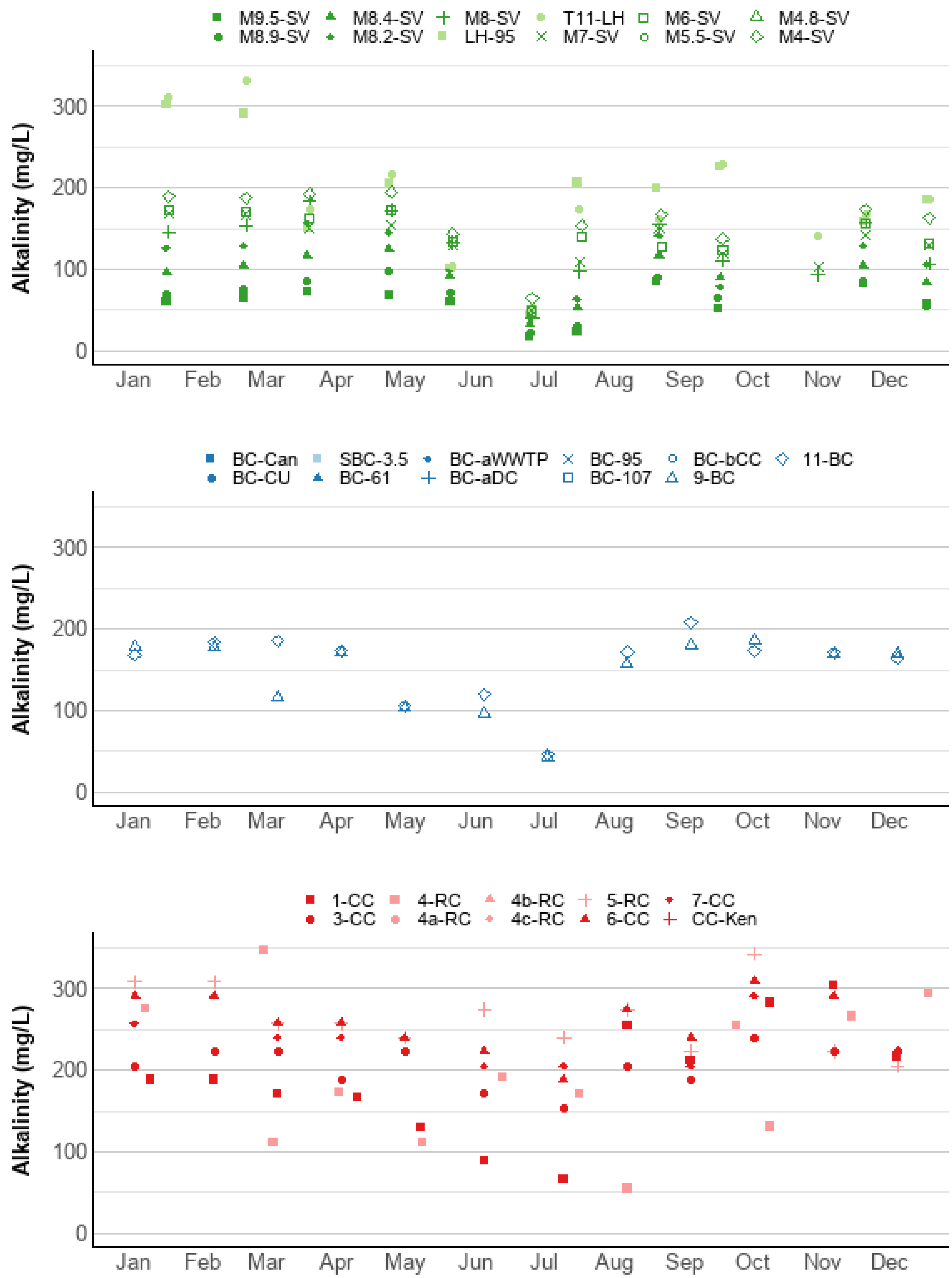


Figure C.3 2019 alkalinity time series plots

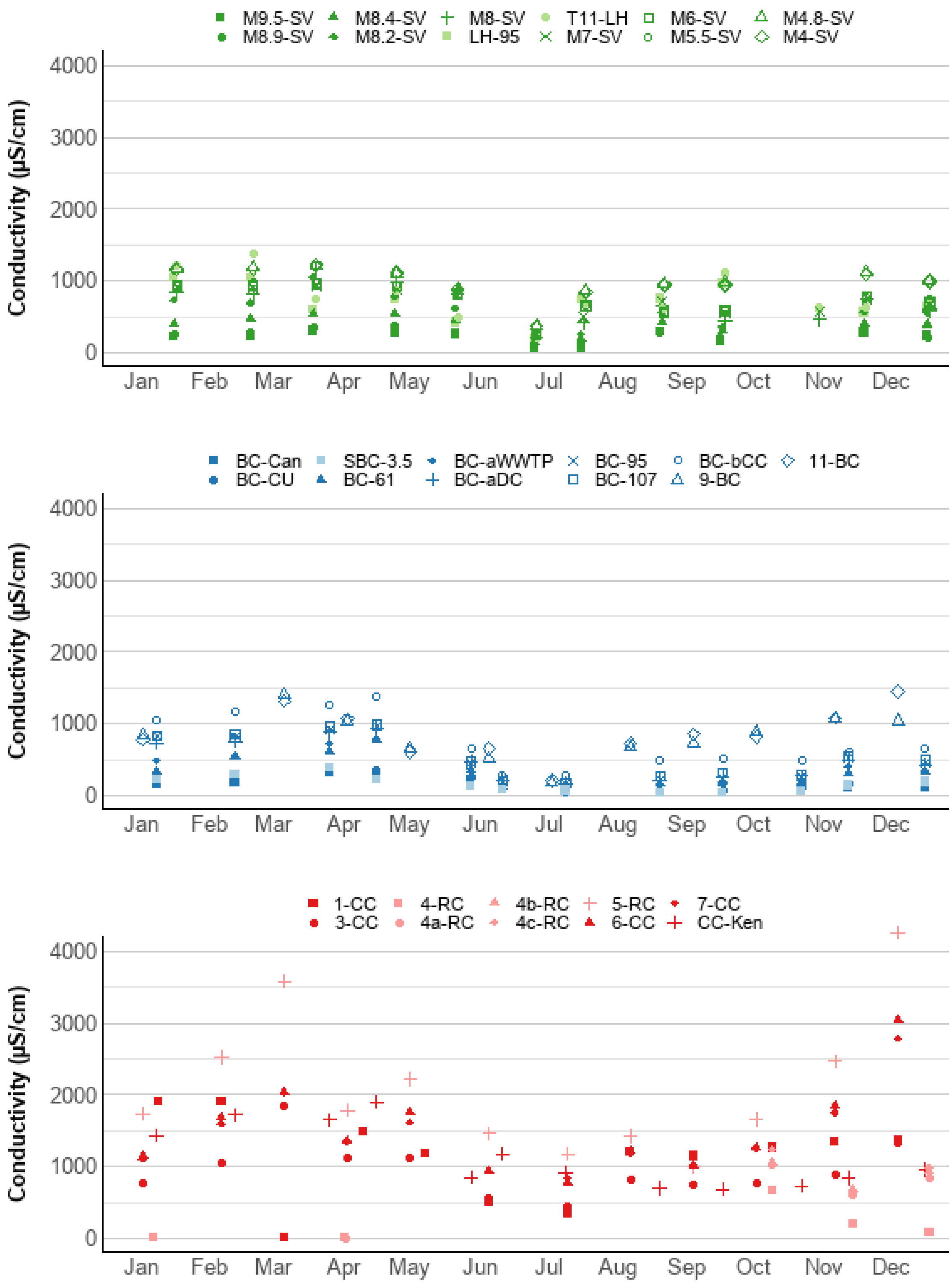


Figure C.4 2019 conductivity time series plots

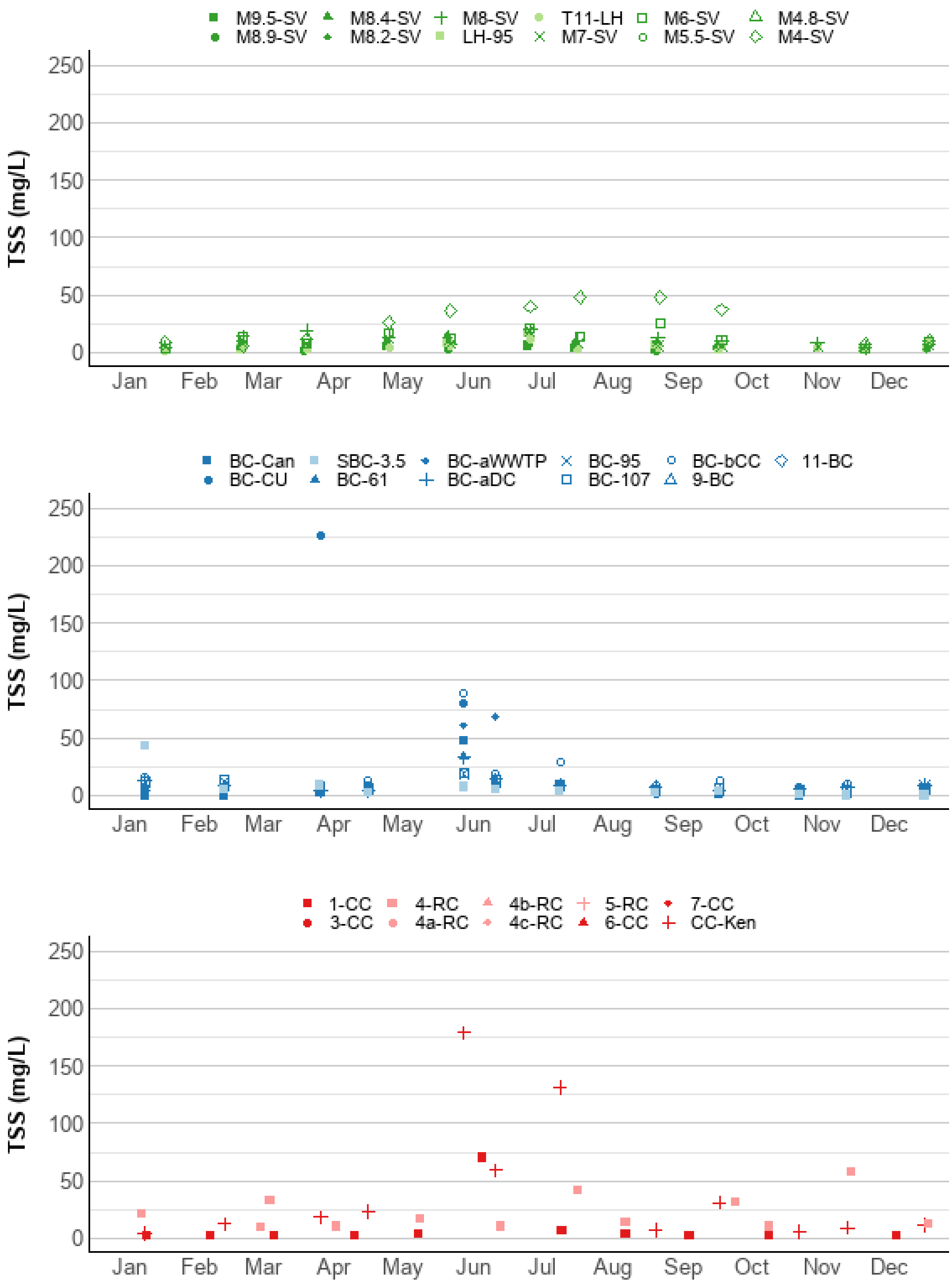


Figure C.5 2019 total suspended solids time series plots

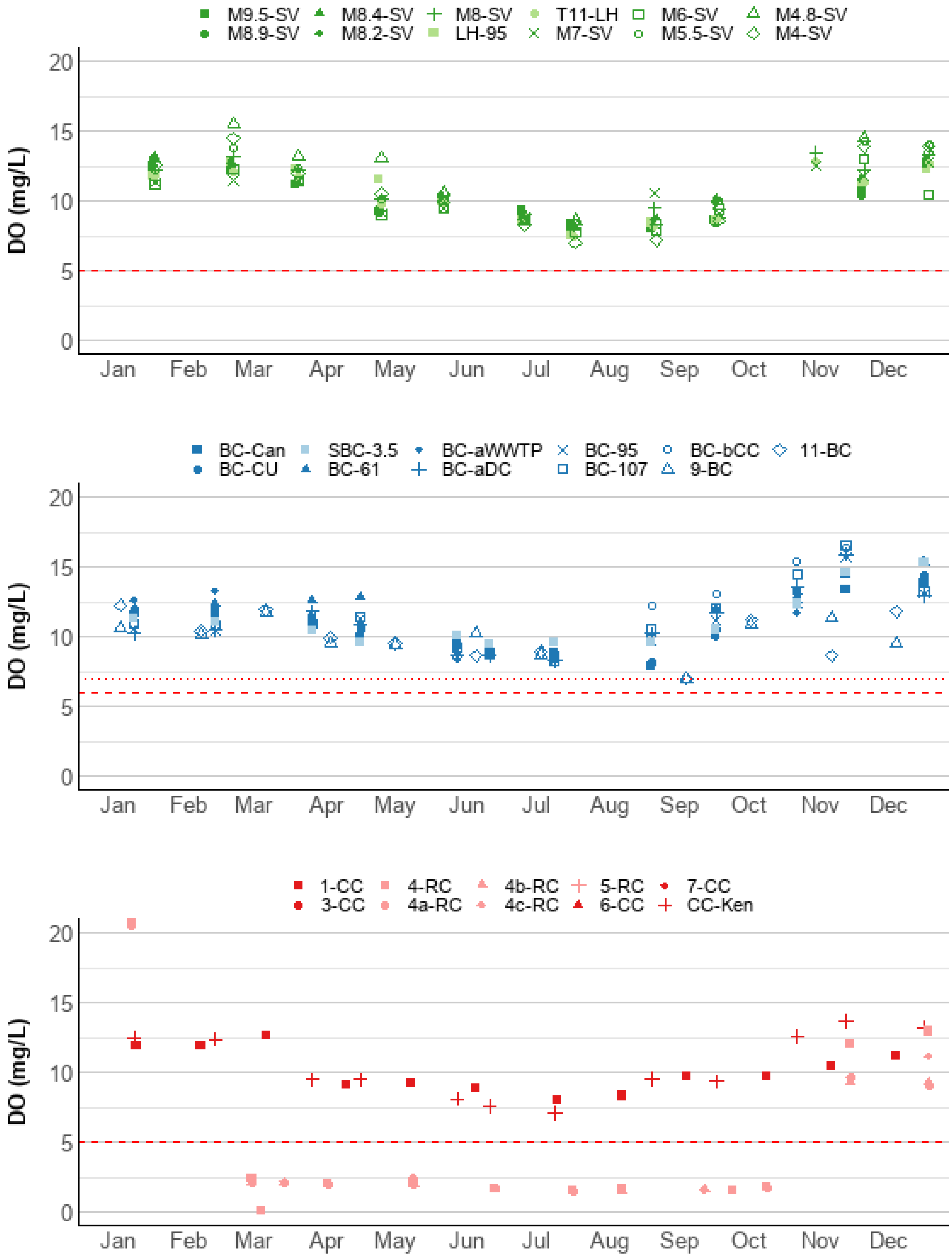


Figure C.6 2019 dissolved oxygen time series plots, red dashed line depicts chronic standard for all sites (except BC-Can, BC-CU, and SBC-3.5 for which the standard is depicted with a dotted red line; fish spawning standard for these three sites is not pictured)

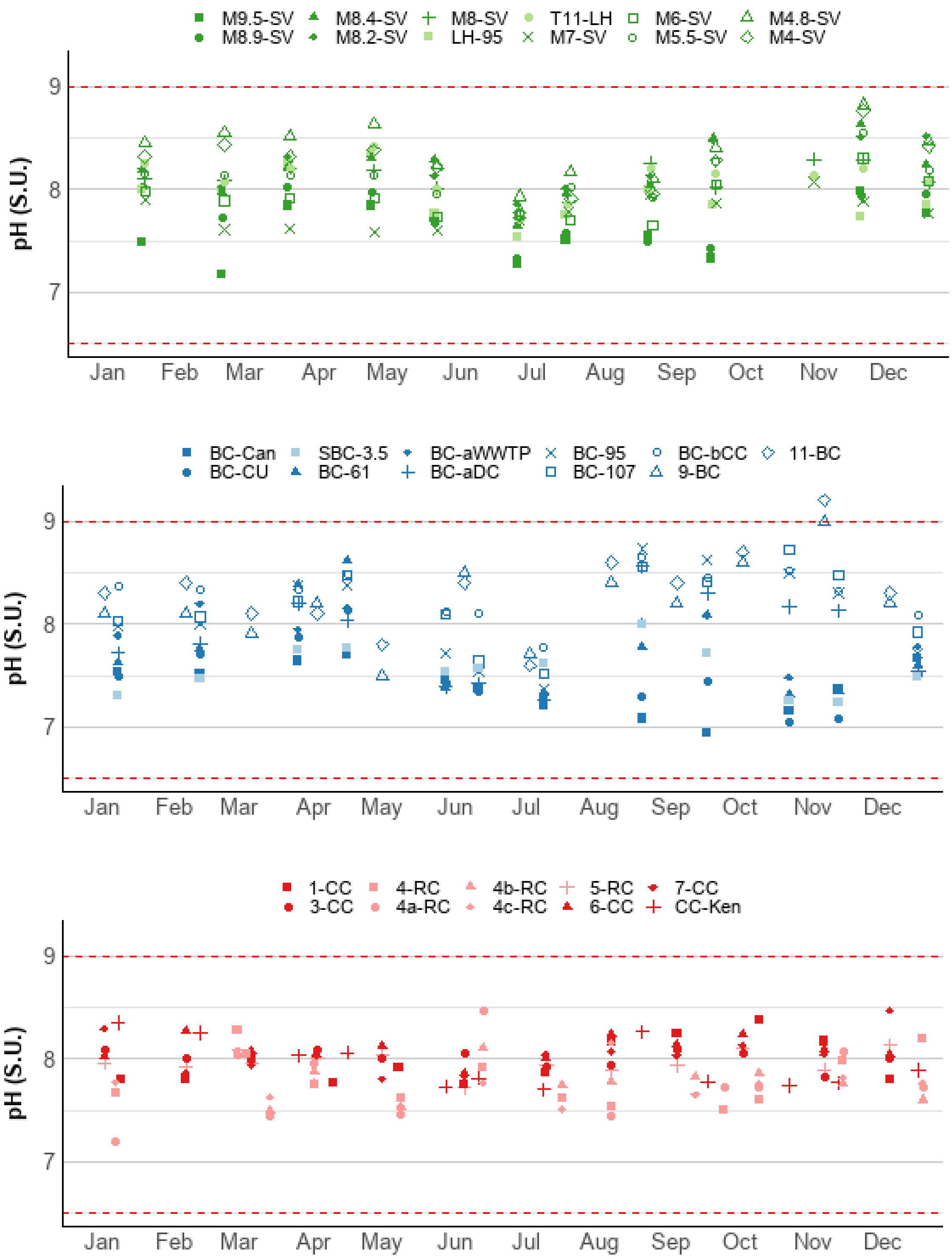


Figure C.7 2019 pH time series plots, red dashed line depicts chronic standard

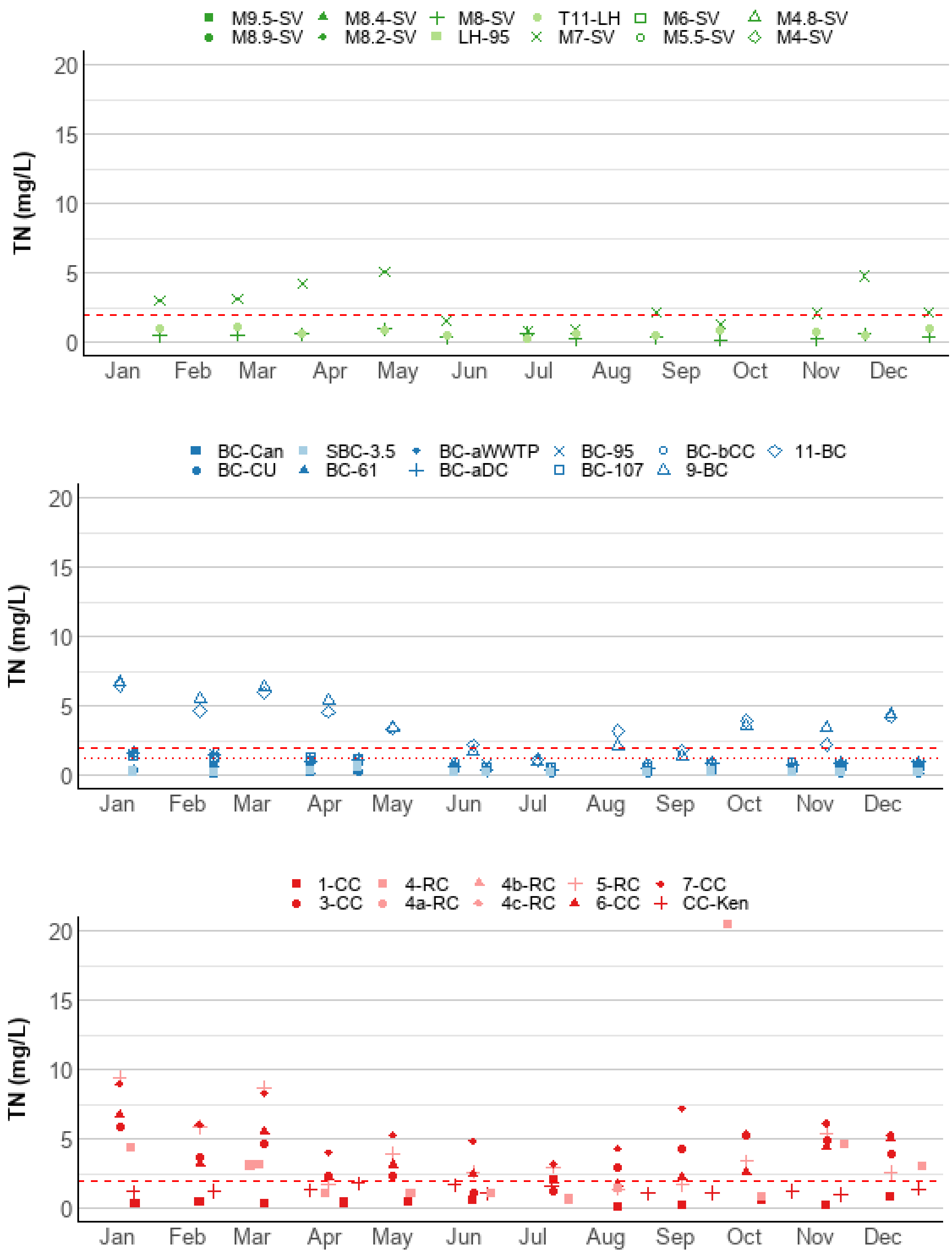


Figure C.8 2019 total nitrogen time series plots, red dashed line depicts interim chronic standard (except BC-Can, BC-CU, and SBC-3.5 for which the standard is depicted with a dotted red line) which does not apply to effluent sites and has not yet been implemented for instream sites downstream of major WWTPs

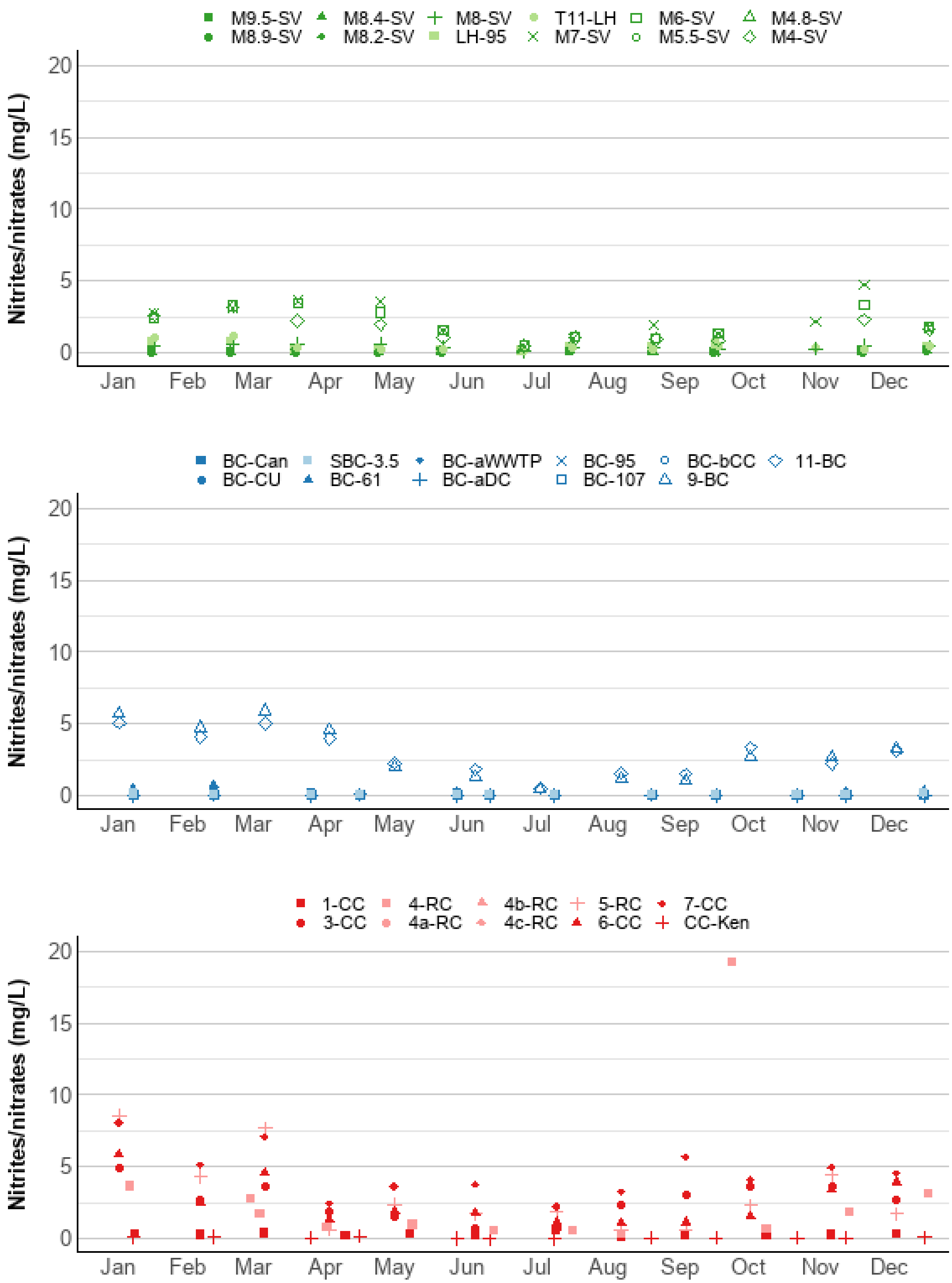


Figure C.9 2019 nitrites and nitrates time series plots

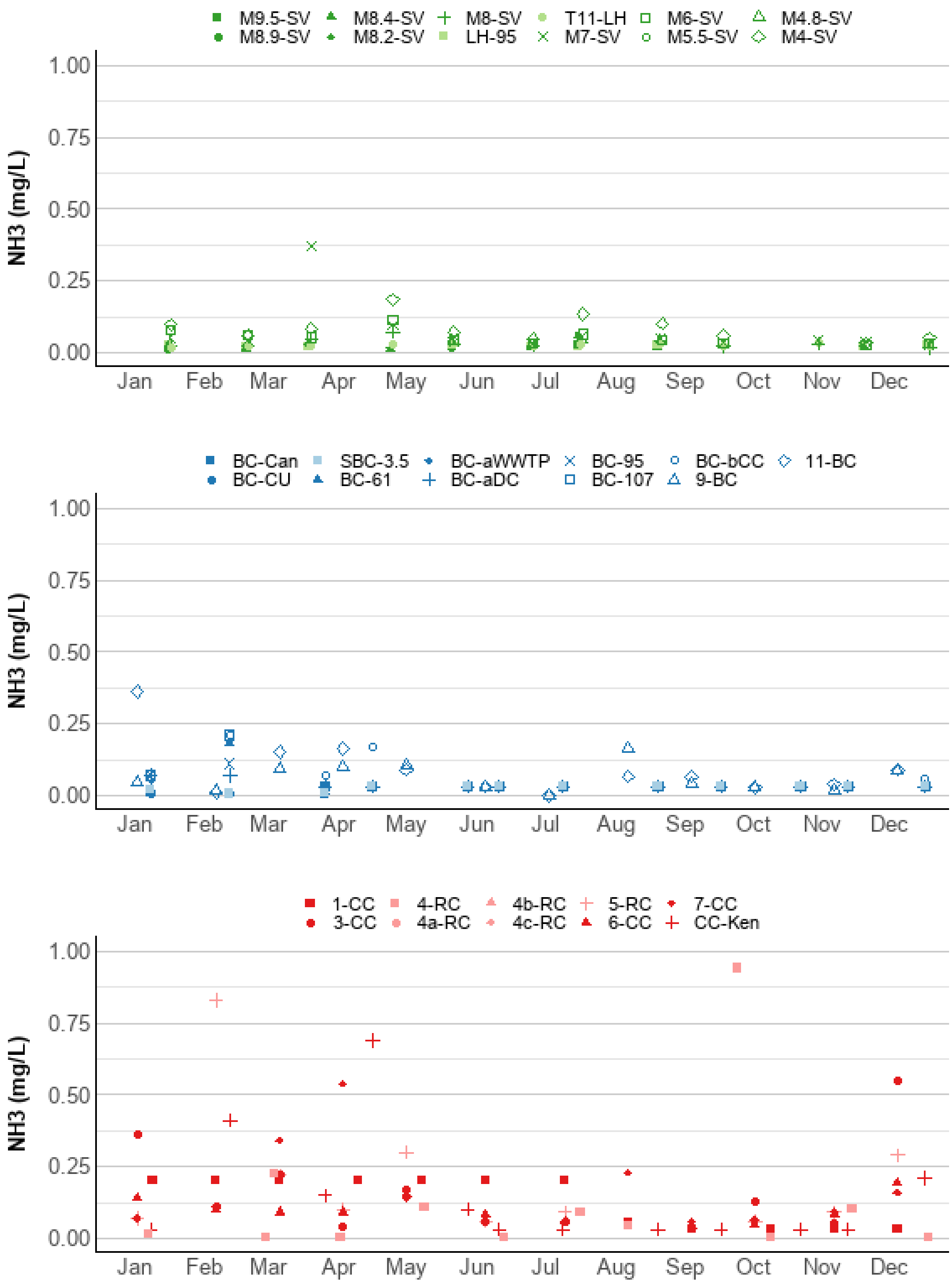


Figure C.10 2019 total ammonia time series plots

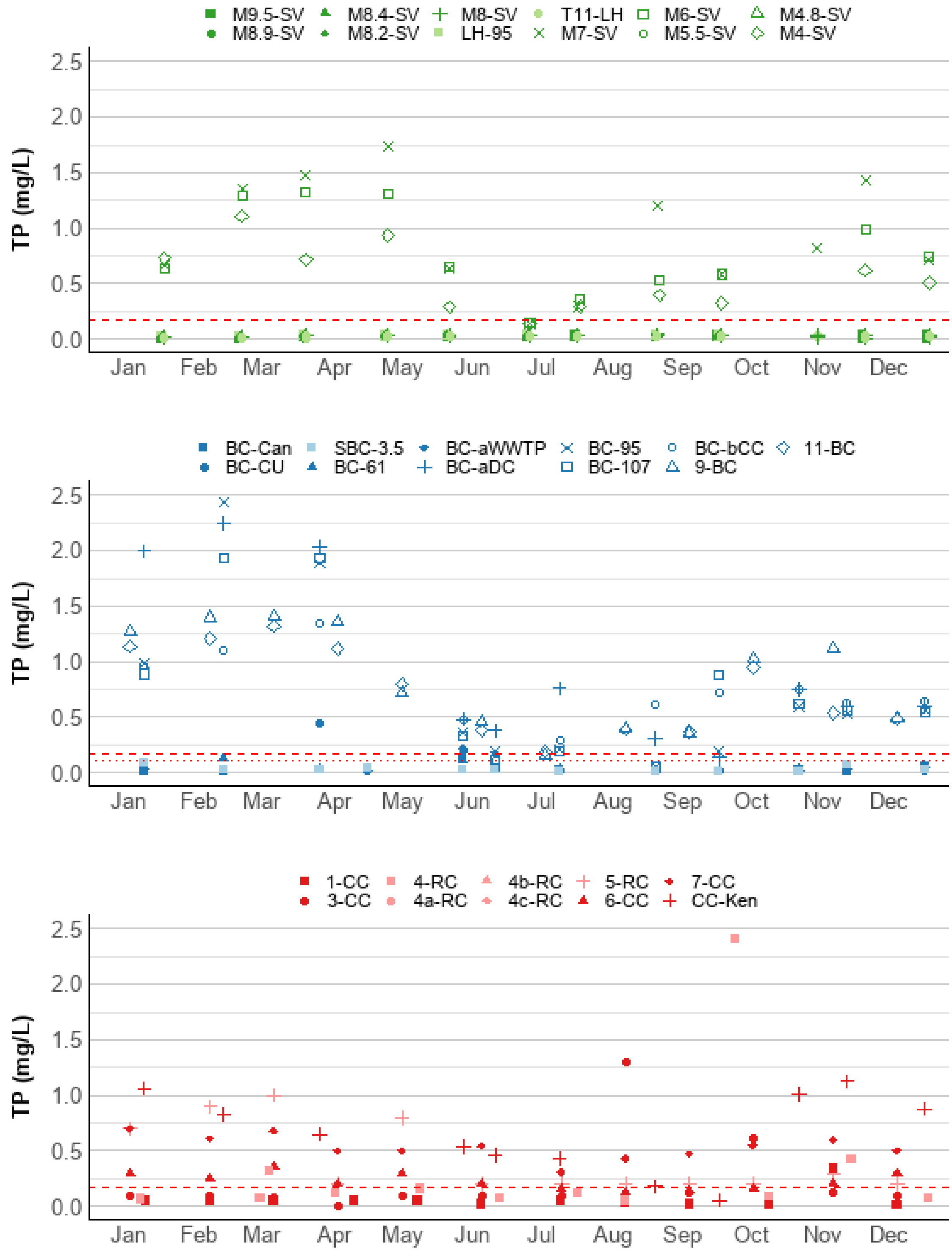


Figure C.11 2019 total phosphorus time series plots, red dashed line depicts interim chronic standard (except BC-Can, BC-CU, and SBC-3.5 for which the standard is depicted with a dotted red line) which does not apply to effluent sites and has not yet been implemented for instream sites downstream of major WWTPs

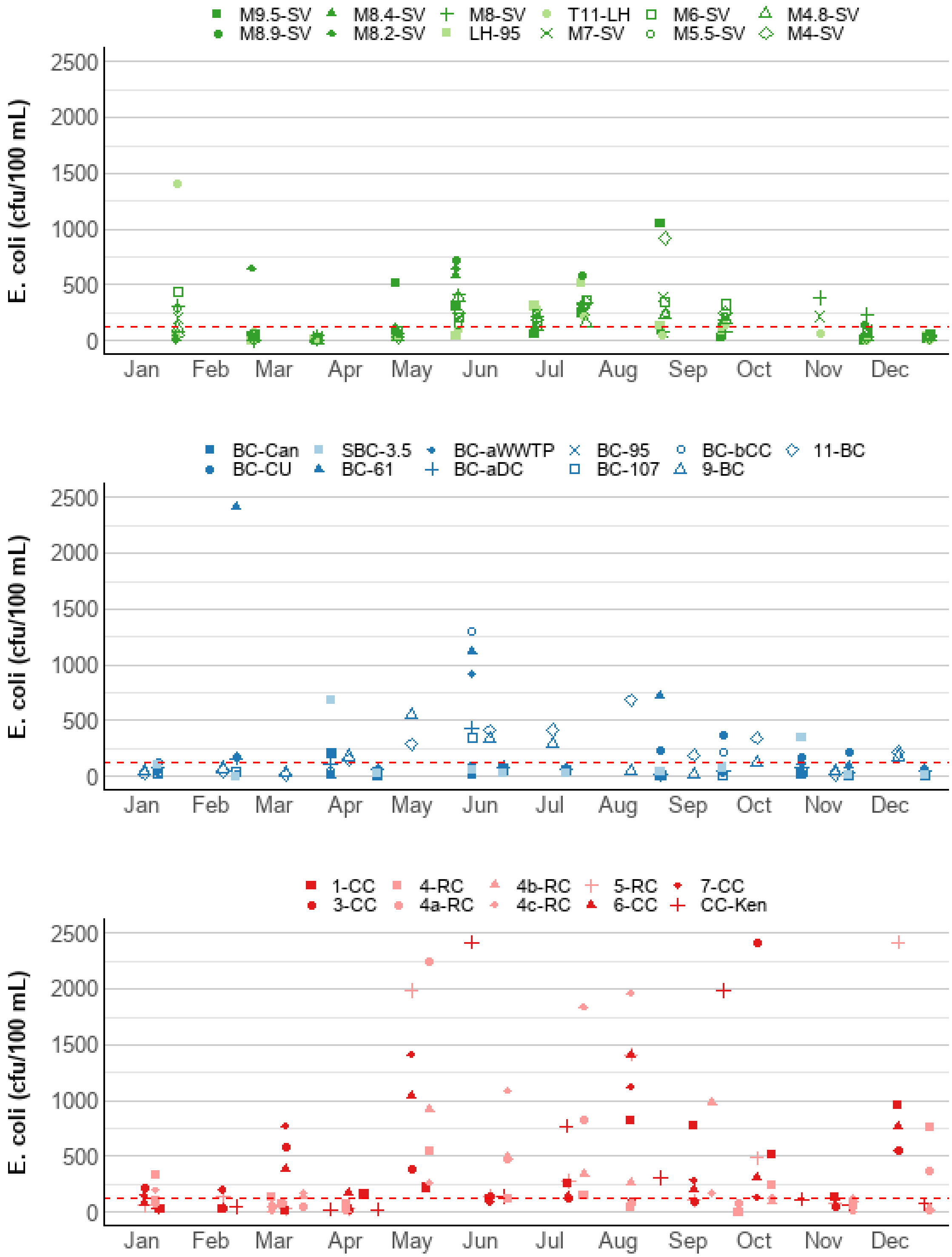


Figure C.12 2019 *E. coli* time series plots, red dashed line depicts chronic standard

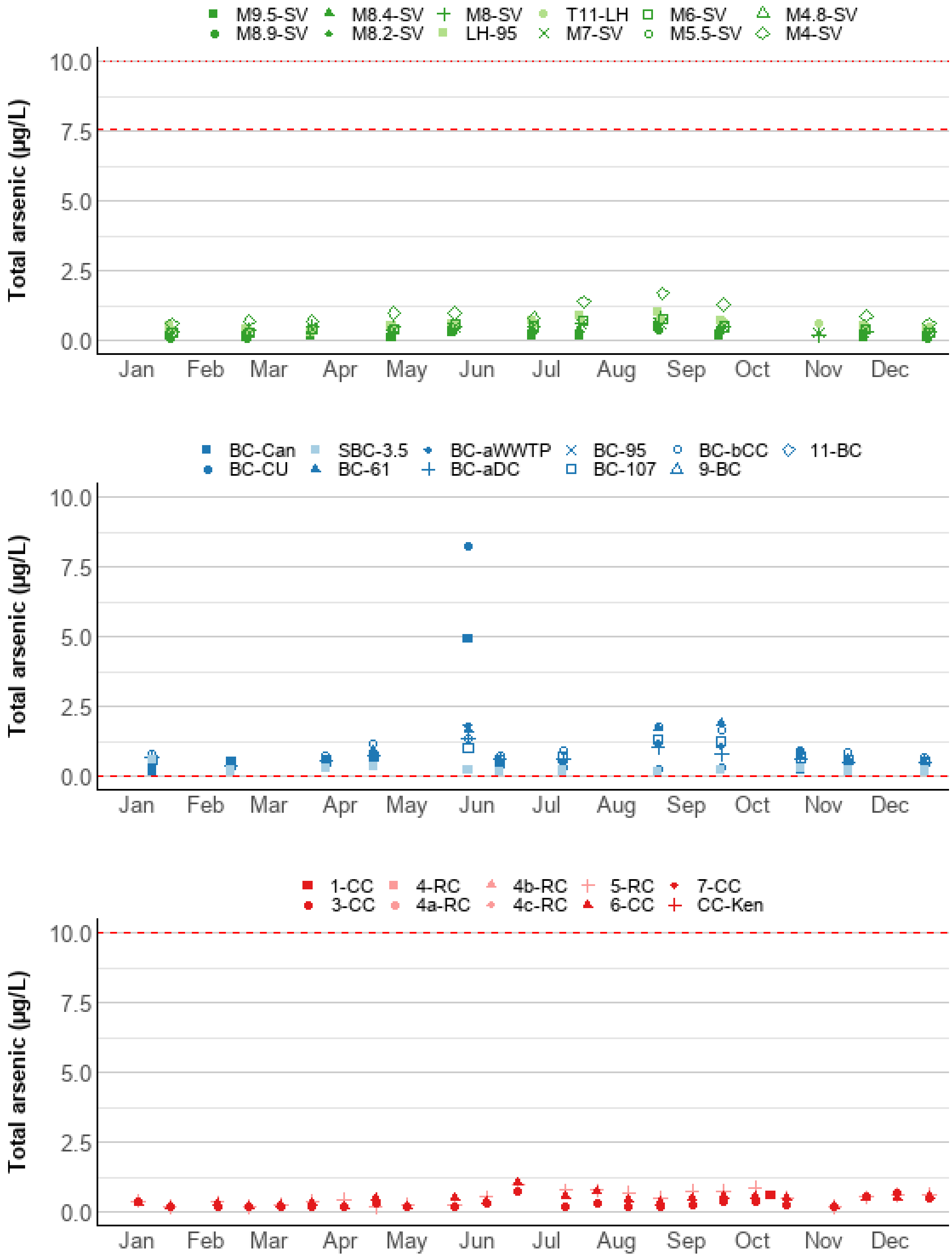


Figure C.13 2019 total arsenic time series plots, red dashed line depicts chronic standard (except for sites LH-95 and T11-LH for which the standard is depicted with a dotted red line)

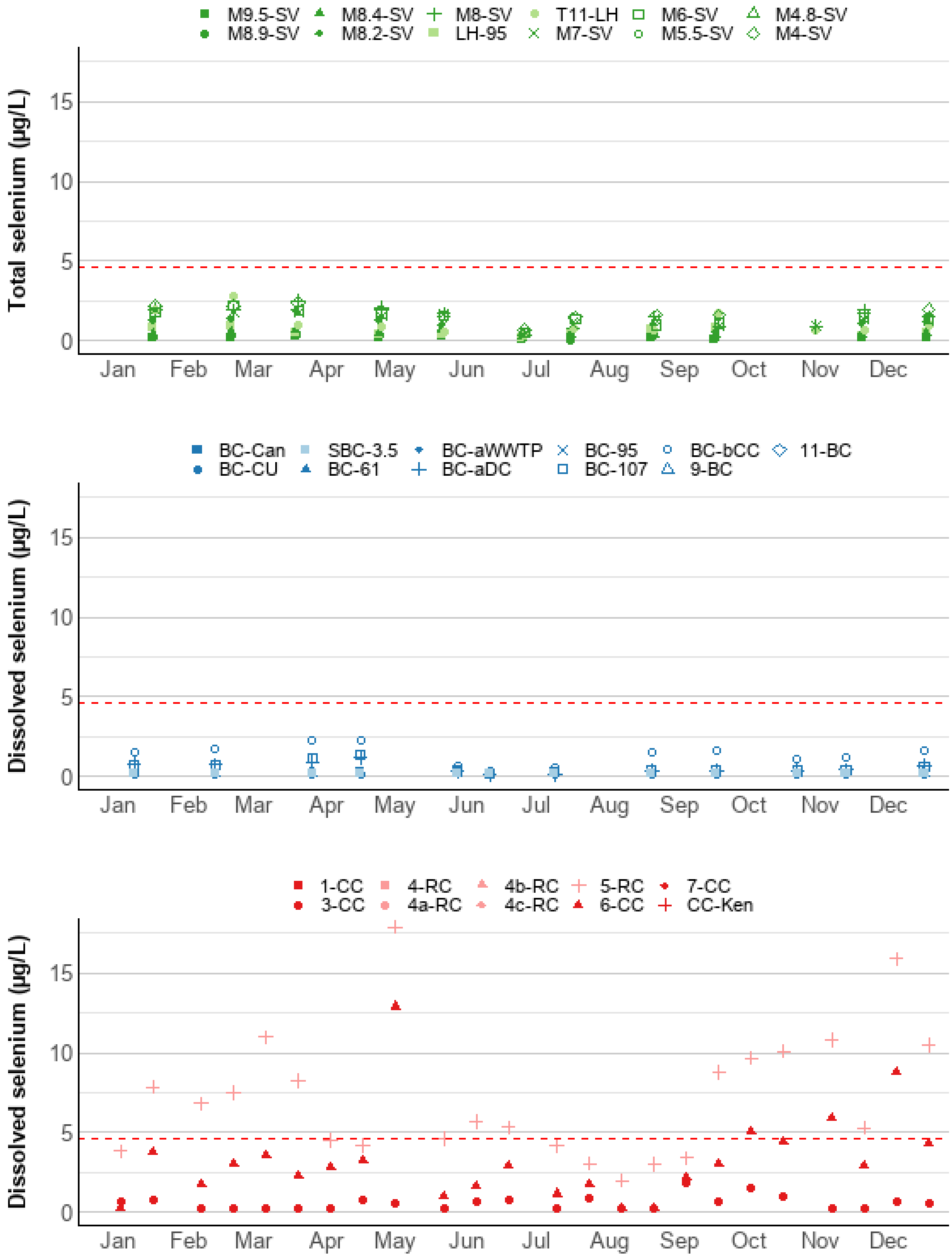


Figure C.14 2019 selenium time series plots, red dashed line depicts chronic standard (note total selenium is depicted for St. Vrain and Left Hand Creek sites)

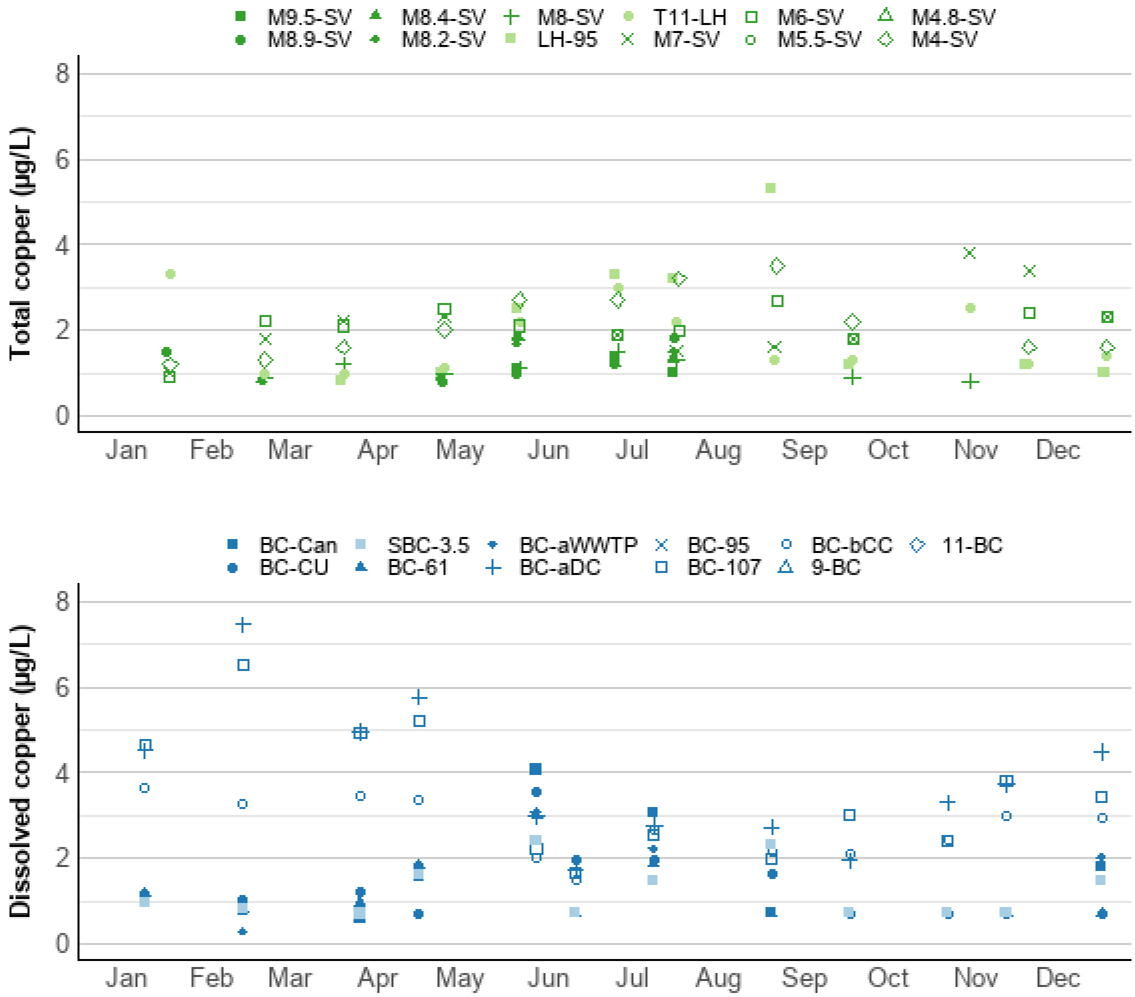


Figure C.15 2019 copper time series plots

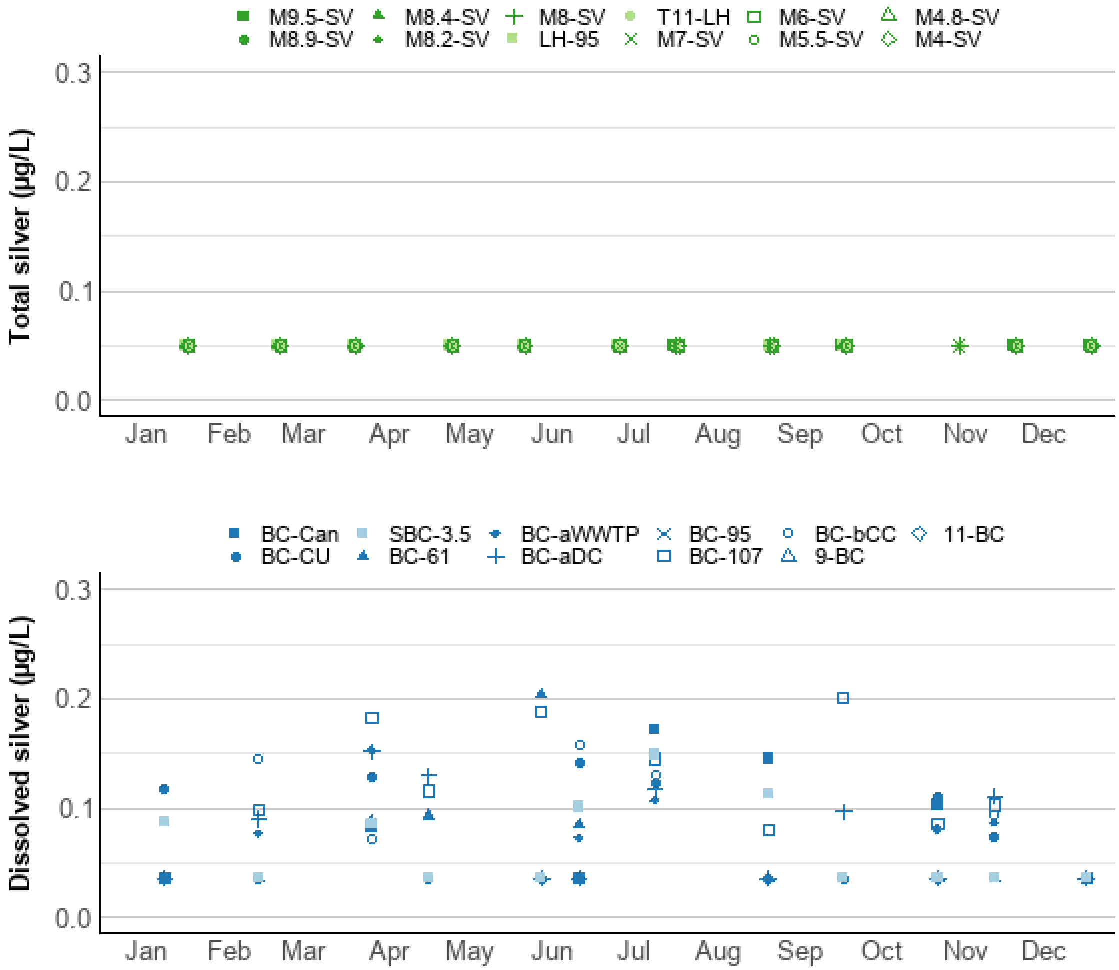


Figure C.16 2019 dissolved silver time series plots

Appendix D

Sampling events

Table D.1 provides a summary of all reported field duplicate samples. The cities of Longmont and Lafayette provided field duplicate data for this report.

Site	Date	Analytes
M9.5-SV	3/19/2019	Hardness, Alkalinity, Conductivity, NO_x, NH_3, TP, *E. coli*, Arsenic (total), Selenium (total), Copper (total), Silver (total)
M9.5-SV	12/17/2019	
M8.9-SV	2/19/2019	
M8.9-SV	11/19/2019	
M8.4-SV	9/17/2019	
M8.2-SV	8/21/2019	
LH-95	4/24/2019	
T-EFF	5/22/2019	
T-EFF	10/30/2019	
M6-SV	7/18/2019	
M4-SV	1/17/2019	
M4-SV	6/26/2019	
BC-CU	1/8/2019	TSS, *E. coli*, TKN, NO_3, NO_2, NH_3, TP
BC-CU	2/12/2019	
BC-CU	3/26/2019	
BC-CU	4/16/2019	
BC-CU	5/28/2019	
BC-CU	6/11/2019	
BC-CU	7/9/2019	
BC-CU	8/20/2019	
BC-CU	9/17/2019	
BC-CU	10/22/2019	
BC-CU	11/12/2019	
BC-CU	12/16/2019	
3-CC	11/6/2019	NO_3, NO_2, NH_3, TKN, TP, *E. coli*
5-RC	2/6/2019	
6-CC	8/7/2019	
7-CC	5/1/2019	

Table D.1 Summary of reported 2019 field duplicate samples

Table D.2 includes all field duplicate samples that exceed the reporting limit and a 25% relative percent difference (RPD), as discussed in the *Data Characteristics* section. *E. coli* data was log transformed prior to evaluating the RPD. Most of these observations occur at low concentrations, where the overall difference is relatively small, or are observations of *E. coli*. Bacteria measurements in stream environments are often highly variable and a moderate difference between duplicate values does not necessarily indicate any data quality issues.

Site	Date	Analyte	Sample 1	Sample 2	RPD
M9.5-SV	3/19/2019	*E. coli*	5.2 MPN/100 mL	11 MPN/100 mL	37%
M9.5-SV	12/17/2019	NO_x	0.1396 mg/L	0.0679 mg/L	69%
M8.4-SV	9/17/2019	Selenium (total)	0.3 µg/L	0.4 µg/L	29%
T-EFF	5/22/2019	Copper (total)	4.0 µg/L	6.5 µg/L	48%
BC-CU	16-Apr-19	E. coli	6.2 CFU/100mL	12.1 CFU/100mL	31%
BC-CU	26-Mar-19	E. coli	18.7 CFU/100mL	6.3 CFU/100mL	46%
BC-CU	17-Sep-19	E. coli	365.4 CFU/100mL	22.8 CFU/100mL	61%
BC-CU	16-Apr-19	TSS	2.3 mg/L	1.7 mg/L	30%
BC-CU	22-Oct-19	TSS	3.9 mg/L	6.1 mg/L	44%
BC-CU	20-Aug-19	TSS	1.8 mg/L	3.4 mg/L	62%
BC-CU	17-Sep-19	TSS	1.9 mg/L	5 mg/L	90%

Table D.2 Summary of field duplicates exceeding relative percent difference (RPD) threshold, RPD for *E. coli* is calculated after log transformation

Table D.3 provides a summary of all reported field blank samples for analytes included in this report. The cities of Longmont and Lafayette provided field blank data for this report. There were no observed cases where field blank samples exceeded the associated reporting limit.

Data provider	Date	Analytes
City of Longmont	1/17/2019	Hardness, Alkalinity, Conductivity, NO_x, NH_3, TP, *E. coli*, Arsenic (total), Selenium (total), Copper (total), Silver (total)
	2/20/2019	
	3/20/2019	
	4/25/2019	
	5/22/2019	
	6/26/2019	
	7/17/2019	
	8/21/2019	
	9/18/2019	
	10/30/2019	
	11/20/2019	
	12/18/2019	
City of Boulder	1/8/2019	TSS, *E. coli*, TKN, NO_3, NO_2, NH_3, TP
	2/12/2019	
	3/26/2019	
	4/16/2019	
	5/28/2019	
	6/11/2019	
	7/9/2019	
	8/20/2019	
	9/17/2019	
	10/22/2019	
	11/12/2019	
	12/16/2019	
City of Lafayette	2/6/2019	NO_3, NO_2, NH_3, TKN, TP, *E. coli*
	11/6/2019	
	5/1/2019	NO_3, NO_2, NH_3, TKN, *E. coli*
	8/7/2019	

Table D.3 Summary of reported 2019 field blank samples

Table D.4 provides a summary of all 2019 sampling dates for the analytes at stream sampling sites considered within this report. The numbers in each cell are the number of unique dates for that combination of sites and analyte. Cells are highlighted in gray where there were less than two sampling events for a given analyte. Cells marked with an asterisk are where the total fraction was sampled instead of the dissolved fraction.

Site	Temp.	Hardness	Alkalinity	Conduct.	TSS	DO	pH	TN	NOx	NH3	TP	*E. coli*	Arsenic (Total)	Copper	Selenium	Silver
M9.5-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
M8.9-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
M8.4-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
M8.2-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
M8-SV	12	12	12	12	12	12	12	12	12	12	12	12	12	12*	12*	12*
LH-95	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
T11-LH	12	12	12	12	12	12	12	12	12	12	12	12	12	12*	12*	12*
M7-SV	12	12	12	12	12	12	12	12	12	12	12	12	12	12*	12*	12*
M6-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
M5.5-SV	11			11		11	11					11				
M4.8-SV	11			11		11	11					11				
M4-SV	11	11	11	11	11	11	11		11	11	11	11	11	11*	11*	11*
BC-Can	12	12		12	12	12	12	12	12	12	12	12	12	12	12	12
BC-CU	12	12		12	12	12	12	12	12	12	12	12	12	12	12	12
SBC-3.5	12	12		12	12	12	12	12	12	12	12	12	12	12	12	12
BC-61	12	12		12	12	12	12	12	12	12	12	12	12	12	12	12
BC-aWWTP	12	11		12	12	12	12	12	12	12	12	12	12	12	12	12
BC-aDC	12	12		12	12	12	12	12	12	12	11	12	12	12	12	12
BC-95	12	0		12	12	12	12	12	12	12	11					
BC-107	12	12		12	12	12	12	12	12	12	11	12	12	12	12	12
BC-bCC	12	12		12	12	12	12	12	12	12	11	12	12	12	12	12
9-BC	12	12	12	11		11	12	12	12	12	12	12				
11-BC	12	12	12	11		11	12	12	12	12	12	12				
1-CC	12	11	12	12	11	12	12	12	12	12	12	12	1	1	1	1
3-CC	12	12	12	12			12	12	12	12	12	12	24		24	
4-RC	12	12	12	5	12	12	12	12	12	12	12	12			10	
4a-RC	12			4		12	12					11			11	
4b-RC	11			4		11	11					11			12	
4c-RC	12			4		12	12					12			12	
5-RC	12	12	12	12			12	12	12	12	12	12	24		24	
6-CC	12	12	12	12			12	12	12	12	12	12	24		24	
7-CC	12	12	12	12			12	12	12	12	12	12				
8-CC																
CC-Ken	12			12	12	12	12	12	12	12	11	12				

Table D.4 Number of 2019 sampling dates for each analyte and stream sample site, asterisks mark observations where total fraction was measured instead of dissolved fraction