2019 ANNUAL REPORT

Upper Cache la Poudre Watershed Collaborative Water Quality Monitoring Program

June 24, 2020

PREPARED FOR
City of Fort Collins
City of Greeley
Soldier Canyon Water Authority

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EXECUTIVE SUMMARY

BACKGROUND

The Upper Cache la Poudre Collaborative Water Quality Monitoring Program (hereafter referred to as the Upper CLP monitoring program) is designed to assist the City of Fort Collins, the City of Greeley and the Soldier Canyon Water Treatment Authority in meeting current and future drinking water treatment goals by reporting current water quality conditions and trends within the Upper Cache la Poudre River (CLP) watershed and summarizing issues that potentially impact watershed health and source water quality.

SCOPE OF ANNUAL REPORT

This annual report summarizes climatic and hydrologic conditions in the Upper CLP watershed over the 2019 calendar year and water quality data collected as part of the Upper CLP monitoring program. Spatial trends in water quality are evaluated at key monitoring locations throughout the Mainstem and North Fork CLP watershed, and temporal trends are evaluated at monitoring sites located near water treatment facility intakes on the Poudre River. This report compares water quality information from 2019 to baseline conditions defined as the period of record from 2008 to 2012.

STATE OF UPPER CACHE LA POUDRE WATERSHED WATER QUALITY

The Upper CLP remains a high-quality drinking water supply for Fort Collins, City of Greeley and surrounding communities served by the Soldier Canyon Water Treatment Authority. Consistent with previous years, the Mainstem and the North Fork exhibited different water quality characteristics due to differences in geology, land use, hydrology and elevation. No significant water quality concerns were identified for the Mainstem or North Fork CLP that immediately impact drinking water quality or treatment operations.

Below average temperatures and wet weather throughout the spring and early summer delayed the timing and duration of snowmelt runoff. As a result, peak streamflow occurred nearly three weeks later than expected and higher streamflow extended into late-summer and fall. Cool, wet conditions in late-spring and early-summer were followed by record breaking temperatures and extremely dry conditions in the late-summer and fall.

No significant water quality concerns were identified for the Mainstem or North Fork CLP that directly impact drinking water quality or treatment operations. The typical challenges for water treatment were observed on the Mainstem and the North Fork throughout spring runoff. Raw water from these two sources exhibited elevated TOC and turbidity levels, low alkalinity and hardness concentrations, and decreased pH levels. In general, concentrations for most parameters were within the expected baseline range of variability.

The most notable impacts to water quality over the 2019 water year were caused by a shift in the timing and duration of snowmelt runoff and associated patterns in streamflow. The typical water quality changes observed as a result of snowmelt runoff were experienced later than baseline due to cooler weather delaying snowmelt runoff in late-spring and early summer. Similarly, these changes in water quality were observed for a longer period of time due to the longer duration runoff observed over the 2019 water year.

Collecting water quality samples on Joe Wright Creek in June of 2019.

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LIST OF ABBREVIATIONS & ACRONYMS

%	percent
cfs	cubic feet per second
CLP	Cache la Poudre River
DO	Dissolved Oxygen
DBP	Disinfection By-Product
EPA	Environmental Protection Agency
FCWQL	Fort Collins Water Quality Lab
FCWTF	Fort Collins Water Treatment Facility
JWC	Joe Wright Creek above the Poudre River (key monitoring site)
mg/L	milligrams per liter
NBH	North Fork of the Poudre River below Halligan Reservoir (key monitoring site)
NDC	North Fork of the Poudre River above Dale Creek Confluence (key monitoring site)
NFG	North Fork of the Poudre River below Seaman Reservoir (key monitoring site)
NFL	North Fork of the Poudre River at Livermore (key monitoring site)
ng/L	nanograms per liter
NTU	Nephelometric Turbidity Units
^{o}C	degrees Celsius
PBD	Poudre River at the Bellvue Diversion (key monitoring site)
PBR	Poudre River below Rustic (key monitoring site)
PJW	Poudre River above the confluence with Joe Wright Creek (key monitoring site)
PNF	Poudre River above the North Fork (key monitoring site)
PSF	Poudre River below confluence with South Fork (key monitoring site)
ppt	parts per trillion
SCWTA	Soldier Canyon Water Treatment Authority
SNOTEL	Snow telemetry network
SWE	Snow water equivalent
T&O	Taste & Odor
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
µg/L	micrograms per liter
µS/cm	microSeimens per centimeter
USGS	United States Geological Survey
WTP	Water Treatment Plant

1.0 INTRODUCTION

1.1 BACKGROUND

The Upper Cache la Poudre (CLP) River is an important source of high-quality drinking water supplies for communities served by the City of Fort Collins Water Treatment Facility (FCWTF), the City of Greeley-Bellvue Water Treatment Plant (WTP), and the Soldier Canyon Water Treatment Authority's (SCWTA) Soldier Canyon Filter Plant (SCFP). In the shared interest of sustaining this high-quality water supply, the City of Fort Collins, the City of Greeley, and the SCWTA partnered in 2007 to design the Upper CLP Collaborative Water Quality Monitoring Program (Program). The Program was subsequently implemented in spring 2008. The goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals by providing up-to-date information about water quality and trends within the Upper CLP watershed.

Raw CLP River water quality parameters that have historically had the most impact on treatment at the three treatment plants include:

- turbidity
- total organic carbon (TOC)
- pH
- alkalinity
- temperature
- pathogens (*Giardia* and *Cryptosporidium*)
- taste and odor (T&O) compounds (geosmin and 2-methlyisoborneol)

Seasonal updates, annual water quality reports, and five-year reports for the Program are prepared by City of Fort Collins' Watershed Program staff to keep participants informed of current conditions, spatial trends, and short- and long-term trends in water quality of the Upper CLP watershed. Seasonal updates are provided throughout the monitoring season. These updates include a seasonal summary of the Upper CLP watershed by highlighting precipitation, streamflow, and water quality conditions in the spring, summer and fall. The purpose of annual reports is to summarize hydrologic, climatic, and water quality conditions for the previous water year. For the purposes of this report the water year is defined as the months of December through November as opposed to the months of October through September. The five-year trend report provides a more in-depth analysis of both spatial and temporal trends in watershed hydrology, climate and water quality. The first five-year trend report was completed for the years 2008-2012 (Oropeza & Heath, 2013). The second five-year trend report was prepared in 2018 and evaluated trends for the 10-year period of record from 2008 through 2017 (Heath et al., 2018). The Program's reports are available on the City of Fort Collins Utilities Source Water Monitoring website:

www.fcgov.com/ source-water-monitoring.

The goal of this monitoring partnership is to assist the participants in meeting current and future drinking water treatment goals…

1.2 WATERSHED DESCRIPTION AND SAMPLING LOCATIONS

Sampling efforts are divided between the Mainstem CLP River watershed (including Joe Wright Creek, the Big South and the Little South Fork Cache la Poudre River) and North Fork CLP River watershed. Collectively these watersheds encompass approximately 645,500 acres of forest, other natural land types, and agricultural land (Table 1). An additional 4,700 acres, representing less than 1% of land surface, is developed for commercial, industrial, utility, urban or residential purposes.

Table 1 – Land use comparison between Upper North Fork and Mainstem CLP watersheds. Areas were calculated using US Geological Survey Seamless Geographic Information System data sets.

Land Use Comparison	North Fork (acres)	North Fork (%)	Mainstem (acres)	Mainstem (%)
Developed land (commercial, industrial, residential, urban, and utilities)	2,817	0.8	1,945	0.7
Agricultural use and grassland (Cropland, pasture, other agriculture, scrub and grasses)	183,719	52.3	54,765	18.3
Forest (forest and brush)	154,654	44.1	213,879	71.5
Natural lands (exposed rock, bare ground, wetlands, tundra, lakes)	9,926	2.8	28,473	9.5
Total	351,116	100	299,062	100

The monitoring network consists of 18 sampling locations selected to characterize the headwaters, major tributaries and downstream locations of the Upper CLP River near the City of Fort Collins, SCWTA, and City of Greeley raw water intake structures (Figure 1.1). A description and rationale for each site is provided in Attachment 1.

1.3 SAMPLING SCHEDULE AND PARAMETERS

The sampling frequency for the Program was determined based on both statistical performance and cost considerations. Parameters were selected based on analyses of historical data and aim to provide the best information possible within current budgetary constraints. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the Program design document by Billica, Loftis and Moore (2008). The annual sampling schedule is provided in Attachment 4 of this report.

1.4 SAMPLE COLLECTION AND ANALYSIS

Field sampling is conducted by staff members from the City of Fort Collins. Sampling methods, including those for the collection of physical field measurements for temperature, pH, conductivity, turbidity and dissolved oxygen are documented in the Program's Standard Operating Procedures.

All water samples are analyzed by the City of Fort Collins Water Quality Lab (FCWQL). The analytical methods and detection limits for the FCWQL parameters are included in Attachment 3.

Consistent with the quality assurance guidelines outlined in Section 5.5 of Billica, Loftis and Moore (2008), field blanks and field duplicates are collected alongside at least ten percent of samples for a subset of parameters, which are identified in the Annual Operating Plan (Attachment 4). A summary of quality assurance and quality control field blanks and field duplicates is discussed in Section 4 of this document.

1.5 SCOPE OF 2019 ANNUAL REPORT

This annual report summarizes climate and hydrology in the Upper CLP watershed over the 2019 water year and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program. For the purpose of this report, the water year is defined as December 1, 2018 to November 30, 2019. Spatial trends in water quality are evaluated at key monitoring locations throughout the Upper Mainstem and North Fork CLP watersheds, and temporal trends are evaluated at monitoring sites located near water treatment facility intakes on the Poudre River. The report compares water quality information from 2019 to baseline conditions, defined as the period of record from 2008 to 2012.

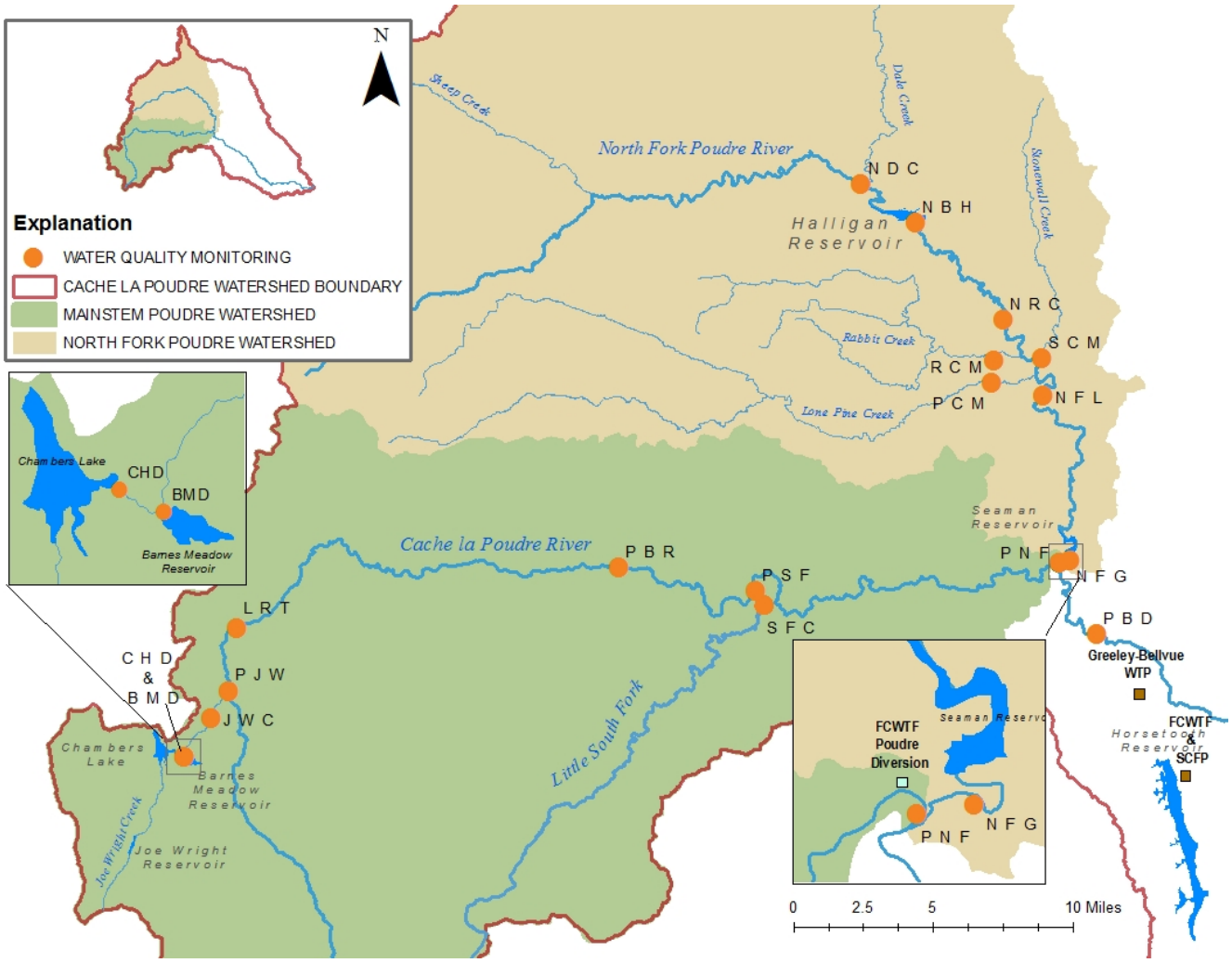


Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

2.0 HYDROLOGY & CLIMATE

Hydrology and climate play an important role in regulating the water quantity and quality in the Upper CLP watershed. Precipitation events and snowmelt runoff largely control the quantity and timing of deliveries of material to the river. The amount or volume of water in the system at a given time influences the concentration of most water quality constituents. Changes to the timing, magnitude, frequency and duration of snowmelt runoff and the associated effects on water quality have implications to future water treatment operations.

Hydrologic and Climatic Data Sources

The snow telemetry (SNOTEL) network, managed by the Natural Resource Conservation Service, includes approximately 600 automated monitoring sites located in remote mountain watersheds throughout the United States that measure snow water equivalent (SWE), total precipitation and air temperature. Joe Wright SNOTEL is located near Joe Wright Reservoir at an elevation of 10,120 feet and contains the longest record of continuous measurements in the Cache la Poudre Watershed dating back to 1978.

The Cache la Poudre at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station managed by *the* Colorado Department of Water Resources contains the longest record of continuous streamflow in the Upper CLP watershed dating back to 1883. The streamflow monitoring station is located at the Canyon Mouth and includes streamflow contributions from both the Mainstem and North Fork watersheds.

Evaluating annual and seasonal trends

Average monthly mean air temperature, monthly total precipitation and total monthly streamflow volume for the 2019 water year are compared to the average calculated over the baseline period of record from 2008 to 2012. Seasonal statistics were calculated for winter (DJF), spring (MAM), summer (JJA), and fall (SON).

2.1 AIR TEMPERATURE

The average mean air temperature in 2019 was 34.4°F and measured 0.3°F cooler than baseline (Table 2). The water year ranked as the 11th warmest on record (30 years; 1990 to 2019) at the Joe Wright SNOTEL. Temperature was warmer than baseline in the winter and slightly below or near baseline in the spring, summer and fall.

The winter season was slightly warmer (0.6°F) than baseline (Table 2) and ranked as the 11th warmest winter on record. Temperature in the months of December and February measured near baseline and temperature in the month of January measured 1.4°F warmer than baseline (Figure 2.1), which ranked as the 6th warmest January on record.

The spring season was 1.2°F cooler than baseline (Table 2). Temperature was 3.0°F cooler than baseline in the months of March and May. May of 2019 ranked as the 4th coolest May on record. In contrast, the month of April was 2.4°F warmer than baseline (Figure 2.1) and ranked as the 3rd warmest April on record.

The summer season was slightly cooler (0.5°F) than baseline (Table 2). The cooler temperatures observed in the month of May continued into June. Temperature in the month of June was 3.6°F cooler than average and ranked as the 9th coldest June on record. In contrast, temperatures in the months of July and August were warmer than baseline (0.4°F and 1.8°F, respectively; Figure 2.1). The month of July ranked as the 7th warmest July on record and the month of August was warmest August recorded over the past 30 years at the Joe Wright SNOTEL.

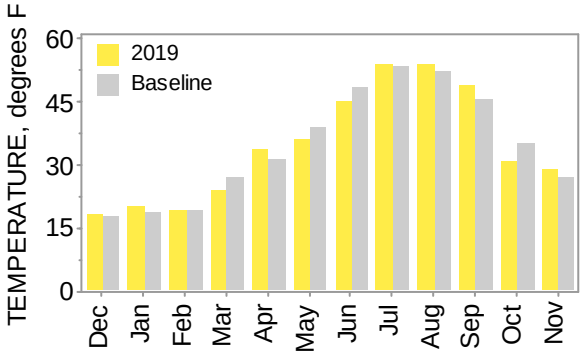


Figure 2.1 –Monthly mean air temperature compared to baseline air temperature measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

Table 2 – Seasonal summary statistics for temperature, precipitation, and streamflow in Upper CLP watershed in 2019 compared to baseline (period of record is 2008 – 2012).

Season	Period of Record	Temperature (deg F)		Precipitation (in)		Streamflow (acre-ft)	
		Average	*Departure*	*Total*	*% Average*	*Total*	*% Average*
Winter	2019	19.0	0.6	11.1	88%	9,624	127%
	Baseline	18.4		12.7		7,602	
Spring	2019	31.3	-1.2	15.6	104%	39,999	84%
	Baseline	32.5		15.0		47,547	
Summer	2019	51.0	-0.5	9.0	134%	189,074	112%
	Baseline	51.5		6.7		168,506	
Fall	2019	36.3	0.0	8.2	75%	15,539	121%
	Baseline	36.3		11.0		12,877	
Annual (WY)	2019	34.4	-0.3	43.9	97%	254,236	107%
	Baseline	34.7		45.3		236,531	

Although temperature during the fall season was normal compared to baseline, it ranked as the 8th warmest fall on record (Table 2). The exceptionally hot conditions that were observed in the months of July and August continued through the month of September. Temperature in the month of September was 3.2°F warmer than baseline and ranked as the 2nd warmest September on record. In contrast, the month of October ranked as the 2nd coldest on record measuring 4.4°F cooler than baseline. Warmer conditions returned in the month November, which measured 1.8°F warmer than baseline (Figure 2.1) and ranked as the 6th warmest on record.

2.2 PRECIPITATION

Total Precipitation

Total precipitation over the 2019 water year was 97% of baseline with a total of 43.9 inches measured at the Joe Wright SNOTEL (Table 2). Precipitation was at or below baseline in the winter and fall, slightly above baseline in the spring and well above baseline over the summer season.

Precipitation measured over the winter season was below baseline with a total of 11.1 inches of precipitation (Table 2). Precipitation measured over the months of December and January was near baseline. The month of February was the driest winter month at 68% of baseline (2.9 inches) (Figure 2.2), which ranked as the 9th driest February on record (1979 to 2019; 41 years).

Total precipitation measured over the spring season was 104% of baseline with a total of 15.6 inches of precipitation (Table 2). The start of the spring season was particularly wet with 6.8 inches of precipitation falling in the month of March, which ranked as the 6th wettest March record. In contrast, precipitation over the month of April measured 67% of baseline (4.5 inches). Total precipitation in the month of May was 98% of baseline (Figure 2.2).

Total precipitation measured over the summer season was 134% of average with 9.0 inches of precipitation and ranked as the 5th wettest summer on record (Table 2). Most of the precipitation that fell over the summer season was measured in the month of June. Precipitation over the month of June was 257% of baseline and ranked as the wettest June on record. The months of July and August were below baseline and measured 81% and 71% of baseline, respectively. The month of August ranked as the 6th driest August on record with only 1.2 inches of precipitation recorded at the Joe Wright SNOTEL.

Dry conditions persisted into the fall season. Total precipitation was 75% of baseline with a total of 8.2 inches of precipitation, which ranked as the 6th driest fall on record (Table 2). Only 1.4 inches of precipitation was measured in the month of September, which ranked as the 9th driest September on record. Precipitation over the month of October was near baseline. Only half the expected precipitation was measured in the month of November, which ranked as the 6th driest November on record (Figure 2.2).

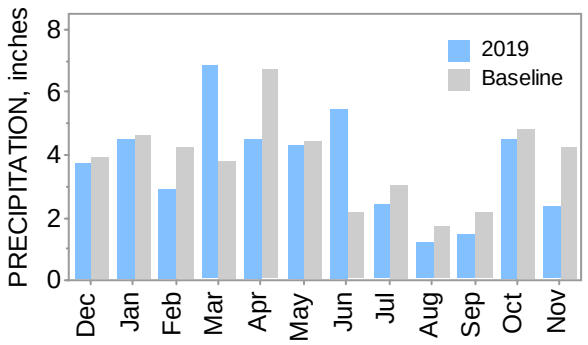


Figure 2.2 – Monthly precipitation totals compared to baseline totals measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

Cache la Poudre Basin Snowpack

Snow water equivalent (SWE) data were analyzed from five NRCS SNOTEL stations and five snow course monitoring sites to evaluate differences across the basin as well as between years (Figure 2.3). Deadman Hill, Red Feather, and Black Mountain sites represent snow conditions in the North Fork watershed; Cameron Pass and Hourglass Lake represent conditions in the South Fork watershed; and Joe Wright, Long Draw, Big South, and Bennet Creek represent conditions in the Upper Mainstem CLP watershed (Figure 2.3).

The maximum amount of water contained in the snowpack, referred to as peak SWE, across the entire Cache la Poudre Watershed was 105% of the expected peak SWE based on the long-term median (1981-2010). The Mainstem and North Fork Poudre basins were above the long-term median at 102% and 117%, while the South Fork was slightly below the long-term median at 94% (Figure 2.3).

The peak SWE measured at the Joe Wright SNOTEL was observed on April 19th, which was slightly earlier than normal. Below average temperatures and wet weather throughout the spring and early summer delayed snowmelt and extended the snow accumulation season into early June. The snowpack measured 161% of normal at the Joe Wright SNOTEL before snowmelt runoff began in early June. A late June storm brought additional snow to higher elevations of the Upper CLP watershed and extended snowmelt into early July. The snowpack at the Joe Wright SNOTEL was completely melted on July 1st – 12 days later than normal.

2.3 STREAMFLOW

The Mainstem and North Fork watersheds exhibit snowmelt-dominated hydrographs. Water is stored in the snowpack as snow accumulates through the winter and is subsequently released as runoff in the spring and summer as the snowpack melts.

Mainstem Cache la Poudre River

The total volume of water that flowed down the Mainstem CLP River over the 2019 water year (as measured at the Canyon Mouth stream gage) was 254,236 acre-feet, which was 107% of baseline (Table 2). Streamflow was above baseline in the winter, summer and fall, and below baseline in the spring.

Streamflow measured over the winter season was 127% of average with a total of 9,624 acre-feet of water (Table 2). The month of December measured near baseline at 101% of baseline. The months of January and February were notably higher than baseline and measured 134% and 155% of baseline, respectively.

Streamflow measured over the spring season was 84% of baseline and totaled 39,999 acre-feet (Table 2). Streamflow remained higher than baseline in the months of March and April at 148% and 123% of baseline, respectively. In contrast, streamflow in the month of May measured only 73% of baseline due to cooler temperatures regulating snowmelt from higher elevations in the watershed (Figure 2.4).

Streamflow during the summer season was 112% of baseline and totaled 189,074 acre-feet (Table 2). Cooler temperatures continued in early-June slightly slowing the rate of snowmelt runoff. Streamflow in the month of June was 95% of baseline. Streamflow was well above baseline in the months of July and August at 139% and 136% of baseline, respectively (Figure 2.4). Peak streamflow was measured on July 1st at 2,740 cubic feet per second. The peak streamflow in 2019 was 137% of the historical average peak streamflow (137 years) and occurred nearly three weeks later.

Streamflow during the fall season was 121% of baseline and totaled 15,539 acre-feet (Table 2). All months over the fall season measured above baseline. The month of September was 130% of baseline. Streamflow was 101%

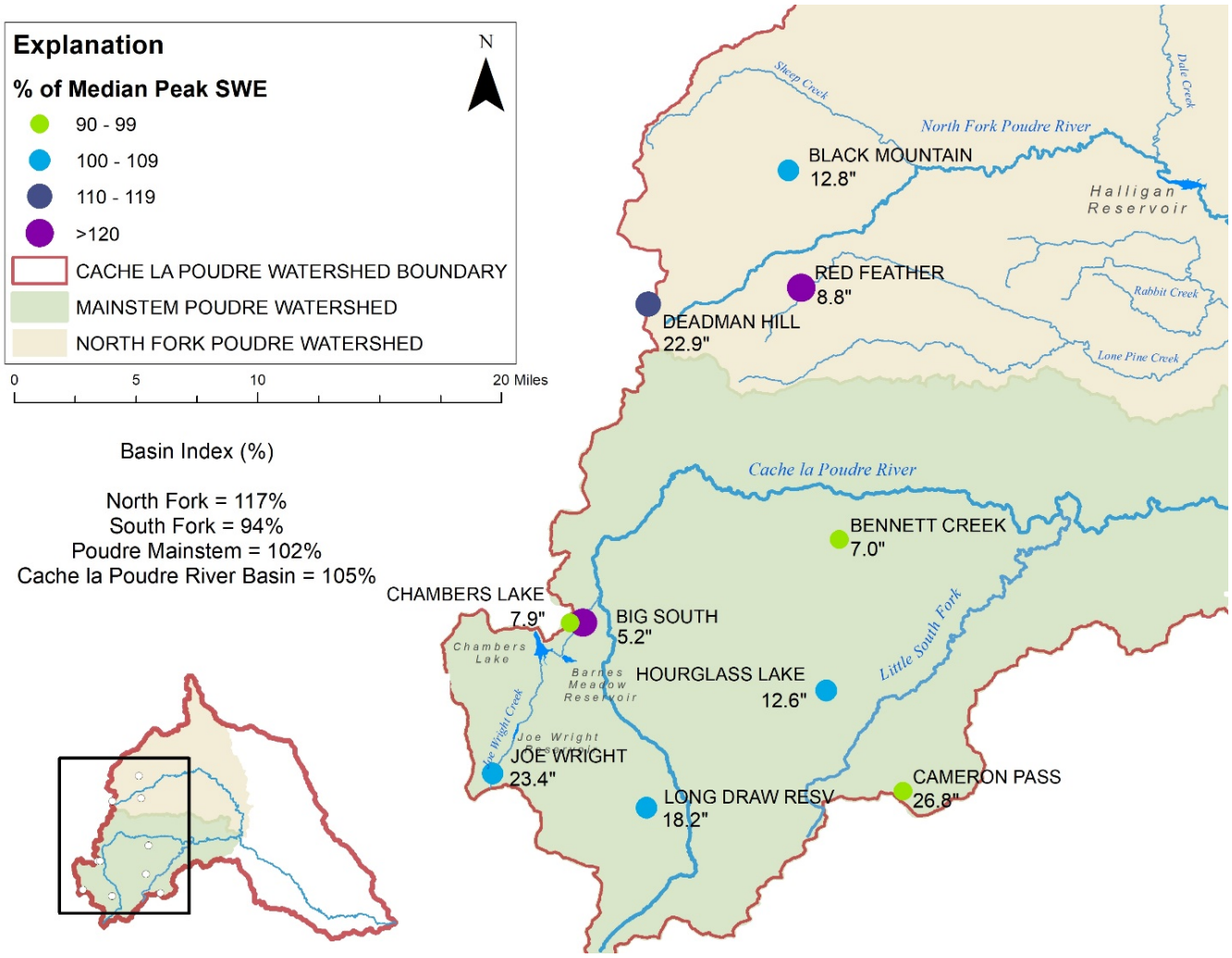


Figure 2.3 – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2019 water year.

of baseline in the month of October and 117% of baseline in the month of November (Figure 2.4).

North Fork Cache la Poudre River

The total volume of water that flowed down the North Fork CLP River near Livermore (NFL) over the 2019 water year was 42,694 acre-feet, which was 107% of baseline (Figure 2.4). Streamflow was below baseline in the winter and fall and above baseline in the spring and summer.

Streamflow measured over the winter season was 45% of baseline with a total of 1,811 acre-feet of water. All winter months were well below baseline at 52%, 44% and 38% for the months of December, January and February.

Streamflow measured over the spring season was 114% of baseline and totaled 18,776 acre-feet. All spring months were above baseline at 142%, 120% and 111% for the months of March, April and May. (Figure 2.4).

Streamflow during the summer season was 105% of baseline and totaled 21,327 acre-feet. The month of June was slightly below baseline at 94%. Streamflow in the month of July was well above baseline at 188% and remained higher than baseline in the month of August at 143% (Figure 2.4).

Streamflow during the fall season was 91% of baseline and totaled 1,372 acre-feet (Figure 2.4).

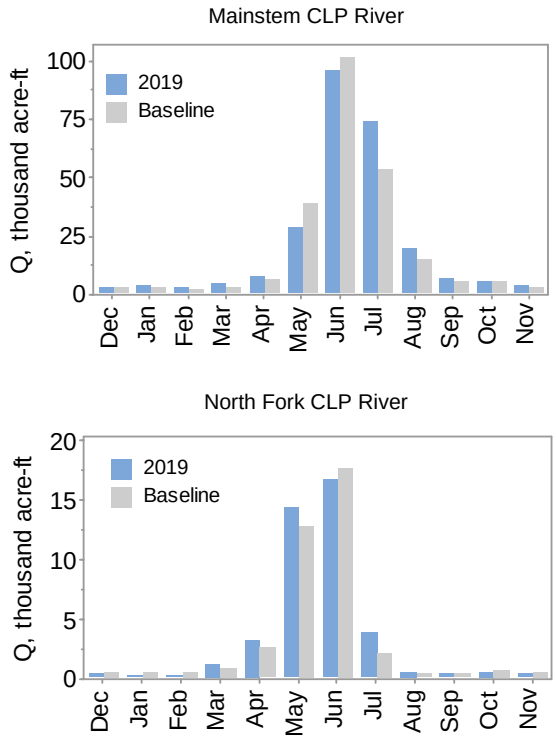


Figure 2.4 –Total monthly streamflow in 2019 compared to average total monthly mean streamflow measured on the Mainstem CLP River near the Canyon Mouth (top) and North Fork CLP river near Livermore (bottom).

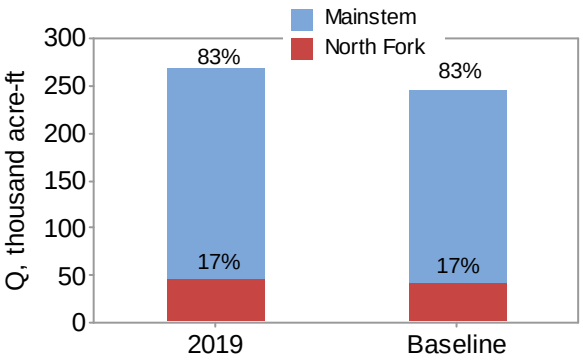


Figure 2.5 – Proportion of average Mainstem and North Fork contributions at PBD in 2019 compared to average.

Streamflow Contributions

There are several tributaries, diversions, and water storage reservoirs that contribute to the overall streamflow and water quality on the Mainstem CLP River above the North Fork. The two highest elevation diversions in the Upper CLP include Michigan River Ditch, which diverts water from the Upper North Platte basin to Joe Wright Reservoir and the Grand Ditch, which diverts water from the Upper Colorado River basin into Long Draw Reservoir. The contributions of these diversions are not presented in the report, but contributions released from the reservoirs in which these waters are stored are addressed. A summary of 2019 water contributions to the Mainstem CLP River above the Munroe Tunnel is presented in Table 3.

During snowmelt runoff, from April through June, most of the streamflow originated from the Big South. Contributions were more evenly distributed across the basin in July, although the highest contributions were from the Big South. Flow contributions in the late-summer and fall were dominated by reservoir releases, in addition to native flows from the Big South.

The combined volume of water from the Mainstem and North Fork, as measured at the City of Greeley's diversion on the CLP River was 269,847 acre-feet (Figure 2.5). The North Fork contributed 17% (45,615 acre-feet) of the total volume and the Mainstem contributed 83% (224,232 acre-feet) of the total volume (Figure 2.5). Approximately 15,816 acre-feet of water was diverted at Poudre Valley Canal upstream of the City of Greeley's Diversion.

An estimated 271,552 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2019 and 47,320 acre-feet of water was diverted through the Munroe and City of Fort Collins diversions.

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in WY2019. Contributions highlighted in red indicated the greatest monthly contribution to the Mainstem. Note: AF = acre-feet.

*Total volume does not include water contributions from Long Draw Reservoir, which releases water to the Big South.

Month	Barnes Meadow		Chambers Lake		Laramie River Tunnel		Long Draw Reservoir		Little South Fork Poudre		Big South* & Mainstem Tributaries		Poudre above Munroe	
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%
Dec '18	-	-	615	19%	-	-	-	-	1,402	43%	1,247	38%	3,264	------
Jan '19	176	5%	495	13%	-		-		1,448	38%	1,700	45%	3,819	------
Feb	197	6%	580	17%	-	-	-	-	1,284	38%	1,342	39%	3,403	------
Mar	220	6%	921	25%	-	-	-	-	1,638	44%	931	25%	3,710	------
Apr	214	2%	635	7%	-	-	-	-	2,496	28%	5,475	62%	8,820	------
May	71	0%	824	3%	583	2%	-	-	5,885	23%	18,629	72%	25,993	------
Jun	-	-	10,053	11%	91	0%	6,992	8%	14,444	16%	59,900	65%	91,480	------
Jul	-	-	11,183	14%	6,624	9%	13,482	17%	14,004	18%	32,267	42%	77,559	------
Aug	-	-	4,466	15%	2,513	8%	9,582	31%	7,602	25%	6,348	21%	30,512	------
Sep	-	-	4,061	31%	-	-	3,718	28%	2,144	16%	3,386	25%	13,308	------
Oct	-	-	2,316	38%	-	-	79	1%	1,457	24%	2,183	36%	6,035	------
Nov	-	-	439	12%	-	-	-	-	1,374	38%	1,836	50%	3,649	------
Total	**878** (0.3%)		**36,588** (13%)		**9,811** (4%)		**33,853** (12%)		**55,178** (20%)		**135,244** (50%)		**271,552**	

3.0 SPATIAL TRENDS IN UPPER CACHE LA POUDRE WATER QUALITY

Spatial water quality trends discussed in the 2019 Annual Report focus primarily on monitoring sites located on the Mainstem and North Fork CLP Rivers that are considered representative of water quality conditions throughout the Mainstem and North Fork CLP watersheds. The following lists key sites from upstream to downstream:

- Mainstem CLP River
  - JWC – Joe Wright Creek above the Poudre River
  - PJW – Poudre above Joe Wright Creek
  - PBR – Poudre below Rustic
  - PSF – Poudre below South Fork
  - PNF – Poudre above North Fork
  - PBD – Poudre at Bellvue Diversion

- North Fork CLP River
  - NDC – North Fork above Dale Creek
  - NBH – North Fork below Halligan Reservoir
  - NRC – North Fork above Rabbit Creek
  - NFL – North Fork at Livermore
  - NFG – North Fork at Gage

Discussion of the results will focus primarily on these key sites; however, data from all sites were reviewed and analyzed and any notable events and trends are included in the discussion.

Presentation of Results

Boxplots presented in this report display summary statistics (maximum, median, and minimum) for the current monitoring year compared to baseline conditions defined as the period of record from 2008 through 2012. Arrows represent median values for the current monitoring year. A full list of monitoring sites, abbreviations and descriptions is available in Attachment 1. Finalized raw data are available upon request from the City of Fort Collins Watershed Program.

Selected Variables and Monitoring Sites

Data review and analyses were performed on all monitoring sites throughout the Upper CLP watershed for the water quality parameters listed below:

- Field Parameters – temperature, pH, specific conductivity, turbidity
- General – alkalinity, hardness, total dissolved solids
- Total Organic Carbon
- Nutrients – nitrogen and phosphorus
- Biological – *E. coli* and total coliforms
- Metals
- Taste & Odor Compounds
- Macroinvertebrates

These water quality parameters were selected because they either have a direct impact on water treatment processes or serve as key indicators for pollutants that may influence water treatment and source water quality.

3.1 FIELD PARAMETERS

Water Temperature

Water temperature influences other water quality parameters and is a major driver of biological activity, including algal growth in reservoirs and rivers. Some species of cyanobacteria can produce the taste and odor compounds, geosmin and 2-Methylisoborneol (2-MIB), which are discussed in Section 3.5.

Water temperature throughout the Mainstem and North Fork CLP watersheds was near baseline in 2019 at nearly all monitoring sites (Figure 3.1).

Mainstem

Water temperature increased with decreasing elevation on the Mainstem over the monitoring season and ranged from a minimum temperature near or slightly above 1°C at all sites to a maximum temperature of 18.4°C at the City of Greeley's Diversion (PBD). Minimum water temperatures were slightly warmer than baseline at all monitoring sites except at the City of Greeley's Diversion. Median water temperatures were near baseline at higher elevation monitoring sites on Joe Wright Creek (JWC) downstream to the Mainstem below Rustic (PBR) and warmer than baseline from the Mainstem below the South Fork (PSF) downstream to the City of Greeley's Diversion (PBD). The largest departure from baseline was measured on the

Laramie River Diversion Tunnel (LRT), but the thermal inputs from this site did not appear to influence water temperature downstream on the Mainstem below Rustic (PBR). Maximum water temperatures were cooler than baseline at all monitoring sites.

North Fork

Water temperature on the North Fork ranged from a minimum temperature near 0°C on the North Fork above Dale Creek (NDC) to a maximum temperature of 21.6°C on the North Fork below Seaman Reservoir (NFG). Minimum water temperatures on the North Fork were below or near baseline from the North Fork above Dale Creek (NDC) to North Fork at Livermore (NFL) and warmer than baseline below Seaman Reservoir (NFG). Minimum water temperature on the North Fork below Seaman Reservoir (NFG) was 1.5°C warmer than the baseline minimum. Median water temperature on the North Fork above Halligan Reservoir (NDC) was warmer than baseline and cooler than baseline on the North Fork below Halligan (NBH). The cooling trend was not observed downstream on the North Fork above Rabbit Creek (NRC) where median water temperature was slightly above baseline. In contrast, water temperature on the North Fork at Livermore (NFL) was 2.9°C cooler than baseline. This location was likely influenced by upstream tributaries (Stone Wall Creek, Rabbit Creek and Lone Pine Creek) that experienced cooler than baseline water temperatures in 2019. Median water temperature on the North Fork remained cooler than baseline below Seaman Reservoir (NFG). Maximum water temperatures were below baseline at all sites except on the North Fork below Halligan Reservoir (NBH). The maximum temperature at this site was measured on July 16th and was 0.5°C warmer than the baseline maximum.

pH

pH is a measure of the amount of free hydrogen (H^+) and hydroxide (OH^-) ions in water and is measured on a logarithmic scale ranging from 0 to 14. Water with a pH near 7 is considered neutral, with more acidic conditions occurring below 7 and more basic, or alkaline conditions, occurring above 7. pH is an important water quality parameter to monitor because it influences the solubility and biological availability of chemical constituents, including nutrients and heavy metals.

pH values throughout the North Fork watershed were within the baseline range of values at all monitoring sites and pH values throughout the Mainstem watershed were near baseline at most locations (Figure 3.1).

Mainstem

pH values along the Mainstem were comparable across most monitoring sites and ranged from 6.23 on the Mainstem above Joe Wright Creek (PJW) to 8.45 at the City of Greeley's Diversion (PBD). pH values at the higher elevation monitoring sites were lower compared to mid- and lower elevation monitoring sites. pH values on Joe Wright Creek (JWC) were comparable to pH values on the Mainstem despite lower pH water released from Chambers Lake (CHD) and Barnes Meadow Reservoir Dam (BMD). pH values were much lower than baseline at these two monitoring sites; however, the range of pH values measured downstream on Joe Wright Creek (JWC) was comparable to the baseline. pH values on the Mainstem above Joe Wright Creek were also much lower than baseline.

Minimum pH values were higher than baseline at all monitoring sites except on the Mainstem above Joe Wright Creek (PJW) where a minimum pH of 6.23 was measured on August 12th. Median pH values were below baseline on Joe Wright Creek (JWC) and the Mainstem above Joe Wright Creek (PJW) downstream to the Mainstem below the South Fork (PSF). pH values were slightly above baseline at the City of Fort Collins and City of Greeley's diversions (PNF and PBD, respectively). The largest departure from the baseline median pH was observed on the Mainstem above Joe Wright Creek (PJW). The median pH at this monitoring site was 6.69 compared to the baseline median of 7.34. pH values at this site measured below 7.00 from late-May through August which is likely correlated to the shift in snowmelt runoff and streamflow patterns observed in 2019. Despite the slightly more acidic water contributed from this site, downstream locations were similar to baseline conditions. Maximum pH values were below baseline on Joe Wright Creek (JWC) and the Mainstem above Joe Wright Creek (PJW) and near or slightly above baseline from the Mainstem below Rustic (PBR) to the City of Fort Collins Diversion (PNF). The maximum pH measured at the City of Greeley's Diversion (PBD) was lower than the baseline maximum.

North Fork

pH along the North Fork was more alkaline compared to the Mainstem and ranged from a minimum pH of 6.67 on the North Fork above Halligan Reservoir (NDC) to 8.73 on the

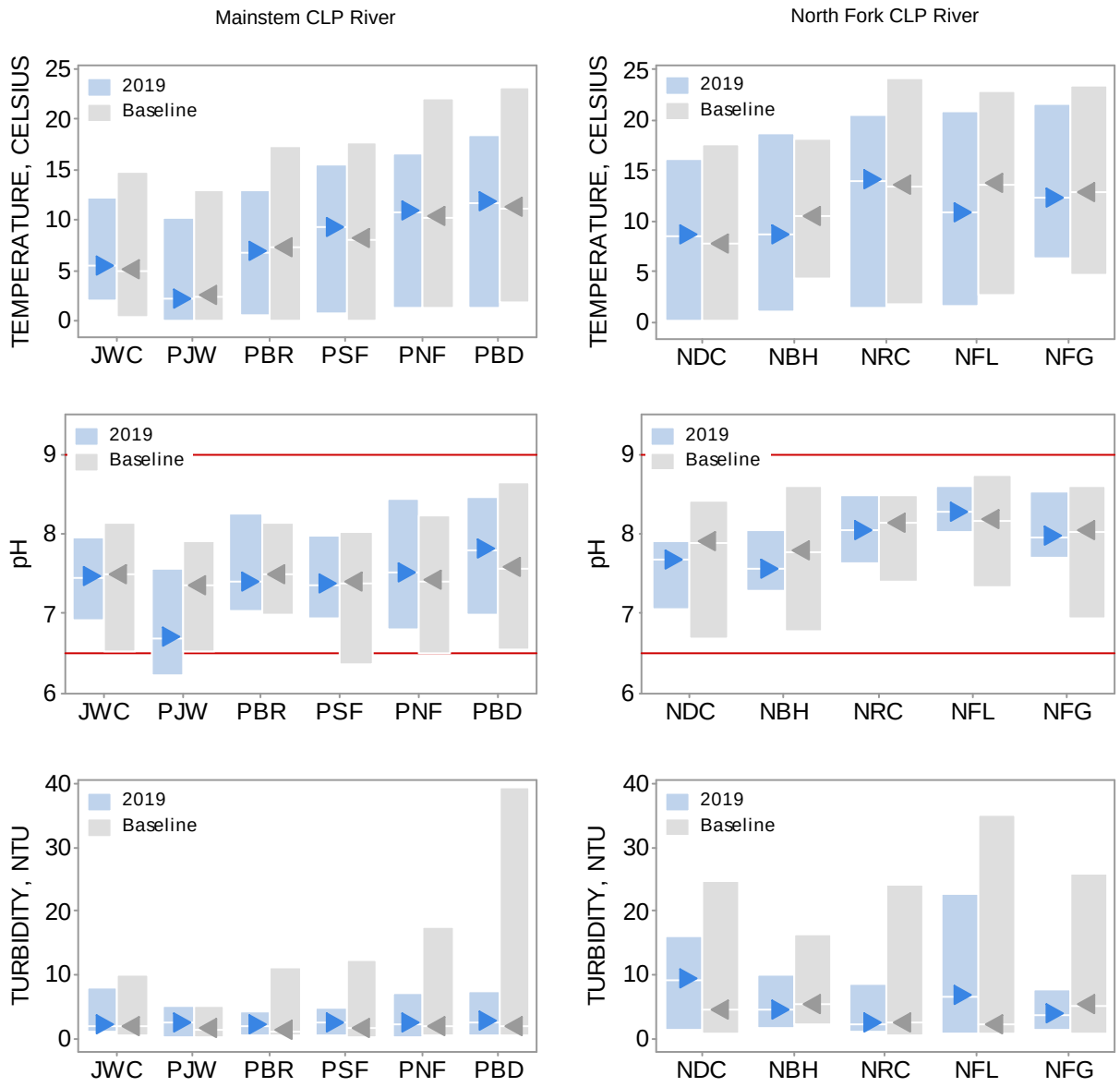


Figure 3.1 – Water temperature, pH, and turbidity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2019 compared to the baseline period of record. The red reference lines for pH indicate the Colorado Department of Public Health and Environment water quality standard to protect aquatic life.

North Fork near Livermore (NFL). There was slightly more variability between monitoring sites along the North Fork, specifically between the North Fork below Halligan Reservoir (NBH) downstream to the North Fork above Rabbit Creek (NRC). pH continued to increase moving downstream to the North Fork near Livermore (NFL) likely due to inputs from North Fork tributaries, Stonewall Creek, Rabbit Creek and Lone Pine Creek. Minimum pH values were notably higher than baseline at all monitoring sites. Median pH was slightly more acidic than baseline at all monitoring sites except the North Fork near Livermore (NFL). pH values were slightly above baseline at this monitoring site which is likely due to the higher alkaline water contributed from Stonewall Creek (SCM). pH values at SCM ranged from 8.15 to 8.49. Maximum pH values were below baseline at all North Fork monitoring sites.

Turbidity

Turbidity is a measurement of the amount of light capable of passing through water. This water quality parameter is often monitored to track changes in water clarity, which is influenced by the presence of algae and/or suspended solids introduced to surface waters through various land use activities, including runoff and erosion, and urban storm water runoff and drainage from agricultural lands. Turbidity concentrations can signal changes in land use activity. For water treatment, turbidity is an important indicator of the amount of suspended material that is available to harbor pollutants such as heavy metals; bacteria and other pathogens; nutrients; and organic matter.

Turbidity along the Mainstem and North Fork CLP Rivers was within the expected baseline range of values at nearly all monitoring sites (Figure 3.1).

Mainstem

Turbidity was consistently low along the Mainstem and ranged from below 1 NTU at all monitoring sites to a maximum of 7.2 NTU at the City of Greeley's Diversion (PBD). Minimum turbidity was near or below baseline at all monitoring sites. Median turbidity was near or slightly above baseline at all monitoring sites. Turbidity measured on Joe Wright Creek was normal from below Chambers Reservoir (CHD) to above the confluence with the Mainstem (JWC). The largest departure from baseline median was observed on the Mainstem above the confluence with Joe Wright Creek (PJW) and the Laramie River Diversion (LRT). Median turbidity was slightly higher than baseline on the Mainstem above Joe Wright Creek (PJW) downstream to the City of Greeley's Diversion (PBD); however, turbidity was still low (<3 NTU). Maximum turbidity was notably lower than baseline at all monitoring sites except on the Mainstem above Joe Wright Creek (PJW) where the maximum turbidity was slightly higher than baseline.

North Fork

Turbidity was generally consistent along the North Fork over the 2019 water year and ranged from near 1 NTU at all monitoring sites to a maximum of 22 NTU on the North Fork near Livermore (NFL). Turbidity was higher on the North Fork above and below Halligan Reservoir (NDC and NBH) and on the North Fork CLP River near Livermore (NFL). Minimum turbidity was slightly higher than baseline at all monitoring sites except the North Fork below Halligan Reservoir (NBH). Median turbidity was notably higher on the North Fork CLP River above Halligan Reservoir (NDC) and near baseline below Halligan Reservoir (NBH) downstream to the North Fork above Rabbit Creek (NRC). Median turbidity on the North Fork near Livermore (NFL) was higher than baseline, which was likely due to higher turbidity contributions from both Stonewall Creek (SCM) and Lone Pine Creek (PCM). Maximum turbidity was notably lower than baseline at all monitoring sites except Stonewall Creek. A maximum turbidity of 58 NTU was measured on May 21st following a storm event over the Stonewall Creek drainage. The high turbidity from Stonewall Creek was observed downstream on the North Fork near Livermore (NFL) where turbidity reached 23 NTU. This was still lower than the maximum turbidity measured on the North Fork near Livermore (NFL) over the baseline period of record.

3.2 GENERAL PARAMETERS

Alkalinity, Hardness & Specific Conductance

Specific conductance is an index of dissolved ionic solids in water, and hardness is an index of the total calcium (Ca) and magnesium (Mg) in water. Alkalinity is a measure of the effective acid buffering capacity of water and is derived from the dissociation of mineral carbonates (CO_3^-), bicarbonates (HCO_3^-), and hydroxides (OH^-). Conductivity, hardness, and alkalinity are influenced by local geology, as well as other dissolved constituents derived from land use practices throughout the watershed.

Concentrations of these constituents are influenced by the magnitude and timing of streamflow and by the size of the contributing watershed area. The highest concentrations are observed during times of low flow in late-fall and winter, while minimum concentrations are observed during snowmelt runoff. In general, concentrations increase with decreasing elevation and increasing contributing watershed area.

Alkalinity, hardness and specific conductivity concentrations along the Mainstem and North Fork CLP Rivers were within the baseline range of values at all monitoring sites (Figure 3.2). These parameters highlight chemical and physical differences between the Mainstem and North CLP watersheds and across sites on the North Fork CLP River.

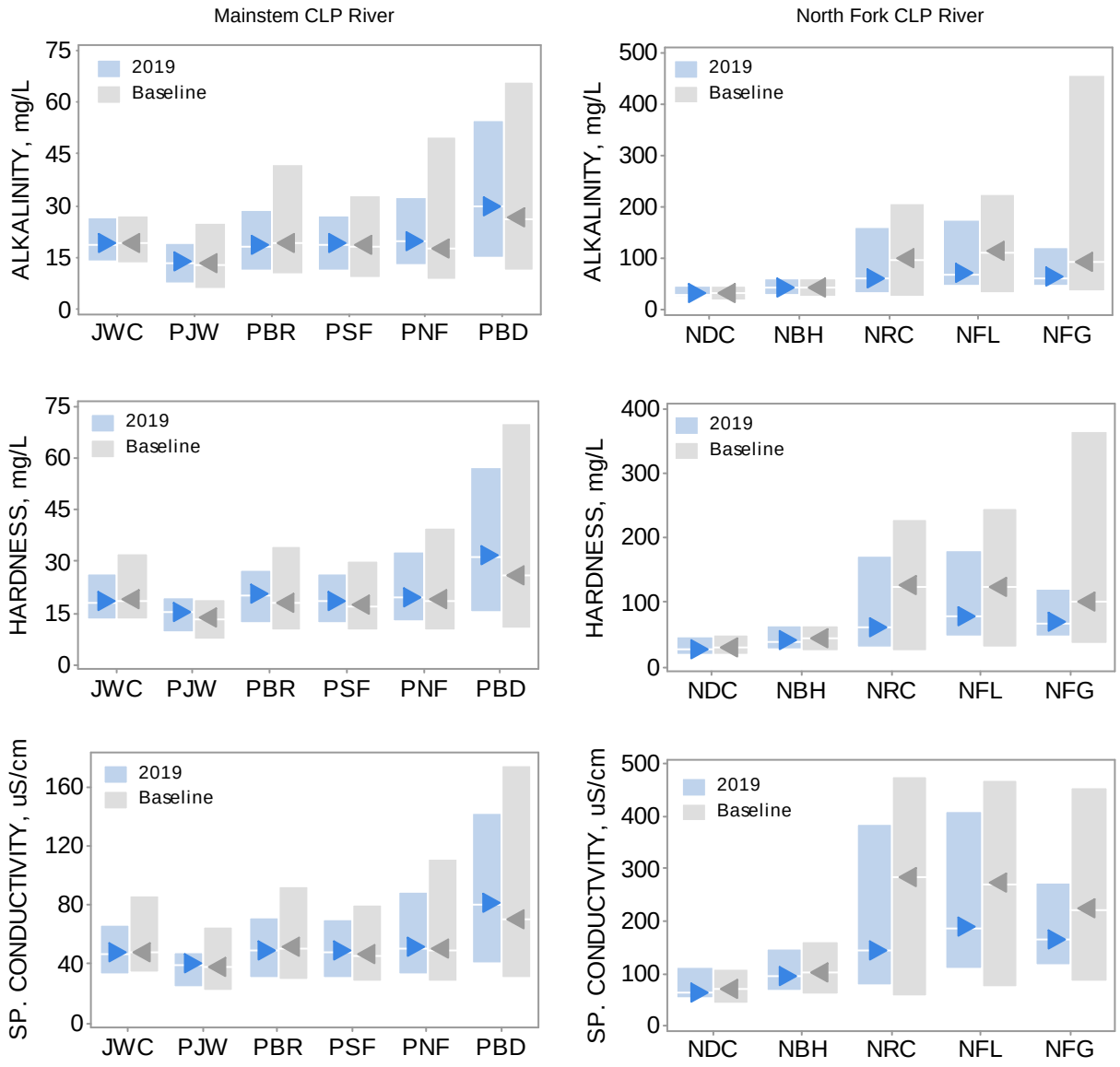


Figure 3.2 – Alkalinity, hardness and specific conductivity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2019 compared to the baseline period of record.

Mainstem

Alkalinity, hardness and specific conductivity concentrations increased slightly from Joe Wright Creek downstream to the City of Greeley's Diversion. Alkalinity concentrations ranged from 7.60 mg/L $CaCO_3$ to 54.6 mg/L $CaCO_3$; hardness concentrations ranged from 8.01 mg/L to 57.4 mg/L; and specific conductivity ranged from 22.9 µS/cm to 142.2 µS/cm. Minimum concentrations of these parameters were observed on the Mainstem above Joe Wright Creek (PJW) and maximum concentrations were observed at the City of Greeley's Diversion (PBD). Minimum and median concentrations were near or above baseline at all monitoring sites. The largest departure from baseline was observed near the City of Greeley's Diversion (PBD) for all parameters. Maximum concentrations were notably lower than baseline at all monitoring sites.

North Fork

A notable increase in alkalinity, hardness and specific conductivity concentrations was measured between the North Fork below Halligan Reservoir (NBH) to the North Fork above the confluence with Rabbit Creek (NRC). This change is likely associated with significant changes in streamflow downstream of the North Poudre Canal and a larger influence of groundwater and potentially agricultural land use practices on the North Fork as it enters and passes through the Livermore Valley. Concentrations were similar from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Alkalinity concentrations ranged from 21.2 mg/L $CaCO_3$ to 212.0 mg/L $CaCO_3$; hardness concentrations ranged from 16.0 mg/L to 232.2 mg/L; and specific conductivity ranged from 51.3 µS/cm to 493.5 µS/cm. Minimum concentrations were measured on the North Fork above Dale Creek (NDC) and maximum concentrations were measured on the North Fork near Livermore (NFL). Minimum concentrations were near or above baseline at all monitoring sites. Median concentrations were near or below baseline at all monitoring sites. Median concentrations were notably lower on the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Maximum concentrations were near or below baseline at all monitoring sites, especially on the North Fork below Seaman Reservoir (NFG).

Total Dissolved Solids

Total dissolved solids (TDS) provide a qualitative measure of dissolved ions comprised of inorganic salts (calcium, magnesium potassium, sodium, bicarbonates, chlorides, and sulfates) and a small portion of organic matter. Sources of TDS in surface water consist of natural weathering and erosion of geologic material, mining, industrial and sewage effluent, and agriculture.

Elevated TDS concentrations in drinking-water sources do not pose a health risk, but high levels can cause aesthetic risks including corrosion, salty or brackish taste, and scale formation. Because of these potential risks the Environmental Protection Agency established a secondary drinking water standard for TDS. Elevated TDS concentrations may also be used as an indicator of elevated ions; some of which have primary or secondary drinking water standards.

Total dissolved solids (TDS) were near or above baseline along the Mainstem CLP River and near or below baseline along the North Fork CLP River (Figure 3.3).

Mainstem

Total dissolved solids were similar at all sites on the Mainstem except at the City of Greeley's Diversion (PBD) where total dissolved solids were generally higher. Total dissolved solids ranged from a minimum 10 mg/L on the Mainstem below Rustic (PBR) to a maximum 103 mg/L at the City of Greeley's Diversion (PBD). Minimum total dissolved solids concentrations were lower than baseline at all sites except on Joe Wright Creek (JWC). Median total dissolved solids concentrations were higher than normal at all sites, especially on Joe Wright Creek (JWC) and at the City of Fort Collins' and Greeley's Diversions (PNF and PBD, respectively). The higher median concentrations were driven primarily by the spring (April and May) and fall (Sep-Oct) seasons when TDS concentrations were higher. Maximum total dissolved solids concentrations were substantially higher than baseline from the Mainstem above

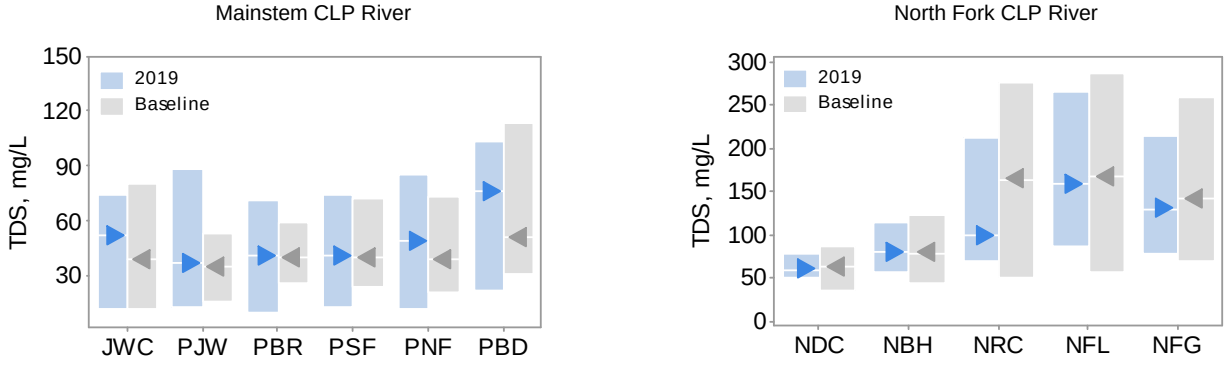


Figure 3.3 – Total dissolved solids (TDS) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2019 compared to the baseline period of record.

Joe Wright Creek (PJW) downstream to the City of Fort Collins' Diversion (PNF).

North Fork

In general, total dissolved solids increased from the North Fork above Dale Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Total dissolved solids concentrations ranged from a minimum 35 mg/L on the North Fork above Dale Creek (NDC) to a maximum 286 mg/L on the North Fork near Livermore (NFL). There was a notable increase in the variability of total dissolved solids concentrations between the North Fork below Halligan Reservoir (NBH) and the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). This trend is likely associated with changes in hydrology below the North Poudre Canal. Minimum concentrations were above baseline at all monitoring sites. Median total dissolved solids concentrations were near or below baseline. The largest departure from baseline was measured on the North Fork above Rabbit Creek (NRC) where the concentration was 66 mg/L lower than baseline. The lower concentrations measured at this monitoring location are likely associated with above average streamflow conditions on the North Fork from April through July. Maximum total dissolved solids concentrations were lower than baseline at all monitoring sites.

3.3 TOTAL ORGANIC CARBON

Total organic carbon (TOC) is a measure of the total concentration of dissolved and particulate organic matter in water. TOC is derived from both terrestrial and aquatic sources. Terrestrial TOC originates from soils and plant materials that are leached and/or delivered to surface waters during storms and spring snowmelt runoff, whereas aquatic-derived TOC originates from algal production and subsequent decomposition within surface waters.

Total organic carbon is an important indicator of water quality, particularly as it relates to water treatment. Water treatment requires the effective removal of TOC because the interaction between residual TOC and chlorine during treatment can form disinfection by-products (DBPs). DBPs are strictly regulated in finished water due to their carcinogenic potential. Increases in source water TOC concentrations pose concern due to the potential for higher residual TOC (post-filtration) and increased DBP formation potential. In addition, increased levels of TOC in source waters require additional removal requirements at the water treatment facility based on alkalinity levels (Table 4).

Total organic carbon concentrations were near baseline along the Mainstem CLP River and North Fork CLP River (Figure 3.4).

Table 4 – Total organic carbon removal requirements for water treatment facilities based on source water alkalinity and total organic carbon concentrations.

TOC (mg/L)	Source water alkalinity (mg/L as $CaCO_3$)		
	<60	60-120	>120
2-4	40%	30%	20%
4-8	45%	35%	25%
>8	50%	40%	30%

Mainstem

Total organic carbon concentrations were similar across most monitoring sites on the Mainstem and ranged from a minimum 1.75 mg/L to a maximum 10.9 mg/L on the Mainstem above Joe Wright Creek (PJW). Higher values were measured at the Laramie River Tunnel Diversion (LRT maximum = 15.5 mg/L) and Barnes Meadow Reservoir Dam (BMD maximum = 12.3 mg/L), but total organic carbon contributions from these sites were diluted most of the year by higher streamflow on the Mainstem CLP River and Joe Wright Creek, respectively. Minimum total organic carbon concentrations were above or near baseline at all monitoring sites and ranged between 2 – 4 mg/L except on the Mainstem above Joe Wright Creek (JWC) where the minimum concentration was below 2 mg/L. Median total organic carbon concentrations were slightly above baseline at all monitoring sites except on the Mainstem above Joe Wright Creek (PJW) where the median concentration was slightly below baseline. Median concentrations were at or slightly above 4 mg/L at all sites except on Joe Wright Creek (JWC). Total organic concentrations at this site were higher than baseline with a median concentration of 5.7 mg/L. The higher median at this monitoring site likely correlates with the higher total organic carbon waters released upstream from Barnes Meadow Reservoir (BDM) in the spring and late fall when less water was being released from Chambers Lake. Maximum total organic

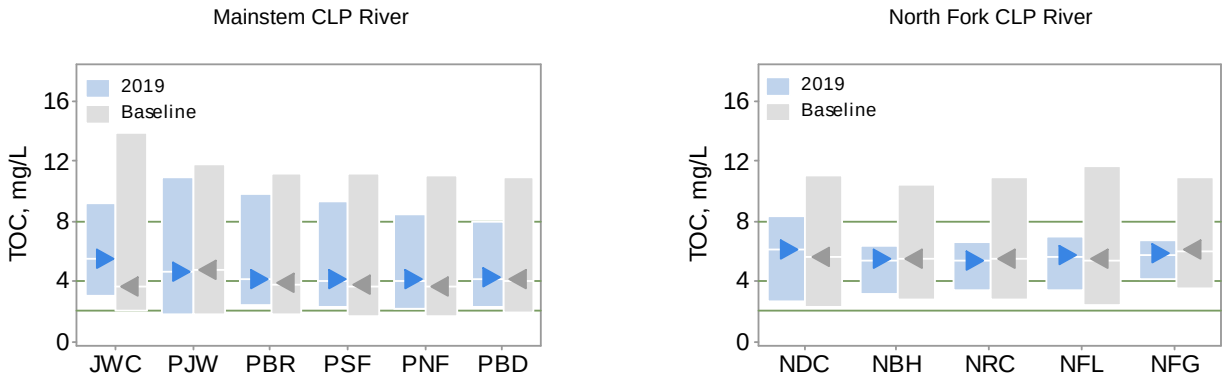


Figure 3.4 – Total organic carbon (TOC) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2019 compared to the baseline period of record. The green reference lines indicate thresholds for TOC removal requirements set by the Environmental Protection Agency. Note that the removal requirements also consider raw water alkalinity concentrations.

carbon concentrations were lower than baseline at all monitoring sites. The maximum concentration of total organic carbon was measured at the end of May and early June at most monitoring sites. Maximum total organic carbon concentrations exceeded the 8 mg/L threshold at all sites.

North Fork

Total organic carbon concentrations were comparable across all sites along the North Fork CLP River. The North Fork above Dale Creek (NDC) had the greatest variability with a range of 2.6 mg/L to 8.3 mg/L. The higher variability is likely associated with the more natural streamflow conditions found above the water supply reservoirs. The highest total organic carbon concentrations were observed on Lone Pine Creek (PCM) and Rabbit Creek (RCM) during runoff, which slightly increased concentrations downstream on the North Fork near Livermore (NFL). Total organic carbon concentrations from the North Fork below Halligan (NBH) downstream to the North Fork below Seaman Reservoir (NFG) were less variable and levels were comparable across monitoring sites. Minimum total organic carbon concentrations were higher than baseline at all monitoring sites and were within the 2 – 4 mg/L removal requirement threshold except on the North Fork below Seaman Reservoir (NFG) where minimum concentrations were slightly above 4 mg/L. Median total organic carbon concentrations were near baseline at all monitoring sites and were within the 4 – 8 mg/L removal requirement threshold. Maximum total organic carbon concentrations were considerably lower than baseline at all monitoring sites. The maximum concentration of total organic carbon across all sites fell within the 4 – 8 mg/L threshold except on the North Fork above Dale Creek (NDC).

3.4 NUTRIENTS

Nutrients are an important component of source water quality monitoring. In high concentrations and under certain environmental conditions, nutrients can lead to excessive algal growth. Elevated nutrients can also cause cyanobacteria blooms, which can produce cyanotoxins and taste and odor compounds in drinking water supplies. Potential sources of nutrients in aquatic systems include animal waste, leaking septic systems, fertilizer run-off, soil erosion, and atmospheric deposition.

Total nitrogen (TN) and total phosphorus (TP) serve as aggregate measures of potential nitrogen and phosphorus availability in aquatic systems.

Nitrogen

Total nitrogen (TN) is the sum of organic (TKN) and inorganic (NO_3-N and NO_2-N) nitrogen. Inorganic forms of nitrogen are more readily available for plant uptake. TKN is a measure of ammonia plus organic nitrogen and comprises the largest fraction of TN, with inorganic nitrogen representing a lesser fraction. In the calculation of TN (TKN + NO_3-N + NO_2-N), concentrations below their respective reporting limit were reported as half the reporting limit (Helsel and Hirsch, 2002).

Mainstem

Total nitrogen concentrations were similar across monitoring sites on the Mainstem (Figure 3.5). Concentrations ranged from below the reporting limit (90 µg/L) at most monitoring sites to a maximum 481 µg/L on the Mainstem above Joe Wright Creek (PJW). Higher concentrations were measured at the Laramie River Tunnel Diversion (LRT maximum = 654 µg/L) and Barnes Meadow Reservoir Dam (BMD maximum = 609 µg/L), but total nitrogen contributions from these sites were diluted most of the year by higher streamflow on the Mainstem and Joe Wright Creek, respectively. Minimum total nitrogen concentrations were slightly higher than baseline (reporting limit) at all monitoring sites. Median total nitrogen concentrations were near or slightly above baseline at all monitoring sites. The largest departure from baseline was observed on the Mainstem above Joe Wright Creek (PJW). The higher total nitrogen concentrations measured at this site are likely related to higher than baseline nitrate concentrations (as discussed below). Median concentrations were still well below the interim water quality standard for total nitrogen of 1,250 µg/L at all monitoring sites. Maximum total nitrogen concentrations were well below baseline at all monitoring sites.

Nitrate concentrations were measured below the reporting limit (40 µg/L) for most of the monitoring season at nearly all sites. The highest nitrate concentrations were observed on the Mainstem above Joe Wright Creek (PJW). Concentrations were above the reporting limit throughout the monitoring season and generally increased from April through November. The highest concentration (190 µg/L N) was measured on November 11th, which appeared to have a slight influence on downstream monitoring sites. Nitrate concentrations at most other monitoring sites were below the reporting limit except in the months of June, July and August, although concentrations were generally low (<100 µg/L).

Ammonia concentrations were below or slightly above the reporting limit (10 µg/L) at nearly all sites. Concentrations were slightly above the reporting limit during snowmelt runoff but were below 20 µg/L at all sites except Barnes Meadow Reservoir Dam (BDM) where concentrations exceeded 40 µg/L in April. The higher ammonia concentrations at this monitoring site did not appear to have a noticeable impact on concentrations at downstream monitoring sites. Ammonia concentrations were elevated at all monitoring sites in August. These were the highest ammonia concentrations measured over the 2019 water year (except at BMD), but were still very low (< 30 µg/L).

As expected, nitrite concentrations were measured below the reporting limit at all monitoring sites.

North Fork

Total nitrogen concentrations were similar across monitoring sites on the North Fork (Figure 3.5). Concentrations ranged from below the reporting limit (90 µg/L) on the North Fork above Dale Creek (NDC) to a maximum 823 µg/L on the North Fork above Rabbit Creek (NRC). Higher concentrations were measured on the North Fork tributaries (Stonewall Creek, Rabbit Creek and Lone Pine Creek) and ranged from 223 µg/L to 1047 µg/L. Minimum total nitrogen concentrations were higher than baseline at all monitoring sites except on the North Fork above Dale Creek (NDC). Median total nitrogen concentrations were near or slightly below baseline at all monitoring sites and well below the interim water quality standard for total nitrogen of 1,250 µg/L. Maximum total nitrogen concentrations were well below baseline at all monitoring sites except on Stonewall Creek (SCM) and Lone Pine Creek (PCM). Higher concentrations on Stonewall Creek (SCM) were likely caused by a storm event and associated pulse of nitrate that occurred prior to the May 21st sampling event

Ammonia concentrations were slightly above baseline at all monitoring sites, despite maximum concentrations below both Halligan (NBH) and Seaman Reservoirs (NFG) measuring lower than baseline. The lower maximum concentrations are likely due to the delayed and longer duration snowmelt runoff and associated increased flushing of the reservoir. Similarly, maximum nitrate concentrations were lower than baseline below both Reservoirs (NBH and NFG). Higher than baseline maximum nitrate concentrations were observed on the North Fork above Dale Creek (NDC), which was driven by higher concentrations measured in April.

Nitrite concentrations were measured below the reporting limit at all monitoring sites throughout the 2019 water year.

Phosphorus

Total phosphorus (TP) is a measure of dissolved phosphorus as well as phosphorus bound to sediments and organic matter. Orthophosphate is more readily available for plant uptake.

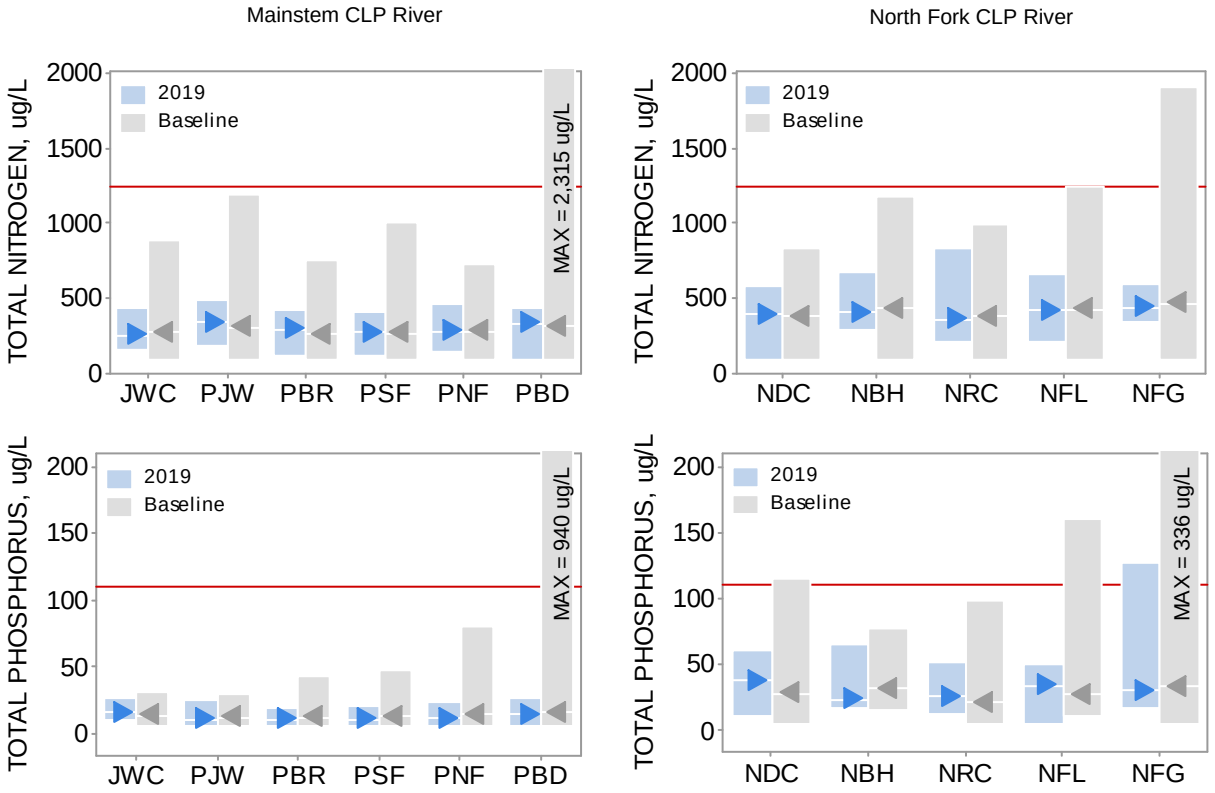


Figure 3.5 – Total nitrogen and total phosphorus concentrations measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2019 compared to the baseline period of record. The red reference lines indicate interim water quality standards (TN = 1,250 µg/L and TP = 110 ug/L) set by the Colorado Department of Public Health and Environment to protect aquatic life.

Mainstem

Total phosphorus concentrations were similar across monitoring sites on the Mainstem CLP River over the 2019 water year (Figure 3.5). Concentrations ranged from below the reporting limit (10 µg/L) at all monitoring sites to a maximum 27 µg/L at the City of Greeley's Diversion (PBD). Higher concentrations were observed on the Barnes Meadow Reservoir Dam (BMD), especially during summer and fall releases and the Laramie River Tunnel Diversion (LRT) in April. Minimum and median total phosphorus concentrations were near baseline at all monitoring sites and measured near or below the reporting limit. Concentrations measured above the reporting limit throughout the duration of snowmelt runoff (April – June). Following snowmelt runoff, concentrations were at or below the reporting limit at most monitoring sites. Maximum total phosphorus concentrations were below baseline at all monitoring sites on the Mainstem, especially at the City of Greeley's Diversion (PBD). Maximum total phosphorus concentrations were observed in late-April and early-May at most monitoring sites.

Orthophosphate measured below the reporting limit (5 ug/L) at all monitoring sites for most of the 2019 water year. Concentrations were measured above the reporting limit in April at high elevation sites on Joe Wright Creek (CHD, BDM and JWC) and the Mainstem above Joe Wright Creek (PJW), below the South Fork (PSF) and at the City of Greeley's Diversion (PBD). Detectable concentrations ranged from 6.5 µg/L at PBD at the City of Greeley's Diversion (PBD) to 47 µg/L on Joe Wright Creek above the confluence with the Mainstem CLP River. Orthophosphate was also detected in August (<20 µg/L) at the Barnes Meadow Reservoir Dam (BDM) and at the City of Greeley's Diversion (BDM).

North Fork

Total phosphorus concentrations were within the baseline range of values for most monitoring sites over the 2019 water year (Figure 3.5). Concentrations ranged from below the reporting limit (10 µg/L) on North Fork near Livermore (NFL) to a maximum 126 µg/L on the North Fork below Seaman Reservoir (NFG). The maximum concentration on the North Fork tributary Stonewall Creek was slightly higher at 128 µg/L. Minimum total phosphorus concentrations were higher than baseline at all monitoring sites except on the North Fork near Livermore (NFL). Median total phosphorus concentrations were slightly higher on the North Fork above Halligan Reservoir (NDC) and from the North Fork above Rabbit Creek (NRC) downstream to the North Fork near Livermore (NFL). The most notable departures from baseline were observed on the North Fork above Dale Creek (NDC) and the North Fork near Livermore (NFL); however, median concentrations were still quite low (<40 µg/L). Maximum total phosphorus concentrations were below baseline at all monitoring sites on the North Fork CLP River. The interim water quality standard for total phosphorus of 110 µg/L was briefly exceeded on the North Fork below Seaman Reservoir (NFG) in August, which is likely due to anoxic conditions in the reservoir.

Orthophosphate concentrations fluctuated around the reporting limit (5 µg/L) at most monitoring sites. The highest concentrations were measured on the North Fork tributaries (SCM, RCM and PCM) and the North Fork below Halligan and Seaman Reservoirs (NBH and NFG, respectively). Concentrations ranged from below the reporting limit to a maximum of 83 µg/L on the North Fork below Seaman Reservoir (NFG) in August.

3.5 TASTE & ODOR COMPOUNDS

Geosmin and 2-Methylisoborneol (2-MIB) are naturally occurring organic compounds that are produced by some species of cyanobacteria. These compounds can introduce an earthy odor to drinking water that can be detected by the most sensitive individuals at concentrations as low as 4 nanograms per liter (ng/L) or 4 parts per trillion (ppt). These compounds do not pose a public health risk but are of concern because they can negatively affect customer confidence in the quality of drinking water. Early detection of elevated concentrations of these compounds is important so that they can be removed during the water treatment process.

Geosmin and 2-MIB are monitored on the Mainstem below Rustic (PBR) and at the City of Fort Collins Diversion (PNF) during routine upper CLP water quality monitoring events. A summary of geosmin and 2-MIB concentrations can be found in Table 5. No discernable spatial or temporal trends were observed for geosmin or 2-MIB over the 2019 water year. Geosmin was measured above the reporting limit in June at both monitoring locations and 2-MIB was measured above the reporting limit at PNF in July and November. Both geosmin detections were below the taste and odor threshold of 4 ng/L.

Table 5 – Poudre River geosmin and 2-MIB concentrations (ng/L or ppt) during the fall of 2018 at Poudre above the North Fork (PNF) and Poudre below Rustic (PBR) monitoring locations. Note: Reporting limits are 2 ng/L for geosmin and 5 ng/L for MIB. Concentrations below the reporting limits are estimates. Concentrations above the reporting limit are highlighted in red.

Month	PBR		PNF	
	Geosmin	2-MIB	Geosmin	2-MIB
Apr	1.56	nd	1.33	nd
May	1.42	nd	1.62	nd
Jun	2.30	3.84	2.68	2.01
Jul	nd	4.11	nd	5.17
Aug	1.92	nd	0.96	nd
Sep	nd	2.19	nd	nd
Oct	1.10	1.87	0.99	2.69
Nov	1.06	3.25	1.25	6.45

3.6 METALS

The presence of metals in source water supplies is most often due to mineral weathering and soil erosion. Metals enter the river via snowmelt runoff, wind, precipitation and other natural processes. Additional sources of metals may include atmospheric deposition. Snowmelt runoff generally results in elevated metals concentrations, as do storm events.

Metals were sampled once in the spring (May) and fall (October) on the Mainstem upstream of the confluence with the North Fork (PNF) and on the North Fork below Seaman Reservoir (NFG). A summary of dissolved metals concentrations can be found in Table 6. As anticipated, detectable metals were higher in the spring during spring snowmelt runoff.

Table 6 – Dissolved metals concentrations measured in spring (May) and fall (October) of 2019 on the Mainstem and North Fork Poudre River. Cells highlighted in light red indicate concentrations reported above the laboratories reporting limit.

Metal (ug/L)	Spring		Fall	
	PNF	NFG	PNF	NFG
Al	452	178	<10	<10
As	<1	<1	<1	1
Cd	<1	<1	<1	<1
Cr	<1	<1	<1	<1
Cu	2	1	<1	<1
Fe	322	181	22	26
Mn	3	12	1	97
Ni	<1	<1	<1	<1
Pb	<1	<1	<1	<1
Se	<5	<5	<5	<5
Zn	<10	<10	<10	<10

3.7 MICROORGANISMS

Coliforms are types of bacteria that are found naturally in the environment in plant and soil material but can also be found in the digestive tract of warm-blooded animals, including humans. Disease causing bacteria or pathogens can be introduced to the raw drinking water supply from fecal contamination. The presence of bacterial contamination was measured using total coliforms, a group of indicator organisms for the presence of pathogenic microorganisms. In addition, *Escherichia coli* (*E. coli*) was measured and used as an indicator of human or animal fecal waste pollution since the origin is more specific than total coliforms.

Total Coliform

Total coliform concentrations were similar across monitoring sites on the Mainstem over the 2019 water year, but slightly higher on the North Fork below Seaman Reservoir (NFG). The higher concentrations had a minimal influence on downstream concentrations at the City of Greeley's Diversion (PBD) (Figure 3.6). Concentrations ranged from a minimum 21 cells/100 mL at the City of Fort Collins Diversion (PNF) to a maximum 10,462 cells/100 mL on the North Fork below Seaman Reservoir (NFG). Minimum and median total coliform concentrations were near baseline at all monitoring sites. Maximum concentrations were measured in July on the North Fork and in August on the Mainstem. Maximum total coliform concentrations were much lower than baseline at all monitoring sites.

E. coli

Escherichia coli concentrations were generally similar across monitoring sites over the 2019 water year. Concentrations were more variable along the Mainstem and ranged from a minimum 0 cells/100 mL at all monitoring sites to a maximum of 58 cells/100 mL at the City of Greeley's Diversion (PBD) (Figure 3.6). There was very little variability on the North Fork below Seaman Reservoir (NFG) where concentrations ranged from 0 cells/100 mL to 14 cells/100 mL. Minimum concentrations were near baseline at all monitoring sites. Median *E. coli* concentrations were greater than baseline on the Mainstem below Rustic (PBR) and less than baseline from the Mainstem below the South Fork (PSF) to the City of Greeley's Diversion (PBD) and on the North Fork below Seaman Reservoir (NFG). Maximum *E. coli* concentrations were well below baseline for at all monitoring sites, especially on the North Fork below Seaman Reservoir (NFG).

3.8 MACROINVERTEBRATES

Aquatic macroinvertebrates are animals that live in water, lack a backbone and are visible without the aid of a microscope. The Poudre River supports a diverse community of aquatic macroinvertebrates, including a wide variety of insects, shrimp, crayfish, worms, leeches, snails, clams and other groups. These animals live most of their lives on or within the streambed of the river, where they occupy a wide variety of ecological roles or "niches" in terms of their feeding habits, mobility, habitat and life cycles.

Macroinvertebrate community metrics are often used to evaluate water quality and ecological health in streams and are particularly useful when paired with chemical and physical water quality data. Routine macroinvertebrate community metrics were used in this report to establish baseline biological condition and to make comparisons between key study locations (Table 7). Analyses in

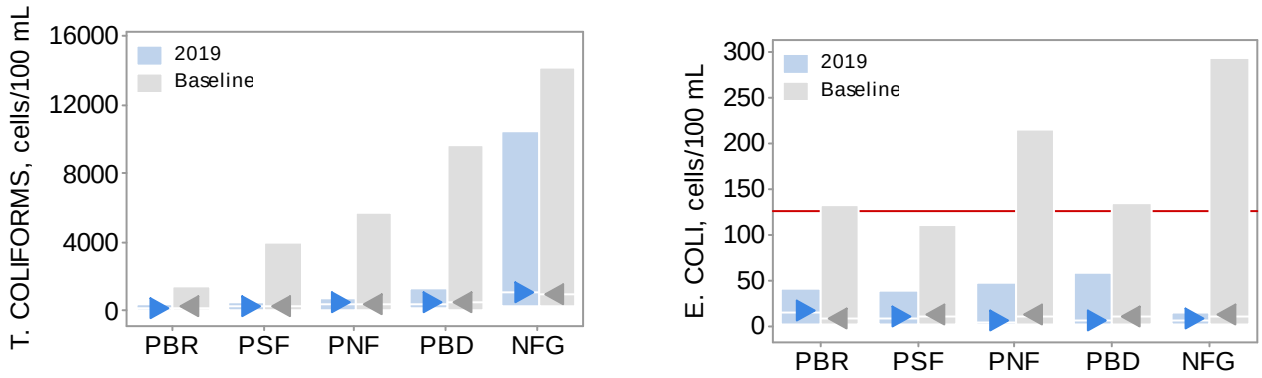


Figure 3.6 – Total coliforms (top) and E. coli (bottom) concentrations measured at key monitoring locations on the Mainstem CLP River and North Fork CLP River – mainstem and NF sites in this figure are combined, as opposed to other figures – in 2019 compared to the baseline period of record. The red reference line indicates the E. coli water quality standard set by the Colorado Department of Public Health and Environment to protect recreational use.

subsequent years will be expanded to include short-and long-term trends, impacts and recovery from future pollution events, and specific cause and effect relationships between pollutants and the biota.

Key monitoring locations occur in three separate *EPA Level IV Ecoregions*. The Mainstem above Joe Wright Creek (PJW) is located within the Crystalline Subalpine Forests Ecoregion; the Mainstem below Rustic (PBR), the Mainstem below the South Fork (PSF) and the Mainstem near the City of Fort Collins' Diversion (PNF) are located within the Crystalline Mid-Elevation Forests; and the Mainstem near the City of Greeley's Diversion (PBD) is located within the Foothills Shrublands Ecoregion. Macroinvertebrate communities in the Crystalline Subalpine Forests Ecoregion are naturally less productive, are structured differently and are not directly comparable to communities in the two lower elevation ecoregions. Communities in monitoring locations in the Crystalline Mid-Elevation Forests and Foothills Shrublands are considered directly comparable for the purposes of this report.

Species Diversity

Species diversity is a measure of the number of different macroinvertebrate species within a community. Communities with good water quality generally have higher species diversity than those with poor water quality. As expected, species diversity was considerably lower (28) on the Mainstem above Joe Wright Creek (PJW) and increased at downstream monitoring locations. The exception to this pattern was at the City of Fort Collins Diversion (PNF), which had relatively low species diversity (32).

Shannon's H

Shannon's H combines measures of species diversity and the relative abundance of each species within a macroinvertebrate community. Values >3 generally indicate good community condition and water quality, whereas values <1 indicate poor community condition and water quality. Shannon's H was >3 at all monitoring locations except at the City of Greeley's Diversion (PBD). Shannon's H measured 2.9 at this monitoring location indicating that macroinvertebrate community condition and water quality is generally good.

EPT

EPT is an abbreviation for the sum of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species. EPT are widely regarded as intolerant of water quality pollution, and therefore, higher measures of EPT diversity and percent of EPT in a community generally indicate that water quality is good. As expected, EPT diversity was the lowest on the Mainstem above Joe Wright Creek (PJW) and generally increased in a downstream direction across monitoring locations, indicating good water quality. Percent EPT was consistently high across most monitoring locations except at the City of Greeley's Diversion (PBD) where EPT was much lower indicating a shift in community structure as compared to upstream sites.

Density

A measure of the number of individual organisms per square meter of the streambed. Decreases in density are often associated with water quality pollution. Macroinvertebrate density generally decreased from the Mainstem above Joe Wright Creek (PJW) downstream to the City of Fort Collins' Diversion (PNF). The reason for this change in density is unknown. The density of macroinvertebrates was nearly three times higher at the City of Greeley's Diversion (PBD) due to a marked increase in species that are adapted to filtering and feeding on organic matter.

Collectors-Filters

Percent filter-feeders refers to the percentage of macroinvertebrate species that feed on tiny organic particles that are suspended in the streamflow. The relative abundance of these organisms often increases dramatically in locations exposed to elevated organic pollution. As expected, the percentage of collector-filterers on the Mainstem above Joe Wright Creek (PJW) was the lowest among sites. In contrast, the Mainstem below Rustic (PBR) and at the City of Greeley's Diversion (PBD) indicating that there is organic pollution effecting these sites to varying degrees.

Collector-Gatherers

Percent filter-feeders refers to the percentage of macroinvertebrate species that feed on tiny organic particles within the streambed. The percentage of collector-gatherers was relatively consistent across all sites except at the City of Greeley's Diversion (PBD). The lower percentage of collector-gatherers at this site was strongly affected by a shift in the community toward more collector filter feeding species.

Algae Scrapers

Percent scrapers refers to the percentage of macroinvertebrate species that are adapted to feeding by scraping algae from streambed surfaces. Changes in the abundance of scrapers is often in response to increases in fine sediment (silt and sand) pollution from events such as post-wildfire erosion or road construction. The number of algae scraping species generally trended lower when comparing upstream to downstream study sites, which is likely a natural shift in community structure.

Leaf Shredders

Percent shedders refers to the percentage of macroinvertebrate species that feed on leaves, pine needles, twigs and other large organic matter that is washed into the river. Decreases in the percent of shredders in a community can indicate that riparian vegetation has been impacted and is providing less food for these organisms. Shredders made up a progressively larger percentage of the community between the Mainstem above Joe Wright Creek (PJW) (<1%), the Mainstem below Rustic (PBR) (4%) and the Mainstem below the South Fork (PSF) (10%) which may indicate a natural increase in riparian vegetation between these sites. Shredders at the Cities of Fort Collins' and Greeley's Diversion (PNF and PBD) made up around 1% of the of the community; the reason for the decrease in shredders at these sites is unknown.

MMI Version 4

The MMI Version 4 is the Colorado Department of Public Health and Environment's (CDPHE) multi-metric water quality index, which combines several ecological metrics into a single score that is compared to thresholds related to reference condition. The MMI Version 4 is used by CDPHE to determine whether the community meets the State's surface water quality standards for the Aquatic Life Use. All study locations attained CDPHE's MMI Version 4 aquatic life standards thresholds.

Macroinvertebrate sample collection and leaf shredding stoneflies (inset).

Table 7 – Routine macroinvertebrate community metric results from key study locations along the Mainstem CLP.

Community Metric	PJW	PBR	PSF	PNF	PBD
Level IV Ecoregion	Crystalline Subalpine Forests	Crystalline Mid-Elevation Forests	Crystalline Mid-Elevation Forests	Crystalline Mid-Elevation Forests	Foothills Shrublands
Species Diversity	28	38	41	32	41
Shannon's H	3.3	3.7	4.2	3.8	2.9
EPT Diversity & Percent EPT	14 (74%)	22 (76%)	22 (70%)	19 (68%)	23 (46%)
Density (#/m^2)	3,470	3,326	2,170	1,539	10,228
Percent Collector-Filterers	12%	19%	16%	18%	56%
Percent Collector-Gatherers	50%	40%	41%	55%	24%
Percent Algae Scrapers	30%	24%	15%	14%	17%
Percent Leaf Shredders	<1%	4%	10%	1%	<1%
MMI version 4	73.3 (Attainment)	80.0 (Attainment)	77.7 (Attainment)	76.7 (Attainment)	74.4 (Attainment)

4.0 SOURCE WATER QUALITY TRENDS AND TREATMENT IMPLICATIONS

Temporal trends discussed in Section 4 focus primarily on monitoring sites located near the City of Fort Collins' Diversion upstream of the confluence with the North Fork CLP River (PNF) and the City of Greeley's Poudre River Diversion downstream of the confluence with the North Fork CLP River (PBD). It is assumed that water quality measured at PNF is representative of water quality upstream at the Munroe Tunnel Diversion. Monthly trends in water quality are strongly correlated with changes in hydrology and seasonal weather patterns.

Presentation of Results

Bar charts presented in Section 4 display monthly median values measured over the 2019 monitoring season for the months of April, May and June when sampling is conducted twice per month, and monthly values from July through November. These data are compared to baseline median values calculated over the period of record from 2008 to 2012.

Selected Variables

The water quality parameters listed below are the focus of these trend analyses because they have a direct impact on water treatment processes.

- Alkalinity
- pH
- Total Organic Carbon
- Turbidity

4.1 ALKALINITY

Alkalinity was higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) (Figure 3.2). Seasonal trends in alkalinity were comparable to baseline at both monitoring locations with lower concentrations measured during snowmelt runoff and higher concentrations as streamflow receded through the summer and fall months. In general, seasonal concentrations were equal to or greater than baseline at both monitoring locations.

City of Fort Collins' Diversion

The median alkalinity concentration at the City of Fort Collins' Diversion was 19.6 mg/L, which was 2.0 mg/L higher than baseline. Concentrations ranged from a minimum of 12.6 mg/L in the month of June to a maximum 32.4 mg/L measured in the month of April. Alkalinity was greater than baseline in the spring months of April and May. Concentrations remained higher than baseline in June and fell below baseline in late summer (July and August). Alkalinity concentrations were above baseline in the early fall months of September and October and dropped well below baseline in November. The largest departure from baseline was measured in the month of October when the concentration was 4 mg/L higher than baseline (Figure 4.1).

City of Greeley's Diversion

The median alkalinity concentration at the City of Greeley's Diversion was 29.8 mg/L, which was 3.6 mg/L higher than baseline. Concentrations ranged from a minimum of 15.2 mg/L in the month of July to a maximum of 54.6 mg/L measured in the month of April. Alkalinity was greater than baseline in the spring months of April and May. Concentrations remained higher than baseline in June and fell below baseline in late summer (July and August). Alkalinity concentrations were above baseline in the early fall month of September and October and dropped well below baseline in November. The largest departure from baseline was measured in the month of April when the concentration was 17 mg/L higher than baseline (Figure 4.1).

4.2 pH

pH was higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2019 (Figure 3.1). Seasonal trends in pH differed from baseline at both monitoring locations.

City of Fort Collins' Diversion

The median pH value at the City of Fort Collins' Diversion was 7.50, which was 0.10 pH units higher than baseline. Concentrations ranged from a minimum 6.80 in the month

of July to a maximum 8.42 measured in the month of April. pH was above baseline in April and then below baseline from May through July. The largest departure was measured in the month of July when the pH was 0.61 units below baseline. pH measured over the late summer and fall was greater than baseline in all months except October, which was slightly below baseline. The lowest pH values are typically observed over the months of August and September at the City of Fort Collins Diversion (PNF). In contrast, the lowest pH values in 2019 were observed in June and July, while pH in the months of August and September was notably higher than baseline (Figure 4.1).

City of Greeley's Diversion

The median pH value at the City of Greeley's Diversion was 7.79 compared to the baseline median of 7.56. Concentrations ranged from a minimum of 6.97 in the month of July to a maximum 8.45 measured in the month of September. In comparison to baseline trends, the highest pH values are typically observed in April and minimum pH values are measured in the summer and early fall. pH values were greater than baseline over the spring months of April and May and near baseline in June. pH values were lower than baseline in July. A notable divergence from the baseline seasonal trend was observed in the months of August and September. pH values decreased in October and November but remained higher than baseline for those months (Figure 4.1).

4.3 TOTAL ORGANIC CARBON

Total organic carbon was slightly higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2019 (Figure 3.4). Seasonal trends in total organic carbon were comparable to baseline at both monitoring locations with higher concentrations measured during snowmelt runoff and lower concentrations following runoff in the late-summer and fall months.

City of Fort Collins' Diversion

The median TOC concentration at the City of Fort Collins' Diversion was 4.03 mg/L compared to the baseline median of 3.60 mg/L. Concentrations ranged from a minimum of 2.14 mg/L in the month of November to a maximum of 8.50 mg/L measured in the month of June. As expected, the highest concentrations were observed during snowmelt runoff in May and June. TOC concentrations were higher than baseline from April through June. The TOC concentration in April was notably higher than baseline and exceeded the 4 mg/L removal requirement threshold (Table 3). Concentrations were slightly above baseline in May and June and were near the 8 mg/L removal requirement threshold. TOC decreased substantially in July but remained elevated compared to baseline and exceeded the 4 mg/L removal requirement threshold. TOC concentrations fell below baseline from August through November except in September when concentrations were higher than baseline. As expected, concentrations in these months were still low and within the 2-4 mg/L removal requirement threshold (Figure 4.1).

City of Greeley's Diversion

The median TOC concentration at the City of Greeley's Diversion was 4.18 mg/L compared to the baseline median of 4.03 mg/L. Concentrations ranged from a minimum 2.24 mg/L in the month of November to a maximum 7.89 mg/L measured in the month of June. The highest concentrations were observed during snowmelt runoff in May and June. TOC concentrations in April were higher than baseline and exceeded the 4 mg/L removal requirement threshold. Concentrations were below baseline in May and above baseline in June. As expected, TOC concentrations during this time were slightly lower than the 8 mg/L removal requirement threshold. Concentrations remained elevated in July and exceeded the 4 mg/L removal requirement threshold but dropped below this threshold in the month of August. TOC concentrations were below baseline from August through November except in September when concentrations were slightly higher than baseline. As expected, concentrations in these months were still low and within the 2-4 mg/L removal requirement threshold (Figure 4.1).

4.4 TURBIDITY

Turbidity was slightly higher than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2019 (Figure 3.1). Seasonal trends in turbidity varied compared to baseline with the timing of maximum turbidity occurring in June instead of May. Turbidity decreased following the seasonal maximum and followed closer to the expected seasonal trends.

City of Fort Collins' Diversion

The median turbidity level at the City of Fort Collins' Diversion was 2.2 NTU compared to the baseline median of 1.8 mg/L. Concentrations ranged from a minimum of less

than 1 NTU in the month of November to a maximum of 5.7 NTU measured in the month of June. Turbidity in April was low, but nearly three times higher than baseline. Turbidity in the month of May was slightly lower than baseline and higher than baseline in the month of June. Turbidity decreased significantly in the month of July but remained elevated compared to baseline. Turbidity was well below baseline from August through September (Figure 4.1).

City of Greeley's Diversion

The median turbidity level at the City of Fort Greeley's Diversion was 2.5 NTU compared to the baseline median of 1.8 NTU. Concentrations ranged from a minimum of less than 1 NTU in the month of November to a maximum of 6.9 NTU measured in the month of June. Turbidity in the month of April was higher than baseline and notably lower than baseline in the month of May when turbidity is usually the highest. Turbidity continued to increase in the month of June and was notably higher compared to the baseline. Baseline turbidity generally begins to decrease in the months of June and July following peak streamflow. In 2019, turbidity remained higher than baseline into July before falling below baseline from August through November (Figure 4.1).

Measuring water quality field parameters at the City of Greeley's Diversion (PBD).

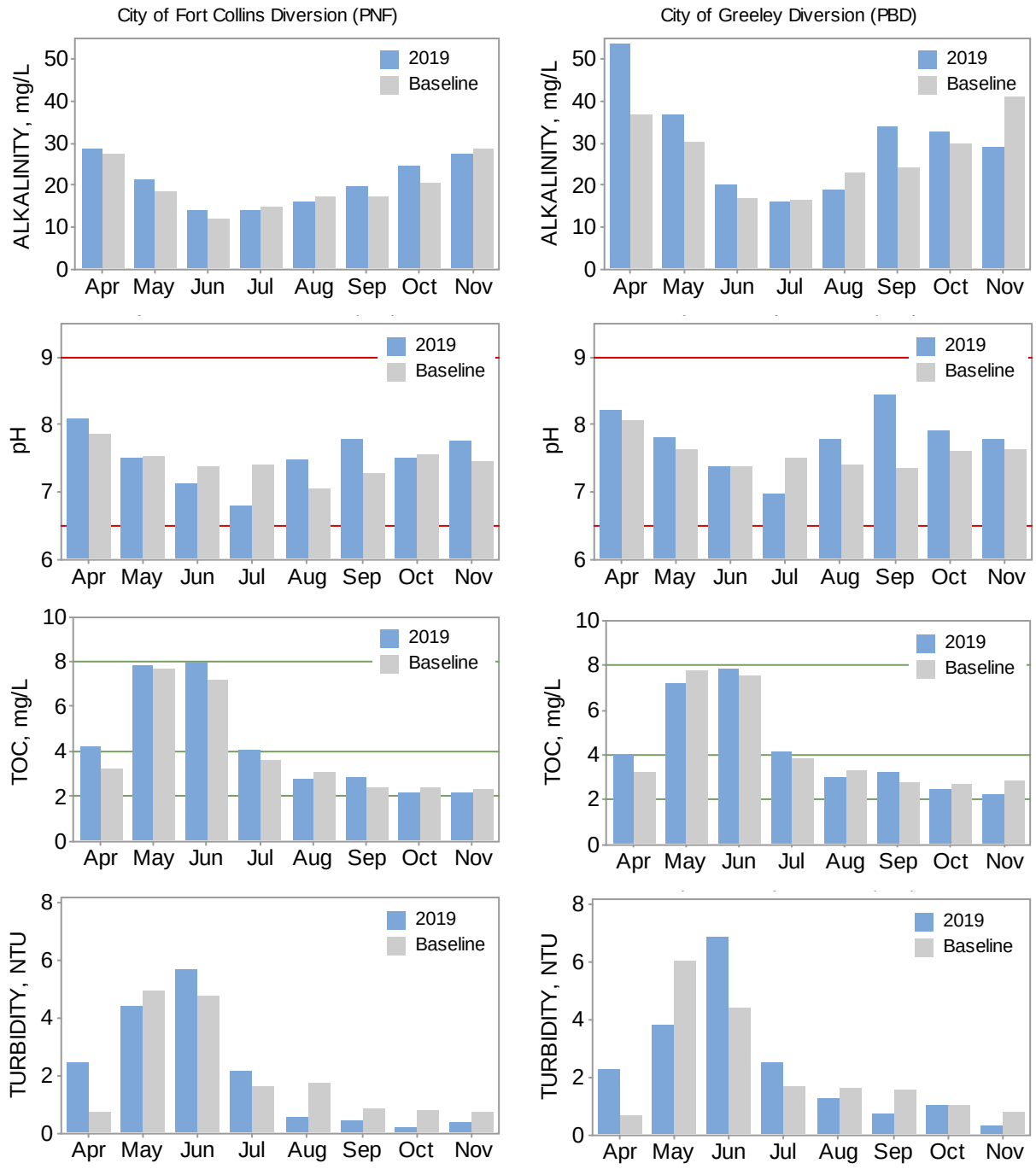


Figure 4.1 – Monthly alkalinity, pH, total organic carbon, and turbidity levels measured on the Mainstem CLP River at the City of Fort Collins Diversion (left) and City of Greeley Diversion (right) in 2018 compared to the baseline period of record. The red reference lines for pH indicate water quality standards set by the Colorado Department of Public Health and Environment to protect aquatic life and green reference lines for TOC indicate thresholds for TOC removal requirements. Note that the TOC removal requirements also consider raw water alkalinity concentrations.

5.0 SUMMARY

5.1 PROGRAM PERFORMANCE

Review of the 2019 Upper CLP water quality monitoring program data indicates that the program adequately captures temporal trends in water quality and provides a spatial context for examining notable events. The results of the field quality assurance and control sampling indicate that data precision and accuracy were acceptable.

5.2 HYDROLOGY AND CLIMATE

Temperature measured over the 2019 water year was slightly cooler than baseline; however, there were a notable seasonal extreme. The winter and early spring were slightly warmer than baseline. Cooler conditions were observed in late-spring and early-summer, which was followed by record breaking temperatures in the late-summer and fall.

Total precipitation measured over the 2019 water year was near the baseline average. Peak snow water equivalent across the entire Cache la Poudre Watershed was slightly above average. Precipitation was at or below baseline in the winter and fall, slightly above baseline in the spring and well above baseline over the summer season due to the wettest month of June on record. Below average temperatures and wet weather throughout the spring and early summer extended the snow accumulation season into early June. Significantly dry conditions were observed from mid-summer through fall with several months reporting in the top 10 driest on record.

Streamflow measured over the 2019 water year was near baseline. Streamflow was above baseline in the winter, summer and fall, and below baseline in the spring. Below average temperatures and wet weather throughout the spring and early summer delayed the timing and duration of snowmelt runoff. As a result, peak streamflow occurred nearly three weeks later than expected and higher streamflow extended into late-summer and fall.

5.3 UPPER CACHE LA POUDRE RIVER WATER QUALITY

No significant water quality concerns were identified for the Mainstem or North Fork CLP that directly impact drinking water quality or treatment operations. The typical challenges for water treatment were observed on the Mainstem and the North Fork during snowmelt runoff. Specifically, raw water from these two sources exhibited high TOC and turbidity levels, lower alkalinity and hardness concentrations, and decreased pH during spring runoff. In general, concentrations for most parameters were within the expected baseline range of variability.

The most notable impacts to water quality over the 2019 water year were caused by a shift in the timing and duration of snowmelt runoff and associated patterns in streamflow. The typical water quality changes observed as a result of snowmelt runoff were experienced later than baseline due to cooler weather delaying snowmelt runoff in late-spring and early summer. Similarly, these changes in water quality were observed for a longer period of time due to the longer duration runoff observed over the 2019 water year.

Physical parameters, including temperature, pH, specific conductivity and turbidity, were within the baseline range of values for nearly all monitoring sites on both the Mainstem and North Fork. As expected, these parameters varied between watersheds, across monitoring locations and over time. In general, the North Fork exhibits higher temperature, pH, specific conductivity and turbidity compared to the Mainstem CLP river. These differences are likely associated with greater groundwater contributions to the river in combination with the natural geology of the North Fork CLP watershed and hydrologic regime. There was a notable departure from the baseline pH observed on the Mainstem above Joe Wright Creek (PJW). pH was lower at this monitoring location for much of the monitoring season, which is likely correlated to the longer duration snowmelt runoff causing a decrease in pH due to precipitation (snow) being naturally more acidic. pH at downstream monitoring locations was less affected, which is likely due to an increase in buffering capacity (alkalinity) from the larger contributing watershed area.

No significant water quality concerns were identified for the Mainstem or North Fork Cache la Poudre...

General parameters, including alkalinity, hardness and total dissolved solids, were within the baseline range of values for nearly all monitoring sites on both the Mainstem and North Fork. As expected, concentrations were diluted during snowmelt runoff and higher during the summer and fall when streamflow was lower. One notable observation was identified for total dissolved solids on the Mainstem. The variability in total dissolved solids concentrations was notably higher at nearly all monitoring locations compared to baseline, which is likely related to the shift in both the timing and duration of snowmelt runoff.

Total organic carbon was within the baseline range of values within the Mainstem and North Fork CLP watersheds. Concentrations increased during spring snowmelt runoff and decreased during the summer and fall as streamflow receded to lower flows. Total organic carbon was similar across watersheds and monitoring locations; however, the variability in concentrations along the Mainstem was higher compared to the North Fork. This difference is likely associated with differences in the hydrologic regime between these two watersheds.

Nutrients (total nitrogen and total phosphorus) were quite low in both the Mainstem and North Fork watersheds and were well within the range of baseline concentrations at all monitoring sites. In general, nutrients were detected above the reporting limit during spring snowmelt runoff and near or below the reporting limit for the remainder of the year. Monitoring locations located near or directly below reservoirs experienced late season increases in nutrients; however, concentrations were much lower than baseline due to increased flushing within these reservoirs as well as potential operational changes due to the shift in the timing and duration of snowmelt runoff in 2019. Potential taste and odor compounds (geosmin and 2-MIB), associated with algal blooms caused by high nutrients and other environmental factors, were rarely measured above their reporting limits.

Microorganisms (total coliforms and *E. coli*) were with the baseline range of values and no notable changes were observed in 2019. The macroinvertebrate community and associated metrics generally indicated good water quality throughout the watershed. The most notable changes in macroinvertebrate community metrics were observed on the Mainstem downstream of the North Fork. This shift in community metrics is consistent with changes in water quality at this site due to contributions from the North Fork.

In summary, the Upper CLP watershed remains a high-quality drinking water supply for Fort Collins, City of Greeley and surrounding communities served by the Soldier Canyon Water Treatment Authority. Consistent with previous years, the Mainstem and the North Fork CLP rivers exhibited different water quality characteristics, but North Fork CLP water quality did not appear to influence water quality at the City of Greeley's. No significant water quality concerns were identified for the Mainstem or North Fork CLP that immediately impact drinking water quality or treatment operations; however, emerging trends will be important to monitor into the future to further help inform water treatment operations and track watershed health.

Measuring water quality field parameters on the North Fork Cache la Poudre River below Halligan Reservoir.

6.0 DATA QUALITY ASSURANCE AND CONTROL

The Upper CLP watershed collaborative monitoring program assures comparability and validity of data by complying with monitoring methods and implementing quality assurance and quality control (QAQC) measures. QAQC measures are good practice in environmental monitoring and can be used to determine potential error in data due to contamination of water samples, sampling error, equipment contamination, and/or laboratory error. The Upper CLP monitoring sites are representative of the goals and objectives outlined previously and demonstrate the true character of the watershed at the time of sampling. The remainder of this section summarizes QAQC data collected over the 2019 monitoring season.

6.1 FIELD QUALITY CONTROL

Field duplicates and field blanks were obtained at PNF and NFG during each monitoring event to determine precision of data and to identify potential for sample contamination. The field data quality sampling schedule is outlined in the 2019 annual sampling plan (Attachment 4). QAQC samples and accuracy of field equipment is reviewed by Source Watershed Program staff.

In 2019, eleven percent (269 out of 2372) of the environmental samples collected were QAQC samples. The results of the field quality assurance and control sampling indicate that precision and accuracy were acceptable.

Field Duplicates

Precision is a measure of the deviation from the true value. For most constituents, duplicate determinations should agree within a relative percent difference of 10%. Duplicate samples that differ greater than 10% were flagged for further quality assurance and control measures. Table 8 outlines relative percent difference statistics for duplicate samples and illustrates that UCLP water quality data are of high precision. All duplicate samples were within 10% agreement at the 75th percentile, except for ammonia and TKN.

Field Blanks

Blank samples should not contain analytes above the reporting limit. Field blanks were analyzed in the laboratory for a total of 18 different water quality parameters in 2019. Eighty-eight percent of field blank samples reported below

Table 8 – Data quality assurance statistics calculated for duplicated samples collected at PNF and NFG.

Constituent	Range in QAQC sample concentration		Reporting Limit	Absolute Mean Difference	Relative Percent Difference (%)		
					Percentile		
	min	*max*			*25th*	*50th*	*75th*
Alkalinity (mg/L)	11	117	2	4	0.2	0.6	1.9
Hardness (mg/L)	11.8	130.7	5	1.2	0.2	0.6	2.0
Chloride (mg/L)	0.5	13.2	1	0.04	0.1	0.2	0.3
Nitrate (ug/L)	<40	107	40	2	0.6	1.7	5.2
Sulfate (mg/L)	<5	10.9	5	0.02	0.1	0.2	0.3
Calcium (mg/L)	3.9	33.9	0.5	0.24	0.2	0.9	1.5
Potassium (mg/L)	0.6	1.5	0.3	0.03	0.3	1.0	2.1
Magnesium (mg/L)	0.9	7.9	0.2	0.06	0.3	0.8	1.3
Sodium (mg/L)	1.5	11.1	0.4	0.08	0.4	0.8	1.7
Ammonia (ug/L)	8.1	59.8	10	4	5.4	9.8	18.8
Orthophosphate (ug/L)	<5	115	5	8	2.8	4.1	6.4
Total dissolved solids (mg/L)	22	187	10	7.9	1.4	2.7	7.6
Total kjeldahal nitrogen (ug/L)	<100	514	100	53	2.8	4.9	10.9
Total organic carbon (mg/L)	2.0	8.4	0.5	0.04	0.2	0.4	0.8
Total phosphorus (ug/L)	<10	202	10	1	0.8	1.8	3.0

the constituent's respective reporting limits. The 12% of field blank samples that were detected above the reporting limits included alkalinity, hardness, ammonia, TDS and TKN (Table 9). This was consistent with constituent exceedances reported in previous years except for alkalinity and hardness.

Concentration exceedances were reported only slightly above the reporting limit for most samples and concentrations were minimal compared to concentrations of environmental samples. Notable exceedances were reported for alkalinity and TDS with max exceedances significantly greater than the laboratory's reporting limit.

Potential causes of these contaminants are listed below:

- Atmosphere/particulates in the air slightly increasing ammonia and total dissolved solids. It is recommended to cap sample bottles between rinses as quickly as possible following the blank sample collection and sample transfer in the laboratory.

- Inadequate rinsing of sample bottles either in the field or laboratory may have left residuals increasing total dissolved solids. It is recommended that sample bottles be subject to a final rinse with deionized water in the laboratory prior to storage and triple rinsed in the field with deionized water prior to blank sample collection.

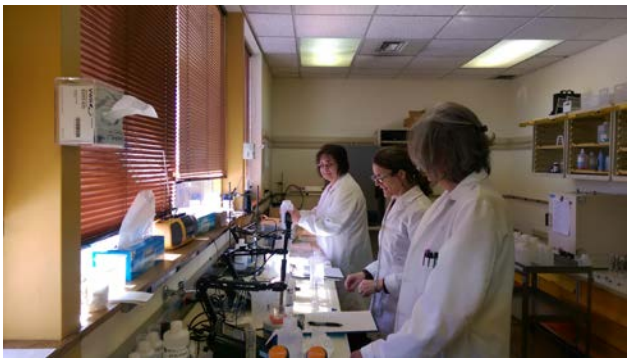
- Ammonia and TKN contamination may be introduced by the field sampler and/or laboratory staff accidentally breathing on the sample. It is suggested to limit the amount of time the sample is exposed to the environment by immediately capping the sample bottle following sample collection and/or sample processing in the laboratory.

Instrument Accuracy

Accuracy is a measure of the degree of closeness a measurement is to the true measurement. Equipment calibrations were conducted prior to field monitoring exhibitions using certified standards to assure the accuracy of sensors on the multi-parameter water quality sonde. Quality assurance checks were conducted following field sampling missions to verify sensor accuracy.

6.2 LABORATORY QUALITY CONTROL

Upper CLP water quality samples analyzed by the Fort Collins Water Quality Laboratory are reviewed by the Quality Assurance Coordinator to ensure data are free of sample contamination, analytical, and/or data entry errors.



Water quality laboratory staff analyze samples at the City of Fort Collins Water Quality Laboratory.

The City of Fort Collins Water Quality Laboratory implements analytical QAQC measures by conducting laboratory blank, duplicate, replicate, and spiked samples. The City of Fort Collins WQL conducts most analyses for the Source Water Quality Monitoring Program and is a U.S. EPA Certified Drinking Water Laboratory with an established QA plan that is applied to all samples received by the laboratory (Elmund et al, 2013). The primary features of their QA protocol include:

- Precision: one duplicate sample is analyzed for every 10 samples; relative deviation should be less than 10%.

- Accuracy: one external QCS sample is analyzed with each set of samples analyzed. Methods may specify an acceptable recovery range. In general, Standard Methods limits are ± 5% and EPA methods are ± 10%.

- Recovery: one sample is spiked for every 10 samples; if there are different matrices, at least one sample per matrix is spiked. Limits for most methods are ± 15%. If one type of matrix spike fails and all other QC passes, those samples may be flagged.

A complete description of laboratory personnel, equipment, and analytical QA methods is outside of the scope of this report and is not addressed in detail here. As part of the City's Water Quality Services Division the WQL operates under the guidance of a general QA plan (Hill, 2019).

Table 9 – Blank samples detected above their respective reporting limit (RL), percent (%) exceedance and the percent of quality assurance and quality control samples collected over the 2019 monitoring season.

WQ Parameter	Sample >RL	Total QAQC samples	% exceedance	Total Samples	%QAQC
Alkalinity	3	19	16%	171	11%
Hardness	3	19	16%	175	11%
Chloride	0	12	0%	92	13%
Nitrite	0	19	0%	171	11%
Nitrate	0	19	0%	171	11%
Sulfate	0	12	0%	92	13%
Calcium	0	12	0%	90	13%
Potassium	0	12	0%	90	13%
Magnesium	0	12	0%	90	13%
Sodium	0	12	0%	90	13%
Ammonia	11	19	58%	171	11%
Orthophosphate	0	19	0%	171	11%
E. coli	0	3	0%	54	6%
Total coliforms	0	3	0%	54	6%
Totals dissolved solids	6	20	30%	166	12%
Total kjedhal nitrogen	8	19	42%	181	10%
Total organic carbon	0	19	0%	171	11%
Total phosphorus	0	19	0%	172	11%

7.0 REFERENCES

Billica, Loftis and Moore, 2008. Design of a Collaborative Water Quality Monitoring Program for the Upper Cache la Poudre River. July 14, 2008.

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Helsel, D.R. and R.M. Hirsch, 2002. Statistical Methods in Water Resources, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Hydrological Analysis and Interpretation, *United States Geological Survey*, 524 pages.

Hill, L., 2019. Quality Assurance Plan, *Internal Water Quality Services Division Document,* City of Fort Collins, June 1, 2019, 20 pages.

Oropeza, J. and J. Heath, 2013. Water Quality Trends Report 2008-2012 Upper Cache la Poudre Watershed Collaborative Water Quality Monitoring Program, *Internal Water Production Report*, August 20, 2013, 85 pages plus appendices.

ATTACHMENT 1

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM SAMPLING SITES

	Site ID	Station Name	Lat/Long
Mainstem	100CHR	Joe Wright Creek below Chambers Lake	40.60065, -105.8367
	101CHD	Joe Wright Creek below Chambers Lake Dam	40.6023, -105.843
	090BMR	Barnes Meadow Reservoir Outflow	40.60065, -105.8367
	091BMD	Barnes Meadow Reservoir Dam	40.60044, -105.837
	080JWC	Joe Wright Creek	40.61979, -105.819
	070PJW	Poudre above Joe Wright	40.63411, -105.807
	060LRT	Laramie River Tunnel	40.66803, -105.808
	050PBR	Poudre Below Rustic	40.70002, -105.545
	040SFM	South Fork above Mainstem	40.61824, -105.5254
	041SFC	South Fork at Confluence	40.68506, -105.447
	030PSF	Poudre below South Fork	40.69464, -105.448
	020PNF	Poudre Above North Fork	40.70157, -105.241
	010PBD	Poudre at Bellvue Diversion	40.66436, -105.217
North Fork	280NDC	North Fork above Dale Creek	40.89759, -105.376
	270NBH	North Fork below Halligan Reservoir	40.87763, -105.3386
	240SCM	Stonewall Creek Mouth	40.80754, -105.2535
	260NRC	North Fork above Rabbit Creek	40.8092, -105.2685
	250RCM	Rabbit Creek Mouth	40.81023, -105.2857
	230PCM	Lone Pine Creek Mouth	40.79478, -105.2873
	220NFL	North Fork at Livermore	40.78773, -105.2525
	200NFG	North Fork below Seaman Reservoir	40.70222, -105.234

ATTACHMENT 2

2018 UPPER CLP MONITORING PARAMETER LIST

Field Parameters		
Specific Conductance	Indicator of total dissolved solids.	All sites with water quality sonde.
Dissolved Oxygen	Profile indicates stratification, importance for aquatic life and chemical processes.	All sites with water quality sonde.
Temperature	Reflects seasonality; affects biological and chemical processes; water quality standard.	All sites with water quality sonde.
pH	Measure of acidity.	All sites with water quality sonde.
General & Miscellaneous Parameters		
Alkalinity	Indicator of carbonate species concentrations; Acid neutralizing capacity of water; treatment implications.	
Discharge	Necessary for flow dependent analysis and load estimation.	Measured during sampling at NRC, RCM, SCM, PCM, PJW, SFC when conditions allow
Geosmin	Taste and odor compound	Measured monthly at PBR and PNF
Hardness	Treatment implications. Hard water causes scaling and soft water is considered corrosive.	
Total Dissolved Solids (TDS)	Indicator of overall water quality; includes both ionic and non-ionic species.	
Total Organic Carbon (TOC)	Important parameter for water treatment; precursor of disinfection byproducts.	
Turbidity	Indicator of suspended material; important for water treatment.	
Nutrients		
Nitrogen, Ammonia	Primary source of nitrogen to algae, indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition; water quality standard.	
Nitrate	Primary source of nitrogen to algae; indicator of pollution by sewage, septic tanks, agriculture, and atmospheric deposition; water quality standard.	
Nitrite	Toxic inorganic nitrogen species; rarely encountered at significant concentrations; water quality standard.	
Total Kjeldahl Nitrogen	Sum of organic nitrogen and ammonia.	
Orthophosphate (Soluble Reactive Phosphorus)	Form of phosphorous (dissolved PO_4^{-3}) most available to algae; indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition.	
Total Phosphorus	Includes dissolved and adsorbed, organic and inorganic forms of phosphorus, indicator of pollution by sewage, septic tanks, agriculture and atmospheric deposition.	

Major Ions		
Calcium	Major ion.	6x/yr
Chloride	Major ion.	6x/yr
Magnesium	Major ion.	6x/yr
Potassium	Major ion, minor importance as a nutrient.	6x/yr
Sodium	Major ion.	6x/yr
Sulfate	Major ion.	6x/yr
Biological Constituents		
E. Coli	Indicator of human or animal waste contamination; water quality standard.	Only from Rustic downstream, and NFG
Total Coliform	Indicator of human or animal waste contamination.	Only from Rustic downstream, and NFG
Macroinvertebrates	Community species metrics can be used to indicate pollution and overall watershed health.	PJW, PBR, PSF, PNF, PBD
Metals		
Aluminum, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; Aesthetic effects to drinking water	Only PNF & NFG
Arsenic, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Cadmium, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Chromium, dissolved	Natural occurs in rocks and soil. Water quality standard.	Only PNF & NFG
Copper, dissolved	Natural occurs in rocks and soil. Water quality standard.	Only PNF & NFG
Iron, total & dissolved	Natural occurs in rocks and soil. Affects aesthetic quality of treated water.	Only PNF & NFG
Lead, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Manganese, total & dissolved	Natural occurs in rocks and soil. Aesthetic effects to drinking water; water quality standard	Only PNF & NFG
Nickel, dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels; water quality standard.	Only PNF & NFG
Silver, dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG
Zinc, total & dissolved	Natural occurs in rocks and soil. Indicator of pollution from mining activity at elevated levels.	Only PNF & NFG

ATTACHMENT 3

ANALYTICAL METHODS, REPORTING LIMITS, SAMPLE PRESERVATION, AND HOLDING TIMES

	Parameter	Method	Reporting Limit	Preser-vation	Holding Time
Micro-biological	Total Coliform, *E.coli* - QT	SM 9223 B	0	cool, 4C	6 hrs
	Giardia & Cryptosporidium (CH Diagnostics)	EPA 1623	0	cool, 4C	4 days
	Algae I.D. (Phyto Finders)	SM 10200E.3, SM 10200F.2c1		Lugol's Solution, cool, 4C	12 mo
General & Misc.	Alkalinity, as $CaCO_3$	SM 2320 B	2 mg/L	cool, 4C	14 days
	Chlorophyll a	SM10200H modified	0.6 ug/L	cool, 4C	48 hrs
	Hardness, as $CaCO_3$	SM 2340 C	2 mg/L	none	28 days
	Specific Conductance	SM 2510 B		cool, 4C	28 days
	Total Dissolved Solids	SM 2540 C	10 mg/L	cool, 4C	7 days
	Turbidity (NTU)	SM2130B,EPA180.1	0.01 units	cool, 4C	48 hrs
Nutrients	Ammonia - N	Lachat 10-107-06-2C	0.01 mg/L	H_2SO_4	28 days
	Nitrate	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Nitrite	EPA 300 (IC)	0.04 mg/L	cool, 4C (eda)	48 hrs
	Total Kjeldahl Nitrogen	EPA 351.2	0.1 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Total	SM 4500-P B5,F	0.01 mg/L	H_2SO_4 pH<2	28 days
	Phosphorus, Ortho	SM 4500-P B1,F	0.005 mg/L	filter, cool 4C	48 hrs
Major Ions	Calcium	EPA 200.8	0.05 mg/L	HNO_3 pH <2	6 mos
	Chloride	EPA 300 (IC)	1.0 mg/L	none (eda)	28 days
	Magnesium, flame	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Potassium	EPA 200.8	0.2 mg/L	HNO_3 pH <2	6 mos
	Sodium, flame	EPA 200.8	0.4 mg/L	HNO_3 pH <2	6 mos
	Sulfate	EPA 300 (IC)	5.0 mg/L	cool, 4C (eda)	28 days
Metals	Cadmium	EPA 200.8	0.1 ug/L	HNO_3 pH <2	6 mos
	Chromium	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Copper	EPA 200.8	3 ug/L	HNO_3 pH <2	6 mos
	Iron, (total & dissolved)	EPA 200.8	10 ug/L	HNO_3 pH <2	6 mos
	Lead	EPA 200.8	1 ug/L	HNO_3 pH <2	6 mos
	Nickel	EPA 200.8	2 ug/L	HNO_3 pH <2	6 mos
	Silver	EPA 200.8	0.5 ug/L	HNO_3 pH <2	6 mos
	Zinc	EPA 200.8	50 ug/L	HNO_3 pH <2	6 mos
TOC	TOC	SM 5310 C	0.5 mg/L	H_3PO_4pH <2	28 days
Analysis conducted by City of Fort Collins Water Quality Lab (FCWQL), unless otherwise noted.					
Reporting Limit = lowest reportable number based on the lowest calibration standard routinely used.					

ATTACHMENT 4

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM 2018 SAMPLING PLAN

2019 Upper Cache la Poudre Water Quality Monitoring Program

Mainstem Cache la Poudre River

	Apr 8	Apr 22	May 6	May 20	Jun 3	Jun 17	Jul 15	Aug 12	Sep 16	Oct 14	Nov 11
CHD	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
BMD[1]	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
JWC	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,,N	F,GM,I,N	F,GM,,N	F,GM,I, N	F,GM,I,N
PJW	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,Mc,N	F,GM,I, N	F,GM,I,N
LRT	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
PBR	E,F,G,GM,N	E,F,GM,I,N	E,F,G,GM,N	E,F,GM,I,N	E,F,G,GM,N	E,F,GM,I,N	E,F,G,GM,N	E,F,G,GM,I,N	E,F,G,GM,Mc,N	E,F,G,GM,I, N	E,F,G,GM,I,N
SFC	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,I,N
PSF	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,Mc,N	E,F,GM,I,N	E,FGM,,I,N
PNF[2]	E,F,G,GM,N	E,F,GM,I,N	E,F,G,GM,N	E,F,GM,I,M,N	E,F,G,GM,N	E,F,GM,I,N	E,F,G,GM,N	E,F,G,GM,I,N	E,F,G,GM,Mc,N	E,F,G,GM,I,M,N	E,F,G,GM,I,N
PBD	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,N	E,F,GM,I,N	E,F,GM,Mc,N	E,F,GM,I,N	E,F,GM,I,N

North Fork Cache la Poudre River

	Apr 9	Apr 23	May 7	May 21	Jun 4	Jun 18	Jul 16	Aug 13	Sep 17	Oct 15	Nov 12
NDC	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GC,GM,I,N	F,GC,GM,N	F,GC,GM,I,N	F,GC,GM,I,N
NBH	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GM,I,N	F,GC,GM,N	F,GC,GM,I,N	F,GC,GM,N	F,GC,GM,I,N	F,GC,GM,I,N
NRC	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,I,N
RCM	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N					
SCM	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM,I,N					
PCM	D,F,GM,N	D,F,GM I,N	D,F,GM,N	D,F,GM,I,N	D,F,GM,N	D,F,GM I,N					
NFL	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
NFG[2]	E,F,GC,GM,N	E,F,GM,I,N	E,F,GC,GM,N	E,F,GM,I,M,N	E,F,GC,GM,N	E,F,GM,I,N	E,F,GC,GM,N	E,F,GC,GM,I,N	E,F,GC,GM,N	E,F,GC,GM,I,M,N	E,F,GC,GM,I,N

[1]Call River Commissioner to determine whether water is flowing.

[2] Field blanks and duplicates (denoted with red text in table) will be collected for the following parameters: *E. coli*; general and miscellaneous; major ions; metals; nutrients and TOC; and geosmin/MIB

D = discharge
E = *E. coli* and total coliform
F = field data (dissolved oxygen, pH, temperature and turbidity)
G = geosmin/MIB
GC = *Giardia/Cryptosporidium*
GM = general and miscellaneous (alkalinity, hardness as $CaCO_3$ and total dissolved solids)
I = major ions (sulfate, chloride, calcium, potassium, sodium, magnesium)
M = metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc
N = nutrients (ammonia-N, nitrate-N, nitrite-N, Total Kjeldahl Nitrogen, Total Phosphorus and ortho phosphorus) and TOC