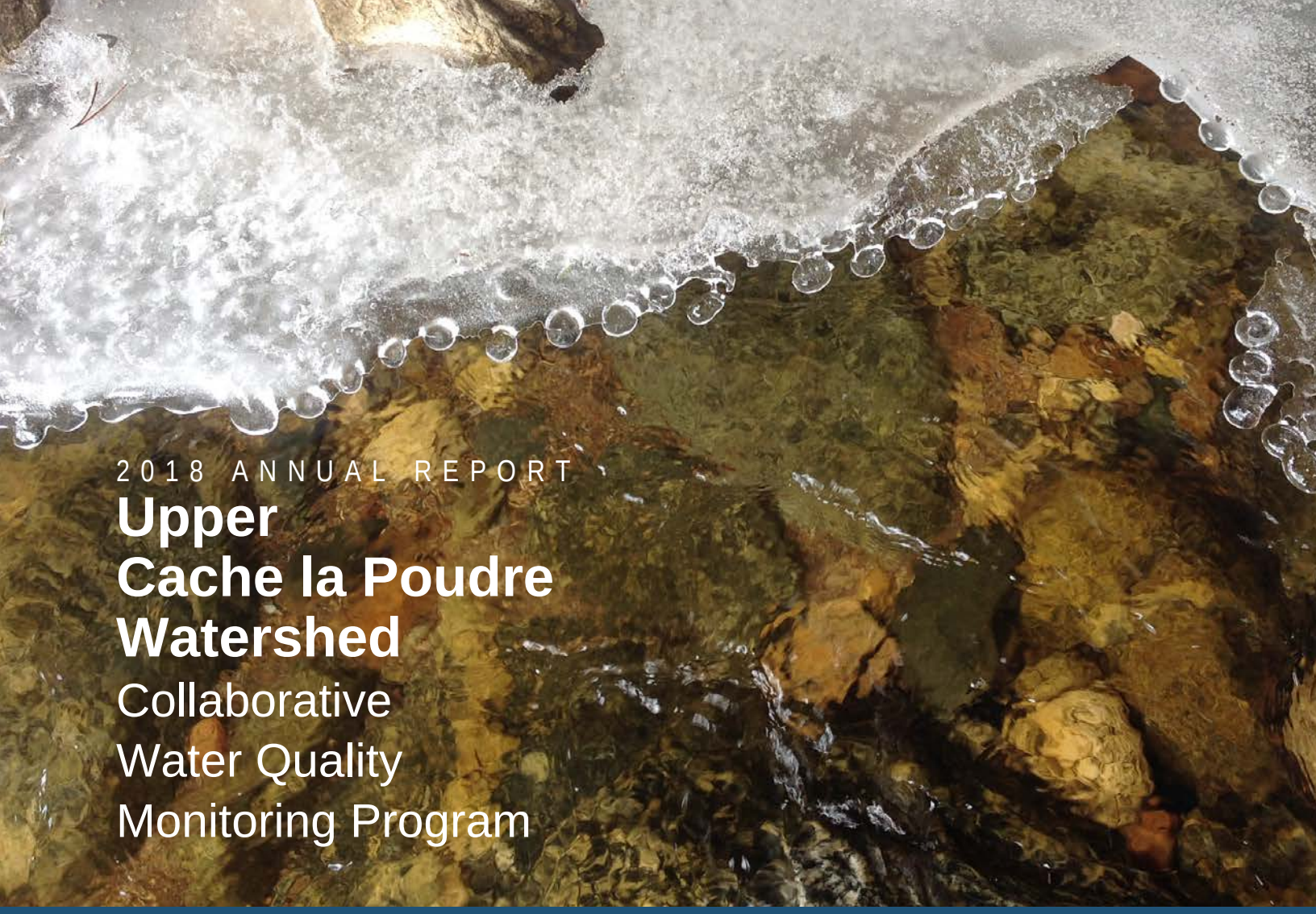

2018 ANNUAL REPORT

Upper Cache la Poudre Watershed

Collaborative Water Quality Monitoring Program

06/13/2019

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 2018 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 2018 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.

The 2018 calendar year ranked as the 5th warmest on record (30 years). Warmer temperatures in the spring caused snowmelt runoff to begin earlier than normal. 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.

The earlier start to runoff and warm, dry conditions during and following spring runoff resulted in below baseline streamflow through the summer and fall months. As expected, alkalinity, hardness, specific conductivity, and total dissolved solids were more concentrated than baseline, and total organic carbon and turbidity levels were lower during these months.

An increasing seasonal trend was observed in pH levels throughout the Mainstem CLP watershed from July through September, indicating possible algae blooms in high elevation reservoirs that supply water to the Mainstem during this time of year. Following this trend, the highest concentrations of taste and odor compounds (geosmin and 2-MIB) were measured in October providing further evidence of possible reservoir algal blooms. Fortunately, the concentrations of these compounds were still very low in the source water supply and further reduced during the water treatment process.

Collecting water quality grab samples on the Mainstem CLP River near the City of Fort Collins Diversion.

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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. 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 collaborative 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 calendar year. 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). Upper CLP 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 Upper Mainstem (including the Little South Fork Cache la Poudre River) and North Fork Cache la Poudre River watersheds. Collectively these drainages 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)	Mainstem (acres)	North Fork (%)	Mainstem (%)
Developed land (commercial, industrial, residential, urban, and utilities)	2,817	1,945	0.8	0.7
Agricultural use and grassland (Cropland, pasture, other agriculture, scrub and grasses)	183,719	54,765	52.3	18.3
Forest (forest and brush)	154,654	213,879	44.1	71.5
Natural lands (exposed rock, bare ground, wetlands, tundra, lakes)	9,926	28,473	2.8	9.5
Total	351,116	299,062	100	100

The 2018 monitoring network consisted 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 Upper CLP monitoring program was determined based on both statistical performance and cost considerations. Parameters included in the monitoring program 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

In 2018, field sampling was 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 Upper CLP Collaborative Water Quality Monitoring Program Standard Operating Procedures.

All water samples were 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 were 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 2018 ANNUAL REPORT

This annual report summarizes climate and hydrology in the Upper CLP watershed over the 2018 calendar year and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program. 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 2018 to baseline conditions, defined as the period of record from 2008 to 2012.

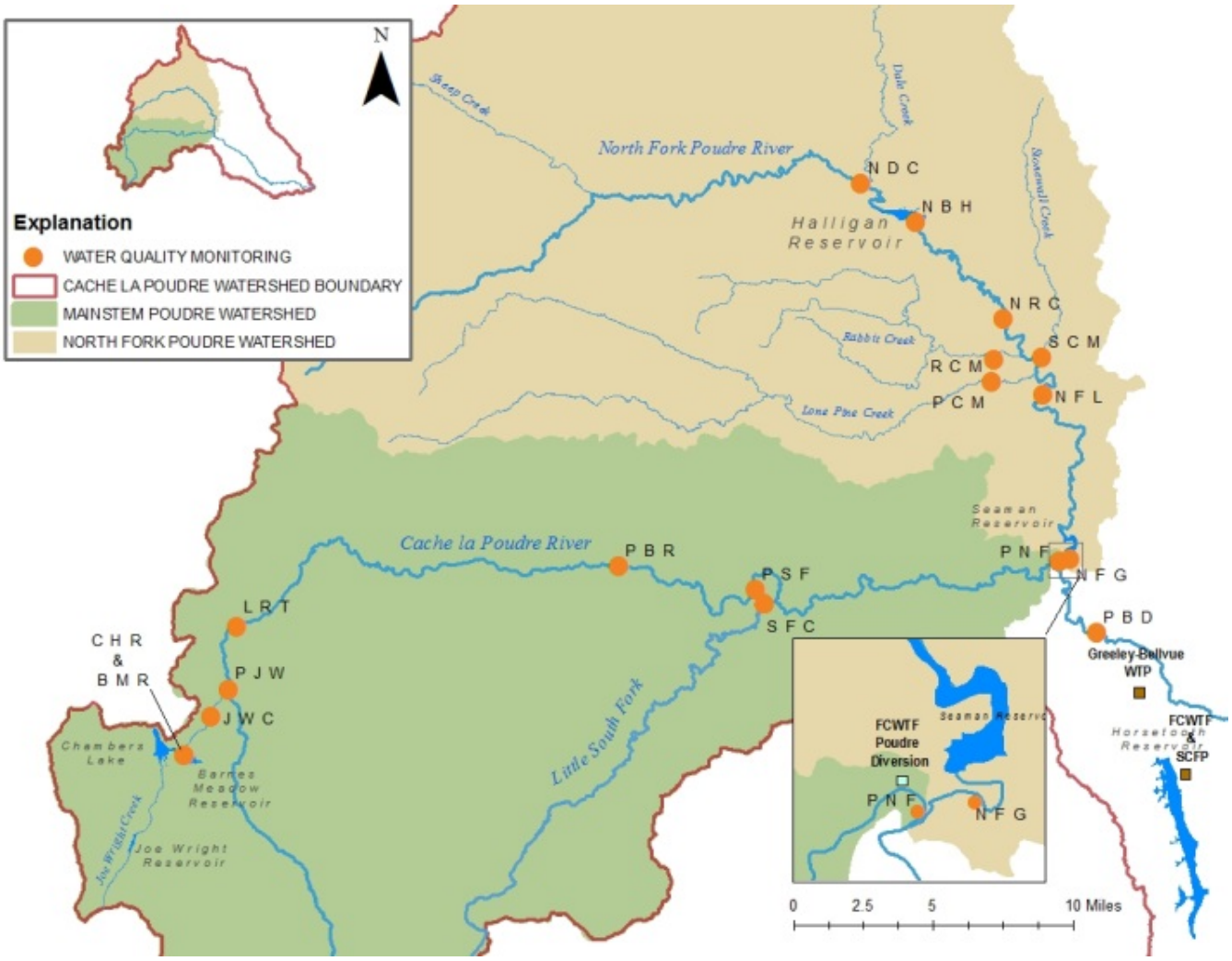


Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

2.0 HYDROLOGY & CLIMATE

Hydrology and climate play an important role in determining 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, and the amount of water in the system at a given time influences the concentration of most water quality constituents. Changes to the historic timing, magnitude, 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, located near Joe Wright Reservoir at an elevation of 10,120 feet, contains the longest record of continuous measurements in the Cache la Poudre Watershed dating back to 1978 (*https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=551*).

The Cache la Poudre at Canyon Mouth near Fort Collins (CLAFTCCO) streamflow monitoring station managed by the Colorado Department of Water Resources (*http://www.dwr.state.co.us/*) 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 for the 2018 calendar year are compared to the average calculated over the period of record from 2008 to 2012.

Seasonal statistics were calculated for winter (December, January and February), spring (March, April and May), summer (June, July and August), and fall (September, October and November).

2.1 AIR TEMPERATURE

The average annual mean air temperature in 2018 was 35.8°F and measured 1.1°F warmer than average (Table 1). The year ranked as the 5th warmest on record (30 years) at the Joe Wright SNOTEL.

The 2017/2018 winter season was 4.2°F warmer than average (Table 1) and ranked as the warmest winter on record. December and January were particularly warm, measuring 5.4°F warmer than average (Figure 2.1) and ranked as the warmest on record.

The spring season was 1.5°F warmer than average (Table 1) and ranked as the 5th warmest spring on record. Temperature in the month of March was slightly below average, but the month of May was unusually warm and measured 4.0°F warmer than average (Figure 2.1). May of 2018 ranked as the warmest May on record.

The summer season was 1.2°F warmer than average (Table 1) and ranked as the 2nd warmest summer on record. The unusually warm temperatures observed in the month of May continued into June. Temperature in the month of June was 3.4°F warmer than average and ranked as the 2nd warmest June on record. Temperatures in the months of July and August were near average (Figure 2.1).

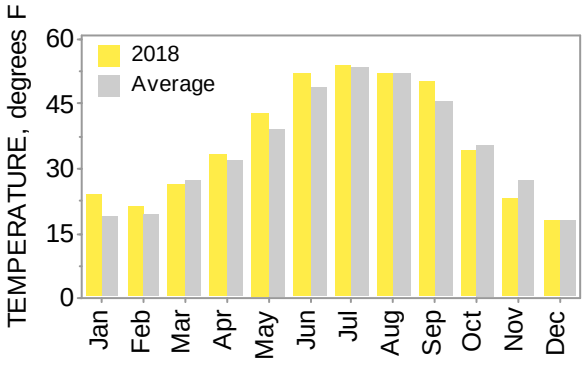


Figure 2.1 –Monthly mean air temperature in 2018 compared to baseline monthly mean air temperature measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

Table 2 – Seasonal summary statistics for temperature, precipitation, and streamflow in Upper CLP watershed in 2018 compared to average (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	2018	22.7	4.2	12.7	100%	7,607	100%
	Average	18.5		12.7		7,602	
Spring	2018	34.0	1.5	13.8	92%	79,184	167%
	Average	32.5		15.0		47,547	
Summer	2018	52.7	1.2	5.4	80%	109,369	65%
	Average	51.5		6.7		168,506	
Fall	2018	35.7	-0.6	11.7	107%	10,266	80%
	Average	36.3		11.0		12,877	
Annual (CY)	2018	35.8	1.1	43.3	96%	203,302	86%
	Average	34.7		45.3		236,349	

In contrast, the fall season was cooler than average (Table 2). Exceptionally hot conditions returned in the month of September. The average monthly mean temperature was 4.2°F warmer than average and ranked as the warmest on record; however, the months of October and November were 1.4°F and 4.2°F colder than average (Figure 2.1). November ranked as the 8th coldest on record.

2.2 PRECIPITATION

Total Precipitation

In 2018, total precipitation was 96% of average with a total of 43.3 inches measured at the Joe Wright SNOTEL over the 2018 calendar year (Table 2). Precipitation was generally at or above average in winter and fall and below average in spring and summer.

Precipitation measured over the 2017/2018 winter season was average with a total of 12.7 inches of precipitation (Table 2). February was the wettest winter month with 4.7 inches of precipitation (Figure 2.2) and ranked as the 9th wettest February on record (41 years).

Total precipitation measured over the 2018 spring season was 92% of average with 13.8 inches of precipitation (Table 2). The start of the spring season was particularly wet with 6.0 inches of precipitation falling in March. Precipitation patterns shifted in late spring. Precipitation over the month of April was slightly below average. Total precipitation in May was 45% of average (Figure 2.2) and ranked as the 2nd driest May on record.

Dry conditions continued through the 2018 summer season. Total precipitation measured over the 2018 summer season was 80% of average with 5.4 inches of precipitation (Table 2). Below average precipitation was measured in all summer months (Figure 2.2) and ranked as the 10th driest summer on record.

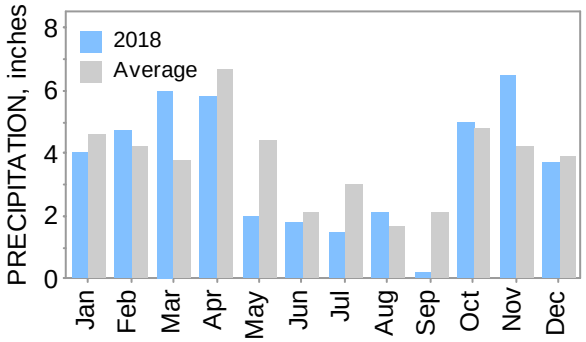


Figure 2.2 – Monthly precipitation totals in 2018 compared to average monthly mean precipitation totals measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

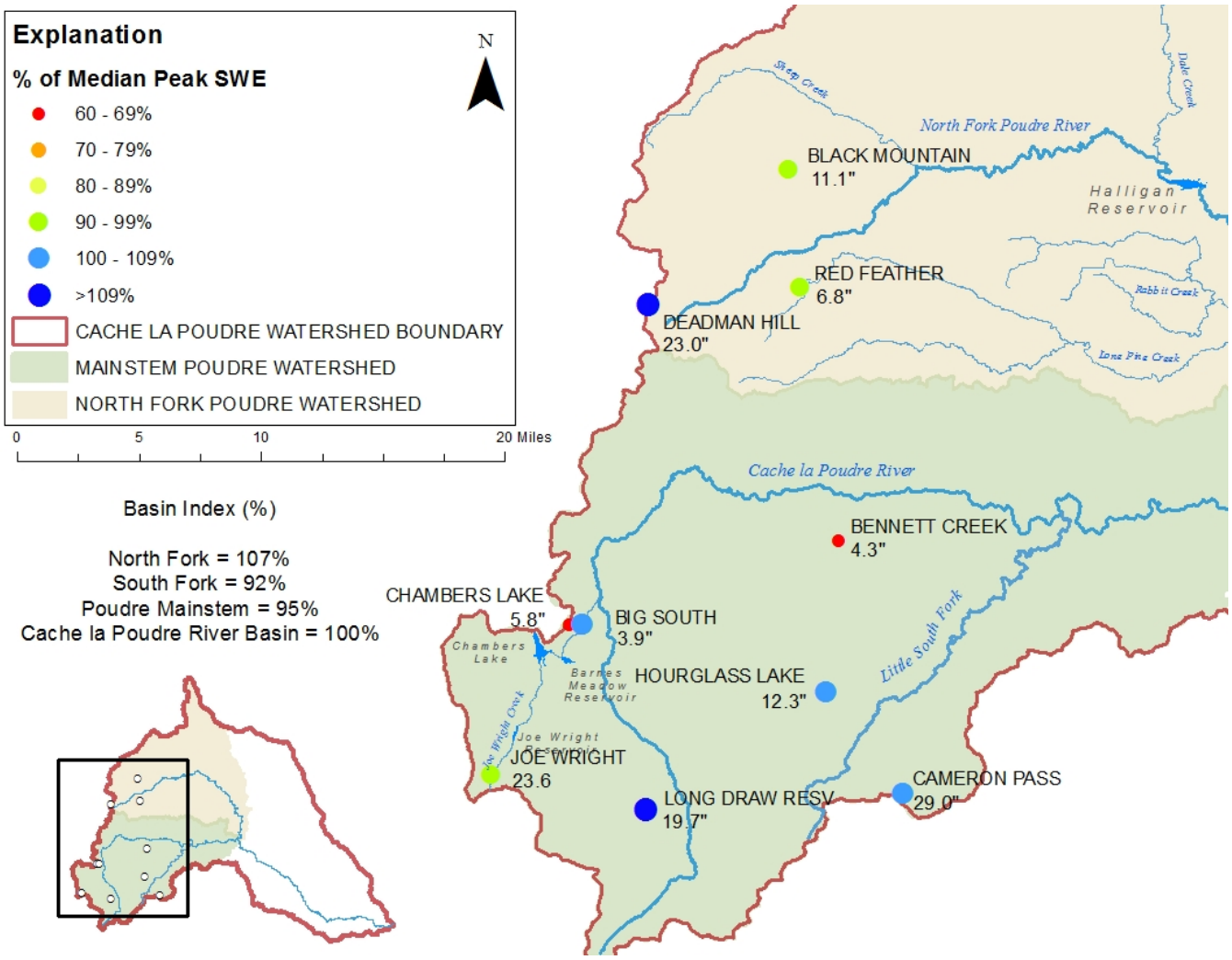


Figure 2.3 – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2018 water year.

Total precipitation measured over the 2018 fall season was 107% of average with 11.7 inches of precipitation (Table 2). Only two tenths of an inch of precipitation was measured in September, which ranked as the driest September on record. Precipitation conditions improved through the rest of the fall season with well above average precipitation in the months of October and November (Figure 2.2), which ranked in the top ten wettest months, respectively, on record.

Cache la Poudre Basin Snowpack

Peak 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).

In 2018, peak SWE across the entire Cache la Poudre Watershed was 100% of the expected peak SWE based on the long-term median (1981-2010). The North Fork basin was slightly above the long-term median at 107%, while the South Fork and Mainstem Poudre basins were slightly below the long-term median reporting basin indices of 92% and 95%, respectively (Figure 2.3).

2.3 STREAMFLOW

The Mainstem and North Fork watersheds exhibit snowmelt-dominated hydrographs. Water is stored in the snowpack as precipitation 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 in 2018 (as measured Canyon Mouth stream gage) was 203,302 acre-feet, which was 86% of the historic average (Table 2). This value is a slight underestimate as flow records were unavailable for part of the winter season, as discussed below.

Streamflow measured over the 2017/2018 winter season was 100% of the average with a total of 7,607 acre-feet of water (Table 2). December and February were above average at 140% and 173%. The total volume of water measured over the winter season is underestimated as flow records were unavailable, due to ice, from December 23, 2017 to February 6, 2018.

Streamflow measured over the 2018 spring season was 167% of average due to an early start to snowmelt runoff and early peak (Table 2). Streamflow contributions in the month of May were nearly two times higher (189%) than average and was the 2nd highest runoff in May measured over the past ten years (Figure 2.4). Peak streamflow was measured on May 27th at 2,230 cubic feet per second. The peak streamflow in 2018 was 112% of the historical average peak streamflow (137 years) and occurred nearly two weeks earlier.

The early and rapid runoff observed in May, in combination with the warm, dry conditions observed over the spring and summer seasons resulted in streamflow that was well below average over the summer season (Table 1). Streamflow was only 65% of average over the summer season and measured 109,369 acre-feet. All summer months were well below average, but streamflow in July was very low and measured 42% of average (Figure 2.4).

Streamflow conditions improved slightly over the fall season to 80% of average. Streamflow over the months of September and October were well below average, while November streamflow was slightly above average at 103% (Figure 2.4).

North Fork Cache la Poudre River

Streamflow on the North Fork CLP near Livermore (NFL) was exceptionally low in 2018 as compared to average. The total amount of water that flowed down the North Fork CLP at the Livermore stream gage was 30% of average and measured 11,935 acre-feet (Figure 2.4).

Streamflow was well below average in all months except the month of October. Winter streamflow was measured slightly below average. Streamflow on the North Fork was only 41% of average over the spring season and 13% of average over the summer season due to exceptionally low streamflow from March through August (Figure 2.4).

Streamflow improved in the fall season and measured 110% of average on the North Fork near Livermore. This was primarily driven by above average streamflow in the month of October, which was likely caused by above average precipitation (Figure 2.4).

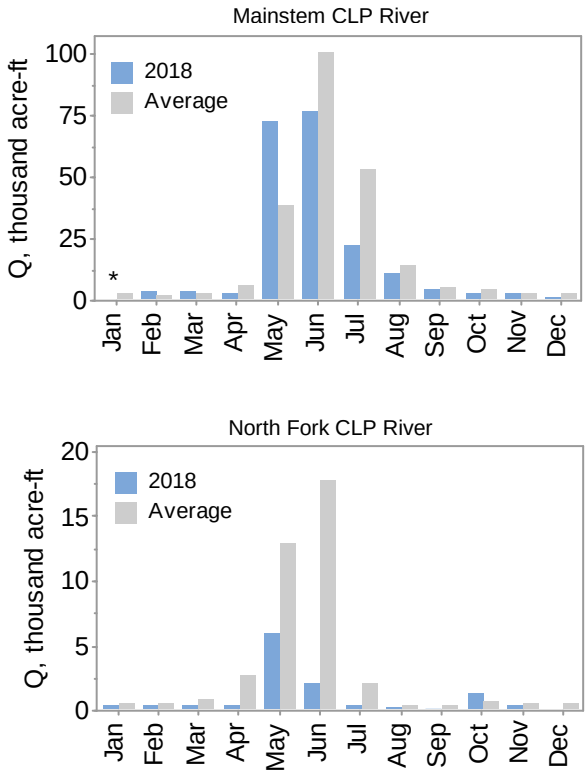


Figure 2.4 –Total monthly streamflow in 2018 compared to average total monthly mean streamflow measured on the Mainstem CLP River near the Canyon Mouth (top) and North Fork CLP river near Livermore (bottom).

Streamflow Contributions

An estimated 222,276 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2018 and approximately 37,630 acre-feet were diverted through the Munroe and City of Fort Collins diversions. These approximations underestimate the total water volume because streamflow records were unavailable, due to ice, from December 23, 2017 to February 6, 2018 at Poudre River near Canyon Mouth gaging station. Streamflow data for these winter months are estimated by the operating agency and will not be available until summer 2019.

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 2018 water contributions to the Mainstem CLP River above the Munroe Tunnel is presented in Table 3.

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 203,302 acre-feet in 2018 (Figure 2.5). Approximately 3,355 acre-feet of water was diverted upstream at the Poudre Valley Canal. The North Fork contributed 11% of total acre-feet to the Mainstem, which was slightly lower than average contributions (Figure 2.5).

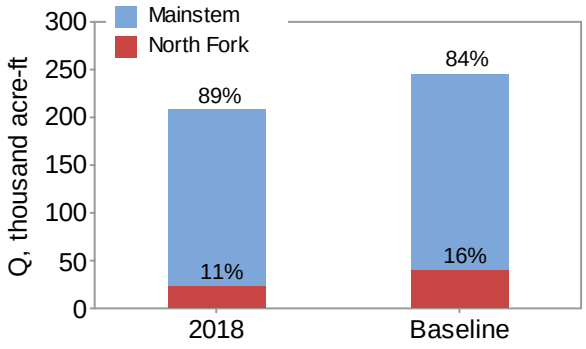
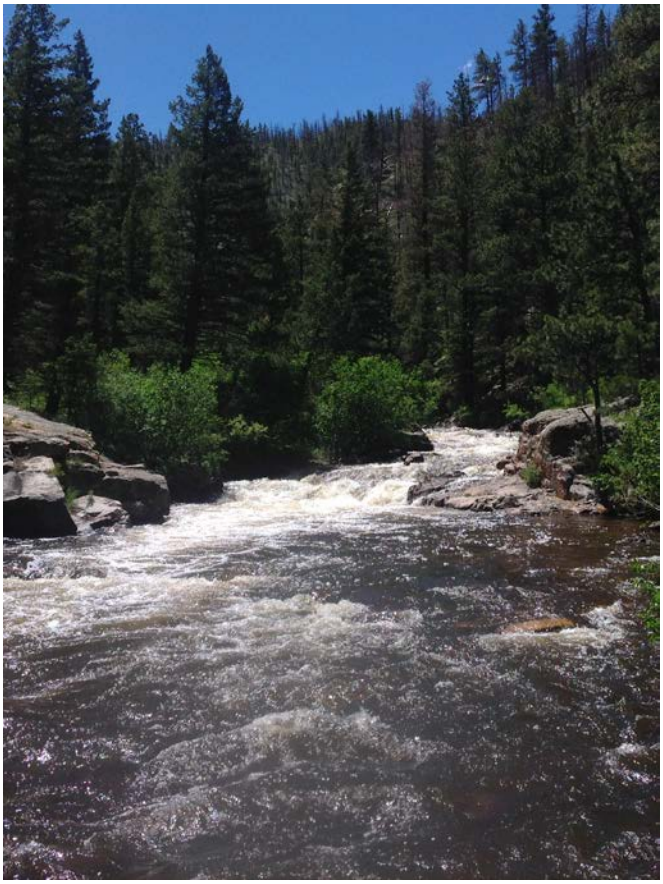


Figure 2.5 – Proportion of average Mainstem and North Fork contributions at PBD in 2018 compared to average.



High streamflow on the Little South Fork of the Cache la Poudre River in early-May.

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in 2018. Contributions highlighted in red indicated underestimates due to incomplete data sets and contributions highlighted in **bold** indicated the greatest monthly contribution to the Mainstem. Note: AF = acre-feet

Month	Barnes Meadow		Chambers Lake		Laramie River Tunnel		Long Draw Reservoir		Little South Fork Poudre		Mainstem Tributaries		Poudre above Munroe	
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%
Jan	-	-	-	-	-	-	-	-	-	-	-	-	-	------
Feb	-	-	1,254	42%	-	-	-	-	**1,420**	**48%**	292	10%	2,965	------
Mar	-	-	1,230	37%	-	-	-	-	**1,605**	**49%**	464	14%	3,299	------
Apr	250	4%	1,190	21%	419	8%	-	-	1,628	29%	**2,090**	**37%**	5,578	------
May	131	0%	5,944	9%	2,696	4%	2,116	3%	10,748	16%	**47,118**	**69%**	68,753	------
Jun	-	-	11,100	14%	4,050	5%	12,827	16%	13,956	17%	**38,559**	**48%**	80,493	------
Jul	-	-	5,128	17%	5,212	17%	6,352	21%	**8,562**	**28%**	5,389	18%	30,643	------
Aug	-	-	3,261	21%	2,885	19%	**5,759**	**38%**	3,505	23%	(119)	-	15,291	------
Sep	-	-	**2,832**	**42%**	430	6%	1,452	22%	1,267	19%	737	11%	6,717	------
Oct	-	-	**2,375**	**48%**	-	-	199	4%	1,221	25%	1,186	24%	4,981	------
Nov	-	-	-	-	-	-	-	-	**1,429**	**53%**	1,262	47%	2,692	------
Dec	-	-	-	-	-	-	-	-	**478**	**55%**	386	45%	864	------
Total	**381** (0%)		**34,313** (15%)		**15,692** (7%)		**28,705** (13%)		**45,820** (21%)		**97,365** (44%)		**222,276**	

3.0 SPATIAL TRENDS IN UPPER CACHE LA POUDRE WATER QUALITY

Spatial trends discussed in the 2018 Annual Report focus primarily on monitoring sites located directly on the Mainstem and North Fork CLP Rivers that are considered representative of water quality conditions throughout the Mainstem CLP watershed. 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 each period of record. 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:

- Physical – 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

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.

3.1 PHYSICAL PARAMETERS

Water Temperature

Water temperature influences other water quality parameters and is a major driver of biological activity, including algal growth in rivers. Some blue-green algae species 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 warmer in 2018 compared to baseline at nearly all monitoring sites (Figure 3.1).

Mainstem

Water temperature increased with decreasing elevation on the Mainstem CLP River over the 2018 monitoring season and ranged from minimum temperatures below 1°C at all sites to a maximum temperature of 22.1°C at the City of Greeley's Diversion (PBD). Minimum water temperatures were below or near baseline at all monitoring sites. Median water temperatures were cooler than baseline at higher elevation monitoring sites on Joe Wright Creek (JWC) and the Poudre above Joe Wright Creek (PJW) and warmer than baseline from the Mainstem CLP River below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). The largest departure from baseline was measured on the Poudre River downstream of the confluence with the South Fork (PSF). Maximum water temperatures were

cooler than baseline at all monitoring sites, except at PSF where the maximum water temperature measured in 2018 exceeded baseline.

North Fork

Water temperature on the North Fork CLP River ranged from a minimum temperature below 1°C on the North Fork above Dale Creek (NDC) to a maximum temperature of 24.0°C on the North Fork above Rabbit Creek (NRC). Minimum water temperatures on the North Fork CLP River 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). Median water temperatures were warmer than baseline at all monitoring sites with the largest departure from baseline measured below Seaman Reservoir (NFG). Median water temperature on the North Fork below Halligan Reservoir was notably warmer than the upstream monitoring site on the North Fork above Dale Creek (NDC). A similar but lower magnitude trend was observed downstream at NRC and NFL. Water temperature measured on the tributaries

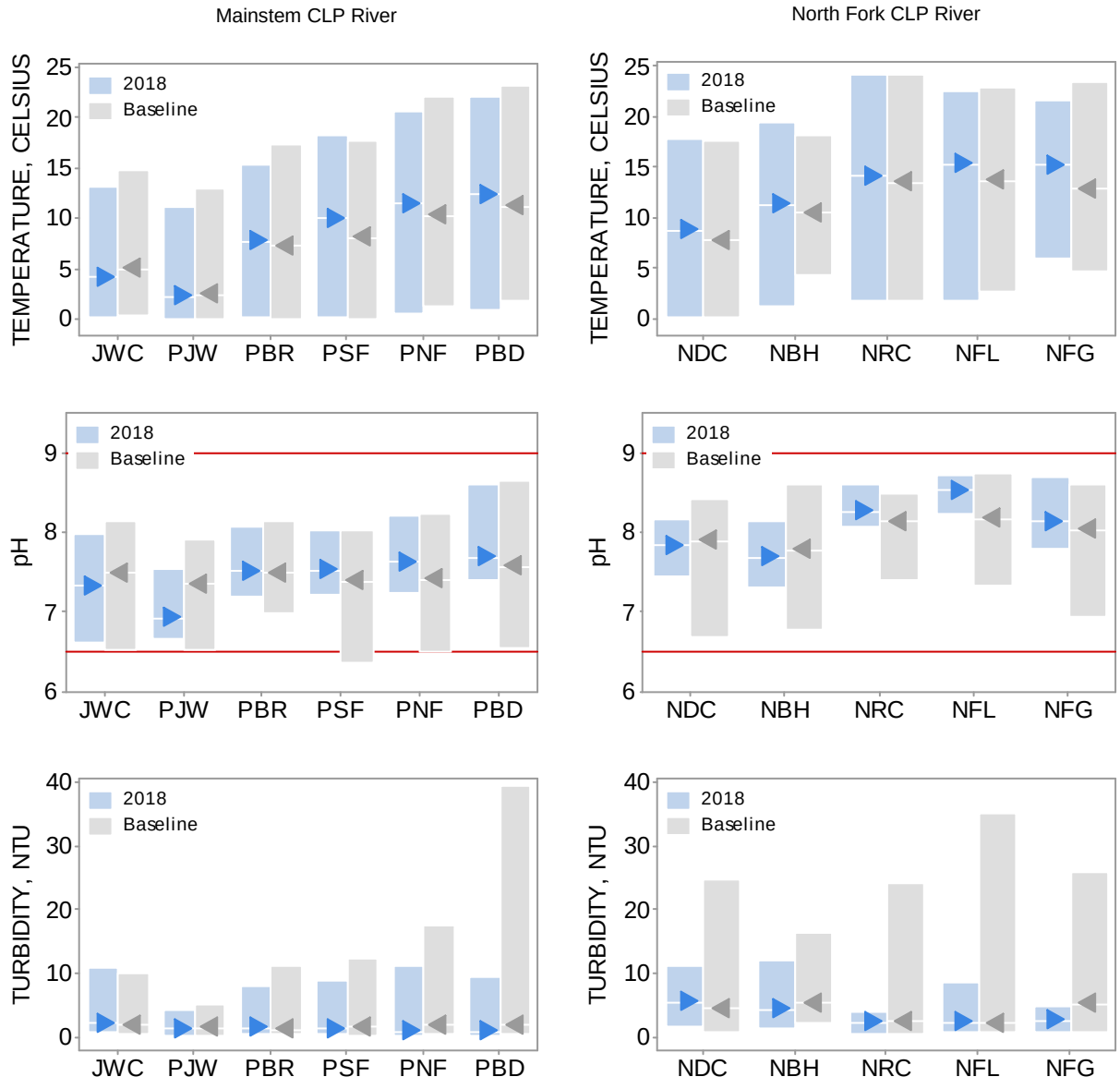


Figure 3.1 – Water temperature, pH, and turbidity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2018 compared to the baseline period of record. The red reference lines for pH indicate the Colorado Department of Public Health and Environment water quality standard to protect aquatic life.

to the North Fork between these monitoring locations were all above baseline contributing to the warmer water temperature observed downstream at NFL. Maximum water temperatures exceeded baseline at NDC and NBH but were below baseline from the North Fork CLP river above Rabbit Creek to the North Fork CLP below Seaman Reservoir.

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 throughout the Mainstem and North Fork CLP watersheds in 2018 was within the baseline range of values at all monitoring sites and were either near neutral or slightly alkaline (Figure 3.1).

Mainstem

The range of pH values measured in 2018 along the Mainstem CLP River was comparable across all monitoring sites and ranged from a minimum pH of 6.61 on the Poudre above Joe Wright Creek (PJW) to 8.60 at the City of Greeley's Diversion (PBD). Minimum pH values were notably higher than baseline at all monitoring sites. Median pH values were more acidic than baseline at higher elevation monitoring sites on Joe Wright Creek (JWC) and the Poudre above Joe Wright Creek (PJW) and more alkaline than baseline from the Mainstem CLP River below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). The largest departure from baseline was measured on the Poudre above Joe Wright Creek (PJW), where the 2018 median was lower than baseline. Maximum pH values were near or slightly more basic than baseline at all monitoring sites.

North Fork

pH along the North Fork CLP River was more alkaline compared to the Mainstem CLP River and ranged from a minimum pH of 7.29 on the North Fork below Halligan Reservoir (NBH) to 8.70 on the North Fork above Seaman Reservoir (NFL). There was slightly more variability between monitoring sites along the North Fork CLP River, 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. Minimum pH values were notably higher than baseline at all monitoring sites. Median pH was more acidic than baseline at higher elevation monitoring sites above and below Halligan Reservoir (NDC and NBH) and more alkaline than baseline from the North Fork CLP River above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). The largest departure from baseline was measured on the North Fork near Livermore (NFL). Maximum pH values were well below baseline on the North Fork above and below Halligan (NDC and NBH) and above or near baseline from North Fork above Rabbit Creek (NRC) downstream.

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 lower than baseline at nearly all monitoring sites in 2018 (Figure 3.1).

Mainstem

Turbidity levels were consistent along the Mainstem CLP River over the 2018 monitoring season and ranged from below 1 NTU at all monitoring sites to a maximum of 11 NTU at the City of Fort Collins' Diversion (PNF). Minimum and median turbidity levels were below or near baseline at all monitoring sites. Maximum turbidity levels were notably lower than baseline at all monitoring sites except on Joe Wright Creek (JWC) where the maximum turbidity level was slightly higher than baseline.

North Fork

Turbidity levels were generally consistent along the North Fork CLP River over the 2018 monitoring season and ranged from near 1 NTU at all monitoring sites to a maximum of 12 NTU on the North Fork CLP River below Halligan Reservoir (NBH). Turbidity levels were slightly higher on the North Fork CLP River above and below Halligan Reservoir. Minimum and median turbidity levels were near baseline at all monitoring sites. The largest departure from baseline was measured on the North Fork CLP River below Seaman Reservoir (NFG). Maximum turbidity levels were notably lower than baseline at all monitoring.

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 near baseline at nearly all monitoring sites in 2018 (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.

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 8.40 mg/L $CaCO_3$ to 49.6 mg/L $CaCO_3$; hardness concentrations ranged from 12.2 mg/L to 49.9 mg/L; and specific conductivity ranged from 23.8 µS/cm to 124.8 µS/cm. Minimum concentrations of these parameters were observed on the Poudre 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 Fort Collins Diversion upstream (PNF) 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 CLP River from below Halligan Reservoir (NBH) to 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 decreased from the North Fork CLP river above Rabbit Creek downstream to below Seaman Reservoir (NFG). Alkalinity concentrations ranged from 20.2 mg/L $CaCO_3$ to 203.0 mg/L $CaCO_3$; hardness concentrations ranged from 21.1 mg/L to 209.6 mg/L; and specific conductivity ranged from 47.2 µS/cm to 464.7 µS/cm. Minimum concentrations of these parameters 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 above baseline at all monitoring sites. Median concentrations were near baseline at all monitoring sites, except on the North Fork CLP River above Rabbit Creek (NRC) where concentrations were notably higher than baseline. Maximum concentrations were near or below baseline at all monitoring sites, especially on the North Fork below Seaman Reservoir (NFG).

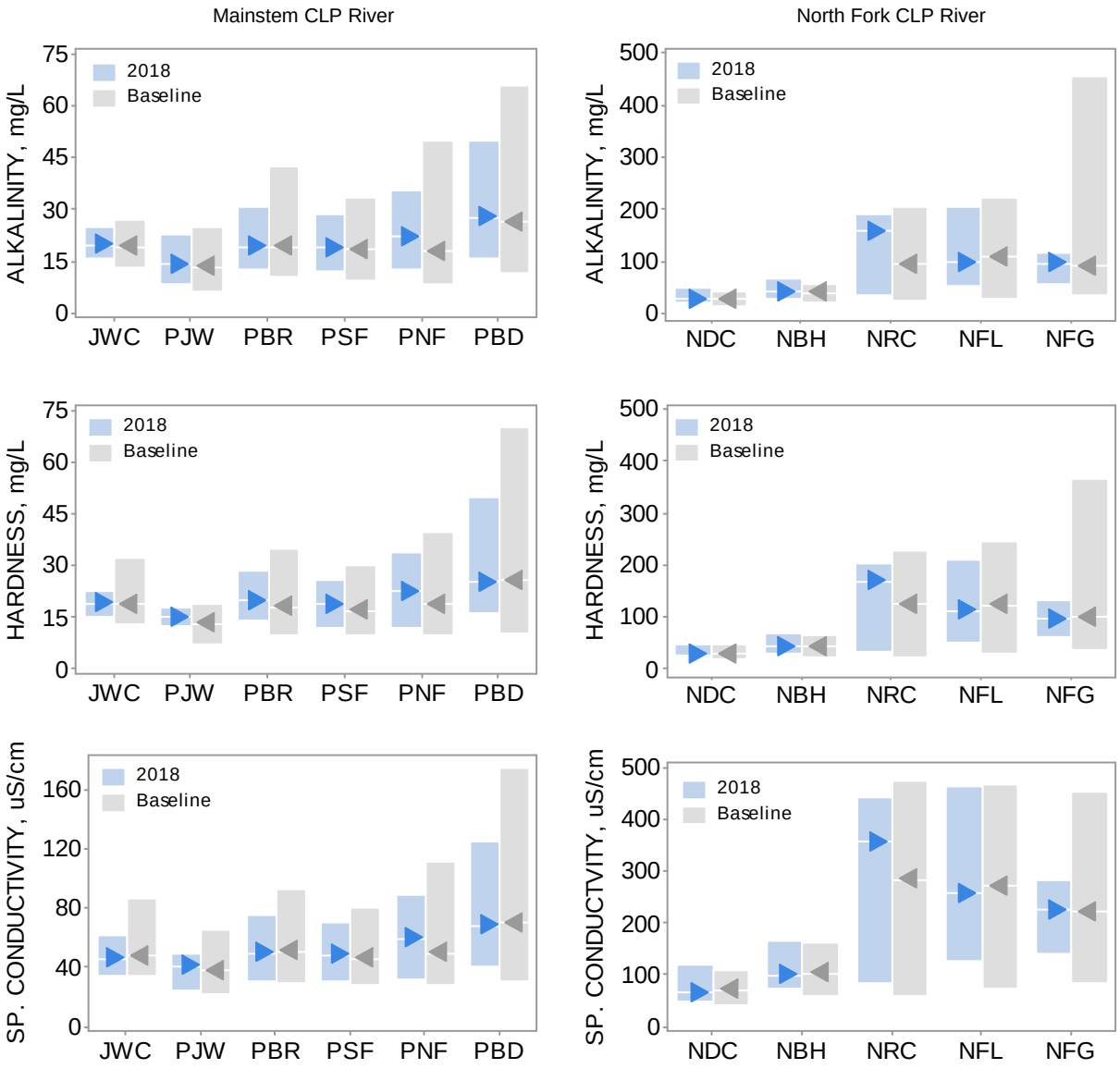


Figure 3.2 – Alkalinity, hardness and specific conductivity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2018 compared to the baseline period of record.

Total Dissolved Solids

Total dissolved solids (TDS) provides 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.

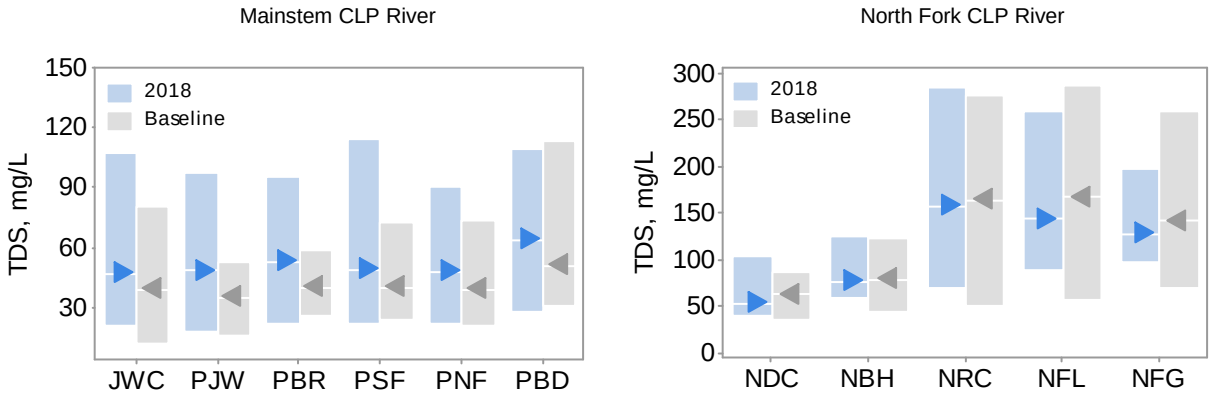


Figure 3.3 – Total dissolved solids (TDS) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2018 compared to the baseline period of record.

Total dissolved solids (TDS) were higher than baseline along the Mainstem CLP River and near or below baseline along the North Fork CLP River in 2018 (Figure 3.3).

Mainstem

Total dissolved solids concentrations were similar at all sites on the Mainstem CLP River over the 2018 monitoring season and ranged from a minimum 18 mg/L on the Poudre above Joe Wright Creek (PJW) to a maximum 114 mg/L below the confluence with the South Fork CLP River (PSF). Minimum total dissolved solids concentrations were higher than baseline on Joe Wright Creek (JWC) and the Poudre above Joe Wright Creek (PJW) and near or below baseline on the Mainstem CLP River below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD). Median total dissolved solids concentrations were higher than normal at all sites, especially the Poudre above Joe Wright Creek (PJW) and Mainstem CLP River below Rustic (PBR) where median concentrations approached the baseline maximum. The higher median concentrations were driven primarily by the months of May and October when TDS concentrations were notably higher than baseline. Maximum total dissolved solids concentrations were substantially higher than baseline at all monitoring sites except at the City of Greeley's Diversion (PBD). The maximum concentration of total dissolved solids was measured on May 7th at all monitoring sites and averaged 33.2 mg/L higher than baseline.

North Fork

Concentrations decreased from the North Fork above Rabbit Creek (NRC) downstream below Seaman Reservoir (NFG). Total dissolved solids concentrations ranged from a minimum 38 mg/L on the North Fork above Dale Creek (NDC) to a maximum 284 mg/L on the North Fork above Rabbit Creek (NRC). There was a notable increase in the concentration of total dissolved solids between the North Fork below Halligan Reservoir (NBH) to North Fork above Rabbit Creek (NRC), which is likely associated with significant changes in streamflow below the North Poudre Canal. Minimum concentrations were above baseline at all monitoring sites. Median concentrations were near or below baseline. Maximum TDS concentrations were higher than baseline on the North Fork above and below Halligan Reservoir (NDC and NBH), and on the North Fork above Rabbit Creek (NRC). Maximum concentrations on the North Fork above and below Seaman Reservoir (NRC and NFL) were lower than baseline.

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.

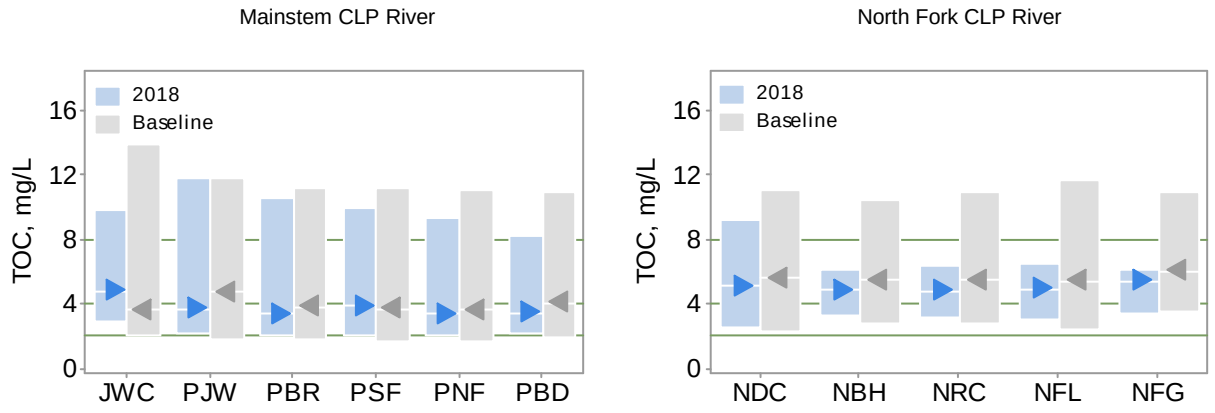


Figure 3.4 – Total organic carbon (TOC) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2018 compared to the baseline period of record. The green reference lines indicate thresholds for TOC removal requirements set by the Environmental Protection Agency. Note that the removal requirements also consider raw water alkalinity concentrations.

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 regulated 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 higher than baseline along the Mainstem CLP River and lower than baseline along the North Fork CLP River in 2018 (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 monitoring sites on the Mainstem CLP River over the 2018 monitoring season and ranged from a minimum 2.0 mg/L at the City of Fort Collins Diversion (PNF) to a maximum 11.8 mg/L on the Poudre above Joe Wright Creek (PJW). Minimum TOC concentrations were marginally higher than baseline at all monitoring sites and ranged between 2 – 4 mg/L or lower. Median TOC concentrations were also near baseline at most monitoring sites and ranged between 2 – 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 4.7 mg/L. Maximum total organic carbon concentrations were lower than baseline at all monitoring sites. The maximum concentration of TOC was measured on May 7th at all monitoring sites, which exceeded the 8 mg/L threshold.

North Fork

Total organic carbon concentrations were comparable across all sites along the North Fork CLP River over the 2018 monitoring season. The North Fork above Dale Creek (NDC) had the greatest variability with a range in TOC concentrations of 2.5 mg/L to 9.1 mg/L. The higher variability is likely associated with the more natural streamflow conditions found above the water supply reservoirs. Total organic carbon concentrations from the North Fork below Halligan (NBH) downstream to the North Fork below Seaman Reservoir (NFG) were less variable (likely due to the smaller dataset in 2018 compared to

baseline) and levels were comparable across monitoring sites. Minimum TOC concentrations were higher than baseline at all monitoring sites and were within the 2 – 4 mg/L removal requirement threshold. Median TOC concentrations were below baseline at all monitoring sites and were on the lower end of 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 TOC in 2018 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 algal growth. Elevated nutrients can 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.

Total 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 CLP River over the 2018 monitoring season (Figure 3.5). Concentrations ranged from below the reporting limit (90 µg/L) at most monitoring sites to a maximum 1,001 µg/L on Joe Wright Creek (JWC). Minimum total nitrogen concentrations were equal to baseline at all monitoring sites except on the Poudre above Joe Wright Creek where the minimum concentration was slightly higher than baseline. Median total nitrogen concentrations were above baseline at all monitoring sites. The largest departure from baseline was observed on the Poudre river near Rustic (PBR) downstream to the City of Fort Collins' Diversion (PNF). Median concentrations were still 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 Joe Wright Creek (JWC) and occurred during the high streamflow months of May and June.

North Fork

Total nitrogen concentrations were similar across monitoring sites on the North Fork CLP River over the 2018 monitoring season (Figure 3.5). Concentrations ranged from below the reporting limit (90 µg/L) on the North Fork above Dale Creek (NDC) to a maximum 1,007 µg/L on the North Fork below Seaman Reservoir (NFG). Minimum total nitrogen concentrations were slightly higher than baseline at all monitoring sites. Median total nitrogen concentrations were 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. The highest concentration was measured on the North Fork below Seaman Reservoir at 1,007 µg/L.

Total Phosphorus

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

Mainstem

Total phosphorus concentrations were similar across monitoring sites on the Mainstem CLP River over the 2018 monitoring season (Figure 3.5). Concentrations ranged from below the reporting limit (10 µg/L) at all monitoring sites to a maximum 45 µg/L at the City of Fort Collins Diversion (PNF). Minimum and median total phosphorus concentrations were near baseline at all monitoring sites. Concentrations from the Poudre above Joe Wright Creek (PJW) downstream to the City of Fort Collins Diversion (PNF) were below the reporting limit indicating very low levels of phosphorus for most of the monitoring season. Maximum total phosphorus concentrations were below baseline at all monitoring sites on the Mainstem CLP River, especially at the City of Greeley's Diversion (PBD). This trend is likely due to lower TP loads from the North Fork in

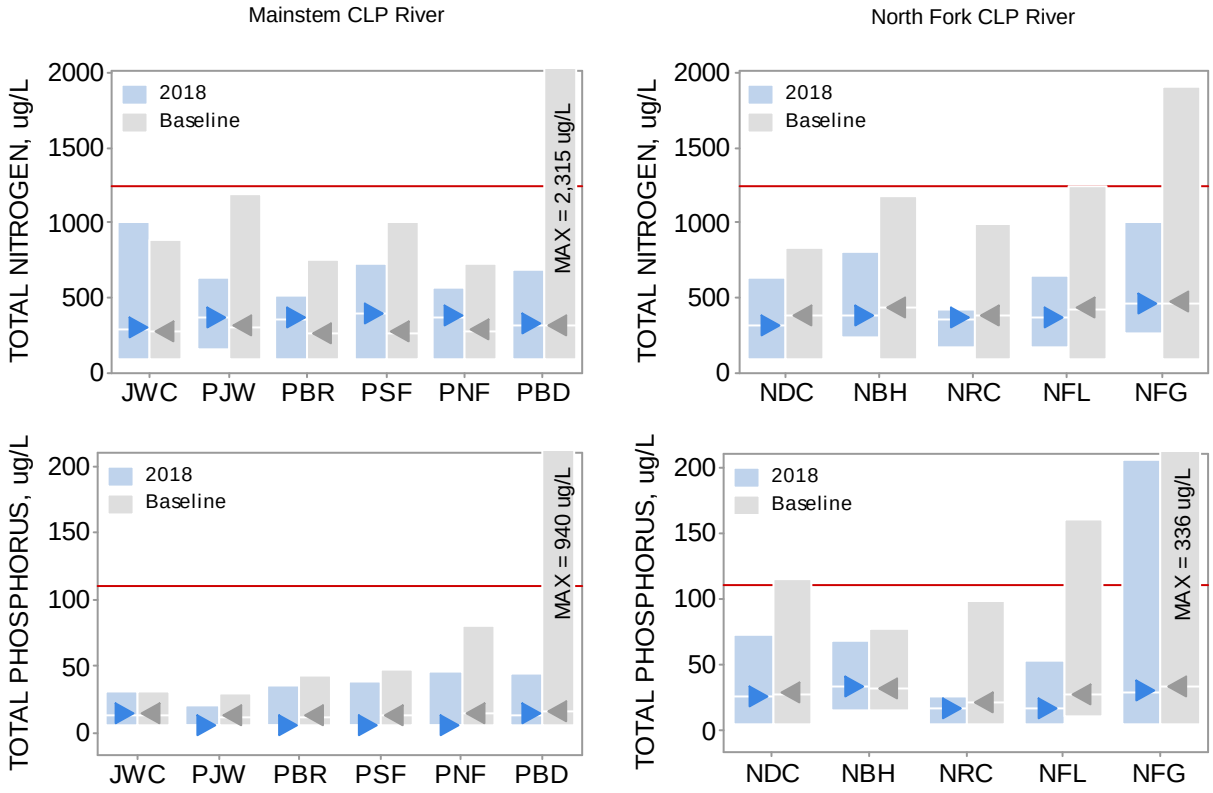


Figure 3.5 – Total nitrogen and total phosphorus concentrations measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2018 compared to the baseline period of record. The red reference lines indicate interim water quality standards (TN = 1,250 µg/L and TP = 110 ug/L) set by the Colorado Department of Public Health and Environment to protect aquatic life.

2018. Maximum TP concentrations on Joe Wright Creek (JWC) were slightly higher than baseline. The maximum concentration of total phosphorus was measured on May 7th at all monitoring sites.

North Fork

Total phosphorus concentrations were slightly higher on the North Fork above and below Halligan Reservoir (NDC and NBH), and on the North Fork below Seaman Reservoir (NFG) over the 2018 monitoring season (Figure 3.5). Concentrations ranged from below the reporting limit (10 µg/L) at most monitoring sites to a maximum 205 µg/L on the North Fork below Seaman Reservoir (NFG). Minimum total phosphorus concentrations were equal to or below baseline at all monitoring sites. Median total phosphorus concentrations were below baseline at all monitoring sites except on the North Fork below Halligan Reservoir (NBH). Maximum total phosphorus concentrations were below baseline at all monitoring sites on the North Fork CLP River and the timing varied between monitoring sites. Maximum concentrations were measured on June 19th on the North Fork above Dale Creek and Rabbit Creek (NDC and NRC). Maximum concentrations were measured six weeks earlier on the North Fork near Livermore (NFL) when total phosphorus contributions on North Fork tributaries were at a maximum. Maximum concentrations below the Reservoirs were measured later in the season on August 14th.

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 at PBR and PNF during routine upper CLP water quality monitoring events. A summary of Geosmin and 2-MIB concentrations can be found in Table 5.

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	2.13	nd	2.37	nd
May	2.46	nd	**4.43**	nd
Jun	1.07	4.88	nd	nd
Jul	2.94	7.19	2.17	3.45
Aug	2.29	nd	1.25	nd
Sep	1.99	9.97	1.38	2.58
Oct	**5.97**	10.73	**4.62**	8.81
Nov	2.22	nd	nd	2.53

3.6 METALS

The presence of metals in source water supplies is most often due to mineral weathering and soil. 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 2018 on the Mainstem and North Fork Poudre River.

Metal (ug/L)	Spring		Fall	
	PNF	NFG	PNF	NFG
Al	340	147	<10	<10
As	<1	<1	<1	<1
Cd	<1	<1	<1	<1
Cr	<1	ND	<1	<1
Cu	2	<1	<1	<1
Fe	219	152	25	12
Mn	3	17	2	66
Ni	<1	<1	<1	<1
Pb	<1	<1	<1	<1
Se	<5	<5	<5	<5
Zn	101	25	<5	<5

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 source of origin is more specific than total coliforms.

Total Coliform

Total coliform concentrations were similar across monitoring sites on the Mainstem CLP River in 2018 (Figure 3.6), but slightly higher on the North Fork below Seaman Reservoir (NFG) and downstream at the City of Greeley's Diversion (PBD). Concentrations ranged from a minimum 26 cells/100 mL on the Mainstem near the City of Fort Collins Diversion (PNF) to a maximum 8,164 cells/100 mL on the North Fork Below Seaman Reservoir (NFG). Minimum concentrations were near baseline at all monitoring sites. Median total coliform concentrations were equal to baseline on the Mainstem CLP River above the confluence with the North Fork. Median concentrations were slightly higher than baseline downstream of the confluence at the City of Greeley's Diversion (PBD) and on the North Fork below Seaman Reservoir (NFG). Maximum total coliform concentrations were much lower than baseline at all monitoring sites.

E. coli

Escherichia coli concentrations were variable across monitoring sites on the Mainstem CLP River in 2018 and ranged from a minimum 0 cells/100 mL at all monitoring sites to a maximum 185 cells/100 mL on the Mainstem upstream of the confluence with the North Fork near the City of Fort Collins Diversion (PNF) (Figure 3.6). Minimum concentrations were near baseline at all monitoring sites. Median *E. coli* concentrations were below baseline at all monitoring sites except on the Mainstem CLP river below Rustic (PBR). Maximum *E. coli* concentrations were much lower than baseline at all monitoring sites except at the City of Greeley's Diversion (PBD). The maximum concentration in 2018 at this monitoring location was 30 cells/100 mL higher than baseline maximum. The maximum *E. coli* concentration on the North Fork below Seaman Reservoir (NFG) was considerably lower in 2018 compared to baseline.

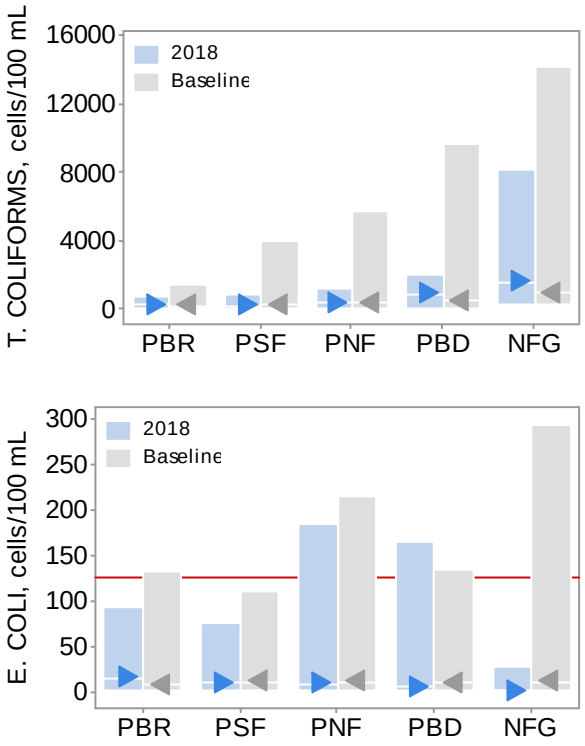


Figure 3.6 – Total coliforms and E. coli concentrations measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) – mainstem and NF sites in this fig are combined, as opposed to other figures in 2018 compared to the baseline period of record. The red reference line indicates the E. coli water quality standard set by the Colorado Department of Public Health and Environment to protect recreational use.

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 climate.

Presentation of Results

Bar charts presented in Section 4 display monthly median values measured over the 2018 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 in 2018 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.

City of Fort Collins' Diversion

The median alkalinity concentration at the City of Fort Collins' Diversion was 21.8 mg/L, which was 4.2 mg/L higher than baseline. Concentrations ranged from a minimum of 12.8 mg/L in the month of June to a maximum 34.2 mg/L measured in the month of April. Alkalinity was higher than baseline in all months except the month of May, which was slightly below baseline. The largest departure from baseline was measured in the month of April when the concentration was 6.8 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 27.6 mg/L, which was only 1.4 mg/L higher than baseline. Concentrations ranged from a minimum of 15.7 mg/L in the month of June to a maximum of 48.4 mg/L measured in the month of April. Alkalinity was near or below baseline in all months except the months of April and September when concentrations were higher than baseline. The largest departure from baseline was measured in the month of April when the concentration was 12 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 2018 (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 7.62, which was 0.22 pH units higher than baseline. Concentrations ranged from a minimum 7.28 in the month of June to a maximum 8.16 measured in the month of April. The lowest pH is generally measured in the months of August and September. Notable increases were observed in these months and the pH was 0.56 and 0.78 pH units higher than baseline. pH was also measured above baseline in the months of April, October and November, but its departure from baseline was much lower than the months of August and September. pH was below baseline from May through July (Figure 4.1).

City of Greeley's Diversion

The median pH value at the City of Greeley's Diversion was 7.68 compared the baseline median of 7.56. Concentrations ranged from a minimum 7.39 in the month of June to a maximum 8.60 measured in the month of September. In comparison to baseline trends, the highest pH values are typically observed in April and minima pH values are measured in the summer and early fall. A notable divergence from the baseline seasonal trend was observed in the months of August and September when pH values were markedly higher than baseline. pH returned to near baseline values in October and November (Figure 4.1).

4.3 TOTAL ORGANIC CARBON

Total organic carbon was lower than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2018 (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 measured before snowmelt runoff and as streamflow receded through the summer and fall months.

City of Fort Collins' Diversion

The median TOC concentration at the City of Fort Collins' Diversion was 3.33 mg/L compared to the baseline median of 3.60 mg/L. Concentrations ranged from a minimum of 1.97 mg/L in the month of November to a maximum of 8.88 mg/L measured in the month of May. As expected, the highest concentrations were observed during snowmelt runoff in May and June; however, the TOC concentration in May was higher than baseline and exceeded the 8 mg/L removal requirement threshold (Table 3). Total organic carbon was slightly above baseline in April and below baseline from July through November. TOC concentrations in these months were 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 3.42 mg/L compared to the baseline median of 4.03 mg/L. Concentrations ranged from a minimum 2.20 mg/L in the month of October to a maximum 8.15 mg/L measured in the month of May. Like the seasonal trend observed upstream, the highest concentrations were observed during snowmelt runoff in May and June; however, the TOC concentration in May was higher than baseline and exceeded the 8 mg/L removal requirement threshold. Total organic carbon was slightly above baseline in April and below baseline from July through November. TOC concentrations in these months were within the 2-4 mg/L removal requirement threshold (Figure 4.1).

4.4 TURBIDITY

Turbidity was lower than the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2018 (Figure 3.1). Seasonal trends in turbidity were comparable to baseline at both monitoring locations with higher concentrations measured during snowmelt runoff and lower concentrations as streamflow receded through the summer and fall months.

City of Fort Collins' Diversion

The median turbidity concentration at the City of Fort Collins' Diversion was less than 1 NTU and slightly lower than baseline. The maximum turbidity concentration was measured in May at 7.45 NTU, which was 3.45 NTU higher than baseline. Turbidity decreased in the following months and measured below baseline in all months except July (Figure 4.1).

City of Greeley's Diversion

The median turbidity concentration at the City of Greeley's Diversion was less than 1 NTU and slightly lower than baseline. The maximum turbidity concentration was measured in May at 6.81 NTU, which was slightly higher than baseline. Like the seasonal trend observed upstream at PNF, turbidity decreased in the following months and measured below baseline in all months except July (Figure 4.1).

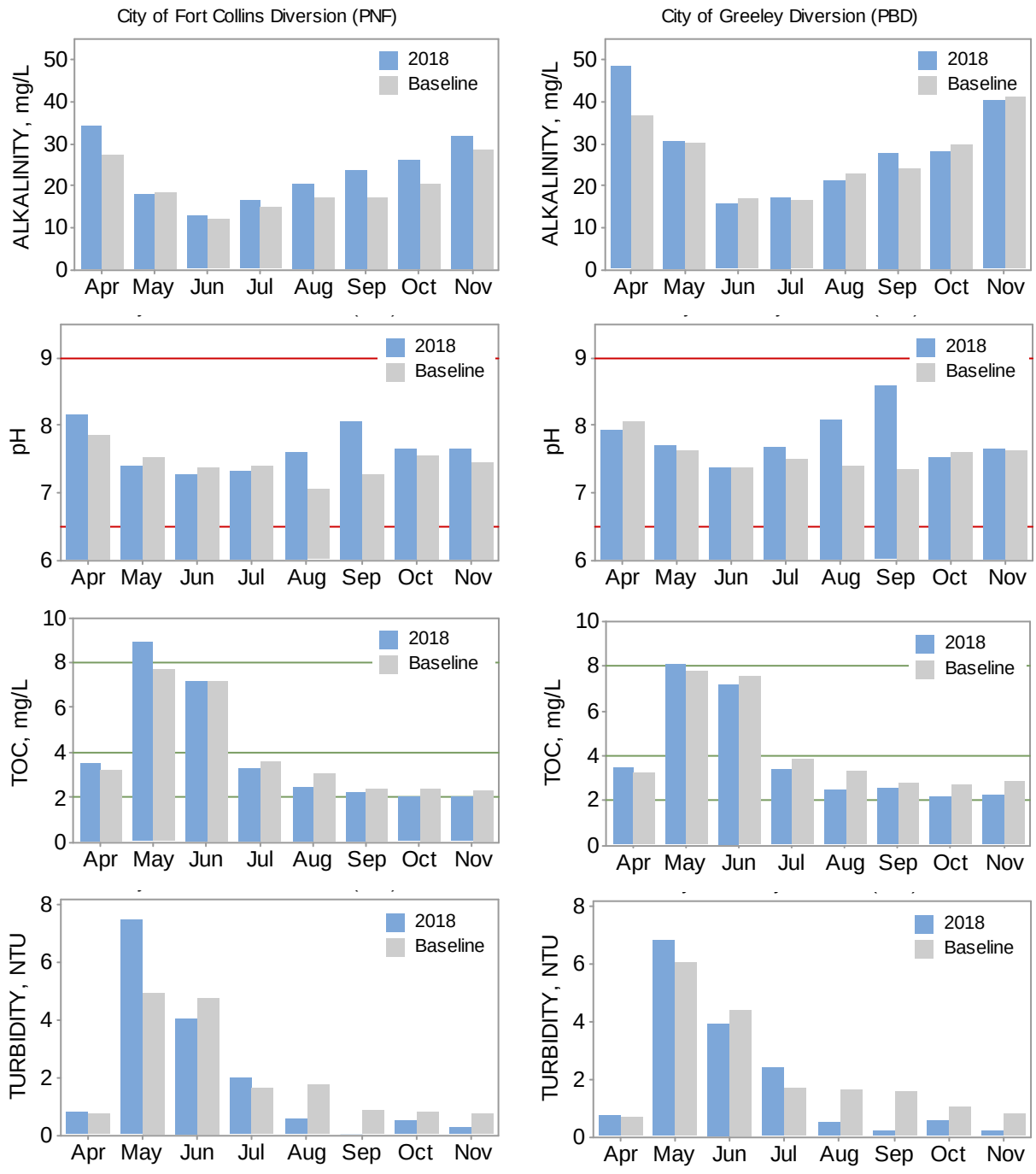


Figure 4.1 – Monthly alkalinity, pH, total organic carbon, and turbidity levels measured on the Mainstem CLP River at the City of Fort Collins Diversion (left) and City of Greeley Diversion (right) in 2018 compared to the baseline period of record. The red reference lines for pH indicate water quality 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 2018 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

The 2018 calendar year ranked as the 5th warmest on record as a result of notably warmer weather over the winter, spring, and summer seasons. Several months during this period, and into the fall season, ranked among the warmest on record.

Total precipitation was slightly below average in 2018. Peak snow water equivalent across the entire Cache la Poudre Watershed was normal, but drier conditions occurred from late-spring through early-fall. Precipitation improved in the later fall season bringing the total annual precipitation to near average by the end of 2018.

Streamflow was below average in 2018. Snowmelt runoff was observed earlier than normal with most of spring runoff occurring over the months of April and May. Notably lower streamflow was measured following snowmelt runoff into the summer and through the remainder of the year.

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. During spring runoff, the typical challenges for water treatment were observed on the Mainstem and the North Fork. 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 and followed normal seasonal, temporal, and spatial trends.

Water temperature throughout the Mainstem and North Fork CLP watersheds was warmer in 2018 as a result of warmer than average temperatures and low streamflow in the summer and fall months. The highest water temperatures were observed along the North Fork CLP from above the confluence with Rabbit Creek to below Seaman Reservoir. Streamflow is highly regulated along this reach of the North Fork CLP river and the hot, dry weather condtions in combination with below average streamflow in the summer and fall likely influenced water temperatures.

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

General water quality parameters, including alkalinity, hardness, and specific conductivity, along the Mainstem and North Fork CLP Rivers were near or slightly above baseline at most monitoring sites in 2018. The fact that similar trends were observed spatially across the watershed suggests that the water quality changes throughout the Upper CLP watershed in 2018 were primarily driven by hydrology and climate as opposed to site specific impacts. As expected, concentrations were diluted during spring snowmelt runoff and concentrated during the summer and fall when streamflow was low. In contrast to baseline conditions, dilution occurred slightly earlier due to an early onset of spring snowmelt runoff. Following spring runoff, streamflow was notably lower than average resulting in higher concentrations of these parameters in the summer and fall. The North Fork CLP river, especially from above the confluence with Rabbit Creek downstream to below Seaman Reservoir, had higher concentrations compared to the Mainstem CLP river. This trend has been observed over the baseline period of record and is associated with differences in watershed hydrology, geology and land use practices.

Turbidity and total organic carbon were within the range of concentrations measured over the baseline period of record along the Mainstem and North Fork CLP watersheds. In

general, turbidity levels were comparable between the Mainstem and North Fork CLP watersheds. Total organic carbon concentrations were slightly higher throughout the North Fork CLP watershed, which did not appear to have much influence on TOC concentrations at the City of Greeley's Diversion. As expected, turbidity and TOC levels were high during spring snowmelt runoff and low during the summer and fall when streamflow was low. Streamflow conditions in 2018 resulted in higher than baseline turbidity and TOC levels during the spring months due to an early and rapid start to snowmelt runoff and below baseline levels in the summer and fall due to lower than average streamflow conditions.

pH was within the baseline range of values at all monitoring sites and near neutral to alkaline. As expected, pH levels were more alkaline on the North Fork CLP river compared to the Mainstem CLP river. The higher pH values (more alkaline), especially from the North Fork above Rabbit Creek to below Seaman Reservoir, are likely associated with greater groundwater contributions to the river in combination with the natural geology of the North Fork CLP watershed. A notable increasing trend in pH was observed on the Mainstem CLP river in August and September at nearly all Mainstem monitoring sites. Increasing pH levels in rivers and lakes can be an indicator of algal growth. During this time, most water contributions to the Mainstem were from high elevation reservoirs including Long Draw Reservoir, Chambers Lake, and water supply reservoirs in the Little South Fork Watershed. Based on the time of year, the climatic and hydrologic conditions, and the major contributing water sources, the elevated pH levels on the Mainstem CLP River may be attributed to higher algal productivity within water supply reservoirs.

The highest concentrations of taste and odor compounds (geosmin and 2-MIB) on the Mainstem were also measured during the same period, providing further evidence of possible algal blooms in reservoirs and impact on mainstem Poudre River water quality. Fortunately, the concentrations of these compounds were still considered very low for a source water supply and were further mitigated during the water treatment process.

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 monitoring into the future to further help inform water treatment operations and track watershed health.

Ice begins to form along the banks of the Poudre above Joe Wright Creek of the Mainstem CLP River in late fall.

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 2018 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 2018 annual sampling plan (Attachment 4). QAQC samples and accuracy of field equipment is reviewed by Source Watershed Program staff.

Field Duplicates

In 2018, twelve percent (31 out of 269) of the environmental samples collected were QAQC samples. 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. Blank samples should not contain analytes above the reporting limit. The results of the field quality assurance and control sampling indicate that precision and accuracy were acceptable.

Table 7 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.

Table 7 – Data quality assurance statistics calculated for duplicated samples collected at PNF and NFG monitoring locations in 2018.

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
ortho-phosphate (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 kjedhal 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

Field Blanks

Field blanks were analyzed in the laboratory for a total of 18 different water quality parameters in 2018. Eighty-eight percent of field blank samples reported below 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 8). 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.

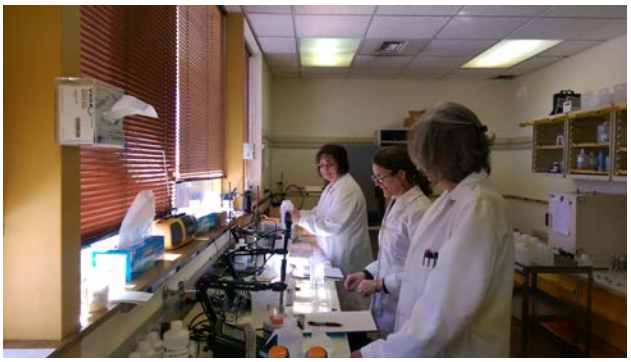
- Ammonia and TKN contamination may be introduced by the field sampler and/or laboratory staff accidentally breathing on the sample. It is suggested to limit the amount of time the sample is exposed to the environment by immediately capping the sample bottle following sample collection and/or sample 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 8 – Blank samples detected above their respective reporting limit in 2018.

WQ Parameter	Sample >DL	Total QAQC samples	Exceedance (%)	Reporting Limit (mg/L)	Max Exceedance
Alkalinity	3	19	16%	2	199
Hardness	3	19	16%	5	10
Ammonia	11	19	58%	0.01	0.02
TDS	6	20	30%	10	42
TKN	8	19	42%	0.1	0.56

7.0 REFERENCES

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ATTACHMENT 1

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM SAMPLING SITE

MAINSTEM	Description	Rationale	GPS Coordinates
100CHR	Chambers Lake Outflow	Outflow from Chambers Lake	N 40° 36.039 W 105° 50.203
090BMR	Barnes Meadow Reservoir outflow	High TOC and nutrients compared to CHR	N 40° 36.039 W 105° 50.203
080JWC	Joe Wright Creek at Aspen Glen Campground	Joe Wright Creek above confluence with mainstem	N 40° 37.233 W 105° 49.098
070PJW	Poudre at Hwy14 crossing (Big South Trailhead)	Above confluence Joe Wright Creek	N 40° 38.074 W 105° 48.421
060LRT	Laramie River at Tunnel at Hwy 14 crossing	Laramie River diversion water	N 40° 40.056 W 105° 48.067
050PBR	Poudre below Rustic	Midpoint between Laramie River Tunnel and South Fork; impacts to river from Rustic	N 40° 41.967 W 105° 32.476
040SFM	South Fork at bridge on Pingree Park Rd. *Discontinued in 2015*	Only access point on South Fork; South Fork water quality differs from main stem	N 40° 37.095 W 105° 31.535
041SFC	South Fork above confluence with Mainstem	Capture 15% more watershed area than SFM	
030PSF	Poudre below confluence with South Fork - Mile Marker 101	Below confluence with South Fork	N 40° 41.224 W 105° 26.895
020PNF	Poudre above North Fork 1/2 mile upstream from Old FC WTP#1	Represents water diverted at Munroe Tunnel and at Old FC WTP #1	N 40° 42.087 W 105° 14.484
010PBD	Poudre at Bellvue Diversion	Greeley WTP Intake	N 40° 39.882 W 105° 12.995
NORTH FORK			
280NDC	North Fork above Halligan Reservoir; above confluence with Dale Creek	Inflow to Halligan Reservoir	N 40° 53.852' W 105° 22.556'
270NBH	North Fork at USGS gage below Halligan Reservoir	Outflow from Halligan Reservoir	N 40° 52.654' W 105° 20.314'
260NRC	North Fork above Rabbit Creek	Main stem North Fork above Rabbit Creek; downstream of Phantom Canyon	N 40° 49.640 W 105° 16.776
250RCM	Rabbit Creek Mouth	Tributary to North Fork; drainage area includes agricultural/grazing lands; significant flows late spring to early summer only	N 40° 48.615 W 105° 17.146
240SCM	Stonewall Creek Mouth	Tributary to North Fork; drains area east of Hwy 287	N 40° 48.458 W 105° 15.195
230PCM	Lone Pine Creek Mouth	Tributary to North Fork; drainage area includes Red Feather Lakes; significant flows late spring to early summer only	N 40° 47.696 W 105° 17.231
220NFL	North Fork at Livermore	At USGS gage	N 40° 47.269 W 105° 15.130
210SER	Seaman Reservoir *Discontinued in 2015*	Reservoir profiles; impacts to water quality from nutrient loadings	N 40° 42.274 W 105° 14.210
200NFG	North Fork below Seaman Reservoir	At gage below Seaman Res; sample before flow enters Poudre main stem	N 40° 42.143 W 105° 14.064

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.	
Ortho-Phosphorus (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
Microbiological 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
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

2018 Upper Cache la Poudre Water Quality Monitoring Program

Mainstem Cache la Poudre River

	Apr 9	Apr 23	May 7	May 21	Jun 4	Jun 18	Jul 16	Aug 13	Sep 10	Oct 15	Nov 12
CHR	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
BMR[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	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
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,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,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,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,N	E,F,GM,I,N	E,F,GM,I,N

North Fork Cache la Poudre River

	Apr 10	Apr 24	May 8	May 22	Jun 5	Jun 19	Jul 17	Aug 14	Sep 11	Oct 16	Nov 13
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