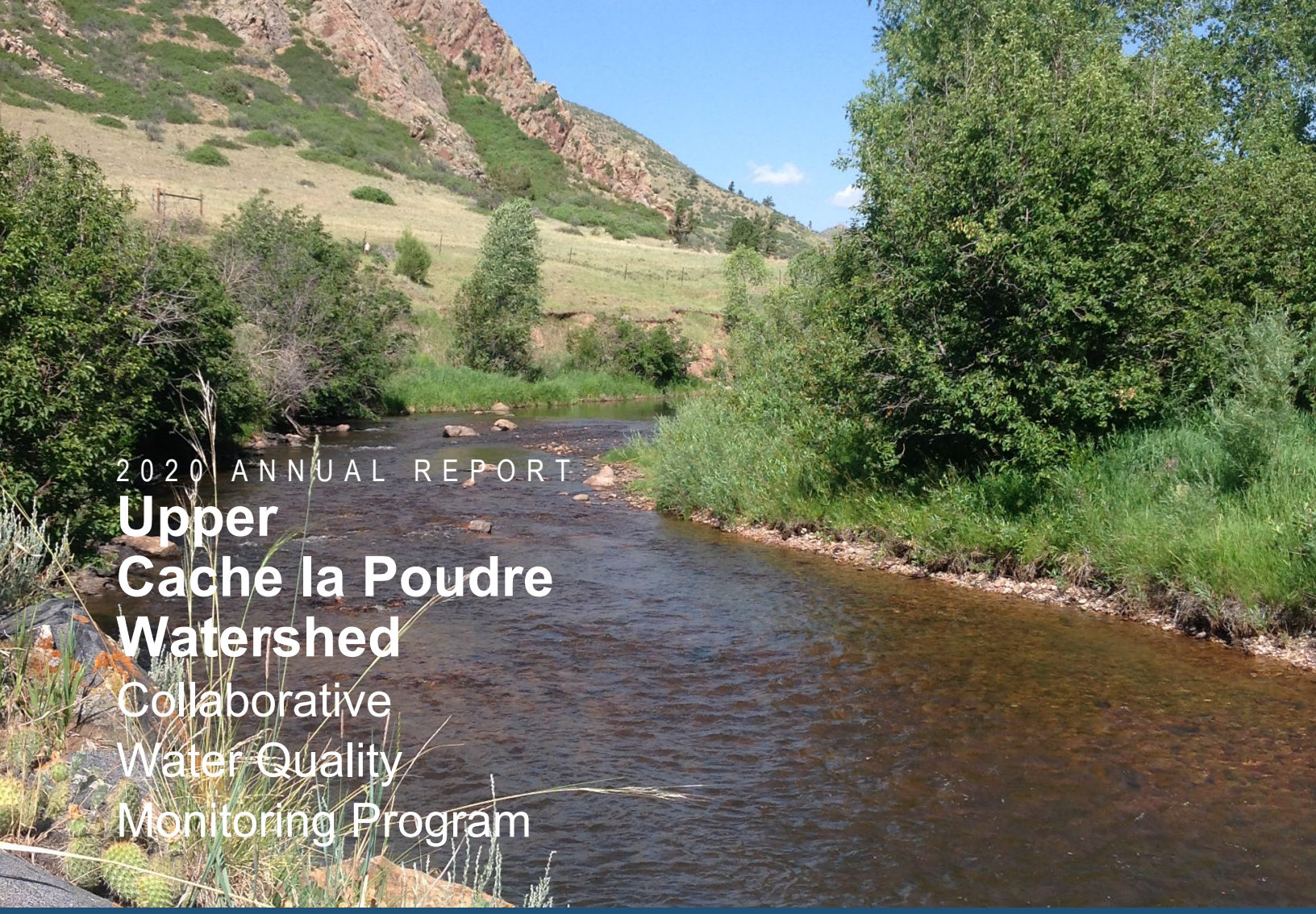

2020 ANNUAL REPORT

Upper Cache la Poudre Watershed

Collaborative Water Quality Monitoring Program

June 8, 2021

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

PREPARED BY:
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City of Fort Collins Utilities

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, 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 2020 water 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 2020 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.

Record breaking temperatures and below average precipitation throughout the spring and early summer accelerated the timing and duration of snowmelt runoff. As a result, peak streamflow was higher than average and occurred nearly ten days earlier than expected. Record breaking temperatures and extremely dry weather persisted into summer and through the fall, which resulted in streamflows that were well below average for much of the summer and fall.

The Upper CLP remains a high-quality drinking water supply for the Cities of Fort Collins and Greeley and surrounding communities...

In general, concentrations for most parameters were within the expected baseline range of variability and no significant water quality concerns were identified. 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 near neutral pH levels.

A shift in the timing and duration of snowmelt runoff and associated patterns in streamflow impacted water quality. The typical water quality changes observed during snowmelt runoff were measured earlier than normal due to warmer weather hastening snowmelt runoff. In addition, these changes in water quality were shorter in duration due to the abbreviated runoff period. After runoff, precipitation and streamflows were well below average, resulting in higher concentrations of many constituents as compared to baseline concentrations.

The Cameron Peak Fire ignited on Thursday, August 13th, near Chambers Lake in the upper elevations of CLP watershed near Cameron Pass. It is considered the largest wildfire in Colorado's history, burning just under 209,000 acres across both the Cache la Poudre and Big Thompson watersheds. No immediate impacts to drinking water quality or water treatment operations were observed; however, emerging trends will be important to monitor into the future to inform water treatment operations, track watershed health, and evaluate the impacts of the Cameron Peak Fire on this important water supply.

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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
°C	degrees Celsius
PBD	Poudre River at the Bellvue Diversion (key monitoring site)
PBR	Poudre River below Rustic (key monitoring site)
PJW	Poudre River above the confluence with Joe Wright Creek (key monitoring site)
PNF	Poudre River above the North Fork (key monitoring site)
PSF	Poudre River below confluence with South Fork (key monitoring site)
ppt	parts per trillion
SCWTA	Soldier Canyon Water Treatment Authority
SNOTEL	Snow telemetry network
SWE	Snow water equivalent
T&O	Taste & Odor
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
µg/L	micrograms per liter
µS/cm	microSeimens per centimeter
USGS	United States Geological Survey
WTP	Water Treatment Plant

1.0 INTRODUCTION

1.1 BACKGROUND

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

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

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

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

https://www.fcgov.com/utilities/what-we-do/water/water-quality/source-water-monitoring/water-quality-reports .

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

1.2 WATERSHED DESCRIPTION AND SAMPLING LOCATIONS

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

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

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

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

1.3 SAMPLING SCHEDULE AND PARAMETERS

The sampling frequency for the Program was determined based on both statistical performance and cost considerations. Parameters were selected based on analyses of historical data and aim to provide the best information possible within current budgetary constraints. Complete discussions of parameter selection and sampling frequency are provided in Sections 5.3 and 5.4, respectively, of the Program design document by Billica, Loftis and Moore (2008). In 2020, both COVID-19 and the Cameron Peak Fire impacted sampling frequency and operations of the UCLP Monitoring Program. The Cameron Peak Fire had the biggest impact on Mainstem sampling, especially upstream of the City of Fort Collins' diversion (PNF). Data analysis for these sites may be skewed due to missing data in the spring and fall when these impacts were most detrimental. The annual sampling schedule is provided in Attachment 4 of this report.

1.4 SAMPLE COLLECTION AND ANALYSIS

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

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

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

1.5 SCOPE OF 2020 ANNUAL REPORT

This annual report summarizes climate and hydrology in the Upper CLP watershed over the 2020 water year and water quality data collected as part of the Upper CLP Collaborative Water Quality Monitoring Program. For the purpose of this report, the water year is defined as

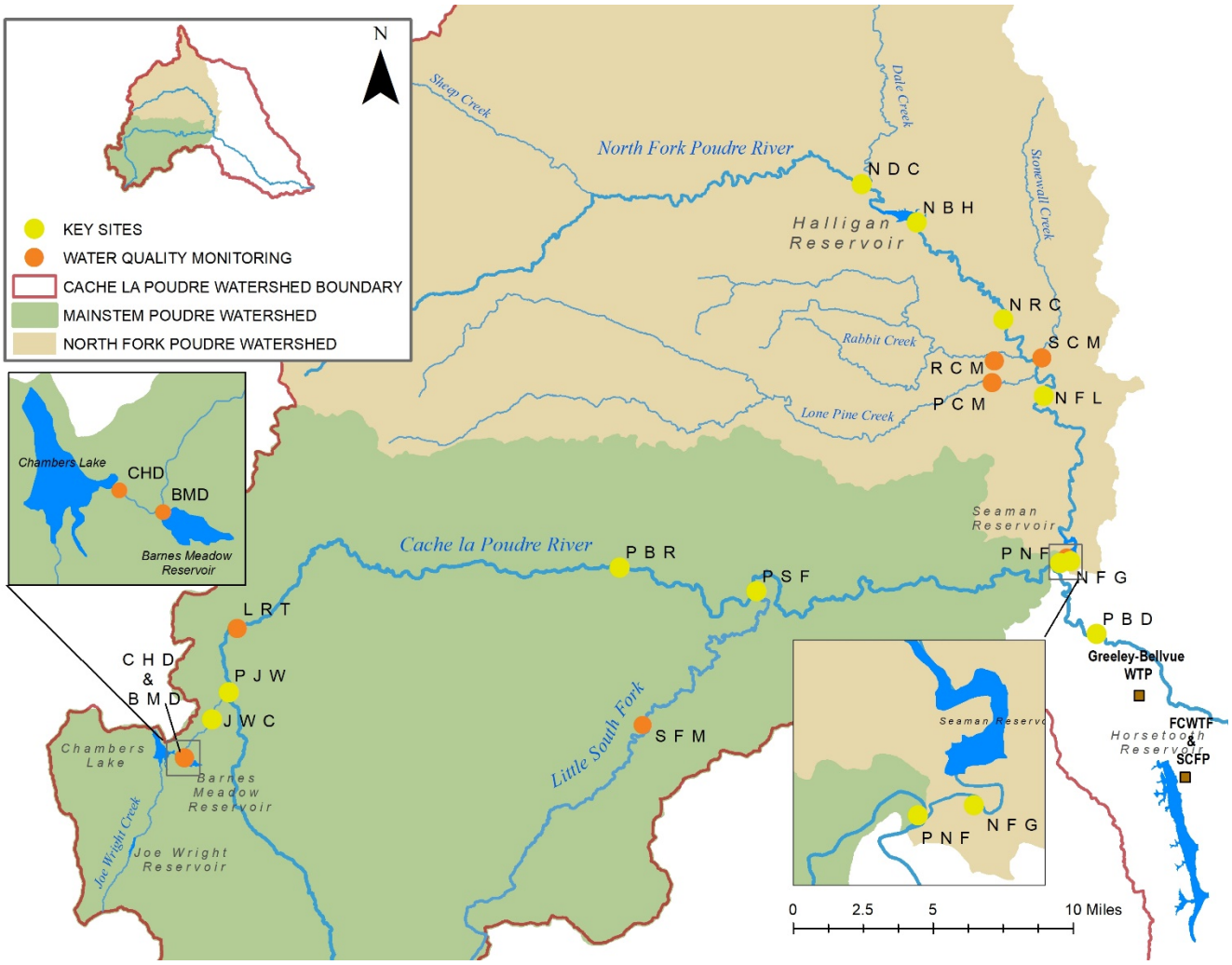

Figure 1.1 – Map of the Upper CLP collaborative water quality monitoring network.

December 1, 2019 to November 30, 2020. 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 2020 to baseline conditions, defined as the period of record from 2008 to 2012.

1.6 CAMERON PEAK WILDFIRE

The Cameron Peak wildfire ignited on Thursday, August 13th, near Chambers Lake in the upper elevations of CLP watershed near Cameron Pass. The Cameron Peak wildfire is the largest wildfire in Colorado's history, burning just under 209,000 acres across both the Cache la Poudre and Big Thompson watersheds.

Several long-term water quality monitoring sites associated with UCLP Collaborative Water Quality Monitoring Program are located either within or downstream of the area impacted by the wildfire. Water quality data collected as part of this monitoring program were very useful in understanding the impacts from the 2012 High Park Fire on water quality as well as watershed recovery. Water quality impacts that were observed following the High Park Fire and that can be anticipated from the Cameron Peak Fire include:

1) Abrupt changes in turbidity and suspended sediment, especially during and following storm events and snowmelt runoff.
2) Elevated background (non-storm event) concentrations in alkalinity, hardness, and total dissolved solids.
3) Increased background (non-storm event) concentrations in nutrients.
4) Elevated turbidity, total organic carbon, nutrients, and metals (dissolved and total) during snowmelt runoff and storm events.

During the winter of 2020-2021, partners within the UCLP Collaborative Water Quality Monitoring Program will determine whether adding additional water quality sampling study locations would be useful for monitoring post-fire impacts on water quality from the Cameron Peak wildfire.

2.0 HYDROLOGY & CLIMATE

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

Hydrologic and Climatic Data Sources

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

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

Evaluating annual and seasonal trends

Average monthly mean air temperature, monthly total precipitation and total monthly streamflow volume for the 2020 water year are compared to the average calculated over the baseline period of record from 2008 to 2012. Seasonal statistics were calculated for winter (DJF), spring (MAM), summer (JJA), and fall (SON).

2.1 AIR TEMPERATURE

The average mean air temperature in 2020 was 36.1°F and measured 1.4°F warmer than baseline (**Table 2**). The water year ranked as the 6th warmest on record (31 years; 1990 to 2020) at the Joe Wright SNOTEL. Temperature was cooler than baseline over the winter season and warmer than baseline over the spring, summer and fall seasons.

The average mean air temperature over the winter season was 19.0°F and measured 0.6°F cooler than baseline (**Table 2**). Temperature in the months of December and January measured 2.4°F and 1.4°F warmer than baseline, respectively, and ranked as the 4th and 6th warmest on record. In contrast, temperature in the month of February measured 2.0°F cooler than baseline (**Figure 2.1**), which ranked as the 9th coldest February on record. Despite the cooler temperatures in February, the winter 2020 season ranked as the 11th warmest winter on record.

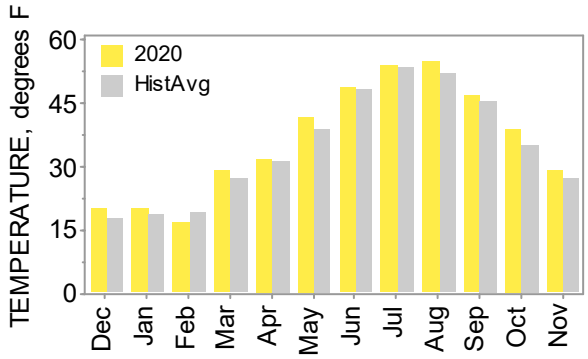

Figure 2.1 –Monthly mean air temperature compared to baseline air temperature measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

The average mean air temperature over the spring season was 34.3°F and measured 1.8°F warmer than baseline (**Table 2**). The months of March, April and May measured 2.0°F, 0.4°F and 3.0°F warmer than baseline and ranked as the 5th, 12th and 2nd warmest on record **(Figure 2.1**). Due to the notably warmer temperatures from March through April, the spring 2020 season ranked as the 4th warmest spring on record.

The average mean air temperature over the summer season was 52.7°F and measured 1.2°F warmer than baseline (**Table 2**). The months of June and July measured 0.4°F warmer than baseline and ranked as the 11th and 7th

Table 2 – Seasonal summary statistics for temperature, precipitation, and streamflow in Upper CLP watershed in 2020 compared to baseline (period of record is 2008 – 2012).

Season	Period of Record	Temperature (deg F)		Precipitation (in)		Streamflow (acre-ft)	
		Average	*Departure*	*Total*	*% Average*	*Total*	*% Average*
Winter	2020	19.0	0.6	15.8	125%	8,896	117%
	Baseline	18.4		12.7		7,602	
Spring	2020	34.3	1.8	11.5	77%	62,765	132%
	Baseline	32.5		15.0		47,547	
Summer	2020	52.7	1.2	4.5	67%	113,088	67%
	Baseline	51.5		6.7		168,506	
Fall	2020	38.3	2.1	6.5	59%	8,616	67%
	Baseline	36.3		11.0		12,877	
Annual (WY)	2020	36.1	1.4	38.3	84%	193,365	82%
	Baseline	34.7		45.3		236,531	

warmest on record. The month of August measured 2.8°F warmer than baseline, which ranked as the hottest August on record **(Figure 2.1**). Although the months of June and July were only slightly warmer than baseline, the summer 2020 season ranked as the 2nd warmest summer on record.

The average mean air temperature over the fall season was 38.3°F and measured 2.1°F warmer than baseline (**Table 2**). The months of September, October and November measured 1.2°F, 3.6°F and 1.8°F warmer than baseline and ranked as the 7th, 3rd, and 6th warmest on record **(Figure 2.1**). The exceedingly warm temperatures continued through the fall months and the fall 2020 season ranked as the 2nd warmest fall on record.

2.2 PRECIPITATION

Total Precipitation

Total precipitation over the 2020 water year was 84% of baseline with a total of 38.3 inches measured at the Joe Wright SNOTEL (**Table 2**). Precipitation measured above baseline over the winter season and below baseline over the spring, summer and fall seasons.

The total precipitation measured over the winter season was 125% of baseline and totaled 15.8 inches (**Table 2**). Precipitation measured over the months of December and January was near baseline at 119% and 79%, respectively. The month of February was the wettest winter month over the 2020 season and measured 179% of baseline (**Figure 2.2**). The month of February ranked as the 2nd wettest February on record (1979 to 2020; 41 years) and the winter 2020 season ranked as the 6th wettest winter on record.

The total precipitation measured over the spring season was 77% of baseline and totaled 11.5 inches (**Table 2**). The highest precipitation totals were observed over the month of April, as expected based on the historical record; however, the month of April measured only 67% of baseline. The month of March had normal precipitation and measured 99% of baseline. The month of May had the lowest precipitation total over the spring season and measured 73% of baseline (**Figure 2.2**). The spring 2020 season ranked as the 9th driest spring on record.

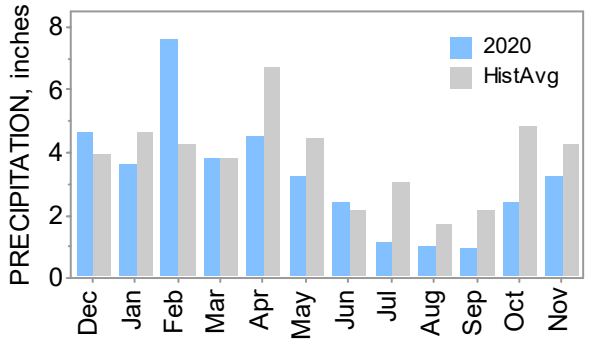

Figure 2.2 – Monthly precipitation totals compared to baseline totals measured at the Joe Wright Snow Telemetry Station near Cameron Pass.

The total precipitation measured over the summer season was 67% of baseline and totaled 4.5 inches (**Table 2**). The highest precipitation was measured over the month of June with a total of 2.4 inches (114% of baseline). The months of July and August were notably dry and measured 37% and 60% of baseline, respectively. There was less precipitation measured over these two months combined compared to the month of June. The months of July and August ranked as the 6th and 5th driest on record with only 2.1 inches of precipitation recorded at the Joe Wright SNOTEL over the two-month period. The summer 2020 season ranked as the 9th driest summer on record.

Exceptionally dry conditions persisted into the fall season. The total precipitation measured over the fall season was 59% of baseline and totaled 6.5 inches (**Table 2**). The month of September was the driest fall month and measured 43% of baseline with less than 1.0 inch of precipitation recorded. The month of September ranked as the 4th driest September on record. The total precipitation over the month of October was 50% of baseline and ranked as the 10th driest October on record. Conditions improved slightly in the month November and precipitation measured 75% of baseline. Despite this slight improvement, the significant precipitation deficit observed over the months of September and October led to the 2nd driest fall season on record (**Figure 2.2**).

Cache la Poudre Basin Snowpack

Snow water equivalent (SWE) data were analyzed from five NRCS SNOTEL stations to evaluate differences across the basin as well as between years (**Figure 2.3**). Deadman Hill and Black Mountain SNOTELs represent snow conditions in the North Fork watershed; Hourglass Lake SNOTEL represents conditions in the South Fork watershed; and Joe Wright and Long Draw SNOTELs represent conditions in the Upper Mainstem CLP watershed (**Figure 2.3**).

The maximum amount of water contained in the snowpack, referred to as peak SWE, across the entire Cache la Poudre Watershed was 116% of the expected peak SWE based on the long-term median (1981-2010). The Mainstem and North Fork Poudre basins were slightly above the long-term median at 113% and 112%, while the South Fork was well above the long-term median at 138% (**Figure 2.3**).

The peak SWE measured at the Joe Wright SNOTEL was observed on April 28th, which was slightly earlier than normal. Above average temperatures and dry weather throughout the spring and summer accelerated snowmelt and shortened the snow accumulation season by approximately one month. By June 1st, the snowpack measured only 54% of normal at the Joe Wright SNOTEL. The snowpack at the Joe Wright SNOTEL was completely melted by June 13th – nearly one month earlier than normal.

2.3 STREAMFLOW

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

Mainstem Cache la Poudre River

The total volume of water that flowed down the Mainstem CLP River over the 2020 water year (as measured at the Canyon Mouth stream gage) was 193,365 acre-feet, which was 82% of baseline (**Table 2**). Streamflow was above baseline over the winter and spring seasons and below baseline over the summer and fall seasons.

Streamflow over the winter season measured 117% of baseline and totaled 8,896 acre-feet (**Table 2**). The month of December measured near baseline at 107%. Streamflow over the months of January and February measured 121% and 127% of baseline, respectively. The highest streamflow contribution over the winter season was measured in the month of January at 3,183 acre-feet.

Streamflow over the spring season measured 132% of baseline and totaled 62,765 acre-feet (**Table 2**). Streamflow remained higher than baseline in the months of March, April, and May at 122%, 111% and 136%, respectively. Consistent with the historical trends, the highest streamflow contribution over the spring season was measured in the month of April at 52,270 acre-feet (**Figure 2.4).**

Streamflow over the summer season measured 67% of baseline and totaled 113,088 acre-feet (**Table 2**). Streamflow in the month of June was 84% of baseline. Streamflow in the months of July and August was well below baseline and measured 41% and 45%, respectively (**Figure 2.4).** The month of August ranked as the 7th lowest August streamflow on record (138 years). Peak streamflow was measured on June 1st at 3,020 cubic feet per second.

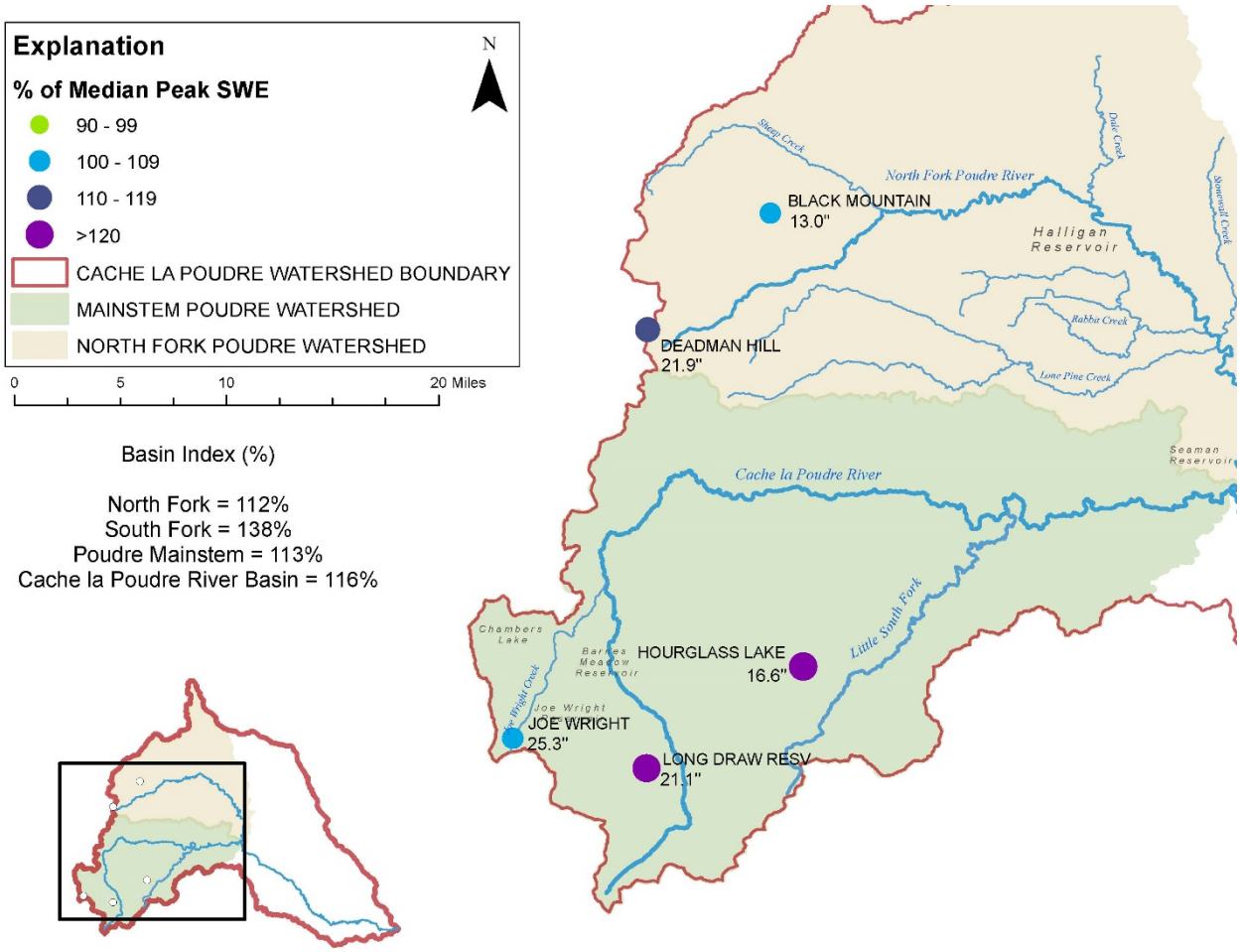

Figure 2.3 – Locations of SNOTEL and snow course monitoring sites in the UCLP and percent of median peak snow water equivalent (SWE) in for the 2020 water year.

The peak streamflow in 2020 was 151% of the historical average peak streamflow and occurred nearly ten days earlier than average. Consistent with the historical trends, the highest streamflow contribution over the summer season was measured in the month of June at 84,984 acre-feet (**Figure 2.4).**

Streamflow over the fall season measured 67% of baseline and totaled 8,616 acre-feet (**Table 2**). Streamflow over the months of September and October was notably lower and measured 57% and 59% of baseline, respectively. The month of September ranked as the 7th lowest September streamflow on record. Streamflow conditions improved in November and measured 88% of baseline. As expected, the highest fall streamflow contributions were measured over the month of September (**Figure 2.4).**

North Fork Cache la Poudre River

The total volume of water that flowed down the North Fork CLP River near Livermore (NFL) over the 2020 water year was 19,294 acre-feet, which was 48% of baseline (**Figure 2.4**). Streamflow was below baseline in the winter, spring and summer, and near baseline in the fall.

Streamflow measured over the winter season was 51% of baseline with a total of 925 acre-feet of water. All winter months were well below baseline at 60%, 47% and 45% for the months of December, January, and February.

Streamflow measured over the spring season was 74% of baseline and totaled 12,155 acre-feet. The months of March and May were below baseline at 87% and 59%,

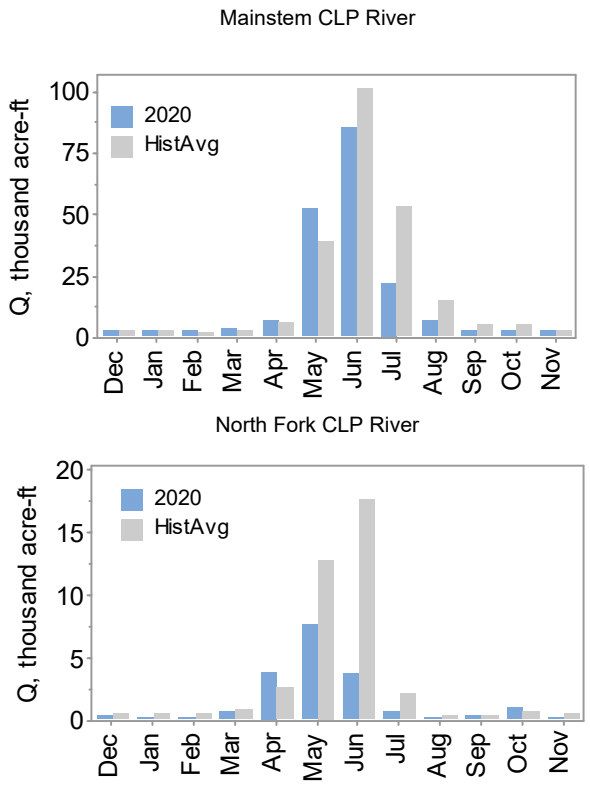

Figure 2.4 –Total monthly streamflow in 2020 compared to average total monthly mean streamflow measured on the Mainstem CLP River near the Canyon Mouth (top) and North Fork CLP river near Livermore (bottom).

respectively. The month of April was above baseline at 141% (**Figure 2.4).**

Streamflow measured over the summer season was 23% of baseline and totaled 4,578 acre-feet. All summer months were well below baseline at 21%, 32% and 60% for the months of June, July, and August (**Figure 2.4).**

Streamflow measured over the fall season was 108% of baseline and totaled 1,628 acre-feet. The months of September and October measured near baseline at 101% and 93%, respectively, while the month of November measured below baseline at 65% (**Figure 2.4).**

Streamflow Contributions

There are several tributaries, diversions, and water storage reservoirs that contribute to the overall streamflow and water quality on the Mainstem CLP River above the North Fork. The two highest elevation trans-mountain 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 2020 water contributions to the Mainstem CLP River above the Munroe Tunnel is presented in **Table 3**.

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

The combined volume of water from the Mainstem and North Fork, as measured at the City of Greeley's diversion on the CLP River was 204,245 acre-feet (**Figure 2.5**). The North Fork contributed 11% (21,556 acre-feet) of the total volume and the Mainstem contributed 89% (182,688 acre-feet) of the total volume (**Figure 2.5**). Approximately 10,269 acre-feet of water was diverted at Poudre Valley Canal upstream of the City of Greeley's Diversion.

An estimated 260,700 acre-feet of water flowed down the Poudre River above the Munroe Tunnel and North Fork in 2020 and a combined 78,012 acre-feet of water was diverted through the Munroe and City of Fort Collins diversions.

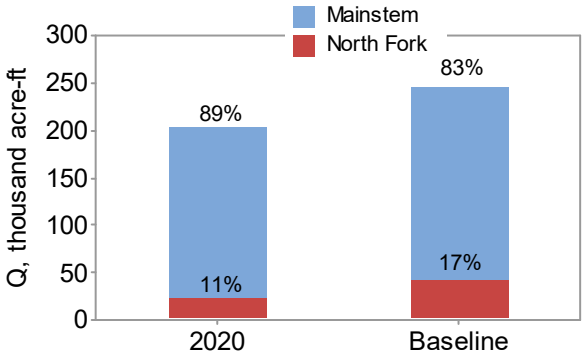

Figure 2.5 – Proportion of average Mainstem and North Fork contributions at PBD in 2020 compared to average.

Table 3 – Tributary contributions by month to the Mainstem Cache la Poudre River above the Munroe Tunnel in WY2020. Contributions highlighted in red indicated the greatest monthly contribution to the Mainstem. Note: AF = acre-feet.

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

Month	Barnes Meadow		Chambers Lake		Laramie River Tunnel		Long Draw Reservoir		Little South Fork Poudre		Big South* & Mainstem Tributaries		Poudre above Munroe	
	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%	AF	%
Dec	296	9%	-	-	-	-	-	-	-	-	3,070	91%	3,366	------
Jan	295	8%	-	-	-	-	-	-	-	-	3,483	92%	3,777	------
Feb	267	9%	-	-	-	-	-	-	-	-	2,845	91%	3,112	------
Mar	344	9%	-	-	-	-	-	-	-	-	3,612	91%	3,956	------
Apr	-	-	-	-	-	-	-	-	165	3%	5,990	97%	6,155	------
May	-	-	3,498	6%	3,729	7%	937	2%	7,034	13%	40,677	73%	55,875	------
Jun	-	-	12,186	13%	10,788	11%	10,790	11%	12,859	13%	48,801	51%	95,424	------
Jul	-	-	4,967	15%	2,888	9%	9,025	28%	6,396	20%	9,418	29%	32,694	------
Aug	-	-	2,975	20%	-	-	5,902	39%	3,558	24%	2,663	18%	15,098	------
Sep	-	-	981	16%	-	-	1,929	31%	1,057	17%	2,220	36%	6,187	------
Oct	-	-	2,384	49%	-	-	-	-	466	10%	1,980	41%	4,830	------
Nov	-	-	1,426	5%	-	-	-	-	-	-	28,801	95%	30,227	------
Total	**1,202 (0.5%)**		**28,417 (11%)**		**17,405 (7%)**		**28,583 (11%)**		**31,534 (12%)**		**153,559 (59%)**		**260,700**	

3.0 SPATIAL TRENDS IN UPPER CACHE LA POUDRE WATER QUALITY

Spatial water quality trends discussed in the 2020 Annual Report focus primarily on monitoring sites located on the Mainstem and North Fork CLP Rivers that are considered representative of water quality conditions throughout the Mainstem and North Fork CLP watersheds. The following lists key sites from upstream to downstream:

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

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

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

Presentation of Results

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

Selected Variables and Monitoring Sites

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

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

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

3.1 FIELD PARAMETERS

Water Temperature

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

Water temperature throughout the Mainstem and North Fork CLP watersheds was above baseline in 2020 at all monitoring sites (**Figure 3.1**).

Mainstem

Water temperature increased with decreasing elevation in the Mainstem over the monitoring season and ranged from a minimum temperature below 1°C at most sites to a maximum temperature of 19.6°C at the City of Greeley's Diversion (PBD). Minimum water temperatures were slightly above or near baseline at all monitoring sites. Median water temperatures were above baseline at all monitoring sites. The largest departures from baseline were measured from Joe Wright Creek (JWC) downstream to the Mainstem above Joe Wright Creek (PJW). Water temperature was nearly 4°C warmer at these sites in 2020. Median water temperatures at lower monitoring sties from the Mainstem below the South Fork (PSF) to the City of

Greeley's Diversion (PBD) were around 2°C warmer than baseline. Maximum water temperatures were cooler than baseline at all monitoring sites.

North Fork

Water temperature on the North Fork ranged from a minimum temperature near 0°C on the North Fork above Dale Creek (NDC) to a maximum temperature of 20.7°C on the North Fork at Livermore (NFL). Minimum water temperatures on the North Fork were below or near baseline from the North Fork above Dale Creek (NDC) to the North Fork below Halligan Reservoir (NBH) and warmer than baseline from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Median water temperatures on the North Fork were 2 - 3°C warmer than baseline at all sites. The largest departures from baseline were observed on the North Fork below Halligan and Seaman Reservoirs (NBH and NFG, respectively). Maximum water temperatures were below baseline at all sites except on the North Fork below Halligan Reservoir (NBH). The maximum temperature at this site was 1.4°C warmer than the baseline maximum.

pH

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

pH values throughout the Mainstem and North Fork CLP watersheds were near baseline in 2020 at most monitoring sites (**Figure 3.1**).

Mainstem

pH values along the Mainstem were comparable across most monitoring sites, except at the City of Greeley's Diversion (PBD) where pH values were higher than sites located upstream on the Mainstem. pH values ranged from 6.80 in the Mainstem above Joe Wright Creek (PJW) to 8.54 at the City of Greeley's Diversion (PBD). In general, pH values at the higher elevation monitoring sites were lower compared to mid- and lower elevation monitoring sites. Minimum pH values were notably higher than baseline at all monitoring sites. Median pH values were below baseline in Joe Wright Creek (JWC) and in the Mainstem above Joe Wright Creek (PJW). pH values were near or above baseline from the Mainstem below Rustic (PBR) downstream to City of Greeley's Diversion (PBD). The largest departure from the baseline median pH was observed at the City of Greeley's diversions (PBD). The median pH at this monitoring site was 8.02 compared to the baseline median of 7.56. Maximum pH values were below baseline at all monitoring sites.

North Fork

pH in the North Fork was slightly more alkaline compared to the Mainstem especially in the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). pH values in the North Fork ranged from a minimum pH of 6.92 in the North Fork above Halligan Reservoir (NDC) to 8.65 in the North Fork above Rabbit Creek (NRC). There was slightly more variability between monitoring sites along the North Fork, specifically from the North Fork below Halligan Reservoir (NBH) downstream to the North Fork above Rabbit Creek (NRC). pH continued to increase moving downstream to the North Fork near Livermore (NFL) likely due to inputs from North Fork tributaries, Stonewall Creek (SCM), Rabbit Creek (RCM) and Lone Pine Creek (PCM). Minimum pH values were notably higher than baseline at all monitoring sites except in the North Fork below Halligan Reservoir (NBH). Minima pH values at this site were closer to the baseline minimum. Median pH was below baseline in the North Fork above Dale Creek (NDC) and below Halligan Reservoir (NBH). Median pH was above baseline from the North Fork below Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Maximum pH values were below baseline at all North Fork monitoring sites, except on the North Fork above Rabbit Creek (NRC). The maximum pH value at this site measured 8.65 compared to the baseline maximum of 8.47.

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

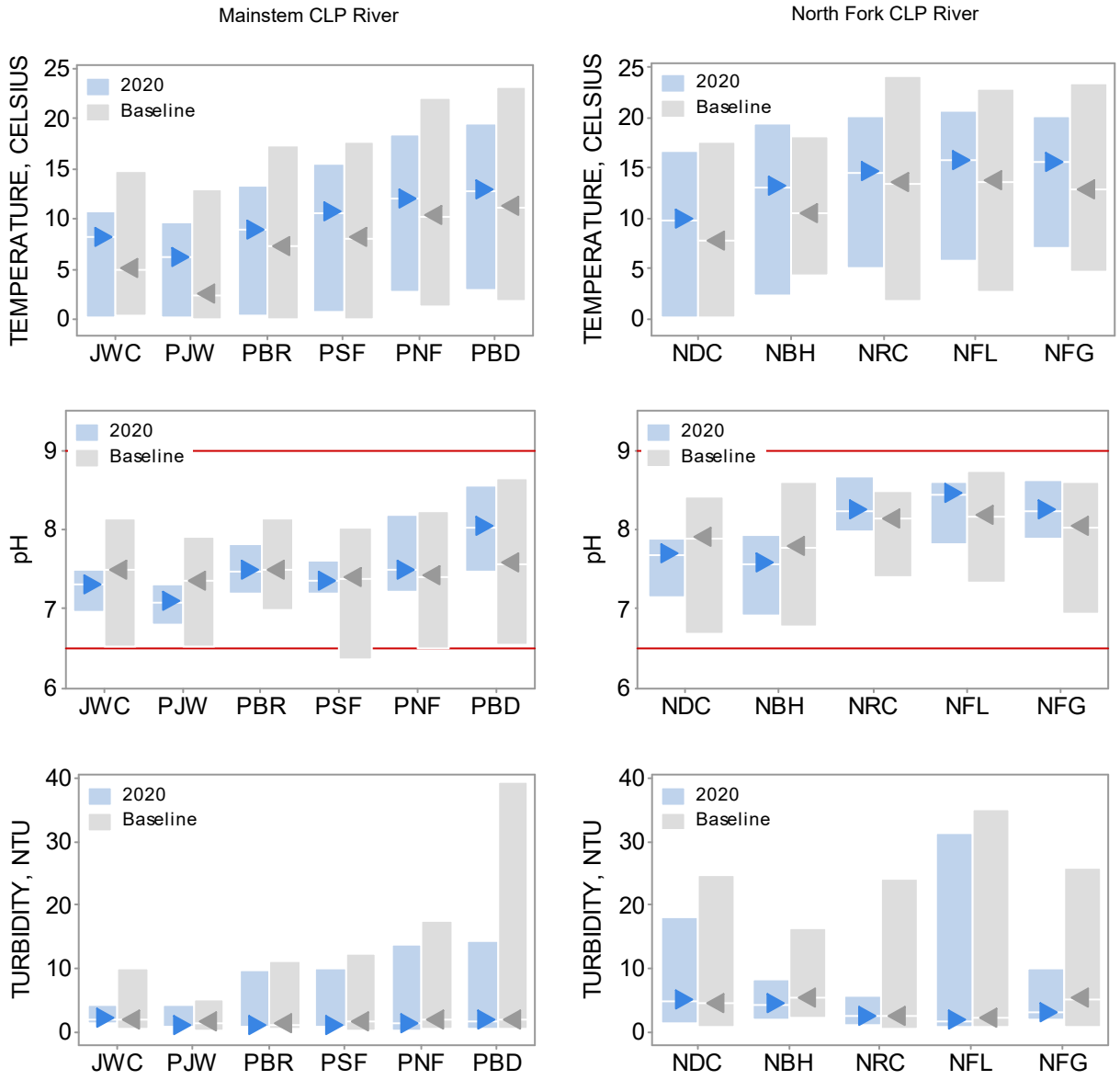

Figure 3.1 – Water temperature, pH, and turbidity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2020 compared to the baseline period of record. The red reference lines for pH indicate the Colorado Department of Public Health and Environment water quality standard to protect aquatic life.

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

Mainstem

Turbidity was consistently low in the Mainstem and ranged from a minimum of near 1 NTU at all monitoring sites to a maximum of 14.2 NTU at the City of Greeley's Diversion (PBD). Minimum and median turbidity values were near or slightly above baseline at all monitoring sites. As expected, median turbidity at all sites was below 2 NTU. Maximum

turbidity was lower than baseline at all monitoring sites. Higher variably was observed in turbidity across sites ranging from 4.3 NTU in the Mainstem above Joe Wright Creek (JWC) to 14.2 NTU at the City of Greeley's Diversion (PBD). In general, higher turbidity values were measured less frequently than lower turbidity values, which was consistent with baseline data.

North Fork

Turbidity was slightly higher in the North Fork compared to the Mainstem. Turbidity values ranged from a minimum of less than 2 NTU at all monitoring sites to a maximum of 31 NTU in the North Fork near Livermore (NFL). Minimum turbidity was near baseline at all monitoring sites. Median turbidity was at or below baseline at all monitoring sites. Turbidity was generally higher in the North Fork below Dale Creek (NDC) and below Halligan Reservoir (NBH) where median values were near 5 NTU. Median turbidity values from the North Fork above Rabbit Creek (NRC) to below Seaman Reservoir were lower and did not exceed 3 NTU. Maximum turbidity was notably lower than baseline at all monitoring sites except in the North Fork near Livermore (NFL). A maximum turbidity of 31 NTU was measured in April. This value was only 4 NTU lower than the maximum turbidity measured on the North Fork near Livermore (NFL) over the baseline period of record.

3.2 GENERAL PARAMETERS

Alkalinity, Hardness & Specific Conductance

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

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

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

Mainstem

Alkalinity, hardness and specific conductivity concentrations increased slightly from Joe Wright Creek (JWC) downstream to the City of Greeley's Diversion (PBD). Alkalinity concentrations ranged from 9.80 mg/L $CaCO_3$ to 66.8 mg/L $CaCO_3$; hardness concentrations ranged from 8.96 mg/L to 79.7 mg/L; and specific conductivity ranged from 20.9 µS/cm to 194.8 µS/cm. Minimum concentrations of these parameters were observed in the Little South Fork (SFC) and maximum concentrations were observed at the City of Greeley's Diversion (PBD). Minimum concentrations were above baseline at all monitoring sites. Median concentrations were below baseline from Joe Wright Creek (JWC) downstream to Mainstem below the South Fork (PSF) and above baseline at the City of Fort Collins' and City of Greeley's Diversions (PNF and PBD). Maximum concentrations were below baseline at all monitoring sites except at the City of Greeley's Diversion (PBD). The median and maximum concentrations from Joe Wright Creek (JWC) downstream to the Mainstem below the South Fork (PSF) were skewed toward lower values due to missing data (explained in Section 1.3) from the spring and fall seasons when concentrations of these constituents are typically elevated.

North Fork

A notable increase in alkalinity, hardness and specific conductivity concentrations was measured between the North Fork below Halligan Reservoir (NBH) to the North Fork above the confluence with Rabbit Creek (NRC). This change is likely associated with significant changes in streamflow downstream of the North Poudre Canal; groundwater and return flows from agricultural land use practices on the North Fork as it enters and passes through the Livermore Valley; and contributions from the North Fork tributaries, Rabbit Creek (RCM), Stonewall Creek (SCM) and Lone Pine Creek (PCM). Concentrations were similar from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG), although there was less variability in concentrations

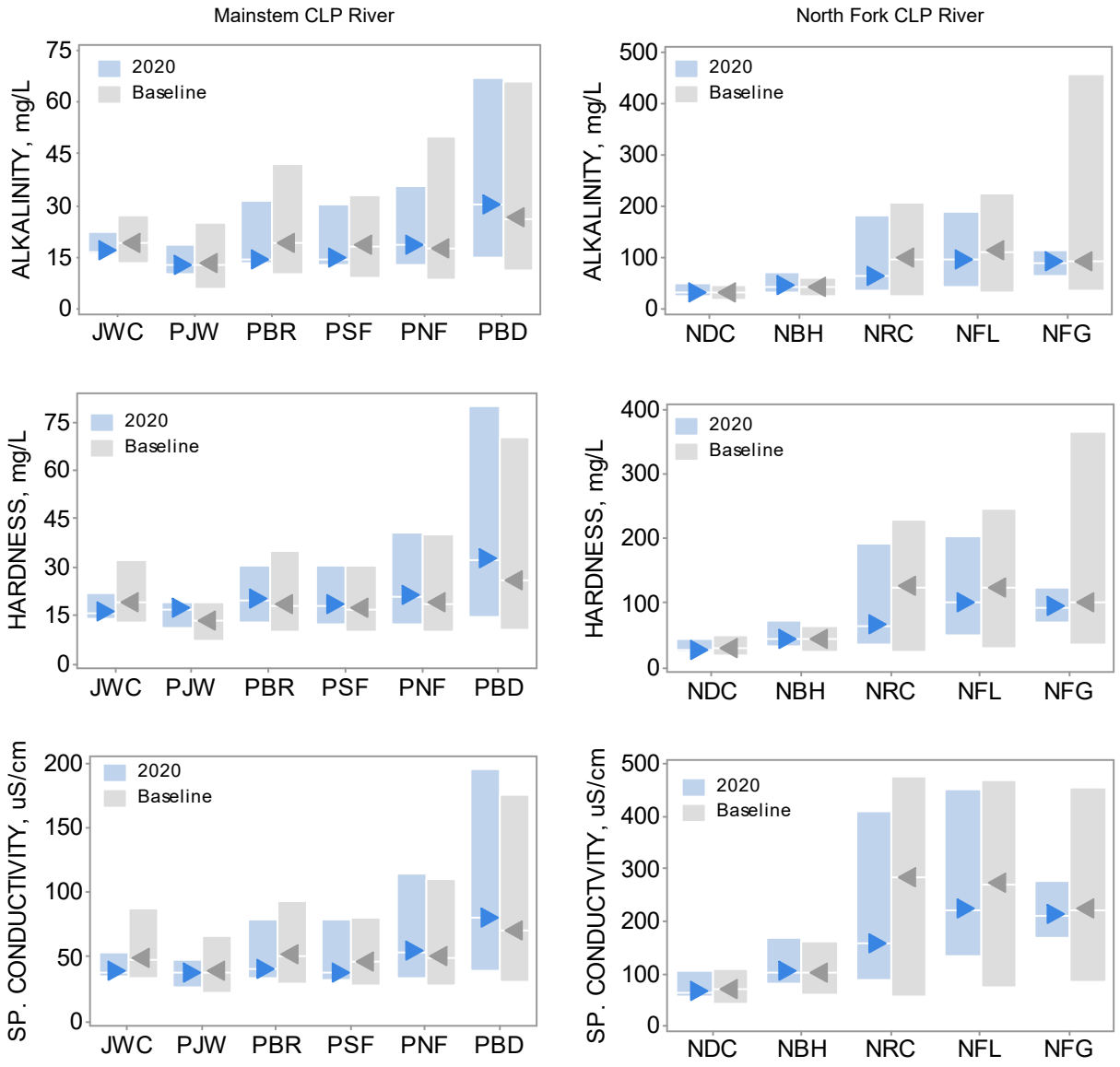

Figure 3.2 – Alkalinity, hardness and specific conductivity measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2020 compared to the baseline period of record.

observed in the North Fork below Seaman Reservoir (NFG). The lower concentrations observed in the North Fork above Rabbit Creek (NRC) and in the North Fork near Livermore (NFL) may be associated with lower groundwater contributions because of the substantial dry conditions observed throughout much of the monitoring season. Concentrations were generally higher in the North Fork tributaries, Rabbit Creek (RCM), Stonewall Creek (SCM) and Lone Pine Creek (PCM), and contributions from these tributaries did influenced water quality downstream in the North Fork near Livermore (NFL).

Alkalinity concentrations at key sites ranged from 23.4 mg/L $CaCO_3$ to 189.0 mg/L $CaCO_3$; hardness concentrations ranged from 22.7 mg/L to 204.0 mg/L; and specific conductivity ranged from 56.2 µS/cm to 449.6 µS/cm. Minimum concentrations were measured in the North Fork above Dale Creek (NDC) and maximum concentrations were measured in the North Fork near Livermore (NFL).

Minimum concentrations were above baseline at all monitoring sites. Median concentrations were near baseline above and below Halligan Reservoir (NDC and NHB) and below baseline from the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). Median concentrations were notably lower in the North Fork above Rabbit Creek (NRC). Maximum concentrations were below baseline at all monitoring sites except in the North Fork below Halligan Reservoir (NBH). Maximum concentrations were especially lower than baseline in the North Fork below Seaman Reservoir (NFG).

Total Dissolved Solids

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

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

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

Mainstem

Total dissolved solids were similar at all monitoring sites on the Mainstem except at the City of Fort Collins' and City of Greeley's Diversions (PNF and PBD) where total dissolved solids concentrations were generally higher. Total dissolved solids ranged from a minimum 14 mg/L in Joe Wright Creek (JWC) and in the Mainstem at the City of Fort Collins Diversion (PNF) to a maximum 110 mg/L at the City of Greeley's Diversion (PBD). Minimum total dissolved solids concentrations were near or lower than baseline at all monitoring sites. Minimum concentrations were notably lower than baseline at the City of Fort Collins' Diversion (PNF). Median and maximum total dissolved solids concentrations were near or below baseline from Joe Wright Creek (JWC) downstream to the Mainstem below the South Fork (PSF). Median concentrations at the City of Fort Collins' and City of Greeley's Diversions (PNF and PBD) were notably higher than baseline. Maximum total dissolved solids concentrations at the City of Fort Collins' Diversion (PNF) were much higher than baseline, while maximum concentrations at the City of Greeley's Diversion (PBD) were near baseline. The higher median and maximum concentrations at these sites were driven primarily by the spring (April – May) and fall (Sep – Oct) seasons when TDS concentrations were higher. Median and maximum concentrations from Joe Wright Creek (JWC) downstream to the Mainstem below the South Fork (PSF) were skewed toward lower values due to missing data (explained in Section 1.3) during this period.

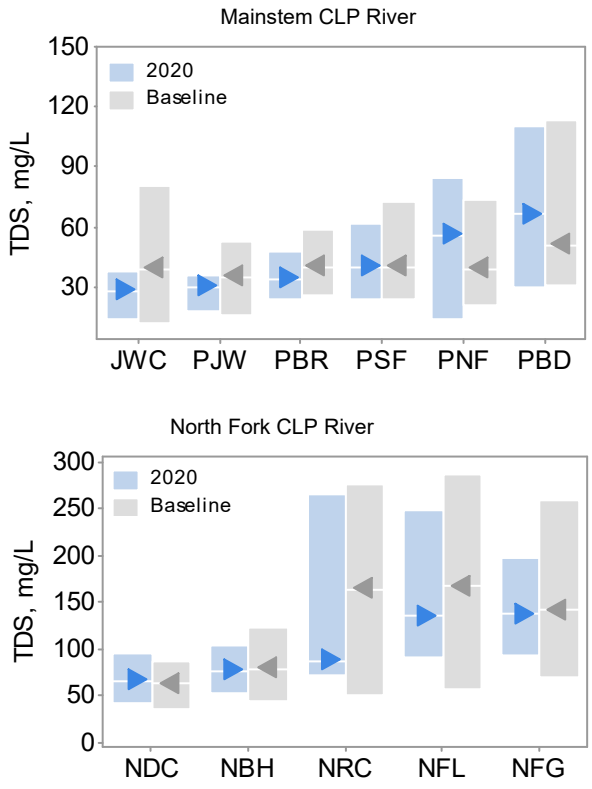

Figure 3.3 – Total dissolved solids (TDS) measured at key monitoring locations on the Mainstem CLP River (top) and North Fork CLP River (bottom) in 2020 compared to the baseline period of record.

North Fork

In general, total dissolved solids increased from the North Fork above Dale Creek (NRC) downstream to the North

Fork below Seaman Reservoir (NFG). Total dissolved solids concentrations increased between the North Fork above Rabbit Creek (NRC) and North Fork near Livermore (NFL) suggesting influence from the North Fork tributaries where total dissolved solids concentrations were generally higher. Total dissolved solids concentrations at key sites ranged from a minimum 42 mg/L in the North Fork above Dale Creek (NDC) to a maximum 248 mg/L on the North Fork near Livermore (NFL). There was a notable increase in the variability of total dissolved solids concentrations between the North Fork below Halligan Reservoir (NBH) and the North Fork above Rabbit Creek (NRC) downstream to the North Fork below Seaman Reservoir (NFG). This trend is likely associated with changes in hydrology below the North Poudre Canal, groundwater and return flow contributions and contributions from the North Fork tributaries. Minimum concentrations were above baseline at all monitoring sites. Median total dissolved solids concentrations were near baseline above and below Halligan Reservoir (NDC and NBH) and in the North Fork below Seaman Reservoir (NFG). Median concentrations on the North Fork above Rabbit Creek (NRC) to the North Fork near Livermore (NFL) were below baseline, especially in the North Fork above Rabbit Creek (NRC). The lower concentrations observed in the North Fork above Rabbit Creek (NRC) and in the North Fork near Livermore (NFL) may be associated with lower groundwater contributions because of the substantial dry conditions observed throughout much of the monitoring season. Maximum total dissolved solids concentrations were lower than baseline at all monitoring sites except in the North Fork above Halligan Reservoir (NDC).

3.3 TOTAL ORGANIC CARBON

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

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

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%

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

Mainstem

Total organic carbon concentrations were similar across most monitoring sites on the Mainstem and ranged from a minimum 1.68 mg/L to a maximum 10.5 mg/L in the Mainstem above Joe Wright Creek (PJW). Minimum total organic carbon concentrations were above or near baseline at all monitoring sites, except in the Mainstem above Joe Wright Creek (PJW) where the minimum concentration was less than the baseline minima. Minimum concentrations were less than 2 mg/L at all sites, except in Joe Wright Creek (JWC) and at the City of Greeley's Diversion (PBD) where concentrations were between 2 – 4 mg/L. Median total organic carbon concentrations were near baseline in Joe Wright Creek (JWC) and at the City of Fort Collins' and City of Greeley's Diversion (PBD and PNF). Median concentrations were below baseline from the Mainstem above Joe Wright Creek (PJW) downstream to the Mainstem below the South Fork (PSF). Median concentrations were between 2 – 4 mg/L at all sites except at the City of Greeley's Diversion (PBD) where the median concentration was slightly above 4 mg/L. Maximum total

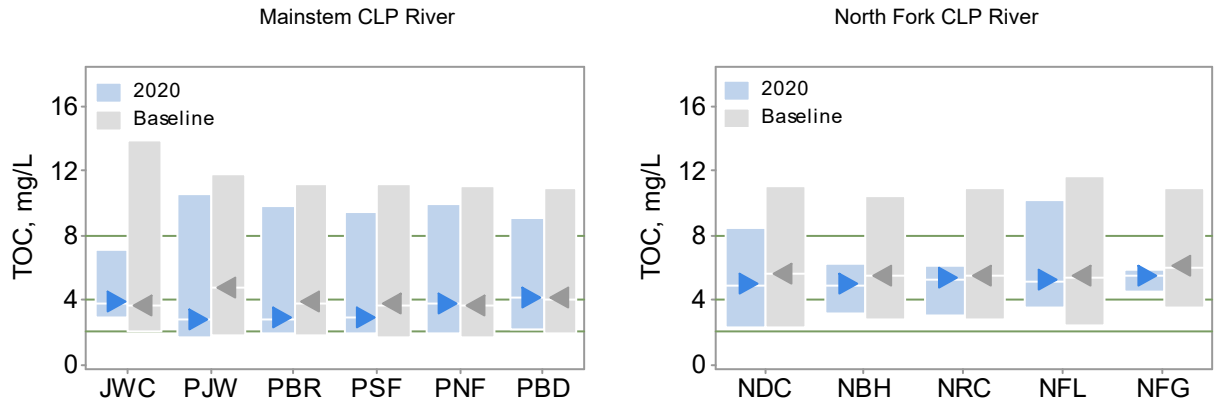

Figure 3.4 – Total organic carbon (TOC) measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2020 compared to the baseline period of record. The green reference lines indicate thresholds for TOC removal requirements set by the Environmental Protection Agency. Note that the removal requirements also consider raw water alkalinity concentrations.

organic carbon concentrations were lower than baseline at all monitoring sites. Maximum total organic carbon concentrations were measured in May at all sites and exceeded the 8 mg/L threshold at all sites, except in Joe Wright Creek (JWC).

North Fork

Total organic carbon concentrations were similar across most monitoring sites in the North Fork CLP River and ranged from a minimum 2.28 mg/L in the North Fork above Dale Creek (NDC) to a maximum 10.2 mg/L in the North Fork near Livermore (NFL). The North Fork above Dale Creek (NDC) and the North Fork near Livermore (NFL) had the greatest variability. The higher variability in the North Fork above Dale Creek (NDC) was likely associated with the more natural streamflow conditions above the water supply reservoirs. The highest total organic carbon concentrations were observed in Lone Pine Creek (PCM) and Rabbit Creek (RCM) during runoff, which slightly increased concentrations downstream in the North Fork near Livermore (NFL). Total organic carbon concentrations below Halligan and Seaman Reservoirs (NBH and NFG) were less variable. Minimum total organic carbon concentrations were higher than baseline at all monitoring sites and fell within the 2 – 4 mg/L removal requirement threshold except in the North Fork below Seaman Reservoir (NFG) where minimum concentrations were slightly above 4 mg/L. Median total organic carbon concentrations were below baseline at all monitoring sites and fell within the 4 – 8 mg/L removal requirement threshold. Maximum total organic carbon concentrations were lower than baseline at all monitoring sites, especially below Halligan and Seaman Reservoirs (NBH and NFG) and in the North Fork above Rabbit Creek (NRC). The maximum concentration of total organic carbon across all sites fell within the 4 – 8 mg/L threshold except in the North Fork above Dale Creek (NDC) and North Fork near Livermore (NFL) where maximum concentrations exceeded 8 mg/L.

3.4 NUTRIENTS

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

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

Nitrogen

Total nitrogen (TN) is the sum of organic (TKN) and inorganic (NO_3-N and NO_2-N) nitrogen. Inorganic forms of nitrogen are more readily available for plant uptake. TKN is a measure of ammonia plus organic nitrogen and

comprises the largest fraction of TN, with inorganic nitrogen representing a lesser fraction. In the calculation of TN (TKN + NO_3-N + NO_2-N), concentrations below their respective reporting limit were reported as half the reporting limit (Helsel and Hirsch, 2002).

Mainstem

Total nitrogen concentrations were similar across monitoring sites on the Mainstem (**Figure 3.5)**. Concentrations ranged from below the reporting limit (90 µg/L) in the Mainstem below Rustic and below the South Fork (PBR and PSF) to a maximum 900 µg/L at the City of Greeley's Diversion (PBD). Minimum total nitrogen concentrations were slightly higher than baseline (reporting limit) at all monitoring sites. Median total nitrogen concentrations were near or above baseline at all monitoring sites, except in the Mainstem below the South Fork (PSF). The largest departure from baseline was observed in the Mainstem above Joe Wright Creek (PJW). Median concentrations were still well below the interim water quality standard for total nitrogen of 1,250 µg/L at all monitoring sites. Maximum total nitrogen concentrations were below baseline at all monitoring sites.

Nitrate concentrations were measured below the reporting limit (40 µg/L) for most of the year at nearly all monitoring sites. As expected, the highest nitrate concentrations were observed in the Mainstem above Joe Wright Creek (PJW) and in the Mainstem below Rustic (PBR). Median nitrate concentrations at these sites measured 110 µg/L and 60 µg/L, respectively. Detectable concentrations were observed at most key sites in June during snowmelt runoff. The highest concentration (170 µg/L N) was measured in November in the Mainstem above Joe Wright Creek (PJW), which did not appear to have an influence on downstream monitoring sites.

As expected, nitrite concentrations were measured below the reporting limit (40 µg/L) at all monitoring sites.

Ammonia concentrations were at or below the reporting limit (10 µg/L) at nearly all sites. The highest concentrations were measured in the South Fork (SFM) and at the City of Greeley's diversion (PBD) in July when concentrations measured only 20 µg/L.

North Fork

Total nitrogen concentrations were similar across most monitoring sites on the North Fork (**Figure 3.5)**. Concentrations ranged from 170 µg/L to a maximum 1,280 µg/L on the North Fork near Livermore (NFL). Minimum total nitrogen concentrations were higher than baseline at all monitoring sites and detected above the reporting limit (90 µg/L). Median total nitrogen concentrations were near 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 below baseline at all monitoring sites except in the North Fork near Livermore (NFL). A maximum concentration of 1,280 µg/L was measured in April at this site, which slightly exceeded the interim water quality standard. During this time, total nitrogen concentrations were notably higher in Rabbit Creek (RCM) and Lone Pine Creek (PCM). Concentrations in the North Fork above these tributaries (NRC) were much lower (410 µg/L), which highlights the influence of these tributaries on downstream total nitrogen concentrations during snowmelt runoff.

Nitrate concentrations were generally low across North Fork sites, and all median concentrations were near baseline and below the reporting limit (10 µg/L). Detectable concentrations were measured in the North Fork below Halligan Reservoir and Seaman Reservoir (NBH and NFG), and in the North Fork near Livermore (NFL). Nitrate was measured in the North Fork near Livermore (NFL) in April during snowmelt runoff (230 µg/L). Nitrate was also detected in Rabbit Creek (RCM) and Lone Pine Creek (PCM) during this time, while concentrations upstream of these tributaries were measured below the reporting limit. Again, this trend highlights the influence of these tributaries on North Fork nitrate concentrations during snowmelt runoff. In contrast, detectable levels of nitrate below Halligan and Seaman Reservoirs (NBH and NFG) were measured during late-summer and fall. Elevated nitrate concentrations during this time were likely caused by anoxic conditions in the reservoirs and the release of nutrients from reservoir sediments into the North Fork. A maximum concentration of 330 µg/L was measured below Halligan Reservoir in November, which was well above the baseline maximum.

Nitrite concentrations were measured below the reporting limit at all monitoring sites throughout the 2020 water year.

Similar trends were observed in ammonia concentrations across the North Fork. Ammonia concentrations were near baseline at all monitoring sites. The highest concentrations were observed on the North Fork below Halligan and Seaman Reservoirs (NBH and NFG). Concentrations were consistently above the reporting limit at these sites, but the

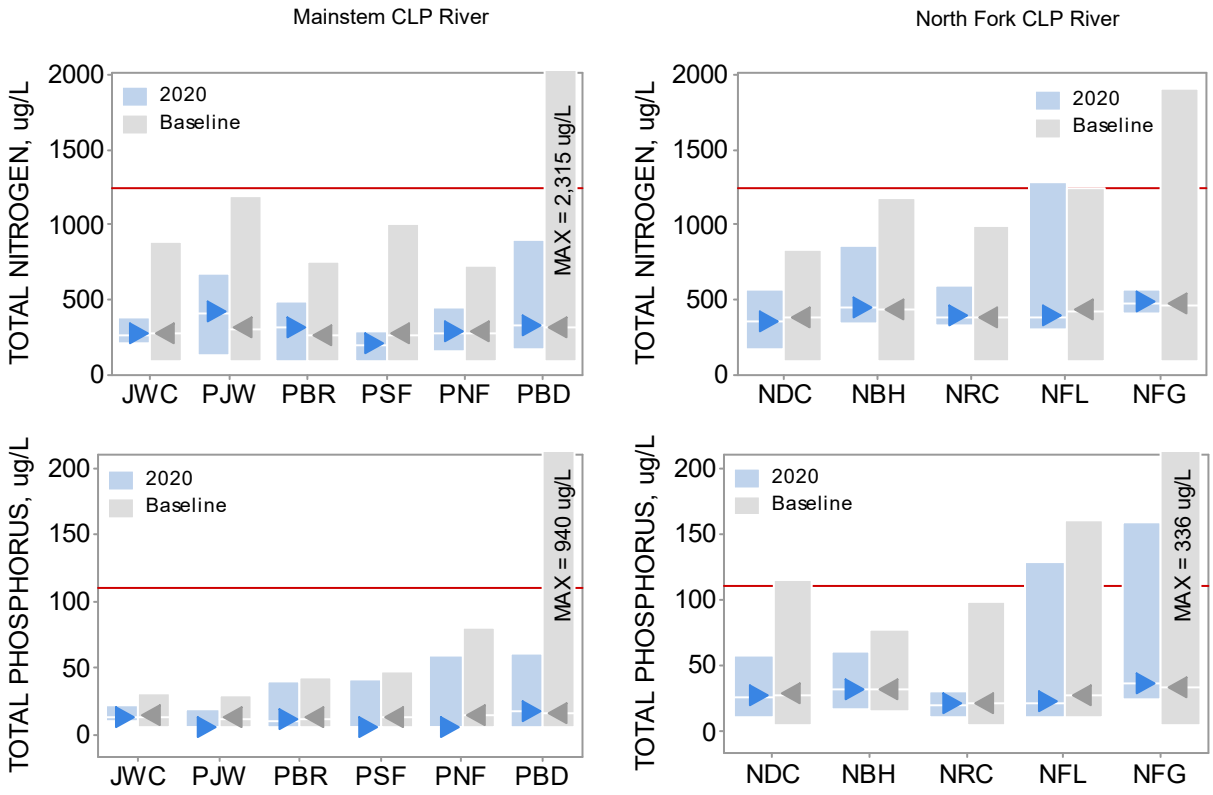

Figure 3.5 – Total nitrogen and total phosphorus concentrations measured at key monitoring locations on the Mainstem CLP River (left) and North Fork CLP River (right) in 2020 compared to the baseline period of record. The red reference lines indicate interim water quality standards (TN = 1,250 µg/L and TP = 110 ug/L) set by the Colorado Department of Public Health and Environment to protect aquatic life.

highest concentrations were measured in the fall when the reservoirs were anoxic. Maximum concentrations of 140 µg/L and 90 µg/L were measured below Halligan and Seaman Reservoirs (NBH and NFG) in August and November, respectively. Ammonia concentrations in the North Fork near Livermore (NFL) and upstream tributaries were below or near the reporting limit for most of the monitoring season.

Phosphorus

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

Mainstem

Total phosphorus concentrations were similar across monitoring sites on the Mainstem CLP River. The highest concentrations were observed from the Mainstem below Rustic (PBR) downstream to the City of Greeley's Diversion (PBD) (**Figure 3.5**). Concentrations ranged from below the reporting limit (10 µg/L) at all key monitoring sites to a maximum 60 µg/L at the City of Greeley's Diversion (PBD). Minimum and median total phosphorus concentrations were near baseline at all monitoring sites and measured near or below the reporting limit. Concentrations measured above the reporting limit throughout the duration of snowmelt runoff (April – June). Following snowmelt runoff, concentrations were at or below the reporting limit at most monitoring sites. Maximum total phosphorus

concentrations were below baseline at all monitoring sites on the Mainstem, especially at the City of Greeley's Diversion (PBD). Maximum total phosphorus concentrations were observed in late-April and early-May at most monitoring sites. Total phosphorus concentrations were measured above the reporting limit at all sites in November, which may be associated with the Cameron Peak Wildfire. Typically, total phosphorus concentrations in November are measured below the reporting limit at all sites except for monitoring sites located directly below water supply reservoirs (CHD, BMD, JWC and PBD).

Orthophosphate measured below the reporting limit (5 µg/L) at all monitoring sites for most of the year, except at the City of Greeley's Diversion (PBD). Orthophosphate at this monitoring site measured above the reporting limit throughout the monitoring season except in April and November. A maximum concentration of 37 µg/L was measured at this site in June. The higher orthophosphate concentrations at this site are likely associated with contributions from the North Fork CLP River. Detectable concentrations were also measured below Chambers Lake from August through November with a maximum of 18 µg/L measured in August. In contrast to previous years, orthophosphate was detected above the reporting limit in November from Joe Wright Creek (JWC) downstream to City of Fort Collins' Diversion (PNF). Like the late season trend observed in total phosphorus, the elevated late season orthophosphate concentrations may be associated with the Cameron Peak Fire.

North Fork

Total phosphorus concentrations were within the baseline range of values for most monitoring sites (**Figure 3.5)**. Concentrations ranged from below the reporting limit (10 µg/L) in the North Fork near Livermore (NFL) to a maximum 158 µg/L in the North Fork below Seaman Reservoir (NFG). Minimum total phosphorus concentrations were higher than baseline at all monitoring sites except in the North Fork near Livermore (NFL). Median total phosphorus concentrations were near or slightly below baseline at all monitoring sites except on the North Fork below Seaman Reservoir (NFG). Maximum total phosphorus concentrations were below baseline at all monitoring sites in the North Fork CLP River. The interim water quality standard for total phosphorus of 110 µg/L was briefly exceeded on the North Fork near Livermore (NFL) in April when contributions from North Fork tributaries were high. The standard was also exceeded in the North Fork below Seaman Reservoir (NFG) in August, which was likely due to anoxic conditions in the reservoir.

Table 5 – Poudre River geosmin and 2-MIB concentrations (ng/L or ppt) 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. n.s. = no sample collected

Month	PBR		PNF	
	Geosmin	2-MIB	Geosmin	2-MIB
May	n.s.	n.s.	2.54	nd
Jun	n.s.	n.s.	nd	nd
Jul	nd	3.10	nd	nd
Aug	nd	2.78	nd	nd
Sep	n.s.	n.s.	n.s.	n.s.
Oct	n.s.	n.s.	n.s.	n.s.
Nov	nd	6.71	nd	3.89

Median orthophosphate concentrations fluctuated around the reporting limit (5 µg/L) at most monitoring sites. The highest concentrations were measured in the North Fork tributaries (SCM, RCM, and PCM) and in the North Fork below Seaman Reservoirs (NFG). Concentrations ranged from below the reporting limit to a maximum of 243 µg/L in the North Fork below Seaman Reservoir (NFG) in August, which was likely due to anoxic conditions in the reservoir.

3.5 TASTE & ODOR COMPOUNDS

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

Geosmin and 2-MIB are monitored on the Mainstem below Rustic (PBR) and at the City of Fort Collins Diversion (PNF) during routine upper CLP water quality monitoring events.

A summary of geosmin and 2-MIB concentrations can be found in **Table 5**. No discernable spatial or temporal trends were observed for geosmin or 2-MIB over the 2020 water year. Geosmin was measured above the reporting limit in April at the City of Fort Collins' intake (PNF) and 2-MIB was measured above the reporting limit on the Mainstem below Rustic (PBR) in November.

3.6 METALS

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

Metals were sampled once in the spring (May) and fall (October) on the Mainstem upstream of the confluence with the North Fork (PNF) and on the North Fork below Seaman Reservoir (NFG). A summary of dissolved metals concentrations can be found in **Table 6**. As anticipated, detectable metals (aluminum, copper, iron, manganese) were higher in the spring during spring snowmelt runoff, except for manganese on the North Fork below Seaman Reservoir, which was likely due to anoxic conditions in the reservoir and the release of manganese from reservoir sediments.

Table 6 – Dissolved metals concentrations measured in spring (May) and fall (October) of 2020 on the Mainstem and North Fork Poudre River. Cells highlighted in light red indicate concentrations reported above the laboratories reporting limit.

Metal (ug/L)	Spring		Fall	
	PNF	NFG	PNF	NFG
Al	377	179	10	<10
As	<1	<1	<1	1
Cd	<1	<1	<1	<1
Cr	<1	<1	<1	<1
Cu	1	<1	<1	<1
Fe	295	172	29	22
Mn	6	24	8	42
Ni	<1	<1	<1	<1
Pb	<1	<1	<1	<1
Se	<5	<5	<5	<5
Zn	<10	<10	<10	<10

3.7 MICROORGANISMS

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

Total Coliform

Total coliform concentrations were similar across monitoring sites on the Mainstem over the 2020 water year, but slightly higher on the North Fork below Seaman Reservoir (NFG). The higher concentrations had a minimal influence on downstream concentrations at the City of Greeley's Diversion (PBD) (**Figure 3.6**). Concentrations ranged from a minimum 23 cells/100 mL at the City of Fort Collins Diversion (PNF) to a maximum 48,800 cells/100 mL on the North Fork below Seaman Reservoir (NFG). Minimum and median total coliform concentrations were near baseline at all monitoring sites. Maximum concentrations were below baseline on the Mainstem and notably higher than baseline on the North Fork below Seaman Reservoir (NFG). The maximum total coliform concentration at this monitoring site was measured in June during snowmelt runoff.

E. coli

Escherichia coli concentrations were generally similar across monitoring sites over the 2020 water year. Concentrations were less variable along the Mainstem and ranged from a minimum 0 to 2 cells/100 mL at all monitoring sites to a maximum of 43 cells/100 mL at the City of Fort Collins' Diversion (PNF) (**Figure 3.6**). Concentrations were generally higher on the Mainstem below Rustic and below the South Fork (PBR and PSF) compared to the Mainstem at the City of Fort Collins' and City of Greeley's Diversion (PNF and PBD); however, the higher median concentrations on the Mainstem below Rustic and below the South Fork (PBR and PSF) are likely skewed due to

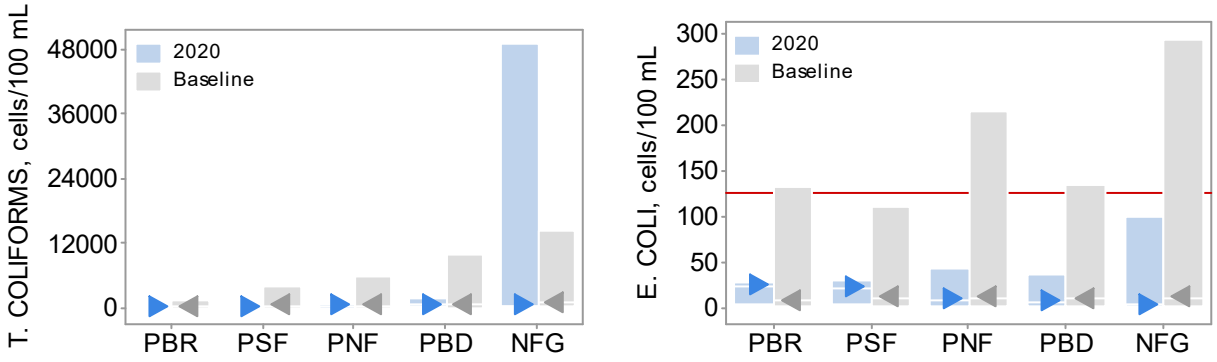

Figure 3.6 – Total coliforms (left) and E. coli (right) concentrations measured at key monitoring locations on the Mainstem CLP River and North Fork CLP River – mainstem and NF sites in this figure are combined, as opposed to other figures – in 2020 compared to the baseline period of record. The red reference line indicates the E. coli water quality standard set by the Colorado Department of Public Health and Environment to protect recreational use.

missing data (explained in Section 1.3). Minimum concentrations were baseline at all Mainstem monitoring sites. Median E. coli concentrations were above baseline on the Mainstem below Rustic and below the South Fork (PBR and PSF) and below baseline on the Mainstem at the City of Fort Collins' and City of Greeley's Diversion (PNF and PBD). Maximum concentrations, which were observed during snowmelt runoff, were much lower than baseline at all Mainstem monitoring sites and below the water quality standard.

There was more variability on the North Fork below Seaman Reservoir (NFG) where concentrations ranged from 0 cells/100 mL to 100 cells/100 mL. Minimum concentrations were near baseline. Median and maximum *E. coli* concentrations were less than baseline. Concentrations were low throughout much of the monitoring season. The highest *E. coli* concentration was measured in July and was below the water quality standard.

3.8 MACROINVERTEBRATES

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

Macroinvertebrate community metrics are often used to evaluate water quality and ecological health in streams and are particularly useful when paired with chemical and physical water quality data. Routine macroinvertebrate community metrics were used in this report to establish baseline biological condition and to make comparisons between key study locations (**Table 7**). Analyses in subsequent years will be expanded to include short-and long-term trends, impacts and recovery from future pollution events, and specific cause and effect relationships between pollutants and the biota.

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

Species Diversity

Species diversity is a measure of the number of different macroinvertebrate species within a community. Communities with good water quality generally have higher

species diversity than those with poor water quality. Species diversity was generally similar across all study locations, with the Mainstem below Rustic (PBR) having the highest number of species (43). The exception to this pattern was at the City of Fort Collins' Diversion (PNF), which had low species diversity (32) relative to other sites.

Shannon's H

Shannon's H combines measures of species diversity and the relative abundance of each species within a macroinvertebrate community. Values > 3 generally indicate good community condition and water quality, whereas values <1 indicate poor community condition and water quality. Shannon's H was >3 at all monitoring locations except at the Mainstem above Joe Wright Creek (PJW) and City of Fort Collins Diversion (PNF), which measured 2.8 and 2.9, respectively. Shannon's H across all monitoring locations generally indicate that macroinvertebrate community condition and water quality are good.

EPT Diversity and % EPT

EPT is an abbreviation for the sum of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species. EPT are widely regarded as intolerant of water quality pollution, and therefore, higher measures of EPT diversity and percent of EPT in a community generally indicate that water quality is good. EPT diversity was generally similar across all monitoring locations, with the exception of the Mainstem near the City of Fort Collins' Diversion (PNF) (18). Percent EPT was consistently high across all monitoring locations.

Density

Density is a measure of the number of individual organisms per square meter of the streambed. Changes in density can be associated with water quality pollution. Macroinvertebrate density was the highest at the Mainstem near the City of Greeley's Diversion (PBD) (6,221) and above Joe Wright Creek (PJW) (5,316), whereas the Mainstem below the South Fork (PSF) had the lowest density (2,945).

Collectors-Filters

Percent filter-feeders refers to the percentage of macroinvertebrate species in a community that feed by filtering tiny organic particles suspended in the streamflow. The abundance of these organisms often dramatically increases in locations exposed to elevated organic pollution. The percentage of collector-filterers on the Mainstem above Joe Wright Creek (PJW) and the Poudre at City of Fort Collins Diversion (PNF) were the lowest among sites at 1%. In contrast, the Mainstem below Rustic (PBR) (12%) and at the City of Greeley's Diversion (PBD) (15%) had the highest percentages among sites, indicating that there is organic pollution effecting these sites.

Collector-Gatherers

Percent collector-gatherers refers to the percentage of macroinvertebrate species that feed on tiny organic particles deposited on or within the streambed, rather than through filtration. The percentage of collector-gatherers was consistently high across all sites but was lowest at the Mainstem below Rustic (PBR) (43%) and at the Mainstem near the City of Greeley's Diversion (PBD) (30%). The lower percentage of collector-gatherers at these sites was strongly affected by a shift in these communities toward more collector filter-feeding species.

Algae Scrapers

Percent scrapers refers to the percentage of macroinvertebrate species that are adapted to feeding by scraping algae from streambed surfaces. Changes in the abundance of scrapers is often in response to increases in fine sediment (silt and sand) pollution from events such as post-wildfire erosion or road construction. The number of algae scraping species generally trended higher when comparing upstream to downstream study sites and was the highest (48%) at the Mainstem near the City of Greeley's Diversion (PBD).

Leaf Shredders

Percent shedders refers to the percentage of macroinvertebrate species that feed on leaves, pine needles, twigs and other large organic matter that is washed into the river. Decreases in the percent of shredders in a community can indicate that riparian vegetation has been impacted and is providing less food for these organisms. Shredders made up a progressively larger percentage of the community between the Mainstem above Joe Wright Creek (PJW) (2%), the Mainstem below Rustic (PBR) (5%) and the Mainstem below the South Fork (PSF) (6%) which may indicate a natural increase in riparian vegetation between these sites. Shredders at the Cities of Fort Collins' and Greeley's Diversions (PNF and

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

Community Metric	PJW	PBR	PSF	PNF	PBD
Level IV Ecoregion	Crystalline Subalpine Forests	Crystalline Mid-Elevation Forests	Crystalline Mid-Elevation Forests	Crystalline Mid-Elevation Forests	Foothills Shrublands
Species Diversity	40	43	40	32	37
Shannon's H	2.8	4.2	4.1	2.9	3.6
EPT Diversity & Percent EPT	20 (89%)	23 (73%)	21 (69%)	18 (94%)	22 (90%)
Density (#/m^2)	5,316	3,315	2,945	3,270	6,221
Percent Collector-Gatherers	69%	43%	59%	61%	30%
Percent Algae Scrapers	20%	24%	14%	30%	48%
Percent Predators	8%	15%	13%	4%	7%
Percent Collector-Filterers	1%	12%	5%	1%	15%
Percent Leaf Shredders	2%	5%	6%	2%	<1%
CDPHE Biotype	1	2	2	2	2
MMI version 4	63.8 (Attainment)	76.3 (Attainment)	73.2 (Attainment)	74.5 (Attainment)	86.5 (Attainment)

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PBD) made up around 2% and <1% of the of the community, respectively; the reason for the decrease in shredders at these downstream sites is unknown.

MMI Version 4

The MMI Version 4 is the Colorado Department of Public Health and Environment's (CDPHE) multi-metric water quality index, which combines several ecological metrics into a single score that is compared to thresholds related to reference condition. The Mainstem above Joe Wright Creek (PJW) is in CDPHE's biotype 1. The Mainstem below Rustic (PBR), the Mainstem below the South Fork (PSF), the Mainstem near the City of Fort Collins' Diversion (PNF) and the Mainstem near the City of Greeley's Diversion (PBD) are in CDPHE's biotype 2. The MMI Version 4 is used by CDPHE to determine whether a stream community meets the State's surface water quality standards for the Aquatic Life Use. All study locations attained CDPHE's MMI Version 4 aquatic life standards thresholds.

4.0 SOURCE WATER QUALITY TRENDS AND TREATMENT IMPLICATIONS

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

Presentation of Results

Bar charts presented in Section 4 display monthly median values measured over the 2020 monitoring season for the months of April, May, and June when sampling is conducted twice per month, and monthly values from July through November. Please make note that because of COVID-19 the 2020 sampling season did not begin until the end of April. Only one data point was collected in April, so these values may be slightly skewed toward higher or lower concentrations depending on the parameter. These data are compared to baseline median values calculated over the period of record from 2008 to 2012.

Selected Variables

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

- **Alkalinity**
- **pH**
- **Total Organic Carbon**
- **Turbidity**

4.1 ALKALINITY

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

City of Fort Collins' Diversion

The median alkalinity concentration at the City of Fort Collins' Diversion was 18.5 mg/L, which was slightly higher (<1.0 mg/L) than baseline. Concentrations ranged from a minimum of 12.8 mg/L in the month of June to a maximum 35.6 mg/L measured in the month of April. Alkalinity over the spring season was greater than baseline in the month of April and slightly below baseline in the month of May. As expected, concentrations were lower over the summer months of June, July and August which measured near baseline. Alkalinity concentrations were notably higher than baseline over the fall months from September through November. Baseline alkalinity concentrations range from 17.2 mg/L to 28.4 mg/L from September through October. In 2020, alkalinity concentrations over the fall season ranged from 23.0 mg/L to 33.6 mg/L. The largest departure from baseline was measured in the month of October when the concentration was 12 mg/L higher than baseline. The higher concentrations during this time were likely associated with below average streamflow during the fall season. (**Figure 4.1**).

City of Greeley's Diversion

The median alkalinity concentration at the City of Greeley's Diversion was 30.3 mg/L, which was 4.1 mg/L higher than baseline. Concentrations ranged from a minimum of 15.4 mg/L in the month of June to a maximum of 66.8 mg/L measured in the month of April. Alkalinity was greater than baseline in the spring months of April and May. In the month of April, the alkalinity was nearly double the expected baseline concentration. Concentrations fell below baseline in June and increased above baseline in late summer (July and August). Concentrations were slightly higher than baseline in these months. Alkalinity concentrations remained above baseline in the early fall months of September and October and dropped slightly below baseline in November. The largest departure from

baseline was measured in the month of October when the concentration was greater than 35 mg/L higher than baseline (**Figure 4.1**). The notably higher alkalinity concentrations during this time were likely associated with below average streamflow on the Mainstem and higher alkalinity water from the North Fork. The North Fork comprised approximately 40% of the flow at Greeley's Diversion in October, when alkalinity concentrations measured over 100 mg/L on the North Fork below Seaman Reservoir (NFG).

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 2020 (**Figure 3.1**). Seasonal trends in pH were comparable to baseline at both monitoring locations, except in late summer. In general, pH slightly decreases from the spring through the summer and begins to increase in the fall.

City of Fort Collins' Diversion

The median pH value at the City of Fort Collins' Diversion was 7.48, which was 0.08 pH units higher than baseline. Concentrations ranged from a minimum 6.80 in the month of July to a maximum 8.17 measured in the month of April. pH was above baseline in April and near or below baseline from May through July. pH measured over the late summer and fall was notably higher than baseline in all months except September when pH was slightly below baseline. The largest departure in pH was measured in the month of August when the pH was 0.50 units greater than baseline. The higher pH values observed in the late summer and fall were likely related to the above average temperatures and lower streamflow. Higher temperatures and lower streamflow may have resulted in greater algal productivity and correspondingly higher pH values. The sudden drop in pH in September was likely associated with the early season snowstorm and cool weather during this time, which likely slowed instream algal productivity (**Figure 4.1**).

City of Greeley's Diversion

The median pH value at the City of Greeley's Diversion was 8.02 compared to the baseline median of 7.56. Concentrations ranged from a minimum of 7.49 in the month of July to a maximum 8.54 measured in the month of April. pH values were greater than baseline throughout the monitoring season. A notable divergence from the baseline seasonal trend was observed in the months of August and September. The largest departure in pH was measured in the month of September when pH was 1.14 pH units higher than baseline. The higher pH values during this time were likely related to the above average temperatures and higher pH contributions from the North Fork. pH on the North Fork below Seaman Reservoir (NFG) during September and October was greater than 8.50 and streamflow from the North Fork comprised 20% and 40%, respectively, of the total flow at the City of Greeley's Diversion (**Figure 4.1**). The much higher pH contributions from the North Fork were likely related to elevated algal productivity in Seaman Reservoir. In contrast to the drop in pH measured at the City of Fort Collins' Diversion (PNF) in the month of September, pH remained high at the City of Greeley's Diversion, which highlights the influence of North Fork and Seaman Reservoir on Mainstem water quality during this time of year.

4.3 TOTAL ORGANIC CARBON

Total organic carbon was near the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2020 (**Figure 3.4**). Seasonal trends in total organic carbon were comparable to baseline at both monitoring locations with higher concentrations measured during snowmelt runoff and lower concentrations following runoff in the summer and fall months.

City of Fort Collins' Diversion

The median TOC concentration at the City of Fort Collins' Diversion was 3.71 mg/L compared to the baseline median of 3.60 mg/L. Concentrations ranged from a minimum of 1.89 mg/L in the month of November to a maximum of 9.71 mg/L measured in the month of May. As expected, the highest concentrations were observed during snowmelt runoff in May and June. TOC concentrations were notably higher than baseline in April and May. The TOC concentration in April exceeded the 4 mg/L removal requirement threshold, while concentrations in May exceeded the 8 mg/L removal requirement threshold (**Table 3**). The elevated TOC concentrations in April and May were associated with the above average streamflow observed during this time. TOC fell below baseline in June and remained below baseline for the remainder of the monitoring season due to below average streamflow conditions observed after snowmelt runoff. Concentrations were between the 2 – 4 mg/L removal requirement threshold from July through September and fell below 2 mg/L in October and November (**Figure 4.1**).

City of Greeley's Diversion

The median TOC concentration at the City of Greeley's Diversion was 4.06 mg/L compared to the baseline median of 4.03 mg/L. Concentrations ranged from a minimum 2.17 mg/L in the month of November to a maximum 8.69 mg/L measured in the month of May. As expected, the highest concentrations were observed during snowmelt runoff in May and June. TOC concentrations were notably higher than baseline in April and May. The TOC concentration in April exceeded the 4 mg/L removal requirement threshold, while concentrations in May exceeded the 8 mg/L removal requirement threshold (**Table 3**). The elevated TOC concentrations in April and May were associated with the above average streamflow observed during this time. TOC fell below baseline in June and remained below baseline into August. In contrast to trends observed upstream at the City of Fort Collins' Diversion (PNF), TOC concentrations were above baseline in September and October. Like seasonal trends in other water quality constituents, the higher TOC concentrations during this time of year were likely associated with higher TOC (~5 mg/L) water contributed from the North Fork compared to the Mainstem (<2 mg/L). Streamflow from the North Fork comprised 20% and 40% of the total flow at the City of Greeley's Diversion in September and October, respectively. Concentrations were still low during this time and fell between the 2 – 4 mg/L removal requirement threshold. In November, TOC concentrations fell below baseline and measured slightly higher than the 2 mg/L removal requirement threshold (**Figure 4.1**).

4.4 TURBIDITY

Turbidity was near the baseline median at both the City of Fort Collins' Diversion (PNF) and City of Greeley's Diversion (PBD) in 2020 (**Figure 3.1**). Seasonal trends in turbidity were comparable to baseline with increasing turbidity during snowmelt runoff followed by decreasing turbidity into the summer and fall seasons.

City of Fort Collins' Diversion

The median turbidity at the City of Fort Collins' Diversion was 1.2 NTU compared to the baseline median of 1.8 mg/L. Concentrations ranged from a minimum of less than 1 NTU from August through November to a maximum of 10.6 NTU measured in the month of May. In the months of April and May, turbidity measured above baseline. Turbidity was nearly three times higher than baseline in the month of April and twice as high in the month of May. The higher values during this time were likely related to early snowmelt runoff and above average streamflow conditions. Following snowmelt runoff, turbidity measured well below baseline from June through November. The below baseline turbidity in June was due to the earlier and quicker than expected runoff, while the low concentrations from July through August were due to below average streamflow following snowmelt (**Figure 4.1**).

City of Greeley's Diversion

The median turbidity at the City of Greeley's Diversion was 1.7 NTU compared to the baseline median of 1.8 NTU. Concentrations ranged from a minimum of less than or equal to 1 NTU from August through November to a maximum of 10.2 NTU measured in the month of May. In the months of April and May, turbidity measured above baseline. Turbidity was nearly two times higher than baseline in these months. Like observations at the City of Fort Collins' Diversion (PNF), the higher values during this time were likely related to early snowmelt runoff and above average streamflow. Following snowmelt runoff, turbidity measured well below baseline from June through November. The below baseline turbidity in June was due to the earlier and quicker than expected runoff, while the low concentrations from July through August were due to below average streamflow following snowmelt. Streamflow contributions from the North Fork did not appear to influence turbidity at the City of Greeley's Diversion (**Figure 4.1**).

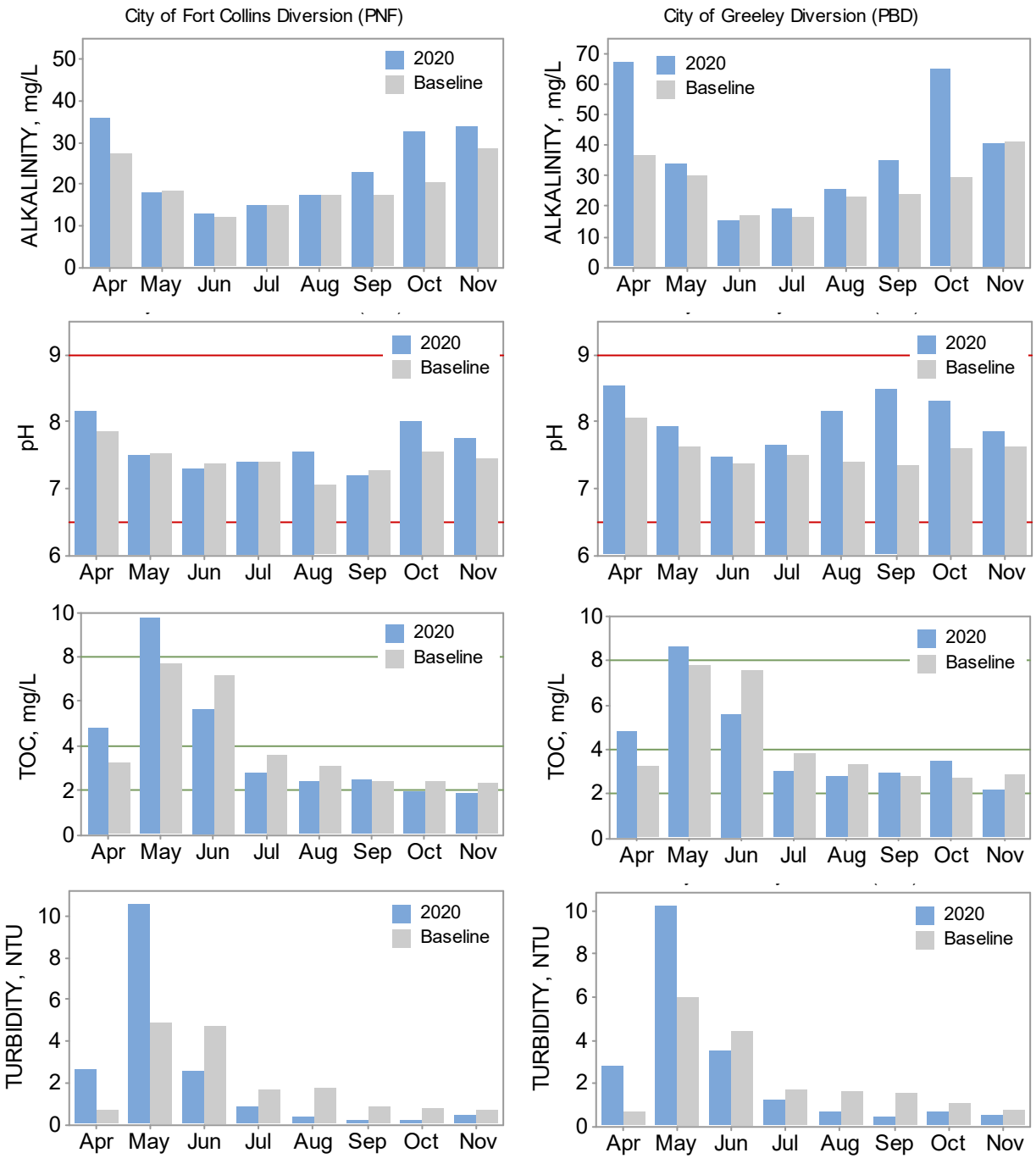


Figure 4.1 – Monthly median alkalinity, pH, total organic carbon, and turbidity levels measured on the Mainstem CLP River at the City of Fort Collins Diversion (left) and City of Greeley Diversion (right) in 2020 compared to the baseline period of record. The red reference lines for pH indicate water 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 2020 Upper CLP Collaborative 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

Air temperature measured over the 2020 water year was warmer than baseline and ranked as the 6th warmest on record (31 years; 1990 to 2020) at the Joe Wright SNOTEL. Cooler conditions were observed over the winter season followed by record breaking temperatures in the spring, summer, and fall.

Total precipitation measured over the 2020 water year was less than the baseline average. Peak snow water equivalent across the entire Cache la Poudre Watershed was slightly above average. Precipitation measured above baseline over the winter season and below baseline over the spring, summer and fall seasons. Significantly dry conditions were observed over the fall season, which ranked as the 2nd driest fall season on record

Streamflow measured over the 2020 water year was below baseline. Streamflow was above baseline over the winter and spring seasons and below baseline over the summer and fall seasons. Above average temperatures and dry weather throughout the spring and summer hastened the timing and duration of snowmelt runoff. As a result, peak streamflow was higher than average and occurred nearly ten days earlier than normal . The persistently dry and hot weather in 2020 resulted in a shorter duration runoff season followed by well below average streamflow for much of the summer and fall.

5.3 UPPER CACHE LA POUDRE RIVER WATER QUALITY

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

The most notable impacts to water quality over the 2020 water year were caused by extremely dry and warm weather conditions and the resulting impacts on the timing and duration of snowmelt runoff and subsequently low baseflow conditions in the summer and fall. The typical water quality changes driven by snowmelt runoff were experienced earlier than baseline due to warm and dry weather expediating snowmelt runoff in spring and early summer. In addition, water quality constituents that become more concentrated under low flow conditions were more elevated this year due to below average baseflow conditions, in combination with extremely hot and dry weather conditions influence temperature dependent water quality constituents.

Physical parameters, including temperature, pH, specific conductivity, and turbidity, were within the baseline range of values for nearly all monitoring sites on both the Mainstem and North Fork. As expected, these parameters varied between watersheds, across monitoring locations and over time. In general, the North Fork exhibits higher temperature, pH, specific conductivity, and turbidity compared to the Mainstem CLP river. These differences are likely associated with greater groundwater contributions to the river in combination with the natural geology of the North Fork CLP watershed and hydrologic regime.

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

General parameters, including alkalinity, hardness, and total dissolved solids, were within the baseline range of values for nearly all monitoring sites on both the Mainstem and North Fork. As expected, concentrations decreased during snowmelt runoff when streamflow was high and increased during the summer and fall when streamflow was low. Maximum concentrations of these parameters exceeded the baseline maximum at the City of Fort Collins' and City of Greeley's Diversions, except for alkalinity at the City of Fort Collins' Diversion. Another notable observation was concentrations of these parameters at the City of Fort Collins' and City of Greeley's Diversions were seasonally higher than baseline through much of the summer and fall due to low streamflow conditions on the Poudre River.

Total organic carbon was within the baseline range of values within the Mainstem and North Fork CLP watersheds. Concentrations increased during spring snowmelt runoff and decreased during the summer and fall as streamflow receded to lower flows. Total organic carbon was similar across watersheds and monitoring locations; however, the variability in concentrations along the Mainstem was higher compared to the North Fork. This difference is likely associated with differences in the hydrologic regime between these two watersheds. Higher maximum total organic carbon concentrations were observed at both the City of Fort Collins's and City of Greeley's Diversion in May, but fell below baseline for the remainder of the season due to the shorter duration snowmelt runoff season and low baseflow conditions following runoff.

Nutrients (total nitrogen and total phosphorus) were quite low in both the Mainstem and North Fork watersheds and were well within the range of baseline concentrations at all monitoring sites. In general, nutrients were detected above the reporting limit during spring snowmelt runoff and near or below the reporting limit for the remainder of the year. Monitoring locations located near or directly below reservoirs experienced late season increases in nutrients. Potential taste and odor compounds (geosmin and 2-MIB) associated with algal blooms caused by elevated nutrients and other environmental factors, were rarely measured above their reporting limits.

Microorganisms (total coliforms and *E. coli*) were within the baseline range of values and no notable changes were observed in 2020, except the North Fork below Seaman Reservoir. The maximum total coliforms at this monitoring site measured nearly four times higher than the baseline maximum. The cause of this unusual level of total coliforms is unknown. The macroinvertebrate community and associated metrics generally indicated good water quality throughout the watershed. The most notable changes in macroinvertebrate community metrics were observed on the Mainstem downstream of the North Fork. This shift in community metrics is consistent with changes in water quality at this site due to contributions from the North Fork.

In summary, the Upper CLP watershed remains a high-quality drinking water supply for the City of 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 have much influence on water quality at the City of Greeley's diversion. No significant water quality concerns were identified for the Mainstem or North Fork CLP that immediately impact drinking water quality or treatment operations; however, emerging trends will be important to monitor into the future to further help inform water treatment operations, track watershed health, and evaluate the impacts of the Cameron Peak Wildfire on this important water supply.

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 2020 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 2020 annual sampling plan (Attachment 4). QAQC samples and accuracy of field equipment are reviewed by Watershed Program staff.

In 2020, 17 percent (494 out of 2988) of the environmental samples collected were blank samples and 15 percent (442 out of 2988) of the environmental samples collected were field duplicates. The results of the field quality assurance and control sampling indicate that precision and accuracy were acceptable.

Field Duplicates

Precision is a measure of the deviation from the true value. For most constituents, duplicate determinations should agree within a relative percent difference of 10%. Duplicate samples with measured concentrations that differ by greater than 10% from field samples were flagged for further quality assurance and control evaluation. **Table 8** (a and b) outlines relative percent difference statistics for duplicate samples and illustrates that Upper CLP water quality data are of high precision. All duplicate samples were within 10% agreement at the 75th percentile during North Fork sampling (**Table 8a**). This result indicates that most of the duplicate samples were in agreement during North Fork sampling events. During Mainstem sampling, 75% of the total coliform samples, 50% of the total dissolved solids, and 25% of the E. coli samples exceeded a relative percent difference of 10% (**Table 8b**). The high variability in total coliform and E. coli samples was not unexpected. All other duplicate samples collected on the Mainstem were less than a relative percent difference of 10% for at least 75% of the samples. Detectable metals, which are not listed in Table 8, were all within a relative percent difference of less than 10%.

Field Blanks

Blank samples should not contain analytes above the reporting limit. Field blanks were analyzed in the laboratory for a total of 35 different water quality parameters in 2020. Ninety-six percent of field blank samples reported below the constituent's respective reporting limits. The 4% of field blank samples that were detected above the reporting limits included alkalinity, ammonia, hardness, orthophosphate, total dissolved solids, and total phosphorus (**Table 9**). This was consistent with constituent exceedances reported in previous years.

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.
- Inadequate rinsing of sample bottles either in the field or laboratory may have left residuals increasing total dissolved solids.
- Ammonia, orthophosphate, and total phosphorus contamination may be introduced by the field sampler and/or laboratory staff accidentally breathing on the sample (ammonia), touching sample bottle or lid or introduced by the lab instrument, if not properly cleaned.

Table 8 – Data quality assurance statistics calculated for duplicated samples collected at NFG (a) and PNF (b). The range in sample concentrations (minimum and maximum) was calculated for the combined environmental and duplicate samples collect over the monitoring season. The absolute mean difference was calculated by taking the difference between the environmental and duplicate sample concentration for individual monitoring events and then by calculating and average difference for the monitoring season. The relative percent difference was calculated by taking the difference between the environmental and duplicate sample concentrations divided by the average concentration between samples for each monitoring event. Percentiles (25th, 50th and 75th percentiles) were then calculated from these data to describe the distribution of relative precent differences for each constituent.

a) NFG constituents	Range in QAQC sample concentration		Reporting Limit	Absolute Mean Difference	Relative Percent Difference (%)		
					Percentile		
	min	*max*			*25th*	*50th*	*75th*
Ammonia as N (µg/L)	<10	90	10	1	0.00	0.00	0.00
Chloride (mg/L)	7.08	13	1	0.08	0.24	0.49	0.52
Nitrate as N (µg/L)	<40	140	40	1	0.00	0.00	0.00
Nitrite as N (µg/L)	<40	<40	40	0	0.00	0.00	0.00
Orthophosphate (µg/L)	<5	77.4	5	3	0.98	2.41	8.32
Sulfate (mg/L)	<5	9.57	5	0.05	0.17	0.28	0.47
Total Dissolved Solids (mg/L)	92	198	10	13	0.34	3.88	7.68
Total Kjeldahl Nitrogen (µg/L)	340	550	100	18	1.22	2.12	2.95
Total Organic Carbon (mg/L)	4.46	6.32	0.5	0.05	0.35	0.44	0.55
Total Phosphorus (µg/L)	22.5	157.6	10	1	0.43	1.03	1.58

b) PNF constituents	Range in QAQC sample concentration		Reporting Limit	Absolute Mean Difference	Relative Percent Difference (%)		
					Percentile		
	min	*max*			*25th*	*50th*	*75th*
Ammonia as N (µg/L)	<10	10	10	0	0.00	0.00	0.00
Chloride (mg/L)	<1	7.07	1	0.06	0.00	0.43	0.52
Coliforms, Total (cfu/100 mL)	32	579		81	11.35	14.20	18.01
E. coli (cfu/100 mL)	0	50		3	7.53	7.69	13.04
Nitrate as N (µg/L)	<40	80	40	3	0.00	0.00	1.67
Nitrite as N (µg/L)	<40	<40	40	0	0.00	0.00	0.00
Orthophosphate (µg/L)	<5	5.5	5	0.3	0.00	0.00	0.00
Sulfate (mg/L)	<5	6.19	5	0.05	0.00	0.00	0.00
Total Dissolved Solids (mg/L)	14	84	10	11	3.70	13.64	22.22
Total Kjeldahl Nitrogen (µg/L)	<100	890	100	63	5.88	7.14	13.04
Total Organic Carbon (mg/L)	1.88	9.54	0.5	0.03	0.22	0.31	0.53
Total Phosphorus (µg/L)	<10	59	10	0.3	0.00	0.00	0.00

*cfu = colony forming unitis

Table 9 – Blank samples detected above their respective reporting limit (RL), percent (%) exceedance and the percent of quality assurance and quality control samples collected over the 2020 monitoring season.

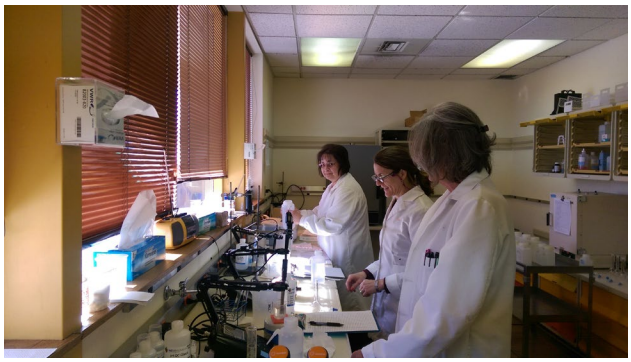
WQ Parameter	Sample >RL	Total QAQC samples	% exceedance	Total Samples	%QAQC
2-Methylisoborneol	0	2	0%	15	13%
Alkalinity	2	2	100%	111	2%
Aluminum	0	21	0%	95	22%
Ammonia as N	2	18	11%	111	16%
Arsenic	0	21	0%	97	22%
Cadmium	0	21	0%	98	21%
Calcium	0	9	0%	88	10%
Chloride	0	12	0%	72	17%
Chromium	0	21	0%	98	21%
Coliforms, Total	0	4	100%	34	12%
Copper	0	21	0%	98	21%
E. coli	0	4	100%	34	12%
Fluoride	0	3	0%	10	30%
Geosmin	0	2	0%	15	13%
Hardness	1	1	100%	100	1%
Iron	0	21	0%	93	23%
Lead	0	21	0%	98	21%
Magnesium	0	9	0%	88	10%
Manganese	0	21	0%	97	22%
Mercury	0	20	0%	168	12%
Molybdenum	0	3	0%	11	27%
Nickel	0	21	0%	98	21%
Nitrate	0	17	0%	111	15%
Nitrite	0	17	0%	111	15%
Orthophosphate	3	18	17%	111	16%
Potassium	0	9	0%	64	14%
Selenium	0	21	0%	98	21%
Silver	0	20	0%	86	23%
Sodium	0	9	0%	64	14%
Sulfate	0	12	0%	72	17%
Total Dissolved Solids	10	18	56%	111	16%
Total Kjeldahl Nitrogen	0	18	0%	111	16%
Total Organic Carbon	0	18	0%	111	16%
Total Phosphorus	1	18	6%	111	16%
Zinc	0	21	0%	98	21%

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).

7.0 REFERENCES

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

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

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

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

ATTACHMENT 1

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM SAMPLING SITES

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

ATTACHMENT 2

2018 UPPER CLP MONITORING PARAMETER LIST

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

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

ATTACHMENT 3

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

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

ATTACHMENT 4

UPPER CLP COLLABORATIVE WATER QUALITY MONITORING PROGRAM 2020 SAMPLING PLAN

2020 Upper Cache la Poudre Water Quality Monitoring Program											
Mainstem Cache la Poudre River											
	Apr 6	**Apr 20**	**May 4**	**May 18**	**Jun 8**	**Jun 22**	**Jul 13**	**Aug 10**	**Sep 14**	**Oct 12**	**Nov 16**
CHD							F,GM,N	F,G,GM,I,N	F,G,GM,N	F,G,GM,I,N	F,G,GM,I,N
BMD[1]							F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
JWC				F,GM,I,N		F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
PJW				F,GM,I,N		F,GM,I,N	F,GM,N	F,G,GM,I,N	F,G,GM,Mc,N	F,G,GM,I,N	F,G,GM,I,N
LRT							F,GM,N	F,GM,I,N	F,GM,N	F,GM,I,N	F,GM,I,N
PBR				E,F,GM, I,N		E,F,GM, I,N	E,F,G, GM,N	E,F,G, GM,I,N	E,F,G, GM,Mc,N	E,F,G, GM,I,N	E,F,G, GM,I,N
SFM							D,F,GM,N	D,F,G,GM, I,N	D,F,G, GM,N	D,F,G,GM, I,N	D,F,G,GM, I,N
PSF				E,F,GM, I,N		E,F,GM, I,N	E,F,GM,N	E,F,GM, I,N	E,F,GM, Mc,N	E,F,GM, I,N	E,F,GM, I,N
PNF[2,3]		E,F,GM,I, M,N	E,F,G,GM, M,N	E,F,GM,I ,M,N	E,F,G,GM, M,N	E,F,GM,I, M,N	E,F,G,GM, M,N	E,F,G,GM,I, M,N	E,F,G,GM,Mc, M,N	E,F,G,GM,I, M,N	E,F,G,GM, I,M,N
PBD		E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I ,M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM,Mc, M,N	E,F,GM,I, M,N	E,F,GM,I, M,N
North Fork Cache la Poudre River											
	Apr 7	**Apr 21**	**May 5**	**May 19**	**Jun 9**	**Jun 23**	**Jul 14**	**Aug 11**	**Sep 15**	**Oct 13**	**Nov 17**
NDC		F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM,I, M,N
NBH		F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM,I, M,N
NRC		D,F,GM,I ,M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM,I, M,N
RCM		D,F,GM,I ,M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N					
SCM		D,F,GM,I ,M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N					
PCM		D,F,GM,I ,M,N	D,F,GM, M,N	D,F,GM,I, M,N	D,F,GM, M,N	D,F,GM,I, M,N					
NFL		F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM, M,N	F,GM,I, M,N	F,GM,I, M,N
NFG[2]		E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM, M,N	E,F,GM,I, M,N	E,F,GM,I, M,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