Colorado-Big Thompson and Windy Gap Water Quality Monitoring Program

Water Quality Department

Northern Water began collecting water quality data within the Colorado-Big Thompson (C-BT) and Windy Gap systems in 1991. Since then, the program has significantly evolved into a robust monitoring program that spans the Continental Divide and eight watersheds. The following describes Northern Water's water quality monitoring program that supports the C-BT and Windy Gap projects.

The objectives of the C-BT and Windy Gap Water Quality Monitoring Programs are to:

- Monitor current conditions.
- Monitor trends and changes in water quality in lakes and reservoirs and flowing sites (streams, rivers, and canals).
- Assess potential impact of introduction of C-BT and Windy Gap projects water in streams.
- Assess compliance with state water quality standards and potential inclusions on 303(d) List of impaired waters or Colorado's M&E List.
- Support development of total maximum daily loads (TMDLs), if required.
- Support water quality modeling efforts.
- Support current and future permitting requirements.
- Assess water quality impacts from adverse events such as floods, wildfires, and spills.

The program provides a high quality and consistent data set that can be used for all the objectives listed above. Northern Water believes that the collection of data for this program is a proactive approach to identifying water quality issues and assessing solutions that best serve their interests and mission.

EAST TROUBLESOME AND CAMERON PEAK FIRES

In 2020, two of the largest fires in Colorado's history occurred within the C-BT Watershed: The East Troublesome Fire and the Cameron Peak Fire. Collectively, these fires burned 402,725 acres in the Upper Colorado River, Big Thompson River, and Poudre River Watersheds (Figure 1). The Upper Colorado and Big Thompson Watersheds are the source water supply for the C-BT Project collection system.

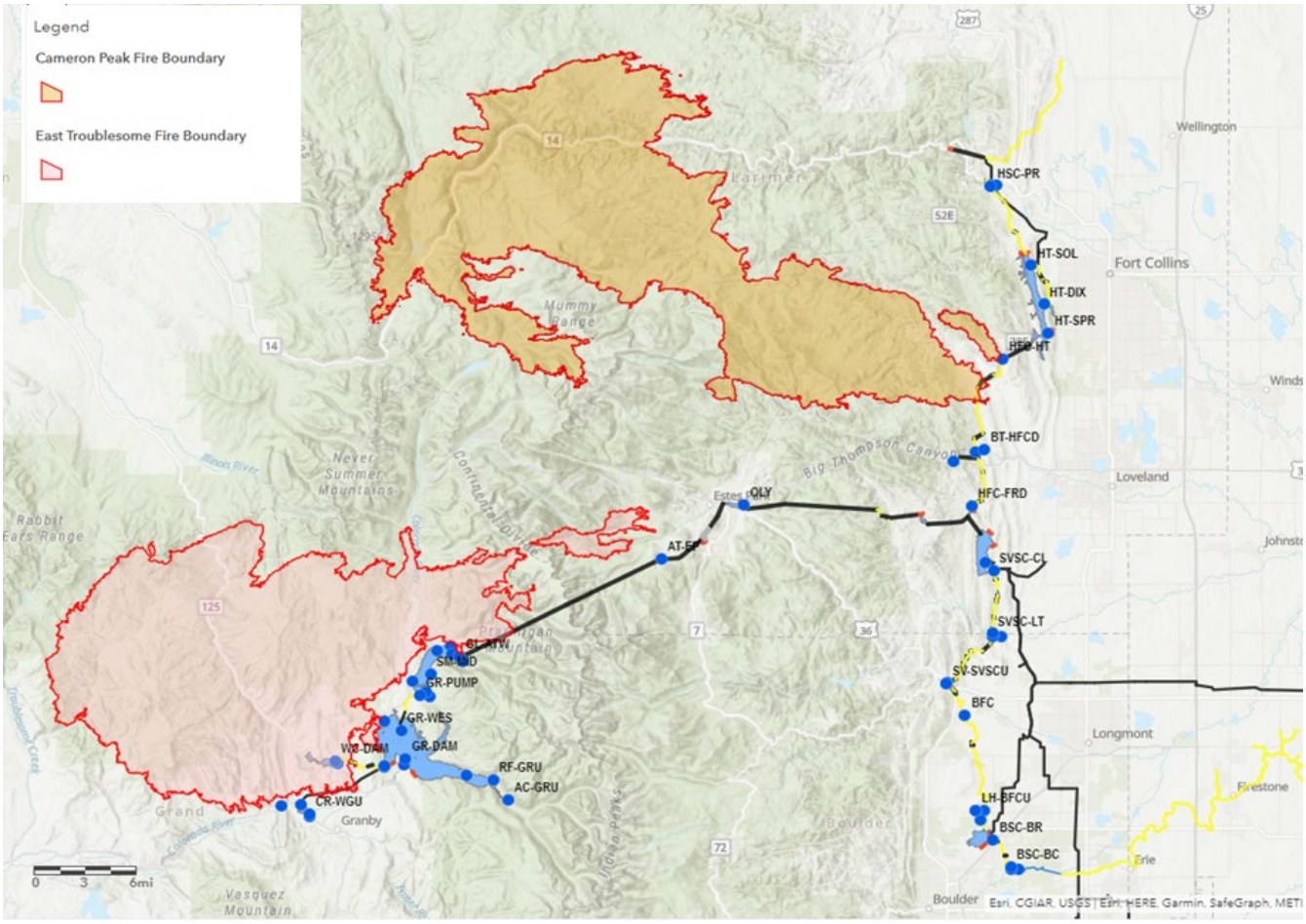

Figure 1 - Map of East Troublesome and Cameron Peak fire boundaries in relation to water quality program monitoring locations.

In response to the known impacts fires can have on water quality, and the proximity of these fires to the C-BT Project source water supply, several changes were made to the program in effort to assess fire impacts to water quality within the system. Changes were first made to the program in 2021, continued in 2022, 2023, 2024 and will resume in 2025. They are documented in the following sections.

Figure 2 - Sampling at the North Inlet of the Colorado River after a rainstorm in the burn *scar of the East Troublesome Fire.*

PARAMETERS AND LABORATORY ANALYSIS

The program includes monitoring for nutrients, metals, general chemistry, physical parameters, zooplankton, phytoplankton, and chlorophyll. There is a short list of parameters and long list of parameters for both the reservoir and flowing sites. The long lists include a more comprehensive suite of parameters, and the short lists include an abbreviated suite of parameters (primarily nutrients).

In the lakes and reservoirs, nutrients, metals, and general chemistry samples are collected at a depth 1 meter below the surface and approximately 1 meter above the bottom. Profiles of the physical parameters are taken at one-meter increments until a depth of 25 meters, then the increment increases to every 5 meters to approximately 1 meter above the bottom of the water body. The depth of the bottom profile measurement is the same depth at which the bottom sample is collected. Chlorophyll and phytoplankton samples are a composite sample of the water column from 0-5 meters. Zooplankton samples are collected with a 64-micrometer mesh zooplankton net from 0-10 meters, except in Shadow Mountain where only 0-5 meters are sampled due to the shallow depth. Secchi depth is measured at all reservoir sampling sites both with and without a view-scope.

Table 1 defines each of the sampling activity lists. Table 2 shows which parameters are included for various sampling activity lists. Modified sampling activities to assess fire impacts are highlighted in red on these tables. Table 1 defines each of the sampling activity lists. Table 2 shows which parameters are included for various sampling activity lists. Modified sampling activities to assess fire impacts are noted in dark red, and under the section of RF, on these tables.

Table 1 – Definition of Sampling Activity Lists

L1	Long list of parameters sampled at flowing sites
S1	Short list of parameters sampled at flowing sites
N1	Nutrients only plus TSS
N2	Nutrients only
RL	Long list of parameters sampled at reservoir sites
RS	Short list of parameters sampled at reservoir sites
RL^{S}	Abbreviated long list of parameters sampled at reservoir sites
RS^{S}	Abbreviated short list of parameters sampled at reservoir sites
LU	Long list of parameters to include U total and dissolved
SU	Short list of parameters sampled at flowing sites to include Uranium total and dissolved
RU	Long list of parameters sampled at reservoir sites to include Uranium total and dissolved
RSU	Short list of parameters sampled at reservoir sites to include Uranium dissolved
RF*	Lists that contain an 'F' indicate temporary modifications to existing sampling activity lists to assess fire impacts.

Table 2 – Field Parameter Lists

Type	Constituent	L1	S1	N1	N2	RL	RS	RL_s	RS_s	LU	SU	RU	RSU	RF
Field Parameters	Dissolved Oxygen	x	x	x	x	x	x	x	x	x	x	x	x	x
	pH	x	x	x	x	x	x	x	x	x	x	x	x	x

Type	Constituent	L1	S1	N1	N2	RL	RS	RL_s	RS_s	LU	SU	RU	RSU	RF
	Specific Conductance	x	x	x	x	x	x	x	x	x	x	x	x	x
	Temperature	x	x	x	x	x	x	x	x	x	x	x	x	x
	Turbidity	x	x	x	x	x	x	x	x	x	x	x	x	x
	Secchi Depth			x	x	x	x	x	x		x	x	x	x
Major Ions, carbon, misc.	Calcium	x				x	x	x	x	x	x	x	x	
	Magnesium	x				x	x	x	x	x	x	x	x	
	Potassium	x				x		x		x		x		
	Sodium	x				x		x		x		x		
	Chloride	x				x		x		x		x		
	Sulfate	x				x		x		x		x		
	Total Organic Carbon	x	x	x	x	x	x	x	x	x	x	x	x	X
	Total Alkalinity	x				x		x		x		x		
	Total Suspended Solids	x	x	x		x	x	x	x	x	x	x	x	X
Metals	Arsenic, total	x				x		x		x		x		
	Boron, total													
	Cadmium, total	x				x		x		x		x		
	Chromium, total	x				x		x		x		x		
	Iron, total	x				x		x		x		x		
	Lead, total	x				x		x		x		x		
	Manganese, total													
	Molybdenum, total	x				x		x		x		x		
	Nickel, total	x				x		x		x		x		
	Thorium, total									x	x	x	x	
	Uranium, total									x	x	x	x	
	Copper, dissolved	x				x	x	x		x	x	x	x	
	Iron, dissolved	x				x	x	x		x	x	x	x	
	Manganese, dissolved	x				x	x	x		x	x	x	x	
	Arsenic, dissolved	x				x		x		x		x		
	Cadmium, dissolved	x				x		x	x	x		x		
	Chromium, dissolved	x				x		x	x	x		x		
	Lead, dissolved	x				x		x	x	x		x		

Type	Constituent	L1	S1	N1	N2	RL	RS	RL_s	RS_s	LU	SU	RU	RSU	RF
	Nickel, dissolved	x				x		x		x		x		
	Selenium, dissolved	x				x		x		x		x		
	Silver, dissolved	x				x		x		x		x		
	Thorium, dissolved									x	x	x	x	
	Uranium, dissolved									x		x	x	
	Zinc, dissolved	x				x		x		x		x		
Nuntstrie	Ammonia as N	x	x	x	x	x	x	x	x	x	x	x	x	x
	Nitrate + Nitrite as N	x	x	x	x	x	x	x	x	x	x	x	x	x
	Total Kjeldahl Nitrogen	x	x	x	x	x	x	x	x	x	x	x	x	x
	Orthophosphate as P	x	x	x	x	x	x	x	x	x	x	x	x	x
	Total Phosphorus	x	x	x	x	x	x	x	x	x	x	x	x	x

The short list at the reservoir sites includes five parameters that are not included in the short list for the flowing sites: calcium, magnesium, copper, iron, and manganese. Iron and manganese are monitored in the lakes and reservoirs because they are good indicators of in-lake processes and important from a water treatment perspective. Copper is included on the list because there have been concentrations that exceed the state water quality copper standard on the east and west slope with potential 303d listings. Calcium and magnesium are included to calculate hardness to assess acute water quality standards.

There is an abbreviated long and short parameter list for the reservoir sites (RL_s and RS_s). These lists are the same as the RL and RS lists except they do not include phytoplankton and zooplankton. Phytoplankton and zooplankton data are not necessary at all the reservoir sites in the program.

SAMPLING SCHEDULE

Monitoring frequency varies from monthly to weekly depending on the time of the year and site location. Generally, sites are sampled monthly during the ice-off seasons except for sites associated with Windy Gap and Willow Creek pumping. Samples are collected at these sites more frequently when the pumps are operating.

Figure 3 – Water quality sample collection on the Colorado River.

Figure 4 – Water quality sample collection on the Hansen Feeder Canal.

Flowing Sites Sampling Schedule

At the flowing sites, the long list is scheduled five times a year: twice during runoff (May and June), once post-runoff (July), once during the late summer (September) and once in the winter (November on the West Slope and January on the East Slope). This schedule provides a baseline of data for various flow regimes and seasons. The scheduled short lists vary from monthly to weekly depending on the site and time of year and are shown in Table 3.

Table 1 - Monitoring Schedule for the Flowing Sites

Station	Oct				Nov				Dec	Jan				Feb	Mar				Apr					May				Jun					Jul				Aug				Sep				
	10/7	10/14	10/21	10/28	11/4	11/11	11/18	11/25	12/30	1/6	1/13	1/20	1/27	2/3	3/3	3/10	3/17	3/24	3/31	4/7	4/14	4/21	4/28	5/5	5/12	5/19	5/26	6/2	6/9	6/16	6/23	6/30	7/7	7/14	7/21	7/28	8/4	8/11	8/18	8/25	9/1	9/8	9/15	9/22	9/29
AC-GRU	S1				L1					S1					S1				S1					L1				L1					L1				S1				L1				
ST-GRU	S1				L1					S1					S1				S1		N1			L1		N1		L1		N1			L1				S1				L1				
RF-GRU	S1				L1					S1					S1				S1					L1				L1					L1				S1				L1				
EI-GLU	S1				L1					S1					S1				S1		N1			L1		N1		L1		N1			L1				S1				L1				
NI-GLU	S1				L1					S1					S1				S1		N1			L1		N1		L1		N1			L1				S1				L1				
CR-SMU	S1				L1					S1					S1				S1		N1			L1		N1		L1		N1			L1				S1				L1				
CR-SMD	S1				L1					S1					S1				S1					L1				L1					L1				S1				L1				
GR-PUMP	S1				L1					S1					S1				S1		S1			L1		S1		L1		S1			L1				S1				L1				
CR-WGU	S1				L1					S1					S1						S1			L1				L1					L1				S1				L1				
FR-WGU	S1				L1					S1					S1						S1			L1				L1					L1				S1				L1				
CR-WGD	S1				L1					S1					S1						S1			L1				L1					L1				S1				L1				
WC-PUMP	S1		S1		L1		S1								S1	S1	S1	S1	S1	S1	S1	S1	S1	L1	S1	S1	S1	L1	S1	S1	S1	S1	L1	S1	S1	S1	S1	S1	S1	S1	L1	S1	S1	S1	S1
WC-WCRD	S1				L1					S1					S1				S1					L1				L1					L1				S1				L1				
CR-GRD	S1				L1					S1					S1				S1					L1				L1					L1				S1				L1				
WG-PUMP																					S1	S1	S1	L1	S1	S1	S1	L1	S1	S1	S1	S1	L1	S1	S1	S1	S1								
BFC	S1				L1					S1					S1									L1				L1					L1								L1				
BFC-BR	S1																							L1				L1					L1								L1				
BFC-LH	S1																							L1				L1					L1								L1				
LH-BFCD	S1																							L1				L1					L1								L1				
LH-BFCU																								L1				L1					L1								L1				
BSC-BR	S1																							L1				L1					L1								L1				
BC-BSCD	S1																							L1				L1					L1								L1				
BC-BSCU																								L1				L1					L1								L1				
BSC-BC	S1																							L1				L1					L1								L1				
HFC-BT	S1				S1					L1					S1				S1					L1				L1					L1				S1				L1				
BT-HFCD	S1				S1					L1									S1					L1				L1					L1				S1				L1				
BT-HFCU					S1					L1									S1					L1				L1					L1				S1				L1				
HFC-FRD	S1				S1					L1					S1				S1					L1				L1					L1				S1				L1				
HFC-HT	S1				S1					L1					S1				S1					L1				L1					L1				S1				L1				
HSC-PR	S1																		S1					L1				L1					L1								L1				
PR-HSCD	S1																		S1					L1				L1					L1								L1				
PR-HSCU																			S1					L1				L1					L1								L1				
SVSC-CL	S1																		S1					L1				L1					L1								L1				
SVSC-LT	S1																		S1					L1				L1					L1								L1				
LT-SVSCD	S1																		S1					L1				L1					L1								L1				
LT-SVSCU																			S1					L1				L1					L1								L1				
SVSC-SV	S1																		S1					L1				L1					L1								L1				
SV-SVSCD	S1																		S1					L1				L1					L1								L1				
SV-SVSCU																			S1					L1				L1					L1								L1				

No Sampling

No Sampling

Note: The schedule presented in Table 3 is in a weekly format to better show when weekly sampling occurs; monthly sampling can occur during any week of the month, not necessarily the week indicated in the table.

Lakes and Reservoir Sampling Schedule

In the lakes and reservoirs, monthly sampling occurs from May through October on the West Slope and April through November on the East Slope. There are two scheduled events on the West Slope (January and March) and one on the East Slope (January or when ice conditions allow). The long parameter lists are scheduled three times a year to capture seasonality: January, June, and September. The short lists are scheduled for the remainder of the sampling events. The reservoir sampling schedule is shown in Table 2.

Figure 5 - Winter water quality sampling on Willow Creek Reservoir.

Table 2 - Lakes and Reservoirs Monitoring Schedule

Station	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	2-Jul	Aug	2-Aug	Sep	2-Sep
GL-MID	RL		No Sampling	RL	No Sampling	RS		RS	RL	RS	RF	RS	RF	RS	RF
GL-ATW	RL^S			RL^S		RS^S		RS^S	RL^S	RS^S		RS^S		RS^S	
SM-MID	RL			RL		RS		RS	RL	RS	RF	RS	RF	RS	RF
SM-DAM	RL			RL		RS		RS	RL	RS		RS		RS	
GL-CHL	RL			RL		RS		RS	RL	RS		RS		RS	
GR-DAM	RL			RL		RS		RS	RL	RS		RS		RS	
GR-EAS	RL^S			RL^S		RS^S		RS^S	RL^S	RS^S		RS^S		RS^S	
GR-WES	RL^S			RL^S		RS^S		RS^S	RL^S	RS^S	RF	RS^S	RF	RS^S	RF
WC-DAM	RL			RL		RS		RS	RL	RS	RF	RS	RF	RS	RF
WG-DAM				RL^S				RS^S	RL^S	RS^S		RS^S		RL^S	
HT-SPR*	RL	RS		RL			RS	RS	RL	RS		RS		RS	
HT-DIX*	RL	RS		RL											
HT-SOL*	RL	RS		RL			RS	RS	RL	RS		RS		RS	
HT-DAM							RMn	RMn	RMn	RMn		RMn		RMn	
CL-DAM1*	RL	RS		RL			RS	RS	RL	RS		RS		RS	

Sampling in the channel that connects Shadow Mountain Reservoir to Grand Lake is done at two different locations depending on the time of the year. Sampling from May through October it is conducted from a boat on the Grand Lake side of the channel (GL-CHL). During the winter sampling events, ice conditions are not favorable for a boat and sampling is done in the channel from the foot bridge, near Grand Lake (SM-CHL) (Figure 9).

Figure 6 – Aerial image of Shadow Mountain Reservoir channel water quality sampling locations.

Changes to Sampling Schedule

In response to the fires, sampling frequency was increased at several locations in 2021. These increases remained in place since and include:

- Increased sampling frequency at the inlets to the Three Lakes that were impacted by the fire (NI-GLU, CR-SMU, ST-GRU and EI-GLU) to monitor nutrients, TOC and TSS from 1x per month to 2x per month during runoff (Apr-July). This provides information on nutrient loading into the system during runoff. Increased frequency better captures changes that can result from a flashy hydrograph and supports development of a more robust post-fire baseline.
- Increased sampling frequency on some East Slope flowing sites (AT-EP, HFC-HT) to monitor nutrients, TOC and TSS from 1x per month to 2x per month (Apr-Sep). This provides information on nutrient loading into East Slope reservoirs. Additional monitoring in the Hansen Feeder Canal supports assessment of both the East Troublesome and Cameron Peak Fires and allows for a characterization of the spatial propagation of water quality degradation from the Three Lakes to East Slope terminal reservoirs.
- Increased sampling frequency on the West Slope lakes and reservoirs (GL-MID, SM-MID, GR-DAM, WC-DAM, WG-DAM) to monitor nutrients, TOC, TSS and algae from 1x per month to 2x per month in Jul-Sep. This was modified slightly compared to 2021 where the 2x per month sampling did not include September. September was included in 2022 because in 2021 there was significant algal productivity during September. This provides information on internal lake processes that may result from increased nutrient loading into the system. Focus is on the summer months when algae blooms are most likely to occur and could lead to cyanotoxin production.

Sample Collection, Analysis, and Data Processing

Northern Water operates the program and performs most of the sample collection. The United States Geological Survey (USGS) conducts sampling at some sites. All flowing sites, except AT-EP and OLY, are sampled by Northern Water Field Services (NWFS). Sampling at AT-EP and OLY is conducted by the USGS. Prior to 2021, sampling on the lakes and reservoirs was conducted by NWFS except during the winter months on the west slope (January to March); this sampling was conducted by the USGS with assistance from NWFS. In 2021, Northern Water expanded their partnership with the USGS and in 2021, 2022 and 2023, the USGS conducted all the sampling on the West Slope lakes and reservoirs. This change was implemented due to the additional resources needed for NWFS to conduct field activities related to the East Troublesome Fire for this Program as well as other Northern Water monitoring efforts. In 2024, the NWFS resumed all sampling on west slope lakes and reservoirs except for second sampling events in July, August, and September.

Samples for nutrients and TSS are analyzed at High Sierra Water Lab; a USGS certified private laboratory whose analytical methods have low level detection limits. Samples for metals and general chemistry are analyzed at Huffman Hazen Laboratories; a USGS certified private laboratory whose analytical methods for metals have low level detection limits. Zooplankton and Phytoplankton samples are analyzed at BSA Environmental Services, Inc. Chlorophyll samples are analyzed by Northern Water Field Services in the laboratory at Northern Water's headquarters.

All sample collection is done utilizing protocols documented in Northern Water's "Standard Operating Procedures (SOP's) for Northern Water's Water Quality Monitoring Programs." Data collected in the field and received from laboratories are subject to thorough QA/QC following protocols documented in Northern Water's SOP "Standard Operating Procedures (SOP's) for Northern Water's Water Quality Monitoring Programs." The final data are accessible at Northern Water's website, Northern Water Database Interface.

MONITORING LOCATIONS

The program covers 55 monitoring locations in eight watersheds on both sides of the Continental Divide in Northern Colorado. There are 41 flowing sites (canals, river, and streams) located upstream and downstream of reservoirs, in the canals at points of release to streams and in the streams upstream and downstream of these release points. There are 14 lake and reservoir sites located in seven waterbodies. In each lake/reservoir, there are sampling locations at the deepest points in the waterbodies. The larger lakes/reservoirs have additional sampling locations to monitor the spatial variability of water quality within the waterbody. The monitoring locations are shown in Figure 3 and Figure 4 and listed in Table 1 – Monitoring Locations Tables.

Table 3 – Lakes and Reservoirs Monitoring Locations.

Station	Description	Latitude	Longitude	Slope
GL-ATW	Grand Lake West Portal	40.2411	-105.8045	West
GL-MID	Grand Lake Mid-Section	40.2433	-105.8133	West
GR-DAM	Granby Reservoir near the Dam	40.1497	-105.8649	West
GR-EAS	Granby Reservoir on the East Side	40.135	-105.7964	West
GR-WES	Granby Reservoir on the West Side	40.175	-105.8697	West
SM-CHL	Shadow Mountain Channel in Grand Lake at channel mouth	40.2445	-105.8247	West
SM-DAM	Shadow Mountain Reservoir near the Dam	40.2101	-105.8421	West
SM-MID	Shadow Mountain Reservoir Mid-Section	40.2252	-105.8372	West
WC-DAM	Willow Creek Reservoir at Dam	40.1497	-105.9435	West
WG-DAM	Windy Gap Reservoir at Dam	40.1085	-105.9825	West
CL-DAM1	Carter Lake Dam #1	40.3253	-105.2152	East
HT-DIX	Horsetooth Reservoir at Dixon Canyon Dam	40.5543	-105.1506	East
HT-DAM	Horsetooth Reservoir at North Dam	40.5983	-105.1709	East
HT-SOL	Horsetooth Reservoir at Soldier Canyon Dam	40.5888	-105.1649	East
HT-SPR	Horsetooth Reservoir at Spring Canyon Dam	40.5292	-105.1456	East

Table 2 – Flowing Sites Monitoring Locations.

Station	Description	Latitude	Longitude	Slope
AC-GRU	Arapahoe Creek at Monarch Lake outlet upstream Granby Reservoir	40.1128	-105.7497	West
CR-GRD	Colorado River downstream of Granby Reservoir	40.1444	-105.8672	West
CR-SMD	Colorado River downstream of Shadow Mountain Reservoir	40.2059	-105.838	West
CR-SMU	North Fork Colorado River upstream of Shadow Mountain Reservoir	40.2190	-105.8577	West
CR-WGD	Colorado River downstream of Windy Gap Reservoir	40.1082	-106.0037	West
CR-WGU	Colorado River upstream Windy Gap/Fraser River Confluence	40.1003	-105.9726	West
EI-GLU	East Inlet upstream of Grand Lake	40.2369	-105.801	West
FR-WGU	Fraser River upstream of Colorado River Confluence	40.0984	-105.9727	West
GR-PUMP	Granby Pump Canal at foot bridge on Shadow Mountain Reservoir	40.2068	-105.8495	West
NI-GLU	North Inlet upstream of Grand Lake	40.2507	-105.8148	West
RF-GRU	Roaring Fork inlet upstream of Granby Reservoir	40.1308	-105.7671	West
SMC-CRU	Smith Creek upstream of Colorado River	40.1004	-105.9701	West
ST-GRU	Stillwater Creek upstream of Granby Reservoir	40.1829	-105.8892	West
WC-PUMP	Willow Creek Pump Canal inflow into Granby Reservoir	40.1430	-105.8888	West
WC-WCRD	Willow Creek directly downstream Willow Creek Reservoir	40.1456	-105.9404	West
WG-PUMP	Windy Gap Pump Canal inflow into Granby Reservoir	40.1429	-105.8888	West
AT-EP	Adams Tunnel East Portal near Estes Park	40.3278	-105.5782	East
BFC	Boulder Feeder Canal at Hygiene Road	40.1889	-105.2388	East
BFC-BR	Boulder Feeder Canal at inlet to Boulder Reservoir at Star Turnout	40.0947	-105.2209	East
BFC-LH	Boulder Feeder Canal at Left Hand Creek	40.1040	-105.227	East
LH-BFCD	Left Hand Creek downstream of Boulder Feeder Canal	40.1033	-105.217	East
LH-BFCU	Left Hand Creek upstream of Boulder Feeder Canal	40.1038	-105.2272	East
BSC-BC	Boulder Supply Canal at Boulder Creek at Jay Road	40.0530	-105.1877	East
BC-BSCD	Boulder Creek downstream of Boulder Supply Canal	40.0514	-105.179	East
BC-BSCU	Boulder Creek upstream of Boulder Supply Canal	40.0507	-105.1874	East
BSC-BR	Boulder Supply Canal at outlet from Boulder Reservoir	40.0775	-105.2071	East
HFC-BT	Hansen Feeder Canal downstream of trifurcation at gage	40.4234	-105.2265	East
BT-HFCD	Big Thompson River downstream of Hansen Feeder Canal	40.4258	-105.2167	East
BT-HFCU	Big Thompson River upstream of Hansen Feeder Canal	40.4149	-105.2510	East
HFC-FRD	Hansen Feeder Canal downstream of Flatiron Reservoir	40.3748	-105.2306	East
HFC-HT	Hansen Feeder Canal at inlet to Horsetooth	40.5056	-105.197	East

Station	Description	Latitude	Longitude	Slope
HSC-PR	Hansen Supply Canal at release into Cache La Poudre River	40.659	-105.2098	East
PR-HSCD	Cache La Poudre River downstream of Hansen Supply Canal	40.6606	-105.2032	East
PR-HSCU	Cache La Poudre River upstream of Hansen Supply Canal	40.6601	-105.2094	East
OLY	Olympus Tunnel at Lake Estes	40.3764	-105.4858	East
SVSC-CL	Saint Vrain Supply Canal at Carter Lake outlet	40.3173	-105.2068	East
SVSC-LT	Saint Vrain Supply Canal at release to Little Thompson River	40.2615	-105.2083	East
LT-SVSCD	Little Thompson River downstream of Saint Vrain Supply Canal	40.2584	-105.1977	East
LT-SVSCU	Little Thompson River upstream of Saint Vrain Supply Canal	40.2584	-105.2074	East
SVSC-SV	Saint Vrain Supply Canal at Saint Vrain Creek	40.2182	-105.2582	East
SV-SVSCD	Saint Vrain Creek downstream of Saint Vrain Supply Canal	40.2166	-105.2596	East
SV-SVSCU	Saint Vrain Creek upstream of Saint Vrain Supply Canal	40.2173	-105.2595	East

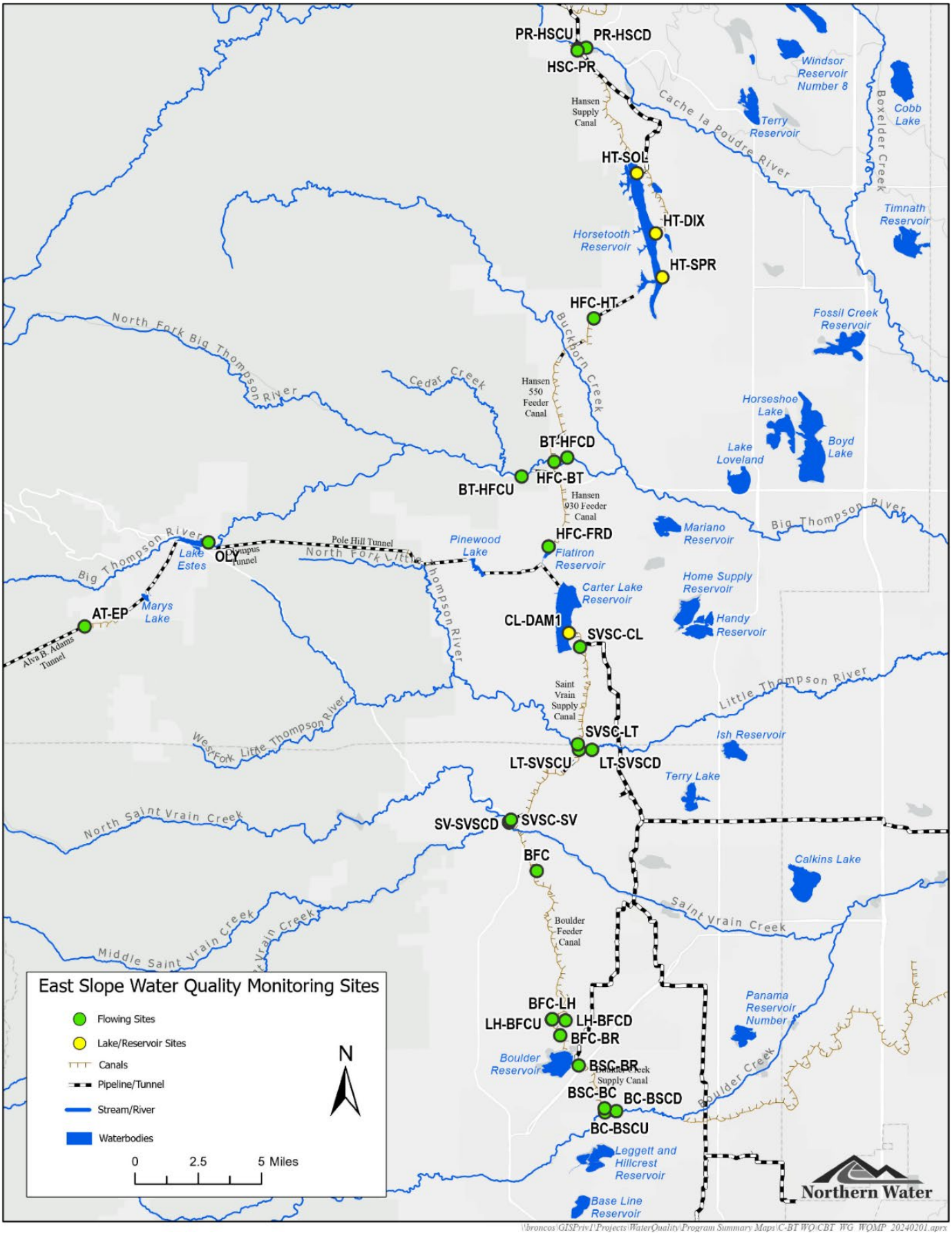

Figure 7 -Map of East Slope water quality monitoring locations.

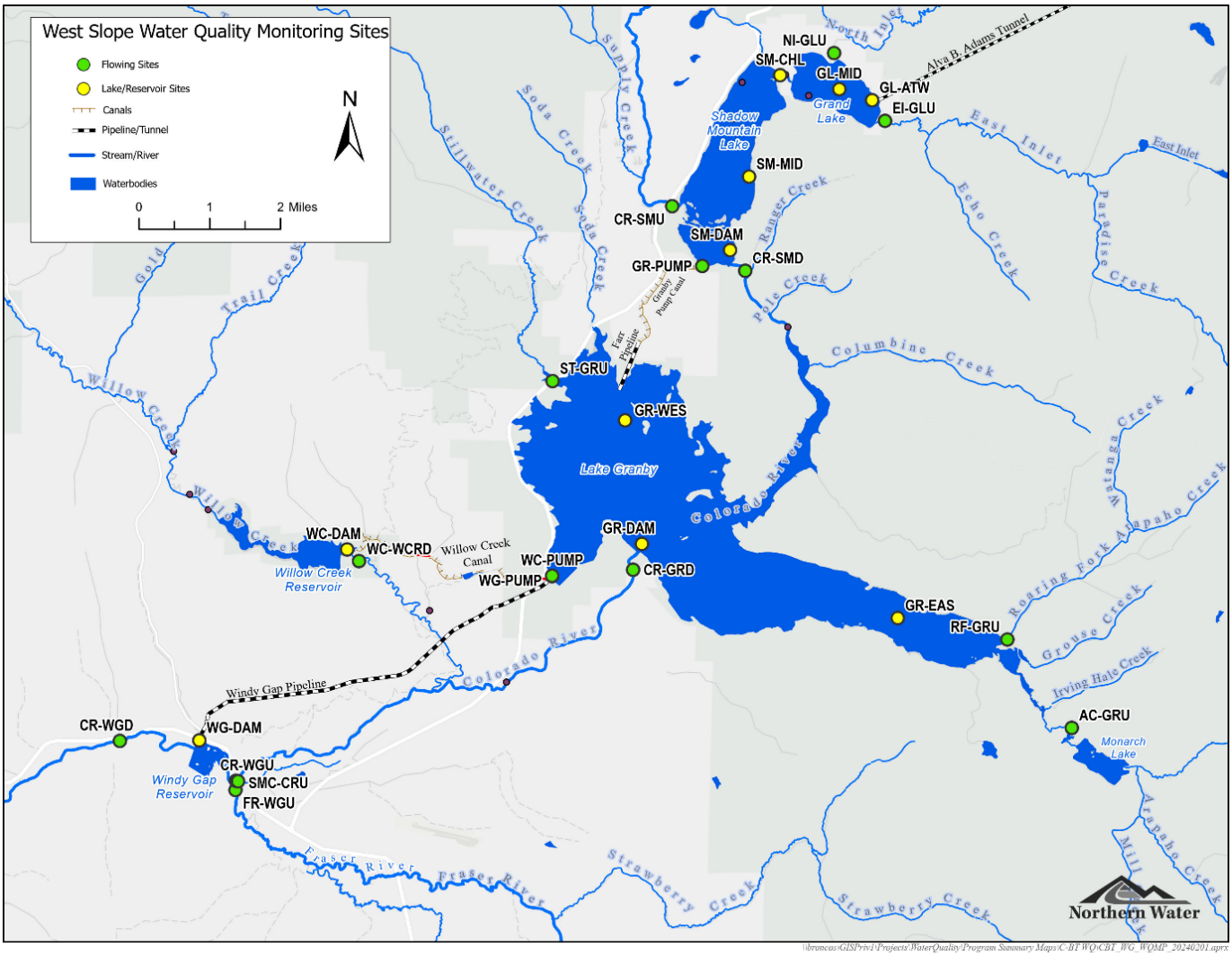

Figure 8 - Map of West Slope water quality monitoring locations.

APPENDIX 1 – HISTORY OF PROGRAM CHANGES

The three tables below outline changes to the Colorado- Big Thompson and Windy Gap Water Quality Monitoring Program since it began in 2008. Note that these changes are outlined by calendar year, not water year.

Table A1 - Changes to sampling schedule, monitoring frequency and sample collection.

Year	Description of Change
2011	Increased sampling frequency at the inlets to and interflows between the Three Lakes (AC-GRU, CR-SMU, EI-GLU, NI-GLU, RF-GRU, ST-GRU and CR-SMD, SM-CHL) from Apr-Nov from monthly to every other week. The additional sampling focused on nutrients to support a better understating of the system and modeling efforts related to Grand Lake Clarity.
	Increased sampling frequency in the Granby Pump Canal from Apr-Oct (when pumping) from monthly to weekly. The additional sampling focused on nutrients to support a better understating of the system and modeling efforts related to Grand Lake Clarity.
	Increased sampling frequency in the Three Lakes in Aug-Sep from 1x per month to 2x per month. The additional sampling focused on nutrients to support a better understating of the system and modeling efforts related to Grand Lake Clarity.
2013	USGS lakes profile data changed from foot increments to meter increments. Monthly sampling in Feb, Mar, Oct, Nov; Bimonthly sampling April-Sept
	Discontinued sampling at CR-KRM. This site was monitored in cooperation with the USGS and Denver Water. This site was monitored to establish baseline conditions for the Wild and Scenic group. Data collected to date met this objective.
	Discontinue sampling at ST-IRU, ST-RDD and ST-BAS. These sites were added to gain a better understanding of nutrients in the Stillwater Creek watershed. Data collected to date provide adequate information to meet this objective.
	Discontinue sampling at HT-SCC. This site was added in 2012 to assess impacts from the High Park Fire. The post-fire data collected at this site and in Horsetooth do not show adverse impacts to water quality.
2014	Northern Water began collecting the samples in the West Slope lakes and reservoirs. This sampling was previously conducted by the USGS. This change was made to make Northern Water's program more efficient from both a cost and management perspective.
	Discontinued sampling at ST-JRD2. This site was established to serve as a surrogate when samples could not be collected at ST-GRU due to high reservoir elevation in Granby. ST-JRD2 was not a good site to collect samples for several reasons (channel access, proximity to ditch inflows, no place to take flow measurements). In addition, a relationship could not be established based on concurrent data collected at ST-JRD2 and ST-GRU.
	Discontinued collecting chlorophyll samples for the 0-2 meter composite in Grand Lake. In 2008, a report by Rob Buirgy "An Assessment of Correlation Between Secchi Depth and Selected Water Quality Parameters in Grand Lake, Colorado" showed a correlation between Secchi depth and chlorophyll concentration at the 0-2 meter depth. In response to this, chlorophyll samples were collected at both 0-2 meters and 0-5 meters since 2009. Review of these data showed no correlation between Secchi and 0-2 meter chlorophyll data. Chlorophyll data will be collected at the 0-5 meter depth which is consistent with the chlorophyll data collected at all other sites.

Year	Description of Change
	Modified the sampling depths for phytoplankton and zooplankton. Prior to 2014, both were collected at two different depths intervals: 0-5 meters and 5-10 meters. Review of the data and discussion with biologists concluded that the depth intervals could be modified while still meeting program objectives. Phytoplankton data collection was changed to 0-5 meters which corresponds with algal productivity and chlorophyll data collection. Zooplankton data collection was changed to 0-10 meters (except for Shadow Mountain which is too shallow, and the sampling depth is 0-5 meters) which will capture the vertical migration of the species and still be comparable to historic data collected at both depth intervals. This was done as part of a program review with the Bureau of Reclamation in an effort to reduce monitoring costs.
2015	Added a long parameter list in place of the short parameter list to the flowing sites in May on the East Slope and in June on the West Slope. This provides two sampling events with the long list of parameters during runoff.
	Changed the parameter list schedule on the West Slope. July was changed from a long list to a short list and September was changed from a short list to a long list. This is consistent with the East Slope schedule and provides a late summer sampling event with the long list of parameters on the West Slope.
	Discontinued sampling in December and February at the Windy Gap sites (CR-WGU, FR-WGU, CR-WGD, WC-WCRD, and CR-GRD). Monthly winter sampling was added to these sites in WY2011. Removing the winter sampling for the months of December and February is consistent with the schedule at the inlet sites during the winter months. There is no pumping in the winter months, so monthly sampling at these sites is not necessary. The November, January and March sampling events should provide a sufficient baseline of data for low-flow winter conditions.
2016	Reduced sampling frequency at the inlets to and interflows between the Three Lakes (AC-GRU, CR-SMU, EI-GLU, NI-GLU, RF-GRU, ST-GRU and CR-SMD, SM-CHL) from Apr to Nov from every other week to monthly. This was done as part of a large-scale program review in effort to reduce monitoring costs.
	Reduced sampling frequency in the Granby Pump Canal from Apr-Oct (when pumping) from weekly to monthly. This was done as part of a large-scale program review in effort to reduce monitoring costs.
	Reduced sampling frequency in the Three Lakes in Aug-Sep from 2x per month to 1x per month. This was done as part of a large-scale program review in effort to reduce monitoring costs.
2018	The August sampling event on the East Slope flowing sites was removed from the sampling program (except at AT-EP and OLY). The August event sampled a short parameter list (nutrients and total organic carbon) which is not a primary focus of the East Slope flowing sites water quality monitoring. The long parameter list (nutrients, metals, general chemistry, and ions) provides more complete information on overall water quality, but the cost is considerably higher than the short parameter list. By removing the East Slope August sampling event from the sampling schedule there was more flexibility in the budget to add an additional long parameter list event to the program.

Year	Description of Change
	The July sampling event for the flowing sites was changed from a short parameter list (nutrients and total organic carbon) to a long parameter list (nutrients, metals, general chemistry, and ions).
2021-2024	Partnered with USGS for West Slope lakes and reservoir monitoring due to the increased monitoring needed to assess impacts from the East Troublesome Fire.
	Increased sampling frequency at the inlets to the Three Lakes that were impacted by the fire (NI-GLU, CR-SMU, ST-GRU and EI-GLU) to monitor nutrients, TOC and TSS from 1x per month to 2x per month during runoff (Apr-Jul). This provides information on nutrient loading into the system during runoff. Increased frequency better captures changes that can result from a flashy hydrograph. Support the ability to develop a more robust post-fire baseline.
2021-2022	Increased sampling frequency on some East Slope flowing sites (AT-EP, HFC sites) to monitor nutrients, TOC and TSS from 1x per month to 2x per month (Apr-Sep). This provides information on nutrient loading into East Slope reservoirs. Additional monitoring in the Hansen Feeder Canal supports assessment of both the East Troublesome and Cameron Peak Fires and allows for a characterization of the spatial propagation of water quality degradation from the Three Lakes to East Slope terminal reservoirs.
2021	Increased sampling frequency on the West Slope lakes and reservoirs (GL-MID, SM-MID, GR-DAM, WC-MID, WG-MID) to monitor nutrients, TOC, TSS and algae from 1x per month to 2x per month in **Jul-Aug**. This provides information on internal lake processes that may result from increased nutrient loading into the system. Focus is on the summer months when algae blooms are most likely to occur and could lead to cyanotoxin production.
2022-2023	Added an additional month - Increased sampling frequency on the West Slope lakes and reservoirs (GL-MID, SM-MID, GR-DAM, WC-MID, WG-MID) to monitor nutrients, TOC, TSS and algae from 1x per month to 2x per month in **Jul-Sep**. This provides information on internal lake processes that may result from increased nutrient loading into the system. Focus is on the summer months when algae blooms are most likely to occur and could lead to cyanotoxin production.
2024	For clarity period (2x) sampling, GR-DAM site was replaced with GR-WES.
	Sampling at HT-DAM instead of HT-DIX **April-Sep**. to compare results with HT-SOL.
2026	Removed second (post-fire investigation) sampling events from west slope inlet sites in January 2026.

Appendix A2 – Changes to the program parameter lists and analysis.

Year	Description of Change
2008	Began using High Sierra Water Laboratory for all nutrient analysis
2009	Began using Huffman Laboratory (Now Hazen Laboratory) for all metals and general chemistry analysis
2010	No changes from 2009
2011	Added NVSS to parameter lists specific to assessing Grand Lake Clarity. The data will provide a better understanding of TSS composition and may be helpful for modeling purposes.
2012	Added UV254 and DOC to the lakes and reservoir sites top and bottom depths. UV254 is a parameter which utilizes light at the UV 254nm wavelength to be able to detect organic matter in water and wastewater. It is used to characterize DOC by calculated the SUVA (Specific UV Absorption) which is the ratio of UV254 to DOC. The value of the SUVA indicates whether the DOC is of algal origin, humic sources, or both. This information is of particular interest to the water treatment facilities that use Northern Water for a water source supply.
	Metals and general chemistry analysis changed from USGS National Water Quality Lab to Huffman (Hazen) at AT-EP and OLY sites.
	Mercury analysis changed from Test America to Accutest. Accutest uses the same lab method, provides low-level results, and is more cost effective.
2013	Removed total ions from all parameter lists. These parameters are a function fo geology, and a sufficient baseline of data had been established.
	Added total dissolved solids to all parameter lists that included total suspended solids. Added total Arsenic to all long-parameter lists to address 303(d) listings.
2014	Removed total suspended solids and mercury from all lists. Removed total iron, calcium, magnesium, and alkalinity from the short lists. Removed chlorophyll at the flowing sites. This was done as part of a program review with the Bureau of Reclamation in an effort to reduce monitoring costs.
	Removed NVSS analysis from parameter lists specific to assessing Grand Lake Clarity. These data were collected to better understand the organic matter composition of TSS. The detection limits for the analysis were not low enough to detect NVSS and therefore these data were not meaningful for this assessment.
	Added dissolved boron, total and dissolved chromium, and dissolved uranium to the long lists of parameters since all these have water quality standards. Added major ions back to the long lists since there are water quality standards fro sulfate and 303(d) listings for segments within the monitoring program. Major ions were removed in 2013.
	High Sierra Water Lab began analyzing for TSS since they have a low-level method with a method detection limit (MDL) of 0.1 mg/L. This analysis was previously done by Huffman (Hazen) Laboratories, MDL of 1 mg/L.
2015	Fort Collins Water Laboratory began analyzing for chlorophyll. This was previously performed by the USBR Lab in Denver but was discontinued to outside agencies.
	Removed copper, iron, and manganese from the flowing sites short list. It was not deemed necessary to monitor these metals from every sampling event. Iron and manganese were maintained on the lakes and reservoirs short list as they are good indicators of internal lake processes and important in terms of drinking water treatment.

Year	Description of Change
	Added copper to the lakes and reservoirs short list in respojnse to the copper exceedances in the Three Lakes area and potential 303(d) listings.
2016	Removed UV254 and DOC from the monitoring program. UV254 and DOC sampling was intended to last a few years, or until a strong baseline of data was established. The data were reviewed in 2015 and indicated the 2012-2015 dataset established a sufficient baseline.
	Addition of total aluminum to the flowing sites long parameter list. This addition was to address water quality issues in the Big Thompson River that were related to a concrete spill in the North Fork of the Big Thompson River during construction work, where aluminum concentrations were thought to be extremely elevated. This was a short-term addition to obtain baseline total aluminum data.
2017	Total aluminum was removed from the program in 2017.
2018	In 2016, the Colorado Water Quality Control Division (WQCD) added total cadmium, total lead, and total nickel to the list of regulated compounds. To collect data that allow for assessment of state water quality standards, total cadmium, total lead, and total nickel were added to the long parameter lists.
	Data assessments for acute water quality standards for metals can only be performed when there are paired hardness data available. Calcium and magnesium were added to the reservoir short lists so that hardness can be calculated, and acute assessements can be done for the metals that are collected during these sampling events.
	Removed dissolved boron from the parameter lists. There is an applicable chronic boron standard of 750 ug/L for all the segments monitoring for the C-BT baseline program. Dissolved boron has been part of the program since WY2014. Concentrations of boron colleected during this time are typically below 20 ug/L. The data collected since WY2014 provide a baseline of typical concentrations in the system that can be referred to in the future if needed. Given all concentrations have been well below the standard, it is not necessary to continue monitoring dissolved boron.
	Removed dissolved uranium from the parameter lists. The water quality standards for uranium are not applicable in the segments monitorjng for the C-BT Baseline Program. Dissolved uranium has been part of the program since WY2014. These data provide a baseline of typical concentrations that van be referred to in the future if needed.
2019	No changes made.
2020	In October 2019, Northern Water Field Services began analyzing chlorophyll at their laboratory located at their campus in Berthoud.
	The reporting limit for dissolved zinc was increased from 1 ug/L to 2 ug/L.
2021-2022	Addtition of parameters specific for assessing impacts from the East Troublesome Fire. These parameters included dissolved organic carbon (DOC) and total and dissolved inorganic carbon (DIC and TIC). These parameters provide a more complete measure of the ash entering and moving through the system. The ash will be comprised of particulate organic material (measured by TOC minus DOC), inorganic solids, and inorganic carbon (mineral carbonates, etc.). TIC and DIC will allow calculation of PIC (particulate inorganic carbon), which is an indication of the inorganic part of the ash. These parameters were included in fire specific parameter lists used at sites impacted by the fire.

Year	Description of Change
2023	Removed the total inorganic carbon, dissolved inorganic carbon (TIC and DIC) from fire specific parameter lists for sites impacted by the East Troublesome Fire.
2025	Added U and Th analysis at all east slope sites (flowing and reservoir) to long and short lists for remainder of year beginning July 1.
2026	Field Services begins tracking lot numbers for sampling bottles used in order to provide additional troubleshooting in the case of sample contamination investigations.

Appendix A3 – Changes to program monitoring locations.

Year	Description of Change
2012	Moved ST-GRU from upstream of Highway 34 to downstream of Highway 34 as there was no longer access to private property at the upstream site. This move will result in less frequent sampling at ST-GRU because when Granby Reservoir's elevation is high, it floods the sampling location. Since data from Stillwater Creek are important for Grand Lake Clarity, sampling will occur at an alternate site, ST-JRD2, off the right-a-way by CR42. This site combindes time-weighted composite samples from Stillwater Creek and from a ditch that enters Stillwater at this location. The intent is that ST-JRD2 can be used as a surrogate sampling location when samples cannot be collected at ST-GRU.
2014	Moved WG-DAM from sampling in the reservoir via canoe to off the platform of the Windy Gap Pump Plant. This change occurred in parallel with Northern Water conducting sample collection on the West Slope instead of the USGS.
2020	12 station IDs located on the East Slope were not named according to Northern Water standard naming convention. These site IDs were updated to match the standard nomenclature: LH-BHCD, LH-BFCU, BC-BSCD, BC-BSCU, BT-HFCD, BT-HFCU, PR-HSCD, PR-HSCU, LT-SVSCD, LT-SVSU.
	BFC-BR was moved from directly upstream of Boulder Reservoir to upstream of the Star Headgate (BFC-STAR). This due to operational changes related to the completion of the SWSP (Southern Water Supply Project) II that will often result in no flow at the historic site upstream of Boulder Reservoir.
2021	Moved ST-GRU upstream of Highway 34 due to new access on private property., Sampling done at the upstream location in 2010 and 2011.
2022	Added a short-term site in Smith Creek (SMC-CRU), upstream of the Colorado River at Windy Gap was added to the program to gather information on its nutrient contributions to the Colorado River upstream of Windy Gap Reservoir.
2025	Added a short-term reservoir site (HT-DAM) on Horsetooth Reservoir to compare to HT-SOL data. While the site has been setup in WISKI, we collected no samples.
2026	Chlorophyll analysis - Motherboard on centerfuge failed in January. During this downtime (1/21/2026 - 2/16/2026), 4 samples were processed at the City of Fort Collins lab.


Northern Water