Standard Operating Procedures (SOPs) for Water Quality Monitoring Programs

Water Quality and Field Services Departments

Northern Water

Northern Water

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1. Introduction

1.1 PROGRAM DESCRIPTION

The Northern Colorado Water Conservancy District's (Northern Water) Water Quality Monitoring Program includes the collection, analysis, management, and reporting of physical, chemical, and biological data associated with waters of the Colorado-Big Thompson (C-BT) Project (*Figure 1*), the Windy Gap Project, Windy Gap Firming (WGFP) Project (*Figure 2*), and the Northern Integrated Supply Project (NISP, *Figure 3*). Northern Water staff collect field data and water quality samples, coordinate with laboratories, assess data quality and quality control samples, conduct database management activities, and analyze and report data associated with several individual water quality monitoring programs (*Table 1*).

Together, these programs involve the collection of data at over 100 monitoring sites in eight watersheds on both sides of the Continental Divide in Northern Colorado. Data may also be collected by Northern Water for a variety of special studies that are outside of these individual programs. Depending on the individual program and special study, data collection may include field measurements of temperature, dissolved oxygen (D.O.), pH, specific conductance, turbidity, discharge, and Secchi depth, and laboratory analysis for nutrients, metals, chlorophyll, organic carbon, total suspended solids, major ions and other general chemistry parameters, phytoplankton, zooplankton, periphyton, and emerging contaminants. Program summaries contain detailed information about the sampling locations, frequency, and parameters applicable to each individual program.

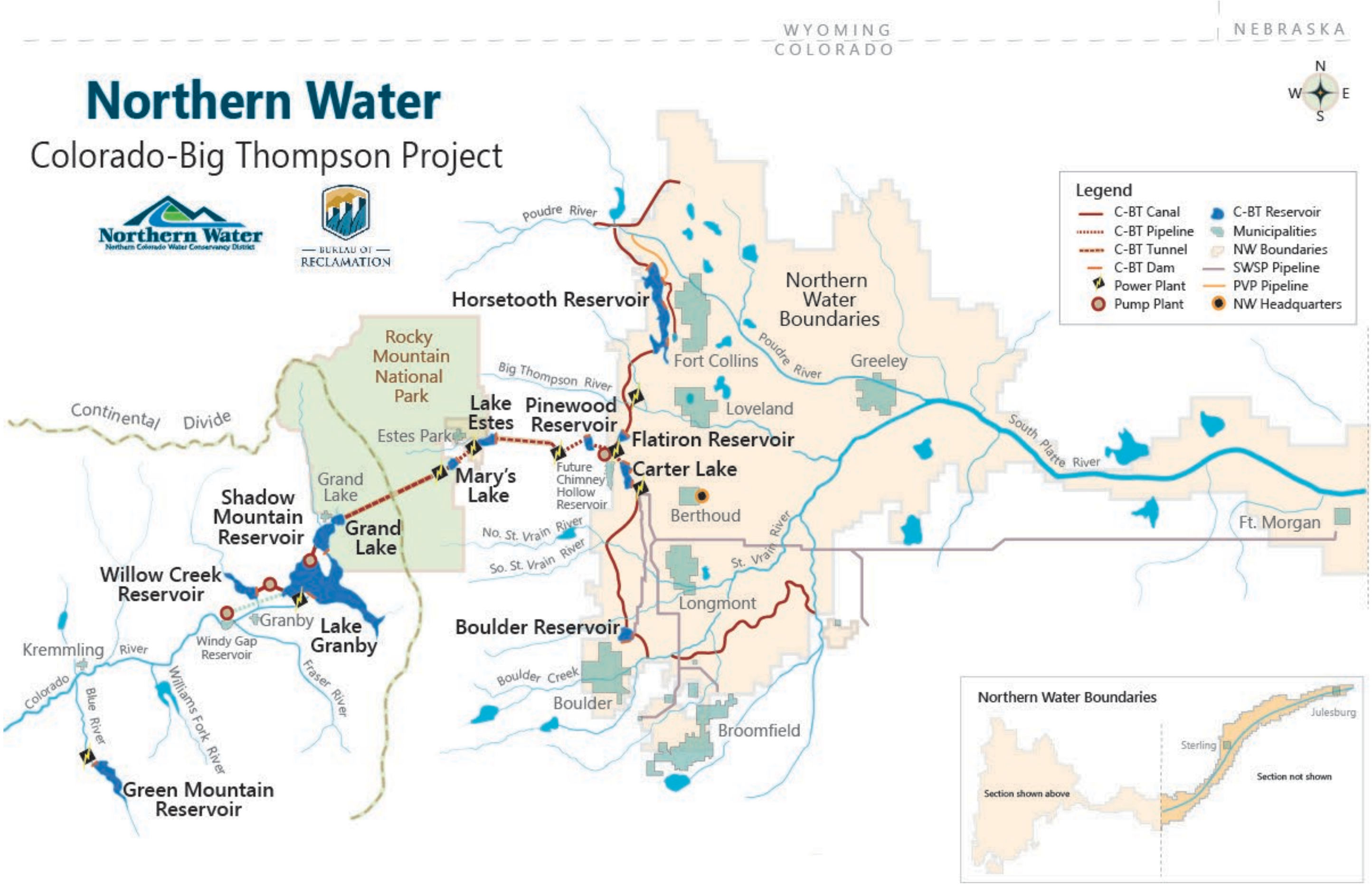


Figure 1 - Map of the Colorado Big Thompson Project.

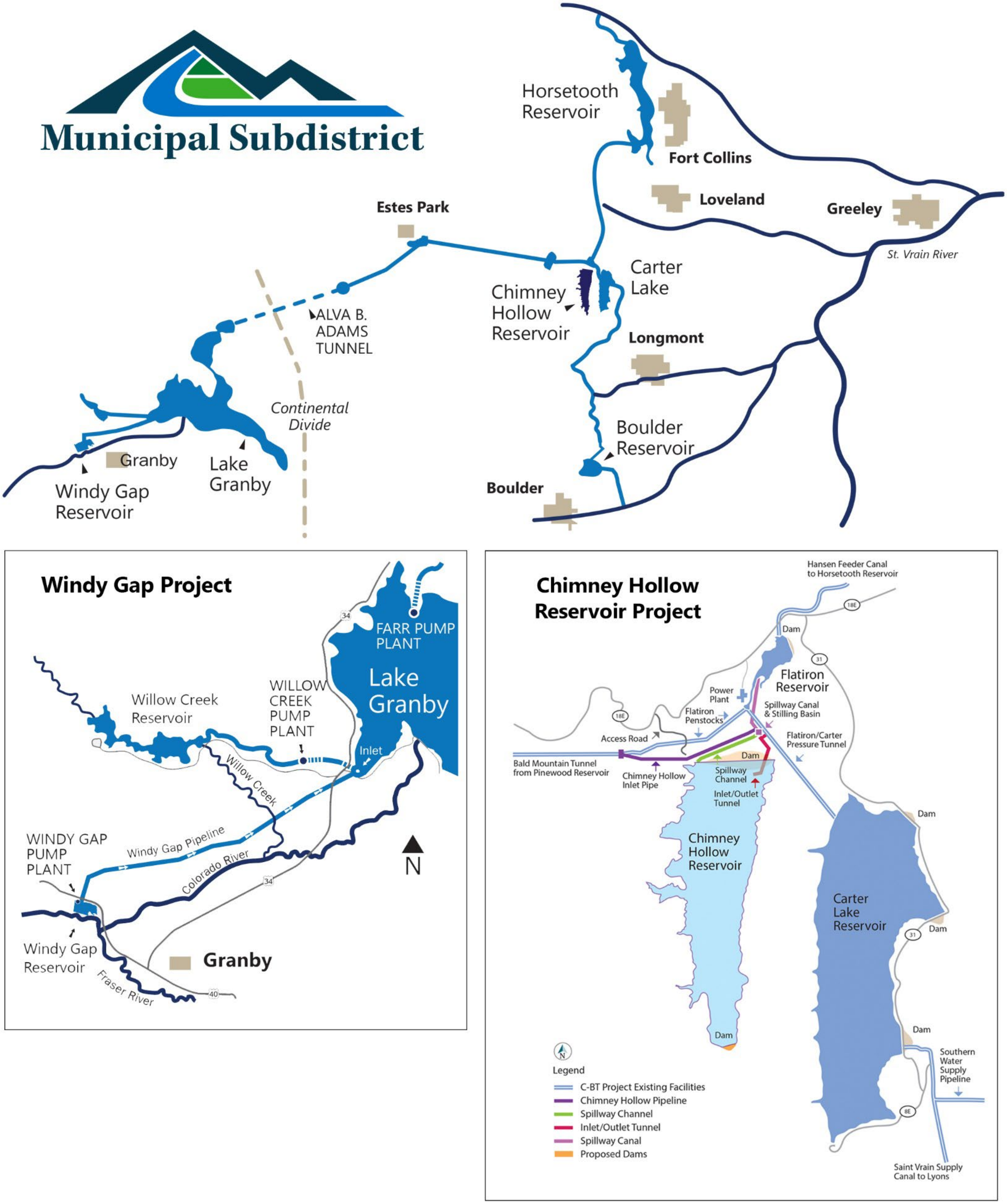


Figure 2 - Map of the Windy Gap and Windy Gap Firming Projects.

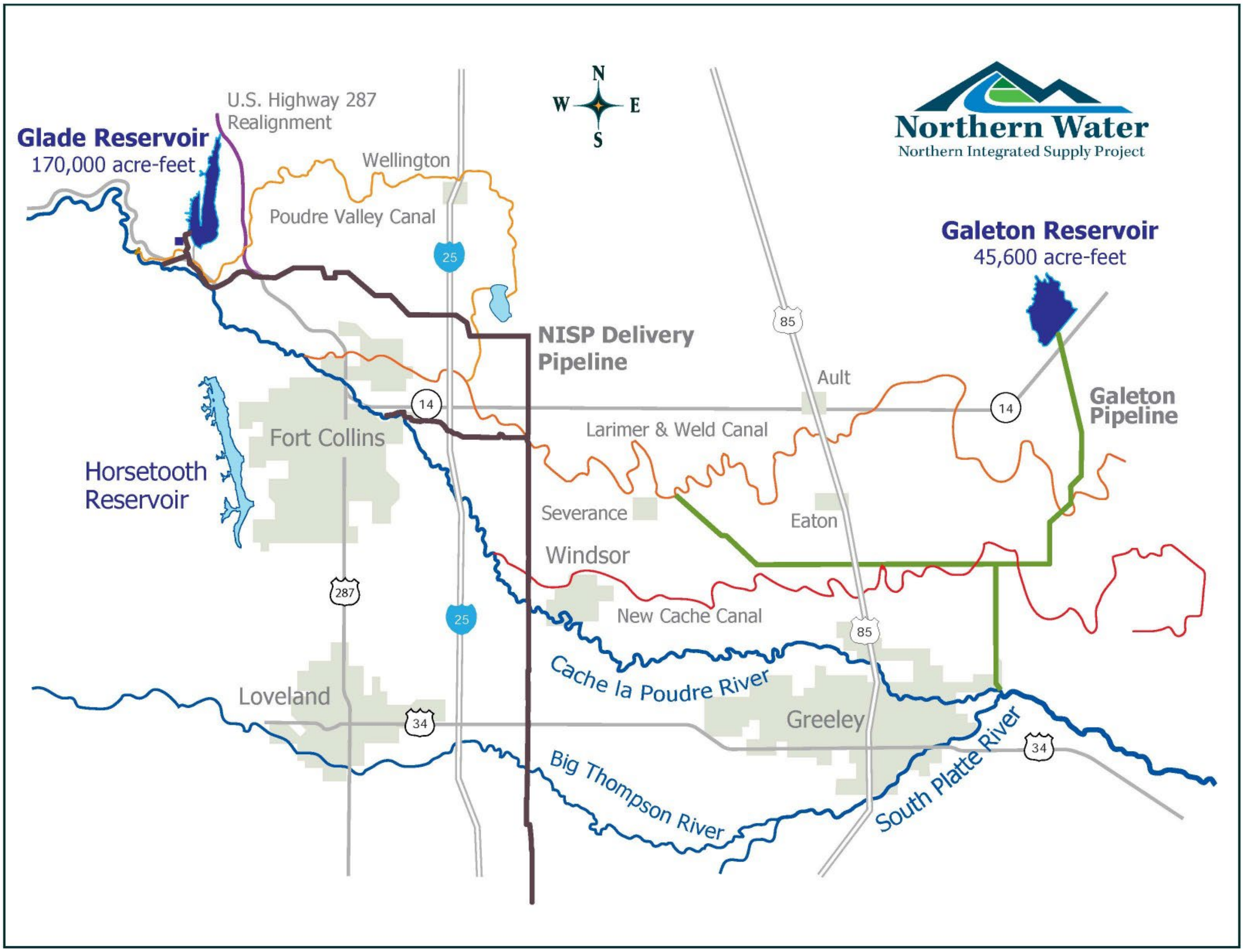


Figure 3 - Map of the proposed Northern Integrated Supply Project.

Table 1 – Water Quality Monitoring Programs Overview

PROGRAM	MONITORING SITES	PARAMETERS	OBJECTIVES
C-BT and Windy Gap Water Quality Monitoring Program	Sites in the C-BT, Windy Gap and WGFP West Slope collection and East Slope distribution systems	Field measurements of temp, D.O., pH, specific conductance, turbidity, discharge, and Secchi depth Lab analysis for major ions and other general chemistry, nutrients, metals, chlorophyll, organic carbon, total suspended solids, phytoplankton, zooplankton	Characterize existing conditions Identify long-term spatial and temporal trends Assess water quality impacts of C-BT and Windy Gap projects Support regulatory standards assessments Identify long-term spatial and temporal trends
Cache la Poudre NISP Water Quality Monitoring	Sites in the Cache la Poudre River and its tributaries from the canyon mouth to the confluence with the South Platte River	Field measurements of temp, D.O., pH, specific conductance, turbidity, discharge, Secchi depth Lab analysis for major ions and other general chemistry, nutrients, metals, chlorophyll, organic carbon, total suspended and dissolved solids, E. coli, phytoplankton, zooplankton	Provide information to support NISP-related water quality mitigation measures and to support adaptive management efforts Comply with monitoring conditions required in 401 and FWMEP certifications Assess compliance with Colorado water quality standards Provide a consistent, high-quality data set Identify long-term spatial and temporal trends
Secchi Monitoring*	Sites in Grand Lake and Shadow Mountain Reservoir	Field measurements with Secchi Disk with and without a view scope	Monitoring spatial and seasonal variations in clarity in Grand Lake and Shadow Mountain Reservoir
Shadow Mountain Real-Time Monitoring	Sites in Shadow Mountain Reservoir and the Granby Pump Canal	Buoy systems in Shadow Mountain: temperature, D.O., pH, Specific conductance, turbidity, Chl a, BGA profiles every 4 hours Granby Pump Canal: temperature, D.O., pH, Specific conductance, turbidity, Chl a, BGA, every 15 minutes	Determine the causes, extent, and duration of low D.O. events in Shadow Mountain Reservoir Provide a better understanding of the thermal structure of Shadow Mountain Reservoir Provide a baseline of data to support development of potential D.O. mitigation strategies

PROGRAM	MONITORING SITES	PARAMETERS	OBJECTIVES
			Support Three Lakes water quality modeling efforts
			Provide seasonal real-time data to support Grand Lake Adaptive Management (GLAM)
Compounds of Emerging Concern (CEC) Collaborative Monitoring*	Canals, streams, and reservoirs within the C-BT distribution system, and other local drinking and source water sites	LC/TOF-MS screening analysis for 100+ compounds LC/MS/MS analysis for 32 pesticides/personal care products/pharmaceuticals and 8 endocrine disrupting compounds	Maintain a baseline of data that monitors current conditions, trends, and changes in water quality
			Assess impacts from adverse events such as floods and wildfires
			Collect data to support the assessment of regulatory issues
			Develop source water protection measures to maintain a high-quality water supply
		Others as per special studies	Maintain a robust and evolving list of compounds
Cache la Poudre Temperature Monitoring	Sites in the Cache la Poudre River from upstream of the South Fork to east of I-25	HOBO Pro v2 continuous temperature loggers and Campbell Scientific 109 Temperature Probes	Track long-term changes in temperature before and after NISP components are built and implemented
			Provide information to support NISP-related water quality mitigation measures and adaptive management efforts
			Comply with monitoring conditions required in 401 and FWMEP certifications and state water quality standards
Willow Creek Monitoring*	Sites in Willow Creek Watershed, including upstream and downstream of WC Reservoir and Church Creek	Field parameters (D.O., pH, specific conductance, temperature, turbidity and discharge), and nutrients	Provide baseline data to support Windy Gap Firming Project nonpoint source nutrient mitigation
C-BT Temperature Monitoring*	Sites in the C-BT, Windy Gap and WGFP West Slope collection and East	HOBO Pro v2 continuous temperature loggers and Campbell Scientific 109 Temperature Probes with data	Collect continuous temperature data for the protection of aquatic life

PROGRAM	MONITORING SITES	PARAMETERS	OBJECTIVES
	Slope distribution system	collected by Northern water and GCWIN	Assess compliance with state water quality temperature standards
			Comply with the monitoring conditons required in permits and agreements for the WGFP
Canal Periphyton Monitoring	Sites in the Hansen Supply, Hansen Feeder, Saint Vrain Supply and Boulder Feeder Canals	Periphyton (attached algae) speciation and estimate of contribution of each species to total biomass	Determine species of periphyton in canals and changes over time
			Determine effectiveness of chemical treatments for algae control
Syntex Monitoring*	Monitoring wells near the St. Vrain Supply Canal northwest of Longmont	Lab analysis on a suite of 70 volatile organic compounds collected by WSP	Monitor the possible migration of the plume of hazardous material from the Syntex Chemicals landfill site in Boulder County
South Platte River Basin Salinity Monitoring	Stations on Lower South Platte River and Cache la Poudre River	Continuous, real-time specific conductivity and water temperature measurements using Campbell Scientific CS547A probes	Provide general measure of water quality in Lower South Platte R. and provide for long-term trending of conditions over time
Three Lakes Inlets Temperature and EC Monitoring	Three Lakes inlet sites (native inflows and pumped flows)	Continuous electric conductivity (EC) and water temperature measurements w/ In-Situ Aqua-TROLL 100 sensors	Support Three Lakes water quality modeling efforts
Cyanobacteria and Cyanotoxin Monitoring*	Sites on Grand Lake, Shadow Mountain Reservoir, Lake Granby, and Willow Creek Reservoir	Visual indicators of Cyanobacteria	Weekly Site Visits Objective: To monitor areas proactively and regularly with high public use and contact recreation
		Field measurements including the “stick test” and “jar test” for visual determination	Contingency Sampling Objective: To investigate reports of potential cyanobacteria blooms
		Abraxis test strips for presence determination	
		Laboratory toxin analysis by BSA Environmental	

*External data collected.

1.2 DOCUMENT OBJECTIVES

The purpose of this document is to outline Northern Water's Standard Operating Procedures (SOPs) and quality assurance/quality control (QA/QC) measures associated with field measurements, sample collection, laboratory analysis, data processing and data management. The equipment, procedures and QA/QC measures outlined in this document are applicable to all Northern Water's individual water quality monitoring programs outlined on *Table 1*, as well as any monitoring that may occur for special studies that are outside of these programs.

QA/QC measures form an important, integral component of Northern Water's Water Quality Monitoring Program and SOPs. QA/QC measures are applied to sample collection, laboratory analysis, and data processing and management to ensure that the data are scientifically valid, defensible, accurate and representative of actual conditions. Quality assurance (QA) is achieved through consistent adherence to the program requirements and the SOPs that are outlined in this document, including requirements for staff training, calibration and maintenance of equipment and instrumentation, collection of quality control (QC) samples, and standardized procedures for sample collection, sample handling and processing, data review and validation, and database management. QC samples are used to measure and maintain the program's data quality, limit errors, and ensure that the data quality objectives are being met.

The body of this document provides a description of the equipment, SOPs and QA/QC measures associated with sample collection, handling and processing, laboratory analysis, and data processing and management. Detailed, step-by-step SOPs are maintained internally. Note that, each year, there may be some minor changes in procedures, equipment, field sheets, sampling parameters, or sample locations. This document along with internal SOPs will be updated to reflect these changes.

1.3 DATA QUALITY OBJECTIVES

The quality of data collected for Northern Water's programs and special studies is assessed in terms of accuracy, bias, precision, analytical sensitivity, and comparability, as outlined below.

Accuracy and Bias

Accuracy is how close a measurement is to its true or expected value and is a combination of precision (random error) and bias (systematic error). The goal is to achieve high accuracy through high precision (low random error) and low bias. Bias can be introduced through poor equipment calibration, unrepresentative sampling, analyte degradation before analysis, and sample contamination (Cavanagh, et al, 1998). Bias is minimized through regular calibration of instruments according to the manufacturer's specifications, using appropriate, known calibration solutions, and by strict adherence to the documented sample collection, handling, and processing protocols. Laboratories use matrix spike samples and laboratory control samples to evaluate analytical accuracy/bias.

Bias due to sample contamination

Field blanks and laboratory method blanks are used to measure bias due to sample contamination. Samples can be contaminated by many sources including the Field Services staff (dirty hands, etc.), improperly cleaned sampling devices or laboratory equipment, contaminated preservatives, reagents, or sample bottles, and/or from dust particles or atmospheric deposition during filtering and preserving (Cavanagh, et al, 1998). However, the strict adherence to the protocols presented in this document minimizes these sources of sample contamination. Blank samples demonstrate that contamination of the environmental samples has not occurred or, if it did, where in the sampling/analysis process it occurred. The acceptance criterion for blank samples is discussed in the 4.8 Quality Control Samples section of this document.

Precison

Precision is a measure of how well repeated measurements agree and how consistent and reproducible the field and lab measurements are. Imprecise data are primarily the result of inconsistent field techniques and lab analysis (Cavanagh, et al, 1998). Precision is monitored through replicate samples or measurements, including split field samples, concurrent field replicate samples, sequential field replicates, laboratory duplicate analysis, and matrix spike duplicate analysis. The relative percent difference (RPD) between two duplicate determinations is used to assess the precision of the sampling and analytical methods. The acceptance criterion for replicate samples depends on the parameter and if it is a field or lab sample and is the 4.8 Quality Control Samples section of this document.

Analytical sensitivity

Sensitivity refers to the minimum concentration that can be measured by a method (i.e., the method detection limit (MDL) or by a laboratory. The laboratories and analytical methods must be selected such that the detection limits are appropriate for meeting the program objectives. Because of low background levels of many metals and nutrients, Northern Water has selected laboratories capable of low-level nutrient and metals analyses. Laboratories analyze low-level QC standards to verify MDLs and demonstrate the ability to recover at the MDL. The combination of precision and accuracy informs the reporting limit (RL) for each lab method. The RL is the minimum value a lab will report, typically two to five times above the MDL, and represents a 99 percent confidence interval that the reported value is accurate and precise.

Comparability

Comparability refers to the degree to which data can be compared directly to similar studies. The use of standard, accepted sampling, analytical, and data management procedures helps ensure that data will be comparable to similar programs. One of Northern Water's data quality objectives is to collect data that are comparable to organizations that are recognized for maintaining high quality data sets, such as the U.S. Geological Survey (USGS).

Northern Water utilizes field sampling protocols guided by the USGS's "National Field Manual for the Collection of Water-Quality-Data" (U.S. Geological Survey, variously dated). Additionally, water chemistry samples are sent to USGS-certified private laboratories for analysis. These steps help ensure that Northern Water's water quality data are comparable to data collected by the USGS, as well as high-quality data collected by other organizations.

1.4 FIELD SAFETY AND TRAINING

The safety and welfare of those working to achieve the Water Quality Monitoring Program goals is of the highest priority. Field Services staff will not put themselves or others at risk when performing the daily activities associated with collecting samples. Field Services staff are trained to take caution when collecting samples from moving water, large water bodies, and around hazardous areas. There are several hazards associated with collecting and processing water quality samples. Field Services staff must follow the safety and/or caution comments outlined in SOPs.

Hepatitis A shots are required for Northern Water's Field Services staff. Hepatitis B shots are recommended but not required. All Field Services staff are trained to be aware of their environment when collecting samples. If conditions lead to allergic reactions, health concerns, or personal risk, Field Services staff have been instructed to leave immediately and notify their supervisor.

With sampling sites located over a wide area on both sides of the Continental Divide, travel is necessary. All federal, state, and local traffic laws must be followed. Caution is needed when driving in adverse conditions. All Northern Water vehicles must be equipped with a fire extinguisher and first aid kit.

Lake and reservoir sampling require the use of a boat. The boat operator must be proficient with boat handling and boat safety and must be knowledgeable of all related state and local regulations. The boat must contain all required safety gear, possess current state registration, and be in good operational condition. Before leaving for a lake or reservoir sampling event, the reservoir and weather conditions are checked to make sure that sites can be safely accessed and sampled.

Sample processing and equipment calibration require the use of chemicals with associated hazards. These chemicals have different properties and different safety considerations. Material Safety Data Sheets (MSDS) are kept on file for all chemicals and are consulted for specific first aid, handling, and disposal procedures.
All staff who perform the activities outlined in this document must have adequate training commensurate with their job responsibilities. Training is provided through instruction, classes, and reference materials. New Field Services staff shadow existing Field Services staff until the Field Services Department Manager is confident that the new staff member can consistently and accurately follow the adopted Field SOPs. Additional training and refresher courses are required as procedures are reevaluated and updated.

2. Analytical Methods, Laboratories, and Lab QA/QC

The analytical methods, laboratories, and detection limits that apply to Northern Water's water quality monitoring programs are outlined in *Table 2* and *Table 3*. More information about the EPA and USGS analytical is available online at https://www.nemi.gov/home/.

Northern Water currently uses six different laboratories for the analysis of the various water quality samples and parameters:

- High Sierra Water Lab (Oakland, OR): Nutrients, TDS, TSS
- Hazen Research, Inc. (formerly Huffman Hazen Laboratory) (Golden, CO;): Metals, major ions, TOC
- Northern Water's Berthoud Lab: Chlorophyll-a
- BSA Environmental Services, Inc. (Beachwood, OH): Phytoplankton, zooplankton, and cyanotoxins
- Timberline Aquatics (Fort Collins, CO): Periphyton
- University of Colorado (Boulder) Center for Environmental Mass Spectrometry (CEMS): Pharmaceuticals, herbicides, pesticides, endocrine disrupting compounds
- City of Fort Collins Wastewater Plant #2 Lab – E.Coli

Each of the laboratories that Northern Water uses is responsible for the accuracy of its data. Each laboratory has its own set of internal QA/QC procedures and conducts its own internal data review and verification before submitting data to Northern Water. The primary quality control procedures used by each of the laboratories are outlined in *Table 4*.

High Sierra Water Lab and Hazen Research Laboratories are USGS-certified laboratories. These laboratories participate in the USGS "Round Robin" program, an inter-laboratory comparison study where Standard Reference Samples are submitted to approximately 150 laboratories (USGS and non-USGS labs) in the spring and fall to evaluate and compare analytical performance (https://bqs.usgs.gov/srs/). These laboratories also undergo annual QC audits that include the analysis of proficiency evaluation samples submitted to them by Northern Water. The proficiency evaluation sample has known concentrations for parameters of interest that are within the typical range of concentrations found in the environmental samples submitted to the laboratory. When the proficiency sample is submitted, it is labeled as an environmental sample, and therefore there is no indication that it is a QA/QC check (aka 'blind' sample). Generally, there is a range of acceptable values provided for each parameter; the value obtained by the laboratory should fall within this range.

Note that the low-level nutrient analysis conducted by High Sierra Water Lab has an associated holding time of ≤ 7 days. Regarding this holding time, Mark Palmer (High Sierra Water Lab) indicated the following in an email to Jen Stephenson (Jan. 14, 2014): "*Since 1988 I have performed water chemistry for low-level nutrients including NO3/NO2 and Ortho-P. I have completed holding time studies for these analyses on samples from pristine lakes and streams. I ran the samples within the 48-hour holding time and then again five weeks later. The results were the same as long as the samples were kept refrigerated at 4 degrees C and kept in the dark. Additionally, clients have asked me to re-run samples two months after collection and results were the same or well within the 15% RPD.*"

Table 2 - Parameters, analytical methods, and method descriptions.

Constituent	Method	Method Description
General Parameters		
Alkalinity (mg/L)	SM 2320B (USGS I-2030-89)	Titration with acid to pH 4.5
Chlorophyll-a (mg/m3), corrected for pheophytin	EPA 446.0	Spectrophotometric determination with acidification
Total Organic Carbon, TOC (mg/L)	SM 5310C	Persulfate – Ultraviolet oxidation
Total Dissolved Solids, TDS (mg/L)	EPA 160.1	Filtrate evaporated to dryness at 180°C
Total Suspended Solids, TSS (mg/L)	EPA 160.2	Sample filtered through 0.45-micron (µm) filter; Residue on filter dried at 103 - 105°C
Nutrients		
Ammonia as N, Dissolved (mg/L)	EPA 350.1 modified	Colorimetric with Indophenol, spectrophotometer
Total Kjeldahl Nitrogen (TKN) as N (mg/L)	EPA 351.2 modified	Digestion followed by colorimetric with Indophenol, spectrophotometer
Nitrate plus Nitrite as N (mg/L)	EPA 353.1 modified	Hydrazine reduction, colorimetric, spectrophotometer
Ortho Phosphate as P (mg/L)	SM 4500-P E	Colorimetric with ascorbic acid, spectrophotometer
Phosphorus, Total (mg/L)	EPA 365.3	Acid-persulfate digestion, colorimetric with molybdate & ascorbic acid, spectrophotometer
Major Ions		
Cations: Calcium, Magnesium, Potassium, Sodium (mg/L)	EPA 200.7 (USGS I-4471-97)	Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES)
Anions: Chloride, Sulfate (mg/L)	EPA 300.1 (USGS I-2057-85)	Ion-exchange chromatography
Metals		
Arsenic, Dissolved (µg/L)	EPA 200.8 (USGS I-4472-97)	Inductively Coupled Plasma – Mass Spectrometry (ICP-MS)
Arsenic, Total Rec (µg/L)		
Boron, Dissolved (µg/L)		
Cadmium, Dissolved (µg/L)		
Copper, Dissolved (µg/L)		
Chromium, Dissolved (µg/L)		
Chromium, Total Rec (µg/L)		
Iron, Dissolved (µg/L)		
Iron, Total Rec (µg/L)		

Constituent	Method	Method Description
Lead, Dissolved (µg /L)		
Manganese, Dissolved (µg/L)		
Nickel, Dissolved (µg/L)		
Selenium, Dissolved (µg/L)		
Silver, Dissolved (µg /L)		
Uranium, Dissolved (µg/L)		
Zinc, Dissolved (µg/L)		
Biological		
Phytoplankton: Species I.D., Density (cells/mL) & Biovolume (µm3/mL)	Membrane Filtration (McNabb 1960)	
Zooplankton: Species I.D. & #/L	Utermohl Chamber Method	
Periphyton: Species I.D. & estimate % contribution to total biomass	Leitz inverted microscope	125X &500X, with Whipple grid

Table 3 - Parameters, analytical methods, laboratories, method detection limits (MDL) and reporting limits (RL) used in Northern Water's Water Quality Monitoring Programs.

Constituent	Method	Lab Name	MDL	RL
General Parameters				
Alkalinity (mg/L)	SM 2320B	Hazen Research Laboratories	1	5
Chlorophyll a (mg/m3)	EPA 446.0	Northern Water East Slope Lab	0.79	1
Total Organic Carbon, TOC (mg/L)	SM 5310C	Hazen Research Laboratories	0.02	0.6
Total Dissolved Solids, TDS (mg/L)	EPA 160.1	High Sierra Water Lab	1	10
Total Suspended Solids, TSS (mg/L)	EPA 160.2; 0.45-µm	High Sierra Water Lab	0.3	0.3
Nutrients				
Ammonia as N, Dissolved (mg/L)	EPA 350.1 modified	High Sierra Water Lab	0.001	0.004
Total Kjeldahl Nitrogen (TKN) as N (mg/L)	EPA 351.2 modified	High Sierra Water Lab	0.035	0.07
Nitrate plus Nitrite as N (mg/L)	EPA 353.1 modified	High Sierra Water Lab	0.001	0.004
Ortho Phosphate as P (mg/L)	SM 4500-PE	High Sierra Water Lab	0.001	0.002
Phosphorus, Total (mg/L)	EPA 365.3	High Sierra Water Lab	0.001	0.003
Major Ions				
Calcium (mg/L)	EPA 200.7	Hazen Research Laboratories	0.003	0.02
Magnesium (mg/L)	EPA 200.7	Hazen Research Laboratories	0.001	0.012
Potassium (mg/L)	EPA 200.7	Hazen Research Laboratories	0.03	0.06
Sodium (mg/L)	EPA 200.7	Hazen Research Laboratories	0.01	0.12
Chloride (mg/L)	EPA 300.1	Hazen Research Laboratories	0.03	0.12
Sulfate (mg/L)	EPA 300.1	Hazen Research Laboratories	0.03	0.18
Metals				
Arsenic, Dissolved (µg/L)	EPA 200.8	Hazen Research Laboratories	0.03	0.06
Arsenic, Total Rec (µg /L)	EPA 200.8	Hazen Research Laboratories	0.4	0.8
Boron, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.5	1
Cadmium, Dissolved (µg/L)	EPA 200.8	Hazen Research Laboratories	0.01	0.02
Copper, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.03	1
Chromium, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.03	0.1
Chromium, Total Rec (µg /L)	EPA 200.8	Hazen Research Laboratories	1	2
Iron, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.04	4

Constituent	Method	Lab Name	MDL	RL
Iron, Total Rec (µg /L)	EPA 200.8	Hazen Research Laboratories	1.8	36
Lead, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.004	0.03
Manganese, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.02	4
Nickel, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.02	0.12
Selenium, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.02	0.06
Silver, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.005	0.01
Uranium, Dissolved (µg /L)	EPA 200.8	Hazen Research Laboratories	0.1	0.2
Zinc, Dissolved (µg/L)	EPA 200.8	Hazen Research Laboratories	0.2	2
Biological				
Phytoplankton: Species I.D., Density (cells/mL) & Biovolume (µm3/mL)	Membrane Filtration (McNabb 1960)	BSA Env. Services, Inc	--	--
Zooplankton: Species I.D. & #/L	Utermohl Chamber Method	BSA Env. Services, Inc	--	--
Periphyton: Species I.D. & estimate percent contribution to total biomass	Leitz inverted microscope, 125X & 500X, with Whipple grid	Timberline Aquatics	--	--

Table 4 - Quality control requirements for laboratory analyses.

Quality Control Procedure/Sample Type	**Purpose**	**Frequency/Number**	**Acceptance Criteria**
Nutrients: High Sierra Water Laboratory			
Matrix Spike	Monitor matrix interferences & method accuracy	1 per 20 samples	NH_3, ortho-P, TP: 80 – 120% recovery NO_3/NO_2 & TKN: 75– 125% recovery
Lab Duplicates	Assess method precision	1 per 20 samples	RPD ≤ 15%
Method Blanks	Assess lab contamination	1 per 20 samples	TKN: < 0.035 mg/L Others: < 0.001 mg/L
Standard Curve Slope	Standard curve slope value should remain consistent from one assay to the next.	Statistics for standard curve of each assay recorded on Standard Curve Statistical Summary Form. Structural curve slope, Y-intercept, correlation coefficient and standard range are noted.	Assay slopes must fall within control limits; control limits defined as ±3sx from the average slope value.
Standard Reference Material	Check calibration using a Standard Reference Material.	1 per 20 samples	RPD ≤ 15% between the actual value & assay value
TDS/TSS: High Sierra Water Laboratory			
Check analytical balance	Verify accuracy of balance	Before sample analysis	< 0.5 mg
Lab Duplicates	Assess method precision	1 per 20 samples	RPD ≤ 15%
Method Blanks	Assess lab contamination	1 per 20 samples	TDS: < 10 mg/L TSS: < 0.3 mg/L
Standard Reference Material	Assess accuracy	1 per 20 samples	RPD ≤ 15% between the actual value & assay value

Quality Control Procedure/Sample Type	Purpose	Frequency/Number	Acceptance Criteria
Phytoplankton and Zooplankton: BSA Environmental Services, Inc.			
Use of standard taxonomic reference materials	Ensure consistency in identification between other labs/programs; ensure use of most current taxa names		Keys and references widely available.
Verification of taxonomic composition by second phycologist or zooplankton taxonomist	Ensure taxonomic accuracy		Differences in taxonomy reconciled.
Selection of minimum acceptable tally for each analysis	Ensure counting precision and accuracy		Phytoplankton: minimum 400 units identified and enumerated/sample Zooplankton: minimum 200 zooplankters identified & enumerated/sample
Major Ions and Metals: Hazen Research Laboratories			
Calibration Check (Continuing Calibration Verification)	Check instrument calibration to confirm proper operation of the system.	1 per 10 samples	±10% of theory
Method Blank (Laboratory Reagent Blank)	Blank (analyte-free) water carried through entire analytical procedure to assess contamination associated with lab prep, solvents, glassware, reagents and analysis	1 per 10 samples	< 2x DL

Quality Control Procendure/Sample Type	Purpose	Frequency/Number	Acceptance Criteria
Laboratory Control Sample, LCS (or Laboratory Fortified Blank)	Samples prepared by lab using contaminant-free reagent water that is spiked with a known quantity of the analyte of interest and used to measure lab accuracy and precision.	Once with each run batch, except for ICP-MS dissolved metals where it is 1 per 10 samples	±10% recovery of theory
Matrix Spike (Laboratory Fortified Matrix Sample)	Environmental sample spiked with known quantity of analyte to determine if the sample matrix contributes bias to the analytical results.	1 per 10 samples	±20% recovery of theory
Matrix Spike Duplicate	A sample prepared simultaneously as a split with the matrix spike sample with each specimen being spiked with identical, known concentrations of targeted analyte. Assess precision associated with laboratory procedures	1 per 10 samples	RPD ≤ 10%, or ± the detection limit for a given element, whichever is greater.
Laboratory Duplicate	Two aliquots of the same environmental sample taken in the laboratory from a single sample bottle and analyzed separately with identical procedures. Analyses of LD1 and LD2 indicates precision associated with laboratory procedures, but not with sample collection, preservation, or storage procedures.	1 per 10 samples	RPD ≤ 10%, or ± the detection limit for a given element, whichever is greater.

Quality Control Procedure/Sample Type	**Purpose**	**Frequency/Number**	**Acceptance Criteria**
Calibration Check (Continuing Calibration Verification)	Check instrument calibration after every 10 samples to confirm proper operation of the system.	1 per 10 samples	±10% of theory
Compounds of Emerging Concern: University of Colorado CEMS			
Method Blank	Assess contamination associated with lab prep, solvents, glassware, reagents & analysis	1 per 20 samples	Less than LOD for each compound
Laboratory Duplicates	Assess precision associated with laboratory procedures	1 per 20 samples	Percent relative standard deviation < 10%
Matrix Spikes for LC-MS-MS samples (Environmental sample spiked with 40 ng/L of all analytes)	Determine if the sample matrix contributes bias to the analytical results	One for each batch of samples	Accuracy: ±15% recovery of theory Percent relative standard deviation < 10%
Calibration Curves developed for all compounds for concentrations between 1 ng/L and 200 ng/L	Accurate quantitation of compounds	1 curve per compound per batch of samples	Correlation coefficients > 0.99
Intra-day (single day) Precision: assessed at two different concentration levels in spiked water extracts; analysis performed in three replicates at each level.	Asess precision	Once per year	Percent relative standard deviation < 5%

Quality Control Procendure/Sample Type	Purpose	Frequency/Number	Acceptance Criteria
Inter-day (5-day) Precision: analyze spiked water extracts in five consecutive days	Asess precision	Once per year	Percent relative standard deviation < 10%
Chlorophyll-a: Northern Water East Slope Lab			
Laboratory Blank	Assess contamination associated with lab prep, solvents, glassware, reagents and analysis.	1 for every batch of samples	< MDL
Standard Curve & Demonstration of Capability	Accuracy of analysis	Once prior to method implementation	
Laboratory Quality Control Sample	Sample prepared by lab using Chl-a standard solution added to 90% acetone solution; used to verify instrument performance and data quality.		
Laboratory Duplicates	Assess precision associated with laboratory procedures.		

3. Sensor Calibration and Maintenance

All sensors are calibrated and maintained according to the manufacturer's instructions and specifications. The general procedures for calibration and maintenance are summarized in this section.

3.1 SONDE CALIBRATION

Calibration of D.O., pH, and specific conductance sensors is conducted at the beginning of each sampling day and a sensor check is conducted at the end of each sampling day. The results of all calibration activities are recorded in a logbook (*Figure 4*) that includes the information shown on the sample calibration sheet in *Figure 5*.

Temperature sensors are not calibrated. Temperature sensors require a quarterly check against a NIST-traceable thermometer in ambient and freezing water to verify that they are performing according to specifications. Temperature sensors that do not perform according to specifications are replaced.

Turbidity sensors undergo a monthly two-point calibration. Note that this frequency is per the manufacturer's recommendation unless there is uncertainty about the field measurements. After calibration, a 0.5 NTU offset is applied to the 0 NTU standard to eliminate negative readings. Chlorophyll and Phycocyanin sensors are calibrated yearly with a Rhodamine solution per manufacturer recommendations (*Table 5*).

At locations where sondes are continuously deployed, D.O., pH, and specific conductance sensors are calibrated bi-weekly, turbidity sensors are calibrated monthly, and chlorophyll and phycocyanin sensors are calibrated yearly. During bi-weekly calibrations, sensors are inspected and cleaned of all debris.

Figure 4 - Recording sonde calibration in logbook.

Table 5 - EXO sensor calibration.

Parameter	Sensor	Calibration Standard	Calibration Activity	Acceptance Criteria
Temperature (°C)	599870	NIST traceable thermometer	Quarterly check of endpoints of temperature range versus NIST thermometer.	± 0.15°C of true value at both endpoints (manufacturer's listed accuracy for the sensor)
Dissolved Oxygen (mg/L)	599100-01	D.O. Calibration Chamber	Calibration: daily, in camper lab, at first site; one-point calibration with air-saturated water.	Calibration: ± 0.2 mg/L of saturated value (100% saturation value obtained from table based on temp & atm pressure)
			Post-sampling (end of day) check: one-point check with air-saturated water.	Post-sampling check: ± 0.2 mg/L of saturated value
pH (units)	599702	Ricca Chemical (VWR) pH 7.00 Buffer and pH 10.00 Buffer	Calibration: daily, in camper lab, at first site; two-point calibration with pH 7.00 and pH 10.00 buffers.	Calibration: Millivolts output after calibration pH 7 Buffer: 0± 50 mv pH 10 Buffer: -180±50 mv 165-180 mv between cal. points
			Post-sampling (end of day) check: Two-point check with pH 7 and pH 10 buffers	Post-sampling check: ± 0.2 pH units from buffer value
Specific Conductance (µS/cm at 25°C)	599870 599827	Ricca Chemical (VWR) 1000 µS/cm Potassium Chloride Conductivity Standard	Calibration: daily, in camper lab, at first site; one-point calibration with 1000 µS/cm standard.	± 0.5% + 1 µS/cm of true value for the 1000 µS/cm Standard
			Post-sampling (end of day) check: One-point check with 1000 µS/cm standard	Post-sampling check: ± 0.5% + 1 µS/cm of true value for the 1000 µS/cm Standard
Turbidity (NTU/FNU) Note: Turbidity is calibrated using FNU turbidity standard, but data are collected and reported in NTUs	599101-01	YSI 124 FNU Turbidity Standard; 0 NTU standard prepared by filtering D.I. water through 0.45-micron disposable capsule filter.	Two-point calibration performed monthly (per manufacturer's recommendation) unless there is uncertainty about field measurements. After calibration, apply 0.5 NTU offset to 0 NTU standard to eliminate negative readings.	Calibration: 0.3 FNU or ± 2% of reading, whichever is greater

Parameter	Sensor	Calibration Standard	Calibration Activity	Acceptance Criteria
Depth (meters)			Calibrated at first lake/reservoir sample site of the day just above surface for 0 m depth.	± 0.1 m
Blue Green Algae (Phycocyanin)	599102-01	0 RFU Filtered DI 16 RFU Rhodamine dilution 0 ug/L Filtered DI 16 ug/L Rhodamine dilution	Yearly SmartQC	SmartQC based on offset and gain factor
Chlorophyll	599102-01	0 RFU Filtered DI 16 RFU Rhodamine dilution 0 ug/L Filtered DI 16 ug/L Rhodamine dilution	Yearly SmartQC	SmartQC based on offset and gain factor

Location ___________________Date _________________Time ________________ Initials _________________

Specific Conductance Calibration

Standard Value µS/cm	Ricca Lot No.	Standard Exp. Date	Standard Temp °C	Initial Reading µS/cm	Adjusted Reading µS/cm	6560 Conductivity Cell Constant
1000						

Accuracy: 0.5 % of reading + 1 µS/cm. Cell Constant range 5.0 ± .45

pH Calibration

pH Buffer	Ricca pH Buffer Lot No.	pH Buffer Exp. Date	pH Buffer Temp °C	pH Buffer Corrected for Temp	Initial pH	Adjusted pH	Millivolts	mv Range	Slope
7								**0 ± 50**	
10								**-180 ± 50**	
4								**+180 ± 50**	

Accuracy: ± 0.2 pH units. To determine the slope calculate the difference in the millivolt readings of the two calibration points. The slope should be within 165 to 180 millivolts.

Dissolved Oxygen Calibration

___ Air-Saturated Water ___ Water-Saturated Air

Calibration Temp °C	Barometric Pressure mm Hg	100% Saturation from chart mg/L	Initial Reading mg/L	Adjusted Reading mg/L	ODO Gain

Accuracy: ± 1% of reading or 0.1 mg/L, whichever is greater. ODO gain range 0.25 to 1.25

Turbidity ___ Calibration ___ Check

Standard Value	Standard Brand	Standard Lot No.	Standard Expiration Date	Calibration Temp °C	Initial Reading NTU	Adjusted Reading NTU
0	Filtered DI	╳	╳			
0.5 NTU Offset	Filtered DI	╳	╳			

Accuracy: ±2 % of reading or 0.3 NTU, whichever is greater

Post Sampling Calibration Check Time ___________

Specific Conductance			**pH**				**DO** BP ___________mmHg		
Std Value µS/cm	Std Temp °C	SC Reading µS/cm	pH Buffer	Buffer Temp °C	Buffer pH Corrected for Temp	pH Reading	Temp °C	DO Table Reading mg/L	DO Reading mg/L
			7						
			10						
1000									

Notes:

Figure 5 - Sonde calibration sheet.

3.2 SONDE MAINTENANCE

Sonde maintenance, cleaning, and storage are performed by Northern Water according to the manufacturer's specifications. Maintenance kits for EXO sondes (*Figure 6*) are taken into the field during all sampling events to address routine maintenance issues that might occur such as the replacement of damaged O-rings.

Figure 6 - YSI EXO sonde maintenance kit.

Routine Cleaning of the pH Probe

Cleaning of the pH probe is required whenever deposits or contamination appear on the glass or when the sensor response becomes slow. Clean water and a soft clean cloth, lens cleaning tissue, or cotton swab are used to remove all foreign material from the glass bulb.

Short-Term Sonde Storage

When a sonde will be inactive for four weeks or less, the sonde is stored with all the sensors left installed in the bulkhead. The sensors are kept hydrated by adding 1/2"of tap water to the bottom of the calibration cup. Deionized water is not used as it can shorten the life span of the pH sensor. It is important to have enough water in the cup so that the sensors stay hydrated, but the sensors should never be immersed in water during storage.

Long-Term Sonde Storage

When a sonde will not be used for a period greater than four weeks, it is prepared for long-term storage. All batteries are removed from the sonde as well as the EXO Handheld. The cable is thoroughly cleaned using Simple Green. The pH sensor is removed from the bulkhead and placed back into the original storage bottle filled with 2M KCL. After the pH sensor is removed, the empty port is plugged. The remaining sensors can be left installed in the bulkhead, but they must be hydrated by adding 1/2" of tap water to the bottom of the calibration cup. The sonde is periodically checked to make sure that the sensors left in the bulkhead remain hydrated.

Annual Sensor Maintenance

EXO central wipers must be factory serviced yearly for replacement of the wiper shaft O-rings. All D.O. membranes and pH sensor caps must be replaced annually. Membrane and pH sensor cap assemblies are purchased from YSI and installed by Northern Water Field Services.

4.Sample Collection and Field Measurements

This section presents an overview of the field procedures used by Northern Water's Field Services staff, with the detailed (step-by-step) field procedures contained in internal SOPs. More information on internal SOPs may be available upon request.

Field Services has dedicated labs at Northern Water's Berthoud and Willow Creek campuses where pre-sampling preparations are conducted including equipment cleaning and decontamination; instrument and sensor maintenance, cleaning, and calibration; and storage and organization of equipment and supplies. Northern Water Field Services has mobile camper labs (*Figure 7*) that are used in the field during sampling events. The camper labs provide a controlled environment that is protected from the elements for conducting many of the tasks associated with sample collection. Final preparations before sampling are conducted in the camper lab. After the samples have been collected, the samples are processed and prepared for shipment in the camper lab.

Figure 7 - Northern Water Field Services mobile camper lab.

4.1 PRE-SAMPLING PREPERATIONS

Checklists are used to guide pre-sampling preparation and tasks performed before leaving for the field. The sampling equipment and supplies checklist and the list of pre-sampling tasks are reviewed to ensure staff are prepared and have all necessary items. Pre-sampling tasks conducted before leaving for the field include cleaning and decontaminating all reusable sampling equipment; gathering all supplies and equipment; packaging all bottle sets; preparing the YSI multi-parameter sonde for data collection; preparing the disposable capsule filters, and printing bottle labels, field sheets, chain-of-custody forms, and shipping labels.

Equipment Cleaning and Deconamination

All reusable sampling equipment and supplies are cleaned and decontaminated at Northern Water's Berthoud lab before use. Equipment and supplies that are cleaned and reused include pump tubing, funnels, graduated cylinders, churn splitters, Van Dorn samplers, Kemmerer samplers, 3-liter polypropylene bottles, DH-81/DH-95 sample bottles, caps and nozzles, and 500-mL chlorophyll sample bottles.

Supplies and equipment used to clean and decontaminate sampling equipment are made of nonmetallic materials that are colorless or white. Equipment cleaning and decontamination are conducted in a dedicated room at Northern Water's Berthoud lab to minimize exposure to contaminants (*Figure 8*). Cleaned and dried equipment is individually stored in protective plastic bags and kept in reserved areas at Northern Water's Berthoud and Willow Creek labs. Equipment blank samples (described in the Blank Samples section of this document) are collected to verify that the equipment is being properly cleaned.

Figure 8 - Equipment cleaning area and storage of cleaned equipment at Northern Water's Berthoud lab.

A separate set of fresh, pre-cleaned equipment is used for each site when multiple sites will be sampled during a sampling trip. The exception is the Van Dorn and Kemmerer samplers used for lake/reservoir sampling, which are rinsed between sites with environmental water before samples are collected.

Sample Bottles and Preservation

When samples are collected, the various water quality parameters may degrade over time due to oxidation, volatilization, adsorption, precipitation, and/or biological processes. Water samples are placed in appropriate containers (bottle types) and are preserved, stored, and transported to the laboratories following established procedures that minimize analyte degradation before analysis. The required sample bottles, sample preservation, and holding times for the routine laboratory parameters are outlined in *Table 6*. Holding times are the maximum length of time that a sample can be stored after collection and before laboratory analysis without significantly affecting the analytical results. Pre-cleaned sample bottles are obtained either directly from the laboratories (Hazen Research, Inc.; University of Colorado Center for Environmental Mass Spectrometry) or purchased from VWR. Bottles used to store chlorophyll samples (before filtration) are cleaned by Northern Water staff before re-use.

If samples are not shipped or delivered the same day to the laboratories, they are stored in refrigerators at Northern Water's Berthoud or Willow Creek lab that are set to maintain temperatures at ≤ 4.0°C. These refrigerators are equipped with an alarm system that is triggered if the temperature rises above 4.0°C. If this happens, the samples are moved to a functioning refrigerator, and the malfunctioning refrigerator is repaired or replaced.

Table 6 - Sample containers, preservation, and maximum holding times.

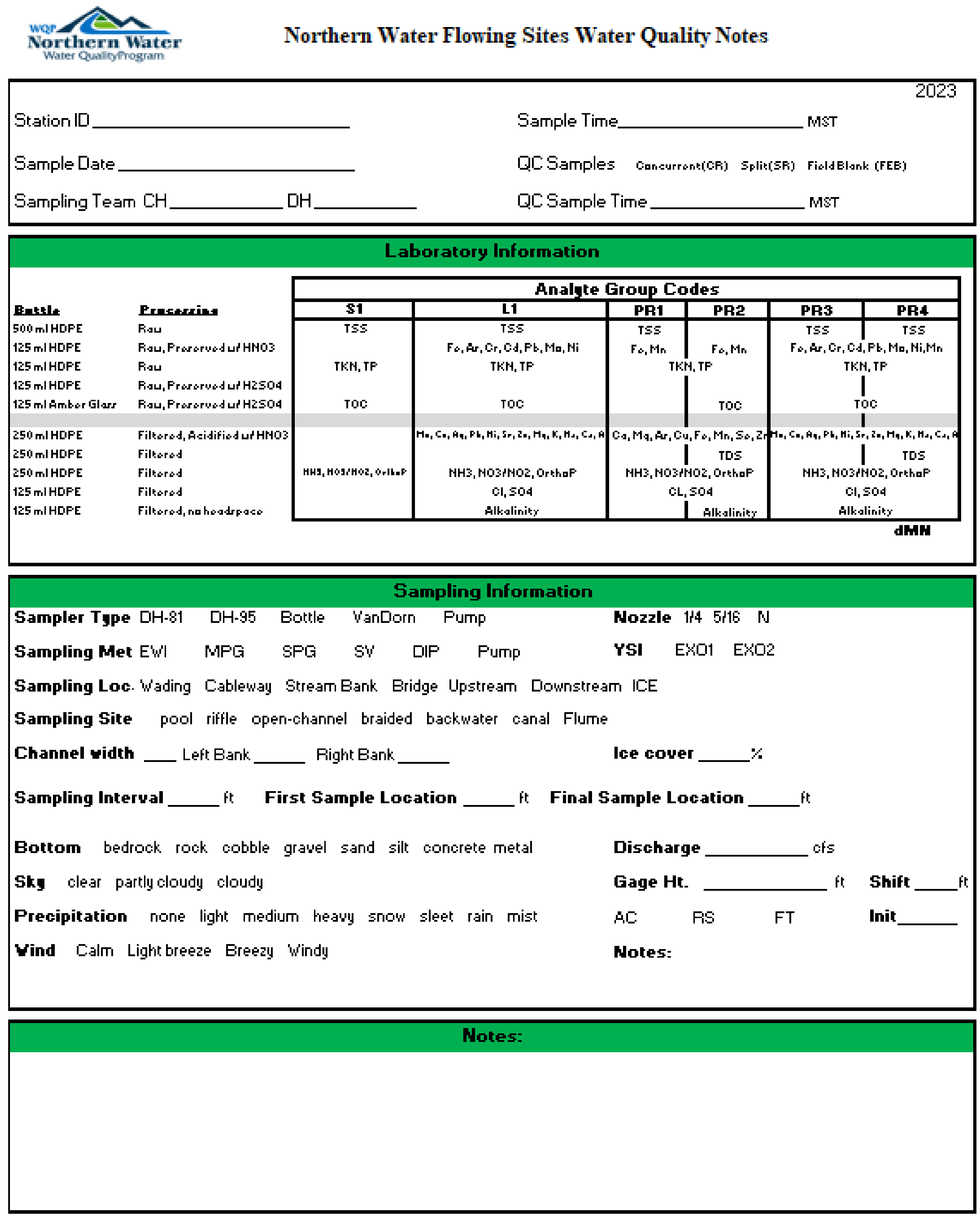
Analyses	Sample Containers	Preservation	Maximum Holding Time
General Parameters			
Alkalinity (mg/L), filtered	125 mL High density polyethylene plastic (HDPE)	Cool to ≤ 4°C	14 days
Chlorophyll (mg/m^3)	500 mL Amber HDPE	Place sample in dark & cool to ≤ 4°C; filter sample within 6 hours; freeze filter	28 days (frozen filter)
Total Organic Carbon, TOC (mg/L)	125 mL baked Amber Glass	1 mL 4.5N H_2SO_4; cool to ≤ 4°C	28 days
Total Inorganic Carbon, TIC (mg/L)	125 mL baked Amber Glass	1 mL 4.5N H_2SO_4; cool to ≤ 4°C	28 days
Dissolved Organic Carbon, DOC (mg/L)	125 mL baked Amber Glass	1 mL 4.5N H_2SO_4; cool to ≤ 4°C	28 days
Dissolved Inorganic Carbon, DIC (mg/L)	125 mL baked Amber Glass	1 mL 4.5N H_2SO_4; cool to ≤ 4°C	28 days
Total Dissolved Solids, TDS, filtered (mg/L)	250 mL HDPE	Cool to ≤ 4°C	7 days
Total Suspended Solids, TSS (mg/L)	500 mL HDPE	Cool to ≤ 4°C	7 days
Nutrients			
Dissolved (filtered) nutrients (mg/L): NH3, NO_3/NO_2, Ortho-P	250 mL HDPE	Place in dark and cool to ≤ 4°C	As soon as possible, ≤ 7 days (for low level nutrient analysis method by High Sierra Lab)
Total nutrients (mg/L): TKN & Total P	125 mL HDPE	Place in dark and cool to ≤ 4°C	28 days
Major Ions and Metals			
Dissolved Metals (µg/L), filtered	250 mL HDPE	2 mL 7.7N Ultrex HNO3; Cool to ≤ 4°C	6 months
Cations (mg/L), filtered			
Anions (mg/L), filtered	125 mL HDPE	Cool to ≤ 4°C	28 days
Total Metals (µg/L)	125 mL HDPE	2 mL 7.7N Ultrex HNO3; Cool to ≤ 4°C	6 months

Analyses	Sample Containers	Preservation	Maximum Holding Time
Biological			
Phytoplankton Density (cells/mL), Biovolume (µm3/mL), and Species I.D.	250 mL wide-mouth Amber HDPE	3 mLs Lugol's iodine solution	6 months
Zooplankton Species I.D. and Density (#/L)	250 mL wide-mouth Amber HDPE	5 mLs Lugol's iodine solution	6 months
Periphyton Species I.D. and percent composition of algal biomass	250 mL Amber HDPE	10 mLs 5% formalin solution	6 months
E. Coli	125 mL glass		6 hours
Cyanobacteria and Cyanotoxins	500 mL Polyethylene terephthalate glycol (PETG)		14 days

4.2 FLOWING SITES SAMPLE COLLECTION

The procedures used by Northern Water Field Services for the collection of water samples from flowing sites (stream/canal) are summarized in this section. After arriving at the parking area for the sampling site, final preparations are made for sampling. In the mobile camper lab, the bottle sets are laid out and the filtering apparatus and chamber are set up. In addition, the paperwork is initially filled out with all the current, known information written on the pre-printed sample bottle labels, the chain-of-custody forms, and the Field Sheet (*Figure 9*). Field sheets document the weather and other environmental conditions, quality control information, how the water samples will be collected, and any important observations that could impact data interpretation. Equipment required to collect samples is gathered and the crew heads out to the flowing site.

The first task when arriving at the site is to place the calibrated sonde in the flowing site *(Figure 10*). The sonde remains in the water while the samples are collected to allow adequate time for the sonde to equilibrate to the stream temperature and for all readings to stabilize. The sonde is placed as close as possible to the center of flow, upstream of where samples are collected so not to disturb or influence sample concentrations.



Northern Water Flowing Sites Water Quality Notes

2023

Station ID ______________________ Sample Time ________________ MST

Sample Date ____________________ QC Samples Concurrent(CR) Split(SR) Field Blank (FEB)

Sampling Team CH __________ DH __________ QC Sample Time ______________ MST

Laboratory Information

		Analyte Group Codes					
Bottle	**Processing**	**S1**	**L1**	**PR1**	**PR2**	**PR3**	**PR4**
500 ml HDPE	Raw	TSS	TSS	TSS		TSS	TSS
125 ml HDPE	Raw, Preserved w/ HNO3		Fe, As, Cr, Cd, Pb, Mo, Ni	Fe, Mn	Fe, Mn	Fe, As, Cr, Cd, Pb, Mo, Ni, Mn	
125 ml HDPE	Raw	TKN, TP	TKN, TP	TKN, TP		TKN, TP	
125 ml HDPE	Raw, Preserved w/ H2SO4						
125 ml Amber Glass	Raw, Preserved w/ H2SO4	TOC	TOC		TOC	TOC	
250 ml HDPE	Filtered, Acidified w/ HNO3		Mo, Cu, Ag, Pb, Ni, Se, Zn, Mg, K, Na, Ca, A	Ca, Mg, As, Cu, Fe, Mn, Se, Z		Mo, Cu, Ag, Pb, Ni, Se, Zn, Mg, K, Na, Ca, A	
250 ml HDPE	Filtered				TDS		TDS
250 ml HDPE	Filtered	NH3, NO3/NO2, OrthoP	NH3, NO3/NO2, OrthoP	NH3, NO3/NO2, OrthoP		NH3, NO3/NO2, OrthoP	
125 ml HDPE	Filtered		Cl, SO4	CL, SO4		Cl, SO4	
125 ml HDPE	Filtered, no headspace		Alkalinity		Alkalinity	Alkalinity	

dMN

Sampling Information

Sampler Type DH-81 DH-95 Bottle VanDorn Pump **Nozzle** 1/4 5/16 N

Sampling Met EWI MPG SPG SV DIP Pump **YSI** EXO1 EXO2

Sampling Loc. Wading Cableway Stream Bank Bridge Upstream Downstream ICE

Sampling Site pool riffle open-channel braided backwater canal Flume

Channel width ___ Left Bank _____ Right Bank _____ **Ice cover** _____%

Sampling Interval _____ ft **First Sample Location** _____ ft **Final Sample Location** _____ft

Bottom bedrock rock cobble gravel sand silt concrete metal **Discharge** ___________ cfs

Sky clear partly cloudy cloudy **Gage Ht.** _____________ ft **Shift** _____ft

Precipitation none light medium heavy snow sleet rain mist AC RS FT **Init** ______

Wind Calm Light breeze Breezy Windy **Notes:**

Notes:

Figure 9 - Flowing sites water quality field sheet.

Figure 10 - Placing calibrated sonde into the stream channel.

After the sonde has been placed in the flowing water, the samples are collected. Northern Water uses six different methods for collecting water samples from the flowing sites depending on conditions. These are outlined in *Table 7*.

Table 7 - Methods used to collect water samples from stream/canal sites.

Method	Device	When Used
Equal-width-increment (EWI), isokinetic, depth-integrated sample	US DH-81 or US DH-95 sampler	1.5 ft/sec ≤ Velocity ≤ 7.6 ft/sec 1 ft ≤ Water Depth ≤ 15 ft
Single Vertical (SV), isokinetic, depth-integrated sample	US DH-81 sampler	When majority of flow is confined to a narrow channel and it can be shown that the water is well mixed across the entire cross-section
Multiple Point Grab (MPG): sample collected from multiple points across the channel, single depth	US DH-81 sampler with or without nozzle	Low flow, shallow depth conditions: Velocity < 1.5 ft/sec Water Depth < 1 ft
Single Point Grab (SPG): sample collected from one location in the cross section.	US DH-81 sampler	Very high flows (i.e., runoff conditions) when it is not possible to collect samples across the cross section
Bottle Dip Grab (Dip): sample collected from one location in the cross section.	Hand-held bottle, or bottle attached to sampling rod	Very low flow when a Multiple Point Grab is not possible; also, for Emerging Contaminant sampling when samples are collected in the sample bottle
Pumped Sample (Pump): sample collected by pumping from a single point in the cross-section.	Peristaltic pump	Sample collection restricted by site conditions (i.e., ice cover, contaminated water, etc.)

Water samples are collected using the equal-width-increment (EWI), isokinetic, depth-integrated sampling procedure at all flowing sites whenever possible (*Figure 11*). This method of sampling provides for samples that integrate both the vertical and cross-sectional variability that exists at a sampling site, producing a discharge-weighted (velocity-weighted) representative sample from the entire flow passing through the cross-section. This type of sample is considered to be less biased and more precise than a grab sample and is considered the best data for calculating accurate constituent loads.

An isokinetic sampler is a sampling device that allows flowing water to approach and enter the sampler intake at the same velocity as the surrounding flowing water. This provides for the collection of samples at a rate proportional to the stream flow. A depth-integrated sample is collected by lowering and raising the isokinetic sampler vertically through the entire depth of the water column. Sampling across the stream/canal cross-section is accomplished by dividing the cross-section into a minimum of 10 equal-width-increments, with depth-integrated samples collected at the center of each increment. The vertical transit rate (the rate at which the isokinetic sampler is lowered and raised) is determined at the deepest section of the stream/canal with the highest velocity, and the same, constant rate is used at every width increment for that site. The subsamples collected at each width increment are composited in an 8-liter churn splitter (*Figure 12*).

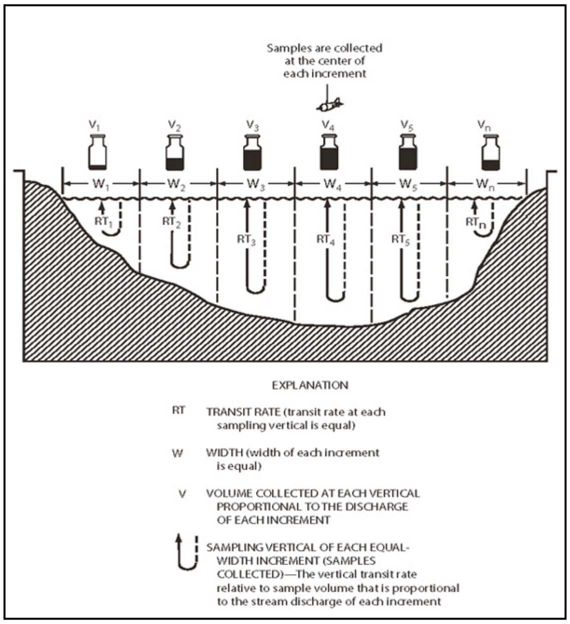


Figure 11 - Equal-width-increment method for collection of water samples (from U.S. Geological Survey, 2006, Collection of water samples, version 2: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A4, p. 42).

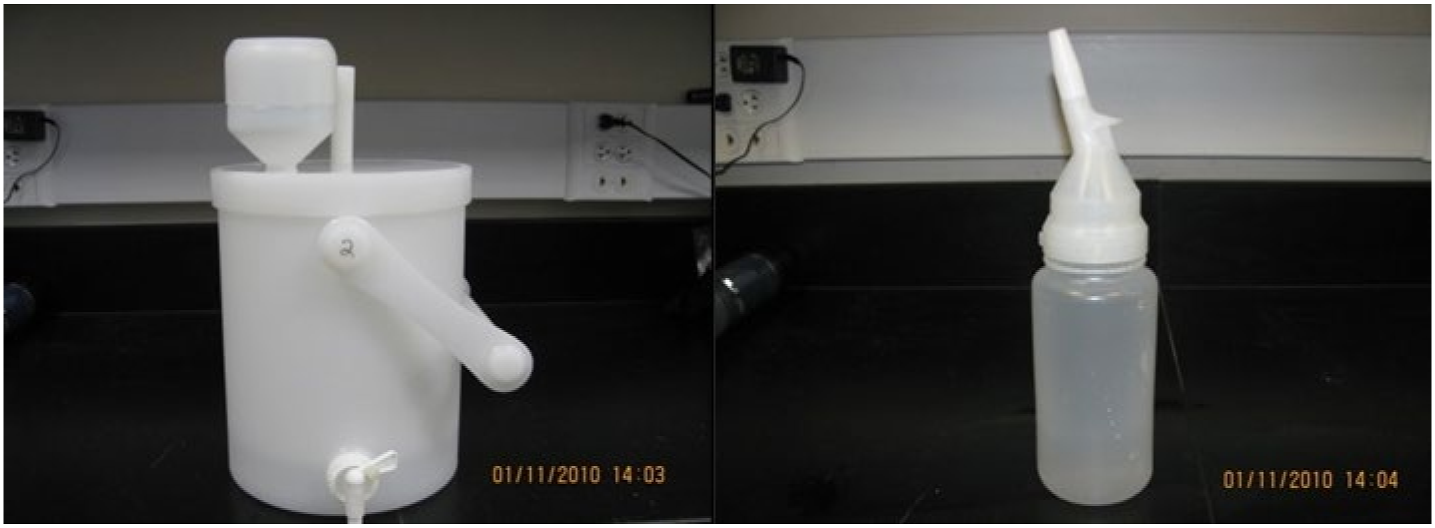


Figure 12 - Sampling equipment: 8-liter churn splitter, and US DH-77 bottle, nozzle, and cap.

The US DH-81 isokinetic depth-integrated sampler with a wading rod is used to collect samples at wadeable stream sites (*Figure 13*). This sampler consists of the US D-77 nozzle, cap, and bottle (*Figure 12*), and the US DH-81a wading rod adapter. The US DH-81 sampler requires average stream velocities be at least 1.5 ft/s but not more than 7.6 ft/s. The US DH-81 has a 4-inch zone between the bottom of the streambed and the intake nozzle that cannot be sampled. In shallow streams, it may not be possible to collect an isokinetic depth-integrated sample using this sampler.

Figure 13 - Collecting samples with the US DH-81 Isokinetic Depth-Integrated Sampler.

The US DH-81, equipped with extension rods, can be used off bridges when stream/canal velocities are low and when depths are shallow. When velocities and depths are unwadeable or too high to use the DH-81, the US DH-95 is used. The DH-95 is a 29-pound isokinetic depth-integrated sampler suspended from a bridge using a bridge board and sounding reel (*Figure 14*). The US DH-95 uses the same US D-77 nozzle, cap, and bottle

(*Figure 12*) combination as the US DH-81, so that it must be used within the same velocity ranges as the US DH-81. The US DH-95 has a 4.8-inch unsampled zone that limits its use in shallow waters.

When stream velocities are above 7.6 ft/s or below 1.5 ft/s, or shallow stream conditions exist, it is not possible to collect an EWI isokinetic depth-integrated sample using the US DH-81 or DH-95 sampler. Samples are collected using the alternative methods outlined in *Table 7*.

Figure 14 - Using the US DH-81 to collect a canal water sample from a bridge.

During the sample collection process, the person collecting the samples is referred to as dirty hands (DH), while the person on the bank accepting the samples is referred to as the clean hands (CH) person. The CH person is the only person to touch the surfaces of equipment that have been cleaned and decontaminated in the lab. Clean hands/dirty hands (CH/DH) sampling procedures are used to collect and process all samples.

After the samples have been collected, the sonde data are recorded in the sonde logbook and logged into the EXO Handheld memory. The churn splitter (containing the composited subsamples) is taken to the mobile camper lab for processing as described in the 4.5 Processing Collected Samples section of this document.

Discharge Measurements

Discharge data are necessary for the calculation of parameter loads. Many of Northern Water's monitoring sites now have stream gages that measure flow continuously. At locations where there are no stream gages discharge measurements are made during routine sampling events. Discharge measurements are also made at West Slope gauged sites as required for gauge calibration. Discharge measurements for gauge calibration are conducted at least once per month.

Northern Water staff use five different devices to measure discharge: the AA Price mechanical current meter, the SonTek FlowTracker1 and FlowTracker2 acoustic Doppler velocimeters, the River Surveyor, and the River Surveyor RS5 (*Figure 15, Figure 16, Figure 17*). The AA Price meter is used when measuring discharge in the canals off a bridge. The acoustic Doppler velocimeter (FlowTracker2) is used to make discharge measurements at all wadable sites. The River Surveyor is used when streams and rivers are not wadable. The River Surveyor RS5 is used on small streams or canals when flow is low.

Figure 15 - Measuring flow with the Flowtracker 2 acoustic doppler velocimeter.

Figure 16 - Measuring flow with the Price AA flow meter and sounding weight.

Figure 17 - Measuring flow with the River Surveyor.

4.3 LAKE AND RESERVOIR SITES SAMPLE COLLECTION

The routine sampling procedures used by Northern Water for lake and reservoir sites are summarized in this section. Note that, due to safety concerns, Northern Water hires the USGS (with specially trained staff) to conduct the lake and reservoir winter sampling during ice cover on the West Slope.

After arriving at the parking area for the sampling site, final preparations are made for sampling. In the mobile camper lab, the bottle sets are laid out and the filtering apparatus and chamber are set up. In addition, the paperwork is initially filled out with all the current, known information written on the pre-printed sample bottle labels, the chain-of-custody forms, and the Reservoir Water Quality Field Sheet. The Field Sheet documents weather and other environmental conditions, quality control information, how the water samples were collected, and any important observations that could impact data interpretation. Any information that cannot be filled out initially is completed at each sampling location. Finally, the boat is prepared for launch (*Figure 18*), and the equipment required to collect samples are loaded onto the boat. After the boat is launched, GPS is used to navigate to the sampling site.

Figure 18 - Northern Water's lakes and reservoir sampling boat.

Lake and reservoir samples are collected at a depth of 1 meter below the surface and 1 meter above the bottom. Composite samples are collected in the 0-to-1-meter, 0-to-5-meter, or 0-to-10-meter depth ranges depending on the parameter and site. The samples are collected in a specific order to ensure the quality of data and minimize possible sources of contamination (*Table 8*).

Table 8 - Sampling order for lake/reservoir sites.

Sample Order	Sample Type
1	1 meter: compounds of emerging concern
2	1 meter: chemistry
3	0-5 (0-1 at SM-CHL) meter: phytoplankton & chlorophyll composite
4	Zooplankton composite: 0-10 meter, except 0-5 m at SM-DAM & SM-MID, 0-1 m at SM-CHL
5	1 meter above bottom: compounds of emerging concern
6	1 meter above bottom: chemistry

Different sampling devices are used depending on the parameter and type of sample collected. As shown in *Figure 19* and *Figure 20*, these devices include a Van Dorn sampler, Kemmerer sampler, phytoplankton hose sampler, and a Wisconsin-Style closing plankton net.

Figure 19 - Sampling with Van Dorn Sampler and a 1.2L Teflon Kemmerer Sampler.

Figure 20 - Sampling devices for lakes/reservoir sites. A Wisconsin-Style closing Plankton Net, 2.2L and 4.2L PVC vertical Van Dorn Samplers, and a Phytoplankton Hose Sampler.

During the sample collection process, the person collecting the samples is referred to as the dirty hands (DH) person, while the person holding the sample bottle is referred to as the clean hands (CH) person. Surfaces of equipment that have been cleaned and decontaminated in the lab are only touched by the CH person. CH/DH sampling procedures are used to collect all samples for chemical analysis.

Samples for chemical analyses are collected using a 4-liter vertical PVC Van Dorn sampler. These samples are decanted into a 3-liter polypropylene bottle that is stored on ice and taken back to the mobile camper lab for processing. Composite samples collected for chlorophyll are taken back to the mobile camper lab for filtering. Phytoplankton, zooplankton, emerging contaminants, cyanotoxins, and geosmin samples are poured directly into their respective labeled sample bottles while on the boat (immediately after collection) and not further processed before shipment. If cyanotoxins, VOCs, or geosmin samples are collected, a Teflon Kemerer is used, and samples are decanted directly into their respective sample bottles leaving no headspace in the sample bottle. Cyanotoxins and geosmin samples do not require further processing. VOC samples have preservation material in the sample vial before collection and are preserved in the field using 3 drops of 1:2 molar HCL.

Unlike other sampling equipment, it is not practical to use a different Van Dorn sampler for every site sampled. Between sites and when not in use, Van Dorn samplers are stored in plastic bags to prevent them from drying out. At each site, the samplers are rinsed with environmental water before samples are collected. Rinsing of the Van Dorn sampler consists of lowering it into the water column at the sample site to a depth of 3 meters below the surface and holding it there for several minutes.

4.4 PHYSICAL DATA COLLECTION

Field measurements made by Northern Water Field Services staff include measurements of temperature, turbidity, conductivity, D.O., pH, Blue-Green algae, and chlorophyll with multi-parameter sondes.

EXO multi-parameter sondes are used by Northern Water to make instantaneous field measurements at routine sites and for continuous monitoring at specific sites (*Figure 21*). Each sonde is equipped with multiple probes and sensors that allow for the simultaneous, in-situ measurement of temperature, turbidity, conductivity, D.O., pH, chlorophyll, and phycocyanin. The specifications of the sensors used by Northern Water are summarized in *Table 9*. The sensors undergo all required routine cleaning and maintenance at Northern Water's Berthoud and Willow Creek labs as specified by the manufacturer. Sensor calibration is conducted at Northern Water's Berthoud lab before leaving for the field as described in the Sensor Calibration and Maintenance section of this document. If a problem arises with a sensor, it can be addressed at the lab. The EXO data logger stores and displays the data and provides for data transfer to computers.

Figure 21 - YSI EXO1, EXO2, and EXO Handheld.

Table 9 - Specifications of the multi-parameter sonde sensors for field measurements of temperature, D.O., pH, specific conductance, turbidity, phycocyanin, chlorophyll-a (EXO1 or EXO2).

Parameter	Sensor	Resolution	Accuracy	Range
Temperature (°C)	EXO Conductivity and Temperature Smart Sensor (Used in EXO1)	0.001°C	-5 to 35 °C: ±0.01 °C (-5 to 35 °C) ±0.05 °C (35 to 50 °C)	-5 to +50°C
	Wiped EXO Conductivity and Temperature Smart Sensor (Used in EXO2)	0.001°C	±0.2 °C	-5 to +50°C
Dissolved Oxygen, D.O. (mg/L)	EXO Optical D.O. Smart Sensor	0.01 mg/L	± 0.1 mg/L or 1% of reading, whichever is greater	0 to 50 mg/L
pH (units)	EXO pH and ORP Smart Sensor	0.01 pH units	± 0.1 pH unit within ±10°C of calibration temperature	0 to 14 units
Specific Conductance (µS/cm at 25°C)	EXO Conductivity and Temperature Smart Sensor (Used in EXO 1)	1 to 10 µS/cm	±0.5% of reading or 0.001 mS/cm, whichever is greater (0 to 100 mS/cm) ±1.0% of reading (100 to 200 mS/cm)	0 to 2,000 µS/cm
	Wiped EXO Conductivity and Temperature Smart Sensor (Used in EXO 2)	1 to 10 µS/cm	±1.0% of reading or 2 µS/cm, whichever is greater	0 to 1,000 µS/cm
Turbidity (FNU/NTU)	EXO Turbidity Smart Sensor	0.1 FNU	0 to 999 FNU: 0.3 FNU or ±2% of reading, whichever is greater 1000 to 4000 FNU: ±5% of reading	0 to 4000 FNU, NTU
Blue-Green Algae, (Phycocyanin)	EXO Total Algae PC Smart Sensor (Used in EXO2)	0.01 µg/L; 0.01 RFU	Linearity: R^2 >0.999 for serial dilution of Rhodamine WT solution from 0 to 100 µg/mL BGA-PE equivalents	1 to 100 µg/L; 1 to 100 RFU
Chlorophyll-a	EXO Total Algae PC Smart Sensor (Used in EXO2)	0.02 µg/L; 0.01 RFU	Linearity: R^2 >0.999 for serial dilution of Rhodamine WT solution from 0 to 100 µg/mL BGA-PE equivalents	1 to 100 µg/L; 1 to 100 RFU

Physical Data Collection in Streams and Canals

An EXO multi-parameter sonde with sensors described in *Table 9* is used to make instantaneous field measurements of temperature, turbidity, conductivity, D.O., and pH at all flowing sites where discrete water quality data is collected.

At flowing sites, the sonde is placed in the stream/canal (as close as possible to the center of flow) before sample collection to allow adequate time for the sonde to equilibrate to the stream temperature and for all readings to stabilize. After the water quality samples have been collected, the sonde is retrieved, and the readings are recorded in the sonde logbook and logged into EXO Handheld memory. Sonde data are uploaded from the EXO Handheld to a computer at Northern Water's office.

Physical Profile Data Collection at Lakes and Reservoirs

Physical data profiles of temperature, turbidity, conductivity, D.O., pH, chlorophyll, and phycocyanin, are collected at lake and reservoir sampling sites using the EXO2 and the EXO Handheld. The sonde is lowered down through the water column using a reel that is mounted on the boat (*Figure 22*). Profile collection begins at 0.5 meters and continues every 1 meter up to 25 meters. From 25 meters to the bottom of the lake or reservoir, measurements are taken every 5 meters along with a final reading at the depth where the bottom sample is collected.

At each depth, the sonde readings are allowed to stabilize before moving down to the next location (usually taking 30 to 60 seconds for stabilization). The readings are considered stable when the variations are less than 0.1ºC for temperature, 0.02 mg/L for D.O., 5 µS/cm for conductivity, and 0.02 units for pH. The stabilized readings are recorded on the reservoir profile data sheet and logged into the EXO Handheld internal memory. Profile data are uploaded from the EXO Handheld data logger to a computer at Northern Water's Berthoud office.

Figure 22 - Sonde being lowered from the boat into a reservoir to collect profile data.

Secchi Disk Measurements

Secci disk measurements are taken at all lake and reservoir sampling locations except Windy Gap Reservoir. The Secchi disk consists of a weighted 8-inch black and white quadrant disk connected to a tape measure marked in both feet and meters (*Figure 23*). Initial Secchi disk measurements are taken without a view scope to provide consistency with historical data, followed by a second measurement with a view scope submerged just below the water surface. Both measurements are conducted by two members of the Field Services staff at each sampling location. Measurements are taken without sunglasses and always off the shady side of the boat. One staff member lowers the Secchi disk through the water column while a second person watches the disk and records when it is no longer visible.

Figure 23 - Measuring Secchi depth with a view scope a Secchi disk with measuring reel.

4.5 PROCESSING COLLECTED SAMPLES

Flowing site samples to be processed are contained in an 8-liter churn splitter, while lake and reservoir samples are contained in a 3-liter polypropylene bottle. The processing of samples includes splitting, filtering, and preserving samples as required for the various chemical analyses. Clean hands/dirty hands protocols are always used during sample processing to minimize the potential of sample contamination. The step-by-step procedures for sample processing are contained in internal SOPs.

Sample processing is always done in the same, specific order. Wholewater (unfiltered) samples are always processed first followed by filtered samples. Filtered samples are always processed in a bagged processing chamber to minimize contamination during filtration (*Figure 24*). Wholewater samples are processed according to volume, with the largest volume being withdrawn from the churn or 3-liter bottle first. *Table 10* shows the order used for processing wholewater and filtered samples.

Figure 24 – Processing collected samples in the mobile camper lab.

Samples for chemical analyses are filtered using 0.45 micron (pore size) disposable Geotech dispos-a-filter^{TM} Filter Capsules. Disposable capsule filters have a one-time use and are prepared in Northern Water's Berthoud lab before each sampling event. The filters must be rinsed with deionized water to remove potential manufacturing residues and to condition the filter membrane.

After the samples are filtered, chemical preservatives are added to the sample bottles (*Table 10*), the sample bottles are placed in zip-lock bags (with bottles going to the same laboratory packaged together), and immediately placed on ice.

Chlorophyll samples are filtered using Millipore filter apparatus (*Figure 25*) with Advantec (or equivalent) Grade GF-75 (0.3-micron pore size), 47-mm diameter, glass fiber filters. After filtering a measured volume of sample, the chlorophyll filter paper is folded, wrapped in aluminum foil, placed in a brown coin envelope, and placed into a portable freezer. The chlorophyll filters are kept frozen until they are analyzed in the laboratory.

Figure 25 - Filtering chlorophyll samples.

Table 10 - Processing order for samples.

Analyte	Bottle	Added Preservative
Wholewater Samples		
1. Total Suspended Solids (TSS)	500 ml HDPE	
2. Chlorophyll (for flowing sites where the portion for chlorophyll analysis is withdrawn from the churn)	500 ml Amber HDPE	
3. Total Metals	125 ml HDPE	2 mL 7.7N Ultrex HNO_3
4. Total Nutrients: Total Kjeldahl Nitrogen (TKN) & Total P	125 ml HDPE	
5. Total Organic Carbon (TOC)	125 ml Amber Glass	1 mL 4.5N H_2SO_4
Filtered Samples (0.45 micron filter)		
1. Dissolved Metals, Cations	250 ml HDPE	2 mL 7.7N Ultrex HNO_3
2. Dissolved Nutrients: NH3, NO3/NO2, Orthophosphate	250 ml HDPE	
3. Anions	125 ml HDPE	
4. Alkalinity	125 ml HDPE (no headspace)	
5. Total Dissolved Solids (TDS)	250 ml HDPE	
6. Dissolved Organic Carbon (DOC)	125 ml Amber Glass	1 mL 4.5N H_2SO_4

4.6 SAMPLING FOR COMPOUNDS OF EMERGING CONCERN

Detection limits for compounds of emerging concern (CEC) are in the trace, parts-per-trillion (nanogram/liter) range. Because of this, special care must be taken to ensure that sample contamination does not occur.

CEC analysis is conducted by the University of Colorado (Boulder) Center for Environmental Mass Spectrometry (CEMS). All samples are collected in baked, 1-liter, amber glass bottles with Teflon-lined caps supplied by CEMS. Along with samples collected by Northern Water, each entity of the Collaborative collects samples at sites of interest. The sample bottles are filled to the top to minimize bottle head space. Samplers are restricted from using insect repellent (i.e., DEET) before and during sampling, and no smoking or coffee is consumed during the sampling event. The disposable gloves that are used by the samplers minimize contamination of the sample bottles from personal care products. Any unusual conditions concerning the sample are noted in a field notebook and copies of these field notes are sent to CEMS with the samples in a waterproof envelope. Samples collected for CEC analysis are not processed before delivery to CEMS. All samples are kept refrigerated at £4°C from the time of collection until sample extraction has taken place at CEMS. The samples are delivered to CEMS (in Boulder, CO) as soon as possible after collection.

Collection of CEC Samples at Flowing Sites

For the majority of CEC samples collected at flowing sites, the samples are collected by hand using the bottle dip grab method (*Table 7*). When sampling off a bridge or along a canal where the water surface cannot be reached, a weighted bottle sampler is used to collect the sample. In all cases, the sample is collected directly into the sample bottle provided by the lab.

Collection of CEC Samples at Lake and Reservoir Sites

All samples that are collected for CEC analysis are collected with the Teflon Kemmerer and decanted directly into the sample bottle provided by CEMS (*Figure 26*).

Figure 26 - Collection of CEC sample at a reservoir site.

4.7 SAMPLING FOR EAST SLOPE CANAL PERIPHYTON

Periphyton samples are collected in a manner to ensure that they are representative of the population of algae that is present at each sampling location. In the Boulder Feeder Canal, samples can usually be collected by hand as the canal is easily accessible from the banks. At the rest of the canal sampling sites, access is limited due to the shape of the canals and the distance from the bank to the water surface. One or more extension handles with a brush attached to the end are used to scrape algae off the sides of the canal walls when access is limited (*Figure 27*). If necessary, a net is used to capture the algae as it floats down the canal after being scraped off.

Figure 27 - Collecting periphyton samples from a canal.

The periphyton samples are placed into 250 ml amber HDPE bottles and then filled with canal water for a total volume of approximately 200 ml. The samples are preserved immediately in the field by adding 10 ml of 5% formalin solution. Samples are delivered to Timberline Aquatics (located in Fort Collins) as soon as possible after collection.

4.8 QUALITY CONTROL SAMPLES

Quality control (QC) samples are used to measure and maintain data quality, limit error, and ensure that the data quality objectives are met. Field quality control samples include several types of blank and replicate samples as listed in *Table 11* and described in this section.

Table 11 - Field Quality Control Samples

QC Sample	Data Quality Indicator	Field QC Sample Type	Collection Frequency	Acceptance Criteria	Corrective Action
Blank Samples	Bias due to sample contamination	Lab DI Water Blank (LDI)	Once/ quarter	≤ Reporting Limit (RL)	Investigate and eliminate source of contamination: improperly cleaned sample bottles, contamination of sample bottles, contamination of the blank water, lab error; flag suspect data.
		Lab Equipment Blank (LEB)	Once/quarter each for Van Dorn Sampler & DH-81 Sampler	≤ RL	Investigate and eliminate source of contamination: improperly cleaned equipment, or sources as above for Lab Water Blank; flag suspect data.
		Field Blank (FEB)	5% for West Slope sites & 2.5% for East Slope sites, of total annual sample count	≤ RL	Investigate and eliminate source(s) of contamination; flag suspect data.
Replicate Samples	Precision	Split Replicates (SR)	SR + CR + SQR = 5% for West Slope sites and = 2.5% for East Slope sites, of total annual sample count	For concentrations > RL: Relative Percent Difference (RPD) ≤ 25%	Investigate and eliminate cause: inconsistent field techniques and sample processing, lab error; request re-analysis of sample; flag suspect data.
		Concurrent Replicate (CR) & Sequential Replicate (SQR)			Investigate cause: natural variability in space and/or time, inconsistent field techniques and sample processing, lab error; request re-analysis of sample; flag suspect data.

Blank Samples

Blank QC samples provide an estimate of bias (systematic error) due to sample contamination that could occur during sample collection, processing, preserving, and shipping. Samples can be contaminated by many sources including the Field Services staff (dirty hands, etc), improperly cleaned sampling devices, contaminated preservatives or sample bottles, and dust particles or atmospheric deposition during filtering and preserving

(Cavanagh, et al, 1998). However, the strict adherence to the protocols presented in this document minimizes these sources of sample contamination. Blank samples demonstrate that contamination of the environmental samples has not occurred or, if it did, where in the sampling process it occurred.

Blank samples are de-ionized (D.I.) water produced at Northern Water's Berthoud lab, free of the analytes of interest. D.I. water is tap water that has been treated by passing through a standard de-ionizing resin column filter.

Routine blank samples collected for Northern Water's program include lab D.I. water blanks (LDI), equipment blanks (LED), and field blanks (FEB). If chronic sample contamination is suspected, additional blank samples are collected at various additional points in the sample collection and processing sequence to help determine exactly where the contamination is occurring.

Lab Water Blanks (LDI)

Lab water blanks are collected before leaving for the field and consist of pouring analyte-free D.I. water, without processing, directly from the D.I. water faucet into sample bottles and then shipping these bottles with the environmental samples to the laboratory for analysis. If analytes of interest are found in the lab water blanks, this can indicate improperly cleaned sample bottles, contamination of the sample bottles, or contamination of the D.I. water. Lab water blanks are collected once per quarter.

Lab Equipment Blanks (LEB)

Equipment blanks are collected to determine if the sampling equipment is thoroughly cleaned and decontaminated before it leaves the lab. Equipment blanks are collected in the same manner as the lab water blanks, except that the analyte-free D.I. water is poured into the sampling equipment before pouring into the sample bottle. Equipment blanks are collected once per quarter.

Field Blanks (FEB)

Field blanks are collected by taking analyte-free D.I. water out to the field and processing it as if it were a sample (*Figure 28*), including filtration and sample preservation. Field blank samples are collected to determine if contaminants are introduced to the sample in the field during collection, processing, preservation, and shipping of samples. Field blanks are collected randomly and at different sites throughout the sampling season. Field blank samples constitute approximately 5% of the total sample load from the West Slope sites and approximately 2.5% of the total sample load from the East Slope sites during any given year.

Figure 28 - Collecting a field blank sample.

The acceptance criterion for blank QC samples is outlined in *Table 11*. Analytical results for blank samples should be less than the laboratory reporting limit (RL). If the blank samples indicate that sample contamination has occurred, the source of contamination is investigated and eliminated. Procedures used by Northern Water to assess, flag, and report the blank sample QC data are presented in the Data Review and Validation section of this document.

Replicate samples

Replicate samples are two samples collected and processed together and should produce essentially identical results when analyzed. Replicate samples or measurements are used to assess precision (random error). Precision is a measure of how well-repeated measurements agree and how consistent and reproducible the field and lab measurements are. Consistent adherence to the protocols presented in this document is the best way to achieve high precision. Imprecision is the result of inconsistent field techniques and/or laboratory analysis.

Field replicate samples included in Northern Water's program include split replicate samples, concurrent replicate samples, and sequential replicate samples. Field replicates are collected randomly and at different sites throughout the sampling season. Field replicate samples constitute approximately 5% of the total sample load from the West Slope sites and approximately 2.5% of the total sample load from the East Slope sites during any given year.

Split Replicates (SR)

Split replicates are samples obtained by splitting one sample into two subsamples and are collected to determine variability in sample processing and laboratory analysis. Split samples are collected like a normal sample, but enough water must be collected to fill two sets of sample bottles. Split replicates are sent to the same laboratory for analysis.

Concurrent Replicates (CR)

Concurrent replicates are two separate sets of samples collected as close as possible to the same location and time to determine variability in space and time of the sample site as well as variability in the collection, processing, and analysis of samples. Since concurrent replicates include natural variability, they are somewhat less precise than split replicates from a single sample, but this variation should be small. Concurrent replicates are collected at the flowing sites by setting up two churns, one designated churn A and the other churn B. Each vertical in the stream cross-section is sampled twice, with the sub-samples alternated between churn A and churn B.

Sequential Replicates (SQR)

Sequential replicates are two samples collected consecutively at the same location (one right after the other) to determine variability in the collection, processing, and analysis of samples. Sequential replicates are collected during lake and reservoir sampling when a replicate sample is desired, but the volume of water needed is too large to process as a split replicate sample (i.e., the volume of water needed is more than what is contained in the Van Dorn or other sampling device), and a concurrent replicate sample is not feasible.

Relative Percent Difference (RPD)

The relative percent difference (RPD) between two replicate determinations is used to assess the precision of the sampling and analytical methods and is calculated using the following equation:

$$RPD = 100 \times \left[\frac{Xs - Xd}{\left(\frac{Xs + Xd}{2} \right)} \right]$$

where:

RPD = relative percent difference, expressed in percent

Xs = analytical result obtained for the sample

Xd = analytical result obtained for the duplicate sample

The maximum acceptable RPD depends on the concentration and the RL. Concentrations below the RL are all considered acceptable even if there is a very large calculated RPD since the concentrations are all very low and the magnitude of the difference is very small from a practical standpoint. For results above the RL, the RPD must be ≤ 25%. The acceptance criteria and corrective action taken by Northern Water for replicating field QC samples are outlined in *Table 11*. Procedures used by Northern Water to assess, flag, and report the replicate sample QC data are presented in the Data Review and Validation section of this document.

Split Samples

Northern Water also occasionally collects split samples which are the same as split replicates, but the two samples are sent to two different laboratories for analysis. Split samples are used when analytical results from two different labs need to be compared for one or more parameters to determine inter-laboratory precision. This may be conducted when changing laboratories or when comparing data collected by different organizations.

CEC Quality Control Samples

The Compounds of Emerging Concern program relies on samples collected by eight entities and has a unique QA/QC program to ensure accurate data collection. QC sampling rotates between entities on a yearly basis, with each entity collecting at least one blank or duplicate during a normal sampling year, except for Northern Water, which collects both a blank and a duplicate yearly. CEMS conducts laboratory QA/QC as described in the *Analytical Methods, Laboratories, and Lab QA/QC* section of this document. After the data has been delivered to Northern Water, it is subject to thurough data QA/QC, as described in the *Lab and Instantaneous Field Data Management* section of this document.

5.Sample Handling, Custody, Shipping

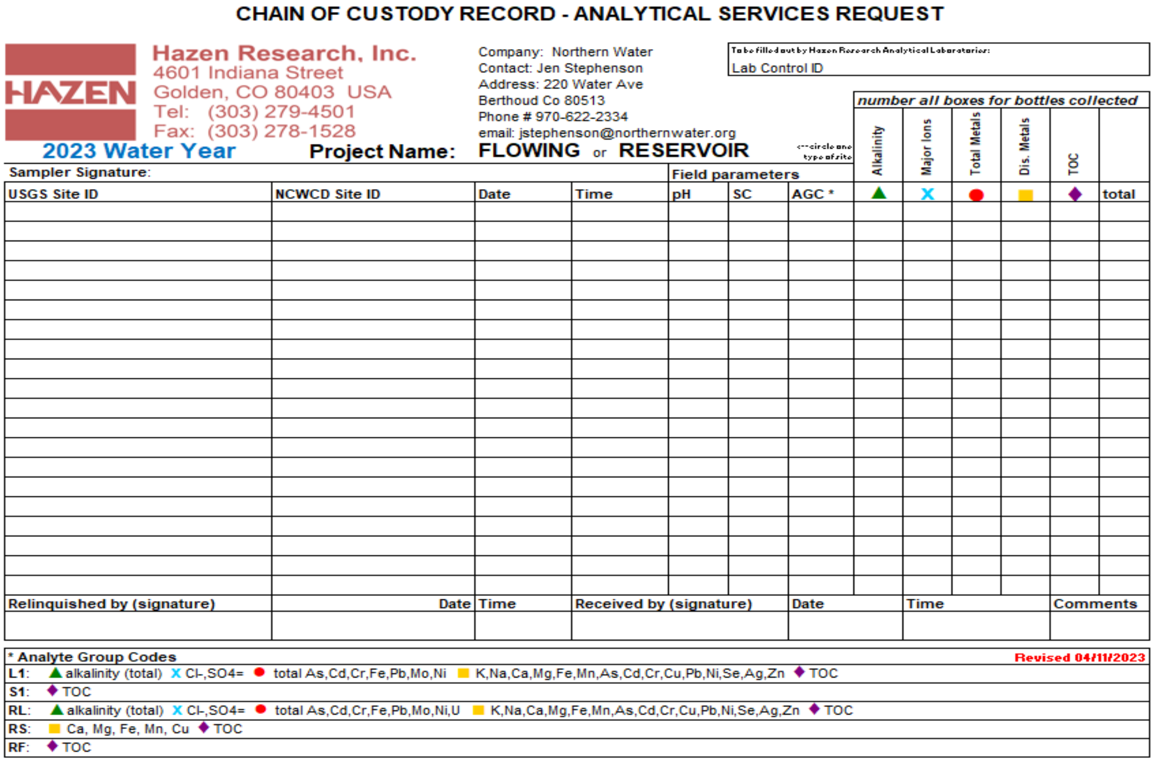
Samples are shipped or delivered to the labs as soon as possible after collection, with particular attention given to those parameters that have short maximum holding times (*Table 6*). Of the laboratories currently used by Northern Water, samples are shipped to High Sierra Water Lab (nutrients, TDS, and TSS; Oakland, OR), Hazen Research Laboratories (metals and other chemistry; Golden, CO), and BSA Environmental Services (phytoplankton and zooplankton; Beachwood, OH), and are hand-delivered to Northern Water's East Slope lab (chlorophyll), the University of Colorado (Boulder) Center for Environmental Mass Spectrometry Lab (emerging contaminants), Timberline Aquatics (periphyton; Fort Collins), and Fort Collins Water Treatment Lab (geosmin, cyanotoxins, VOCs).

Shipped samples are packaged so that melting ice will not leak from the cooler they are being shipped in. All bagged sample sets are placed into a 32" x 50" plastic bag *(Figure 29*). Ice is then added to the bag and the bag is ziplocked closed to prevent leakage. This bag of ice and samples is then placed inside another 32" x 50" plastic bag. An absorbent pad is placed between the bags, and the outer bag is ziplocked closed to prevent leakage. Coolers are then taped closed, and it is assumed that samples in tape-sealed ice chests are secure until received by the laboratory.

Figure 29 - Packing samples into coolers for shipment.

Samples to be hand-delivered are kept at 4ºC until relinquished to the respective labs. The chlorophyll filters are kept frozen in Northern Water's Berthoud lab freezer and/or portable freezer until relinquished to the lab.

Chain of custody (COC) forms are prepared for all samples and laboratories. COC forms provide documentation that the samples were not tampered with and that the samples were under appropriate possession at all times. The COC forms are placed in zip lock bags and placed into the coolers with the samples for shipping or hand delivery. Example COC forms are shown in *Figure 30* and *Figure 31*.



CHAIN OF CUSTODY RECORD - ANALYTICAL SERVICES REQUEST

HAZEN

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

2023 Water Year

Company: Northern Water
Contact: Jen Stephenson
Address: 220 Water Ave
Berthoud Co 80513
Phone # 970-622-2334
email: jstephenson@northernwater.org

Project Name: **FLOWING** or **RESERVOIR** <--circle one type of site

To be filled out by Hazen Research Analytical Laboratories:
Lab Control ID

Sampler Signature:

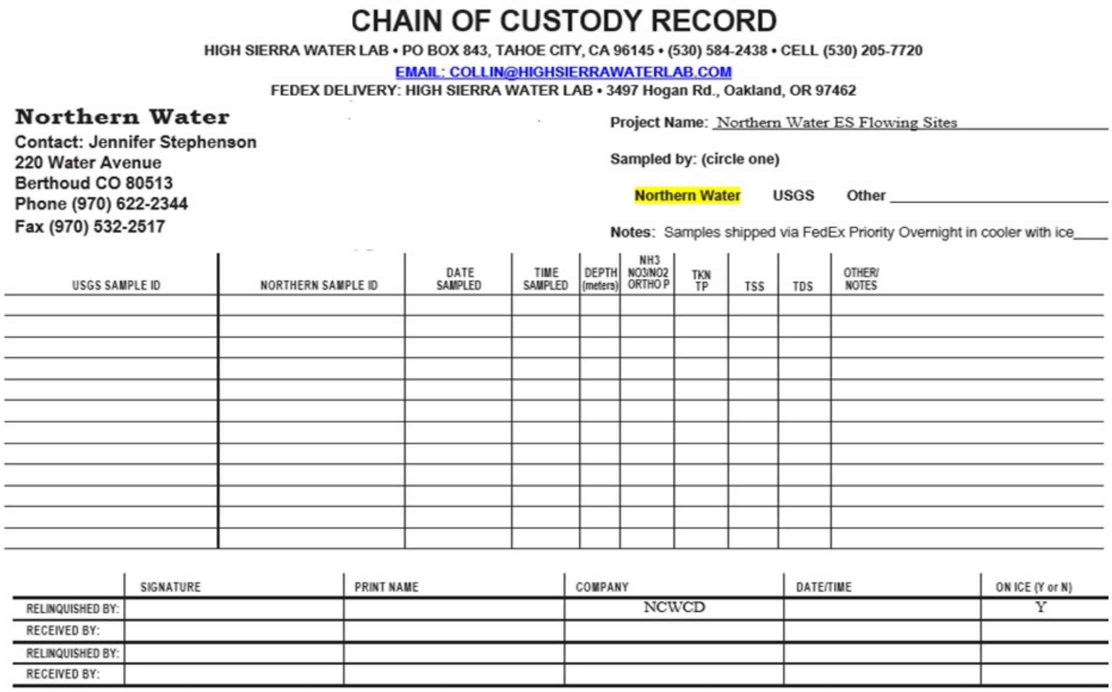
				Field parameters			*number all boxes for bottles collected*					
							Alkalinity	Major Ions	Total Metals	Dis. Metals	TOC	
USGS Site ID	**NCWCD Site ID**	**Date**	**Time**	**pH**	**SC**	**AGC ***	▲	X	●	■	◆	**total**

Relinquished by (signature)	**Date**	**Time**	**Received by (signature)**	**Date**	**Time**	**Comments**

*** Analyte Group Codes** **Revised 04/11/2023**

L1:	▲ alkalinity (total) X Cl-,SO4= ● total As,Cd,Cr,Fe,Pb,Mo,Ni ■ K,Na,Ca,Mg,Fe,Mn,As,Cd,Cr,Cu,Pb,Ni,Se,Ag,Zn ◆ TOC
S1:	◆ TOC
RL:	▲ alkalinity (total) X Cl-,SO4= ● total As,Cd,Cr,Fe,Pb,Mo,Ni,U ■ K,Na,Ca,Mg,Fe,Mn,As,Cd,Cr,Cu,Pb,Ni,Se,Ag,Zn ◆ TOC
RS:	■ Ca, Mg, Fe, Mn, Cu ◆ TOC
RF:	◆ TOC

Figure 30 - Chain of custody form used for samples delivered to Hazen Research Laboratories.



CHAIN OF CUSTODY RECORD

HIGH SIERRA WATER LAB • PO BOX 843, TAHOE CITY, CA 96145 • (530) 584-2438 • CELL (530) 205-7720
EMAIL: COLLIN@HIGHSIERRAWATERLAB.COM
FEDEX DELIVERY: HIGH SIERRA WATER LAB • 3497 Hogan Rd., Oakland, OR 97462

Northern Water
Contact: Jennifer Stephenson
220 Water Avenue
Berthoud CO 80513
Phone (970) 622-2344
Fax (970) 532-2517

Project Name: Northern Water ES Flowing Sites

Sampled by: (circle one)

[✓ Northern Water] USGS Other ______

Notes: Samples shipped via FedEx Priority Overnight in cooler with ice____

USGS SAMPLE ID	NORTHERN SAMPLE ID	DATE SAMPLED	TIME SAMPLED	DEPTH (meters)	NH3 NO3/NO2 ORTHO P	TKN TP	TSS	TDS	OTHER/ NOTES

	SIGNATURE	PRINT NAME	COMPANY	DATE/TIME	ON ICE (Y or N)
RELINQUISHED BY:			NCWCD		Y
RECEIVED BY:					
RELINQUISHED BY:					
RECEIVED BY:					

Figure 31 - Chain of custody form used for samples delivered to High Sierra Water Laboratory.

6. Continuous Data Collection

Northern Water collects continuous physical data including, temperature, turbidity, conductivity, D.O., and pH with multi-parameter sondes at canal and reservoir sites, Specific Conductivity data within rivers, and temperature data using dataloggers in canals and streams.

6.1 MULTIPARAMETER SONDES

Shadow Mountain Reservoir Buoy

Buoy monitoring systems (*Figure 32*) are located in Shadow Mountain Reservoir at two locations, near the dam (SM-DAM) and near mid-reservoir (SM-MID). The buoys continuously collect vertical profiles of temperature, D.O., specific conductance, pH, chlorophyll, periphyton, and turbidity in the reservoir during the summer and early fall. The buoy systems are deployed after ice-off in the spring and then taken out in the fall before ice cover. When deployed, SM-MID profiles are collected at 0.5-meter depth increments, from 1 meter to 6 meters, every four hours. The SM-DAM profiles are collected at 0.5-meter depth increments, from 1 meter to 7 meters, every four hours. Both buoys are equipped with an EXO2 multi-parameter sonde with sensors as outlined in *Table 9*. Data are logged and transferred by telemetry on a real-time basis to Northern Water's WISKI database platform. The buoy sondes are replaced every two weeks with a sonde containing freshly calibrated sensors. As a QA/QC check, profiles collected by the buoy monitoring system are compared to the profiles collected during the routine sampling events conducted for the C-BT and Windy Gap Monitoring Program.

Figure 32 - Shadow Mountain Reservoir buoy monitoring.

Flowing Sites

Multiparameter sondes are located in the North Fork Colorado River, Adams Tunnel, Granby Pump Canal, and the Hansen Feeder Canal. Sensors collect 15-minute data year-round when waterbodies are flowing, which is transmitted via telemetry to Northern Water's WISKI database. Calibration of real-time sondes is discussed in the *Sensor Calibration and Maintenance* section of this document.

6.2 CONTINUOUS STREAM TEMPERATURE MONITORING

Continuous stream temperature monitoring is conducted by Northern Water Field Services at several locations. Northern Water uses HOBO ProV2 temperature loggers with specifications outlined in *Table 12* for continuous temperature monitoring. At sites where real-time instantaneous data is required, Campbell Scientific Model 109 Temperature Probes linked to Campbell dataloggers are used Figure 33.

Table 12 - Specifications for continuous stream temperature monitoring equipment.

	HOBO U22 Water Temp Pro v2	**Campbell Scientific Model 109 Temperature Probe & CR800 Datalogger**	**In-Situ Aqua Troll 100 temperature & conductivity logger**
Range	-20°C to +50°C in Water	-50 to +70°C	-5 to +50°C | 0-100,000 µS/cm
Accuracy	± 0.2°C at 25°C	± 0.25°C over -10 to +70°C	± 0.1°C | ±0.5% + 1 µS/cm
Resolution	0.02°C at 25°C	0.03°C at 25°C	0.01°C | 0.1 µS/cm
Software	HOBOware Pro software	LoggerNet	Win-Situ 5

Figure 33 - Temperature monitoring equipment.

Northern Water Field Services staff visit the HOBO West and East Slope temperature monitoring sites once a month (or as conditions allow) to download the data, clean the housing, and inspect the housing and logger for damage. The general temperature data flow path and data management procedures are discussed in the *Data Processing and Management* section of this document. A detailed description of temperature monitoring protocols, including sensor installationand site selection, can be found in the Northern Water's Temperature Monitoring SOP.

Three Lakes Inlets Temperature and Specific Conductance Monitoring

Continuous temperature and specific conductance monitoring is conducted at the Three Lakes inlet sites. In-Situ Aqua Troll 100 temperature and conductivity sensors (with specifications outlined in *Table 12*) are used to collect data at all stations except for GR-Pump and CR-SMU which are equipped with YSI multiparameter sondes as described in *6.1 Multiparameter* Sondes section of this document. Northern Water has hired GCWIN to maintain the Aqua-Troll 100 sensors using protocols established by Northern Water, including regular calibration checks. The data are downloaded monthly by GCWIN and submitted to Northern Water yearly for QA/QC and uploading into Northern Water's database.

Annual Temperature Accuracy Checks

Once a year, all temperature data loggers are removed from the streams and checked at Northern Water's Berthoud laboratory to determine if the accuracy of the instruments still meets the manufacturer's specifications. Northern Water conducts the accuracy check of its HOBO temperature data loggers in early spring and conducts the accuracy check for the In-Situ Aqua Trolls every winter. The temperature loggers are immersed in a programmable circulating fluid bath and stepped through four different temperature values (0, 8, 16, and 24°C) that bracket yearly temperature values seen in Colorado streams. The bath is programmed to maintain each temperature value for 60 minutes before moving on to the next value. The temperature of the bath fluid is verified by a separate NIST temperature probe. The fluid used in the bath is a 50:50 mixture of ethylene glycol and deionized water that allows the bath to cool the fluid to 0°C without freezing the fluid. Dataloggers and sensors that fail the accuracy check are replaced.

6.3 SOUTH PLATTE CONTINUOUS SALINITY MONITORING

Continuous monitoring of salinity as specific conductivity is conducted by Northern Water Field Services East Slope sites in the Cache la Poudre and South Platte River. Each monitoring station is equipped with a Campbell Scientific CS547A Water Conductivity and Temperature Probe and a Campbell Scientific CR800 Data Logger (*Figure 34*). The CS547A measures conductivity from 0.005 to 7.0 millisiemens per centimeter (mS/cm) with an accuracy of ± 5% of the reading (within the range of 0.44 to 7.0 mS/cm) and temperature from 0°C to 50°C. Continuous readings averaged and reported on a 15-minute basis. A calibration check and cleaning are performed on the conductivity probe twice per month or as conditions allow. Conductivity values are checked against a YSI specific conductivity sensor that is calibrated in the lab before entering the field. Annual calibrations are conducted on CS547A probes based on procedures outlined by Campbell Scientific, followed by a three-point calibration check.

Figure 34 - Continuous salinity monitoring station in the Poudre River at Canyon Mouth (CLAFTCCO).

7. Data Processing and Management

This section addresses the path of the data after it is collected in the field and after samples have been analyzed, verified, and reported to Northern Water by the laboratories. Data processing and data management differ based on the type of data that are collected. Laboratory water quality data and instantaneous field data collected during the sampling events are contained in Northern Water's KiWQM database. Continuously collected physical data are contained in Northern Water's WISKI database (*Table 13)*.

Table 13 - Water quality monitoring program databases.

Data Type	Monitoring Program(s)	Database
Flowing Sites instantaneous field and laboratory data	C-BT Water Quality Monitoring Program, Willow Creek Monitoring Program, Poudre River Monitoring Program, East Slope Canal Periphyton Monitoring Program, SPWCP Water Quality Monitoring Program, and special studies	KiWQM
Lake/Reservoir Sites instantaneous field and laboratory data	C-BT Water Quality Monitoring Program and special studies	KiWQM
Compounds of Emerging Concern laboratory data	Northern Colorado Compounds of Emerging Concern Collaborative Monitoring Program	KiWQM
Continuous Physical Monitoring data	Continuous Stream Temperature Monitoring Program, Three Lakes Inlets Temperature and Specific Conductance Monitoring Program,	WISKI
Real-Time Continuous Physical Monitoring	Shadow Mountain D.O. Monitoring Program (YSI EXO2 Granby Pump Canal data and YSI EXO2 Shadow Mtn Res Buoy profiles); YSI EXO2 data for North Fork Colorado River, Adams Tunnel, Granby Pump Canal, and Hansen Feeder Canal; Campbell 109 temperature data at the Colorado River upstream of Williams Fork, upstream of Hot Sulphur Springs, and downstream of Windy Gap Reservoir; and other special studies as needed.	WISKI

7.1 CONTINUOUS DATA MANAGEMENT

The collection of continuous data is discussed in the *Continuous Data Collection* section of this document. After the data is collected, an initial QA/QC process is conducted if necessary and the data are uploaded into the WISKI database (unless they are automatically uploaded via telemetry), where further data validation and review occur. QA/QC procedures vary depending on the type of data collected and can be found in internal SOPs.

Once QA/QC is complete, data can be queried from WISKI by Northern Water staff as required for data analyses and reporting. The data are also published annually on Northern Water's website at data.northernwater.org.

7.2 LAB AND INSTANTANEOUS FIELD DATA MANAGEMENT

A wide variety of lab and instantaneous data is collected during sampling events, as described in the *Sample Collection and Field Measurements* section of this document. This section discusses the data processing and data management flow path of that data.

Field Data and Records

Field records include instrument calibration logs, sonde data logs, COC forms, and field sheets that are filled out whenever samples are collected. The field sheets contain some data that Field Services staff currently enter by hand into Excel files. This includes Secchi depths recorded at lakes and reservoir sites, sampler type, sampling method, and other observational records at flowing sites.

Record Storage and Retention

Field sheets, calibration logs, and sonde logs are stored in notebooks held by Field Services staff. The completed COCs are stored with hard copies of laboratory data in notebooks held by the Water Quality Department. The sheets in these notebooks are reviewed during the data validation process or as issues arise.

Recipt of Data from Laboratories

Laboratories verify the data that they produce before sending it to Northern Water as described in the *Analytical Methods, Laboratories, and Lab QA/QC* section of this document. Water quality data from the laboratories are received by the Water Quality Department through email. The data are contained in Excel files, with each lab having its specific format. Before receiving the lab data files, PDF files of the corresponding completed COC forms are emailed to the Water Quality Department as the labs receive samples. Generally, several COCs correspond to a single lab report. COCs and data files are organized according to the monitoring program by laboratory and month before being uploaded to the WISKI database.

Data Review and Validation

All data collected in the field and received from the laboratories are subject to thorough data QA/QC review and validation by Northern Water before being uploaded to the WISKI. Data validation and review of the field data is conducted by both Field Services and Water Quality Department staff. Data validation and review of the laboratory data is completed by Water Quality Department staff. Validation and review are an ongoing process even after data are uploaded to the databases, as some data quality issues may not be apparent until detailed data analyses and assessments are performed. During the data validation and review process, the QA/QC flags listed in *Table 14* are assigned to the data as required.

The data validation and review process include the following (these tasks are conducted by Water Quality Department staff unless otherwise noted):

- Review Sonde Data – After uploading sonde data from the EXO Handheld to Excel files, the files are reviewed for unrealistic results and corrected for obvious errors (data not in correct columns, unintended duplicate readings, missing data, etc.). Field Services staff review the sonde data first, followed by a second review by the Water Quality Department.

- Review Other Field Records and Data – Field records are reviewed by Field Services staff as soon as possible after a sampling event to ensure that field sheets and logs are complete, that the writing is legible, and that they do not contain errors. Unusual readings (outliers) from field instruments are noted and checked.

- Verify Sample Dates, Times, and Locations – Dates and times, site names, sample depths, sample types, and lab methods listed on field sheets, COC forms, and lab reports are cross-checked for consistency. Any differences are reconciled, and errors are corrected.

- Errors in Units and Decimal Places – The laboratory reports are reviewed for typos and obvious errors.

- Check Method Holding Times – Data are flagged if the method maximum holding time is exceeded for that parameter (Flag Name = H; this flag is also used with other QC flags to identify the situation more specifically; *Table 14*). Results where the maximum hold time has been violated may be biased low, although depending on the parameter and concentration, the potential bias may not be significant.

- Conduct Reasonable Range Checks – Results are compared to the typical concentration ranges historically observed at the site during the same month or season. Results are also compared to other samples collected during the same sampling event at spatially related sites (i.e., if samples are collected in Horsetooth Reservoir, the results are compared for the top depths at all three sites collected for that event in Horsetooth Reservoir).

- Investigate Data Outliers and Unusual (Unexpected) Data – If an outlier or unusual data are observed, the following steps are taken to validate the value:
  - Field sheets and field notes are reviewed to determine if anything unusual was observed during sampling (for example, if it was raining before/during the sampling event and subsequent runoff resulted in higher-than-normal suspended solids).
  - Results of other parameters that correlate with the parameter in question are investigated to determine if there is consistency of data (for example, high turbidity levels would generally be expected to co-exist with high TSS; high manganese levels at a reservoir bottom generally only exist if the D.O. levels are very low; higher concentrations of major ions co-exist with higher concentrations of TDS and specific conductance).
  - Operation and maintenance activities of the C-BT system are noted if applicable (for example, if the Farr Pumps were recently turned on, lower Secchi depths and higher turbidities may be observed in Shadow Mountain Reservoir).
  - If possible, the data are compared to data collected at that site by other entities (USGS, City of Fort Collins, etc.) at approximately the same date.
  - The lab is contacted to ensure there was not a reporting error.

- Conduct General Logic Checks – For the data collected for Northern Water's monitoring programs, the following general logic checks are performed:
    - The ortho-phosphate concentration must be less than 110% of the total phosphorus concentration.
    - The total ammonia concentration must be less than 110% of the Total Kjeldahl Nitrogen (TKN) concentration.
    - All filtered sample results must be less than 110% of the corresponding unfiltered sample results.

  If any of the general logic checks are exceeded, the corresponding laboratory is contacted to make sure that there was not a reporting error (i.e., dissolved concentration switched for the total concentration, etc.).

- Review Field Replicate Sample Results and Assess Field Precision – QC flags are assigned to the field replicate sample data, including CR for concurrent replicate, SQR for sequential replicate, SR for Split Replicate, and SS for split sample (*Table 14*). The field replicate data are reviewed for inconsistent values and the relative percent difference (RPD) for each pair is calculated. The cause of an RPD exceeding the criteria listed in *Table 4* is investigated. Depending on the type of field replicate, the cause could be natural variability in space or time, inconsistent field techniques and sample processing, or lab error. If a lab error is suspected, the laboratory is asked to re-analyze the sample.

- Assess Sample Contamination Using Field Blank Sample Results – Blank sample results are compared to the criteria listed in *Table 4* to determine if sample contamination has occurred. In some cases, the potential contamination is insignificant relative to the environmental sample concentrations (i.e., <laboratory reporting limits and/or <10% of environmental sample concentration). In cases where sample contamination values (assessed from the field blank samples) approach the environmental sample concentrations, the data collected for that parameter during that particular sample event are likely invalid. If the blank samples indicate chronic sample contamination, the source of contamination is investigated so that it can be eliminated. The Water Quality Department may ask Field Services to collect blank samples at various additional points in the sample collection and processing sequence to help determine exactly where the contamination is occurring.

- Request Laboratory Re-Analysis and Laboratory QA/QC Documentation – Re-analysis is requested of the laboratory to investigate and verify any result that may be suspect after the reasonable range checks, investigation of outliers, general logic checks, or review of field replicate results. Samples that are re-analyzed by the laboratory are flagged as "verified" in the database (Flag Name = V; this flag is generally used in combination with other QC flags to identify the situation more specifically; *Table 14*).

- Flagging of Suspect Data – Data quality issues may not be resolved during the data validation process. Data are flagged as "suspect" if there is still a remaining data quality issue (i.e., unexplained outlier or violation of logic check or exceedance of RPD criteria for field replicates), but the data are not of sufficiently poor quality to be rejected. Data flagged as "suspect" in Northern Water's database (Flag Name = S; *Table 14)* can be returned during data queries and are available for use, but with caution, if desired.

- Rejection of Data – Careful consideration is made on a case-by-case basis to determine if data quality (due to sample contamination, error in sample collection, or error in laboratory analyses) has been reduced to a level where the data must be rejected. For example, in cases where sample contamination values (assessed from field blanks) approach the environmental data values, the data collected for that parameter during that particular sample trip is concluded to be invalid and is rejected. Data may also be rejected if a combination of factors is not met (violations of logic checks, poor comparisons with historical data and spatially related sites, poor comparisons with data from outside sampling programs (USGS or other entities), sample hold time violations, etc.). Rejected data are flagged as "disqualified" in Northern Water's databases. "Disqualified" data are stored in the database, but are not returned during data queries, are not used during data analyses and data assessments and are prevented from public release.

- Records of Validation Activities – Records of validation activities and follow-up actions are documented and kept in the Water Quality Department, particularly in cases where data are flagged as "Suspect" or "Disqualified." Validation records include email exchanges with the laboratories when requesting that values be checked or when requesting that samples be re-analyzed, and email exchanges with the sampling crews (Northern Water Field Services or the USGS) to determine if anything unusual was noted for the sampling date.

Table 14 - Database Flags.

Flag ID	Flag Name	Flag Description
1	{None}	
2	V	Result verified at the laboratory
7	B	Analyte detected at a value between RL and MDL. The associated value is an estimated quantity
9	B,V	Analyte detected at a value between RL and MDL, Result verified at the laboratory.
10	B,J	Analyte detected at a value between RL and MDL, Method blank contamination
11	B,H	Analyte detected at a value between RL and MDL, Analysis performed past holding time
15	Lab Dup	Duplicate analysis preformed at laboratory for internal QA/QC procedure
20	H	Analysis exceeded method holding time
21	J	Method blank contamination. Analyte detected in the associated method blank below method reporting limit.
35	TNC	Too numerous to count (fecal coliform).
38	U	Analyte not detected above laboratory reporting value
39	U,H	Analyte not detected above laboratory reporting value, Analysis performed past holding time
44	SR	Split Replicate. Sample split into subsamples by use of churn, sent to laboratory for duplicate analysis.
45	SS	Split Sample. Sample split between different laboratories for duplicate analysis.
46	SR,Lab Dup	Split Replicate, Duplicate analysis preformed at laboratory
47	CR	Concurrent Replicates. Samples that are collected simultaneously or at approximately the same time.
48	B,SR	Analyte detected at a value between RL and MDL, Split Replicate
49	B,CR	Analyte detected at a value between RL and MDL, Concurrent Replicate

Flag ID	Flag Name	Flag Description
50	B,SS	Analyte detected at a value between RL and MDL, Split Sample
51	D	Sample required dilution due to either insufficient sample or high concentration of target analyte. Reporting limit adjusted accordingly.
52	U,D	Analyte not detected above laboratory reporting value, Sample required dilution
53	SS,Lab Dup	Split Sample, Duplicate analysis preformed at laboratory.
54	B,D	Analyte detected at a value between RL and MDL, Sample required dilution
55	U,SR	Analyte not detected above laboratory reporting value, Split Replicate
56	B,D,SR	Analyte detected at a value between RL and MDL, Sample required dilution, Spilt Replicate
57	CR,Lab Dup	Concurrent Replicate, Duplicate analysis performed at laboratory
58	U,Lab Dup	Analyte not detected above laboratory reporting value, Duplicate analysis preformed at laboratory
59	D,SR	Sample required dilution, Split Replicate
60	D,CR	Sample required dilution, Concurrent Replicate
61	U,CR	Analyte not detected above laboratory reporting value, Concurrent Replicate
65	U,SR,Lab Dup	Analyte not detected above laboratory reporting value, Split Replicate, Duplicate analysis preformed at laboratory
66	U,SS	Analyte not detected above laboratory reporting value, Split Sample
67	V,SR	Result verified at the laboratory, Split Replicate
68	EH	Value estimated, extrapolated at high end
69	EL	Value estimated, extrapolated at low end
70	P	Sample was not properly preserved
71	U,P	Analyte not detected above laboratory reporting value, Sample was not properly preserved
72	B,P	Analyte detected at a value between RL and MDL, Sample was not properly preserved
74	V,CR	Result verified at the laboratory, Concurrent Replicate
75	V,Lab Dup	Result verified at the laboratory, Duplicate analysis preformed at laboratory.
76	D,Lab Dup	Sample required dilution, Duplicate analysis preformed the laboratory
77	D,SR,Lab Dup	Sample required dilution, Split Replicate, Duplicate analysis preformed the laboratory
78	H,Lab Dup	Analysis exceeded method holding time, Duplicate analysis performed at laboratory
79	V,D	Result verified at the laboratory, Sample required dilution
80	SQR	Sequential Replicate. Samples that are collected one after the other.
81	D,H	Sample required dilution, Analysis exceeded method holding time.
82	V,D,SR	Result verified at the laboratory, Sample required dilution, Split Replicate
86	U,Rep	Analyte not detected above laboratory reporting value, Replicate value
87	S	Data suspect
88	U,S	Analyte not detected above laboratory reporting value; Data suspect, value out of line compared to normal conditions
89	cf.	Looks like, used when species identification is not 100%

Flag ID	Flag Name	Flag Description
92	D,CR,Lab Dup	Sample required dilution, Concurrent Replicate, Duplicate analysis preformed the laboratory
93	U,SQR	Analyte not detected above laboratory reporting value, Sequential Replicate
94	B,SQR	Analyte detected at a value between RL and MDL, Sequential Replicate
95	D,P	Sample required dilution, Sample was not properly preserved
96	B,Lab Dup	Analyte detected at a value between RL and MDL, Duplicate analysis preformed at laboratory
97	B,SR,Lab Dup	Analyte detected at a value between RL and MDL, Split Replicate, Duplicate analysis preformed at laboratory
98	B,CR,Lab Dup	Analyte detected at a value between RL and MDL, Concurrent Replicate, Duplicate analysis preformed at laboratory
99	B,H,Lab Dup	Analyte detected at a value between RL and MDL, Analysis exceeded method holding time, Duplicate analysis performed at laboratory
100	U,D,SR	Analyte not detected above laboratory reporting value, Sample required dilution, Split Replicate
102	P,SS	Sample was not properly preserved, Split Sample.
103	P,SS,Lab Dup	Sample was not properly preserved, Split Sample, Duplicate analysis preformed at laboratory.
104	B,P,Lab Dup	Analyte detected at a value between RL and MDL, Sample was not properly preserved, Duplicate analysis preformed at laboratory.
105	P,Lab Dup	Sample was not properly preserved, Duplicate analysis preformed at laboratory.
107	B,P,SS	Analyte detected at a value between RL and MDL, Sample was not properly preserved, Split Sample.
108	B,P,SS,Lab Dup	Analyte detected at a value between RL and MDL, Sample was not properly preserved, Split Sample, Duplicate analysis preformed at laboratory.
109	B,SS,Lab Dup	Analyte detected at a value between RL and MDL, Split Sample, Duplicate analysis preformed at laboratory.
110	V,D,Lab Dup	Result verified at the laboratory, Sample required dilution, Duplicate analysis preformed at laboratory.
111	B,S	Analyte detected at a value between RL and MDL, Data suspect
112	S,SR	Data Suspect, Split Replicate
113	B,S,Lab Dup	Analyte detected at a value between RL and MDL, Data suspect, Duplicate analysis preformed at laboratory.
114	S,D	Data Suspect, Sample required dilution.
115	Q EST	Flow value estimated
116	Q ICE	Channel frozen
117	Q LOW	Flow too low to measure
118	Q HIGH	Flow too high to measure
119	V,SR,Lab Dup	Result verified at the laboratory, Split Replicate, Duplicate analysis preformed at laboratory.
120	H,SR	Analysis exceeded method holding time, Split Replicate.

Flag ID	Flag Name	Flag Description
121	U,D,CR	Analyte not detected above laboratory reporting value, Sample Required dilution, Concurrent Replicate
122	V,B,SR	Analyte detected at a value between RL and MDL, Result verified at the laboratory. Split Replicate
123	V,B,D,SR	Analyte detected at a value between RL and MDL, Result verified at the laboratory, Sample required dilution, Split Replicate
124	Dup	Duplicate value, generally a physical parameter
125	D,H,SR	Sample required dilution, Analysis exceeded method holding time, Split Replicate.
126	P,H	Analysis exceeded method holding time. Sample was not properly preserved.
127	V,S	Result verified by the laboratory, Data Suspect

Database Security

Database security is ensured through user permission settings that restrict access to data records. Only specific individuals in the Water Quality Department have permission to add and edit data contained in the WISKI database. The structure of the WISKI database prevents the import of duplicate data files. Regular database file backup is conducted through Northern Water’s IT Department.

8. References

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9. Contact

Northern Water maintains step-by-step procedures for all water quality monitoring practices. For further information, contact Rob Davis (rdavis@northernwater.org).

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