BCWA PROGRAM GUIDLELINES & OPERATIONS

Approved December 12, 2018; Revisions Accepted January 9, 2019

PGO33- BCWA Surface Water Monitoring Program and Sample Analyses Plan Version 2019.01

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Bear Creek Watershed Monitoring Program

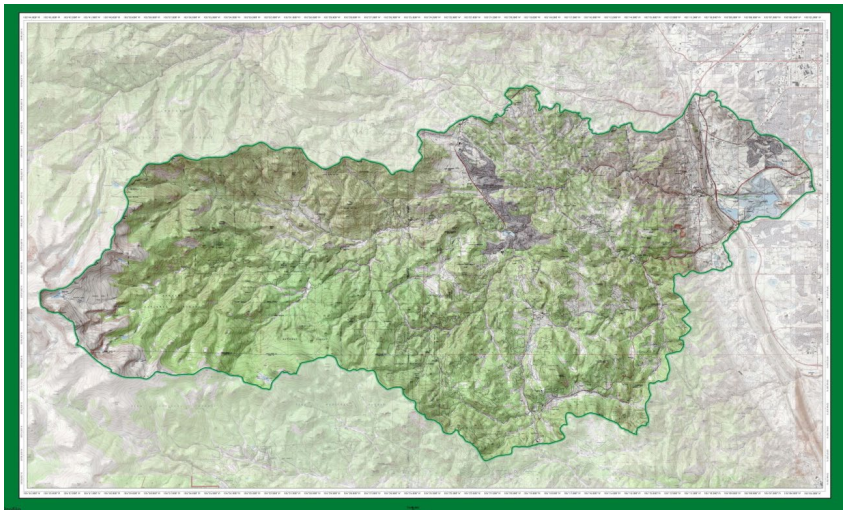
Bear Creek Reservoir Control Regulation # 74

The Bear Creek Watershed (Figure 1) is a specific geographic area identified in the Bear Creek Watershed State Control Regulation (Regulation #74, 5 CCR 1002-74) (Control Regulation) identifying water quality management (BCWA Policy 13 – Vision, Mission & Targets). The watershed includes all tributary water flows that discharge into Bear Creek Reservoir and a small area below the dam as defined in *BCWA Policy 14 – Watershed Boundary*. Essentially, the watershed boundary extends from the Mount Evans Wilderness on the western end past the Town of Morrison on the eastern end. The two major tributaries are Bear Creek and Turkey Creek. The purpose of the Control Regulation is to attain site-specific water quality standards and classifications through control of total phosphorus and chlorophyll.

The Bear Creek Watershed Association (Association) oversees implementation of the Control Regulation. The Association is the local water quality agency responsible for monitoring and tracking water quality in the Bear Creek Watershed. The Association has conducted a generally continuous collection of surface quality data from 1990 for the Bear Creek Watershed and reservoir. Data collection includes specific chemical, physical and biological parameters. Data is collected monthly and bi-monthly at Bear Creek Reservoir and along Turkey Creek and Bear Creek. The Association meets water quality data sampling and analyses objectives established in the Bear Creek Reservoir Control Regulation # 74.

The Association provides watershed reporting as posted on the Association Website www.bearcreekwatershed.org, which serves to keep federal, state, and local governments and others informed on the state of the watershed. The Control Regulation defines specific reporting requirements, which helps the Association keep the Water Quality Control Commission and Water Quality Control Division staff updated on progress of the Association in implementing the Control Regulation.

Figure 1 Bear Creek Watershed



The Association has established a series of management policies and strategies to guide the watershed monitoring programs (See PGO01for a complete list of program documents as incorporated into the Association Watershed Plan; and PGO02 for the Program Document Categories).

Monitoring requirements established by State Control Regulation #85 are designed to evaluate the effectiveness of and to determine the sources and load of nutrients at selected locations, and eventual implementation of appropriate and necessary source controls. The Bear Creek Association watershed monitoring plan includes monitoring elements for wastewater treatment facilities in the watershed, which allows these facilities to meet monitoring requirements in Regulation #85.

Nutrient Regulation #85

All wastewater treatment plants in the watershed are categorized as minor facilities. As such, upstream and downstream monitoring is exempt for the treatment works that surface discharge. All surface discharging wastewater treatment facilities must meet the effluent monitoring requirements of Regulation #85. Each facility has certification

and reporting requirements defined in that regulation. The monitoring data collected for Regulation #85 is not part of the permit DMR reporting.

Implementation of Regulation #85 monitoring is a requirement of permitted surface water dischargers and is not a specific monitoring requirement of the Association. However, the Association board has determined that integrating the monitoring requirements from Regulation #85 into the Association watershed monitoring plan Regulation #74 could serve to improve water quality management in the watershed and have a shared funding benefit. A combined monitoring effort can meet state requirements, but, as importantly, it is an opportunity for the Association to develop a more comprehensive and holistic nutrient management plan that will protect and improve water quality throughout the watershed. Involvement of wastewater treatment facilities in this joint monitoring effort is strictly voluntary. See *BCWA Information Sheet 18 Reg 85 Shared Service Program* for shared service program details.

The Association completed the certification process for all wastewater treatment facilities in the watershed and maintains a copy of the certification in the association data record. However, the Association will only do the reporting requirement for those treatment facilities participating in the voluntary shared service monitoring program. All other non-participating treatment plants are expected to do their own reporting to the WQCD in accordance with the Regulation #85 reporting requirements. The wastewater treatment plants that have volunteered for this sampling effort are shown in Table 1. The Association will pick-up collected effluent samples in coordination with these treatment plants. The Association contract laboratory will process these samples. The eight participating treatment plants in the 2019 monitoring program will compensate the Association for the actual laboratory costs. Data collection will occur on the first or second week of every other month beginning in January 2019.

Table 1 **Wastewater Treatment Plants Involved in a Coordinated Monitoring Plan**

Wastewater Treatment Works	Coordinated with Monthly Stream Samples	Not Participant
Bear Creek Drainage		
JCS Outdoor Lab	**x**	
Brookforest Inn		**x**
Evergreen Metro District	**x**	
West Jefferson County Metro District	**x**	
Kittredge Sanitation and Water District	**x**	
Genesee Water and Sanitation District		**x**
Forest Hills Metro District	**x**	
Morrison	**x**	
Turkey Creek Drainage		
Aspen Park Metro District		**x**
Conifer Metro District		**No Sample**
Conifer Sanitation Association	**x**	
JCS Conifer High School	**x**	
Tiny Town		**No Sample**
Geneva Glen		**No Sample**

Association Monitoring Program Types

The Bear Creek Watershed Association maintains five types of water quality and other monitoring efforts to characterize water and environmental quality within the Bear Creek Watershed:

P1- Routine water quality monitoring at Bear Creek Reservoir (multiple vertical stations), Turkey Creek inflow to reservoir, Bear Creek inflow to reservoir, reservoir discharge into lower Bear Creek, and the lower edge of the watershed near Wadsworth. The P1 sites are long-term reference monitoring sites consistent with the intent of the monitoring program outlined in the Bear Creek Reservoir Control Regulation #74.

P2- Supplemental sampling of tributaries, problem areas, restoration or other project specific sites (e.g., Coyote Gulch in cooperation with the City of Lakewood). These types of monitoring efforts can be either of limited duration, or long-term on a site-specific basis, and generally these programs monitor for specific parameters of interest to the project.

P3- Watershed surface water monitoring along Bear Creek and Turkey Creek drainages for site-specific characterizations (e.g., temperature trends, nutrient loading, flow studies). These are interim and long-term monitoring sites for watershed characterizations. Watershed monitoring stations include both long-term reference sites where multi-year data is desirable, and target sites that may provide only a couple years of data. The nutrient monitoring is on a watershed basis that begins near Summit Lake and extents through Bear Creek Reservoir. The monitoring schedule for the watershed programs are maintained by the Association manager and are available on request.

P4- Supplemental environmental characterizations of Bear Creek watershed including, but not limited to macroinvertebrates, flow analysis, habitat characterizations, fishery evaluations, system productivity, or other environmental factors that potentially affect fisheries or watershed health.

P5- Wastewater treatment facility nutrient sampling consistent with Regulation #85. The wastewater treatment plants in the watershed are listed in Table 2.

Table 2 WWTF in Bear Creek Watershed

Wastewater Treatment Plants	Treatment System Contact	Facility Type	Design Capacity MGD	2019 Effluent Monitoring
Bear Creek Drainage				
JCS Outdoor Lab	JCS	Minor	0.0075	Yes
Brookforest Inn	None currently	Minor	0.009	No
Evergreen Metro District	EMD	Minor	0.99	Yes
West Jefferson County Metro District	EMD	Minor	0.7	Yes
Kittredge Sanitation and Water District	EMD	Minor	0.125	Yes
Genesee Water and Sanitation District	Genesee	Minor	0.8	Yes
Forest Hills Metro District	ORC LLC	Minor	0.05	Yes
Morrison	Town of Morrison	Minor	0.35	Yes
Turkey Creek Drainage				
Aspen Park Metro District	Treatment Tech	Minor	0.025	Yes
Conifer Metro District	Bryan McCarty	Minor	0.043	Yes
Conifer Sanitation Association	Becky Hammer	Outfall	0.019	Yes, CMD
JCS Conifer High School	JCS	Minor	0.052	Yes
Tiny Town	Treatment Tech	Minor	0.005	No
Geneva Glen	Crystal Clear Water Treatment	Minor	0.0105	Yes

Mapped Watershed Features

The BCWA uses Google Earth to track monitoring sites and watershed features of interest. The mapping codes and station types are shown in Table 3. A Google Earth *Myplaces* file is available to the membership for use with Google Earth.

Table 3 BCWA Google Earth Station Types

Code	Station Type
P1	Routine CR Monitoring stations
P1 BCR	BCR Stations
P1 S	Stream Sites for mass balance
P2	Supplemental Water Quality Characterizations in Bear Creek Watershed
P2 Air	BCR Aeration Sites
P2 Coyote	Coyote Gulch Nutrient Reduction
P2 Fen	Summit Fen Study
P2 Gen	Genesee Reservoir
P2 K/S	Kerr and Swede Gulch Special Study
P2 MV	Mount Vernon Creek
P2 Sed	Bear Creek Reservoir Sediment Study
P2 Soda	Soda Lakes
P2 Summit	Summit Plume Study
P2 Temp	Stream Temperature Only Probe
P2 Trib	Special tributary Nutrient loads
P2 Trouble	Troublesome Gulch
P2 TSS	Total Suspended Sediment Sites

P2 Flow	Stream Flow Measurement Sites
P2 Copper	Segment 1e Copper Study
P3	Watershed Monitoring Program Active sites
P3 EGL	Evergreen lake
P3 WS	Watershed
P3 Old	Stream Site Not Active
P4	Supplemental Studies, Education Sites or Informational Features
P4 Ed	Educational site
P4 Fish	CDFW Fishery Surveys
P4 Gage	Gaging Stations
P4 Horse	Horse Stables or Operations
P4 Macro	Macroinvertebrates
P4 Other Group	Other Outside Agency Monitoring Stations
P4 Sign	BCWA Signs
P4 Segments	Mainstem segment brake points
P4 WS	Watershed Features
P4 Weather	Watershed Weather Stations
P5	WWTF
P5 Outfall	WWTF Outfalls

2019 Water Quality Monitoring Program & Quality Assurance Project Plan

The following monitoring plan sections details the 2019 reservoir and watershed monitoring programs as approved by the BCWA Board. This monitoring plan remains consistent with the quality assurance goals of the previously adopted Association QAPP (Bear Creek Watershed Association, 2006). However, this monitoring plan is the working version. The monitoring program version 2019.01 is adapted from the last version of the 2018.02 monitoring plan.

Watershed Field Monitoring Personnel

The Association contracts field monitoring, sampling coordination, and data management with RNC Consulting LLC:

Russell N Clayshulte, RNC Consulting LLC
1529 S Telluride St
Aurora, CO 80017
Office (303) 751-7144 / Cell (303) 638-4931
rclayshulte@earthlink.net

RNC Consulting LLC conducts field sampling in cooperation with Evergreen Metropolitan District (EMD) and the City of Lakewood, and occasionally other members. EMD staff assist with field monitoring, temperature probe maintenance and the annual data report. While several staff of EMD assist with the monitoring program, the EMD primary field manager/ data manager is:

Tony Langowski, Evergreen Metro District
Office (303)674-4112
Cell (303) 301-5507
tlangowski@evergreenmetrodistrict.com

The City of Lakewood assists with sampling on Coyote Gulch, Bear Creek Reservoir, and P1 sites. While several staff of Lakewood Bear Creek Lake Park staff assist with the monitoring program, the Lakewood primary field monitoring assistant is:

Mike Towner, Bear Creek Lake Regional Park
Cell (303) 941-7554
miktow@lakewood.org

All water quality samples for laboratory analyses are delivered by RNC Consulting LLC to GEI Consultants, Inc. / Chadwick Ecological Division within 2 hours of final sample collection.

Field data sheets are scanned and converted into PDF files for electronic storage. Field data is transferred into a master spreadsheet, which contains all annualized data collected for the Association, except for temperature logger data.

BCWA Field Methods

The BCWA has adopted a set of indices forms, field methods and habitat summaries, which are listed and maintained in the PGO1 Master Index List as part of the Association's Watershed Plan (Table 4).

Table 4 BCWA Indices & Methods

	BCWA Indices & Methods
FI01	BCWA Habitat Indices Form
FI02	BCWA Physical Stream Indices Form
ME01	Embeddedness Field Estimation Method
ME02	Gravelometer Pebble Count Method
ME03	Field Flow Estimation Method
ME04	Macroinvertebrate Field Sample Method
ME05	Periphyton Field Estimation Method
ME06	Water Clarity Estimation Method
ME07	Habitat Indices Site BCW
ME08	Erosion Pin Method (Not Currently Used)
ME09	2015 Habitat Indices Summary
ME10	Tributary Assessment Procedure
ME11	Temperature Probes
ME12	Macro Labels

Watershed Field Monitoring Notes and Methods

Treatment facilities listed in Table 2 provide effluent data collected at their respective WWTP's, including analytical results; and /or assistance with special monitoring.

The Interval frequency for temperature dataloggers is every half-hour (48 per day). The dataloggers in wastewater plant discharges will be field-downloaded as needed, 60-90 days, while dataloggers located in the stream will be field-downloaded as needed.

Manual pH, Temperature, DO, Specific Conductivity, Total Nitrogen, Nitrate-nitrogen, Total Ammonia, Total Inorganic Nitrogen and Total Phosphorus data collected at selected temperature datalogger locations. Manual monitoring is performed in the morning to early afternoon, beginning at approximately 08:00 and ending at approximately 15:00. Monthly monitoring provides a check on integrity of dataloggers.

WWTP effluent data collected as part of the typical plant process control performed daily. Effluent pH/Temperature/DO recorded and ammonia sampling performed in accordance with the requirements of each WWTP discharge permit. Total ammonia analyzed for WWTP effluents by the method allowing for the lowest detection limit.

USGS flow measurement obtained at gages above Evergreen Lake and above the Town of Morrison.

Daily weather data (High/low temperature, precipitation) from the NWS station at the EMD WWTP obtained on a monthly basis.

Calibrations of portable equipment documented prior to each use and Certificates of Calibration for all equipment obtained. NIST certifications and Certifications of Compliance are originally obtained for each temperature datalogger used in the study.

GPS points maintained for all new sampling and monitoring locations.

RNC Consulting LLC works with the City of Lakewood to monitor dissolved oxygen in water column in Bear Creek Reservoir and adjust the operation of the reservoir aeration system to maintain DO standards, while minimizing aeration operations. This may require additional vertical probe sampling in the July to October period to monitor DO levels in the water column at site 40.

RNC Consulting LLC maintains photographic points for critical segments and conditions, and documents dewatering of Bear Creek Segment 1b below both the Arnett-Harriman and Ward ditches.

All collected data is maintained in an annual master spreadsheet, which is posted at the completion of the annual monitoring program on the Association Website.

Contract Laboratory and Laboratory Methods

The contract laboratory used by the Association for all laboratory analysis is GEI Consultants, Inc. / Chadwick Ecological Division.

Natalie Love, Laboratory Manager
GEI Consultants, Inc.
Ecological Division
4601 DTC Boulevard, Suite 900
Denver, CO 80237

Macroinvertebrate Analysis

GEI Consultants analyses samples by the BCWA for benthic macroinvertebrates. Samples collected by the Association follow the *BCWA M04 Macroinvertebrate Field Sample Method*. Data for samples are reported as number of organisms per square meter. Percent of total is also reported. The species are counted consistent with the CDPHE EDAS import columns for taxa and species. This data is converted into MMI scores using the EDAS protocols (EDAS CO Master Version - Distributable to 3rd Parties and *A Stepwise Guide to Generating MMI Scores Using Colorado-EDAS*). Table 5 shows the Macroinvertebrate QA performance from the GEI Laboratory.

Table 5 Macroinvertebrate QA Performance

# of Samples for QA	Extractions		Initial Identifications	
	Sample %	Acceptable %	Sample %	Acceptable %
1	98.1	95	99.3	95

Laboratory Methods

The GEI Laboratory methods and limits are summarized as follows:

- Analyte Methods are shown in Table 6.
- General Preservation: preserved with H2SO4 to pH <2.0
- Storage: refrigerated at 4ºC until analyzed
- Number of Replicates/Analyte: 2 for all nutrients
- QA/QC Analyses: 3 standards analyzed at beginning and end of analyses, and at 5 replicate increments, for all nutrients
- Example of a Matrix Spike by analyte report is shown in Table 7.
- Table 8 reports the minimum detection limits used by GEI.
- Table 9 shows the New GEI Lachat Method for Nutrients.
- Nutrient Analysis
  - Preservation: preserved with H_2SO_4 to pH <2.0
  - Storage: refrigerated at 4ºC until analyzed
  - Number of Replicates/Analyte: 2 for all nutrients
  - QA/QC Analyses: 3 standards analyzed at beginning and end of analyses, and at 5 replicate Increments, for all nutrients
- Total Suspended Solids Analysis
  - Storage: refrigerated at 4ºC until filtered
  - Filtration: filtered through a pre-baked Gelman A/E 1.0 µm glass fiber filter
- Chlorophyll a Analysis
  - Filtration: filtered through a pre-baked Gelman A/E 1.0 µm glass fiber filter
  - Storage: filter stored frozen at -20°C, kept in the dark and in desiccator
- E. coli Analysis
  - All testing would follow the Hach colilert method for E. coli adapted from Standard Methods (9223 B) for the Examination of Water and Wastewater (APHA et al, 1998).
  - Sample containers supplied by GEI.
- Copper Study
  - EPA 200.8, filtered and digested samples
  - Hardness Standard Methods 2340 C

Table 6 Analyte Methods

Analyte	Method	Filtered (0.45 µm filter)	Preservation (H2SO4 to pH <2.0)	Allowable Hold Time (unpreserved samples) *
Total Phosphorus	QuickChem 10-115-01-4-B, with manual digestion	No	Yes	48 hours prior to digestion; 7 days prior to analysis
Total Dissolved Phosphorus	QuickChem 10-115-01-4-B, with manual digestion	Yes	Yes	48 hours prior to digestion; 7 days prior to analysis
Total Nitrogen	QuickChem 10-107-04-4-B, with manual digestion	No	Yes	48 hours prior to digestion; 7 days prior to analysis
Nitrate + Nitrite	QuickChem 10-107-04-1-C	Yes	No	48 hours
Ammonia	QuickChem 10-107-06-2-A	Yes	Yes	24 hours
Total Suspended Solids	Standard Methods 2540 D	Yes		7 days before filtration, indefinitely after drying
Chlorophyll *a*	Hot Ethanol Extraction	Yes		28 days
E. coli	Hach colilert method (9223 B)	No	No	24 hours
Copper	EPA 200.8	Yes	No	48 hours
Hardness	Standard methods 2340 C	No	No	48 hours

*all preserved samples have an allowable holding time of 28 days

Table 7 Example of Matrix Spikes by Analyte Reported to Association.

Analyte	Average % Recovery	Number of Samples Spiked	Within Target Range
TP	106	1	Yes
TDP	103	1	Yes
TN	102	1	Yes
NOx	98	1	Yes
NH3	93	1	Yes
Target recovery range is 80-120% recovery.			

Table 8 Minimum Detection Limits

Analyte	Method	MDL (ug/l)	PQL (ug/l)
Total Phosphorus	QuickChem 10-115-01-4-B, with manual digestion	2 ug/l	8
Total Dissolved Phosphorus	QuickChem 10-115-01-4-B, with manual digestion	2 ug/l	8
Total Nitrogen	QuickChem 10-107-04-4-B, with manual digestion	6 ug/l	42
Nitrate+Nitrite	QuickChem 10-107-04-1-C	2 ug/l	8
Total Ammonia	QuickChem 10-107-06-3-A	5 ug/l	35
Total Suspended Solids	Standard Methods 2540 D	4 mg/l	
Chlorophyll *a*	Hot Ethanol Extraction	0.1 ug/l	
Copper	EPA 200.8	0.26 ug/l	
Hardness	Standard Methods 2340 C	2 mg/l	

The GEI Consultants, Inc. (GEI) Laboratory uses a Lachat instrument and accompanying methods used for low-level nutrient analyses. All nutrient samples are analyzed using GEI's Lachat methods (Table 8). All methods are either EPA-accepted, EPA-equivalent or have been approved by the state of Colorado for use in GEI lab. All methods are acceptable under Regulation 85 (Nutrients Management Control Regulation). GEI will continue to follow the same rigorous QA/QC procedures they have always followed under our previous methodology.

Table 9 Lachat Method for Nutrients

Analyte	Old GEI Method	New GEI Method	MDL ug/l	PQL ug/l
NH3	QC 10-107-06-3-D	QC 10-107-06-2-A	5	35
NOx	QC 10-107-04-1-B	QC 10-107-04-1-B	2	14
NO2	QC 10-107-04-1-B	QC 10-107-04-1-B	2	14
TN/TDN	SM 4500-N B (mod)	QC 10-107-04-4-B	6	42
OP	QC 10-115-01-1-T	QC 10-115-01-1-T	2	14
TP/TDP	QC 10-115-01-4-U	QC 10-115-01-4-B	2	14

Laboratory QA/QC Protocols for Nutrient Analyses

Equipment calibrations performed each time new standards are prepared (minimum of once per week). If the r-value of the standard curve is less than 0.999, the instrument is recalibrated or standards are remade. Replicates run on each sample are analyzed and the percent difference must be within 10% if the resultant concentration is above the

minimum detection limit. If results of analyses of replicate samples are not within 10% of one another, samples are placed in a clean test tube and reanalyzed.

During analysis, check standards are analyzed between every 5 samples (or 10 replicates). The check standards consist of one high range standard, one mid-range standard, and the zero (blank). Check standards analyzed before and after each group of samples must be within 10% of the theoretical value. If standards are outside of this range, samples and standards are placed in clean test tubes and reanalyzed to try to determine the source of the problem. Sample values are not accepted until the problem has been resolved and all check standards pass the QC criteria. One matrix spike is run for every 10 samples analyzed. The percent recovery for matrix spikes must be ± 20%.

After sample analyses a final QC check performed to determine if all parameters measured agree. Final analyses for each sample are compared to ensure that concentrations of total phosphorus ≥ total dissolved phosphorus ≥ orthophosphate and that the concentration of total nitrogen ≥ total dissolved nitrogen ≥ nitrate/nitrite and ammonia. If parameters do not agree, samples are reanalyzed.

Chain of Custody

The Association provides the laboratory with a chain-of-custody form with the transfer of samples that identifies each sample, parameters required for sample, date and time of collection, sample personnel and where data is reported. At transfer a staff member from the laboratory signs and dates the chain-of-custody and makes a copy for RNC Consulting LLC. The laboratory uses Table 10 as part of their chain-of-custody.

Table 10 Laboratory Chain-of-Custody

QA Requirement	Yes	No	Note
Chain of Custody received complete			
Samples received within holding times			
Samples at correct temperature (1-8ºC)			
QA/QC Standards within acceptable 10% difference			
Duplicate samples within acceptable 10% difference			
All matrix spikes within target range of 80-120% recovery			

Data Management

RNC Consulting LLC is responsible for all Association water quality and environmental data management, including QA/QC of data. Large quantities of varied data are collected during the annual monitoring program: Monthly stream monitoring and sampling, laboratory results, thirty-minute temperature measurements from dataloggers, wastewater treatment plant effluent process, control, and permit monitoring data (from five treatment plants), weather statistics and stream flows comprise raw data. All data are stored on an office computer, using Microsoft Office 365 software. The majority of the data resides in and analyses occurred in Excel spreadsheet format. Data record is preserved in an off-site cloud storage system.

The Association data is located at two different locations. Watershed data collected with the assistance of EMD staff is maintained on computer systems at the EMD offices. All raw watershed data electronically forwarded from EMD staff to the Manager for data summary and analyses. RNC Consulting LLC maintains all monitoring data for all Association monitoring programs. Data is kept on a computer with back-up to an external cloud-drive. Additionally, some back-up data sets of recent data are kept on flash drives.

The Association incorporates data into a data report, after the study. Electronic data files are transmitted to the Water Quality Control Division, Colorado Division of Wildlife and Evergreen Trout Unlimited after the Association Board has approved the study report. Sampling and Monitoring Plan summaries are provided to the BCWA monthly at meetings, which are open to the public.

Watershed Sampling Dates 2019

The 2019 monitoring schedule, which maybe periodically updated or changed as required by the field monitoring personnel, is maintained by the Association Manager. Changes to the monitoring schedule are sent to the Association through electronic notifications.

Water Quality Monitoring Parameters in 2019

Table 11 lists the 2019 water quality monitoring parameters by monitoring program.

Table 11 Monitoring Parameters

Watershed and Special Stream WQ Studies	
Field Chemistry/ Physical	**Laboratory Analyses**
Temperature (discrete field probe)	Total Nitrogen (GEI)
Temperature (continuous data loggers, 1/2-2m)	Total Phosphorus (GEI)
Dissolved Oxygen, YSI Probe	E. coli, sites 45 and 90 (GEI)
Specific Conductivity, YSI Probe	Total Suspended Sediments, if needed Spring Runoff
pH, YSI Probe	
Manual Flow/ gage readings	
Water Clarity - Staining	
Periphyton Coverage	
Wastewater Treatment Facilities Regulation 85 Requirements	
Field Data	**Laboratory Analyses (GEI)**
Daily average effluent discharge	Total Nitrogen
Temperature (continuous data loggers, Effluent)	Nitrate/Nitrite as N, dissolved
	Total Ammonia
	Total Inorganic Nitrogen (Calculation = NO2+NO3+NH4)
	Total Phosphorus
Monitoring Site Survey - Annual Select Sites	
Macroinvertebrates - 10 sites	Habitat Indices
Pebble Counts	Physical Stream Indices
Embeddedness	
BCR and EGL Sediment Survey - Annual Limited Sites	
Sediment TP (Pore Water): BCR 6 sites, EGL 1 site	Grain Size estimates
% TOC (Organics)	% Total Solids
Reservoirs (BCR and Evergreen)	
Field Data	**Laboratory Analyses**
Temperature (field probe, 1/2-m intervals in central pool)	Total Nitrogen (-1/2m and +1m) (GEI)
Temperature (continuous data loggers, 1/2-2m)	Total Phosphorus (-1/2m and +1m) (GEI)
Dissolved Oxygen (field probe, 1/2-m intervals in central pool thru 4m, then 1m interval)	Chlorophyll a (-1/2m only) (GEI)
Specific Conductivity (field probe, 1/2-m intervals in central pool thru 4m, then 1m interval)	BCR Phytoplankton (June, July, August, September, October) EGL (July, August, September) (GEI)
pH (field probe, 1/2-m intervals in central pool thru 4m, then 1m interval)	Zooplankton - annual, species present (GEI), if needed
Total Depth	
Secchi Reading	

2019 Monitoring Stations and Frequency of Sampling

Table 12 lists the 2019 monitoring stations, type of monitoring, reference sites and frequency of sampling by stream segments.

Table 12 2019 Monitoring Stations

Site ID	Watershed Sites by Stream Segment	2019					Site Type
		Temp Logger	Flows	Field Probe	TN/TP	Copper	
Segment 1a							
Site 58	Bear Creek Below Mt. Evan Wilderness	x	x	x	x		P3 WS
Site 2a	Golden Willow Bridge	x	x	x	x		P3 WS
Site 3a	Above Evergreen Lake at CDOW Site	x	USGS	x	x		P3 WS
Segment 1b							
Site 15a	Bear Creek within Bear Creek Park	x	USGS	x	x		P1 CR
WWTF Site 24	Morrison WWTF	x			R85		P5

Site ID	Watershed Sites by Stream Segment	2019					Site Type
		Temp Logger	Flows	Field Probe	TN/TP	Copper	
Segment 1c							
Sites 40, 41, 42	Bear Creek Reservoir	x		x	x		P1 CR
Segment 1d							
Site 4a/4e	Evergreen Lake	x		x	x		P3 EGL
Segment 1e							
Site 5a	CDOW downtown Little Bear site	x	x	x	x		P3 WS
Site 8a	Bear Creek Cabins at CDOW Site	x	x	x	x		P3 WS
Site 9	O'Fallon Park, west end at CDOW Site	x	x	x	x		P3 WS
Site 12	Lair o' the Bear Park, at CDOW site	x	x	x	x		P3 WS
Site 13a	Below Idledale, Shady Lane CDOW site	x	x	x	x		P3 WS
Site 14a	Morrison Park east end at gaging station	x	USGS	x	x	x	P3 WS
Site 14c	Morrison above Harriman			x		x	
WWTF Site 20	Evergreen Metro District	x			R85		P5
WWTF Site 22	KSWD	x			R85		P5
WWTF Site 23	GWSD	x					P5
Segment 2							
Site 45	Lower Bear Creek, below reservoir trace	x	DNR	x	x		P1 CR
Site 90	Lower Bear Creek Wadsworth	x	USGS	x	x		P1 CR
Segment 3							
Site 25	Vance Creek	x	x	x	x		P3 WS
WWTF Site 71	JCS Outdoor Lab	x			R85		P5
Segment 4a							
Site 47a	Upper Coyote Gulch		x	x	x		P2 Coyote
Site 47b	Lower Coyote Gulch, Above Reservoir		x	x	x		P2 Coyote
WWTF Site 34a	Forest Hills Metro District	x			R85		P5
Site 34b	Mt Vernon Drainage, Morrison Mouth		x	x	x	x	P2 MV
Segment 5							
Site 26	Cub Creek, at mouth	x	x	x	x		P2 Cub
Site 32	Troublesome at mouth		x	x	x		P2 Trouble
Site 64	Troublesome at Culvert above West Jeff		x	x	x		P2 Trouble
WWTF Site 21	West Jefferson County Metro District	x			R85		P5
Segment 6a							
Site 16a	Turkey Creek within Bear Creek Park	x	x	x	x		P3 WS
Site 18	South Turkey Creek Myers Ranch	x	x	x	x		P3 WS
Segment 6b							
WWTF Site 73	Conifer Sanitation District				R85		P5
WWTF Site 59	JCS Conifer High School				R85		P5
Site 19	North Turkey Creek Flying J Ranch	x	x	x	x		P3 WS
Segments 7 and 8							
Site 36	Summit Lake (Segment 8)		x	x	x		P3 WS
Site 37	Bear Creek Mainstem (Segment 7)		x	x	x		P3 WS
Sites 76/95/63	Special Fen Study			x	x		P2 Fen
Segments 10, 11, and 12 (Lake/ Pond Segments)							
	None in 2019						

Wastewater Treatment Facility Regulation #85 Monitoring

The Bear Creek Association watershed monitoring plan includes monitoring elements for wastewater treatment facilities in the watershed, which allows these facilities to meet monitoring requirements in Regulation #85. The monitoring data collected for Regulation #85 is not part of the permit DMR reporting.

The wastewater treatment effluent parameters used to meet Regulation #85 requirements are shown in Table 13. The PQLs and MDLs are lower than those required in Regulation #85 and are shown in Table 14. These MDLs and PQLs are used for all Association nutrient data processed by the Associations contract laboratory.

Table 13 Regulation 85 Parameters

Wastewater Treatment Facilities	
Field Data	**Laboratory Analyses**
Daily average effluent discharge	Total Nitrogen
Temperature (Selected plants continuous data loggers, Effluent)	Nitrate+Nitrite-Nitrogen
	Ammonia-Nitrogen
	Total Inorganic Nitrogen (Calculation = NO2+NO3+NH4)
	Total Phosphorus

Table 14 MDLs and PQLs used for Association Sample Parameters

Analyte	Old GEI Method	GEI Method	MDL (ug/l)	PQL (ug/l)
NH3	QC 10-107-06-3-D	QC 10-107-06-2-A	5	35
NOx	QC 10-107-04-1-B	QC 10-107-04-1-B	2	14
NO2	QC 10-107-04-1-B	QC 10-107-04-1-B	2	14
TN/TDN	SM 4500-N B (mod)	QC 10-107-04-4-B	6	42
OP	QC 10-115-01-1-T	QC 10-115-01-1-T	2	14
TP/TDP	QC 10-115-01-4-U	QC 10-115-01-4-B	2	14

The monitoring frequency is to have 6-monthly samples for treatment plants per year. The State is interested in winter numbers and evenly spaced effluent data. The sample months for Regulation #85 sampling are January, March, May, July, September, November. Data collection will occur on the first or second week of every other month beginning in January 2019.

The Association stream flow monitoring program and analysis plan is sufficient to meet the intent of Regulation #85 and allow the Association to mass-balance nutrients in the watershed

Small treatment plant effluent samples can be grab samples, if defined as such in permit. If a larger plant is required by permit to do composites, then the sample used for Regulation #85 should be a composite that matches permit requirements. Sampling for nutrients is required in the effluent before it is discharged into the receiving water body at the location where monitoring is performed to satisfy other CDPS permit requirements (as per regulation). Total phosphorus data collected under Regulation #85 for small treatment plants may be used to meet Regulation #74 requirements. The nutrient data collected under Regulation #85 are not required to be reported by the permittee in their respective NPDES DMR reporting system; however the collected data can be submitted as part of the DMRs. Each plant is responsible for getting the daily average effluent discharge and reporting this information to the Association on a monthly basis.

The Association will provide the necessary sample bottles to the treatment plants for sample collection that are participating in the cost share program. The treatment plant operators must collect necessary effluent samples. The Association cannot take the samples at the plants.

Treatment Tech, who operates smaller treatment works, is opting out of the Association shared monitoring program. The Association will not be responsible for the annual submittal and data transfer to the state for those treatment facilities not participating in a joint monitoring program.

A certification letter is available for each treatment plant. The Association bundled the available certifications, noting the facility is covered by a watershed monitoring program. The Association maintains a copy of the plant certifications to link with the monitoring plan. The nutrient data collected under the regulation #85 regulations are not required to be reported by the permittee in their respective NPDES DMR reporting system; however the collected data can be submitted as part of the DMRs. See Table 15 for certification status.

Table 15 Certifications Available for WWTF under Regulation #85

Wastewater Treatment Plants	Permit Number	LRP Certification	Effluent Sample Type	Copy of Certification	Latitude/ Longitude
Bear Creek Drainage					

Wastewater Treatment Plants	Permit Number	LRP Certification	Effluent Sample Type	Copy of Certification	Latitude/ Longitude
JCS Outdoor Lab	CO-0032514	Kim Brogan	grab	Yes 2016	To be determined
Brookforest Inn	CO-0030261	Robert Clodfelter	grab	Yes	39.579394/ 105.380764
Evergreen Metro District	CO-0031429	Dave Lighthart	Composite12-hour	Yes	39.38' 16.19/105.18' 56.07
West Jefferson County Metro District	CO-0020915	Dave Lighthart	Composite12-hour	Yes	39.39' 46.05/105.20' 06.62
Kittredge Sanitation And water District	CO-0023841	Dave Lighthart	Composite12-hour	Yes	39.39' 27.75/105.17' 15.04
Genesee Water and Sanitation District	CO-0022951	Chris Brownell	Composite 24-hour	Yes	39.40' 34/ 105.16' 26
Forest Hills Metro District	CO-0037044	Bruce McCreary	Composite12-hour	Yes	39.42' 09/ 105.15' 07
Morrison	CO-0041432	John McEncroe	Composite12-hour	Yes	39.39' 10.89/ 10510' 39.99
Turkey Creek Drainage					
Aspen Park Metro District	CO-0631016	Robert Clodfelter	Composite12-hour	Yes	39.32' 38/ 105.17' 25
Conifer Metro District	CO-047295	Bryan McCarty	Groundwater	Yes	Not Sampled
Conifer Sanitation Association	COX-0047392	Becky Hammer	Grab	Yes	39.31' 49/ 105.18' 16
JCS Conifer High School	CO-047988	Kim Brogan	Composite12-hour	Yes	95.523470/ 105.306350
Tiny Town	CO-0036129	Robert Clodfelter	grab	Yes	39.36' 22/105.13' 38
Geneva Glen	CO-0044652	Ken Atchison	Groundwater	Not Needed	Not Sampled

P1 - Routine Monitoring Program

The routine monitoring program (P1) focuses on Turkey Creek drainage and Bear Creek drainage inputs and discharge from Bear Creek Reservoir (Figure 2) into lower Bear Creek with a central pool characterization of the reservoir near the dam (Site 40). In Figure 3, the outlet structure is near site 41 with Bear Creek inflow near site 44 and Turkey Creek inflow near site 43. The reservoir chemistry and biological characterization occur at site 40. Vertical probe samples at ½ and 1-meter intervals measured at sites 40, 41, and 42 beginning at -1/2-m. Temperature Logger profile of Bear Creek Reservoir at Site 40 with buoy placement and probes attached at ice-off (April-December, first week): ½ m, 1m, 1 ½m, and 2m. Field probe measurements year-round at site 40 with profile interval of ½ m, 1m, 1 ½m, 2m, 2 ½m, 3m, 3 ½ m, 4m, 5m, 6m, 7m, 8m, 9m, 10m, and 11m. Similar profile pattern used at other reservoir sites. The current monitoring program optimizes data generation to evaluate reservoir inflow loading, tropic state changes within the reservoir, and reservoir outflow; while minimizing monitoring cost. The Association measures flow in Bear Creek and Turkey Creek during sampling events. The Association records discharge flows from Bear Creek reservoir for sampling events. The U.S. Army Corps of Engineers maintains records of flow inputs and discharge for the reservoir.

Field Sampling Management: Russell Clayshulte, Association Manager; Field Assistance from Lakewood, Mike Towner.

2019 Routine P1 sampling Sites

The five 2019 P1 routine watershed-monitoring stations, including the reservoir station, are:

1. Mainstem of Turkey Creek prior to discharge into Bear Creek Reservoir, within Bear Creek Park, adjacent to the City of Lakewood Maintenance Yard;

2. Mainstem of Bear Creek prior to discharge into Bear Creek Reservoir, within Bear Creek Park, adjacent to the bridge at the western edge of the park;

3. Tail-water discharge from Bear Creek Reservoir in the concrete channel that starts the lower Bear Creek;

4. Bear Creek Reservoir, center of main pool and supplemental vertical profile stations 40, 41, and 42.

5. Bear Creek Site 90 above Wadsworth.

Figure 2 2019 P1 Bear Creek Reservoir Monitoring Sites

Figure 3 P1 Reservoir Monitoring Stations; Site 40 is the Nutrient P1 station

Wadsworth Boundary BCWA Site 90

a. Monitoring program matches Site 45 protocols and is consistent with the adopted BCWA annual Sample Plan. Includes E. coli monthly.
b. P1 sites sampled monthly in January, February, March, April, May, June, October, November, and December. Growing season samples taken twice in July, August, and September.
c. Parameters

Parameter (units)	Site 90
Flow/ Discharge (cu m/s)	Manual
Probe - Specific Conductance (umhos/cm)	X
Probe - Dissolved Oxygen (mg/l)	X
Probe - Temperature (C) site visit	X
Probe - pH (standard unit)	X
Temperature (C) data logger year round	X
Total Suspended Sediments (mg/l)	Spring Only
E. coli cts/100ml	X Monthly
Total Nitrogen (ug/l)	X
Total Phosphorus (ug/l)	X

d. Annual Measurements

Monitoring Site Survey	
Macroinvertebrates	Habitat Indices
Periphyton Coverage	Physical Stream Indices
Pebble Counts	Embeddedness

e. If E. coli exceeds standards 2-month geometric mean, then invoke process outlined in *BCWA Fact Sheet 51 Reducing Risk of E. coli Contamination in Waterways*.

2. Potential Future P-3 monitoring sites, may include spring/fall TP/TN analyses at Green Mountain or Weaver Gulch.

P1 Sampling Parameters BCR

Table 16 Bear Creek Reservoir Sampling Parameters

Parameter (units)	Reservoir Sites	Reservoir Outflow, Site 45
Physical/Field		
Flow/ Discharge (cu m/s)	Manual and Staff gage	Manual and Staff gage
Specific Conductance (umhos/cm)	(Profiles at sites 40, 41, 42)	X
Secchi (meters)	Sites 40, 41, 42	
Total Depth (m)	Sites 40, 41, 42	
Dissolved Oxygen (mg/l)	(Profiles at sites 40, 41, 42)	X
Temperature (C)	(Profiles at sites 40, 41, 42) Data Logger at site 40	X
Total Suspended Sediments (mg/l)	Seasonal Only Spring	X
pH (standard unit)	(Profiles at sites 40, 41, 42)	X
Biological (Site 40 only)		
Chlorophyll a (ug/l)	X (-1m)	
Zooplankton (August)	Vertical Tow	
Phytoplankton (July, August, September, October)	Composite top 1-meter water	
Nutrients (Reservoir Site 40 only)		
Total Nitrogen (ug/l)	X (top, lower)	X
Total Phosphorus (ug/l)	X (top, lower)	X
Bottom Sediments BCR		
Total Phosphorus (mg/kg)	6 sites	
% Organics (TOC)	6 sites	
% Clay-silt	6 sites	

P1 Stream Sampling Parameters

Table 17 Monitoring Parameters for Sites 15a, 16a, 45 and 90

Watershed and Special Stream WQ Studies	
Field Chemistry/ Physical	**Laboratory Analyses**
Temperature (discrete field probe)	Total Nitrogen
Temperature (continuous data loggers, 1/2-2m)	Total Phosphorus
Dissolved Oxygen, YSI Probe	E. coli, select sites
Specific Conductivity, YSI Probe	Total Suspended Sediments, select sites Spring Runoff
pH, YSI Probe	
Manual Flow/ gage readings	
Water Clarity - Staining	
Periphyton Coverage	
Monitoring Site Survey - Annual Select Sites	
Macroinvertebrates	Habitat Indices
Pebble Counts	Physical Stream Indices
Embeddedness	

P1 Sampling Frequency

P1 sites sampled monthly in January, February, March, April, May, June, October, November, and December. Growing season samples taken twice in July, August, and September.

P2 - Supplemental Water Quality Characterizations in Bear Creek Watershed

Addressing WQ Concerns on Tributary Drainages

1. 2019 special assessment of Mt. Vernon to identify potential tributary load areas.
   a. Conduct ground surveys to identify potential "hot" spots; map
   b. Conduct multiple field probe measurements at intervals to see if any discernible filed data is event. Only collect TP/TN pair if a suspected area is found, will need linked flow data to calculate nutrient loads. After spring rainy period.

Coyote Gulch

The Association coordinates with the City of Lakewood a sampling program on Coyote Gulch in the Bear Creek Park. The monitoring is done at two sampling sites: above the restoration project, and at the discharge into the reservoir (Figure 4). The Association collects the chemistry data for total phosphorus and nitrate-nitrogen. The Association takes monthly flow measurements to determine nutrient loading. The Association also collects data for temperature, pH, specific conductance and Dissolved Oxygen. Data results are incorporated into the Association monthly and annual data summaries. The Association has pre-construction and post-construction loading data. This monitoring project has established a total phosphorus trade credit for use of the Association.

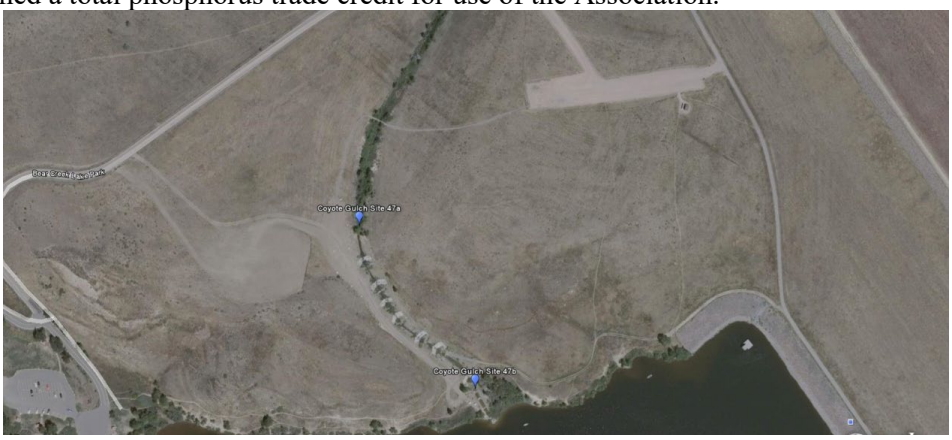


Figure 4 Coyote Gulch Sampling Sites

Bear Creek Reservoir Sediment Study

Sediment Survey Questions

1. What is the distribution of phosphorus in bottom sediments and is this phosphorus load evenly distributed across the reservoir bottom?
2. Do aeration operations affect to release of total phosphorus from bottom sediments?
3. Is the internal loading of phosphorus showing trends over time, temporal?
4. Is there a reliable method to determine if internal phosphorus loading is decreasing over time?
5. What is the potential annual contribution of phosphorus into the water column and when does this nutrient transfer occur?
6. Is the high organic build-up in the reservoir inlets affecting the amount of available phosphorus for transfer into the water column?
7. Does water-column phosphorus chemistry relate to sediment chemistry?

Survey Duration: Annually

Obtained core samples at multiple sites after shut-down of aeration system.

Survey Types: Stratified and Single-stage

Discrete dredge samples from each of three reservoir zones; Central pool, Turkey Creek inlet and Bear Creek inlet using three fixed transects (Figure 6). Bottom samples obtained with a petite Ponar sampler. This sampler takes a grab of the top 5-6 cm of the mud bottom. One dredge drop made at each site resulting in about 0.5 liters of bottom mud. The locations in Figure 6 are estimates. Sub-samples are bagged from the composite mud sampled at the site.

Total Organic Matter

About 5 grams of sample of the air dried sediment was weighed, dried for 1 hour at 103-105 degrees C, reweighed. This value is the total solids content of the sample. The dried sample was then ashed in a muffle furnace at 550 degrees C for 15 minutes and reweighed. This procedure provides a total solids percentage and a total organic carbon or Volatile solid percentage. The total organic matter or total organic carbon (TOC) is volatilized and the percent difference is calculated to determine the estimated percentage of TOC contained in surface bottom muds.

Grain Size Distribution

A mechanical sieve "sandshaker" was used to determine the percentage distribution of selected grain sizes in the dried bottom sediments. The dried sediment was re-loosened into a sandy silt material. All bottom sediment material was less than U.S. Standard sieve 10 (0.08 inches) in diameter. As such all reservoir sediment ranges from coarse sand to clay size. The Sieve distribution used is shown in Table 18.

Table 18 Grain-size distributions used to analyze Bear Creek bottom muds.

Grain-Size Term	ASTM No.	Mesh Opening (in)	Sieve Designation
Very Coarse and Coarse Sand	25	0.026	26 OPN
Medium Sand	60	0.009	9 OPN
Fine Sand	120	0.0046	46 OPN
Very Fine Sand	200	0.0029	29 OPN
Silt and Clay	<200		

Total Phosphorus

Extraction Procedure - Distilled Water
Weigh 4 g of wet mud into 125 ml bottle with lid, add 20 mL of distilled water and shake manually.
Centrifuge at 3,500 rpm for 15 minutes and filter the solution through a 0.7 µm membrane filter.
Use 5 ml for analysis; retain remainder for dilution, as appropriate.

Analysis

Determine total phosphorus as water extractable P in wet mud using HACH method TNT 843.

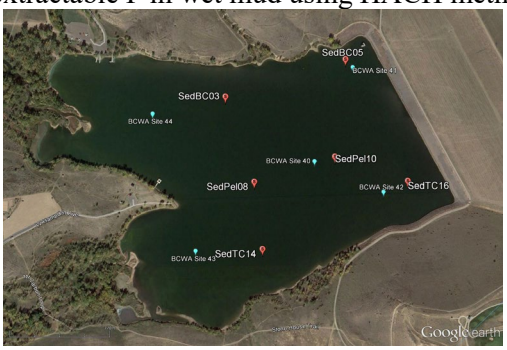


Figure 5 Sediment sampling sites

Summit Lake, Fens and Plume

Bear Creek Watershed Association established two sampling stations at Summit Lake and upper Bear Creek, Mt Evans Wilderness, Clear Creek County Colorado. The Association selected sampling Site 36 (Summit Lake at outfall) and Upper Bear Creek Site 37 to monitor assumed high quality "background" conditions. However, monitoring data shows atypical water quality results. The station data suggests there is a pollution source causing elevated nutrient loads, low pH conditions and reduced dissolved oxygen. Association observations suggests the pollution plume originates from the old toilet vaults area in the Summit Lake parking area and this pollution plume affects data results from sites 36 and 37.

In June 2012, the Association began a special study effort to document the extent and magnitude of the potential pollution plume. The Association walked the area to identify potential problem areas. The Association concluded that the source area was in the vicinity of the parking lot. The Association originally assumed the problem was related to the past waste disposal practice of using pit privies. There are a large number of wetland or bog ponds that occur between the parking lot and upper Bear Creek. The Association noted that some of these ponds in a drainage fall-line had much more algal productivity than those ponds nearer Summit Lake and well downstream from the parking lot. This suggested that the pollution plume was surfacing in-part in some of the ponds.

Special Fen Study

A tributary wetland in the upper watershed near Summit Lake, which is defined as Colorado waters Segment 7, is a fen (BCWA Fact Sheet 49 Wetlands, Fens Water Quality). The Association's 2009-2018 monitoring program shows several of these natural Fen ponds with no notable anthropogenic influences have unexpectedly elevated total

phosphorus concentrations ranging from 45-660 ug/l. These Fen ponds consistently exhibit high algal productivity.

In 2014, the Association conducted a special survey of three Fen ponds to establish background or expected conditions on "non-polluted" Fen Ponds. The Association selected three Fen pond sizes to establish backgrounds: a small Fen (25 square feet, about 1 foot deep), medium Fen (85 square feet, about 2 feet deep), and a larger Fen (125 square feet, about 4 feet deep). There were no indications of any anthropogenic influences on these Fen ponds. Preliminary data strongly suggests the chemistry and nutrient dynamics in the Fen complex is more complicated than predicted. The Association will conduct a five-year special study to establish the background or expected nutrient conditions for the Fen complex.

The Association summarized evidence in the Regulation #38 Rulemaking Hearing for South Platte Basin Standards that suggests fen wetlands have background phosphorus levels that exceed Table Value Standards (TVS) even though streams in the same segment do not have elevated phosphorus levels. It is not yet known what background level would be appropriate or if it varies among these fens. The Colorado Water Quality Commission applauded the efforts of BCWA to obtain data that improves our understanding of existing conditions. Site-specific standards are needed for all, or part, of Segment 7 for which phosphorus standards are required, but there is uncertainty about the habitat type or the geographic scope of applicability for site-specific standards (or conversely for the TVS). Resolving the uncertainty will require additional sampling to obtain representative data. Delaying the effective date by five years gives BCWA, time to collect additional data and propose site-specific phosphorus and Total Nitrogen standards as appropriate for the Fen complex. Total Phosphorus standards were delayed until 12/31/2020.

E. Coli Special Monitoring

BCWA Fact Sheet 39 E. coli identifies standards for waters in the Bear Creek Watershed and lists those stream segments on the Colorado 303(d) list of impaired waters. An alternative BCWA management program that doesn't require the adoption of a formal regulatory total maximum daily load for E. coli in these listed segments or other waterbodies in the watershed with suspected bacterial contamination contains the following management strategies and approaches.

Waterway Source Tracking

Fecal coliform & *E. coli* bacteria found in streams in the watershed originate in human, pet, livestock, and wildlife waste. Irrigation, stormwater runoff, snowmelt and flood water, failed on-site wastewater treatment systems (OWTS) leach fields, broken/leaking sewer lines contaminated with fecal matter pose higher risks. *E. coli* does not occur naturally in soil and vegetation, but can survive for periods in moist soil or on vegetation. It only enters water from fecal contamination.

1. Routine bacterial monitoring at long-term reference sites can be used to detect presence of E. coli over established standards (in lower watershed two-sites below BCR and near Wadsworth on Bear Creek). Routine sites include comprehensive water quality monitoring as defined in the BCWA annual water quality sample plan using established quality assurance protocols.

2. Systematic bacterial monitoring when E. coli is detected can be used to trace upstream potential sources of contamination. A targeted monitoring process can identify and isolate likely problem areas. If a problem area is identified, targeted management solutions for that site can be applied through established watershed partners and land-use decision makers.

3. Predict potential pathways from land uses (e.g., map pastures, large animal grazing or corral operations, parks and open space, dog parks, locate OWTS by sub-drainages, maps of sewer mains, erosional problem areas and high use human recreational areas

4. Establish a water watch program for citizens and businesses that includes education & trained data collection.

5. Apply adaptive management to monitoring program. Provide an annual technical memorandum on E. coli management in the watershed.

Copper Study

In December 2015, The Colorado Water Quality Control Commission adopted a revised 303(d) list of priority

pollutants causing impairment or those needing further monitoring and evaluation. The Colorado 303(d) List identifies those water bodies, where there are exceedances of water quality standards or non-attainment of uses. While the original proposal was to list the entire segment 1e for copper, the BCWA demonstrated successfully that the problem was only documented for a very limited portion of the segment within Morrison (See the Copper Database BCW Segment 1e spreadsheet). There were only four sample dates that exceeded the standard between 2008-2013. As such, the WQCC limited the listing to extend from the mouth of Mount Creek to the inlet of the Harriman Ditch.

WBID	Segment Description	Portion	303(d) Impairment	303(d) Priority
COSPBE01e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	Mount Vernon Creek to the Harriman Ditch	Cu	H

The Association is undertaking a copper specific monitoring program to better document the copper issue and potential identify a copper source(s) near Morrison. The Association will work with the Denver Water Department to obtain their entire water quality database for sites within the watershed and work to coordinate programs. Morrison may assist with the monitoring program. GEI is doing a low-level copper testing, which includes a hardness titration. Since this is a 303(d) listing, a 5-year monitoring program is necessary for delisting purposes. Three monitoring sites will be necessary for each sample date. The monitoring site locations maybe adjusted each year depending on annual data results. If copper source found, then program may become limited.

Monitoring Program

- Sample sites. Upstream of the Harriman Ditch diversion (BCWA Site P3 14c), BCWA sample site 34a on Mount Vernon Drainage, and the USGS gaging station in Morrison Park (BCWA Site 14b).
- Sample Frequency – Monthly during non-ice conditions. Generally, 10 sample sets per year.
- Sample Date - linked with monthly TRS meetings, third Wednesday of month or occasionally may link to Board meeting date on second Wednesday.
- Samples collected as grab samples by Association Manager in sample container provided by contract lab (GEI). Field probe data and flow data is collected with samples.
- The hardness of the samples was measured by GEI (Standard Methods 2340C). The filtration for dissolved copper analysis was completed by GEI, the samples were then sent to *Accutest* for dissolved copper analysis.
- Copper Analytical Method EPA 200.8
    - All samples were digested and analyzed within the recommended method holding time.
    - All method blanks meet method specific criteria.
    - SAMS certifies that data reported for samples received, listed on the associated custody chain or analytical task order, were produced to specifications meeting AMS's Quality System precision, accuracy and completeness objectives except as noted.
    - Estimated non-standard method measurement uncertainty data is available on request, based on quality control bias and implicit for standard methods. Acceptable uncertainty requires tested parameter quality control data to meet method criteria.
    - SAMS is not responsible for data quality assumptions if partial reports are used and recommends that this report be used in its entirety. This report is authorized by SAMS indicated via signature on the report copy.

Stream Flow Data

Manual Site-Specific Measurements

Manual flow measurements are performed at watershed locations through the program period. The Association uses three methods to obtain flow data:

1. Manual stream flow is measured using a OTT MF Pro to measure average water velocity in a stream cross-section. Depth and velocity readings are taken at 2-foot increments in the cross-section. Velocity readings are taken at the mid-water column level. Flow is calculated for each sub-section of the cross-section (Q=V x A) and the subsection flows are added to estimate the stream flow. The manual measures have been checked against the flow measurements taken at both USGS gages and the manual flows are generally within 5% of the USGS estimates.

2. The Association has an OTT MF Pro flow meter. When the sensor is placed in flowing water, a magnetic field around the sensor creates a voltage proportional to the flow velocity. This voltage amplitude, which represents the rate of water flow around the sensor, is detected by electrodes in the sensor and processed by the sensor microprocessor. The processed signal is digitally transmitted through the sensor cable to the portable meter and the information is shown on the meter display. The system includes a portable meter, sensor with cable and a depth probe. Velocity is calculated in user defined cross-sections that allows for a more accurate estimate of stream or conduit flow than the flow probe. The Mean-section method divides the cross-section into individual flow segments. Pairs of adjacent verticals are the limits of the segments. The two edges of the cross-section are given values of 0 for the velocity and depth. The total flow is the sum of the partial flows of all segments.

USGS, Colorado Department of Water Resources and Urban Drainage Gaging Station Stream Flows

Flow data summarizes the flow gages located on Bear Creek. There are four locations in the watershed that produce flow data and include above Evergreen Lake, above Morrison, Bear Creek Park (partial year), and below the dam in the outflow trace.

A USGS stream gage (USGS 06710385) maintains a location above Evergreen Lake, near the CDOW fish survey site. The gage location is adjacent to the Denver Mountain Parks golf course (Keys on the Green) parking lot.

The second gaging station is located below the temperature datalogger location ID MORR10, above the town of Morrison, just west of the Highway 8 Bridge over Bear Creek. This station (BCMORCO 06710500) is maintained by the Colorado Division of Water Resources. Weekly stream flow graphs were printed from both stations and filed for record. Monthly average daily flows from gages exported to a spreadsheet for comparison with historical data. Although flow records began at this location in 1899, the most complete data record exists from 1919 through 2016 for the Morrison gage. A 25-year record recorded in annual data reports.

P3 - Watershed Monitoring Programs

The Bear Creek Watershed Association conducts watershed scale monitoring programs. These P3 monitoring programs focus on characterizing water quality of surface waters in the Turkey Creek and Bear Creek drainages of the watershed. The monitoring year is divided into a warm-season period with more intense sampling and a cold-season period, designed to provide minimal winter and spring data. This data report summarizes temperature and water quality monitoring data, sampling results obtained from in-stream locations, and data from five-wastewater treatment plant (WWTP) effluents. The complete Cold-season and Warm-season water quality data set is an electronic data summary report and spreadsheet.

P3 Field Parameter Probe Measurements

Monthly measurements are performed in the morning and early afternoon. Measurements are recorded with an YSI Professional hand-held meter. The meter utilizes a multi-probe sensor, capable of measuring pH, Temperature, Dissolved Oxygen and Specific Conductance simultaneously. Measurements are logged, retained in the on-board computer, and then manually downloaded. Typically, the logged data is manually downloaded by viewing each file and transcribing data onto monthly Logsheets. The data is entered into a spreadsheet. Prior to the program, the meter is calibrated by certified technicians. Prior to each monitoring event, the meter is calibrated for each parameter, using a purchased calibration solution for specific conductance and purchased pH buffers (two-point calibration, 7.0 and 10.0). Fresh batteries installed in the meter at the start of the program and batteries replaced when the observed battery charge reached 50%. Flow measurements are performed coincidentally with monthly sampling and monitoring. A Global Water flow probe Model FP101 is used and values obtained are combined with stream width and depth measurements to calculate estimated streamflow.

P3 Evergreen Lake Monitoring

Evergreen Lake has a temperature data logger string near the dam structure with temperature logger profile at ice-off (April-May) through November 1: ½ m, 1m, 1 ½m, and 2m. Profile data is collected in May to October for Temperature, DO, specific conductance, pH and Turbidity at 0m, -1m, -2m, -3m, and -4m. Chemical analyses include chlorophyll a, Total Nitrogen, and Total Phosphorus. Water is sampled at -1m and +1m in water column. A total depth and Secchi reading are collected. Chlorophyll is sampled at only -1m. Association may collect data consistent with protection of a major drinking water supply system.

P3 Temperature Datalogger Monitoring Locations

Programmable temperature dataloggers measure and record watershed stream and WWTP effluent temperatures every thirty minutes (Table 19). The loggers used in the Program are Onset Computer Corporation brand, Temp Pro v2 (U22) programmable dataloggers. Every other year all model dataloggers are returned to Onset for a NIST (National Institute of Standards and Technology) one-point certification and a 'tune-up'. The one-point certification is performed against calibration standards at 20°C. The 'tune-up' consists of a new battery and quality control testing, assuring the dataloggers meets manufacturer's operating specifications. The Association maintains a fact sheet with temperature monitoring protocols, as included in the Association annual report.

Table 19 WWTF Temperature Data

WWTF	Continuous effluent measurements every half-hour, Jan 1-Dec 31	No continuous effluent temperature data expected
Morrison	X	
Evergreen Metro District	X	
West Jefferson County Metro District	X	
Kittredge Sanitation and Water District	X	
Genesee Water and Sanitation District	X	
JCS Outdoor Lab		X
Forest Hills Metro District		X
Brookforest Inn		X
Aspen Park Metro District	If surface Discharging	
Tiny Town		X
Geneva Glen		X
Conifer Metro District / Conifer Sanitation Association		X
JCS Conifer High School	X	

The dataloggers are programmed for measurements every thirty minutes at an office computer equipped with the Onset software. At this frequency, the memory capacity is approximately 905 days for the U22 (Water Temp Pro) series logger. The Association employs newer models with delayed-start capabilities. Logsheets are utilized to record the exact time of deployment and retrieval of all units, so that erroneous measurements (measurements recorded out of water) can be omitted during the data evaluation process.

The U22 series loggers are utilized in all watershed stream locations. These loggers are downloaded to a shuttle device. Occasionally, the download process occurred precisely at the measurement instance and a measurement is lost. There are no watertight cases required for the U22 model loggers. The date and deployment time for all loggers is noted on a Logsheet. After downloading the last logger in the Watershed, the laptop and shuttles are transported to the desktop computer with the Onset software at the EMD Administration office. The logger data is transferred from the laptop and from the shuttles to the desktop. The shuttles are connected to the computer via a download cable, and data on the shuttles are individually downloaded into separate program files.

30-minute datalogger temperature measurements are exported from the Onset Computer software into Excel spreadsheets. Each download of temperature data is treated as a file in the Onset software. Once the Onset file formats is exported and saved as separate Excel files, the Excel spreadsheets for each location is combined into one Excel spreadsheet with multiple worksheets. Therefore, each Excel file contains multiple worksheets, one for each separate download of data, and a summary worksheet. The master dataset spreadsheet contains separate worksheets for each Site in the watershed, displaying all temperature datalogger values and statistical analysis, as well as sampling and monitoring data and statistics.

The date and time recorded on the Launch/Retrieval Logsheet is used to eliminate erroneous temperature measurements prior to data analysis. The majority of these erroneous measurements are eliminated by utilizing the shuttle devices to field-download data. Occasionally, the field download process occurs exactly at the time of a measurement, and an erroneous value is recorded or missed. These are also removed from the raw data prior to analysis. Once in a spreadsheet format, the data is evaluated against the underlying standard Weekly Average Temperature (WAT) criteria, against the underlying standard Daily Maximum Temperature (DM) criteria and against the Maximum Weekly Average Temperature (MWAT) criteria. Percentages of compliance are calculated. Weekly Average Temperatures are determined by calculating the mean temperature of seven consecutive days of data

beginning with either April or May or the first day of data collection. Any lack of data collection resulting in a data gap of one day or more, requires that the seven-day period begin anew. Maximum Weekly Average Temperatures are determined by evaluating the calculated Weekly Average Temperatures.

Daily Maximum values are obtained by calculating the average temperature of a two-hour period beginning with the first temperature recorded, and determining the maximum value from each day. Again, any lack of data collection resulting in a data gap more than two hours, requires that the two-hour calculation period begin anew. In most cases, there are four measurements in a two-hour period.

Limited Seasonal Temperature Datalogger Monitoring Locations

Continuous temperature measurements taken by loggers every half-hour, May 15-Nov 15 (ice dependent)

Site 58	Bear Creek below the Mt. Evans Wilderness
Site 25	Vance Creek
Site 2a	Golden Willow on Upper Bear Creek
Site 3a	Above Evergreen Lake at Keys-on-the-Green, CDOW Site
Site 4	Evergreen Lake, at dam (1/2m, then at 1-meter intervals)
Site 26	Cub Creek at mouth

Seasonal Temperature Datalogger Monitoring Locations

Continuous temperature measurements taken by loggers every half-hour, Apr 15-Dec 1 (ice dependent)

Site 19	North Turkey Creek Flying J Ranch
Site 18	South Turkey Creek below APMD
Site 16a	Turkey Creek within Bear Creek Park (Lakewood)
Site 15a	Bear Creek Segment 1b at Gaging Station in Bear Creek Park
Site 40	Bear Creek Reservoir (1/2m-2m)
Site 45	Below Bear Creek Reservoir
Site 90	Bear Creek at Wadsworth
Site 5	Above EMD WWTP, CDOW Downtown Site
Site 8b	Bear Creek Cabins, CDOW Site
Site 9	O'Fallon Park (west end, CDOW Site)
Site 12	Lair o' the Bear, CDOW Site
Site 13a	below Idledale (at Idledale at Shady Lane, CDOW Site)
Site 14a	Morrison Park (west end of town, CDOW Site)

P-4 Colorado Division of Parks &Wildlife Fishery Sites, Macroinvertebrates

Weather (local)

A National Weather Service Cooperative Reporting Station Number 052790 is maintained at the EMD WWTP. Daily high and low air temperatures and precipitation are recorded and transmitted monthly to the National Weather Service. Weather data was tabulated and correlated with Bear Creek stream flows (obtained at the USGS gage above Evergreen Lake) for the Program. Weather data collected during the program period was compared to the available historical weather records, obtained at the NWS High Plains Climate Center.

Fishery Surveys

The Colorado Division of Wildlife (CDOPW) has monitored fish populations in the watershed from 1988 through 2017. Prior to 2005, there were five monitoring sites. In 2010, there were ten survey sites (Table 20). In 2011, Bear Track site 38 was included in survey. All of the CDOPW survey sites incorporated in the Association monitoring network. No fish surveys were done in 2012 due to the low flow conditions. No fish surveys were done in 2013 due to flood conditions. Fishery survey completed in 2014-2017. No survey in September 2018 due to low flow concerns.

Table 20 Colorado Division of Parks and Wildlife Fish Survey Sites

Stream Segment	CDOPW Fishery Reference Sites
Segment 3	Vance Creek (one-time)
Segment 1a	Keys on the Green, Golden Willow Bridge, Site 58
Segment 1e	Little Bear, Bear Creek Cabins, O'Fallon Park, Lair O' the Bear, Idledale, Morrison Park
Segment 7	Bear Tracks (one-time)

These reference sites have coordinated chemistry, biological, physical data collection. This mixed data analysis establishes reference conditions for four stream segments in the watershed. The CDOPW surveys fish populations in September. The survey determines young of the year and adult size classes, species present, total biomass of fish by species and total pounds per acre by species. The Association assists the CDOPW with fish sampling. The CDOPW provides raw and processed data to the Association for the annual data report.

BCWA Macroinvertebrate and Habitat Sampling

See *BCWA ME04 Macroinvertebrate Field Sample Method* for field collection protocols. The reference sites in Table 12 sampled for macroinvertebrates, physical habitat (modified Rapid Bioassessment Protocol) and streambed characterization (modified Wolman Pebble Count). The WQCD's procedure on physical habitat is a visual assessment of the quality of the instream and riparian habitat that influences the structure and function of the aquatic community in a stream. Parameters are ranked as optimal, suboptimal, marginal, or poor based on a 4-point scale, with 4 being the best possible (optimal) conditions and one representing the worst (poor) conditions.

Macroinvertebrate samples have been historically collected at 7 CDOPW fish survey sites along Bear Creek: Morrison Park, Idledale, Lair o' the Bear Park, O' Fallon Park, Bear Creek Cabins, Main Street Evergreen (across from the Little Bear), above Evergreen Lake upstream of the USGS gaging station, Golden Willow Bridge site 2a and site 58. The WQCD previously assisted with data analyses and interpretation. The sampling, data analyses and interpretation is now an Association function. The macroinvertebrate sampling is done by the Association in August with analyze done by GEI. Sample collection done by the state timed-kick net methodology protocol (Benthic Macroinvertebrate Sampling Protocols, Water Quality Control Division, Standard Operation Procedure, WQCDSOP-001, May 2010).

Table 21 shows the Association sample locations for macroinvertebrates, physical habitat (modified Rapid Bioassessment Protocol) and streambed characterization (modified Wolman Pebble Count). Due to stream bed alterations from the September 2013 flooding event, the Association did new physical habitat and streambed characterization in September 2015; additional surveys completed in 2016-2018.

Table 21 BCWA Macroinvertebrate Stations

Primary Target Sites	Secondary Target Sites
Golden Willow Bridge site 2a	Idledale
Dedisse Park near Keys on the Green	Site 58
Little Bear in downtown Evergreen	O' Fallon Park
Bear Creek Cabins	Wadsworth
Lair o' the Bear Park	Site 45
Morrison (gage)	Site 90
BCLP	Turkey Creek