

Bear Creek Watershed Association

2016 Annual Report



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*The Bear Creek Watershed Association protects & restores water & environmental quality
within the Bear Creek Watershed from the effects of land use*

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I. WQCC Summary

The Bear Creek Watershed is a specific geographic area identified in the Bear Creek Watershed State Control Regulation (Regulation #74, 5 CCR 1002-74) that requires special water quality management. The Bear Creek Watershed Association is the local water quality agency responsible for implementation of monitoring and tracking water quality in the Bear Creek Watershed.

Regulation #74 identifies the Association's annual reporting requirements for presentation to the Water Quality Control Commission (WQCC). The Bear Creek Watershed Association Annual Report includes five reporting requirements as listed in the control regulation: 1) Summarize status of water quality in the watershed for the previous calendar year. 2) Provide information on the wastewater treatment facilities loading and compliance with permit limitations. 3) Nonpoint source loading and appropriate best management practices. 4) Demonstrate through in-stream and reservoir data analyses the status of water quality goals and standards for the watershed. 5) Characterize any active phosphorus trading programs.

1. Status of Water Quality

The average inflow into Bear Creek Reservoir from both Turkey Creek & Bear Creek (1987-2014) was 27,100 acre-feet per year. In 2015, 118,925 acre-feet flowed through the reservoir. The 2016 flow remained high at 39,550 acre-feet (Figure 1). The 2015 flow increased the long-term average (1987-2016) inflow to 31,150 acre-feet per year. Most of this flow occurred in April and May (60% of the annual total flow). This resulted in a minor flood stage (> 2,000 ac-ft) for BCR from April 12 to June 15, 2016. In October-December 2016, the U.S. Army Corps of Engineers lowered BCR by about 500 ac-ft for repair work on the dam.

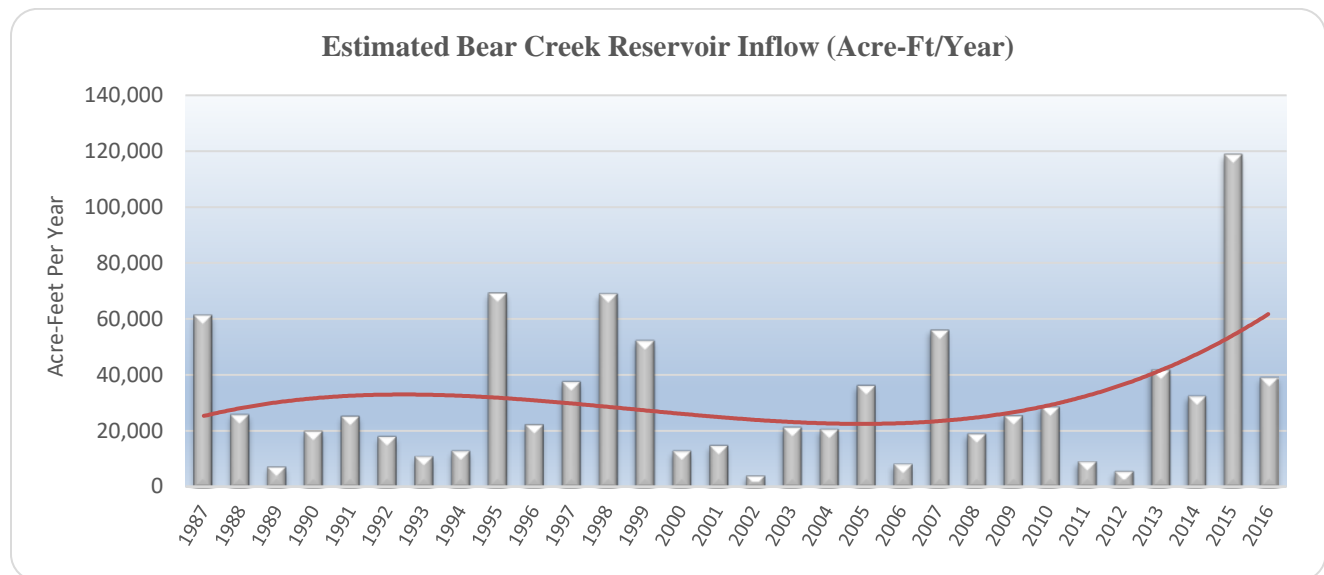


Figure 1 Estimated Bear Creek Reservoir Inflow 1987-2016

The estimated annual discharge from Bear Creek was about 27,615 acre-feet (70%) and 11,935 acre-feet (30%) from Turkey Creek. The internal loading problem (total phosphorus) with Bear Creek Reservoir has not diminished over the last 9-years (Figure 2). The total phosphorus deposition into reservoir bottom sediments is about 32,617 pounds since 2008.

The reservoir continues to experience late summer phytoplankton blooms (2016 peak density of *Aphanizomenon flos-aquae*, Peak Biovolume ($\mu\text{m}^3/\text{mL}$) = 40,202,900; *BCWA TM 2016.19 BCR Phytoplankton Summary*), which are linked to the internal nutrient loading problem. The BCWA has identified some strategies to address the internal loading problem (*BCWA Policy 20 Preferred Management Strategies EGL and BCR*).

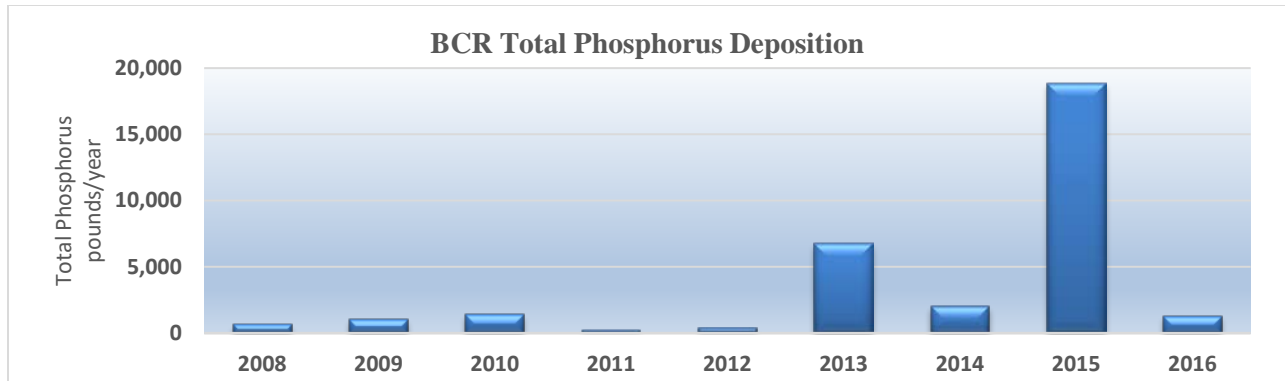


Figure 2 Annual Total Phosphorus Deposition into Bear Creek Reservoir Bottom Sediments

The total phosphorus load from the watershed comes from a combination of wastewater treatment plant point source loads, other sources (e.g., onsite disposal systems; see *BCWA Policy 11 Vault & SS Disposal Systems*), nonpoint sources (e.g., onsite wastewater treatment systems, stabling operations [*BCWA Policy 4 BC Manure Management*], roads, public lands, illegal dumping [*BCWA Policy 18 Illegal Dumping*], and regulated stormwater runoff). The estimated total phosphorus load in 2016 from all sources reaching the reservoir was 5,657 pounds (62% from Bear Creek). There was about 84,580 pounds of total nitrogen loading into the reservoir with 66% derived from the Bear Creek drainage.

The Association monitors watershed nutrients by major stream segments beginning near Mt. Evans (segment 7) and extending downstream to Bear Creek Reservoir. 2016 was an average nutrient monitoring year with 79% of the total phosphorus (Figure 3) and 60% of the total nitrogen (Figure 40) load occurring in the April-May spring runoff period. Most nutrient load comes from the urbanized corridor of segment 1a (above Evergreen Lake to the Clear Creek County Line), and segment 1e, which is the mainstem of Bear Creek from Evergreen Lake to the Harriman Ditch Diversion.

There was about 1,592 pounds of total phosphorus passed through Evergreen Lake, with an additional 250 pounds added from the Cub Creek drainage. Additional total phosphorus loading into Bear Creek between Evergreen to Morrison was over 20,960 pounds during the monitoring season. Mt. Vernon Creek contributed about 875 pounds of total phosphorus. The BCWA has established specific monitoring sites to better characterize specific tributary drainages with elevated total phosphorus loading and develop improved management strategies for these areas (*BCWA Policy 15 Nonpoint Source Strategies and BMPs*). The BCWA also improved integrated planning efforts with other agencies to help resolve several identified pollutant loading problems (*BCWA Policy 29 BCWA Integration with Other Planning Efforts*).

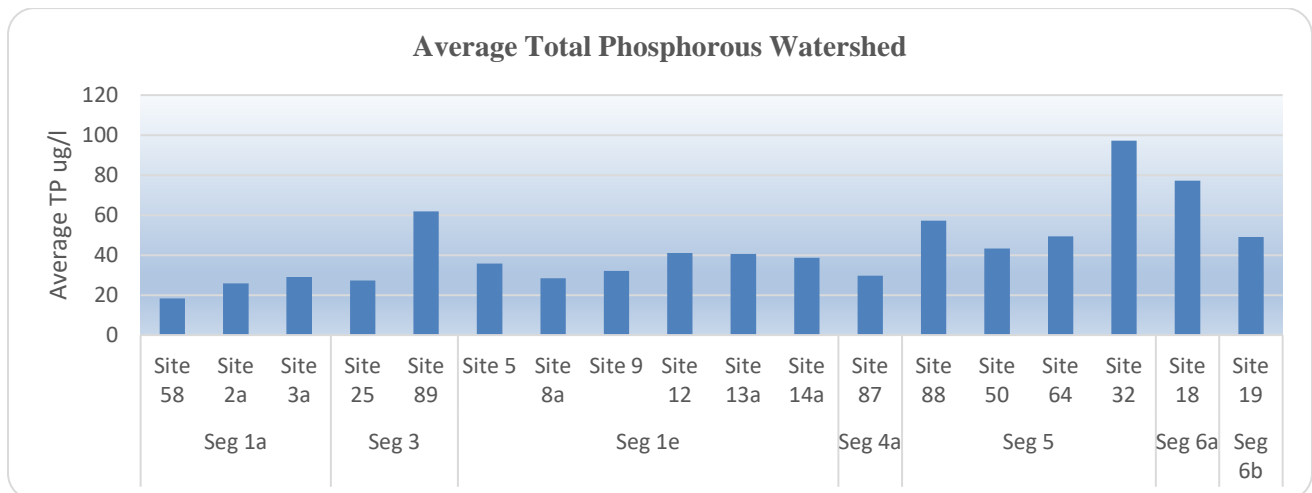


Figure 3 Total Phosphorus Loading by Stream Segments in the Watershed

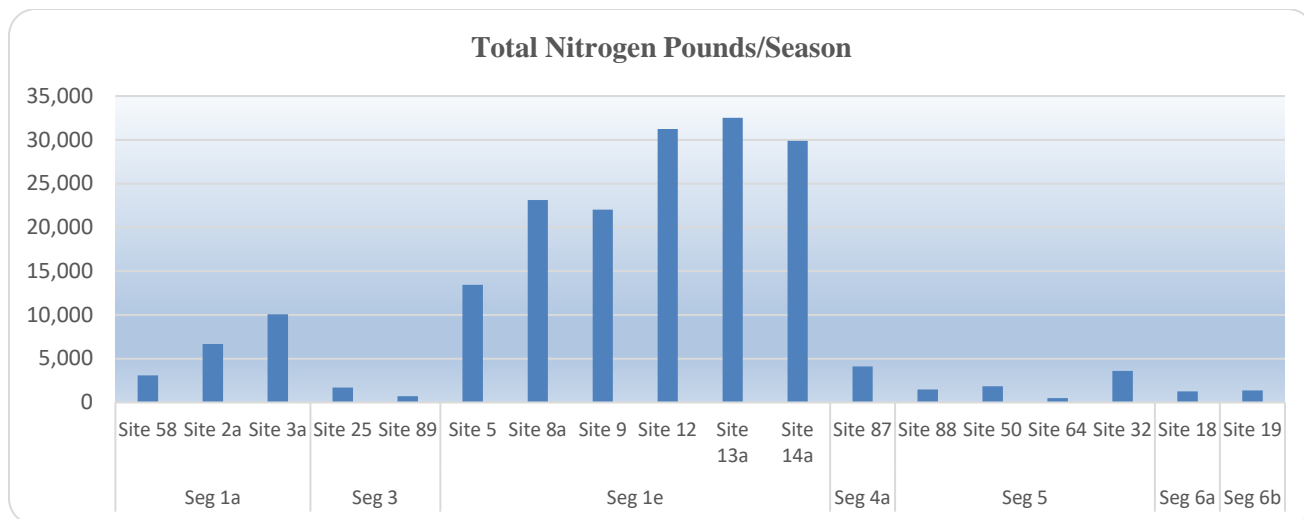


Figure 4 Total Nitrogen Loading by Stream Segment in the Watershed

2. Wastewater Treatment Facilities Loading and Compliance

In 2016, wastewater dischargers reduced total phosphorus waste load contributions to just 1,024 pounds annually. BCWA analysis of the total phosphorus data record indicates that only about 20-35% of this total phosphorus load from permitted dischargers reaches the Bear Creek Reservoir. Significant permit compliance problems were reported for the Brook Forest Inn and Geneva Glen for total phosphorus, which are being addressed under compliance orders with the Water Quality Control Division. The Brook Forest Inn no longer participates in the Association cost share program and is not in compliance with Bear Creek Control Regulation #74.

The Bear Creek Cabins and the Singing River Ranch permitted wastewater treatment facilities are formally closed and converted to onsite wastewater treatment systems. They also no longer participate in the Association cost share program. The Tiny Town operation continues hauling wastewater off site and the treatment facility is non-operational. The Jefferson County Mt. Evans Outdoor Laboratory has a new wastewater facility that began operation in 2016. Some of the smallest dischargers are finding it difficult to meet the total phosphorus permit limit of 1.0 mg/l, but they do meet their annual wasteload allocations.

Regulation 85 monitoring and reporting that took effect in 2014, continues as a watershed program. The program collects nutrient monitoring data for most surface discharging wastewater dischargers. Larger WWTFs chose to participate in BCWA watershed level Regulation 85 sampling and reporting in conjunction with stream sampling for data comparability.

3. Nonpoint Source Loading

The BCWA tracks nutrient loading in the watershed. The studies detail information on OWTS, horse properties and pastures, and unpaved roads. This data includes screening level analysis in EPA BASINS GWLF-E to estimate non-point source contributions. Results and watershed data from the last 10-years indicate the annual nonpoint phosphorus base-flow load from all sources in the watershed ranges from 5,000 to 6,000 pounds, annually. A single major flood event in the watershed can generate 1,000 to 30,000 pounds of total phosphorus. Clearly, only a fraction of this load transports to the Bear Creek Reservoir on an annual basis (Table 1).

The point source load of total phosphorus in 2016 (Table 1) was 1,024 pounds (18%), while the nonpoint source load reaching Bear Creek Reservoir was about 4,633 pounds (82%). On average over 17 years of data record, only about 28% of the potentially generated nonpoint source total phosphorus reached Bear Creek Reservoir. Some of the nonpoint source load reduction can be attributed to improved Jefferson and Clear Creek county management practices for road maintenance, construction practices, stormwater controls and land use controls. This 2016 nonpoint source phosphorus loading was heavily influenced by a record spring runoff period.

Table 1 Point Source versus Nonpoint Source Phosphorus Loading, Bear Creek Reservoir

	2016 Total Phosphorus Loading (Pounds)				
	Total TP Load	PS	%PS	NPS	%NPS
Turkey Creek Drainage	2,142	14	0.2%	2,128	99%
Bear Creek Drainage	3,515	1,010	17.9%	2,505	71%
Discharged into Reservoir	5,657	1,024	18.1%	4,633	82%
Site 45 Outflow BCR	4,369				
BCR Total Phosphorus Deposition	1,288				
Site 90 - Lower Bear Creek	5,722				

The nutrient data shows three areas along the mainstem of Bear Creek where elevated nonpoint source nutrients are commonly measured: the mainstem of Bear Creek between Golden Willow and the Keys on the green (Upper Bear Creek), downtown Evergreen, and below Idledale. The Tributaries with elevated nutrient loading are Troublesome drainage, Cub Creek drainage and Mt. Vernon drainage. Upper Bear Creek, Troublesome and Mt. Vernon are addressed in *BCWA WQSD02 Upper Bear*, *BCWA WQSD01 Troublesome* and *BCWA WQSD04 Mt Vernon*.

The April-May watershed sampling period above Evergreen Lake represented a high flow condition on both the mainstem and tributaries throughout the upper watershed. In this higher flow period, Vance Creek and Yankee Creek were the largest tributary sources of total phosphorus and total nitrogen with Vance Creek contributing 43% of the phosphorus load and Yankee Creek contributing 34% of the load. Under historic flow conditions, these tributaries are only about 7-8% of both the TP and TN load to Bear Creek.

The BCWA special studies have shown an estimated 30-75% of the total phosphorus on the Troublesome Drainage comes from a cluster of homes on OWTS located at the lower confluence of Stagecoach and the northern drainage system. This same area contributes 90-111% of the total nitrogen load in the middle drainage. A single horse stabling operation in lower Troublesome contributes about 25-60% of the TP load and about 12% of the TN load reaching Bear Creek.

A special study of Cub Creek from 2013-2016 shows this tributary discharges from 250 to 3,040 pounds of total phosphorus per monitoring season into Bear Creek downstream of Evergreen Lake. The seasonal average total phosphorus load in upstream waters is 304 pounds with the downstream average substantially increasing to 1,378 pounds. There are an estimated 5,450 people in the Cub Creek drainage that utilize OWTS. The phosphorus load in this drainage is likely a result of seepage from these OWTS located within the alluvial corridor.

The Association online system is a permanent management policy (BCWA Policy 21, December 2013). Watershed plan and administration policies were developed by the Association, related to: priority zones, park latrines, plan development, watershed boundaries, data collection, nonpoint source loading and strategies, membership, recycling, illegal dumping, trading eligibility, and reservoir management strategies (See the *BCWA PGO1 Master Index List* and *PGO2 Document Categories*, > 20 categories of documents). Association policies (35) are an essential component of the Association's interactive online *watershed plan*. The Association's adaptive electronic watershed plan (www.bearcreekwatershed.org) helps to continually improve watershed-planning efforts and provide tools and information to understand watershed dynamics. The Association keeps the community informed about water quality, watershed programs and management activities through a quarterly newsletter.

4. Status of Water Quality Goals and Standards

The Association has 35-years of active service to the watershed in Clear Creek, Jefferson and Park Counties. The Association has 32-years of data and studies to support watershed science. During this time, the Association has removed or immobilized about 375 tons of phosphorus in the watershed. The 86 volunteer-years of effort by Association membership has helped waters in the watershed meet standards and classified uses.

In 2015, the Water Quality Control Commission revised the chlorophyll standard to 12.2 µg/L. The exceedance threshold of 12.2 µg/L was derived with a “translator” developed with data from Bear Creek Reservoir. The translator connects the concentration at the allowable exceedance frequency (once in five years) to the typical concentration at the mesotrophic-eutrophic boundary (8 µg/L). The Commission also revised the phosphorus standard to 22.2 µg/L. The standard is calculated in two steps based on the methodology used to develop statewide nutrient criteria for the 2012 Nutrient hearing. The first step involves the creation of a statistical “linkage” between phosphorus and chlorophyll based on summer average concentrations measured in Bear Creek Reservoir. The linkage is used to define the phosphorus concentration corresponding to the mesotrophic-eutrophic boundary in the reservoir; that concentration is 16 µg/L. The second step involves a translator for phosphorus that performs the same function described for the chlorophyll translator. The concentration at the exceedance threshold is 22.2 µg/L.

The 2016 average seasonal total phosphorus of 95.1 µg/L in Bear Creek Reservoir far exceeds the 22.2 µg/L goal-standard. Average seasonal chlorophyll-a of 14.6 µg/L exceeds the 12.2 µg/L standard. The trophic status of the reservoir remains at the Eutrophic-Hypertrophic boundary based on Carlson and Walker indices. Seasonal average reservoir temperature in the top 2-meters of the water column generally remained below 22° Celsius. There were no exceedances of the *Weekly Average Temperature* (WAT) and 8 exceedances of the *Daily Maximum Temperature* (DM). A new aeration system was installed in Bear Creek Reservoir (*BCWA Fact Sheet 47 New BCR Aeration System*). The Association is monitoring the effectiveness of the aeration configuration and oxygen transfer during the growing season. Lake aeration maintained dissolved oxygen levels at or above 6 mg/L throughout most of the growing season. There were two low oxygen excursions in July and August. There was recreational fishing throughout the year.

In Bear Creek and Turkey Creek segments, there were several temperature compliance problems in the warm and cold seasons with 99% compliance for the WAT and 99.8% compliance for the DM. Sampling and monitoring was performed at 38 sites within the watershed at varying intervals. Measurements of pH and DO showed 98% compliance for pH and 98% compliance for Dissolved Oxygen. There was 93% compliance for the proposed Total Nitrogen of 1250 µg/L and 98% compliance for the proposed Total Phosphorus of 110 µg/L below the treatment facilities. There was an exceedance of new total phosphorus standard measured at the site-specific Summit Lake pollution plume (*BCWA TM 2016.02 UBCW Summary*).

5. Phosphorus Trading Program

There was no active total phosphorus trading by Association membership in 2016 (See Table 23 in the *BCWA 2016 Annual Report* for a status of trading activity summary). The Association has established four trading policies to improve future trading programs (*BCWA Policy 1 Trading Program, BCWA Policy 19 Nutrient Trading Program Eligibility, BCWA Policy 26 Point to Point Trade Administration, and BCWA Policy 35 Membership Entity Termination and Permit Closure*). The Association Coyote Gulch restoration project has established the annual available total phosphorus trade pounds consistent with the Association trade program at 84 pounds (*BCWA TM 2016.03 Coyote Gulch Summary*). The project has effectively reduced total phosphorus loading by about 75% on an annual basis (Figure 5).

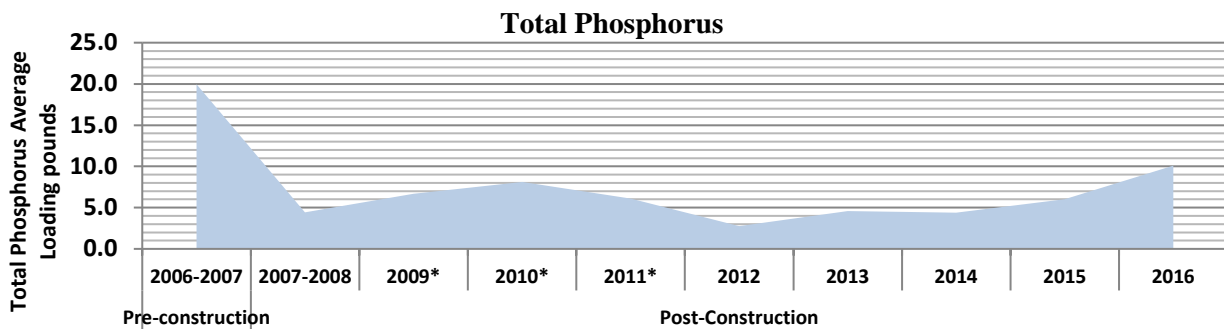


Figure 5 Total Phosphorus Reduction at Coyote Gulch Restoration Site

II. Bear Creek Watershed Association Program

The Bear Creek Watershed (Figure 6) is a specific geographic area identified in the Bear Creek Watershed State Control Regulation (Regulation #74, 5 CCR 1002-74) (Control Regulation) requiring special water quality management. The watershed includes all tributary water flows that discharge into Bear Creek Reservoir (*BCWA Policy 13 Watershed Boundary*). The watershed extends from the Mount Evans Wilderness on the western end to the Town of Morrison on the eastern end (*BCWA Map 01 Watershed Boundary*). The two major tributaries are Bear Creek and Turkey Creek. The goal of the Control Regulation is to attain site-specific water quality standards and classifications through control of total phosphorus and chlorophyll (*BCWA Fact Sheet 10 Control Regulation 74*). The Bear Creek Watershed Association (Association) oversees implementation of the Control Regulation (*BCWA Fact Sheet 1 BCWA Overview; BCWA Policy 12 Vision Mission & Targets*).

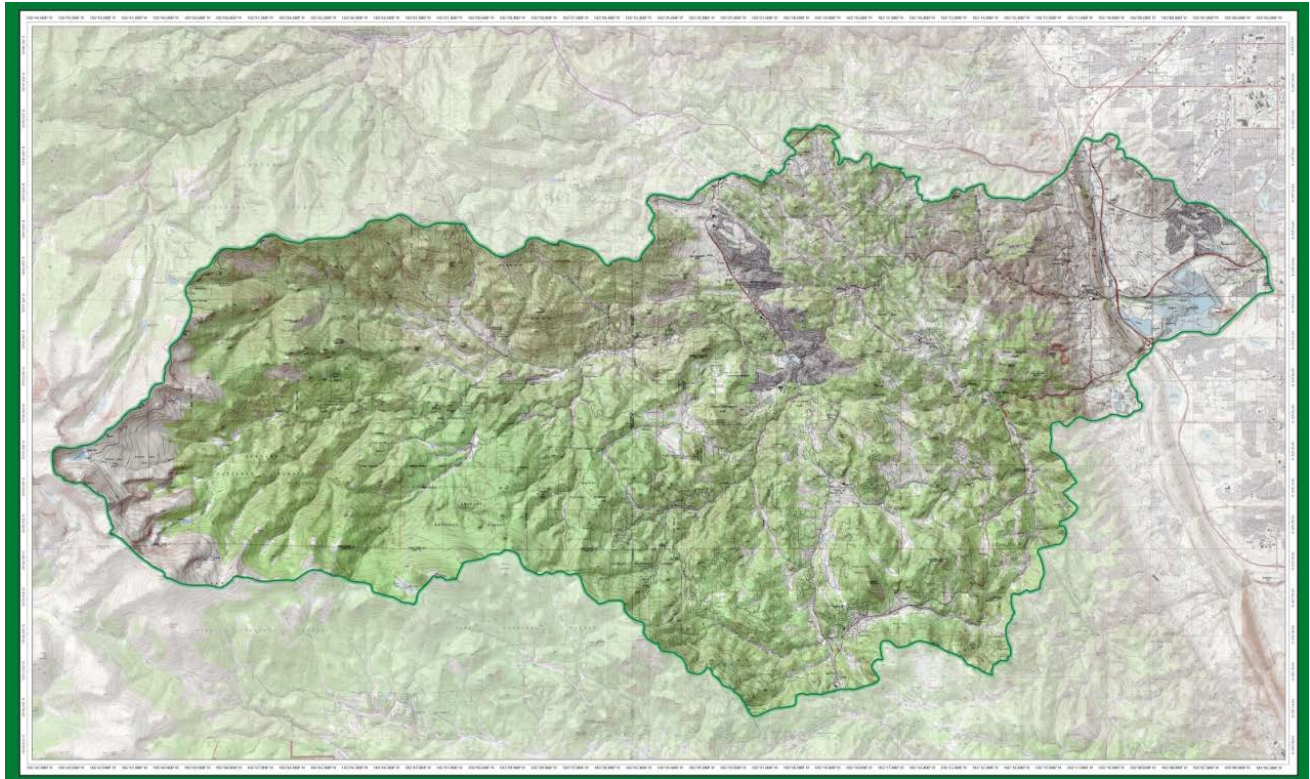


Figure 6 Bear Creek Watershed

The Association is the local water quality agency responsible for implementation of monitoring and tracking water quality in the Bear Creek Watershed (*BCWA Policy 13 Watershed Boundary*). The Association membership includes counties, local general-purpose governments, special districts (wastewater dischargers), associate agencies, and local citizen groups (Table 2). The Association membership monitors point sources and tracks nonpoint source practices, programs and loadings within the watershed. The Association management and implementation programs are at a watershed level (*BCWA Policy 28 BCWA Watershed Plan*).

The Association provides watershed reporting as posted on the Association Website www.bearcreekwatershed.org, which serves to keep federal, state, 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 (*BCWA Policy 29 BCWA Integration with Other Planning Efforts*).

Table 2 Association Membership, Dischargers and Participation

Members & Participants	Wastewater Discharger	2016 Participation Status
Counties		
Jefferson County	No	Active ¹
Clear Creek County	No	Active
Park County	No	Not Active
City and Towns		
City of Lakewood	No	Active
Town of Morrison	Yes	Active
Water & Sanitation Permit Holder		
Aspen Park Metropolitan District	Yes	Active
Brook Forest Inn	Yes	Dues Not Paid, Not Active
Conifer Sanitation Association	Yes	Active
Conifer Metropolitan District	Yes	Dues Paid, Not Active
Evergreen Metropolitan District	Yes	Active
Forrest Hills Metropolitan District	Yes	Active
Genesee Water & Sanitation District	Yes	Active
Geneva Glen	Yes	Dues Paid, Not Active
Jefferson County School District	Yes	Active
Kittredge Water & Sanitation District	Yes	Active
Tiny Town Foundation, Inc.	Yes	Dues Paid, Not Active
West Jefferson County Metropolitan District	Yes	Active
Other Members		
Denver Water Department	No	Active
Participant Agencies		
Denver Environmental Health/ Denver Parks & Recreation	No	Active
U.S. Army Corps of Engineers	No	Not Active
WQCD	No	Active

¹ – Active membership is defined as attending 2 or more Board and/or TRS meetings (*BCWA PGO16 By-Laws*).

III. Status of Water Quality in the Reservoirs and Watershed

Monitoring Program Update

The BCWA monitoring plan details the 2016 reservoir and watershed monitoring programs as approved by the BCWA Board and submitted to the Water Quality Control Division staff (WQCD). This monitoring plan serves as a supplement to the adopted Association Quality Assurance Project Plan (Bear Creek Watershed Association, 2006). The 2016 monitoring program (version 2016.01 and version 2016.02) details changes, updates, major continuation studies and monitoring program elements. The *BCWA Policy 14 Data Collection in the Bear Creek Watershed* defines expectations for other groups or agencies that conduct overlapping monitoring activities within the watershed.

The routine monitoring program (P1) focuses on Turkey Creek drainage and Bear Creek drainage inputs, and discharge from Bear Creek Reservoir into lower Bear Creek with a central pool characterization of the reservoir near the dam (Figure 7; BCWA site 40). The outlet structure is near BCWA site 41 with Bear Creek inflow near BCWA site 44 and Turkey Creek inflow near BCWA site 43 (Site 43 and site 44 were not monitored in 2016). The reservoir chemistry and biological characterization monitoring occurs at BCWA site 40. Vertical probe samples for specific conductance, temperature, dissolved oxygen, and pH measured at ½ and 1-meter intervals at all reservoir sites. The current monitoring program optimizes data generation to evaluate reservoir inflow loading, chemical and biological changes within the reservoir, and reservoir outflow, while minimizing monitoring cost. Figure 8 shows all monitoring stations within Bear Creek Park. The Association maintains maps of recent sampling sites and wastewater treatment plant locations on the Association web site.



Figure 7 Reservoir Monitoring Stations; Site 40 is the Routine P1 Station (2015 image)



Figure 8 Monitoring Stations in Bear Creek Lake Park

Watershed Studies

Stream Flow Studies

The BCWA obtains stream flow data at multiple stations throughout the watershed. Manual flows measured with most watershed-sampling events. For watershed sites, manual flows measured at up to 17 sites during the May to November timeframe. Year-round flows measured at the Kerr-Swede sites and P1 sites. The Association installed stream staff gages were destroyed by the September 2013 flood and they have not been replaced. The Association also conducts tributary stream flow studies.

Hydrology

The BCWA evaluates the basin hydrology. In 2016, the total estimated annual discharge into Bear Creek Reservoir was about 39,551 acre-feet (Figure 9) with about 39,580 acre-feet flow-through and no measurable evaporation and infiltration. The Reservoir was in flood stage for about 1-month (Figure 10) and drawn-down for about 2-months.

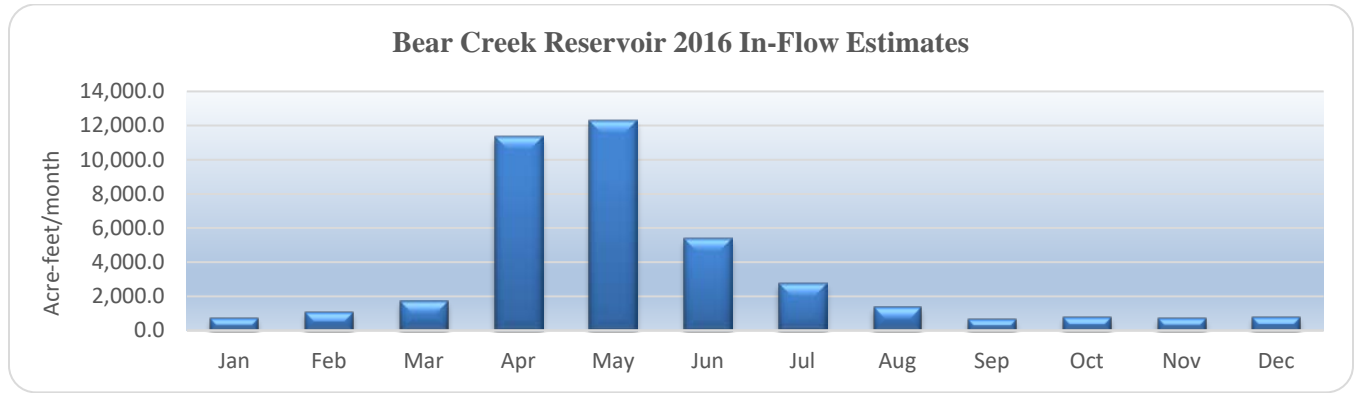


Figure 9 In-Flow Estimates by Month into Bear Creek Reservoir

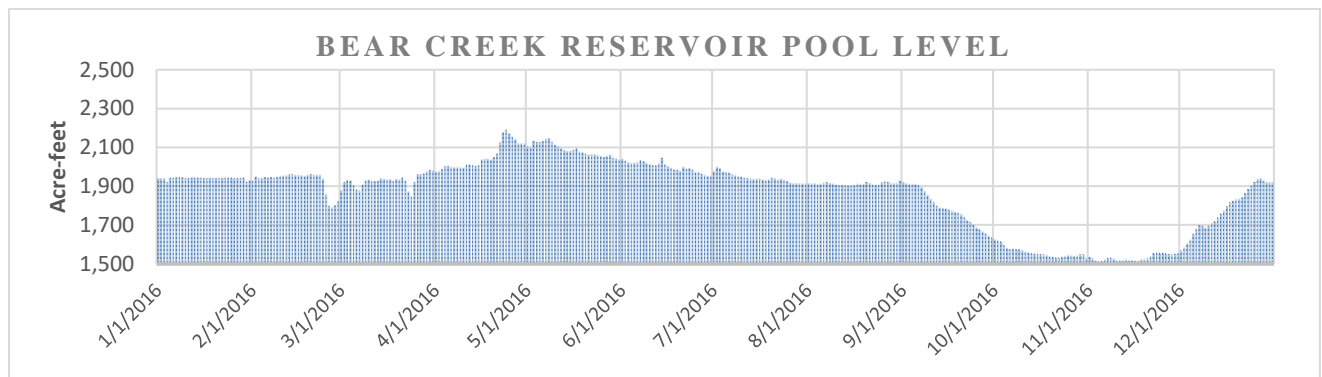


Figure 10 Flood Stage in Bear Creek Reservoir

Bear Creek flow diverts at the Harriman Ditch in Morrison, and a portion of the Turkey Creek flow diverts for water uses. Bear Creek flow diverts into the Arnett-Harriman during the irrigation season. The Arnett-Harriman ditch reduces flows in lower Bear Creek below 10 cfs in the operational season about 35% of the time. The ditch systems can completely dewater lower Bear Creek for periods of up to 15 consecutive days. For example, in 2015, the Harriman diverted water for about 275 days with about 5,000 acre-feet of removal as reported by Denver Water Department. Lower Bear Creek was dewatered (<5 cfs flow) for about 50 days or 15% of the time. The BCWA analyzed the nutrient load removal from the Harriman Ditch (Table 3). The diversion reduces the total phosphorus load to Bear Creek Reservoir by about 20%. The 2016 diversion record is like the reported 1992-2015 data record.

Table 3 Harriman Ditch Nutrient Load Removal

DWD Harriman Ditch					
Segment	BCWA Site	Season May-October			
		Nitrate Pounds	TN Pounds	TP Pounds	Ac-Ft
Seg 1e	Site 14a	12,468	25,806	3,275	24,885
Seg 4a	Site 34	2,803	4,572	85	1,468
Total Above Harriman		15,271	30,378	3,360	26,353
Seg 1b	Site 15a	11,536	25,095	2,652	16,519
Removal Harriman		3,735	5,283	708	9,834
% Removal		24%	17%	19%	37%

Comparing in-flow estimates at the Morrison gaging station (2016, 96,800 ac-feet) and at the BCWA site in Bear Creek Park (2016, 82,900 ac-feet) provides an estimate of the amount of water diverted from the watershed by the Arnett-Harriman Canal and Ward Ditch. For example, in 2015 the Bear Creek water use diversions reduced flow to the reservoir by about 13,900 ac-ft (-24 %).

The reservoir inflow represents flows below the water diversions and is not representative of the total watershed water flows. Figure 11 compares the 2016 reservoir monthly inflow estimates from Bear Creek (70%) and Turkey Creek (30%). Peak spring and stormwater runoff occurred in April-May 2016. Figure 12 shows the Bear Creek in-flow estimates (1987-2016) above Bear Creek Reservoir, in Bear Creek Park. Figure 13 shows the flow estimates at the Evergreen station. Additionally, the longer time trends shown in Figures 12 and 13 depict a basic linear trend of declining flow in Bear Creek.

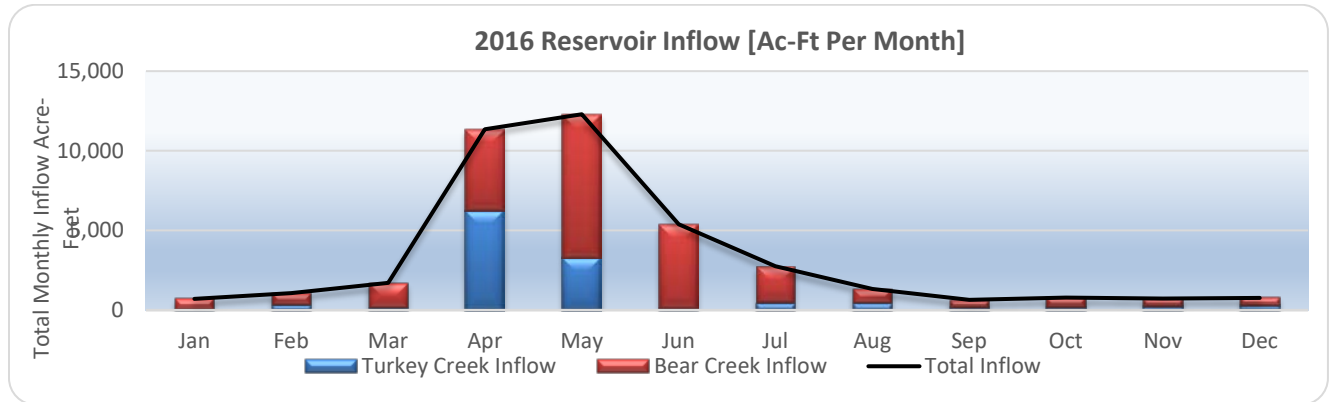


Figure 11 Annual Flows into Bear Creek Reservoir

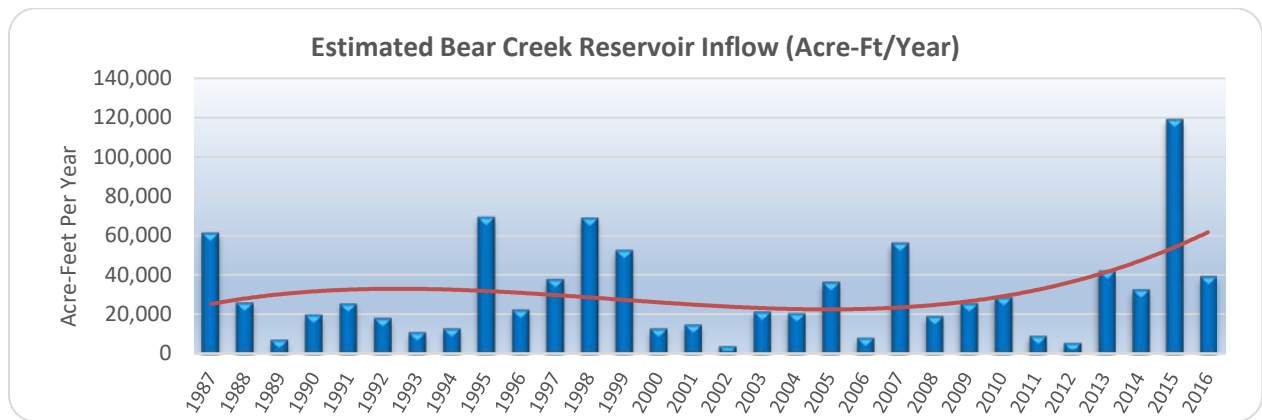


Figure 12 Bear Creek Reservoir Inflow Estimates

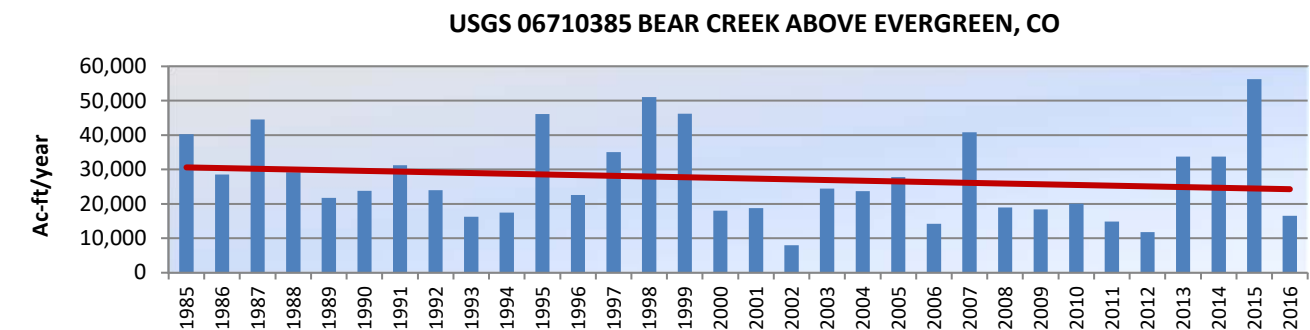


Figure 13 Bear Creek at Keys-on-the-Green, above Evergreen

Water Quality Studies

The BCWA summarizes its watershed-monitoring program in a data report (Bear Creek Watershed Association Data Report, April 2017). The BCWA collects annual water quality data from multiple sampling locations throughout the watershed. The watershed-monitoring program has three major water quality and environmental data generating elements, as defined in the *Water Monitoring Program and Sample Analyses Plan Version 2016.01, BCWA January 2016, and subsequent annual updates*:

1. Bear Creek Watershed surface water characterizations during selected months beginning at the headwaters of both Bear Creek and Turkey with a primary focus on nutrients and base field parameters,
2. Bear Creek Watershed surface water temperature characterization by major stream segments for both the cold and warm seasons, which is also defined in the *Water Monitoring Program and Sample Analyses Plan Version 2016.01, BCWA January 2016, and subsequent annual updates*.
3. Special water quality characterization and analyses studies completed on a site-specific basis.

The 2016 P1 data results are contained in the *2016 Bear Creek Master Spreadsheet* posted on the Association website monitoring page and a specific watershed spreadsheet for the temperature data. Monthly summary reports provided to the Association Board. Stream and lake sampling and monitoring data, including pH, Temperature, Dissolved Oxygen, Specific Conductance, Ammonia, Nitrate +Nitrite, Total Inorganic Nitrogen (calculated), Total Nitrogen, Dissolved Phosphorus, Total Phosphorous, and Total Suspended Solids were collected from July through September, including the special pollution study sites in Mount Evans Wilderness Area. Stream and lake temperature data-loggers placed at 22 sites, including the Evergreen Lake profile station, and the Bear Creek Reservoir profile station, excluding the five WWTPs. Eight selected sites collected data logger temperatures from January through December. The remaining sites collected temperature data from April through September and May through October. Some data-loggers were lost. All loggers were removed and data downloaded after September 2016.

The Association produces an annual series of technical memorandum designed to summarize the site-specific studies for any given year (Table 4).

Table 4 2016 Technical Memorandum of the Association

TM 2016.01	TM 2016.01 Sediment Survey BCR
TM 2016.02	UBCW Summary
TM 2016.03	Coyote Gulch Summary
TM 2016.04	BCR 2016 Summary Statistics and Graphs
TM 2016.05	MBCW 2016 Nutrient Summary
TM 2016.06	P1 Summary
TM 2016.07	Barr Milton TMDL Summary
TM 2016.08	EGL Summary
TM 2016.09	BCR Phytoplankton Summary
TM 2016.10	Fisheries
TM 2016.11	Fall 2016 Macroinvertebrate Data
TM 2016.11b	Macroinvertebrates
TM 2016.12	Copper Study

Table 5 lists the 2016 middle watershed seasonal average chemistry results (full results shown in 2016 Master Spreadsheet). BCWA Technical Memorandum 2016.05 summarizes the middle watershed data. Table 6 lists the Summit Lake area watershed chemistry results (full results shown in 2016 Master Spreadsheet). BCWA Technical Memorandum 2016.02 summarizes the Summit Lake data.

Table 5 Middle Watershed Chemistry

	Site ID	Site Location by Stream Segment	Seasonal Average					
			TN Ug/l	T Phos Ug/l	Flow cfs	Ac-ft	TN Pounds/Season	TP Pounds/Season
Seg 1a	Site 58	Bear Creek Above Singing River Ranch	212	18	14.7	5,364	3,101	268
	Site 2a	Golden Willow Road UBC	165	26	40.6	14,814	6,669	1,042
	Site 3a	Above Evergreen Lake at CDOW Site	185	29	54.8	19,995	10,082	1,579
Seg 3	Site 25	Vance Creek	140	27	12.2	4,451	1,699	331
	Site 91	Yankee Creek, Mouth	169	62	4.3	1,569	724	264
Seg 1e	Site 5	Above EMD WWTP, CDOW downtown site	262	36	51.7	18,864	13,432	1,841
	Site 8a	Bear Creek Cabins at CDOW Site	443	28	52.5	19,156	23,116	1,478
	Site 9	O'Fallon Park, west end at CDOW Site	411	32	54.0	19,703	22,033	1,726
	Site 12	Lair o' the Bear Park, at CDOW site	527	41	59.7	21,783	31,229	2,432
	Site 13a	Below Idledale, Shady Lane at CDOW site	545	41	60.0	21,892	32,509	2,414
	Site 14a	Morrison Park west, CDOW Site	487	39	61.8	22,549	29,902	2,374
Seg 4a	Site 87	Mt Vernon Drainage, Morrison	1,719	30	2.4	876	4,099	71
Seg 5	Site 88	Cub Creek, Upstream	791	57	1.9	693	1,493	108
	Site 50	Cub Creek, Upstream of Cub Creek Park	323	43	5.8	2,116	1,862	250
	Site 64	Troublesome at Culvert Above West Jeff	640	49	0.8	292	508	39
	Site 32	Troublesome Mouth	1,392	97	2.6	949	3,595	251
Seg 6a	Site 18	South Turkey Creek Aspen Park	639	77	2.0	730	1,269	153
Seg 6b	Site 19	North Turkey Creek Flying J Ranch Bridge	370	49	3.7	1,350	1,358	180

Table 6 Upper Watershed (Summit Lake) Chemistry

Site	Parameter	6/29/2016	7/14/2016	8/18/2016	9/15/2016	Average
BCWA Segment Sample Sites						
36 - Outlet Summit Lake	Total Nitrogen, ug/l	335	270	241	237	271
36 - Outlet Summit Lake	Phosphorus, total, ug/l	19	7	6	62	24
37 - Upper Bear Creek	Total Nitrogen, ug/l	292	289	279	279	285
37 - Upper Bear Creek	Phosphorus, total, ug/l	9	9	7	5	8
Site 63 - Bottom Fen	Total Nitrogen, ug/l				89	
	Phosphorus, total, ug/l				242	

Reservoirs*Bear Creek Reservoir and Inflow Nutrients*

The watershed-monitoring program characterizes nutrient loading into Bear Creek Reservoir from two primary drainages: Bear Creek and Turkey Creek. The Association monitors for total phosphorus, dissolved phosphorus, nitrate-nitrite nitrogen, and total nitrogen monthly. The Association has established preferred management strategies for Bear Creek Reservoir (*BCWA Policy 20*). The total phosphorus load from the watershed comes from a combination of wastewater treatment plant point source loads, un-regulated point sources, and nonpoint sources, including runoff. There are over 9,000 septic systems in the watershed. The estimated total phosphorus load in 2016 from all sources reaching the reservoir was 5,657 pounds at a flow of about 39,500 acre-feet. Bear Creek drainage contributed 50% of the TP load (Figure 14). The management program targets reduction of total phosphorus reaching the reservoir on an annual basis. Figure 15 shows the total phosphorus reservoir trend.

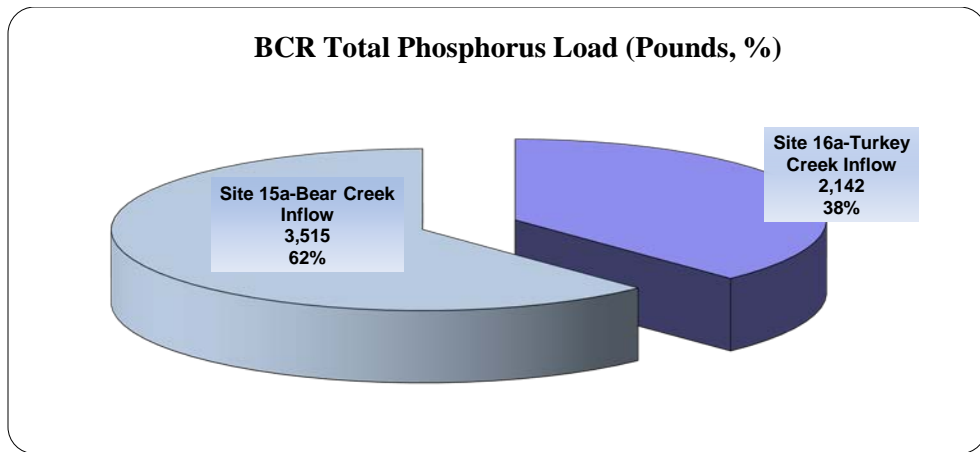


Figure 14 Estimated Total Phosphorus loading into Bear Creek Reservoir

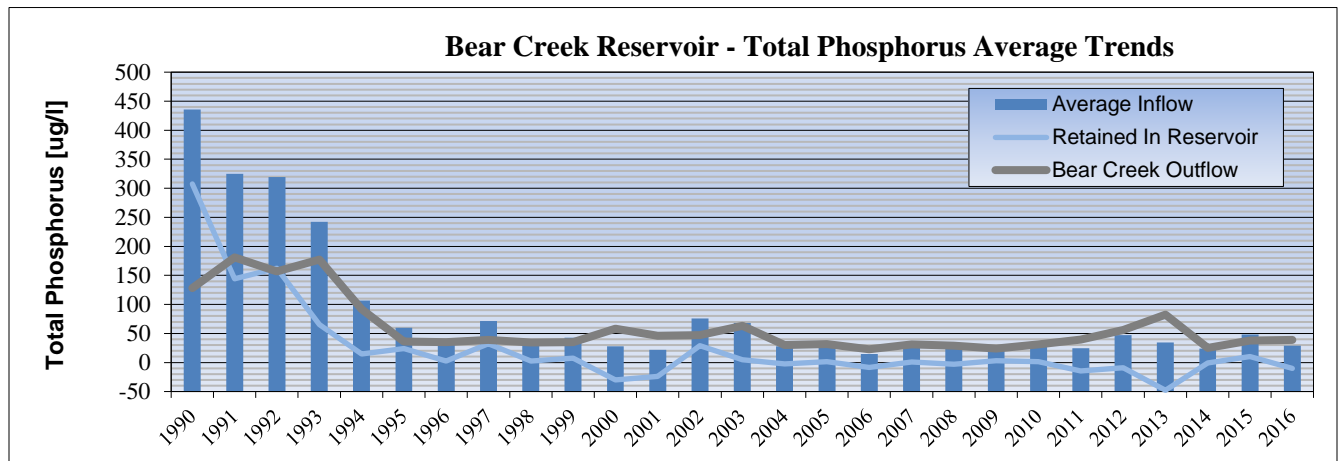


Figure 15 Total Phosphorus Trend BCR

The total nitrogen loading (Figure 16, about 84,580 pounds) had 66% of the load coming from Bear Creek. Figure 17 shows the Total Nitrogen trend in BCR.

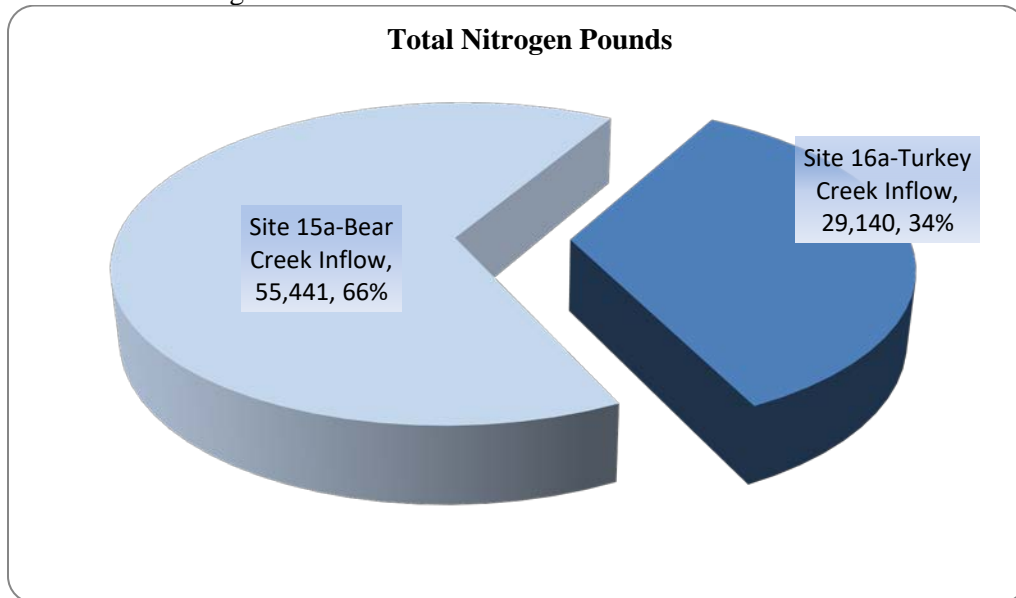


Figure 16 Total Nitrogen Loading into Bear Creek Reservoir

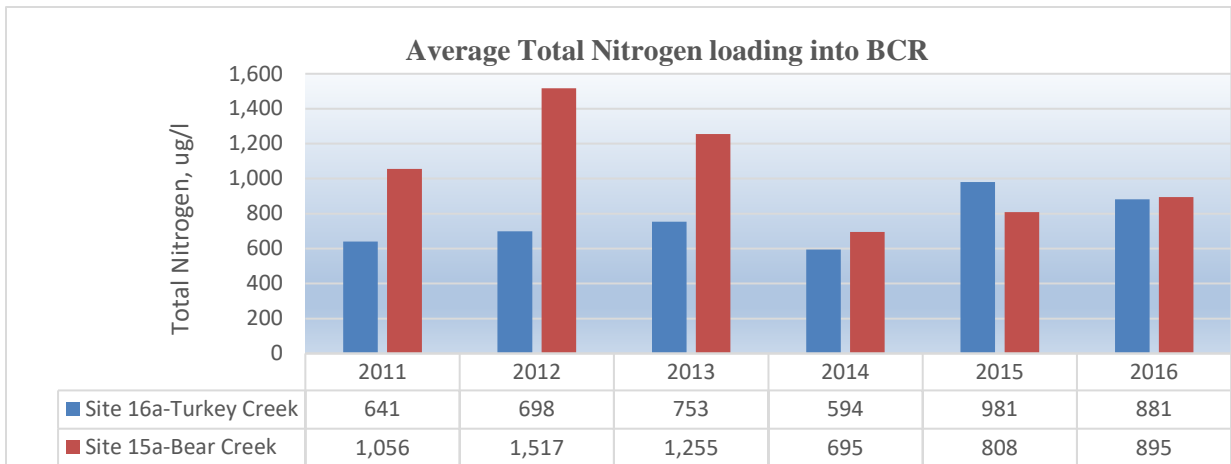


Figure 17 Estimated Total Nitrogen Loading Trend for Bear Creek Reservoir

Bear Creek Reservoir Indicator Trend Variables

The Association’s reservoir monitoring program collects samples to analyze nutrient (nitrogen and phosphorus) concentrations, chlorophyll-a, total suspended sediments, dissolved oxygen, pH, specific conductance, Secchi depth, and phytoplankton population dynamics as trend variables. Table 7 lists the summary statistics for the monitoring variables. Table 8 summarizes the reservoir loading data. Table 9 compares 2016 data with the long-term patterns from 1991 through 2016. In 2016, the chlorophyll concentrations were below the long-term trends, while nitrogen loads were elevated and total phosphorus in the surface waters were reduced. Table 10 summarizes the phytoplankton data. Figure 18 shows the phytoplankton species diversity during summer sampling period. Figure 19 shows the general clarity trend in the water column using Secchi measurements. May through October had the poorest clarity caused by runoff.

Table 7 Bear Creek Reservoir Summary Statistics (July September)

Reservoir Monitoring Parameters	Reservoir
Chlorophyll (Site 40)	
Average Growing Season Chlorophyll-a [ug/l (-1m)]	14.6
Average Annual Chlorophyll-a [ug/l (-1m)]	10.1
Peak Chlorophyll-a [ug/l]	23.9
Total Phosphorus	
Average Annual Total Phosphorus [ug/l]: Water Column	63
Average Annual Total Phosphorus [ug/l] -1m	39
Average Annual Total Phosphorus [ug/l] -10m	93
Growing Season Total Phosphorus [ug/l]: Water Column	95
Growing Season Total Phosphorus [ug/l]: -1m	57
Growing Season Total Phosphorus [ug/l]: -10m	134
Peak Annual Total Phosphorus [ug/l] Water Column	422
Total Nitrogen	
Average Annual Total Nitrogen [ug/l]: Water Column	784
Average Total Nitrogen [ug/l]: -1m	759
Average Total Nitrogen [ug/l]: -10m	799
Growing Season Total Nitrogen [ug/l]: Water Column	670
Growing Season Total Nitrogen [ug/l]: -1m	669
Growing Season Total Nitrogen [ug/l]: -10m	671
Clarity (All Profiles)	
Average Annual Secchi Depth (meters)	1.22
Growing Season Average Secchi Depth (meters)	0.66
Dissolved Oxygen (site 40 Profile)	
Annual Average at -1/2m - 2m [mg/l]	8.56
Seasonal Average at -1/2 - 2m [mg/l]	6.80
Seasonal Minimum at -1/2 - 2m [mg/l]	4.62
pH	
Annual Average at -1/2m - 2m [mg/l]	8.18

Reservoir Monitoring Parameters		Reservoir
Seasonal Average at -1/2 - 2m [mg/l]		8.10
Seasonal Maximum at -1/2 - 2m [mg/l]		8.91
Specific Conductance		
Annual Average at -1/2m - 2m [uS/cm]		398
Seasonal Average at -1/2 - 2m [us/cm]		615
Seasonal Minimum at -1/2 - 2m [us/cm]		261
Phytoplankton Species		
Phytoplankton Co-Dominant Species - Site 40 (July-October 2016)		Aphanizomenon flos-aquae
		Cladophora sp.
		Cryptomonas erosa
		Cymbella minuta
		Cymbella mexicana
		Diatoma vulgare
		Microcystis aeruginosa
		Melosira ambigua
		Melosira granulata
		Melosira varians
		Rhoicosphenia curvata
		Synedra ulna
Peak Phytoplankton		
<i>Aphanizomenon flos-aquae</i>		Density cells/ml = 29,006
<i>Aphanizomenon flos-aquae</i>		Peak Biovolume (um ³ /mL) = 40,202,900

Table 8 Annual Bear Creek Reservoir Load Estimates

Loading - Annual Pound Estimates	
Total Nitrogen -Total Load In to BCR	84,580
Total Nitrogen -Total Load From BCR	90,227
Total Nitrogen -Total Deposition into BCR	-5,646
Total Phosphorus -Total Load In to BCR	5,657
Total Phosphorus -Total Load From BCR	4,369
Total Phosphorus -Total Deposition into BCR	1,288

Table 9 Bear Creek Reservoir Select Trend Parameters

Parameter		2016	91-2016 Mean	91-2016 Median
Chlorophyll-a (ug/L)	Top	10.1	12.5	13.5
Total Nitrogen ug/l	Top	759	733	759
	Bottom	799	435	728
	Water Column	779	368	752
Total Phosphorus (ug/L)	Top	38.7	70.1	39.3
	Bottom	92.8	54.3	61.0
	Water Column	66	30.5	50.7
Secchi Depth (m)	Top	1.2	2.1	2.2

Table 10 Bear Creek Reservoir Phytoplankton Summary Data

Sample Date:	25-Jul-16	25-Jul-16	10-Aug-16	22-Aug-16	12-Sep-16	26-Sep-16	17-Oct-16
Total Density (#/mL):	2,466	1,751	1,066	45,290	70,110	46,755	1,653
Total Biovolume (um³/mL):	2,029,334	1,368,132	388,858	41,700,409	3,474,182	448,372	361,012
Trophic State Index:	54.9	52.1	43.0	76.8	58.8	44.1	42.5

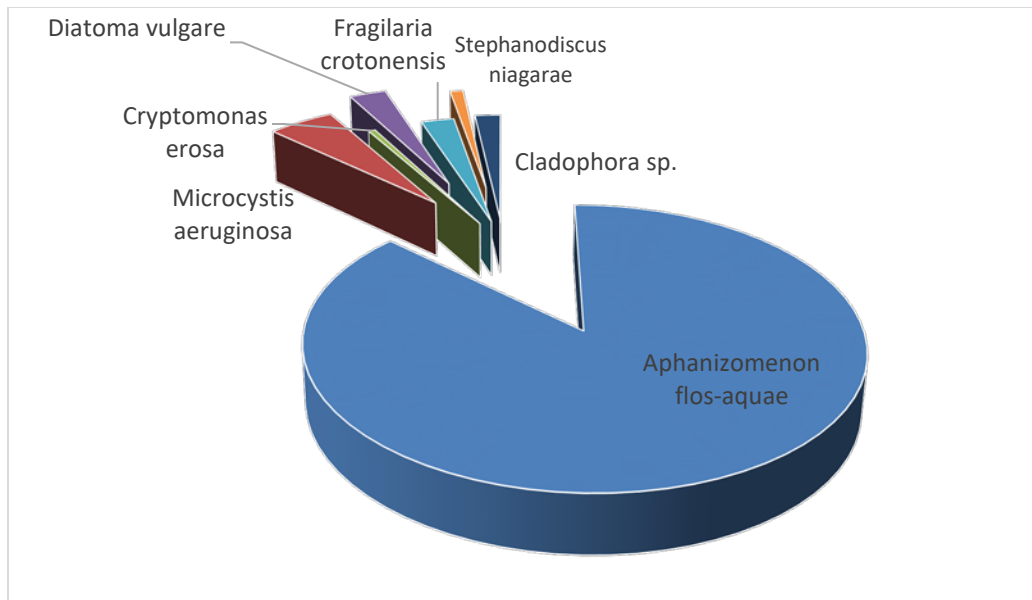


Figure 18 Bear Creek Reservoir Phytoplankton Major Species

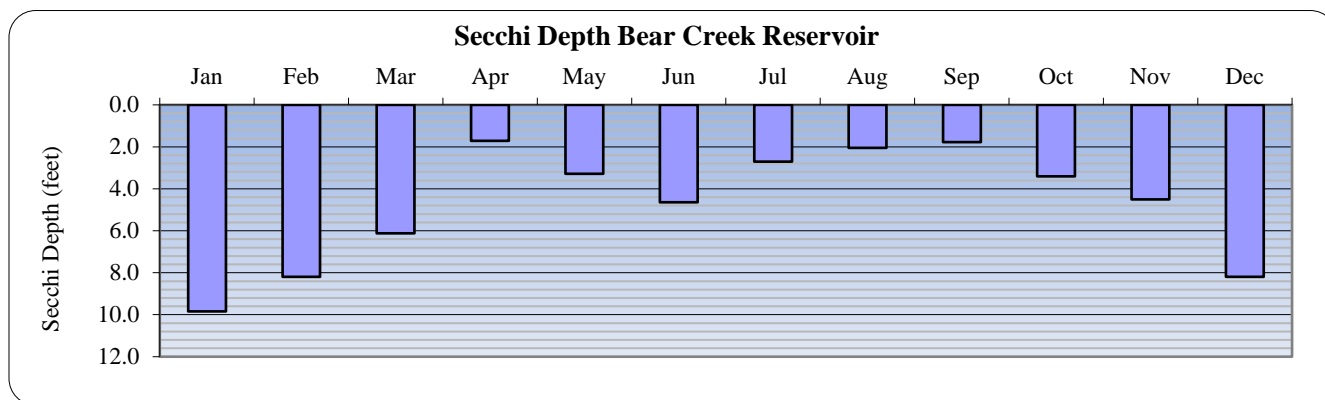


Figure 19 Secchi Depth Bear Creek Reservoir

The reservoir had several algal blooms in 2016 as evidenced by peak August through October chlorophyll concentrations (Figure 20). The peak phytoplankton Biovolume was 40,202,900 $\mu\text{m}^3/\text{mL}$ caused by a blue-greens phytoplankton bloom. Historically, blue-green phytoplankton species are associated with major blooms in the reservoir. The reservoir trophic state was eutrophic (Walker Index, Figure 21). The Carlson Index shows a similar eutrophic trend. Although external nutrient loads were lower than historic trends, the reservoir continues to have an internal nutrient loading problem, which causes eutrophic water quality conditions.

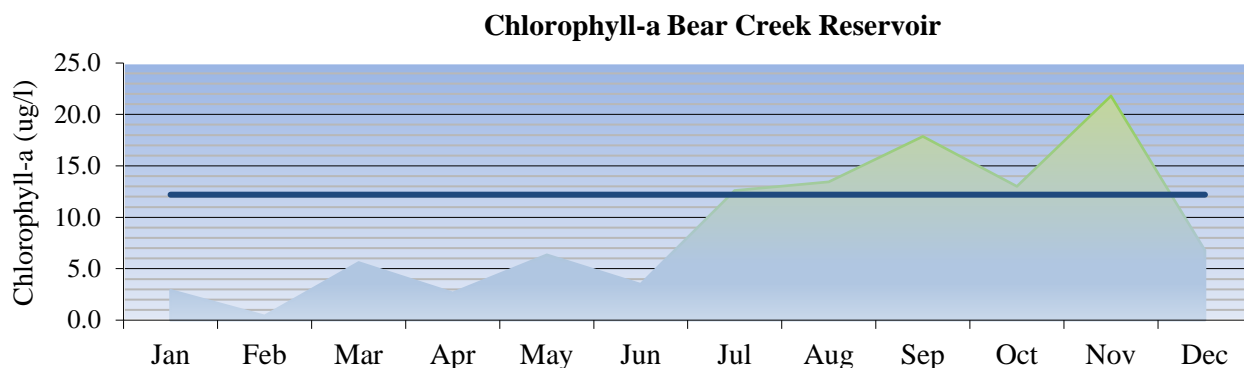


Figure 20 Bear Creek Reservoir Chlorophyll Trend

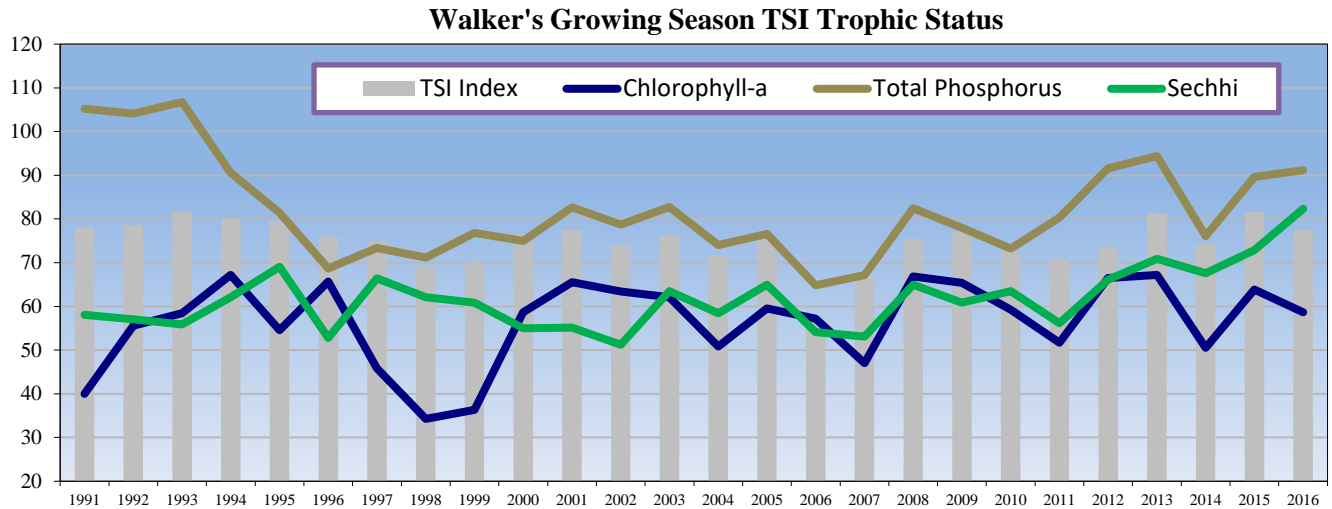


Figure 21 Walker Trophic Index Trend Bear Creek Reservoir

Bear Creek Reservoir Aeration Practice Manages Summer Dissolved Oxygen

The reservoir aeration system reduces chlorophyll productivity, possibly through the partial control of internal nutrient loading that can trigger algal blooms (*BCWA Policy 8 Bear Creek Reservoir Aeration*). The Association adopted a Policy 8 that makes the reservoir aeration system a permanent reservoir management tool. The Association determined through ongoing monitoring that the de-stratifying aeration system in Bear Creek Reservoir is a necessary and long-term or permanent management practice necessary to protect the quality reservoir fishery (Figure 22) and prevent Dissolved Oxygen standard exceedances during summer months of June 1-September 30.

Reservoir aeration is also a necessary management tool in low flow conditions. The aeration system has been operational since the summer of 2002 and uses a fine-bubble diffusion system with aerators distributed across the hypolimnion. In 2016, the Association and Lakewood operated the aeration system to maximize oxygen transfer during phased on-off cycling (Figure 23), with the aeration system phased primarily on in the growing season. In 2016, the Dissolved Oxygen in the upper water column was below the standard in late August and early September. The aeration system can increase the Dissolved Oxygen concentrations throughout the water column by about 2 mg/l within a two-week period.



Figure 22 Fishing Very Popular on Bear Creek Reservoir, Both Winter and Summer

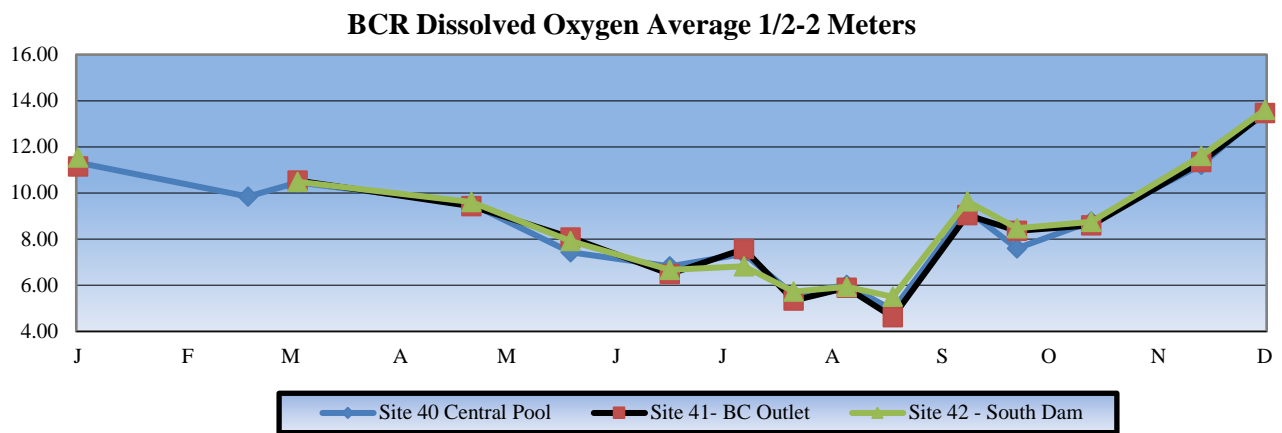


Figure 23 Bear Creek Reservoir Dissolved Oxygen Trend

Aeration System BCR

The September 2013 flood event used Bear Creek Reservoir as a major flood control structure, which caused displacement and reduced efficiency of the in-reservoir aeration system as installed by the City of Lakewood and monitored by the BCWA (*BCWA Fact Sheet 6 Aeration BCR*). A video survey was completed on the BCR aeration system on April 30, 2014 (*BCWA TM2014.01 BCR Video Survey Aerators*). The survey demonstrated air supply line damage (kinks and holes), aeration pan displacement, overturned aeration pans, reduced function, and some losses, which reduced the overall system efficiency by 40-70% (*BCWA Fact Sheet 47 New BCR Aeration System*).

Since FEMA requires *like-kind* replacement, Lakewood determined it would be more cost effective to upgrade and replace the aeration system using Lakewood funding. The BCWA assisted with new aeration configuration, system requirements and replacement options. BCWA and Lakewood staff removed most of the old aeration system and recycled these materials. The company *Underwater Repairs Specialist* installed 6 Quad Duraplate Diffusers (DDP9X4 Keeton Industries) and weighted line in November 2014 with assistance of Lakewood staff that corresponds to the pattern shown in Figure 24. The diffusers are fine bubble (air supplied by a 15 hp compressor) and they will increase the dissolved oxygen transfer into the reservoir water column. Lakewood and BCWA are conducting a three-year evaluation (2016-2018) on the effectiveness and efficiency of the new aeration system in the spring/ summer growing season.



Figure 24 New BCR Aeration Configuration

Sediment Studies Bear Creek Reservoir and Evergreen Lake

The total suspended sediment load in the reservoir has been generally constant over the historic monitoring period with periodic storm events dumping large volumes of sediment into the reservoir. Bottom sediments are a mixture of fine sand, silt and mud. The September 2013 flood event introduced extremely large amounts of sediments. The BCWA had no reliable method to determine the total amount of sediment transported by the

2013 floods. The BCWA approximated the amounts deposited into Evergreen Lake (Table 11) and Bear Creek Reservoir (Table 12). It is very apparent that storm waters moved millions of pounds of sediments. There was extensive erosion throughout the watershed. Streambanks were lost and channels configurations were altered throughout the segment 1e. In August 2016, the BCWA collected sediment samples from six locations in BCR. Sediments were analyzed for total phosphorus content (Table 13 and Figure 25) and organic content (*BCWA TM 2015.01 BCR Sediment Survey*).

Table 11 Estimated Sediment Load into Evergreen lake

Evergreen Reservoir			
Sep-13		Oct-13	
TSS Based (SSL Load)		TSS Based (SSL Load)	
Tons/month	Cubic Yards/Month	Tons/month	Cubic Yards/Month
905	745	28	23
Estimated Bedload		Estimated Bedload	
Tons/month	Cubic Yards/Month	Tons/month	Cubic Yards/Month
13,582	11,179	142	117

Table 12 Estimated Sediment Load into Bear Creek Reservoir

Bear Creek Reservoir			
Sep-13		Oct-13	
TSS Based (SSL Load)		TSS Based (SSL Load)	
Tons/month	Cubic Yards/Month	Tons/month	Cubic Yards/Month
40,933	33,690	1,587	1,306
Estimated Bedload		Estimated Bedload	
Tons/month	Cubic Yards/Month	Tons/month	Cubic Yards/Month
1,023,331	842,248	7,933	6,529

Table 13 Phosphorus Content of BCR Sediments

		mgP/kg Mud
Bear Creek Transect	SedBC03	0.65
	SedBC05	0.47
Pelican Point Transect	SedPel08	1.20
	SedPel10	3.97
Turkey Creek Transect	SedTC14	0.85
	SedTC16	3.64

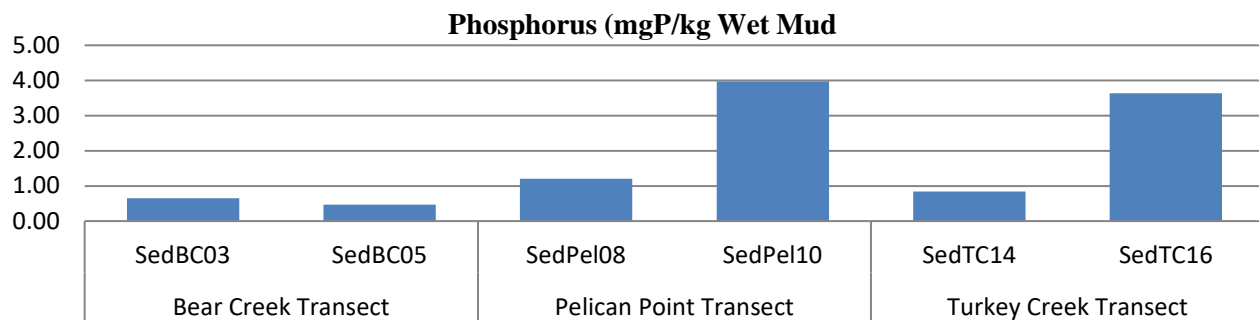


Figure 25 Sediment Phosphorus by Transect in BCR

Evergreen Lake Study

Evergreen Lake (Segment 1d) is a small reservoir constructed in 1927 and serves as a major direct use water supply for the Evergreen community. The lake is an important year-round recreational facility with fishing and winter ice activities. The Evergreen Park & Recreation District provides maintenance around Evergreen Lake. These efforts aid in maintaining good water quality. The District maintains the wetlands located on the west end of the lake, retaining walls and rocks structure that support the road and walking paths, maintains erosion control

features of the area and periodically removes rooted vegetation located along the shoreline and in the lake. In recent years, the Association has increased monitoring efforts to better characterize the reservoir and help protect the quality (Table 14). The Association has established preferred management strategies for Evergreen Lake (BCWA Policy 20).

In the last few years, the dissolved oxygen concentrations in the water column were becoming very low with periodic bottom waters having less than 5 mg/l DO. The Evergreen Metropolitan District in cooperation with the recreation district installed an aeration system near the dam outlet area to help maintain elevated DO levels throughout the lake. The districts in cooperation with the Colorado Department of Parks and Wildlife introduced Grass Carp into the reservoir with the first release of about 100 fish at 20 inches' length. This program reduces the excess Elodea algal (introduced invasive species) growth that contributes to the depressed DO problem. The combination of the aeration system and grass carp program resulted in DO compliance in 2016 monitoring program (Table 14). The Association monitoring program data supports the designation of Evergreen Lake as a direct use water supply.

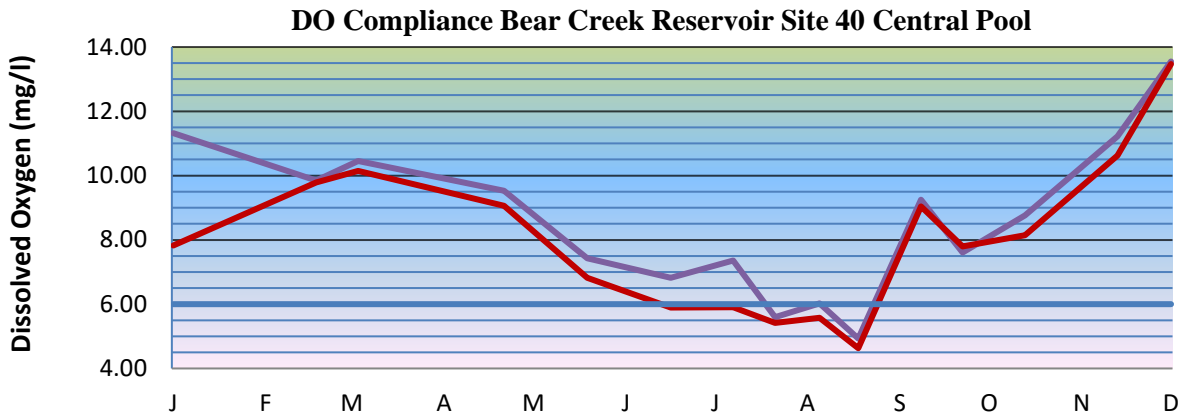
Table 14 Water Quality Data Summary for Evergreen Lake

Evergreen Lake, Segment 1d								
Parameter (ug/l)	4/14/2016	5/26/2016	6/15/2016	7/13/2016	8/10/2016	9/14/2016	10/19/2016	Seasonal Average
Total Nitrogen	308	322	522	341	345	298	278	345
Phosphorus, total	19	27	27	21	28	29	70	32
Residue, Non-Filterable (TSS)	4.0	6.8	6.8	5.2	4.5	7.2	3.6	5
Chlorophyll a		4.1	2.1	2.1	2.9	19.8	8.3	7
Chlorophyll a		4.1	2.1	2.1	4.7			3
Chlorophyll a Average		4.1	2.1	2.1	3.8	19.8	8.3	6.7
Total Nitrogen	331	265	371.0	295	297	253	232	292.0
Phosphorus, total	22.0	26	27.0	21	29	23	67	30.7
Residue, Non-Filterable (TSS)	4.6		8.4					6.5
								Total
Total Nitrogen, Pounds/month	39.8	86.4	137.3	46.9	23.9	13.6	10.6	358
Total Phosphorus, Pounds/month	2.5	7.2	7.1	2.9	1.9	1.3	2.7	26
TSS, pounds/month	517.4	1823.9	1788.7	715.1	311.2	329.4	137.2	5623
Parameter Summary	4/14/2016	5/26/2016	6/15/2016	7/13/2016	8/10/2016	9/14/2016	10/19/2016	
Dissolved Oxygen 1/2-2m		7.29	8.31	8.00	7.42	7.74	9.74	
Temperature (C) 1/2-2m		9.70	13.33	17.30	17.95	14.90	9.93	
pH water column		8.80	8.92	8.28	8.33	7.87	7.99	
Specific Conductance (us/m)		74.8	62.2	61.6	67.7	73.29	77.43	
Bear Creek Keys (cfs) Monthly Avg	47.5	98.5	96.6	50.5	25.4	16.8	14.0	
Bear Creek EGL (cfs) daily		109	105	48	26	15	14	

IV. Meeting Water Quality Goals and Standards for the Watershed

Dissolved Oxygen Compliance in Bear Creek Reservoir

The Association takes multiple profile readings at five profile stations in the reservoir to determine Dissolved Oxygen compliance. The Association Dissolved Oxygen data set from 2003-2016 for Bear Creek Reservoir shows over 99% compliance with the standard for the upper water column (surface through the mixed layer). The monthly Dissolved Oxygen values in the mixed layer in 2016 were generally greater than 6 mg/l (Figure 26). There was an oxygen sag in late August and early September, that correlated with a massive phytoplankton bloom. Data collected in the 2016 growing season shows the aeration system adds a maximum of 1.5 mg/l dissolved oxygen to the water column when under normal operation. Generally, the aeration system increases water column dissolved oxygen by about 1 mg/l, which results in dissolved oxygen compliance within the mixed layer.



	5-Jan	22-Feb	7-Mar	25-Apr	23-May	20-Jun	11-Jul	25-Jul	9-Aug	22-Aug	12-Sep	26-Sep	17-Oct	17-Nov	5-Dec
— Average 1/2-2m (mg/l)	11.32	9.85	10.45	9.53	7.43	6.82	7.36	5.60	6.02	4.93	9.25	7.61	8.76	11.22	13.55
— Profile Average (mg/l)	7.83	9.79	10.15	9.06	6.82	5.89	5.90	5.42	5.58	4.63	9.04	7.80	8.14	10.62	13.47
— DO Compliance (mg/l)	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

Figure 26 DO Compliance Bear Creek Reservoir

Temperature Standards Bear Creek Watershed

Table 15 shows the adopted temperature standards by segment for the watershed.

Table 15 Temperature Standards in Bear Creek Watershed

Segment	Segment	Standard	Month	STANDARD (°C)		Month	STANDARD (°C)	
				(MWAT)	(DM)		(MWAT)	(DM)
1a	Mainstem of Bear Creek from the boundary of the Mt. Evans Wilderness area to the inlet of Evergreen Lake	T=TVS(CS-I) °C	June-Sept	17.0	21.2	Oct-May	9.0	13.0
1b	Mainstem of Bear Creek from Harriman Ditch to the inlet of Bear Creek Reservoir	T=TVS(CS-II) °C; April-Oct; T(WAT)=19.3 °C	April-Oct	19.3	23.8	Nov-March	9.0	13.0
1c	Bear Creek Reservoir.	T=TVS(CLL) °C; April-Dec; T(WAT)=23.3 °C	April-Dec	23.3	23.8	Jan-Mar	9.0	13.0
1d	Evergreen Lake.	T=TVS(CLL) °C	April-Dec	18.2	23.8	Jan-Mar	9.0	13.0
1e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	T=TVS(CS-II) °C; April-Oct; T(WAT)=19.3 °C	April-Oct	19.3	23.8	Nov-March	9.0	13.0
2	Mainstem of Bear Creek from the outlet of Bear Creek Reservoir to the confluence with the South Platte River.	T=TVS(WS-II) °C	March-Nov	27.5	28.6	Nov-March	13.7	14.3
3	All tributaries to Bear Creek, including all wetlands, from the source to the outlet of Evergreen Lake, Except for specific listings in Segment 7.	T=TVS(CS-I) °C	June-Sept	17.0	21.2	Oct-May	9.0	13.0
4a	All tributaries to Bear Creek, including all wetlands, from the outlet of Evergreen Lake to the confluence with the South Platte River, except for specific listings in Segments 5, 6a, and 6b.	T=TVS(WS-I) °C	March-Nov	24.2	29	Dec-Feb	12.1	14.5
5	Swede, Kerr, Sawmill, Troublesome, and Cold Springs Gulches, and mainstem of Cub Creek from the source to the confluence with Bear Creek.	T=TVS(CS-II) °C	April-Oct	18.2	23.8	Nov-March	9.0	13.0

Segment	Segment	Standard	Month	STANDARD (°C)		Month	STANDARD (°C)	
				(MWAT)	(DM)		(MWAT)	(DM)
6a	Turkey Creek system, including all tributaries and wetlands, from the source to the inlet of Bear Creek Reservoir, except for specific listings in Segment 6b.	T=TVS(CS-II) °C	April-Oct	18.2	23.8	Nov-March	9.0	13.0
6b	Mainstem of North Turkey Creek, from the source to the confluence with Turkey Creek.	T=TVS(CS-I) °C	June-Sept	17.0	21.2	Oct-May	9.0	13.0
7	Mainstem and all tributaries to Bear Creek, including wetlands, within the Mt. Evans Wilderness Area.	T=TVS(CS-I) °C	June-Sept	17.0	21.2	Oct-May	9.0	13.0
8	Lakes and reservoirs in the Bear Creek system from the sources to the boundary of the Mt. Evans Wilderness area.	T=TVS(CL) °C	April-Dec	17.0	21.2	Jan-Mar	9.0	13.0
9	Lakes and reservoirs in the Bear Creek system from the boundary of the Mt. Evans Wilderness area to the inlet of Evergreen Lake.	T=TVS(CL) °C	April-Dec	17.0	21.2	Jan-Mar	9.0	13.0
10	Lakes and reservoirs in drainages of Swede Gulch, Sawmill Gulch, Troublesome Gulch, and Cold Springs Gulch from source to confluence with Bear Creek.	T=TVS(CL) °C	April-Dec	17.0	21.2	Jan-Mar	9.0	13.0
11	Lakes and reservoirs in the Bear Creek system from the outlet of Evergreen Lake to the confluence with the South Platte River, except as specified in Segments 1c, 10, and 12; includes Soda Lakes.	T=TVS(CL) °C	April-Dec	17.0	21.2	Jan-Mar	9.0	13.0
12	Lakes and reservoirs in the Turkey Creek system from the source to the inlet of Bear Creek Reservoir	T=TVS(CL) °C	April-Dec	17.0	21.2	Jan-Mar	9.0	13.0

Bear Creek Reservoir Temperature Compliance

The Association takes multiple profile readings at five profile stations in the reservoir and has a temperature data-logger set at site 40 to determine temperature compliance. Figure 27 show temperature standards and the monthly sampling compliance record for Bear Creek Reservoir. The temperature probe string at site 40 measures temperature in the top 2m of the water column (-1/2m, -1m, -1.5m, and 2m); the lower probe was lost during the summer season. Table 16 summarizes the temperature record for the probes. The reservoir had eight daily maximum temperature exceedances in 2016.

Table 16 Temperature Compliance Summary Bear Creek Reservoir

All Temperatures in °C	30-Min Temp. WARM SEASON	Apr 1-Oct 31 Stream Std. WAT (19.3°C)	Apr 1-Oct 31 2-HR Avg. Temp.	Apr 1-Oct 31 Stream DM (23.8°C)
Min	2.2	5.5	2.3	3.6
Max	25.4	23.1	25.0	25.0
Avg	15.4	15.5	15.4	16.0
Std. Dev.	5.3	5.2	5.3	5.3
Measurements	34632	102	8658	720
# 23.3°C WAT exceeded		0		
% Compliance WAT		100%		
# 23.8°C DM exceeded				8
% Compliance DM				99%

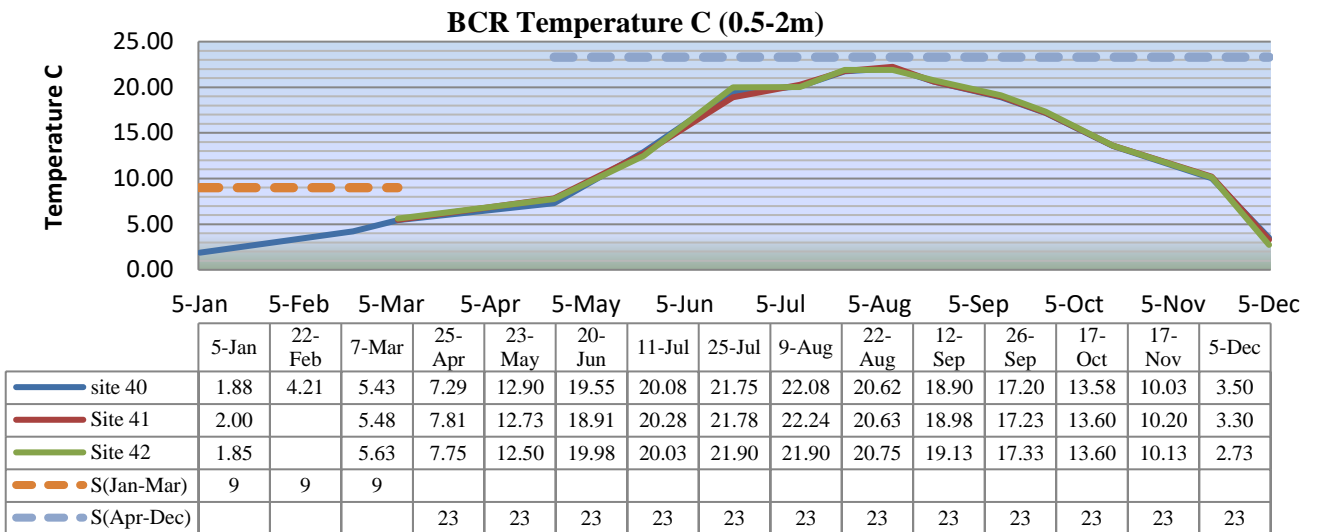


Figure 27 Temperature Compliance Bear Creek Reservoir

Watershed Stream and Lake Compliance

The Association conducts special stream monitoring programs within the Bear Creek Watershed including Bear Creek, and a portion of the Turkey Creek Drainage (North and South Turkey Creek). The monitoring year divides into a warm-season period with more intense sampling and a cold-season period, designed to provide minimal winter and spring data. The Association 2016 Data Report summarizes temperature and water quality monitoring data, sampling results obtained from in-stream locations, and data from five-wastewater treatment plant effluents. The complete water quality data set is an electronic data report.

268,788 individual temperature data points were obtained from the twenty-six data logger sites within the watershed (excluding the WWTP data). The warm-season and cold-season temperature compliance summary is shown in Table 17. A limited number of temperature compliance problems occurred in the cold season during the shoulder season and the warm season.

Table 17 Watershed Temperature Compliance Summary Warm/ Cold Seasons

	Cold-season		Warm Season	
Segment 3	9°C WAT	13°C DM	17°C WAT	21.2°C DM
# Exceedances	1	0	1	0
% Compliance	96	100	96	100
Segment 1a	9°C WAT	13°C DM	17°C WAT	21.2°C DM
# Exceedances	0	0	0	2
% Compliance	100	100	100	99
Segment 1d	9.0°C WAT	13.0°C DM	18.2°C WAT	23.8°C DM
# Exceedances			6	0
% Compliance			95	100
Segment 1e	9°C WAT	13°C DM	19.3°C WAT	23.8°C DM
# Exceedances	0	0	0	0
% Compliance	100	100	100	100
Segment 1b	9°C WAT	13°C DM	19.3°C WAT	23.8°C DM
# Exceedances	0	0	0	0
% Compliance	100	100	100	100
Segment 5	9°C WAT	13°C DM	18.2°C WAT	23.8°C DM
# Exceedances		0	0	0
% Compliance		100	100	100
Segment 6a	9°C WAT	13°C DM	18.2°C WAT	23.8°C DM
# Exceedances	2	0	0	1
% Compliance	75	100	100	99.8
Segment 6b	9°C WAT	13°C DM	17°C WAT	21.2°C DM

	Cold-season		Warm Season	
# Exceedances	0	0	0	0
% Compliance	100	100	100	100
Segment 2	13.7°C WAT	14.3°C DM	27.5°C WAT	28.6°C DM
# Exceedances			0	0
% Compliance			100	100
Segment 1c	9°C WAT	13°C DM	24.0°C WAT	26.0°C DM
# Exceedances			0	8
% Compliance			100	98.9

Stream and lake sampling and monitoring data, including pH, Temperature, Dissolved Oxygen, Specific Conductance, Total Nitrogen and Total Phosphorous was collected from May through October (Table 18). Stream and lake temperature dataloggers located at 28 Sites, including the Evergreen Lake profile station and Bear Creek Reservoir profile station, excluding the five-wastewater treatment plants. Manual flows measured at 22 sites during the May to October timeframe. An aeration system was installed and operational for Evergreen Lake. The only water chemistry exceedances of standards measured in the 2016 watershed-monitoring program occurred at Summit Lake.

Table 18 Water Quality Compliance at Watershed Monitoring Sites

	Stream Std. pH (6.5-9 SU)	Stream Std. DO (6.0 mg/L 2- meter avg.)	Proposed Stream Std Total nitrogen 1250 ug/L	Proposed Stream Std Total Phosphorous (110 ug/L)
Segment 8				
# Exceedances	1	5	0	0
# Measurements	11	11	8	8
% Compliance	82%	55%	100%	100%
Segment 7				
# Exceedances	0	0	0	0
# Measurements	4	4	4	4
% Compliance	100%	100%	100%	100%
Segment 3				
# Exceedances	0	0	0	0
# Measurements	11	11	11	11
% Compliance	100%	100%	100%	100%
Segment 1a				
# Exceedances	0	0	0	1
# Measurements	18	18	18	18
% Compliance	100%	100%	100%	94%
Segment 1d				
# Exceedances	2	0	0	0
# Measurements	70	70	14	14
% Compliance	97%	100%	100%	100%
Segment 1e				
# Exceedances	0	0	0	0
# Measurements	43	43	36	36
% Compliance	100%	100%	100%	100%
Segment 1b				
# Exceedances	0	0	1	0
# Measurements	15	15	15	15
% Compliance	100%	100%	93%	100%
Segment 5				
# Exceedances	0	0	5	2
# Measurements	19	19	19	19
% Compliance	100%	100%	74%	89%
Segment 6a				
# Exceedances	0	0	0	0
# Measurements	21	21	21	21
% Compliance	100%	100%	100%	100%

	Stream Std. pH (6.5-9 SU)	Stream Std. DO (6.0 mg/L 2- meter avg.)	Proposed Stream Std Total nitrogen 1250 ug/L	Proposed Stream Std Total Phosphorous (110 ug/L)
Segment 6b				
# Exceedances	0	0	0	0
# Measurements	4	4	4	4
% Compliance	100%	100%	100%	100%
Segment 4a				
# Exceedances	0	0	6	0
# Measurements	6	6	6	6
% Compliance	100%	100%	0%	100%
Segment 2				
# Exceedances	1	1	1	0
# Measurements	30	30	30	30
% Compliance	97%	97%	97%	100%

303(d) Listing

Table 19 shows the stream segments in the Bear Creek Watershed that are on the Colorado 303(d) list. 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.

Table 19 303(d) List Bear Creek Watershed

WBID	Segment Description	Portion	Colorado's M & E List	303(d) Impairment	303(d) Priority
COSPBE01a	Mainstem of Bear Creek from the boundary of the Mt. Evans Wilderness area to the inlet of Evergreen Lake.	Bear Creek below the confluence with Yankee Creek		Temperature	H
COSPBE01b	Mainstem of Bear Creek from Harriman Ditch to the inlet of Bear Creek Reservoir	all	-	Temperature	M
COSPBE01c	Bear Creek Reservoir	all		Chl-a, phosphorus	H
COSPBE01e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	all	-	Temperature	H
COSPBE01e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	Mount Vernon Creek to the Harriman Ditch	-	Cu	H
COSPBE02	Bear Creek below Bear Creek Reservoir to South Platte River	Below Wadsworth Boulevard	-	<i>E. coli (May-Oct)</i>	H
COSPBE02	Bear Creek below Bear Creek Reservoir to South Platte River	all	-	Aquatic Life (provisional), As	H/L
COSPBE03	All tributaries to Bear Creek, from the source to the outlet of Evergreen Lake	Vance Creek		Temperature	H
COSPBE06a	Turkey Creek system, including all tributaries from the source to the inlet of Bear Creek Reservoir	Turkey Creek below Parmalee Gulch	Temperature		
COSPBE06b	Mainstem of North Turkey Creek, from the source to the confluence with Turkey Creek	all	Temperature		
COSPBE11	Lakes and reservoirs in the Bear Creek system from the outlet of Evergreen Lake to the confluence with the South Platte River	Harriman Reservoir	As		

Barr/Milton Model Input and Bear Creek Load Predictions

The Bear Creek Watershed is in the defined “data” shed for the BMW pH/DO TMDL. Discharge from Bear Creek Reservoir is identified as a “point” source and input to the BMW pH/DO TMDL and model. As such, the BCWA site 45 is a source that contributes about 1.8 % of the external load of Total Phosphorus. The BMW pH/DO TMDL established the limiting contribution of Total Phosphorus from Bear Creek for both Barr Lake and Milton Reservoir at 1,167 kg/year or 2,672.7 pounds/year. In the period from 2000 through 2016, the average Total Phosphorus at BCWA site 45 was 2,786 pound/year (*BCWA TM 2016.07 Barr Milton TMDL Summary*). The Association annually provides the Barr/Milton Watershed Board a technical memorandum detailing water quality data at site 45 BCWA TM 2016.07, March 2017).

Macroinvertebrate Analysis and Aquatic Life Compliance

Since 2004, the Association has conducted macroinvertebrate sampling and data collection at 14 sites, including Colorado Parks and Wildlife fish survey sites along Bear Creek: Morrison (west end), Idledale, Lair o' the Bear Park, O' Fallon Park, Bear Creek Cabins, Main Street Evergreen (across from the Little Bear), above Evergreen Lake upstream within Dedisse Park, Bear Tracks, above Singing River Ranch at the Mt. Evans Boundary area, and Golden Willow Bridge. The sampling design in Bear Creek has targeted a combination of slow and fast riffles with various amounts of cobble substrate at the sites. The program provides information on site variation, including both spatial and temporal variation at each site. Table 20 summarizes existing macroinvertebrate data. There was macroinvertebrate sampling done in 2016 (*BCWA TM2016.11 and 11b Macroinvertebrate Summary*). There was an MMI compliance problem at the Keys on the Green monitoring station.

Table 20 MMI Attainment and Impairment Summary for Bear Creek Watershed

WQCD Station ID	BCWA Station ID	Location	Biotype	MMI						
				2016	2015	2014	2012	2011	2010	2009
5756a	15a	BCLP @ bridge	Transition	67.0	59.1	66.4				
122	14a	Morrison @ Gage	Transition	72.0	73.5	48.8	72.9	74.5	80.5	69.8
122C	13a	Idledale	Transition	50.0	59.2	59.3	68.0	57.1	69.8	62.1
122a	12	Lair O' Bear	Transition	46.0	72.2	49.5	51.3	56.4	62.2	58.5
122b	9	O' Fallon	Transition	57.0	59.1	44.8	49.9	45.5	57.7	53.6
5762	8b	BCC @ Bridge	Transition	59.0	62.3	49.6	44.3	51.1	39.1	55.6
5763	5	Little Bear	Transition	75.0	68.9	56.2	40.0	42.9	56.6	52.3
5764	3a	Keys @ bridge	Mountain	37.0	63.6	43.9	46.9	45.3	36.9	38.6
5768d	2a	Golden Willow	Mountain	65.0	56.6	60.8	71.9			
5768c	58	Mt Evans Wilderness	Mountain	67.0	53.8	67.0	72.5	55.5		
	90	Wadsworth	Transition	55.0						

V. Wastewater Treatment Facilities Loading and Compliance

Wasteload Compliance

The total wasteload allocation of phosphorus from all wastewater treatment facilities in the Bear Creek Watershed is 5,255 pounds per year. Table 21 lists the permitted wastewater treatment facilities. Each discharger is limited to an annual wasteload of total phosphorus, except as provided through trading provisions. Wastewater discharges cannot exceed a total phosphorus effluent concentration of 1.0 mg/l as a 30-day average. No facility exceeded the assigned wasteload allocations (Table 21).

Table 21 Treatment Facility Wasteload Allocations

Bear Creek Watershed Wastewater Treatment Plants by Drainage Basin	WQCC Adopted Phosphorus WLA Pounds/ year	2016 Discharged Phosphorus Pounds/year	% Allocation Used by WWTPs
Bear Creek Drainage			
Jefferson County Schools – Mt. Evans Outdoor Lab	20	6.34	32%
Brook Forest Inn ¹	5	4	80%
Evergreen Metropolitan District	1,500	327.43	22%
West Jefferson County Metro District	1,500	290.98	19%
Kittredge Sanitation and Water District	240	63.32	26%
Genesee Water and Sanitation District	1,015	212.26	21%
Forest Hills Metropolitan District	80	27.82	35%
Town of Morrison	600	77.87	13%
<i>Bear Creek Total</i>	4,960	1,010.02	20%
Turkey Creek Drainage			
Conifer Metropolitan District	40	2.72	7%
Conifer Sanitation Association	40	5.08	13%
Aspen Park Metropolitan District	40	5.1	13%

Jefferson County Schools - Conifer High School	110	1.17	1%
Geneva Glen ²	5	5	100%
Bear Creek Development Corp. - Tiny Town ³	5	Hauling Columbia	
<i>Turkey Creek Total</i>	240	14.07	6%
Total Operational Facilities Lbs./year	5,200	1,024.09	20%
Reserve Pool ⁴	55	0	0%
Total Phosphorus Wasteload lbs./year	5,255		

1-Brook Forest Inn - Compliance Advisory, Reported Effluent Violation, Notice of Significant Non-Compliance by WQCD

2-Geneva Glen- Compliance Advisory, Reported Effluent Violation, Notice of Significant Non-Compliance by WQCD

3-Records from Columbia Sanitary show they hauled 107,300 gallons in the 2016 operation season

4- The reserve pool in the Control Regulation is 2 pounds of total phosphorus, the 55 pounds listed by the BCWA includes pounds from closed treatment facilities (Singing River Ranch (30), The Fort Restaurant (18), Bear Creek Cabins (5)).

Keeping these pounds in the reserve pool maintains the fixed total wasteload allocation established by the Control Regulation at 5,255 pounds/year.

Permit Compliance and Plant Expansions/Actions

Table 22 shows permitted and closed wastewater treatment facilities in the watershed, estimated 5-year status of wastewater planning, and reported permit compliance problems. All wastewater treatment plants in the watershed are minor facilities using the WQCD permit classification system. The Association does continuous planning and review efforts for all facilities, and produced a series of summary information sheets specific for dischargers.

Table 22 Wastewater Treatment Plant Planning Status

Facility	Wastewater Utility Plan	Electronic Planning Documents	Recent Upgrades (3 yrs.)	Facility Upgrades [2017-2022]	Existing Compliance Concerns ¹	Informational Sheet
Evergreen Metropolitan District	Yes	WQCD Fact Sheet, WQA, Permit	Lift Station	Yes	TIN	IFS01
West Jefferson County	Yes	WQCD Fact Sheet, WQA, Permit	No	Yes	TIN	IFS03
Genesee	Yes	WQCD Fact Sheet, WQA, Permit	No	No	TIN	IFS04
Morrison	Yes	WQCD Fact Sheet, WQA, Permit	New WWTF	Yes	Mixing zone, Low Flows Bear Creek	IFS05
Kittredge	Yes	WQCD Fact Sheet, WQA, Permit	No	Yes	TIN	IFS02
Forest Hills Metropolitan District	Yes	Site Application Engineering Report, Permit (2009)	New WWTF	No	TP	IFS06
Conifer Metropolitan District	Yes	WQCD Fact Sheet, WQA, Permit	Yes, TDS	Yes	TDS	IFS08
Conifer Sanitation Association	Yes	Lift Station Rpt	Site Maintenance	Yes	No	IFS08
Aspen Park Metro District	Yes	WQCD Fact Sheet, WQA, Permit	Infiltration gallery, Outfall	Yes	Gallery Operation	IFS07
JCS Conifer High School	Yes	Site Application, Lift Station	Lift Stations, UV	Yes	Ammonia, TRC, UV	IFS10
JCS Mt Evan Outdoor	Yes	Site Application, New Plant Rpt	New WWTF	No	TP	IFS11
Bear Creek Development Corp. - Tiny Town	No	Land Application Rpt	Hauling Columbia	Yes	Reporting, WLA	No
Bear Creek Cabins	No	Permit	No	Closed Permit, Converted OWTS	No	Closed
Brook Forest Inn	No	WQCD Rational, WQA, Permit, Review	New upgrades	Yes	Reporting, WLA/TP, Compliance Order	IFS09
Geneva Glen	No	Permit, WQA, WQCD Fact Sheet	No	New Land Application	Reporting, WLA/TP, Compliance Order	In Progress

Facility	Wastewater Utility Plan	Electronic Planning Documents	Recent Upgrades (3 yrs.)	Facility Upgrades [2017-2022]	Existing Compliance Concerns ¹	Informational Sheet
The Fort	Yes	Site Application, Closed	New OWTS	No	No	Closed
Singing River Ranch	No	WQCD Fact Sheet, WQA, Permit	No	Closed Permit, Converted OWTS	No	Closed

¹ - All treatment facilities have expected new discharge limits (within 5-years) for total phosphorus and temperature. Several facilities are monitoring for temperature. Under Regulation 85 there are expected new nitrogen limits necessary to meet stream nitrogen standards.

Utility Supported Programs

Pharmaceutical Recycling Program

The Association financially supports a used medicine drop-off location in Evergreen (BCWA Fact Sheet 23). The utilities have sent notices with their monthly billings to support pharmaceutical recycling programs.

Sanitary Sewer Incentive Programs in the Evergreen Area.

The Evergreen Metropolitan District and Upper Bear Creek Water and Sanitation District offer a 50% discount to the current sewer tap fee to property owners within the District Boundaries with Individual Septic Disposal Systems willing to connect.

The West Jefferson County Metropolitan District offers a discount of \$9,000 to the current sewer tap fee to property owners within the District Boundaries willing to connect their ISDS to the distribution system.

Trading Program

The Association maintains a pollutant-trading program as defined in *Trading Guidelines* (Association 2006) and in *Bear Creek Reservoir Control Regulation #74* for total phosphorus trades specific to the Bear Creek Watershed: Point source to point source trades (regulation and permit); and Nonpoint source to point source total phosphorus trading specific to the Bear Creek Watershed (*Trading Guidelines*). The *Bear Creek Trading Guidelines* allow permitted point source dischargers (Colorado Wastewater Discharge Permits) to either receive phosphorus pounds for new or increased phosphorus wasteload allocations in exchange for phosphorus loading reductions from nonpoint source pollutant reduction or through approved point source trades. Table 23 lists all Association trades. The reserve pool held 55 pounds in 2016, due to the closure of three WWTFs. The trades in the watershed remain consistent with the total wasteload allocations listed in Table 23. The Association has developed three policies to support the trading program:

1. BCWA Policy 1 Trading Program - The BCWA supports nutrient (nitrogen and phosphorus) trading as a long-term and necessary water-quality management practice for the Bear Creek Watershed. The BCWA will maintain and periodically update Nutrient Trading Guidelines.
2. BCWA Policy 19 Nutrient Trade Eligibility - The BCWA defines eligible participants and sets minimum criteria for eligibility in a Bear Creek Association Trade Agreement.
3. BCWA Policy 26 Point to Point Trade Administration – The BCWA establishes a trade administration program to help assist small wastewater dischargers in the watershed and sets a value to phosphorus trade credits.

Table 23 Phosphorus Trading Activity in Bear Creek Watershed

Involved Agencies	Type of Trade	Active Trading in 2013
Forest Hills Metro District (FHMD) had trade agreement with West Jefferson County Metro District(WJCMD) ¹	Point Source to Point Source	No- Discontinued in 2012
City of Lakewood Coyote Gulch Project	Nonpoint Source trade credits	Under data collection/ reviewed by Association; trade credit calculated in 2011/ confirmed 2013
The Fort Restaurant	Reserve Pool to Point Source (Return to Reserve Pool)	Closure in Progress; Trade reflected in reserve pool limit previously granted by the WQCC

Involved Agencies	Type of Trade	Active Trading in 2013
Jefferson County Schools (Conifer High School and Mt. Evans Outdoor School)	Point Source to Point Source	In Discharge Permits; no change in pounds; reallocation between facilities
Conifer Metropolitan District	Reserve Pool to Point Source	Trade reflected in reserve pool limit previously granted by the WQCC

Watershed Stormwater Management

City of Lakewood MS4 Program

The City of Lakewood has a municipal separate storm sewer permit (*CDPS Stormwater Permit Annual Report for 2016, Municipal Stormwater Permit No.: COS-000002*; City of Lakewood, April 1, 2017). The Stormwater Management Program for the City of Lakewood, Part I.B.1 of the City’s permit, consists of six different programs: Commercial/Residential Management Program, Illicit Discharges Management Program, Industrial Facilities Program, Construction Sites Program, Municipal Facility Runoff Control Program, and the Wet Weather Monitoring Program.

Lakewood supports many stormwater management programs in the watershed, including the *Rooney Road Recycling Center*, which also serves as watershed pollution prevention BMP. Household hazardous waste (includes electronic waste, household chemicals, paints, propane cylinders and automotive products) materials collected at the Rooney facility since 1994 total more than 6,278,498 lbs of potential surface water and ground water pollutants. Unfortunately, yard waste, construction lumber and tree limbs are no longer collected at the facility to be, ground, chipped and 100% recycled into mulch and compost. The Lakewood facility collects multiple types of waste products for proper disposal (includes oil, paint, antifreeze, misc. chemicals, and solid wastes) from the mountain areas as well as the Front Range. This process keeps materials out of septic systems and helps reduce illegal dumping in the watershed.

Lakewood regularly reports to the Association on stormwater management practices and programs. More information about Lakewood’s municipal stormwater program is contained in their CDPS Stormwater Permit Annual Report.

Jefferson County MS4 Program

Jefferson County has a municipal separate storm sewer permit and Jefferson County’s program includes Public Education and Outreach; Public Participation and Involvement; Illicit Discharge Detection and Elimination; Construction Site Runoff Control; Post Construction Site Runoff Control; and Pollution Prevention/Good Housekeeping (Table 24). The county provides opportunities for residents and visitors in the watershed to learn and be involved in environmental stewardship and programs that promote water quality. The county has a comprehensive storm sewer outfall map to trace sources of potential illicit discharges and illegal dumping in the watershed. Jefferson County continues to participate with Rooney Road Recycling Facility and in 2016 the facility collected over 604,000 pounds of household hazardous waste. Jefferson County participated in a number of public events to reach diverse audiences for their MS4 and floodplain management programs.

Table 24 Summary of 2016 MS4 Programs for Inspections and Enforcement Actions

Land Use Agency	Permit Inspections			Permit Enforcement Actions		
	Illicit Discharges	Construction	Post Construction	Illicit Discharges	Construction	Post Construction
Jefferson County	9	1173	4	9	34	0

Jefferson County also maintains an erosion and sediment control program as part of their MS4 permit. The county maintains a small-site erosion control manual that explains the basic principles of erosion control and illustrates techniques to control sediment from small development sites. Jefferson County has an inspection program for illicit discharges, construction activities, and includes post-construction Inspections.

Jefferson County regularly reports to the Association on stormwater management practices and programs. More information about Jefferson County’s municipal stormwater program is contained in their CDPS Stormwater Permit Annual Report.

BCWA Stormwater Monitoring Program

The Association gathers data prior to, during and after storm events occurring in the watershed. Continuous monitoring of storm events could allow up to 36 hours of data. The parameters are temperature, dissolved oxygen, pH, and conductivity. The intent is to measure changes in these parameters due to run off from adjacent properties including roadways, parking lots and open spaces. The Association is developing a separate stormwater data set.

The Association monitors selected stormwater loadings in locations in the middle section of the watershed. The Association identified several potential stormwater runoff locations requiring corrective land use controls. The Association works with local businesses that cause minor nonpoint source runoff from their business sites with the implementation of runoff controls. These runoff control programs are successful. The Association actively identifies erosion problem areas for potential future projects.

The *BCWA Policy 3 4-Step Review Process* used by the Association (referral processes for land use applications from Jefferson and Clear Creek Counties) is directed at land disturbances that have a potential to cause water quality degradation. Specifically, the policy directs the Association to evaluate stormwater runoff and determine if the application contains appropriate techniques to mitigate any significant runoff that could degrade receiving water quality.

Clear Creek County Stormwater Management Program

Clear Creek County has posted several educational materials on the county website directed at stormwater management on home-sites, commercial properties, along mountain roadways and driveways, to protect groundwater and surface water resources. The report *Managing Stormwater to Protect Water Resources in Mountainous Regions of Colorado* (Clear Creek County Community Development, July 2009) outlines appropriate best management practices, techniques to maintain pre-development hydrology, and resource impacts from development in mountainous terrain.

VI. Nonpoint Source Program

Onsite Wastewater Treatment System Management

In 2016, the Association continued limited discussions with Jefferson County Health Department based on previous presentations made to the Jefferson County Board of Health and the Jefferson County Commissioners. Jefferson and Clear Creek counties reviewed their onsite wastewater treatment system (OWTS) regulations. The Association suggest that OWTS in several specific areas in the Bear Creek Watershed contribute to water quality degradation. There are 9,000 +onsite systems in the watershed, depending on the estimation method. Based on existing county taxing records, there are an estimated 12,000+ lots where there is a permitted onsite system, un-permitted system or developable lot.

The Association has two policies directed toward site-specific wastewater treatment/ disposal systems in the watershed.

1. *BCWA Policy 11 Site-Specific Wastewater Treatment/ Disposal Systems* - There are five types of human-generated wastewater treatment/disposal types currently in use within the Bear Creek Watershed. Besides point sources, there are four types of small site-specific wastewater treatment/disposal systems include both publicly-owned and individual or private systems. State and county regulations cover these systems (Clear Creek, Jefferson and Park counties). There are not good inventories, only rough estimates, available to the BCWA for these small site-specific wastewater treatment/disposal systems. *The BCWA asserts any publicly owned and operated site-specific wastewater treatment/disposal systems (SSWDs) have the potential to adversely affect water quality within the Bear Creek Watershed. Pollution caused by SSWDs will be considered by the BCWA as “point sources”. As such, nutrient point source pollution sources in the watershed maybe subject to a wasteload allocation under existing regulation. Water quality degradation associated with publicly owned SSWDs may be included in the BCWA annual report to the Colorado Water Quality Control Commission as an unregulated point source pollution problem.*

2. *BCWA Policy 11 Supplement* – 1) Clear Creek County ISDS Vault and Privy Regulations and 2) Jefferson County ISDS Vault and Privy Regulations

The Association has two special monitoring efforts in progress to determine surface water quality affected from areas on OWTS: Kerr/Swede Gulch and Cub Creek. The Kerr/Swede Gulch focused on a limited number of OWTS (<35) that potentially add nutrients to the lower portion of the drainage between site 52 (Confluence) and site 53 (Riefenberg). The monitoring program suggests there is a nutrient load that is potentially related to OWTS discharge (*TM 2015.03 Kerr Swede 2015 Complete*).

The Association is also monitoring upstream and downstream on Cub Creek where there are > 1,000 OWTS. Many these systems are located within the alluvial corridor. These systems have a greater potential to seep nutrients into Cub Creek (*BCWA WQSD06 Nutrient Loading Cub Creek 2013-2016*).

Total nitrogen and total phosphorus concentrations and loads from Cub Creek [BCWA Sites 38 and 88 (Upper Cub Creek and Site 50 (lower Cub Creek Cub Creek)], indicate a nutrient loading concern that is not attributable to the Brook Forest Inn wastewater discharge (Table 25). There has been speculation that this nutrient loading could be associated with other unspecified upstream nonpoint source loads. The BCWA has sampled Cub Creek from 2012-2016, as part of the watershed sampling program. In 2016, a special field investigation was done to identify potential upstream “hot” spots along this creek. The special survey’s nutrient results are included in this data summary. The total phosphorus load distinctly increases from upstream to downstream. The measured nitrogen levels appear to decrease with instream uptake. The visual evidence of nutrient loading in Cub Creek is very evident at the lower site (50) with the coverage of periphyton (algal growth) on hard substrate in the stream often exceeding 50% by late summer.

A special study of Cub Creek from 2012-2016 shows this tributary discharges from 250 to 3,040 pounds of total phosphorus per monitoring season into Bear Creek downstream of Evergreen Lake. The seasonal average total phosphorus load in upstream waters is 304 pounds with the downstream average substantially increasing to 1,378 pounds. While there are other types of nonpoint source nutrient sources within the Cub Creek corridor, OWTS are the most likely source for the excess total phosphorus loading along Cub Creek. This nutrient loading has also been seen on other tributaries within the watershed that have OWTS (e.g., Kerr/ Swede Gulch, *TM 2015.03 Kerr Swede 2015 Complete* and Yankee Creek, *BCWA WQSD02 Upper Bear*) or at special monitoring sites located downstream of a OWTS cluster (Troublesome, *BCWA WQSD01 Troublesome*). Consequently, the BCWA believes the phosphorus load in this drainage is a result of seepage from these OWTS located within the alluvial corridor. This is a major nutrient contributing tributary in the middle of the watershed.

Table 25 Nutrient Loading on Cub Creek

		Total Phosphorus pounds/month								
Site Location by Stream Segment	Year	May	Jun	Jul	Aug	Sep	Oct	Nov	Seasonal	% Increase
Cub Creek, Upstream @ Brookforest Inn	2013		4	1	1	42	3	1	52	
	2014	8	6	820	5	5	8		851	
	2015	84	22	14	4	2	2		129	
	2016	178	4	1	0	0	1		184	
Cub Creek, Upstream of Cub Creek Park	2013		7	3	17	275	40	18	359	694%
	2014	33	8	2,947	26	7	17		3,038	357%
	2015	336	1,232	102	191	1	2		1,864	1445%
	2016	125	89	16	14	5	2		253	137%
		Total Nitrogen pounds/month								
Site Location by Stream Segment	Year	May	Jun	Jul	Aug	Sep	Oct	Nov	Seasonal	% Increase
Cub Creek, Upstream @ Brookforest Inn	2013		17	17	43	628	91	19	814	
	2014	235	117	1,255	130	82	201		2,020	
	2015	1,019	260	106	47	9	91		1,532	
	2016	746	66	19	18	16	9		874	

Cub Creek, Upstream of Cub Creek Park	2013		72	59	334	2,151	240	278	3,133	385%
	2014	1,295	160	7,145	423	115	402		9,539	472%
	2015	2,274	2,685	552	1,063	11	73		6,658	435%
	2016	1,242	730	340	67	25	6		2,410	276%

Selected Watershed Nonpoint Source Programs

The management of nonpoint sources in the Bear Creek Watershed is a component of the Association planning and management programs. Phosphorus reduction from nonpoint sources is still required in the watershed. A lack of implementation authority limits the nonpoint source program. The Association does maintain a comprehensive watershed-monitoring program to determine sources of nutrient loading into waterways.

Policy Direction

The Association has established policies to help manage nonpoint sources within the watershed:

1. *BCWA Policy 15 Nonpoint Source Strategies and BMPs* - The Association maintains a comprehensive watershed-monitoring program to determine sources, including nonpoint sources, of nutrient loading into waterways. The policy shows management strategies and implementation tools used by the Association.
2. *BCWA Policy 17 Beneficial Recycling of Natural Resources in Bear Creek Watershed* - The Association considers recycling as a best management practice that can help manage natural resources and protect water and environmental quality in the watershed. Recycling programs protect water quality by reducing or eliminating pollutants before they become a problem. Recycling programs can manage household hazardous waste products, organic material/yard wastes, slash, manure generated at stabling operations, clean fill material, recyclable materials (e.g., cans and bottles).
3. *BCWA Policy 18 Illegal Material Dumping as a Pollutant in Bear Creek Watershed* - The Association considers the disposal of, including but not limited to, construction waste, yard waste, organic material (e.g., pine needles) or other plant materials into waterways within the watershed as nonpoint source pollution. This form of waste disposal can harm water quality and is not an acceptable practice in the watershed.
4. *BCWA Policy 27 Source Water Protection* - The BCWA supports the designated areas of concern identified in the Phase 2 Bear Creek Wildfire/Watershed Assessment Report and acknowledges that there is a potentially high risk from wildfires that could significantly impact water supply infrastructure and source waters within portions of the watershed

Water Quality Monitoring Tiers

Activities, unregulated point sources and nonpoint sources in the watershed have the potential to generate water quality pollutants. However, not all activities, unregulated point sources or minor “non-point” sources of pollutants cause measurable degradation of waters within the watershed. As such, the BCWA asserts it will be more effective over the next 6-years (through 2023) to target a more limited subset of unregulated point and non-point sources within the watershed that have the greatest potential to cause either site-specific or watershed-wide water quality degradation (*BCWA Policy 10 Water Quality Monitoring Priority Tier Designations*).

Online Management System (ACM DSS)

Association member organizations and staff were involved in collaborative development of an online watershed management system through a Colorado State University dissertation research case study project. The purpose of the system was to increase the capacity of BCWA to adapt to changing circumstances and to cooperate more effectively with public landowners and community members to achieve greater reductions over time. Modules include issues reporting, interactive maps, group search, a topical knowledge base, projects and options, and watershed plan input.

The Association established an Adaptive Co-Management Decision Support System (ACM DSS) as a BCWA best management practice (*BCWA Policy 21 Online management System*), which can help address nonpoint

sources within the watershed. This online management process is an interactive decision support tool to help manage natural resources and protect water and environmental quality in the watershed. The ACM DSS or online management process functions to: 1) Evolve and document the BCWA membership and manager understanding of the watershed characteristics and responses, risks and uncertainties; 2) Provide a method to learn from past actions and better plan for future actions with an express goal to improve overall watershed resilience; and 3) Maintain an online management mechanism to forge partnerships for shared governance and coordinated response to unexpected events.

The Association can review ACM DSS analytical results as entered and maintained in the *Plan*, *Monitoring Data*, and *Maps* sections of the online program, and use the *Issues Reporting Tool* to report problems in the watershed. The Association membership and manager can create mitigating *Projects*, and then identify stepwise *Options* to pursue these goals, incrementally. Projects and options are by the membership as personal watershed improvement goals. The membership can also agree to create projects with options that require more coordinated actions and pooled resources.

Nonpoint Source Analysis in EPA BASINS GWLF-E

The CSU research project also included detailed analysis of non-point source pollution and system complexity and uncertainty. Wastewater dischargers have already reduced phosphorus discharges by over ninety percent with little effect on seasonal total phosphorus and chlorophyll-a levels or Bear Creek Reservoir trophic status, which remains stably eutrophic. Therefore, it is important to determine other potential sources of nutrients to improve water quality in Bear Creek Reservoir. Geographic Information Systems were used to developed thematic layers for subbasins, soils, landuse, elevation, horse densities and pastures, paved and unpaved roads, streams, point discharges, weather, and urban areas. This information was used in EPA BASINS GWLF-E mass balance analysis to provide a screening level estimate of potential nutrient sources. Modeling results are preliminary and they will require additional refinement using more advanced EPA BASINS extensions.

Results indicate that the over 9,000 septic systems in the watershed may contribute a similar total phosphorus load as wastewater discharges or slightly more. The many roads adjacent to streams, and unpaved private drives, in addition to streambank erosion and urban development, contribute fifteen times more, mostly particulate, phosphorus. The large contribution of sediment-based phosphorus agrees with the original 1990 Clean Lakes Study estimates, USGS Sparrow model results for the greater Missouri Basin, and BCWA's own estimates of suspended load from storms, snowmelt runoff, and flooding events. Statistical analysis also indicates that total phosphorus does not typically decrease with increasing flow, which would be expected as wastewater discharges were diluted, if they were the main cause. This may indicate further reduction in WWTF discharge load allowances may not improve Bear Creek Reservoir water quality. Therefore, policies and projects that more directly address the effects of nonpoint sources and other reservoir management alternatives will be targeted in future years.

Nonpoint Source Education

The Association has an education and outreach program to help raise awareness with watershed citizens on the need for nonpoint source management and controls. Association members are involved in numerous educational and training efforts for schools, clubs, and local agencies and often assist with seminars and conferences. The Association actively promotes use of *smart management practices* to lessen water quality and environmental degradation caused by nonpoint sources (BCWA Policy 15 *Nonpoint Source Strategies and BMPs*).

Watershed Education and Training Efforts

The Association provides information in the form of brochures, fact sheets, maps, training classes and presentations to the community on water quality management and environmental issues and supports educational programs/ activities (e.g., Evergreen Chamber Duck Races, Earthday, Audubon, Evergreen Trout Unlimited, City of Lakewood, and the Clear Creek Water Festival). The Association participated in two panel discussions for Earthday events. The Association held a Watershed 101 class for watershed citizens.

The Association was involved in cooperative meetings with the Barr-Milton Watershed Association, the Lower Bear Creek Watershed Group, Denver Department of Environmental Health, and the Colorado Lake and

Reservoir Management Association. The Association was a member of the special Clear Creek/ Bear Creek Fire Hazard Study.

BCWA Newsletter

The Association has established a triannual newsletter that is distributed to membership and many watershed citizens. The newsletter contains one or more articles directed at nonpoint pollution management or education. The Association newsletter reaches over 300 watershed citizens.

Future Watershed Manager Program

The Association has a future watershed manager program and works with watershed high schools and middle schools to provide educational opportunities, training classes and materials related to watershed and water quality management. The Association has a “Watershed 101” training course and develops more courses as requested for the outreach program. The Association worked with students at Evergreen High School to develop several monitoring and restoration projects on the school property and along Wilmont Creek. These students designed and, built a rain garden that fixes a stormwater runoff problem at the school.

Geo-Locate Sign Program

The Association developed and installed a new educational signage project in the watershed. The 11 kiosks have educational messages that target nonpoint problems and solutions. Signs are located at public accessible sites beginning at the Jefferson County Outdoor School to the Lakewood City buildings. Each sign has a base message and a site-specific message. People will be able to Geo-locate BCWA signs, collect the keywords from each sign, and share findings with Association through the web site www.bearcreekwatershed.org.

Bear Creek Regional Parks, Lakewood

The city has several education and campfire programs held at Bear Creek Park (e.g., Junior Naturalist) that includes environmental and water quality elements. There were >100 education programs for about 4,000 participants (does not include outreach events). The Association has developed education materials, handouts and otherwise supported the park programs. The total visitation for BCLP exceeded 415,000 visitors, excluding bicyclists. The city estimates use for Green Mountain and the Bear Creek Greenbelt (from trail cameras, preliminary estimates) at over 240,000 for the Greenbelt and over 200,000 for Green Mountain.

Evergreen Trout Unlimited

The Association works with Evergreen Trout Unlimited and other partners in identifying and implementing new stream restoration projects/programs. Evergreen Trout Unlimited conducts spring and fall cleanout operations in Evergreen Lake, Bear Creek downtown, O’Fallon. ETU collects over 10 cubic yards of trash and debris, annually. ETU contributes time and materials to the temperature monitoring program. Several Association members are members of ETU.

Wilmot Elementary School in Evergreen

Annually, the fourth-grade classes at Wilmot Elementary School in Evergreen participate in a one-day class on centered on the ecology of Evergreen Lake. They do walking tours around the lake. Several sites around the lake are set up for each group to spend time at, including a stop at the Evergreen Metropolitan District Water Treatment Facility.

Buchanan Ponds

The BCWA worked with science teachers from Evergreen Middle School, on a special water quality study at the nearby Buchanan Ponds (*BCWA Fact Sheet 55 Evergreen Middle School Buchanan Ponds Special Study*). There were 220 students involved in the project (*BCWA WQSD05 Buchanan Ponds*). The program was divided into 4 phases: 1) an introduction presentation to the classes on healthy water quality in the Bear Creek Watershed, 2) an adventurous field trip to the monitoring sites where students made observations, took flow measurements, used a water quality multi-probe to measure water chemistry and collected water for laboratory analyses, 3) a presentation to the classes to review the various field and laboratory findings, and 4) selected junior watershed managers helped develop this report and an article for the BCWA newsletter.

Field probe measurements were done at three sites for temperature, pH, dissolved oxygen, specific conductance or conductivity, and stream flow. Students collected water samples to measure total nitrogen and total

phosphorus concentrations. We calculated nutrient loads and predicted how the two ponds influenced nutrients and water pH. Students make observations on conditions of sites including what things people were doing to change water quality; they found invasive plants and animals, they observed pollutants (like oil, grease, road salts, trash and sediments) and even identified a few fixes or good practices.

The field chemistry data showed that runoff from roads, parking lots, driveways and sidewalks can pollute Buchanan Ponds. The higher than normal conductivity of the water suggested that road salts were reaching the drainage way. The study also showed how the pond ecosystems can change the water chemistry. Nutrients cause the algae and a tiny plant called *Duck Weed* in the ponds to grow and grow, which then changes the pond pH. The more algal growth, the more basic or alkaline the water becomes. If the water pH gets too high and over 9.0 then it can harm the fish. The sun can heat up the water really fast in the ponds and if the water gets too hot for the fish, temperature becomes a pollutant. Some students found the science to be “hard”, others called it “challenging”, learning to look and see water pollutant was “way harder” and best stated – “water is important and we must protect it”.

2016 Urban Waters Bike Tours

The Colorado Foundation for Water Education led two educational bike tours with a total of 70 participants through the Bear Creek watershed. Attendees included a diverse mix of water professionals, elected officials, educators and interested citizens. Together, the groups explored the relationship between water use, river health and community development in terms of stormwater and flood management and water quality assessments and standards for public health. When surveyed after the tour: 85% of respondents said they will use what they learned on the tour in their work and/or personal life; 97% of respondents said they increased their awareness and understanding of the Bear Creek watershed; 100% of respondents felt that the tour was of high or medium value and worthy of their time; and Participants said they increased their understanding of water quality issues and the organizations dedicated to protecting and managing the Bear Creek watershed.

Manure Management

The Bear Creek Watershed Association recognizes animal manure and the associated liquid waste stream is a contributing factor in nonpoint source pollution within Bear Creek Park *BCWA Policy 4 Manure Management* and as evaluated in BCWA Technical Memorandum 2013.04 - Manure Management Bear Creek Park, Lakewood). An *Animal Facility* or similar project can lead to an accumulation of nutrients in the park over the long term, especially in areas with repeated applications, such as the stables and trails. Manure management strategies used in the Bear Creek Park should not increase the total annual load of total nitrogen or total phosphorus above ambient conditions where such waste can potentially reach surface waters in the watershed or alluvial groundwater. Bear Creek Park staff manages manure control practices that include construction of composting bins for large animal waste products and managing trail crossings at waterways.

Summit Lake

Bear Creek Watershed Association continued to monitor four sampling stations at Summit Lake and upper Bear Creek, Mt Evans Wilderness, Clear Creek County Colorado (*BCWA Technical Memorandum 2015.02 - UBCW*). The Association historic sampling Site 36 (Summit Lake at outfall) and Upper Bear Creek Site 37 monitor “background” conditions. Monitoring data show atypical water quality results for an alpine ecoregion. The station data demonstrates there is a pollution source(s) causing elevated nutrient loads, low pH conditions and reduced dissolved oxygen. Association observations suggest that one origin of the pollutants was the new/old toilet vaults at the Summit Lake parking lot. Denver Parks and Recreation in 2013 repaired the new vaults and the 2016 water quality data suggests this helped resolve part of the nutrient loading. The Association provides the City and County of Denver, Colorado Department of Parks and Wildlife, Colorado Water Quality Control Division, State Forest Service and National Forest Service technical memorandums with data results and conclusions. Denver has committed to additional characterizations of the water quality problem(s) and is working towards mitigation of any problem(s) associated with the Denver Mountain Park Facilities.

Although the fen plume monitoring site continues to produce an elevated phosphorus loading, this load is not reflected in the concentrations and load measured downstream at site 37. This indicates that algal productivity is consuming much of the nutrient load prior to this monitoring site. Most of the recent algal grow appears to be

several species of green algae. There does continue to be a potential problematic bluegreen algae that may be associated with the observed fish kills. Almost all of this algal mat material will die over the winter and flush downstream in the spring runoff. As such, the nutrient load gets flushed downstream as organic matter.

Fen Complex Study Summit Lake

A type of tributary wetland in the watershed is called a fen. In the Mt. Evans portion of the watershed, these wetland fens are an important and unique wetland type. They are ancient ecosystems 8,000 to 12,000 years old. They “provide important headwater quality functions,” including carbon storage, water storage, wildlife habitat, and biodiversity. Fens, are peat-forming wetlands that receive nutrients from sources other than precipitation: usually from upslope sources through drainage from surrounding mineral soils and from groundwater movement (*BCWA Fact Sheet 49 Wetlands, Fens and WQ BCW*).

In 2014, the Association conducted a special survey of three Fen ponds to establish background or expected conditions on “non-polluted” Fen Ponds (*BCWA Fact Sheet 52 Mt Evans Fen WQ*). 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. The Fen ponds were sampled on September 17, 2014, with an expectation that this would show the season low nutrient conditions. The results for total nitrogen and total phosphorus were much higher than suspected. The median total phosphorus for this limited special survey was 165 ug/l. The preliminary data strongly suggests the chemistry and nutrient dynamics in the Fen complex is more complicated than predicted. As such, the Association began 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 (*Fact Sheet 53 BCR 2015 Regulation 38 Update*). It is not yet known what background level would be appropriate or if it varies among these fens. The Colorado Water Quality Commission applauds 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 an effective date of 12/31/2020. In 2016, the Association established a control fen located on the south side of Bear Creek. This site has no visible human impact. All the fens on the north side of Bear Creek have varying degrees of anthropogenic degradation (*BCWA TM 2016.02 UBCW Summary*) (Figure 28) and Figure 29).

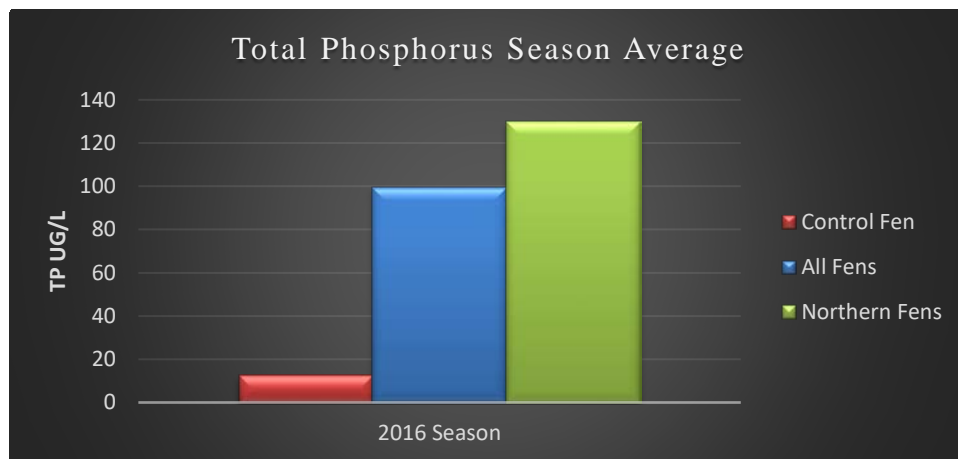


Figure 28 Total Phosphorus Seasonal Averages in Fen Complex

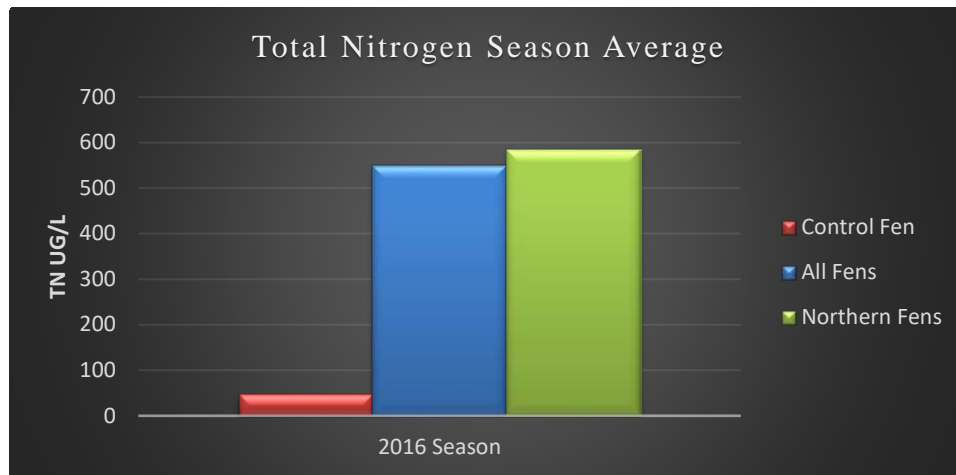


Figure 29 Total Nitrogen Seasonal Averages in Fen Complex

Clear/Bear Creek Wildfire/Watershed Assessment

The Association was a partner in a watershed assessment that identified and prioritized sixth –level creek/watersheds based upon their hazards of generating flooding, debris flows and increased sediment yields following wildfires that could have impacts on water supplies. The study expanded on current wildfire hazard reduction efforts by including water supply watersheds as a community value. The watershed assessment followed procedures prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009). This Bear Creek assessment provides an identification of opportunities and constraints for each Zone of Concern in the watershed (<http://www.jw-associates.org/clearbearcreek.html>).

Evergreen Metropolitan District Source Water Assessment

Evergreen Metro District worked with the Colorado Rural Water Association and a steering committee to develop a Source Water Protection Plan (SWPP). Source water protection is a voluntary, non-regulatory, proactive approach to preventing the pollution of lakes, rivers, streams, and groundwater that serve as sources of drinking water. A SWPP includes: the area in need of protection, the potential sources of contaminants, and management approaches that could help to reduce the risk of contaminants entering the source waters. The wildfire watershed assessment report identifies a zone above the reservoir as a high priority zone of concern. The protection plan includes best management practices necessary to lessen the water quality impact to Evergreen Lake following a major upstream wildfire. It is anticipated that significant nonpoint source pollution could be generated by storm events following a major fire. The district has identified areas in need of protection and several potential sources of contamination. This data is assimilated into the district’s GIS system.

Evergreen Metropolitan District Canal Cleaning Operation

The district monitors and maintains a storm sewer catch basin at Evergreen Lake. Generally, the district on an annual basis removes fine sand and silt from the inlet channel to Evergreen Lake to reduce the sedimentation rate in the lake. In previous years, this material was disposed at a location to prevent subsequent erosion into waterways. The District monitors the performance of this catch basin and evaluates if the installation of additional catch basins along upper Bear Creek would benefit the stream.

Coyote Gulch Nonpoint Source Restoration

The Association is involved in a nonpoint source project sponsored by the City of Lakewood that restored a severely eroded section of Coyote Gulch. Coyote Gulch revegetation began in June 2007 and became well established in 2008. The Association has a paired water-sampling program, which allows a determination on the effectiveness of the restoration effort at phosphorus reduction (Table 26). The Association Technical Memorandum Coyote Gulch Summary (TM 2016.03) provides a summary of the monitoring program and data analysis. Table 27 identifies the annual available total phosphorus trade pounds consistent with the Association trade program. Based on seven years of data, there is 84 pounds of total phosphorus available for the trade program. Figure 30 shows the total phosphorus reduction. The Coyote Gulch restoration project is an effective phosphorus reduction project and management practice.

Table 26 Coyote Gulch Nutrient Base Loads

		Average Loading Pounds by Year			
		Reservoir		Above Project	
		Nitrate	T Phos	Nitrate	T Phos
Pre-construction	2006-2007	200.7	20.0		
Post-Construction	2007-2008	128.7	4.4	160.9	5.2
	2009*	142.0	6.7	185.9	8.9
	2010*	203.7	8.1	222.3	8.5
	2011*	103.0	6.1	163.9	7.0
	2012	106.6	2.7	104.4	4.8
	2013	80.6	4.6	78.8	4.7
	2014	90.3	4.4	131.4	4.8
	2015		6		21.7
	2016		10.1		12.4
		T Nitrogen		T Nitrogen	
	2015	260		500	
	2016	470.3		604.1	
		Loading Pounds After Stable			
		Reservoir		Above Project	
		Nitrate	T. Phos	Nitrate	T Phos
	Total Pounds	11,167	676	14,463	888
	Average	186	11	241	15
	Median	91	4	128	5
		T Nitrogen		T Nitrogen	
	Total Pounds	730.3		1104.1	
	Average	365		552	

2009*/2010*/2011/2015 average loadings per year excludes April storm loadings

Table 27 Coyote Gulch Total Phosphorus Trade Pounds

Total Phosphorus Trade Pounds				
	Total Base Flow		Trade Ration Pounds	
	Monthly	Annual	Monthly	Annual
Average	5.9	70.9	7.0	84.3
Median	6.0	72.0	7.0	83.8
Monthly TRP=PC Base Load-TBF Monthly Pounds/2				
The base trade ratio is 2:1 for Association Trade Projects				
Base Flows Exclude April Storm Loadings				
Annual Trade Pounds Available = 84 pounds Total Phosphorus				

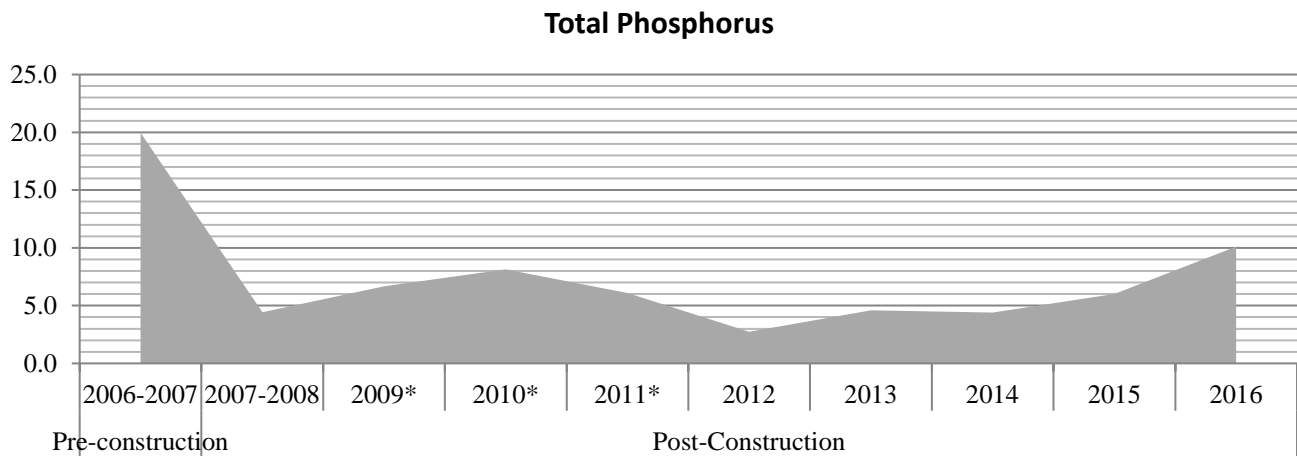


Figure 30 Total Phosphorus Reduction at Coyote Gulch Project

Association Land-Use Review

The Association has 36 “policies” to help with management of the watershed program. The Association is a referral agency to land use agencies within the Bear Creek Watershed, including cities and counties. The Association reviews referral applications for consistency with local, regional, state, and environmental regulations, associated policies and the watershed management plan. To assist the Association in the referral process, a “Referral Review Guidance” (Association 2007) outlines general components of the Association land disturbance mitigation preferences, including Association review and comment guidance. This guidance addresses nonpoint sediment loading before it becomes a watershed problem. Referred land use applications that cause a land disturbance and/or a potential to degrade water quality are subject to review and comment by Association. The Association completed 5 referrals in 2016 that addressed issues related to erosion, septic management, land disturbance, re-zoning, water quality degradation and appropriate use of best management practices. The Association supports Jefferson County and Clear Creek County in the update and development of community plans for select portions of the watershed.

BCWA and Membership Special Programs

Denver Water Department Watershed Assessment

The Denver Water Department completed an independent review of water quality in the Bear Creek Watershed and a cost alternative analysis to determine cost-effective clean-up options (Bear Creek / Turkey Creek Watershed Water-Quality Alternatives and Costs Bear Creek / Turkey Creek Watershed Project Technical Memorandum 2 Contract Number 13223A, Prepared for the Denver Water Board, Hydro Consultants, April 15, 2011). DWD is evaluating implementation programs as addressed in the study and providing findings and recommendations with the Association.

Lakewood Regional Parks Recycling Efforts

The City of Lakewood is in their 13th year of recycling and litter management at their regional parks, including Bear Creek Park. In 2016, the program recycled motor oil, scrap metal, mixed paper, cans, glass and plastic, electronics, all batteries, paints, and other chemicals which are disposed of at the Rooney Road Recycling Center. The city continues trash clean up along Bear Creek and Turkey Creek drainages and around the reservoirs. Activities included maintenance of manure management bins, volunteer erosion control projects, willow planting and wetlands enhancement, park clean-up, trail work, trail stream-crossing closures and vegetation management. There was over 5,000 hours of volunteer effort. Recycle Your Fishing String program also helps keep shorelines clean.

Aspen Park/ Conifer Waste Recycling Program

The Conifer Area Council has maintained a “Recycling / Sustainability Committee”, which supports community recycling. Information from this committee is distributed to the Association membership. The committee has begun a slash removal program for pine beetle damaged trees. The program also takes recycled materials to the Rooney Road Recycling Center.

The Rooney Road Recycling Center

The Rooney Road Recycling Center provides proper disposal programs for residents of Unincorporated Jefferson County and the cities and towns of, Arvada, Golden, Lakewood, Mountain View, Lakeside, Edgewater, Morrison, and Wheat Ridge, to recycle their household hazardous waste (HHW). HHW includes electronic waste, household chemicals, paints, propane cylinders and automotive products. HHW materials collected at the facility since 1994 total more than 6 million lbs of potential surface water and ground water pollutants. The HHW program serviced over 4,000 participants, with City of Lakewood accounting for over 25 % of the total participation and the Bear Creek Watershed accounting for 38% of the total participants.

Invasive Species Protection Programs

Aquatic Nuisance Species Bear Creek Reservoir

Bear Creek Lake Park is involved in Colorado efforts to stop the spread of Aquatic Nuisance Species in Colorado waters. A Watercraft Inspection and Decontamination station is in the Whitetail parking lot. All trailer and motorized boats require inspection by state certified inspectors at the station for any aquatic invaders. Station staffed from 6am to 8pm on Fridays and the weekends, then every morning and evening during the week. During the middle of a weekday, the entrance gate would call out when a boat came in and the nearest staff

member would do the inspection. Annually, the lake closes from November 15 to March 15. The park did > 2,000 standard inspections with no positive samples.

Aquatic Nuisance Species Evergreen Lake

The Evergreen Park & Recreation District requires a permit for all personal watercraft to be on Evergreen Lake. This is an opportunity to do the mussel inspection at the Lake House prior to launch. The Recreation District staff inspects boats and trailers. The recreation district and the Evergreen Metropolitan District have a program to harvest and compost the invasive algal species Elodea from the lake in the summer months. The district introduced grass carp to manage the Elodea growth.

Noxious Weed Management

Clear Creek, Jefferson and Denver Counties have noxious weed management programs. The Association reports sightings of noxious weeds and otherwise cooperates with these programs.

Invasive Algal Species in Bear Creek and Turkey Creek

The Association has begun collecting and identifying invasive algal species found in streams throughout the watershed.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers has an updated master plan for Bear Creek Dam and reservoir (Bear Creek Dam and Lake Project South Platte River, Colorado, Design memorandum PB-10, July 2012). The Corps of Engineers released a sedimentation analysis for Bear Creek Reservoir (Tri-Lakes Sedimentation Studies Area-Capacity Report Revised: July 2011; M.R.B. Sediment Memorandum 23a). There has been a decrease in gross storage capacity:

Gross storage capacity in Bear Creek Lake has decreased from the original capacity of 78,101 acre-feet in 1980 to 77,293 acre-feet in 2009, the year of the latest sediment range line survey. This amounts to a total storage reduction of 808 acre-feet, or an average depletion rate of 27.9 acre-feet per year. The original projected storage depletion rate for Bear Creek Lake was approximately 20 acre-feet per year. The Bear Creek Lake flood control pool storage capacity has decreased from of 28,762 acre-feet in 1980 to 28,514 acre-feet in 2009, an average of 8.6 acre-feet per year.

The U.S. Army Corps of Engineers continued clean-up operations to remove debris, upgrades around the outlet structure, road maintenance and dam stabilization projects.

Colorado Department of Parks and Wildlife

The Association supports the Division of Parks and Wildlife fishery surveys. These surveys characterize how trout populations respond to both natural and human induced alterations, including changes to water and environmental quality. The Association maintains a Fishery Analysis and Protocols Guidance. The *BCWA Fact Sheet 48 Bass and Saugeye Fishery BCR*, summaries a survey of sports fish in Bear Creek Reservoir. There was a 2016 fishery survey (*BCWA TM 2016.10 Fisheries*) (Table 28 and Figure 31).

Table 28 2016 Fishery Summary Results

	Width (ft)	Species	No./Mile Total	No./Acre Total	lbs/Acre Total
Golden Willow	23	Brown Trout	1543	553	83
		Rainbow Trout	15	6	1
		Total	1558	559	84
Dedisse Park	33	Brown Trout	2583	646	75
		Rainbow Trout	158	39	5
		Total	2740	685	79
Downtown Evergreen	34	Brown Trout	1427	346	103
		Rainbow Trout	399	97	29
		Total	1827	443	131
Bear Creek Cabins	32	Brown Trout	1126	290	77
		Rainbow Trout	263	68	18
		Total	1389	358	95
O'Fallon Park	28	Brown Trout	909	268	54

	Width (ft)	Species	No./Mile Total	No./Acre Total	lbs/Acre Total
		Rainbow Trout	57	17	3
		Total	966	285	57
Lair O' the Bear	29	Brown Trout	1293	368	94
		Rainbow Trout	86	24	6
		Total	1379	392	101
Morrison West	30	Brown Trout	1353	372	99
		Rainbow Trout	91	25	7
		Total	1443	397	105

note: No Idledale sample

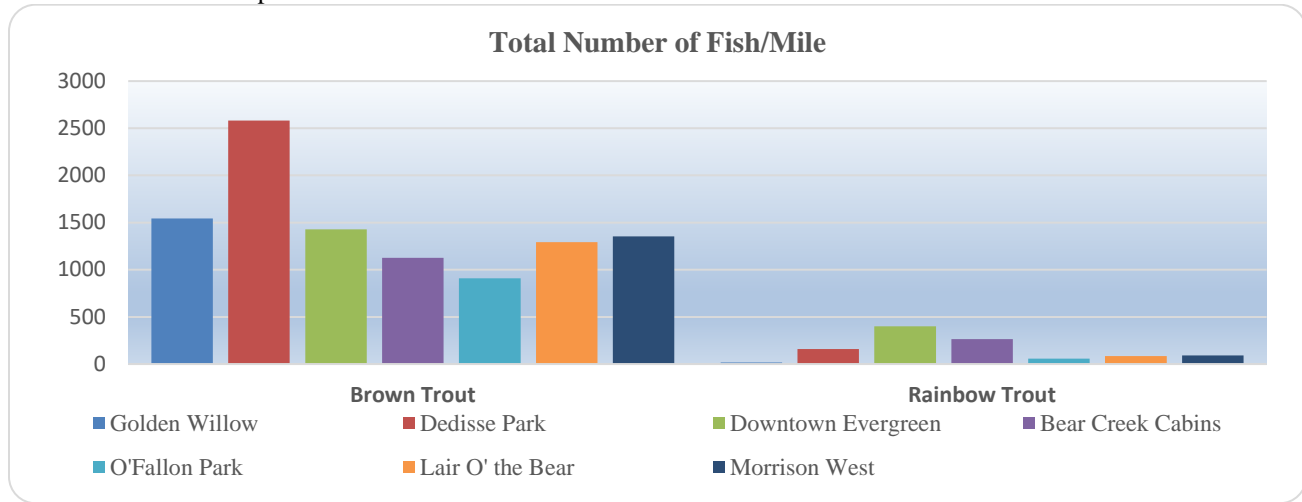


Figure 31 2016 Total Fish per Mile

Evergreen Lake Dredging

In September of 2013, a series of flood events occurred in the Evergreen area over a period of one week. The flooding caused property damage along Bear Creek from above Evergreen Lake to the bottom of the watershed and resulted in a significant amount of sediment being deposited in the Lake. The Bear Creek Watershed Association Manager, Russell Clayshulte, could calculate the approximate volume of sediment deposited in the Lake by using flow and water quality parameters. Evergreen Metropolitan District applied for and received Federal and State grants for removal of the sediment. In 2016, the District contracted to have approximately 12,000 cubic yards of material dredged from Evergreen Lake and the Bear Creek inlet to the lake. The dredging operation began in late May and was completed by the 3rd week of July. The dredging was concentrated on the north side where Bear Creek flows into Evergreen Lake. The dewatered silt was transported to a former solid waste transfer station on Highway 73. After the dredged material was graded, Denver Mountain Parks, which owns the property, seeded the property.

Turbidity curtains were installed to contain sediment that was stirred up because of the dredge operations (Figure 32). Additionally, flow into Evergreen Lake was temporarily re-routed around the main channel to preserve water quality throughout the lake (Figure 33).



Figure 32 Turbidity Curtains

The dredged material was sampled and tested for contaminants at least once a week. Water samples were also tested during dredge operations by both the Bear Creek Watershed Association and Evergreen Metropolitan District. Raw water analysis at the water treatment plant showed no degradation to water quality and required no additional treatment. The inlet channel that was less than 1 foot deep in some areas was dredged to an average depth of 8 feet.

The dredge operation did restrict some access to fishing on the north side of the lake, but did not appear to have any effect to the fishery. Department of Parks and Wildlife maintained their fish stocking program as scheduled throughout the project. There was no effect on other recreational activities on the lake. There appeared to be no impact to local wildlife and elk were still present in the wetland area adjacent to the project.



Figure 33 Dredging in Channel

Based on bathymetric measurements taken of the Lake before and after the dredge project, the District could determine that an additional 60,000 cubic yards of sediment has been deposited in Evergreen Lake since a 1985 dredging operation was completed. To recapture lost water storage capacity, Evergreen Metro District is continuing with the process of obtaining Federal, State, and County permitting to allow for scheduled periodic dredge operations in the Lake.

Climate Modeling

From December 2015 to June 2016, BCWA and Evergreen Metro engaged in a series of webinars and an in-person meeting to conduct a **climate change risk assessment** using the U.S. Environmental Protection Agency's (EPA) Climate Resilience Evaluation and Awareness Tool (CREAT). CREAT provides data for historical and projected climate conditions that users can incorporate into scenarios to help them understand how threats are driven by climate change. BCWA built scenarios by selecting different future conditions defined by changes in annual average and monthly temperature and precipitation, as well as intense precipitation events and hot days that may exacerbate the climate-related threats of concern (*BCWA Fact Sheet 56 Climate Model in Upper Bear Creek Watershed*). While all Global Circulation Models (GCMs) project warming, the projected changes in precipitation vary. Some models project wetter conditions for a given location and others project drier conditions. The models also vary in the changes in the magnitude of intense precipitation events; some project stormier conditions than others. CREAT averages the projected data from climate models to provide data for warmer and wetter, hotter and drier and moderate future conditions.

BCWA and Evergreen Metro are using the assessment to build on existing modeling and monitoring efforts to better understand how climate change threats could affect utility operations and watershed health. BCWA included a number of climate change threats in our assessment that would present water quality and quantity issues through 2050 within the upper Bear Creek Watershed. Predicted increasing temperatures from climate

change could present regulatory and treatment challenges for members, in addition to affecting the health of sensitive fish species in the watershed. A minimal very likely near-term temperature increase of 1 to 2°F will present issues for the cold-water fisheries. Additional concerns include water supply reductions from drought, as well as water quality degradation from wildfires and subsequent flooding. Previous flooding events have resulted in significant sedimentation in Evergreen Lake that diminished the reservoir’s capacity.

BCWA considered how climate change may increase the severity or frequency of these threats, and assessed the risks of water quality or quantity conditions that would challenge their ability to maintain a reliable supply, to treat the incoming raw water and to protect the health of the watershed ecosystem (Table 29). BCWA considered both moderate and hotter and drier conditions with a stormy future. These two scenarios were used to ensure that BCWA members were conducting robust planning that considered different potential future climate conditions. The *Minimum Proactive Plan* includes short-term measures to increase modeling, monitoring, watershed management, staff training and public outreach activities, as well as implementing new green infrastructure in the service area. These measures would improve temperature and water quality data collection as well as modeling capabilities so that BCWA and Evergreen Metro can better understand the potential impacts to their infrastructure and operations due to climate change.

Table 29 Climate Model Predictions

CLIMATE VARIABLE	Baseline scenario	moderate conditions scenario	hotter and drier conditions scenario
Average Annual Temperature	46.26°F	5.18°F increase	6.12°F increase
Average July Temperature	67.4°F	5.75°F increase	5.88°F increase
Average December Temperature	29.82°F	4.39°F increase	5.96°F increase
Hot Days over 90°F	2.3 days	>10 days	>20 days
Total Annual Precipitation	19.27 inches	3.68% increase	0.88% increase
July Precipitation	2.04 inches	4.69% decrease	0.93% increase
December Precipitation	0.82 inches	18.04% increase	5.48% increase
100-Year Storm Event	2.8 inches 6 hours	28.59% increase	28.59% increase

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 Mt Vernon Creek to the inlet of the Harriman Ditch.

The Association is undertaking a copper specific monitoring program to better document the copper issue and potentially identify a copper source(s) near Morrison (Table 30) (*BCWA TM2016.12 Copper Study*). 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 will 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 a copper source(s) are found, then program may become limited.

Table 30 2016 Special Copper Study Results

Segment	Site ID	Site Location by Stream Segment	5/16/2016	6/10/2016	7/7/2016	8/13/2016	9/20/2016	10/18/2016	11/17/2016	12/5/2016	Average	Standard Deviation
Dissolved Copper, ug/l												
1e	Site 14a	Mainstem Bear Creek, Morrison Park west	1.4	1.3	2.6	1.6	1.6	1.7	1.6	1.6	1.7	0.4
4a	Site 87	Mt Vernon Drainage, Morrison	1.6	2.9	2.4	1.1	2.4	1.8	2.0	1.8	2.0	0.6
1e	Site 14c	Mainstem Bear Creek, Morrison at Harriman	1.2	4.7	1.1	1.2	2.4	1.4	1.4	1.7	1.9	1.2
Hardness as CaCO₃, mg/l												
1e	Site 14a	Mainstem Bear Creek, Morrison Park west	58	40	46	62	56	72	70	76	60	13
4a	Site 87	Mt Vernon Drainage, Morrison	378	440	456	482	470	510	510	476	465	43
1e	Site 14c	Mainstem Bear Creek, Morrison at Harriman	76	50	60	76	74	96	104	102	80	20

VII. Association Watershed Plan and Annual Reports

The Association produces an annual data report and a *2016 Master Data Spreadsheet (April 2016)* that includes data analyses, and raw data (Association website www.bearcreekwatershed.org). The Association transmits these data reports to the Water Quality Control Division Staff. The watershed-monitoring program summarized in an Association data report.

Most of the Association annual reporting documents are available electronically and posted on the website. The Association provides multiple reporting documents designed to meet the multiple functions of various groups (BCWA *PGO2 Document Categories*). The reporting helps member entities with reporting to their respective boards, commissions and groups. There is also a citizen interest in the watershed and reporting helps keep the public informed. Many educational groups visit the watershed and it has become a widely used outdoor classroom. The Association supplies water quality and environmental materials for various educational uses.

Be a Watershed Warrior!

Geo-locate all eleven BCWA informational signs, collect the keywords from each sign, and share your findings on our website or by e-mail. If you collect all the keywords, your name will be posted on our Watershed Wall of Fame. Don't forget to look for the different animals on the signs. All of these animals are found somewhere in the watershed. Each sign has GPS coordinates that show where the upstream and downstream signs are found from your present position. You'll find the first sign at the entrance to a Jefferson County School Outdoor Learning Facility. The BCWA challenges you to take a geo-locate trip through our Bear Creek Watershed.

BCWA Watershed Plan

The Association has determined and established a policy that generating a single document to serve the watershed planning elements is not practical or efficient process. A single or fixed watershed plan would be too inflexible and require frequent updating. The Association instead is using a flexible and adaptive watershed planning process maintained electronically and accessible on a designated BCWA Web site. The electronic watershed plan is an Association Watershed Plan table of contents with linked PDF files or spreadsheets, and program element descriptions. The Association Watershed Plan is flexible, adaptive and dynamic. The online watershed plan contains elements and information required to meet 3-types of water quality planning.

The Association has adopted a series of policies, technical reports and factsheets that define the program (*BCWA PGO1 Master Index and PGO2 Document Categories*). The Association maintains a series of standardized maps providing watershed information and characterization. The Association maintains sets of water quality and other environmental data in spreadsheets and data reports. The Association produces annual reports to meet regulatory reporting requirements. The compilation of the various Association watershed planning documents and databases meets the state and Environmental Protection Agency requirements for a watershed plan.