Blue River Watershed Group   Trout Unlimited

Blue River Integrated Water Management Plan
Phase I Report

TETRA TECH

August 2021

PREPARED FOR

Colorado Water Conservation Board

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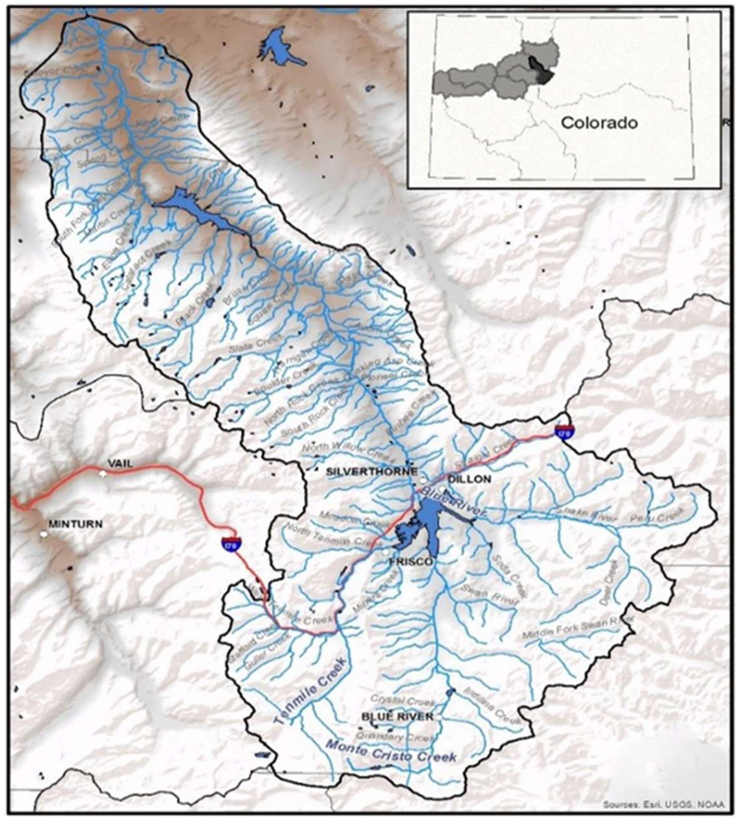
APPENDICES

Acronym or Abbreviation	Full Phrase
AC	Advisory committee
ac-ft	Acre-Feet
BCR	Data collection site, Blue River State Wildlife Area
BIP	Basin Implementation Plan
Blue 1	Data collection site, Blue River downstream of Boulder Creek
Blue 2	Data collection site, downstream of Blue River Campground
Blue 3	Data collection site, downstream of Bald Eagle Drive
Blue 5	Data collection site, Blue River below Dillon Reservoir
BLM	Bureau of Land Management
BREW	Blue River Enhancement Group
BRIWMP	Blue River Integrated Water Management Plan
BRWG	Blue River Watershed Group
BVR	Blue Valley Ranch
CDOT	Colorado Department of Transportation
CDSN	Colorado Data Sharing Network
CDPHE	Colorado Department of Public Health and Environment
cfs	Cubic feet per second
CPW	Colorado Parks and Wildlife
CWCB	Colorado Water Conservation Board
CWP	Colorado Water Plan
DRD	Data collection site, behind Dillon Ranger District
EPA	Environmental Protection Agency
ft	Feet
IHA	Indicators of Hydrologic Alteration
IWMP	Integrated Water Management Plan
LBR	Data collection site, Blue river below Green Mountain Reservoir
MMI	Colorado's Multi-Metric Index, version 4 (MMI v4)
NWCOG	Northwest Colorado Council of Governments
PHABSIM	Physical Habitat Simulation Model
SCR	Data collection site, upstream of Cty Rd 1450
SWQC	Summit County Water Quality Committee
TU	Trout Unlimited
UBR	Data collection site, Blue River upstream of Dillon Reservoir
UPCO	Upper Colorado River Basin Study
USFS	United States Forest Service
USGS	United States Geological Survey
WCF	Watershed Condition Framework

EXECUTIVE SUMMARY

The Blue River watershed sits at the top of the Continental Divide on the west slope of the Rocky Mountains encompassing a relatively small area of 699 square miles and 62 miles of main stem river to its confluence with the Colorado River. The Blue River headwaters are on the west side of the continental divide in the Ten Mile Range. The river flows north past the Towns of Blue River and Breckenridge, then into Dillon Reservoir near the Towns of Dillon and Silverthorne. North of Dillon the river flows north-northwest along the eastern slope of the Gore Range, through Green Mountain Reservoir near the Town of Heeney. From Green Mountain Reservoir the Blue River travels north to its confluence with the Colorado River at Kremmling.



Historic and current impacts within the watershed have been significant, including decimation of river bed from dredge boat mining, water quality issues due to hard rock mining, two major impoundments that alter the natural hydrology over two-thirds of the Blue River main stem, and water development that includes the exportation, or transbasin diversion, of approximately 20 to 30 % of the total average water generated within the watershed. Snow and rain are the only sources of this water and no water is imported into the Blue River watershed from other sources or locations.

The Blue River is an ecological, economical, and recreational resource requiring restoration and protection to remain viable. The health and maintenance of the water resource is vital to the local communities, the environment of the river and watershed, and to the downstream and transbasin water users. To that end, the focus of the Blue River Integrated Water Management Plan (BRIWMP) is to enable consumptive and non-consumptive (recreational and environmental) water users to understand current and future uses and integrate those uses and needs for the maximum benefit of all and for the health and sustainability of the watershed while protecting the existing water resource and existing water rights. The BRIWMP provides a framework for stakeholders to make water planning decisions in the future in the face of changing conditions, such as increased demand or water scarcity. Developing the BRIWMP is a comprehensive process that relies on the input and coordination from all water users in order to integrate solutions in a balanced manner that reflects the communities' values.

Phase 1 of the project began in August of 2019 and generally included an assessment of the health of the river and its ecosystem, identification of issues and concerns, and recommendations for additional study and actionable items to further advance the BRIWMP. Phase 1 set the stage for Phase 2 of the BRIWMP, in which the community will move forward on additional water planning, studies, and projects.

The Executive Summary is intended to synthesize the BRIWMP Phase 1 Report into a short summary to enable community stakeholders to quickly review water related issues throughout the basin and, importantly, review the recommendations for Phase 2. The Executive Summary has four sections: Project Background, Blue River Watershed Overview, Key Issues and a Summary of Key Recommendations.

Project Background

In May 2018 Trout Unlimited (TU) and the Blue River Watershed Group (BRWG) began working together to produce a basin wide integrated water management plan for the Blue River basin in Summit and Grand Counties in Colorado. The long-term goal is to enable consumptive and non-consumptive water users to understand and quantify current and future water use and integrate those uses for the maximum benefit of all users while protecting the existing water resource.

For purposes of this Phase 1 assessment, the focus has been on the physical health of the Blue River and associated aquatic life it supports within the mainstem. The BRWG and TU recognize 1) there are important and critical issues associated with the physical health and aquatic life along tributaries within the watershed, and 2) there are important and critical issues associated with access to and use of the river for recreational water usage. While the topics of river access and recreation are touched on in portions of this Phase 1 IWMP, they are not assessed in detail given the requirements specified in the current scope of work for this Phase 1 report. Future phases present opportunities to expand on both the physical extent and topical content of the BRIWMP. The BRIWMP is a 'process document' sometimes referred to as a 'living document' that will, in time, address additional topics and details as needed to support the communities' interests and water user needs.

Phase One has two primary objectives and four main tasks. The two objectives are to:

I. Work in parallel with the Blue River Enhancement Workgroup (BREW) to understand the reasons for the declining Blue River trout fishery

II. Compile current research, management plans, and stakeholder input to inform on Phase 2 of the BRIWMP

The four main tasks include:

1. The formulation of an advisory team and broad stakeholder outreach
2. Compilation of existing data, information, and studies
3. Determination of the causes for the declining fishery between Dillon and Green Mountain Reservoirs
4. The development of "next steps" focusing on the formulation of the BRIWMP, Phase 2

The BRIWMP follows the recommendations of the state of Colorado for development of integrated water management plans by identifying and implementing projects that achieve the following statewide long-term goals:

- Promote restoration, recovery, sustainability, and resiliency of endangered, threatened, and imperiled aquatic, and riparian dependent species, and plant communities
- Protect and enhance economic values to local and statewide economies that rely on environmental and recreational water uses, such as fishing, boating, waterfowl hunting, wildlife watching, camping, and hiking
- Support the development of multipurpose projects and methods that benefit environmental and recreational water needs as well as water needs for communities or agriculture
- Understand, protect, maintain, and improve conditions of streams, lakes, wetlands, and riparian areas to promote self-sustaining fisheries and functional riparian and wetland habitat to promote long-term sustainability and resiliency
- Maintain watershed health by protecting or restoring watersheds that would affect critical infrastructure and/or environmental and recreational areas

The BRIWMP is a working document that will be updated in the years to come as recommendations are implemented and projects are developed. Recommendations, action items, and projects are not intended to conflict with or injure water rights, nor conflict with Colorado Water Law.

Blue River Watershed Overview

The Blue River watershed generally aligns with the Summit County boundaries, with the exception of 80 square miles that extend into Grand County at the confluence of the Colorado River, and a small area at the head of the Tenmile Basin within Lake County. The watershed encompasses an area of 699 square miles, flowing northward, from elevations reaching 14,270 feet along the southeastern perimeter, to 7,400 feet where it flows into the Colorado River south of Kremmling (NWCOG 2012). Within the Blue River watershed lie the towns of Dillon, Silverthorne, Frisco, Keystone, Blue River, and Breckenridge; four ski areas; 9,000 acres of irrigated agricultural land; and two major water storage reservoirs.

On average, under current conditions, the Blue River watershed generates approximately 310,000 acre-feet (ac-ft) of water per year (NWCOG 2012). Local municipal water users divert an estimated 12,000 AF of water per year or 4% of the average annual yield, while 81,000 to 95,000 AF of the 310,000 AF or 25% to 30% of the average annual yield is moved out of the watershed through transbasin diversions (NWCOG 2012). Typically, municipal water use has a consumptive rate of 13% to 34% with 87% to 66% of the diverted flows being returned to the river basin, while transbasin diversions have no return flows within the basin of origin and can therefore have a significant impact on stream flows. Most of the transbasin water from the Blue River watershed is delivered to the Colorado Front Range (Coley/Forrest 2011).

Until 2016, the Blue River between Dillon and Green Mountain Reservoir was designated a Gold Medal Fishery by Colorado Parks and Wildlife (CPW). A Gold Medal fishery must be able to produce a minimum of 12 "quality trout" (defined as being 14+ inches) per acre and 60 pounds of trout standing stock per acre (CPW 2021). The designation was removed for a portion of this reach due to failure to meet CPW's biological criteria. CPW indicates the low productivity may be due to a combination of sub-optimal physical habitat from too low flows, noted as being less than 100 cfs, and lack of food and/or limited biological productivity. The upstream portion of the reach retained its designation largely in part to restoration efforts by the Town of Silverthorne and stocking of catchable rainbow trout by CPW. Basin wide, the community has placed a high priority on determining the cause(s) of the decline of the fishery and returning the river to its once-productive condition, thereby returning the entire reach to Gold Medal status.

With its large availability of public lands and year-round recreational opportunities, Summit County and the Blue River watershed are exceedingly popular destinations for locals, second homeowners, Colorado Front Range travelers, and out-of-state tourists. In 2018, visitor spending in Summit County totaled over $1.12 billion dollars, creating $48.5 million in local tax revenue for the community (Dean Runyan Associates 2019). Total estimated spending on trips and equipment by activity indicate that fishing accounts for 4%, boating 7 %, and skiing 25%, of which all are directly water dependent. According to the US Forest Service, summer visitation in the Dillon Ranger District of the White River National Forest was estimated to be 2,354,400 people (Richardson 2021).

Agriculture in the Blue River Watershed is an essential component to the community and the watershed basin, protecting open lands, wildlife habitat, cultural values, and pre-compact water rights. The 2007 market value of agricultural products grown in the watershed totaled over $1.1 million. Water to irrigate agricultural land is critically important (Coley/Forrest 2011). Based on the 2012 and 2017 Summit County Census of Agriculture (SCCA 2012 and 2017), there has been little change in the overall acreage of farmlands, currently occupying 26,572 acres, but the number of farms has grown from 41 in 2012 to 55 in 2017, possibly indicating a transition from working farmlands to 'gentleman's ranches.'

Overall, demands on the water resource are significant, and future water demands, combined with climate-impacted conditions, will likely result in peak flows occurring earlier in the year, with April through August flows decreasing and possible mismatches between peak flow timing and species' needs. The Colorado Basin Implementation Plan concludes that the Blue River watershed will likely be facing a gap of 22,000-48,000 acre-feet per year (ac-ft/yr) between water supplies and demands by 2050 (BIP 2015 as cited in HCCC 2019).

Summary of Key Issues

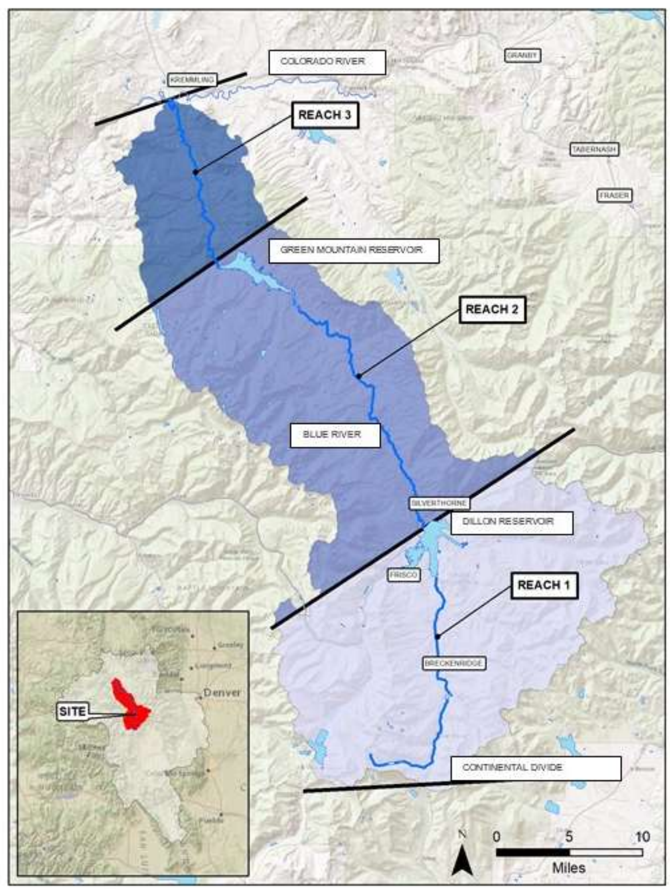
For purposes of this Phase 1 report, the Blue River watershed is divided into three Reaches:

Reach 1: Upper Blue River from its headwaters at the Continental Divide to the outlet at Dillon Reservoir.

Reach 2: Middle Blue River from the outlet at Dillon Reservoir to the outlet at Green Mountain Reservoir.

Reach 3: Lower Blue River from Green Mountain Reservoir outlet to the Colorado River Confluence.

The following provides a brief summary of key issues and recommendations by reach for Phase 2 of the BRIWMP. Additional details, issues and key findings can be found in the body of this report.



BRIWMP Project Area

Summary of Key Issues, Reach 1

- ✓ Water quality is poor at and below the confluence of French Gulch primarily due to historic hard rock mining and acid rock drainage. Constituents exceeding regulatory standards include cadmium, copper, iron, and zinc, and possibly silver and selenium.
- ✓ The Blue River mainstem from the Town of Breckenridge to the confluence of the Swan River was significantly impacted by dredge boat mining activities from the turn of the century until 1940. Some of these impacts have been or are currently being restored.
- ✓ Based on fish surveys performed by CPW (CPW 2019) the fishery downstream of Breckenridge may be in decline possibly due to low flows, fragmentation, and water quality.
- ✓ Macroinvertebrate monitoring immediately upstream of Dillon Reservoir in 2020 indicates minor to moderate stress of the macroinvertebrate community structure.
- ✓ Colorado Springs Utilities is proposing to optimize its existing collection system on the Blue River by increasing storage on the Continental-Hoosier System. Additional analysis is required to understand the impacts from this proposal on stream flows in Reach 1.

Summary of Key Issues, Reach 2

- ✓ Flows in Reach 2 are influenced by Dillon Reservoir flow releases. Flows are released primarily through the outlet works consisting of a 15 feet diameter pipe located at the bottom of the reservoir.
    - o The bottom releases have a capacity up to an estimated 4,000 cubic feet per second (cfs), however, Denver Water aims to limit, when possible, the outflows to a maximum of 1,800 cfs to minimize flooding downstream.
    - o The outlet works include a small power plant which, in 2020 generated enough power to be a "net zero" operation.
    - o Spills occur over the Morning Glory spillway when the reservoir reaches and exceeds elevation 9017.
- ✓ Calculations generated for the Blue River below Dillon Reservoir (USGS gage 09050700), located immediately downstream of the dam, indicate that over the course of a year on approximately 50% of the days, flows are approximately 70 cubic feet per second (cfs) or less eight months a year (see exceedance plots for Reach 2, section 4.2).
- ✓ UPCO reports that generally this reach experiences occasional water supply shortages which will increase under current and future conditions (HRC 2000).
- ✓ Most of the agricultural land in Summit County is concentrated in Reach 2.
    - o Urbanization of agricultural lands, or transition in uses, could reduce irrigated lands.
    - o The agricultural community indicate challenges with infrastructure and an inability to divert full decrees.
- ✓ Recreation opportunities in this reach include angling, rafting, kayaking, paddle boarding, camping, boating, and wildlife viewing.
    - o Under low-flow conditions, rafting and float-fishing are unlikely to be considered significant uses in Reach 2.

- The Town of Silverthorne is currently planning to build a whitewater park located near the Dillon Reservoir outlet. The Town holds a conditional recreational in channel diversion water right that construction of this park could perfect.
- River boating typically occurs when flows are in the 400-700 cfs range. Based on the exceedance plots prepared for Reach 2 (Section 4.2), flows equal to or greater than 400 cfs on the average (50% exceedance), are present from mid-May to early July. Due to the varied flow conditions that can support rafts and other crafts, walk-wade fishing is likely the most popular form of recreation on the Blue River in this reach.
- In 2020, an angler survey conducted by TU found 68% of participants were "neutral" or "dissatisfied" with the overall quality of fishing and angling experience on the Blue River in this reach. There is concern among local outfitters about client experience forcing Outfitters to take clients to other nearby rivers for better quality fishing, such as on the Colorado River and Arkansas River.

✓ Until 2016, Reach 2 was designated a Gold Medal Fishery by CPW. The designation was removed from the northern City limits of Silverthorne to Green Mountain Reservoir due to failure to meet CPW's biological criteria. CPW has indicated that the low productivity may be due to a combination of sub-optimal physical habitat due to low flows, defined as being less than 100 cfs, and lack of food and/or limited biological productivity (Ewert 2018).

- Results from the 2020 field monitoring indicate that benthic macroinvertebrate communities were "impaired" immediately downstream from Dillon Reservoir in the spring and fall, while further downstream benthic macroinvertebrate communities were "impaired" during the summer.
- Improvements in benthic macroinvertebrate were consistently observed moving from upstream (near Dillon Reservoir) to downstream (near Green Mountain Reservoir) of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa.
- Lack of periphyton, or benthic algae, may be limiting invertebrate populations and, subsequently, the fishery. Longitudinal declines in periphyton abundance were seen for the first 1 ½ miles below Dillon Reservoir. Further downstream periphyton abundance sampling indicates some recovery moving further downstream, but remain variable.
- Water temperatures downstream of Dillon Reservoir are frequently below optimal cold water ranges for brown trout (Raleigh, et al. 1986), likely having a negative impact on all life stages of the fishery. Cold temperatures seem to have the largest impact on the growth of adult brown trout.
  - In 2020, a reservoir spill created an increase in temperature of 6.6 °C (4.8 to 11.4 °C) in 48 hours, which is considerable when compared to the conditions on the Blue River upstream of Dillon where water temperatures changed 1.2 °C (7.7 to 8.9 °C) over the same 48 hour period.

- In 2020, only the portion of Blue River below Boulder Creek, 11 miles downstream of Dillon Reservoir, recorded water temperatures during the summer in the optimal temperature ranges for adult brown trout growth.
- November temperatures show a reverse temperature trend with warmer temperatures being released from Dillon Reservoir compared to the downstream reaches.
- Rapid changes in temperature and flow associated with the reservoir surface water spills may negatively impact both fry and juvenile brown trout.
- Wild brown trout populations in rivers below hypolimnetic release at other reservoirs in Colorado have not shown the decline in recent years that has been seen on the Blue River.

Summary of Key Issues, Reach 3

- ✓ Recommended environmental flow ranges developed for the Grand County Stream Management Plan (GCSMP) are commonly present, and often exceeded, within the reach (GCSMP 2010).
- ✓ This reach is currently listed on the state's 303(d) list for exceeding state temperature standards.
- ✓ Rapid changes in streamflow have been identified as a possible issue for the Blue River below Green Mountain Reservoir. Such fluctuations could adversely affect aquatic life and pose a human safety risk for recreationists and others along the river corridor.
- ✓ The Blue Valley Ranch (BVR) monitors water quality through their property with results indicating low levels of phosphorus. Low levels of phosphorus with a normal level of nitrogen results in a condition that allows didymo to flourish and thereby out compete endemic periphyton. The low production of periphyton, in turn, limits the macroinvertebrate populations and fish biomass. The BVR is proposing a nutrient injection study and is in the process of applying for approvals.
- ✓ Trout habitat availability varied widely at study sites assessed for the GCSMP. In general, juvenile trout habitat was more abundant than adult habitat, while the adult brown trout habitat consistently exceeded rainbow trout habitat. Adult and juvenile habitat tended to be more abundant near Green Mountain Reservoir, while spawning habitat varied widely between sites, being about 10 times more abundant closer to the Colorado River.
- ✓ CPW 2006 electrofishing data indicate that brown trout dominate the cold-water fishery (estimate of 1676 fish/mile > 150 mm) with lesser numbers of rainbow trout (estimate of 138 fish/mile > 150 mm) (Ewert 2008). Quality trout (> 356 mm) are abundant, estimated at 549 fish/mile.

Next Steps: BRIWMP Phase 2

Initial results from this Phase 1 effort pointed to the need for additional data in several areas in order to present the community with a comprehensive picture of the health of the main stem of the Blue River in particular, and for the entire watershed more generally. The project team believes that additional data are needed throughout the watershed but is especially important in our effort to pinpoint effective strategies to address the declining fishery between Dillon and Green Mountain Reservoirs. The following tasks will build upon the work completed in Phase 1:

Task 1: Develop scientifically valid restoration strategies through evaluation of existing stream flows, both temporally and quantitatively, in relationship to the geomorphology of the stream (Reaches 1 and 2).

Task 2: Sample macroinvertebrates at 10 sample sites in 2021 following the same protocol from 2020. Eight of these sites were sampled in 2020, and two of these sites will be new in 2021.

Task 3: Sample periphyton at 9 sample sites (coincident with macroinvertebrate sampling sites).

Task 4: Continue temperature monitoring in Reach 2 and add monitoring sites on one or two tributaries.

Task 5: Continue to work closely with stakeholders including the Advisory Committee and BREW to ensure the BRIWMP project stays on track with community priorities and concerns. Members of these groups provide critical expertise in a wide variety of subject areas. Build on contacts made to the agricultural community and initiate additional direct contacts to irrigators that will potentially benefit from delivery and application efficiencies.

Task 6: Integrate the findings of Tasks 1 through 5 of Phase 2 into an updated BRIWMP.

Reach-specific recommendations are included in the body of this report, most of which can be categorized into one of the above tasks, although some of the reach-specific recommendations will align better with future phases of the BRIWMP such as physical restoration, monitoring programs, and support of other agencies and local municipalities for existing and ongoing efforts. Funding has been secured for Phase 2 through grants from the Colorado Water Conservation Board (CWCB), Colorado River District, and private funders including Town of Silverthorne, Summit County, Summit Water Quality Committee, Colorado Trout Unlimited, Trout Unlimited and Cutthroat Anglers.

Report Presentation

The BRIWMP is an evolving effort requiring multiple phases and several years to compile and complete. This report will be used and periodically updated by the Blue River Watershed Group (BRWG) in an effort to provide a "go-to" community resource for basin wide water planning issues that affect consumptive and non-consumptive users. The BRWG will also provide the document and subsequent updates to the Colorado Mesa University Water Center for the Colorado Basin Roundtable BRIWMP resource library.

The remaining report is presented in three main sections as described below, followed by seven appendices.

Section 3: Background (Task 1): This section provides background information including a description of the stakeholder engagement process, an overview of the physical setting, and existing conditions of the Blue River.

Section 4: Reach Descriptions (Tasks 2 - 4): For purposes of the Phase 1 report, the Blue River is divided and presented in three reaches. Each of the three reaches is presented in detail including a description of the river and watershed and findings related to the basin's hydrology and water uses, water quality, aquatic life, and river characterization and condition. The reach descriptions include a summary of the technical review and provide recommendations for next steps. Generally, the reach descriptions rely on existing available reports, with limited data analysis. The exception is Reach 2, which also includes field monitoring and analysis, and findings related to the declining fishery between Dillon and Green Mountain Reservoirs.

Section 5: Recommendations and Next Steps: This section summarizes the recommendations from each of the reaches into one table.

Appendices: There are seven appendices topically divided which include a written description of relevant data, reports, and background documentation. Applicable and key information from the appendices is integrated into the reach descriptions to support the key findings and recommendations. These appendices include the following:

A. Stakeholder Plan and Engagement
B. Hydrology and Water Use
C. Water Quality and Temperature
D. Benthic Macroinvertebrate Biomonitoring/Surveys
E. Periphyton Sampling
F. Blue River Fishery
G. Stream Assessments

1. INTRODUCTION

In 2016, Colorado adopted its first ever comprehensive water plan. The Colorado Water Plan (CWP 2019) lays out a roadmap and provides tools for water management, particularly through locally driven and collaboratively found solutions to water issues. One objective of the CWP is to have a Stream Management Plan (SMP) in place for 80% of Colorado's important rivers and streams, including the Blue River, by the year 2030.

A SMP is intended to utilize biological, hydrological, geomorphological, and other data to assess stream flows and other conditions necessary to support the environment and recreational enjoyment of the local community. While these data and conditions are important components to stream management planning, other factors are recognized as also being critical to realizing a comprehensive planning process which would include both consumptive and non-consumptive water use. To broaden the scope of water related planning, the "Integrated Water Management Plan (IWMP)" concept is employed. The IWMP continues to utilize the original components of the SMP process while engaging consumptive users, recognizing and protecting their water rights and their consumptive water uses in the development of innovative water management techniques, protection of environmental resources, and mitigation and restoration of impaired habitat.

The Colorado Basin Roundtable specifically defines the primary purpose of IWMP as identifying methods to meet environmental flow needs along with the needs of agricultural, municipal, industrial, and residential water users. The Summit County Region Implementation Plan (CWP 2015) specifically notes the following:

> *"The needs of the Summit County Region primarily are focused on protecting, maintaining and restoring healthy rivers and streams…..Summit County is very interested in participating in the development of a basin wide stream management plan necessary to identify criteria for restoration projects and multi-use projects."*

Colorado's Water Plan (CWP 2019) specifically recognizes that water is fundamental to meet growing demands and to protect our natural environment into the future. The CWP seeks to address the state's water supply shortages by implementing solutions that meet Colorado's future water needs while supporting healthy watersheds and the environment; robust recreation and tourism economies; vibrant and sustainable cities; and viable and productive agriculture. From 2013-2015 the Colorado Water Conservation Board (CWCB) and the nine Colorado Basin Roundtables assembled Basin Implementation Plans (BIPs) (BIP 2015) which articulate a list of identified projects and processes (IPPs) to address their respective basin supply gaps. This effort resulted in a specific list of IPPs for the Blue River watershed. In 2018, the CWCB initiated an update to the BIP and the IPPs for each basin. An Implementation Working Group (IWG) made-up of roundtable and Interbasin Compact Committee (IBCC) members was formed and they are now tasked with developing recommendations to be included in the CWP Technical Update that provides an initial roadmap for integrating findings, updating project lists, and developing BIP updates. To that end, recommendations developed from this BRIWMP have been provided for inclusion with the IPPs updates.

2. SCOPE OF WORK

The long-term goal of the BRIWMP (Phase 1 and 2) is to enable consumptive and non-consumptive water users to understand current and future water uses, integrate those uses and needs for the maximum benefit of all and for the health and sustainability of the watershed, while protecting the existing water resource and existing water rights. The BRIWMP will provide a framework for stakeholders in the Blue River watershed to make water planning decisions in the future in the face of changing conditions, such as increased demand or water scarcity.

Developing the BRIWMP is a comprehensive process that relies on the input and coordination from all water users – agricultural, industrial, municipal, environmental, and recreational – in order to reflect local values in a balanced manner. To that end, Trout Unlimited (TU) and the Blue River Watershed Group (BRWG) are working together to produce a basin wide BRIWMP for the Blue River in Summit and Grand Counties in Colorado. Phase 1 of the project began in August 2019 and is projected to conclude in August 2021. Phase 1 generally includes an assessment of the health of the river and its ecosystem for the entire watershed, identification of issues and concerns, the development of goals and objectives, recommendations for additional study needs, and the development of actionable items to further advance the BRIWMP.

Phase 1 of the BRIWMP has two primary objectives: First to assess the declining fishery between Dillon and Green Mountain Reservoirs that lost its Gold Medal fishing status in 2016. Secondly, to compile, review, and integrate existing studies, plans and other information regarding the physical and biological aspects of the Blue River main stem, for the purpose of formulating goals and objectives that will guide future water management and habitat related decisions. This "synthesis" of watershed data and information will identify gaps where additional analysis, studies, and/or reports may be needed and will help identify and prioritize watershed projects for future implementation.

PHASE 1 OBJECTIVES

I. Investigate the declining fishery between Dillon and Green Mountain Reservoirs

II. Compile, review, and integrate existing information regarding the physical and biological aspects of the Blue River

The objectives are addressed following four tasks, all of which have been undertaken by the project team and reported on herein.

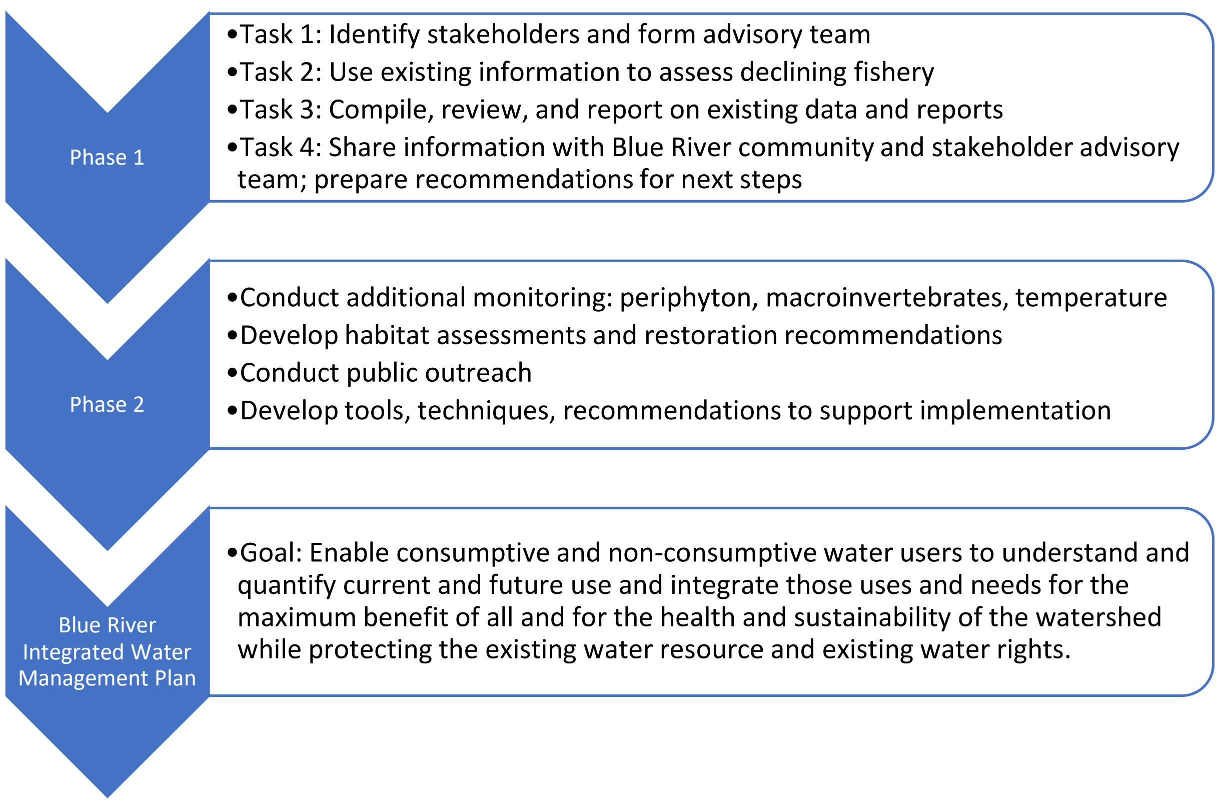
Task 1. Identify stakeholders and form an advisory team to provide input and guidance on objectives and goals. The stakeholder advisory team will guide and inform on the identification of concerns and important issues, goals and objectives, analyses and studies, framework for long-term monitoring, and the development of an acceptable plan.

Task 2. Compile and review existing available data, information, and studies including agricultural, municipal and domestic water use, environmental water related issues, and recreational water use. Synthesize and summarize existing available data, information, and studies in a manner that supports the decision-making process for developing plan objectives and goals.

Task 3. Utilize this baseline information to inform the Blue River community and stakeholder advisory team on relevant issues and support the development of the IMWP goals and objectives. Formulate both multi-use projects, defined as simultaneously serving several purposes, and innovative water management techniques that are beneficial to all users including development of environmental, agricultural and recreational goals identified through the stakeholder process. Prepare recommendations for next steps to complete the BRIWMP.

Task 4. Assess the declining fishery between Dillon and Green Mountain Reservoirs utilizing a combination of existing available data and information, additional macroinvertebrate and periphyton sampling, and temperature monitoring conducted in 2020.

By way of these four tasks, the completion of Phase 1 will provide background and context to enable the Stakeholders to further define the purpose and need of the BRIWMP, identify assessment gaps, selection of objectives and measurable results, and initiate the identification of specific actions. Phase 2 will be the implementation of these specific actions and may include such efforts as additional monitoring and assessments, habitat assessments and restoration recommendations, additional studies, and public awareness outreach to name a few examples.



3. BACKGROUND

Stakeholder Engagement (Task 1)

In 2016, Colorado Parks and Wildlife Gold Medal status was removed from a 19 mile stretch of the Blue River north of Silverthorne. The stretch had not met Gold Medal criteria for 15 years prior. The Blue River Enhancement Workgroup (BREW) was formed later that year to investigate the situation and recommend a path forward. BREW is a key partner in the development of the BRIWMP and a key stakeholder. BREW, in consultation with Dr. William Lewis, head of Limnology-University of Colorado, had already reviewed past studies and suggested several additional studies, field assessments, and analyses to further the understanding of conditions impacting this fishery. To that end, this Phase 1 effort includes a comprehensive sampling of macroinvertebrate and temperature monitoring. This very specific course of action will be combined with the efforts described in Objective 2 (compile and review existing available data, information, and studies) to further the understanding of river conditions and support additional recommendations to improve the fishery.

The BRIWMP project team began the process of developing a basin wide water planning effort by asking key community members to identify key components, issues, projects, etc. that would be the focus for such an effort. Two themes consistently emerged: concern over the declining fishery in the Blue River, as discussed above, and the lack of a current specific water management plans for the basin. These formed the basis for the development of the Phase 1 scope of work.

Concurrently TU and BRWG continued to reach out to the community to build a list of stakeholders (in addition to the original community water leaders) including representatives from local, state, and federal agencies, representatives of local municipalities and counties, the recreational community, and others to help inform on the project. From the Stakeholder members, a core group of participants formed the Advisory Committee (AC). The AC is charged with periodically assessing the results of the project and ultimately advising on the future goals, objectives, and projects identified for Phase 2 of the BRIWMP. In addition, there have been community outreach efforts and community input meetings that have contributed to this effort. Meeting summaries and additional information on these meetings is provided in **Appendix A**.

Finally, to solicit a productive and ongoing dialogue between the BRIWMP project team, the Advisory Committee and the community, the project team has created a list of objectives that expand on the project themes. These objectives align with the CWP and form the basis for the literature and data search performed for Phase 1 of the BRIWMP and help guide the AC and community input. They are intended to be flexible and to be modified over time as directed by the AC and community input. The objectives include:

1. Protect water supplies and support local municipal water users' needs
2. Protect and improve agricultural water uses and operations
3. Support recreational sectors and associated businesses
4. Preserve, enhance, and restore healthy rivers and riparian habitat
5. Develop water management strategies that support aquatic habitat while protecting water rights, water uses, and diversion requirements
6. Assess the declining fishery in the Blue River below Dillon Reservoir

Overview of Existing Conditions

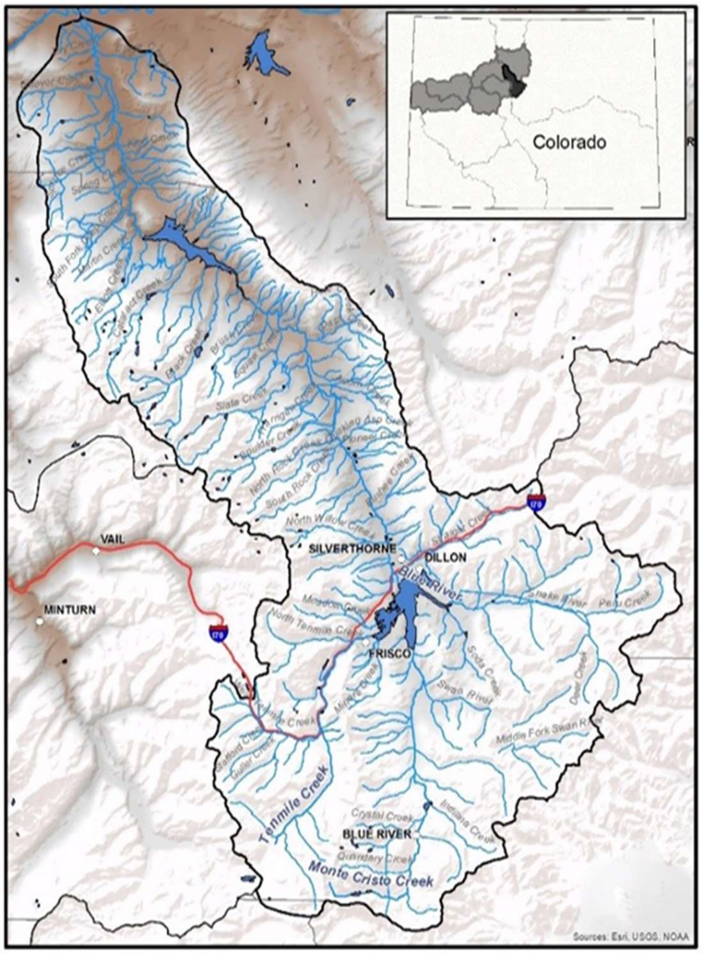


Figure 1. Blue River Watershed Location Map.

The Blue River watershed is located in the Rocky Mountains on the western slopes of the Continental Divide in central Colorado (**Figure 1**). The Blue River watershed generally aligns with the Summit County boundaries, with the exception of 80 square miles that extend into Grand County at the confluence of the Colorado River, and a small area at the head of the Tenmile Basin, which lies within Lake County.

The Blue River basin exhibits a variety of riverine ecosystems - from steep, high mountain creeks to meandering river environments surrounded by irrigated grass-hay pasture. The streams and rivers of the basin support various non-consumptive (recreational and environmental) and consumptive uses (municipal, agricultural and industrial) including the municipal transbasin diversions managed by Denver Water, Colorado Springs Utilities and the City of Golden. The health and maintenance of the water resources is vital to the dependent communities, the environment of the river and watershed, and to the downstream water users.

The watershed encompasses an area of 699 square miles, flowing northward, from elevations reaching 14,270 feet along the southeastern perimeter, to 7,400 feet where it flows into the Colorado River south of Kremmling (NWCOG 2012). The upper watershed is bounded on the west by the Tenmile Range and to the east by the Continental Divide. Major tributaries to the Blue River include the Swan River, Tenmile Creek, Snake River, Straight Creek, Willow Creek, Rock Creek, Boulder Creek, and Cataract Creek.

Monthly average air temperatures in the Dillon area range from a low of 15.1 °F in January to a high of 55.8 °F in July (Western Regional Climate Center 2014 as cited in NWCOG 2012). Precipitation in the Blue River watershed ranges from 10 to 15 inches per year in the lower valleys to 40 to 45 inches per year at the higher peaks (PRISM Group and Oregon Climate Service 2006 as cited in NWCOG 2012). Most precipitation falls as snow during January through April; snowmelt occurs during May through July. Significant rainfall can occur during July and August from thunderstorm activity.

Within the Blue River watershed lie the towns of Dillon, Silverthorne, Frisco, Keystone, Blue River, Heeney, and Breckenridge (Figure 1); four ski areas; 9,000 acres of irrigated agricultural land; and two major water storage reservoirs (Green Mountain Reservoir and Dillon Reservoir). Public lands managed by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM) make up approximately 79% of the total area in Summit County. The Colorado State Demographer estimated the Summit County population in 2012 at 28,160 people and forecasts the population will grow to 50,350 by 2040 (NWCOG 2012).

With its large availability of public lands and year-round recreational opportunities (**Figure 2**), Summit County and the Blue River watershed are exceedingly popular destinations for Colorado Front Range travelers, and out-of-state tourists. The Basin is home to some of the largest and most visited ski resorts in Colorado, including Keystone, Breckenridge, Copper Mountain, and Arapahoe Basin. In 2018, visitor spending in Summit County totaled over $1.12 billion (a 52% increase from 2010), creating $48.5 million in local tax revenue for the community (Dean Runyan Associates 2019). For small towns like Silverthorne, CO, sales tax revenue supports nearly 70% of the town budget (Sienkiewicz 2020). According to the US Forest Service, summer visitation in the Dillon Ranger District of the White River National Forest was estimated to be 2,354,400 people. Total estimated spending on trips and equipment by activity indicate that fishing accounts for 4%, boating 7 % and skiing 25%, of which all are directly water dependent (Richardson 2021).

The agricultural community in the Blue River Watershed is an essential component to the basin, protecting open lands, wildlife habitat, cultural values and pre-compact water rights. Water to irrigate agricultural land is also critically important to retain this important component of the economy and culture of Summit County (Coley/Forrest 2011). The 2007 the market value of products sold totaled over $1.1 million. Based on the Summit County Census of Agriculture, from 2007 to 2017 there appears to be relatively little change in overall acreage of farmlands, but there has been a change in the number of farms. In 2017 there were 55 farms in the County occupying 26,572 acres up from 41 farms and 25,365 acres in 2012, and 25 farms covering 25,365 acres in 2007. Most of the land use is pasturelands (SCCA 2017).

Figure 2. Blue River Watershed.

On average, under current conditions the Blue River watershed generates approximately 310,000 acre-feet of water per year (NWCOG 2012). Snowfall and rainfall are the only sources of this water. No water is imported into the Blue River watershed from other sources or locations. Local municipal water use, including snowmaking and golf course watering, divert an estimated 12,000 AF of water per year or 4% of the average annual yield, while 81,000 to 95,000 ac-ft of the 310,000 AF or 25% to 30% of the average annual yield is moved out of the watershed through transbasin diversions (NWCOG 2012). Typically, in-basin water use involves the withdraw of water, the consumption of water, and the return of excess flows that are not consumed or lost in transmission. For domestic, commercial, and recreation uses the consumptive rates are generally around 13% to 34% with 87% to 66% of the diverted flows being returned to the river basin. Agriculture consumptive varies depending on operations, generally ranging from 68% to 78%. Conversely, transbasin diversions are 100% lost from the basin of origin with no water returns

(Coley/Forrest, Inc. 2011). Typical consumptive uses and return flows are depicted in **Figure 3** (Coley/Forrest, Inc. 2011) which graphically demonstrates the significant impacts of transbasin diversions.

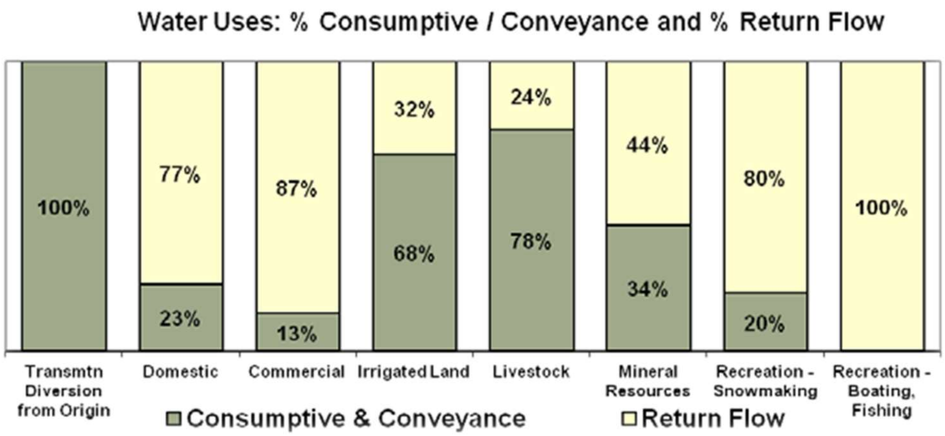


Figure 3. Typical Consumptive Water Uses (Coley/Forrest Inc. 2011).

Demands on this resource are significant. Information developed through the Colorado Water Plan Technical Update, assembled by Colorado Water Conservation Board (CWP 2019) indicates future water demands combined with climate-impacted conditions will likely result in peak flows moving earlier in the year, with April through August flows decreasing and possible mismatches between peak flow timing and species' needs. The *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* scenarios developed in the Flow Evaluation Tool indicate mid- and late-summer flows may be reduced by 60 to 70 % creating high risk for fish from loss of habitat. In addition, downstream from major reservoirs diminished peak flows could create risk for riparian/wetland vegetation and fish habitat if sediment is not flushed (CWP 2019). The Colorado Basin Implementation Plan concludes that the Blue River watershed will likely be facing a gap of 22,000-48,000 acre-feet per year (ac-ft/yr) between water supplies and demands by 2050 (BIP 2015 as cited in HCCC 2019). (See **Appendix B** for additional information).

4. REACH DESCRIPTIONS (TASKS 2 AND 3)

For purposes of this report the Blue River watershed is divided into three distinct reaches (**Figure 4**):

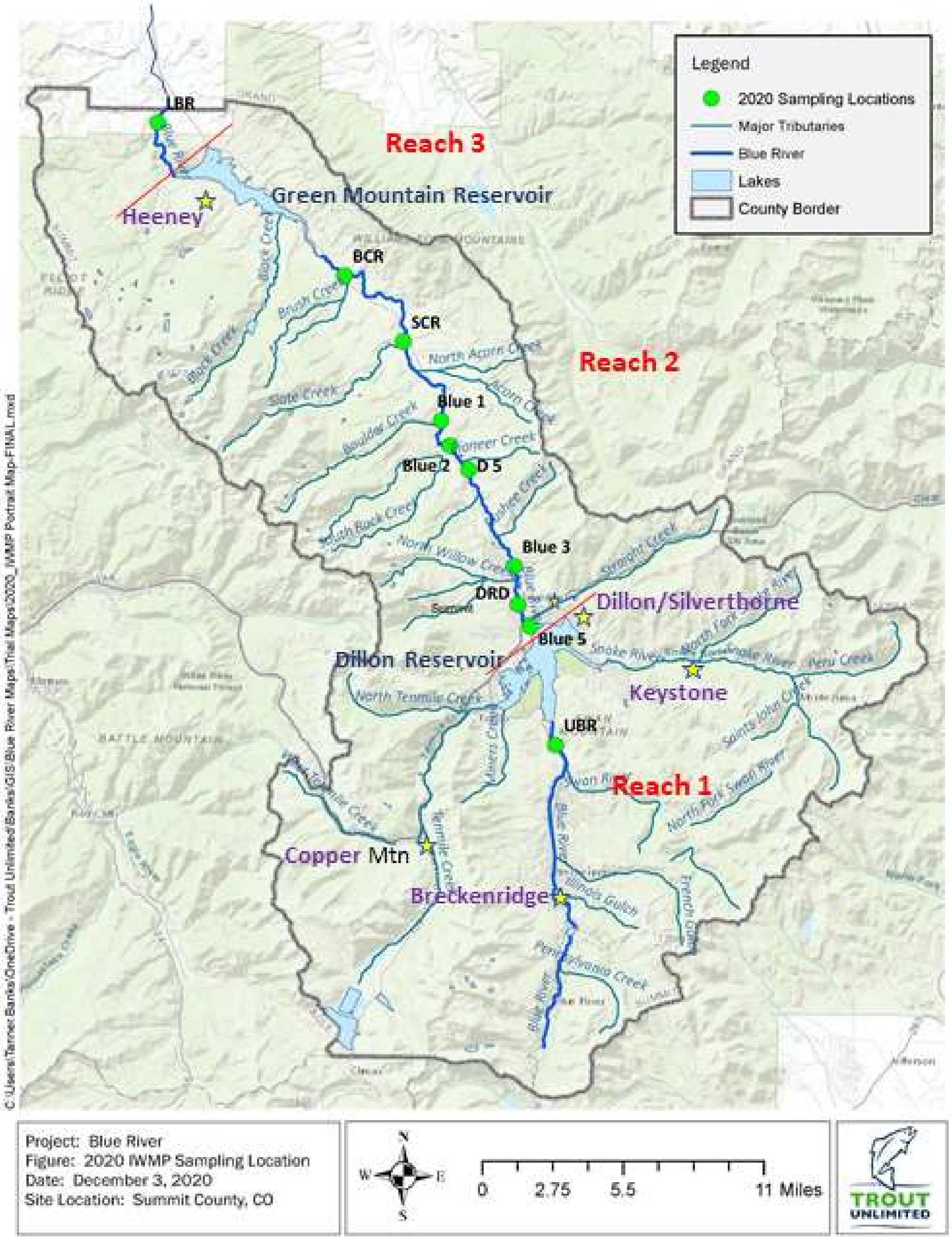


Figure 4. Blue River Reach Designations.

Reach 1: Upper Blue River from its headwaters at the Continental Divide to the outlet at Dillon Reservoir.

Reach 2: Middle Blue River from the outlet at Dillon Reservoir to the outlet at Green Mountain Reservoir.

Reach 3: Lower Blue River from Green Mountain Reservoir outlet to the Colorado River Confluence.

In addition to the three reaches, there are nine sites shown on Figure 4 which represent stream gages and/or sampling and data collection sites used in this report. Sampling and data collection include macroinvertebrates, periphyton, and temperature data. Details on the sampling efforts and data collection are noted herein and within the Appendices.

Tributaries within each reach are generally not included in this Phase 1 report. Several tributaries may be noted in the reach descriptions as they may affect the conditions of the main stem. However, the overall focus of this assessment is on the Blue River main stem. The reach presentations are organized by five primary topics:

1. Water use
2. Hydrology
3. Water quality and temperature
4. Aquatic life
5. Stream assessment

Each reach description includes a brief description of site-specific characteristics and/or issues, unique features, summary of findings from existing available and applicable studies, key findings, and recommendations for next steps. Phase 1, Task 4, which addresses the declining fishery between Dillon and Green Mountain Reservoirs utilizes a more comprehensive combination of existing available data, and field sampling data for macroinvertebrate, periphyton, and temperature monitoring conducted in 2020. This information is presented in Section 4.2.

In addition, a stream health assessment for the Blue River was conducted for the purpose of rating functional ecological conditions of the river to develop a basis for understanding the key physical characteristics of the river and associated aquatic health.

4.1. Reach 1: Blue River – Continental Divide to Dillon Reservoir Outlet.

The watershed area tributary to Reach 1 is about 334 square miles in size measured from the headwaters to the Dillon Reservoir outlet, representing 48 % of the total 699 square mile watershed. The watershed area contributing to Reach 1 includes the towns of Blue River, Frisco, Keystone, Breckenridge and portions of Dillon and Silverthorne; four ski areas, and five water impoundments (Dillon Reservoir, Goose Pasture Tarn, Upper Blue Lake Reservoir, Clinton Reservoir and Old Dillon Reservoir). This watershed also includes two transbasin diversions: Roberts Tunnel and Hoosier Tunnel. The watershed, floodplains and river corridors in Reach 1 have been highly altered by hard rock mining and dredge boat mining (**Figure 5**), both of which have impacted the health of the river and aquatic habitat, the riparian corridor, and the overall landscape.

Figure 5. Reach 1 Blue River at Breckenridge (1990s).

Three major tributaries confluence with the Blue River in Reach 1. These include the Snake River, Tenmile Creek, and Swan River. French Gulch is also a tributary of interest to the Blue River flowing westerly and confluences with the Blue River near the Town of Breckenridge. Both French Gulch and the Snake River have elevated levels of contaminants from hard rock mining which may be impacting the health of those tributaries as well as the health of the Blue River (Bauch et al. 2014).

Reach 1 is approximately 16.6 miles long, measured along the valley floor, and extends from Hoosier Pass on the Continental Divide to Dillon Reservoir. For purposes of this assessment, Reach 1 is further subdivided into four subreaches (**Figure 6**) to represent the changing morphology and starkly different settings, in terms of river form, urban development, and historic disturbance from mining activities. The assessment does not include Dillon Reservoir, nor tributaries to the reservoir and main stem of the Blue River.

- R1.1 Headwaters to Maggie Pond in Breckenridge: Approximately length 7 miles
- R1.2 Maggie Pond in Breckenridge to French Gulch Confluence: Approximately length 3 miles
- R1.3 French Gulch to Swan River to confluences: Approximately length 5 miles
- R1.4 Swan River confluence to Inlet to Dillon Reservoir: Approximate channel length 2 miles

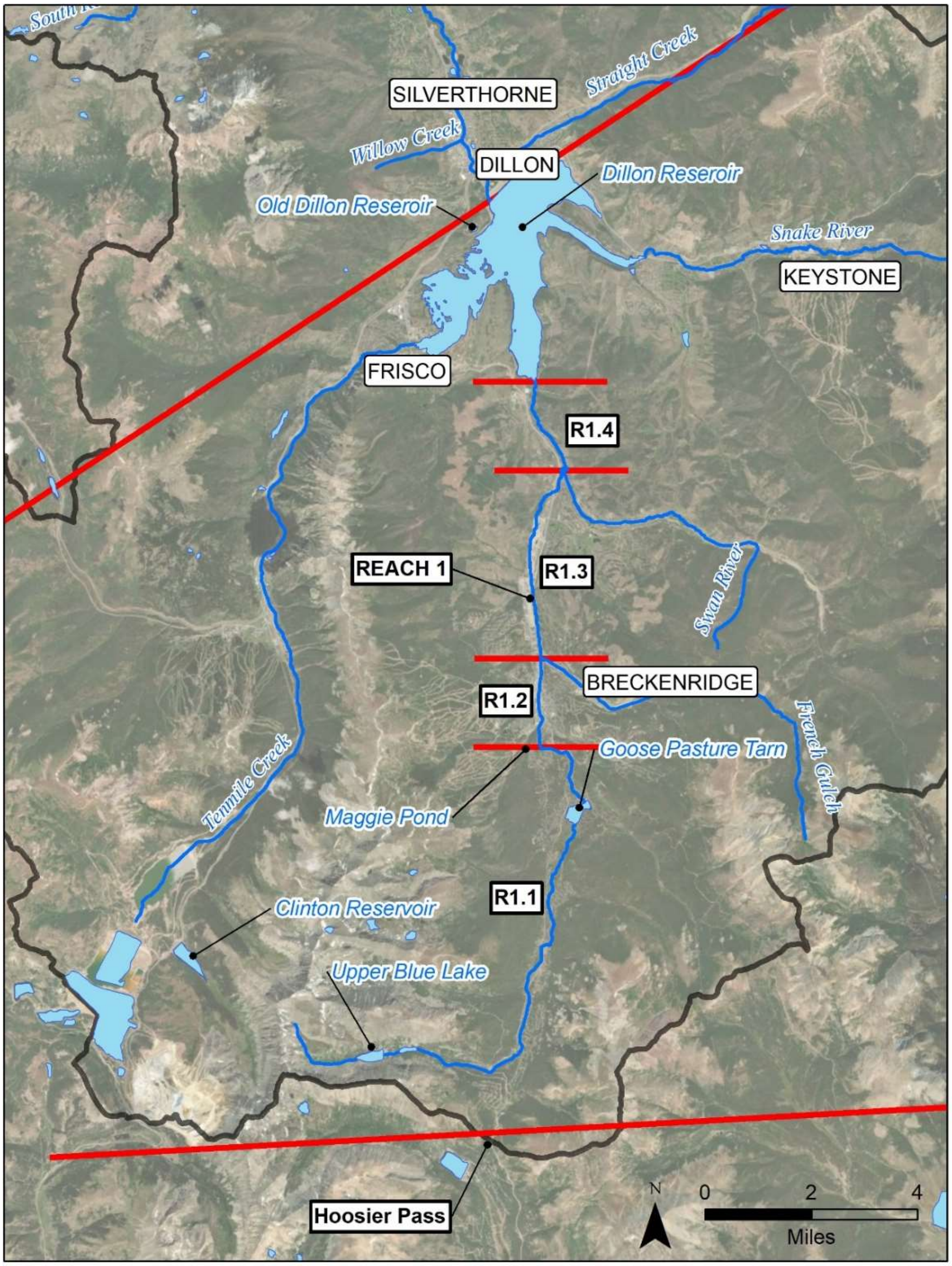


Figure 6. Reach 1 Blue River at Blue River.

The Blue River mainstem within R1.2 and R1.3, had been heavily disturbed by dredge boat mining from the turn of this century until 1940. Dredge boats extracted the river alluvium and sifted through the material for gold, washing fines downstream and leaving behind large piles of rock, often deposited in uniform sizes due to the sorting process. As a result of this activity, the original river channel and surrounding floodplain was destroyed. What remained of the river was an indistinguishable channel containing flows only during snowmelt runoff. As late-season flows receded, the river was conveyed in the subgrade through the voids of the massive dredge rock piles. The dredge tailings were devoid of vegetation, fines and boulders, were highly mobile and very unstable (**Figure 7**).

Figure 7. Blue River north of Breckenridge: left photo is before restoration, middle photo of overbank wetlands pond after restoration; right photo is river channel after restoration.

Since the mid-1980s, the Town of Breckenridge, Summit County and several private property owners have worked to restore the Blue River. Several studies were conducted along this highly disturbed reach to assess the hydrology, groundwater depths, existing vegetation (where present), and a geomorphic evaluation of the highly disturbed floodplain. The following summary is generally described in Blue River Section 206 Aquatic Ecosystem Restoration, Breckenridge, Colorado, Engineering Report (McMillen LLC., Tetra Tech 2013).

The first restoration effort was performed in the 1980's along a 1.25 mile reach of the Blue River between Valley Brook Street and Coyne Valley Road north of the Town of Breckenridge. This project was, at the time, confined to a narrow corridor due to a proposed airport runway to the west and Highway 9 to the east. This resulted in the restoration being constructed using a series of drop structures as opposed to a more sinuous alignment. This project also served to provide offsite wetland mitigation and as such, included narrow bands of wetland pockets adjacent to the river. Groundwater monitoring in this reach indicated relatively shallow depths of disturbance from gravel extraction, thus allowing the capture of stream flows by lowering the channel into the gravel alluvium.

The second restoration effort occurred in the 1990s along a 0.3 mile reach of the Blue River through downtown Breckenridge. Groundwater measurements in this reach of the river indicated variability of water levels that would not support a continuous flow in the river. Thus, the channel subgrade was constructed with a lining in order to contain surface flows. This reach of the river was designed to fit within the Town's urban corridor with multiple pedestrian access points to the rivers.

Beginning in the early 2000s, a conceptual study was developed along a 2-mile reach of the Blue River from the north end of the Town of Breckenridge, downstream to the crossing of the river with Highway 9. Project planning was developed through a grant from EPA, administered by NWCOG. This reach crosses four different properties, all with different ownership including the Town of Breckenridge, two privately held parcels, and Summit County Open Space. A conceptual level study was conducted to evaluate existing geomorphology, hydrology, develop conceptual design strategies, review groundwater levels, and develop recommendations for restoration and parameters to physically link the restoration of the four properties together. Since the mid-2000s, restoration has occurred on three of these sites including both privately held properties and the County parcel. The fourth phase of restoration on the town of

Breckenridge property north of Coyne Valley Road is currently in progress. Due to the depth and significant lateral extent of the dredge boat mining, low-permeability subgrade lining is required to contain flows within the channel for the upper half of this reach, while further downstream the extent of disturbance is narrower and shallower, forcing stream flows back to the surface naturally.

4.1.1. **Water Use**

Primary Municipal Water Users

Water use in this reach includes local municipal water supply, snow making for the ski industry, irrigation at the golf course, and two transbasin diverts.

- Town of Breckenridge: The Town of Breckenridge is the primary municipal water supplier in Reach 1. In 2000, the Upper Colorado River Basin Study (UPCO) report shows water demands in the Town was 2,062 ac-ft. The Town responded to the BRWG water provider survey, indicating projected water demands of 3,700 ac-ft by the year 2050. The Town's main concern relative to water supply is wildfire and replacement of old infrastructure.
- Copper Mountain Consolidated Metropolitan District and the Snake River Water District are both in Reach 1 as they are located on tributaries to Dillon Reservoir. Water demands for the districts are currently 350 and 615 ac-ft, respectively, with both indicating project demands of 750 ac-ft by 2050. Copper's main concerns include drought, wildfire, replacement of old infrastructure while the Snake River water district is concerned about groundwater under the direct influence of surface water.
- Denver Water: On average, the Blue River watershed supplies approximately 30% of Denver Water's needs through diversions from Dillon Reservoir via the Roberts Tunnel. Current average annual diversions through the Roberts Tunnel are 57,415 ac-ft based on Colorado Division of Water Resources streamflow gage data from 1965 to 2019 (Elder 2020). Average annual native yield for the entire watershed is estimated to be 310,00 ac-ft per year, thus diversions through the Roberts Tunnel based on the past 54 years of data, represent approximately 18.5% of the annual average water yield from the watershed. Diversions through the Roberts Tunnel are highly variable and dependent on many factors and therefore the amount of future diversions is unknown. However, Denver Water's existing decrees will allow total diversion to almost 100,000 ac-ft per year at full use (Elder 2021), representing 32.2% of the average annual yield for the entire watershed (Appendix B).
- Continental-Hoosier System: Colorado Springs Utilities is proposing to optimize its existing collection system by increasing storage on the Continental-Hoosier System. The purpose is to capture water that is currently "spilled" due to system storage and capacity limitations. This project could potentially include new or expanded reservoir storage facilities in Reach 1 and enlargement of Montgomery Reservoir in Park County (BIP 2015). These water rights are conditional water rights. Any project must obtain approval through Summit County's 1041 process. Current transbasin diversions through the Continental-Hoosier System are estimated to be 7,900 ac-ft/yr. Future diversions are unknow at this time.
- Water Supply Issues**:** UPCO reports that generally Reach 1 is currently meeting existing water demands and estimates that future water supply needs will generally be met with the exception of some shortages identified for the Breckenridge ski area and golf course (HRC 2003).

Agricultural Operations

Currently there is very little to no active agricultural activity in this reach of the Blue River watershed.

Recreation

The Breckenridge, Copper Mountain, Keystone and Arapahoe ski resorts are all located in Reach 1, with Breckenridge ski resort the only ski resort directly tributary to the Blue River. Copper, Keystone and Arapahoe are with the Ten Mile and Snake River watersheds, both tributary to Dillon Reservoir. Outdoor recreationists in Colorado spent over $36.8 million on trips and equipment in 2017 of which 25% is generated by the ski industry. Snowmaking accounts for approximately 1% of the total annual demand under future full buildout conditions (Appendix B), although the water for snowmaking is typically diverted over a short time period in the fall when flows in the rivers are naturally low. Snow making in the late fall often affects flow regimes in this reach, particularly between the Town of Breckenridge and the confluence of the Swan River. A minimum of 20 cfs (10 cfs from November 1 to May 1) is required to meet minimum instream flows at the State of Colorado 'Blue River at Highway 9 Bridge below Breckenridge' gage (CWCB 2020) .

Dillon Reservoir (Reservoir) is a very popular destination for boating, angling, and other recreation opportunities. Completed in 1963, the 3,233 acre reservoir is owned and operated by Denver Water and is home to two major marinas (Dillon and Frisco) that provide rentals and mooring options for users, as well as host numerous regattas and public events. In 2020, the Dillon Reservoir Recreation Area permit holders (marinas, rental companies, etc.) generated over $700,000 in revenue and engaged over 6,000 users (Mead 2021).

The Dillon and Frisco Marinas are considered "unusable" below water elevations of 8,971 feet and 9,009 feet, respectively. Through provisions in the Colorado River Cooperative Agreement, Denver Water has agreed to use best efforts to maintain the water level of Dillon Reservoir at or above 9,012 feet in elevation between June 18 and Labor Day in order to support reservoir recreation opportunities (Denver Water 2021). In addition to marina use, Dillon Reservoir is a popular destination for standup paddler boarders, kayakers, rowers, sailing, camping, hiking, and wildlife viewing.

Shore and boat fishing are also very popular on the Reservoir. According to Colorado Parks and Wildlife, Dillon Reservoir is "high, deep, and cold," characteristics that make it "relatively unproductive" and managing the fishery a routine challenge. However, ease of access and popularity drive many anglers to hunt for the rainbow and brown trout, kokanee salmon, and arctic char that are available in the lake (Ewert 2020b). CPW currently only stocks rainbow trout fingerlings, maintaining the remaining sport fish populations under "wild fishery" management protocols. Due to the limited food sources available in the lake and competition with other species (e.g., suckers), arctic char, kokanee salmon, and rainbow trout populations have been found to be decreasing in size and number in CPW gillnet surveys, a trend that is closely monitored by the wildlife management agency (Ewert 2020b).

In addition to reservoir recreation, the Blue River and its tributaries offer numerous opportunities for shore angling. Popular areas on the Blue River and tributaries in Reach 1 include: Swan River, Gold Hill access, Breckenridge pond, and the Breckenridge "stair steps" (West 2021). Summit County and numerous partners are currently restoring a section of the Swan River (roughly 4.5 miles upstream of the confluence with the Blue River) from dredge mining impacts to support a more natural stream. This project will increase opportunities for angling in the years to come.

In a 2020 Trout Unlimited survey of local anglers, roughly 65% indicated dissatisfaction or concerns with fishing in Reach 1 citing poor fish quality, habitat, water quality in certain tributaries, litter, and crowding (Omasta 2020). A creel survey, defined as an in-person survey of anglers to estimate the number of catches and assess the fishing experience, was performed at Dillon Reservoir by Colorado State University in 2012. The survey documented a lightly used fishery with low angler effort, catch and harvest, and moderate to poor angler satisfaction. Arctic char were not documented in the angler catch but anecdotal evidence suggests that catch rates of Arctic char are higher during winter when no survey was performed (Johnson 2013).

Float boating and kayaking opportunities in Reach 1 are limited due to the naturally small channel, being in the basin's headwaters, and associated low flows. One kayak park exists in the Town of Breckenridge upstream of Valley Brook Street near the Town's recreational center. The Town holds a recreational water right for the kayak park. The course is 1,800 feet in length and includes 15 water features. Use here is typically May through June.

4.1.2. **Hydrology**

Two USGS gage stations are on the Blue River mainstem within Reach 1, Station 09046490 (Blue River at Blue River) and Station 09046600 (Blue River near Dillon) and have been in operation since 1983 and 1957, respectively, to present. A third gage is also within this Reach, located at the Highway 9 bridge mid-way between Breckenridge and Dillon Reservoir and operated seasonally by the CO Division of Water Resources (BLUNINCO). Daily streamflow exceedance plots of the two USGS records are shown on **Figure 8 and Figure 9.** An exceedance hydrograph represents how often the flows have exceeded a level in the past. For example, the 75% exceedance plot, represents the flows that were equaled or exceeded 75% of the years for each day. Likewise, the 25% exceedance plots represent the flows that were equaled or exceeded 25% of the years for each day. Thus, at Station 09046600 (Blue River near Dillon) shown on Figure 9, the 10% exceedance plot indicates that in mid-June, 10% of the time flows were exceeded by approximately 700 cfs, or alternatively 90% of the time flows were less than 700 cfs.

In 1973, the General Assembly authorized the CWCB to appropriate water rights for instream flows and natural lake levels to preserve the natural environment to a reasonable degree. Since 1973, CWCB has appropriated instream flow water rights on nearly 1,700 stream segments across Colorado covering more than 9,700 miles of stream, and natural lake level water rights on 480 natural lakes. Instream flows for the Blue River in Reach 1 are provided below:

<u>CWCB Instream Flows, Blue River</u>

- Upper watershed to Hwy 9 near Fredonia Gulch* confluence: 2 cfs year-round (1/1 – 12/31)
- Fredonia Gulch* confluence to Goose Pasture Tarn: 5 cfs (5/1-9/30) and 3 cfs (10/1-4/30)
- Pond upstream 1 mile from Swan River confluence to Swan River confluence: 20 cfs (5/1-10/31) and 10 cfs (11/1-4/30)
- Swan River confluence to Dillon Reservoir: 32 cfs (5/1-10/31) and 16 cfs (11/1-4/30)

*Fredonia Gulch is located approximately 3 miles upstream of Goose Pasture Tarn dam.

These instream flows are overlaid on the exceedance plots shown on Figures 8 and 9. These plots show the instream flows at both gage sites are exceeded at least 90% of the time at both gages. Or, from an alternative perspective, the instream flows are quite low compared to the gage flows recorded at these sites.

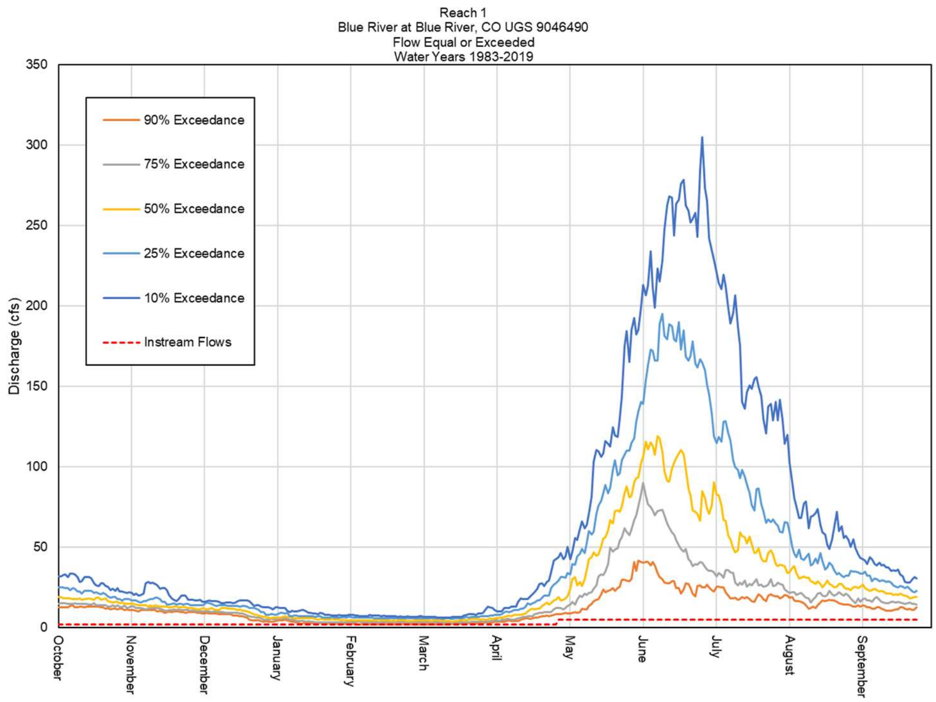


Figure 8. Station 09046490 (Blue River at Blue River) Exceedance Hydrograph.

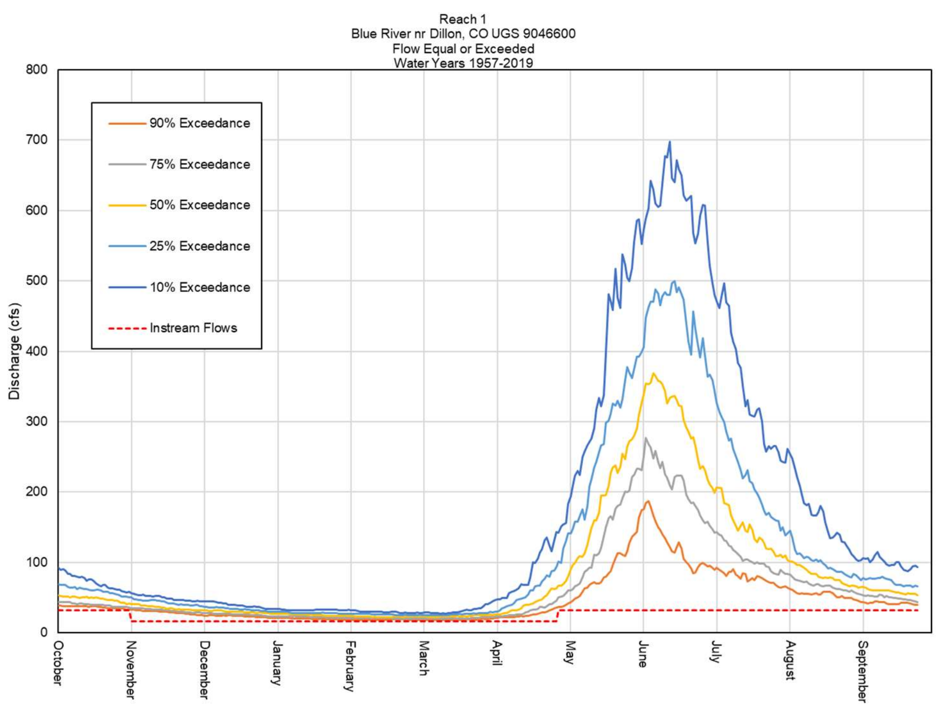


Figure 9. Station 09046600 (Blue River near Dillon) Exceedance Hydrograph.

4.1.3. **Water Quality and Temperature**

Water Quality

The French Gulch/Wellington-Oro Mine Site is located within the French Gulch watershed and drainage from this watershed is a likely the source of several constituents of concern including cadmium, copper, zinc and iron. Environmental contamination of surface water, groundwater, soil, and sediment at the site resulted from mining activities dating to the 1880s. Site investigations have concluded that the underground workings (tunnels, adits, drifts, stopes, and crosscuts) of the site constitute the largest source of metals loading to groundwater and surface water. An on-site seep is the primary conduit of mine pool water into French Gulch. The surface water and groundwater remedy consist of a water treatment plant (WTP), which treats acid rock drainage. The WTP removes zinc and cadmium to improve surface water quality in French Gulch and the Blue River. Review of available data sources indicate that even with the WTP the mainstem of the Blue River in Reach 1 sampled sites exceed some Colorado State standards for water quality. In addition to the impacts of legacy mining in French Gulch, water quality is impacted by mining in several other headwater reaches. USGS, Colorado Division of Reclamation, Mining and Safety, Trout Unlimited, Colorado University at Boulder, and various entities continue work to mitigate impacts of legacy mining throughout Reach 1. A detailed review of existing available water quality data is presented in SGM 2021, attached in **Appendix C** and summarized below.

- Cadmium is present in the Blue River, particularly in Reaches 1.3 and 1.4 below the confluence with French Gulch. The cadmium water quality standards vary by segment.
- Copper is present in the Blue River, particularly at the Breckenridge Recreation Center (CORIVWCH 656) and above Swan Mountain Road (CORIVWCH 657), both located in Reach 1.3. Water quality exceedances have been measured at both the recreation center and above Swan Mountain Road, particularly in spring and summer.
- Iron is present in the Blue River and exceedances have been observed at the Recreation Center, Above Swan Mountain Road, and at Swan Mountain Road, in Reaches 1.3 and 1.4.
- Limited data sources indicate there may be a presence of silver and selenium in Reach 1.
- Zinc concentrations at the Recreation Center and at Swan Mountain Road (Reaches 1.3 and 1.4) exceed water quality standard.

The Climax Molybdenum mine discharges to Ten Mile Creek, a tributary to Lake Dillon within Reach 1. Climax is currently investigating and identifying sources of molybdenum in Climax's discharge and investigating influent control measures and potential water treatment options. The study has confirmed that, in addition to molybdenum from historical mine drainage sources, concentrations of molybdenum in the water system and observed in the discharge from Climax are related to the ore type being mined by Climax. Climax is currently evaluating potential options that involve water management, optimization of water treatment, maximizing available blending, and water treatment influent control. Climax plans to work with the Division on its recommendations.

Water Temperature

Reach 1 is a Tier I stream, defined as Aquatic Life-Class 1 with a maximum weekly average temperature MWAT) of 17.0 ^{o}C and maximum daily average of 21.7 ^{o}C standard. Generally, the data indicate a warming trend moving from upstream to downstream until just above the confluence with the Swan River where temperatures drop. No exceedances were noted in the data (SGM 2021 attached in Appendix C).

4.1.4. **Aquatic Life**

Fish Surveys

CPW fish surveys indicate that the fishery is excellent in the downstream portion of Reach 1 near Fourmile Bridge (Reach 1.4) and exceeds the criteria for Gold Medal designation. However, the data also indicates that there is a potential decline in the fishery. Reasons for the decline could be related to water quality and habitat fragmentation. Closer to Breckenridge at the Valley Brook Road Station, (Reach 1.3) 3.4 miles upstream, the fishery is exceptionally poor, most likely due to low flows, fragmentation and water quality. The absence of sculpin in this upper reach may be an indicator of water quality impacts. This reach is 2,500 linear feet downstream of French Gulch confluence and mine runoff water entering the Blue River at the point may preclude sculpin from persisting in this reach (Ewert 2019).

Macroinvertebrate Monitoring

A review of past macroinvertebrate monitoring coupled with sampling in 2020 indicate the macroinvertebrate community structure and function at the sampling station designated as ‘Upper Blue River or ‘UBR’ located just upstream of Dillon Reservoir at Swan Mountain Road (Reach 1.4), consistently showed evidence of minor to moderate stress, despite supporting a benthic macroinvertebrate community that was considered close to or in ‘attainment’ for aquatic life use. Although this site provided reference information related to reservoir influences, it is likely that this location was also impacted by other anthropogenic stressors, including runoff from an adjacent highway (Timberline Aquatics 2021, attached in **Appendix D**), low flow and water quality. In 2012, macroinvertebrates at the UBR site were sampled by Summit Water Quality Commission (SWQC) with results below the impairment threshold. The 2012 analysis postulates that unknown effects accounting for the impairment at the UBR station (Reach 1.4) could in part also account for low values below the dam and that values below the dam may be accounted for by factors other than the dam (Lewis and McCutchen 2013).

4.1.5. **Stream Assessment**

A stream health assessment for the Blue River in Summit County, Colorado was conducted for the purpose of rating functional ecological conditions of the river to develop a basis for understanding the key physical characteristics of the river and associated aquatic health. This information will provide and support the formulation of restoration opportunities and/or needs for further study. This assessment utilizes the framework outlined in the Functional Assessment of Colorado Streams (FACStream) version 1.0 (EcoMetrics et al. 2015). FACStream uses ten ecological variables to assess the degree of departure from a reference reach, defined as “the river in its state of natural dynamic equilibrium or ‘optimal‘ functioning river system, likely present prior to settlement in or around the 1800s.” this degree of departure is represented by a letter score.

FACStream can be employed as a reconnaissance (Level 1), routine (Level 2), or intensive (Level 3) effort. The assessment conducted for this Phase 1 IWMP falls between a ‘Level 1 reconnaissance’ and ‘Level 2 routine’ assessment utilizing observable factors and review of existing available information. A desktop analysis was conducted utilizing existing available information collected and/or developed for the draft BRIWMP including hydrologic analysis, aerial imagery, channel profile information, water quality, and land use. Field assessments were conducted in the fall of 2020 to help inform on observable variables such as vegetation, morphology, and channel obstructions. The assessment does not include Dillon Reservoir, or tributaries to the reservoir. Details of the assessment and scoring can be found in **Appendix G**. Brief highlights are provided below and presented in **Table 1**.

> Reach 1.1 is the upper subreach (headwaters) and generally has had minor impacts compared to the downstream reaches in terms of historic mining and urban development. Reach 1.1 hydrology is impacted by transbasin diversions and degraded

water quality from sanding operations for winter maintenance along the highway. There is one on-line dam (Goose Pasture Tarn) and encroachment from rural development. However, overall impacts are relatively minor, particularly compared to downstream reaches. Reach 1.2 extends through the Town of Breckenridge to the French Gulch confluence. This reach was significantly impacted by dredge boat mining until the 1940s and more recently reconstructed. Generally, this is a relatively straight reach within a confined urban setting. Reach 1.2 hydrology is impacted by transbasin diversions and local municipal use.

Reach 1.3 extends from French Gulch to the Swan River and was significantly impacted by dredge boat mining until the 1940s. Without restoration efforts this reach would be rated as "F or Profound" due to significant disturbance from mining. Restoration efforts began 30 years ago in the upper portion of this reach and continue to today. This subreach has been or is being reconstructed and restored.

Reach 1.4 is located below the confluence with the Swan River and as a consequence has more flows in the channel than the upstream reaches. This reach was not disturbed by dredge boat mining and a riparian corridor is present. Rural development, large acreage homes, and Highway 9 all encroach on the floodplain to some degree.

Table 1. Blue River Report Card, Reach 1, FACStream Summary

Blue RiverReport Card FACStream Summary						
Scale	Variable		1.1	1.2	1.3	1.4
Watershed	V_{hyd}	Flow Regime	B	B-	B	B-
	V_{sed}	Sediment Regime	A-	A-	B	A-
	V_{chem}	Water Quality	B+	C+	C	C
Riparian	V_{con}	Floodplain Connectivity	A	B-	C+	B-
	V_{veg}	Riparian Vegetation	A	C	C	B-
	V_{deb}	Debris	A-	C-	D	C+
Stream	V_{morph}	Stream Morphology	A-	C+	C	B-
	V_{stab}	Stability	A	B	B	B
	V_{str}	Physical Structure	A-	B-	C	B
	V_{bio}	Biotic Structure	B+	C	C	B-
Overall FCI			0.80	0.62	0.56	0.64
Reach Condition Score			A-	B-	C+	B-
Degree of Impairment of Reach			Negligible /mild	Mild/ significant	Significant /mild	Mild/ significant

4.1.6. Reach 1: Summary of Key Issues

- ✓ On average, the Blue River watershed supplies approximately 30% of Denver Water's needs through diversions from Dillon Reservoir through the Roberts Tunnel. Current average annual diversions through the Roberts Tunnel are 57,415 ac-ft based on Colorado Division of Water Resources streamflow gage data from 1965 to 2019, which accounts for 18.5% of the average annual yield from the watershed (Elder 2021). Denver Water diversions do not have a direct impact on stream flows in Reach 1 as the point of diversion, Roberts Tunnel, is located in Dillon Reservoir.
- ✓ Colorado Springs Utilities is proposing to optimize its existing collection system by increasing storage on the Continental-Hoosier System. This project could potentially include new or expanded reservoir storage facilities in Reach 1 and enlargement of Montgomery Reservoir in Park County (BIP 2015). These water rights are conditional water rights. Any project must obtain approval through Summit County's 1041 process. Current transbasin diversions through the Continental-Hoosier System are estimated to be 7,900 ac-ft/yr. Additional analysis is needed to understand any potential stream flow impacts to Reach 1. This project could potentially include new or expanded reservoir storage facilities in Reach 1 and enlargement of Montgomery Reservoir in Park County (BIP 2015).
- ✓ UPCO reports that generally Reach 1 is currently meeting existing water demands and estimates that future water supply needs will generally be met with the exception of some shortages identified for the Breckenridge ski area and golf course (HRC 2003).
- ✓ Water quality is poor in Reaches 1.3 and 1.4 due to historical mining and acid rock drainage. Constituents of concern include cadmium, copper, iron and zinc, and possibly silver and selenium.
- ✓ Water quality in Ten Mile is impacted by molybdenum discharges from Climax Mine, which may affect water quality in the main stem of the Blue River. Standards and proposed treatment should be monitored.
- ✓ The fishery appears to be in decline in Subreach 1.4, while upstream the fishery is exceptionally poor in Reach 1.3, most likely due to fragmentation, low flows and impaired water quality (Ewert 2019).
- ✓ A review of past macroinvertebrate monitoring coupled with sampling in 2020 indicate the macroinvertebrate community structure and function at the UBR sampling station located just upstream of Dillon Reservoir at Swan Mountain Road, consistently shows evidence of minor to moderate stress.
- ✓ The Blue River mainstem within R1.2 and R1.3, was significantly impacted by dredge boat mining activities. The Town of Breckenridge, Summit County, and several private property owners have worked to restore the Blue River in these reaches over the past 30 years. Several restoration projects are currently in various stages of completion.

4.1.7. Reach 1: Recommendations and Opportunities

1. Evaluate hydrologic data describing streamflow regimes in the Blue River and, where possible, how that regime has been altered and could potentially be altered due to additional transbasin diversions. Colorado Springs Utilities has indicated they would coordinate with the Advisory Committee members on modeling platforms and assumptions.

2. Perform geomorphic assessment(s) in combination with the hydrologic analysis to assess hydrologic flow alterations relative to aquatic habitat. Develop restoration strategies reflective of the results of the stream assessments.
3. Extensive monitoring and restoration efforts have been or are being undertaken by Summit County, Town of Breckenridge, CPW, TU, and other federal and state agencies to support ongoing restoration, of extensively disturbed floodplains from dredge boat mining, and restoration for water quality improvements from hard rock mining. Additional support to these entities could be provided for efforts that might include continued macroinvertebrate monitoring, additional water quality monitoring, additional fish surveys, site specific restoration designs, and development of new projects.

4.2. Reach 2: Blue River – Dillon Reservoir Outlet to Green Mountain Reservoir Outlet

The contributing watershed to Reach 2 is about 263 square miles in size, representing 38 % of the total 699 square mile watershed and includes the Town of Silverthorne, Dillon, Frisco, Copper Mountain, keystone and Heeney. This reach also includes Green Mountain Reservoir. The dominant land cover outside of the floodplain is high alpine meadows and forest land.

Six major tributaries confluence along Reach 2 including Straight Creek, Willow Creek, Rock Creek, Slate Creek, Black Creek, and Boulder Creek. With the exception of the Town of Silverthorne, much of the Blue River in this reach flows through either public land, including two USFS campgrounds, or agricultural property. Urban encroachments are relatively minimal except through the Town of Silverthorne, and much of the river includes a riparian fringe that provides stream bank habitat, cover, and shading.

Reach 2 is approximately 20 miles long, measured along the valley floor from the Dillon Dam outlet (**Figure 10**) to Green Mountain Reservoir inlet. Green Mountain Reservoir is operated by the U.S. Bureau of Reclamation. For purposes of this assessment, Reach 2 is further subdivided into three subreaches to represent the changing morphology and different settings in terms of river form, urban development, and land use. The assessment does not include tributaries to the main stem of the Blue River or Green Mountain Reservoir.

Figure 10. Reach 2: Blue River downstream (north) of Dillon Reservoir.

Reach Description: Approximate channel length 20 miles subdivided as follows (**Figure 11**):

- R2.1: Dillon Dam outlet to 13th Street in Silverthorne, approximate valley length 2.5 miles
- R2.2: Blue River from 13th Street in Silverthorne to County Road 1376 at confluence with Boulder Creek, approximate length 8.0 miles
- R2.3 Blue River from County Road 1376 at confluence with Boulder Creek to the inlet of Green Mountain Reservoir, approximate length 9.5 miles

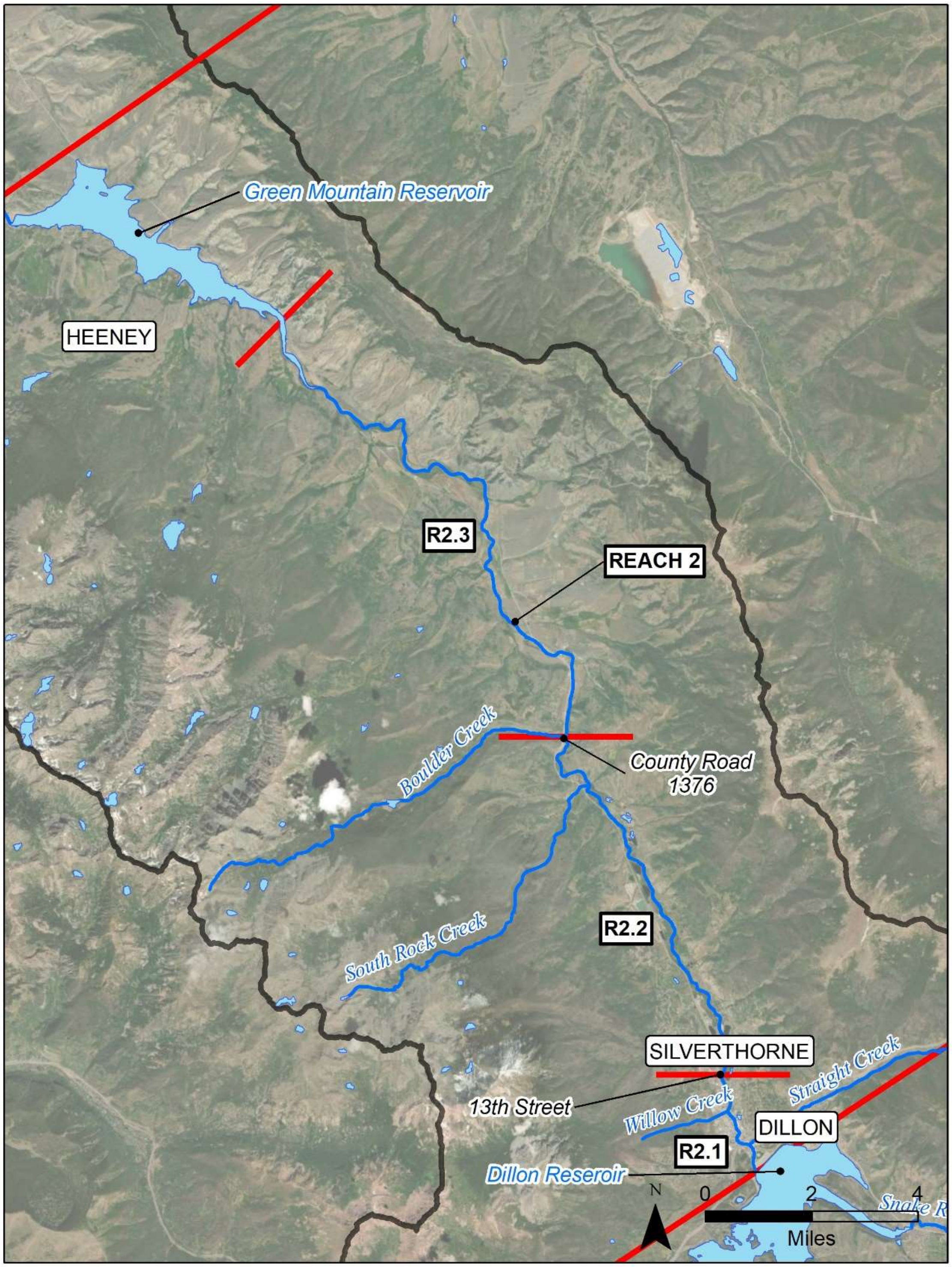


Figure 11. Reach 2 Subreaches.

Approximately 3 miles of Reach 2 is within the Town of Silverthorne boundaries where the channel is generally confined by a narrow band of vegetated steep and tall banks. A pedestrian/bike path runs adjacent to the river for several miles making the river relatively easy to access. There are numerous pedestrian public access points both within the Town of Silverthorne and on USFS lands north of Silverthorne. Denver Water Board owns 162 acres of land immediately downstream of the reservoir outlet where public access is available to approximately ½ mile of the Blue River.

Until 2016, Reach 2 was designated a Gold Medal Fishery by CPW. Gold Medal designation is given only to fisheries that are able to produce a minimum of 12 "quality trout" (14+ inches) per acre, able to produce 60 pounds of trout biomass per surface acre standing stock (the amount of living organisms in the ecosystem including fish, plants, and macroinvertebrates), and be accessible to the public for a minimum of 2 stream miles. The designation was removed from Hamilton Creek Road bridge near the northern City limits of Silverthorne, to Green Mountain Reservoir (most of R2.2 and R2.3) due to failure to meet CPW's biological criteria. CPW has indicated the low productivity may be due to a combination of sub-optimal physical habitat particularly when Dillon Reservoir releases are less than 100 cfs, and food or biological productivity limitations (Ewert 2018). Basin wide, the community has placed a high priority on determining the cause(s) of the decline of the fishery and returning the river to its once-productive condition, thereby resuming Gold Medal status. In 2017, the Blue River Enhancement Workgroup (BREW) was created to identify the causes and develop solutions for the declining fishery. The BRWG is working closely with BREW to support this effort by implementing assessments and developing actionable recommendations in this BRIWMP.

4.2.1. **Water Use**

Primary Municipal Water Users

- Town of Silverthorne: The Town of Silverthorne is the primary municipal water supplier in Reach 2. In 2000, the UPCO report shows water demands in the Town was 465 acre-feet (ac-ft), with a projected increase to 2298 ac-ft by 2030.
- Other water providers within Reach 2 include Dillon Valley District, Mesa Cortina Water and Sanitation District, and East Dillon Water District, reporting a current total demand of just under 1000 ac-ft per year for all three districts.
- The responses to the BRWG water provider survey indicates main concerns relative to water supply are transport of hazardous materials through the I-70 corridor, wildfire, transbasin diversions, drought, and supply shortages.
- UPCO reports that generally this Reach is experiencing occasional water supply shortages which will increase under and future conditions. Under full buildout the estimated maximum annual shortage in Reach 2 is about 1,800 ac-ft (HRC 2003).
- While Denver Water diversions are technically in Reach 1, the diversions and reservoir operations controlling the diversions influence flows in Reach 2.

Agricultural Operations

Agriculture in the Blue River Watershed is an essential component to the community and the watershed basin, protecting open lands, wildlife habitat, cultural values, and pre-compact water rights. The 2007 market value of agricultural products grown in the watershed totaled over $1.1 million. Water to irrigate agricultural land is critically important (Coley/Forrest 2011). Based on the 2012 and 2017 Summit County Census of Agriculture (SCCA 2012 and 2017), there has been little change in the overall acreage of farmlands, currently occupying 26,572 acres, but the number of farms have grown from 41 in 2012 to 55 in 2017, possibly indicating a transition from working farmlands to 'gentlemen's ranches.'

Despite the importance of agriculture, urbanization of agricultural lands, or transition use could continue resulting in a reduction in irrigated lands particularly in areas relatively close to the ski resorts and Dillon Reservoir. The CWP anticipates that while irrigated acreage could decrease, the irrigation water requirements will likely increase due to a warmer future climate. Emerging technology, including adoption of higher system efficiencies, may mitigate some climate impacts. However, overall, the CWP estimates the future incremental gap for future agriculture needs will range from 0 to 4 % of baseline demand within the Colorado River basin (CWP 2019).

Feedback received by the BRWG from the agricultural community indicate challenges facing agricultural irrigators throughout the Western Slope of Colorado including problems with infrastructure and lack of capital to repair or upgrade the infrastructure, head gate issues, transmission losses, lack of measuring devices, and an inability to divert full decrees (Appendix B).

Recreation

Recreation opportunities in this reach include angling, rafting, kayaking, stand up paddle boarding (SUPing), camping, boating (Green Mountain Reservoir), and wildlife viewing. In 2000 and 2002, the Town of Silverthorne completed two in-channel restoration projects designed to improve fish habitat at increasingly regular low flows (considered to be around 52 cfs) and stabilize nearby banks to reduce erosion. The restoration projects improved habitat from the base of Dillon Reservoir Dam through the town stretch to Wildernest Road (Reuter 2002). This effort, aided by regular stocking of catchable rainbow trout broodstock, also enabled the Town of Silverthorne to maintain its Gold Medal Status within this section of the Blue River when CPW removed the designation further downstream.

In addition to fish habitat, the Town of Silverthorne is currently planning to build a whitewater park near the Wilderness Road Bridge. The course will consist of three control structures, spaced approximately 100 to 150 feet apart and will create recreational experiences consisting of watercraft passage under low flows and whitewater kayaking at higher flow. The Town has obtained a conditional Recreational In-Channel Diversion water right of 100 cfs flow for May-September with the ability to call for up to 600 cfs during major holiday weekends to provide for enhanced recreational experiences (Brown and Caldwell 2004). It is important to note that this water right is junior to the obligations of Denver Water and most downstream water users.

There are several heavily utilized public access points with Reach 2 including: immediately downstream of Dillon Reservoir, Silverthorne outlet mall, North Pond Park, Blue River Campground, Columbine Landing Recreation Area, Acorn Creek confluence boat ramp, and Green Mountain Reservoir, among others.

Under low-flow conditions, rafting and float-fishing are unlikely to be considered significant uses in Reach 2. When flows are in the 450-700 cfs range commonly floated reaches include (Shook 2013):

- Forest Service Building to Hammer Bridge (Class I/II 7 miles) Minimum Flow: 450 cfs
- Hammer Bridge to Columbine Landing (Class II/III 6 miles) Minimum Flow: 450 cfs
- Blue River Campground to Columbine Landing (Class II/III 3.5 miles) Minimum Flow: 450 cfs
- Columbine Landing-Heeney Bridge (unimproved access point) (Class I/II 10 miles). Minimum flow: 500 cfs

According to the Colorado River Outfitters Association, commercial user days on the Blue River range from 0 (2002, 2012, 2013) to 11,006 (2019) (CROA 2019). This wide range of commercial use may be a result of varied flows that limit commercial operations in Reach 2. In 2019, direct expenditures to commercial operators on the Blue was just under $1.5 million, generating an overall economic impact of over $3.8 million (CROA 2019).

Due to the varied flow conditions that can support rafts and other crafts, walk-wade fishing is likely the most popular form of recreation angling on the Blue River in this reach. Ideal flow conditions, defined by the ability of an angler to safely navigate the river on foot and availability of quality fishable water, range from 100 cfs to 350 cfs (McCormick 2020). While the river is still considered to be fishable at lower flows, it is unknown whether productive fish habitat is available in many of the public reaches.

In the 2020 TU Angler Survey, 68% of participants indicated being "neutral" or "dissatisfied" with this reach and expressed concern about crowding, quality of the fishing, lack of public access below Silverthorne, and gill lice in Green Mountain Reservoir (Omasta 2020). While the survey mainly targeted local anglers, there is concern among local outfitters about client experience that may impact future visitation. Outfitters may also be forced to take clients to other nearby rivers for better quality fishing such as on the Colorado River and Arkansas River.

Green Mountain Reservoir is operated by the U.S. Bureau of Reclamation as part of the Colorado-Big Thompson project. The reservoir provides good fishing for lake trout, rainbow trout, brown trout, and kokanee salmon. Colorado Highway 9 runs along the east side of the reservoir, making for easy access. Recreational access is managed by the U.S. Forest Service, Dillon Ranger District (Ewert 2020). There are three primary challenges to managing the fishery in Green Mountain Reservoir: 1) the large annual fluctuations in lake levels that impact fish mobility, competition, and spawning areas; 2) illegal introduction and proliferation of Northern Pike; and 3) prevalence of gill lice since 2008 (Ewert 2020). CPW has implemented a bounty program to encourage anglers to catch and harvest Northern Pike which prey on the more desirable sportfish populations. To reduce gill lice, CPW has ceased stocking the reservoir with rainbow trout and kokanee salmon, the most impacted species, in order to reduce the available hosts for the parasite. CPW planned to resume stocking of kokanee in 2020. While the snagging and harvest of salmon by anglers in the Blue was once considered to be high, the decline in kokanee populations in the lake as a result of gill lice has had a negative effect on the number of fish that spawn in the Blue River (Ewert 2020).

4.2.2. Hydrology

Flows in Reach 2 of the Blue River are affected by releases from Dillon Reservoir. The outlet works consist of a 15 feet diameter tunnel that releases flows from the bottom of the reservoir and a surface water spillway, referred to as the Morning Glory Spillway. The tunnel is set at elevation 8,791 and the spillway is located 226 feet above the pipe outlet at elevation 9,017. Water 226 feet below the reservoir surface does not circulate so it can be uniform in temperature throughout the year, typically being colder than the surface water during summer months and warmer in winter months.

The bottom releases have a capacity to release up to an estimated 4,000 cfs, however, Denver Water aims to limit, when possible, the outflows to a maximum of 1,800 cfs to minimize overbank flooding through Silverthorne. Based on the peak discharges from the Summit County Flood Insurance Study (FIS) (FEMA 2018), 1,800 cfs would be less than a 10-year flood event. The outlet works includes a small power plant which in 2020 generated enough power to be a "net zero" operation.

One USGS gage station has been operated within Reach 2, Station 09050700, Blue River below Dillon, CO, from 1960 to present. Daily streamflow exceedance hydrographs from the USGS records between 1960 to 2019 are shown in **Figure 12**. An exceedance hydrograph represents how often the flows have exceeded a level in the past. For example, at Station 09050700 (Blue River below Dillon) shown on Figure 12, the 10% exceedance plot indicates that in early-June, 10% of the time flows have exceed approximately 1,300 cfs, or alternatively 90% of the time flows have been less than 1,300 cfs.

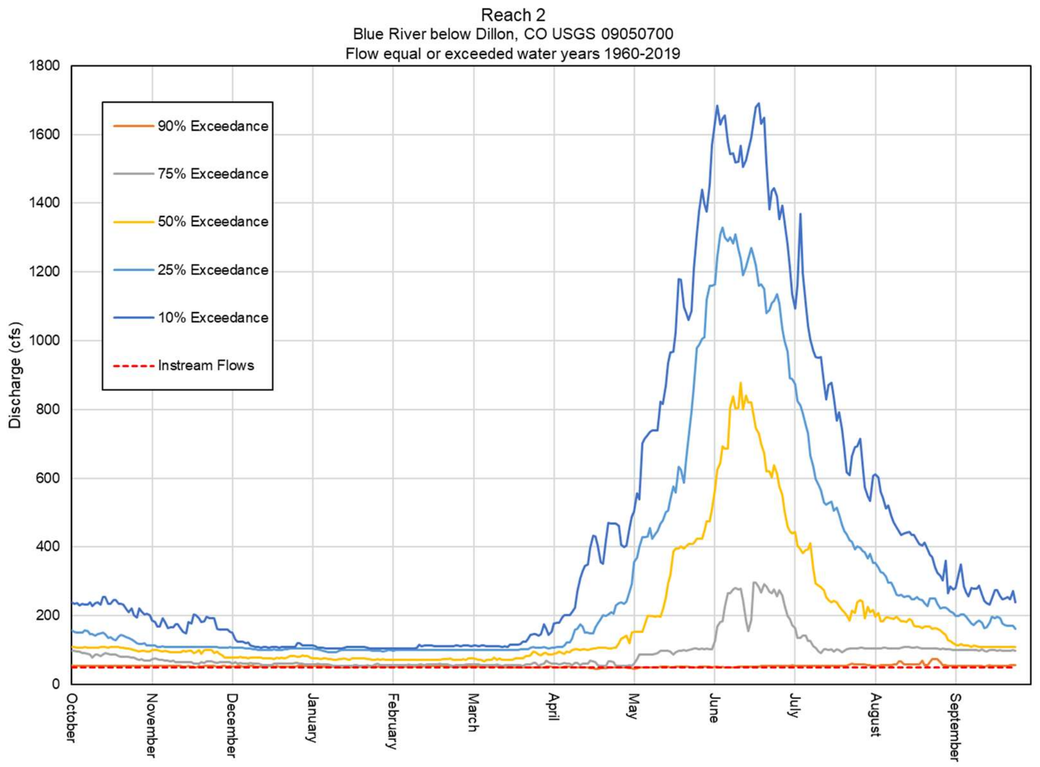


Figure 12. Station 09050700 (Blue River below Dillon) Exceedance Hydrograph.

In 1973, the General Assembly authorized the CWCB to appropriate water rights for instream flows and natural lake levels to preserve the natural environment to a reasonable degree. Since 1973, CWCB has appropriated instream flow water rights on nearly 1,700 stream segments covering more than 9,700 miles of stream, and natural lake level water rights on 480 natural lakes. Instream flows for the Blue River in Reach 2 are provided below. These instream flows are also shown on the exceedance plots shown on Figure 12.

<u>CWCB Instream Flows, Blue River</u>

- 50 cfs Dillon Reservoir to Straight Creek (year-round)
- 50 to 55 cfs Straight Creek to Willow Creek (varies year-round)
- 75 cfs Willow Creek to Rock Creek (year-round)
- 90 to 115 cfs Rock Creek to Boulder Creek (varies year-round)
- No flushing flow recommendations on any segments

4.2.3. Water Quality, Temperature, Aquatic Life

The review of existing available data, information and studies related to water quality, temperature, and aquatic life are integral to the assessment of the declining fishery between Dillon and Green Mountain Reservoirs, combined with field-based data collection gathered in 2020. This data collection included macroinvertebrate sampling, periphyton sampling, and continuous temperature monitoring. Refer to Section 4.2.5 for detailed information.

In the spring of 2021, the Town of Silverthorne initiated a sampling program to assess the water quality from stormwater runoff. These data will be added and incorporated into Phase 2 results.

4.2.4. **Stream Assessments**

A stream health assessment for the Blue River in Summit County, Colorado was conducted for the purpose of rating functional ecological conditions in Reach 2. Details of the assessment can be found in Appendix G. Brief summaries are provided below and shown in **Table 2**.

Reach 2.1 is located below Dillon Reservoir outlet. Transbasin diversions and flow regulations reduce the volume and timing of flows which may be diminishing habitat conditions. Temperature monitoring of river flows conducted to date indicate values are below narrative standards recommended by USFWS for brown trout (Raleigh et al. 1986). Urban development has encroached into the floodplain and limits healthy and expected lateral movement of the river. Fish surveys conducted by CPW (2018) report characteristics that indicate slow growth in the brown trout fishery. Macroinvertebrate sampling in 2020 indicated this reach failed to reach attainment designations, as defined by CDPHE in spring, summer, and fall.

Reach 2.2 is located downstream of the Town of Silverthorne. Transbasin diversions and flow regulations reduce the volume and timing of flows which may be diminishing habitat conditions. Temperature monitoring of river flows conducted to date, indicate values are below narrative standards recommended by USFWS. Review of 1954 aerial mapping indicates this portion of the Blue River was moderately vegetated with numerous side channels. Current conditions show denser vegetation adjacent to the river which reduces the lateral movement of the river compared to pre-dam conditions (see Appendix G). This may be due to lower flows since 1954 with the construction of Dillon Reservoir. Colorado's Multi-Metric Index, version 4 (MMI v4) MMI v4 scores for 2020 macroinvertebrate sampling generally indicate impairment to slightly above attainment in spring, summer, and fall.

Reach 2.3 is located upstream of Green Mountain Reservoir and runs primarily through agricultural lands. While there is some encroachment, overall development is outside of the historically active floodplain. Some straightening appears to have occurred adjacent to the river banks as evident by the lack of side channels and riparian vegetated floodplain. Portions of this reach are on USFS and CPW land. Transbasin diversions limit the release of flows out of Dillon Reservoir thereby reducing flows in this reach of the Blue River. These low flows may be mitigated by inflow from the tributaries downstream of Dillon Reservoir, although there is currently no data to inform on the magnitude of tributary inflows. Dillon Reservoir also lowers water temperatures by releasing water from the bottom of the reservoir. Temperature monitoring conducted in 2020 indicate these temperatures remain cold and below the temperatures of the river above the reservoir for at least the first 10 to 11 miles downstream of Dillon Reservoir. These temperatures are also at or below the lower ranges of narrative standards recommended by USFWS. MMI scores for 2020 macroinvertebrate sampling generally indicate attainment to slightly impaired in spring, summer, and fall.

Table 2. Blue River Report Card, Reach 2, FACStream Summary

Blue RiverReport Card FACStream Summary					
Scale	Variable		2.1	2.2	2.3
Watershed	V_{hyd}	Flow Regime	C	C+	B
	V_{sed}	Sediment Regime	C	B	B
	V_{chem}	Water Quality	C	B	B
Riparian	V_{con}	Floodplain Connectivity	C	B	B
	V_{veg}	Riparian Vegetation	B	B	B
	V_{deb}	Debris	C-	B	B
Stream	V_{morph}	Stream Morphology	B	B	B
	V_{stab}	Stability	B	B	B
	V_{str}	Physical Structure	B-	B	B
	V_{bio}	Biotic Structure	D	C	B
Overall FCI			0.54	0.67	0.70
Reach Condition Score			C	B	B
Degree of Impairment of Reach			Significant	Mild	Mild

4.2.5. **Declining Fishery Between Dillon and Green Mountain Reservoirs**

As previously noted, in 2016 the Gold Medal Fishery designation was removed for a portion of Reach 2 from the northern City limits of Silverthorne to Green Mountain Reservoir. Basin wide, the community has placed a high priority on determining the cause(s) of the decline of the fishery and returning the river to its once-productive condition, thereby returning to Gold Medal status. To that end, several efforts were undertaken in 2020 to collect and assess additional data. These include the following:

1. Temperature monitoring: Surface water temperatures were collected and reviewed for nine locations along the Blue River including six sites with temperature loggers installed, monitored, and read by TU in 2020. Other data were obtained from the USFS. Sites were selected based on a combination of factors including locations relative to tributaries, access, and previous USFS temperature monitoring sites. Two of these sites, UBR and LBR are considered “reference sites,” uninfluenced by Dillon Reservoir.
2. Benthic Macroinvertebrate Biomonitoring/Surveys: In 2020, seasonal monitoring (spring, summer, and fall) was conducted at ten locations along the Blue River to evaluate the health of benthic macroinvertebrate communities in the Blue River. This work was completed by Timberline Aquatics (attached in **Appendix D)**. Highlights of Timberline Aquatics report are noted here to provide a basis for Phase 2 recommendations and opportunities.
3. Periphyton: Under contract to the Summit Water Quality Control Commission (SWQC), Trout Unlimited completed benthic algae, periphyton, sampling in 2020 at nine monitoring sites in the Blue between Dillon Reservoir and Green Mountain Reservoir (TU 2020). A copy of this report is attached in **Appendix F**. Highlights of the report findings are noted in this section of the report to provide a basis for recommendations and opportunities.
4. Review of Blue River Fishery: Ksqrdfish Aquatics, LLC prepared a report to summarize and inform on existing and available fish surveys and studies that provide insight on the declining fishery in the Blue River below Dillon Reservoir (Ksqrdfish 2021 attached in Appendix G). The report includes review of the macroinvertebrate and temperature data collected in 2020. Highlights of the report findings are noted in this section of the report to provide a basis for recommendations and opportunities. Sample site locations are described in **Table 3** and shown on **Figure 13**.

Table 3. Sample Site Locations, Temperature, Macroinvertebrate Monitoring and Periphyton Sampling*

Site ID	description	latitude	longitude	data source	Station line (Distance from Dillon Reservoir), miles
UBR	Blue River upstream of Dillon Reservoir	39°33'59.44"N	106° 2'57.71"W	USFS	-4.26
	Dam outlet				0
Blue 5	Blue River below Dillon Reservoir	39°37'33.65"N	106° 4'1.60"W	USFS & BRWG	0.38
	Tributary: Straight Creek				0.44
DRD	Behind Dillon Ranger District	39°38'10.98"N	106° 4'30.77"W	BRWG	1.43
	Tributary: Willow Creek				2.92
Blue 3	Downstream of Bald Eagle Drive	39°39'22.19"N	106° 4'39.02"W	USFS	2.92
	Tributary: Bushee Creek				4.61
TYL	Downstream of County Road 1908	39°40'30.79"N	106° 5'30.80"W	BRWG	4.7
	Tributary: Maryland Creek				6.71
D5	Upstream of Cty Rd 1870	39°42'18.81"N	106° 6'41.15"W	USFS & BRWG	7.31
	Tributary: Rock Creek				9.14
Blue 2	Downstream of Blue River Campground	39°43'36.23"N	106° 8'0.98"W	BRWG	9.66
	Tributary: Boulder and Pebble Creeks				10.56
Blue 1	Blue River downstream of Boulder Creek	39°44'36.69"N	106° 7'58.13"W	USFS	11.04
SCR	Upstream of Cty Rd 1450	39°46'56.14"N	106° 9'39.05"W	BRWG	14.76
	Tributary: Slate Creek				14.84
	Tributary: Pass Creek				16.38
	Tributary: Brush Creek				19.99
BCR	Blue River State Wildlife Area	39°49'16.36"N	106°12'16.09"W	BRWG	20.13
	Tributary: Black Creek				24.17
	Tributary: Otter Creek				24.78
	Tributary: Cataract				25.78
	Dam outlet				28.87
	Approximate cty line-Grand/Summit				30.9
	Spring Creek Road				32.99
LBR	Lower Blue below Green Mountain Reservoir	39°56'5.00"N	106°21'10.75"W	USFS	34.14

* Blue text denotes station line of tributaries
TYL data not used due to logger location; SCR data not retrievable due to access limitations.

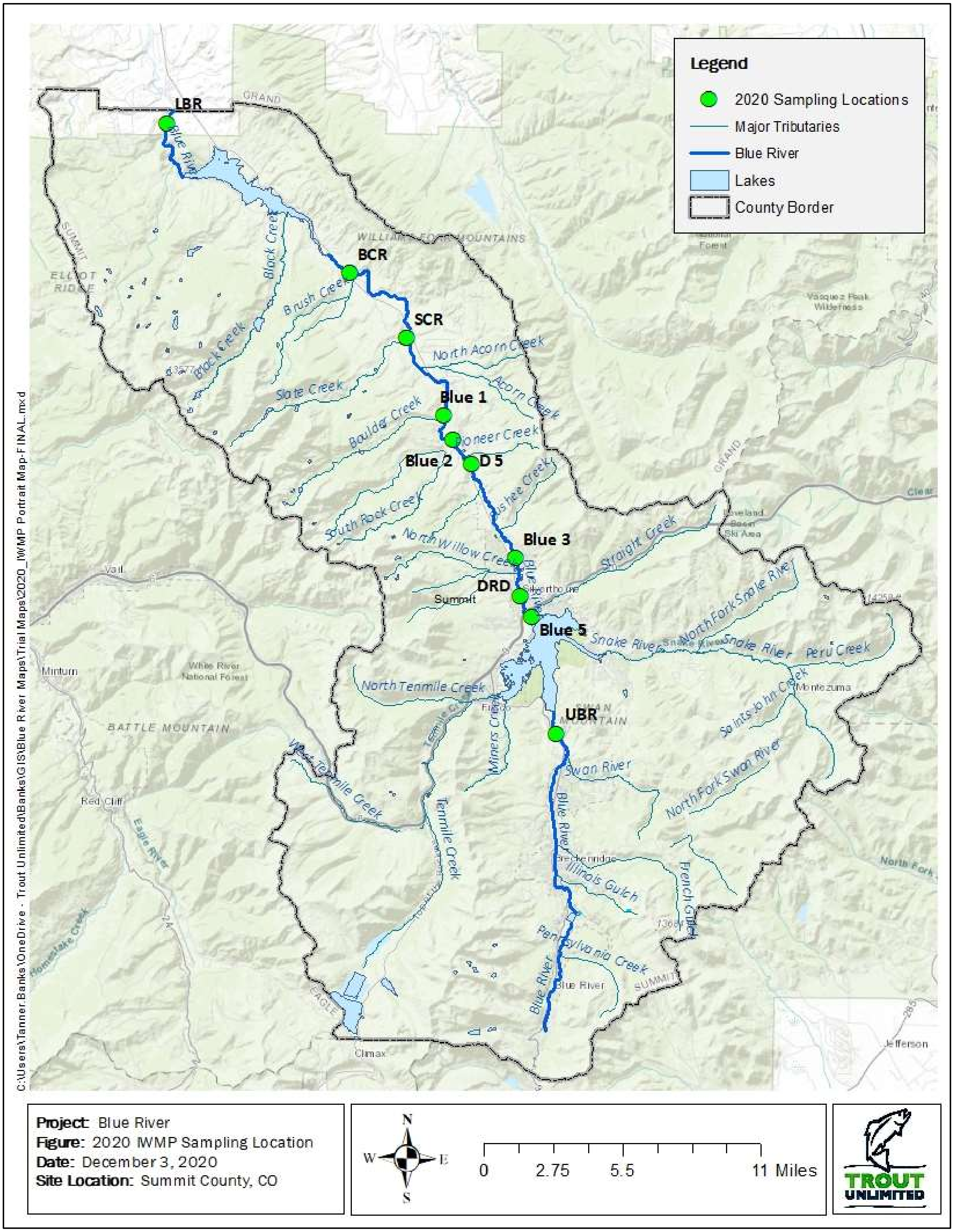


Figure 13. 2020 sampling site locations for the BRIWMP.

4.2.6. Temperature Monitoring

Water temperature is perhaps the single most important environmental parameter for fish (Magnusen et al. 1979 as cited by KA 2021). Ambient water temperature drives fish survival (Brinkman et al. 2013 as cited by KA 2021), behavior (Cook and Bergersen 1988, Rogers 1998 as cited by KA 2021), and growth (Selong et al. 2001, Bear et al. 2007, Brinkman et al. 2013 as cited by KA 2021) and also is known to define the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005 as cited by KA 2021).

The Colorado Department of Public Health and Environment (CDPHE) lists Blue River as Aquatic Life Cold 1 – Cold Water Aquatic Life with temperature limits noted in **Table 4**. These standards are established to protect the aquatic community from the harmful effects of high-water temperatures, based on the thermal requirements of fish species found in the Blue River and its tributaries. The chronic standard, measured as the Maximum Weekly Average Temperature (MWAT), is the largest mathematical mean of multiple, equally spaced daily temperatures over a seven-day consecutive period with a minimum of three data points spaced equally throughout the day.

Table 4. Temperature Standards applied to the Project

Temperature Tier	Standards	Species Expected to be Present	Applicable Months	Temperature Standard (°C)[1]	
				MWAT	DM
Cold Stream Tier I	WQCC	Brook trout, cutthroat trout	June-Sept	17.0	21.7
	WQCC		Oct-May	9.0	13.0
N/A	USFS		Winter-Spring	3.6	N/A

[1] Regulation No. 33. Classifications and Numeric Standards for Upper Colorado River Basin and North Platte River (Planning Region 12). 5 CCR 1002-33 (Regulation No. 33).

Minimum temperature standards or metrics are not set by the CDPHE. For purposes of this BRIWMP, low water temperature standards defer to narrative standards developed by the USFWS for different life stages of brown trout (Raleigh et al. 1986, Elliot and Hurley 1999, Elliot and Elliot 2010). These standards include:

- Optimal growth temperature range for adult brown trout: 11^{0}C and 19^{0}C
- Optimal growth to 1-year temperature range: 7^{0}C to 15^{0} C
- Optimal temperature for spawning to hatching: 2^{0}C to 7^{0}C

Hourly temperatures were analyzed into several temperature statistics. Daily temperature metrics were calculated from hourly daily temperatures. Monthly, growing season (May 1 to Oct 31) and comparative annual statistics, when available, were all calculated from daily metrics. Further analysis and graphics were completed in Microsoft Excel (2021). Average daily temperatures with highlighted optimal adult growth range, growth during the first year of life, and spawning range for brown trout are shown on **Figure 14.** Temperatures seen in the Blue River in 2020 meet the criteria for adult growth only at the UBR site above Dillon Reservoir and the lower two stations, Blue 1 and BCR, from approximately July-August. Stream temperatures in 2020 seem to potentially limit growth of adult brown trout in the Blue River (KA 2021 attached as Appendix G).

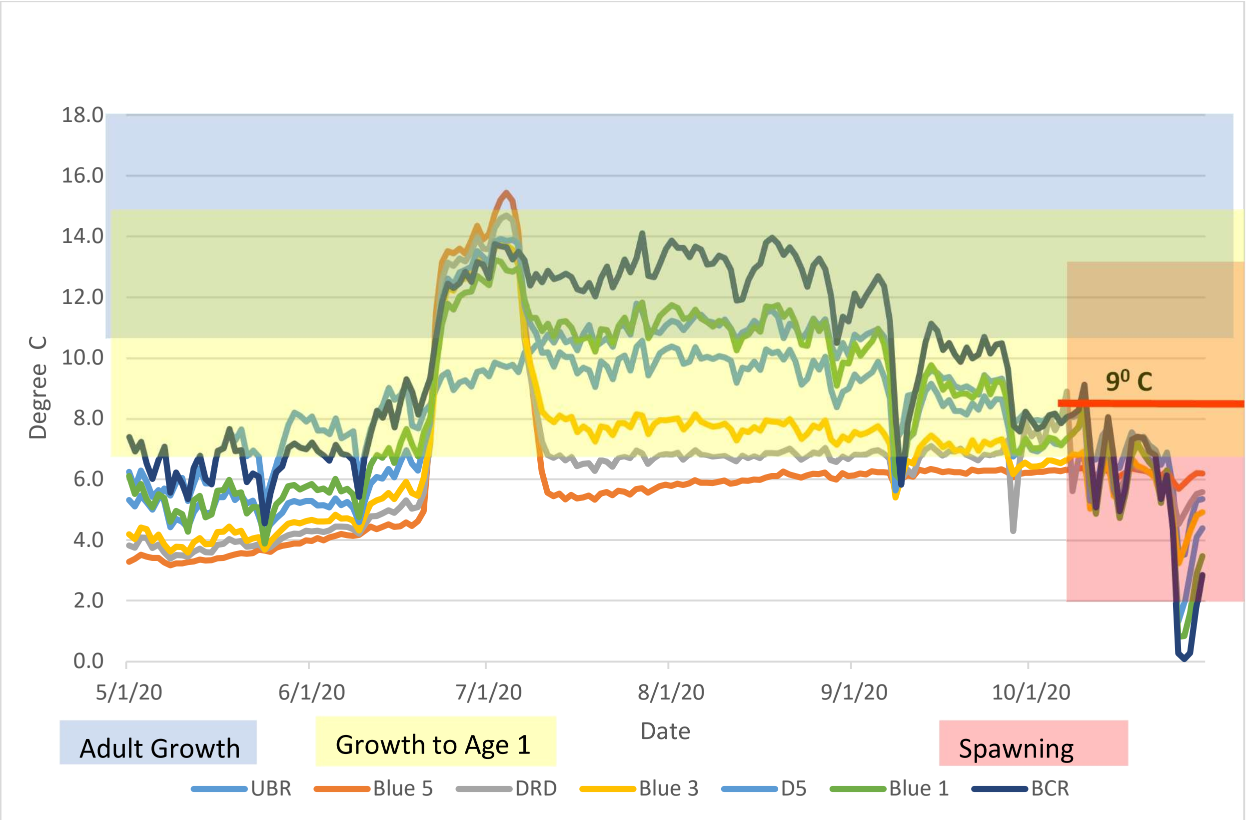


Figure 14. Temperature Ranges for Optimal Growth and Spawning for brown trout presented with Blue River Daily Average Temperatures.

Profile plots were also developed to assess the influence of thermal warming and tributaries on water temperatures along the profile between Dillon and Green Mountain Reservoir using 2020 and average daily temperatures for each month. These plots, shown on **Figure 15**, **Figure 16**, **Figure 17**, **Figure 18**, and **Figure 19,** include the UBR site located immediately upstream of Dillon Reservoir to provide a reference for water temperatures without the influence of the reservoir. These plots also depict tributaries along the 20 mile profile between Dillon reservoir and BCR at the upstream end of Green Mountain Reservoir. Several trends are seen in these plots. First, surface water spills through the Morning Glory Spillway occurred in June 2020 and are reflected in the '75th percentiles' for these months. June surface water temperatures, shown on Figure 16, show the average daily temperatures well below optimal ranges for adults and slightly below optimal ranges for 'growth to age 1.' However, the 75th percentile is in the optimal range for both age classifications indicating that surface water spills have the potential to propagate warmer temperatures for the full 20 miles to Green Mountain Reservoir. This is also evident from the plot shown on Figure 14.

Secondly, in months with no surface water spills, such as May and August, the temperatures downstream of Dillon Reservoir have little fluctuation between the 25th and 75th percentile and are below optimum temperatures for adult brown trout for at least the first 11 miles downstream of Dillon Reservoir. For "growth to age-1" the 25th and 75th percentile in August are below optimum temperatures for the first 3 to 5 miles below Dillon Reservoir. Temperatures in May are also below optimum temperatures for both age groups.

October temperatures appear relatively constant through the full reach and November temperatures show a reverse trend with warmer temperatures being released from Dillon Reservoir compared to the downstream reaches, although they appear to be within the optimal temperature ranges for spawning.

In 2020, the reservoir spilled over the Morning Glory spillway which resulted in an increase in stream temperatures of 6.6^0 C (4.8^0-11.4^0 C) in 48 hours, which is considerable when compared to conditions on the Blue River above Dillon which changed 1.2^0 C (7.7^0-8.9^{0}C) over the same time period. These relatively rapid increases in temperature below the reservoir during the spill events may create temperature shock as well as limit habitat for brown trout fry and invertebrates. Slow changes in temperature or flow within the natural range of variability are needed to avoid negative impact on juvenile salmonids (Brown et al, 2011 as cited by KA 2021).

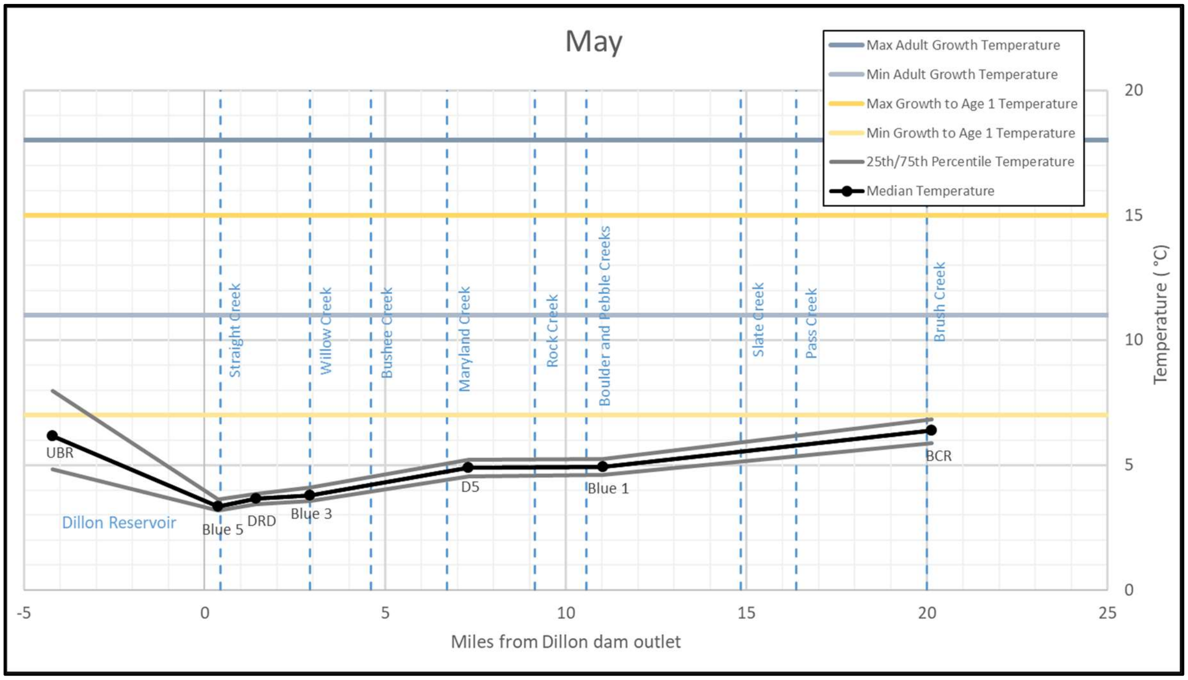


Figure 15. Temperature Profile Plots, May 2020.

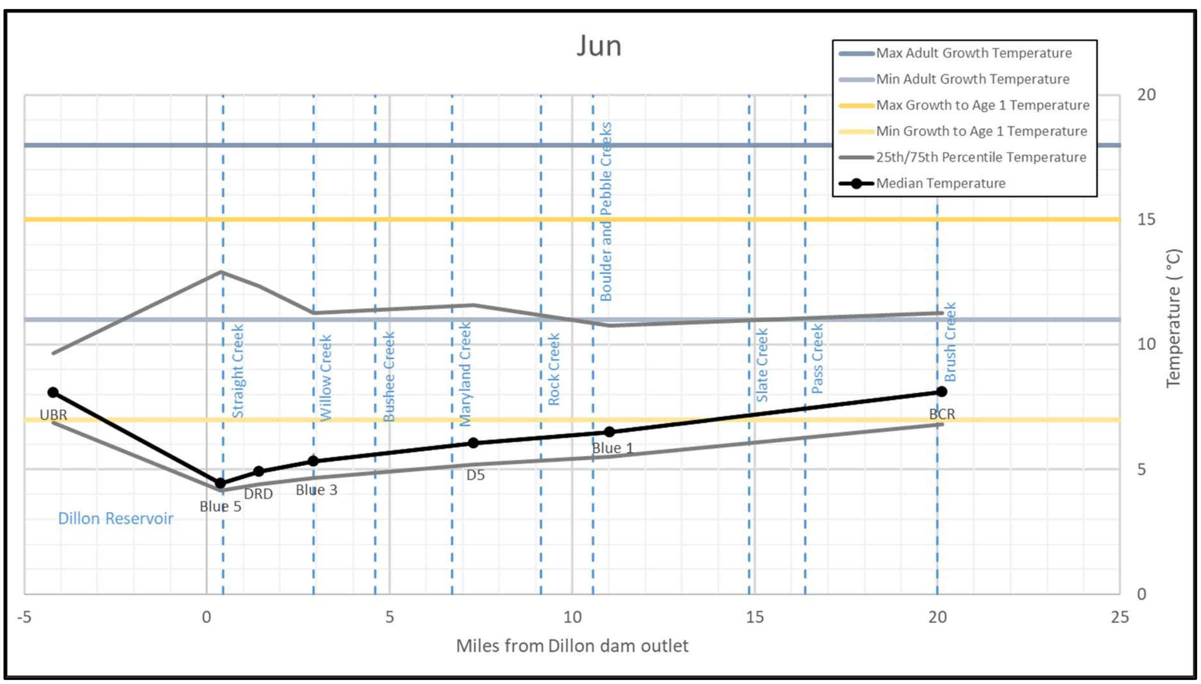


Figure 16. Temperature Profile Plots, June 2020.

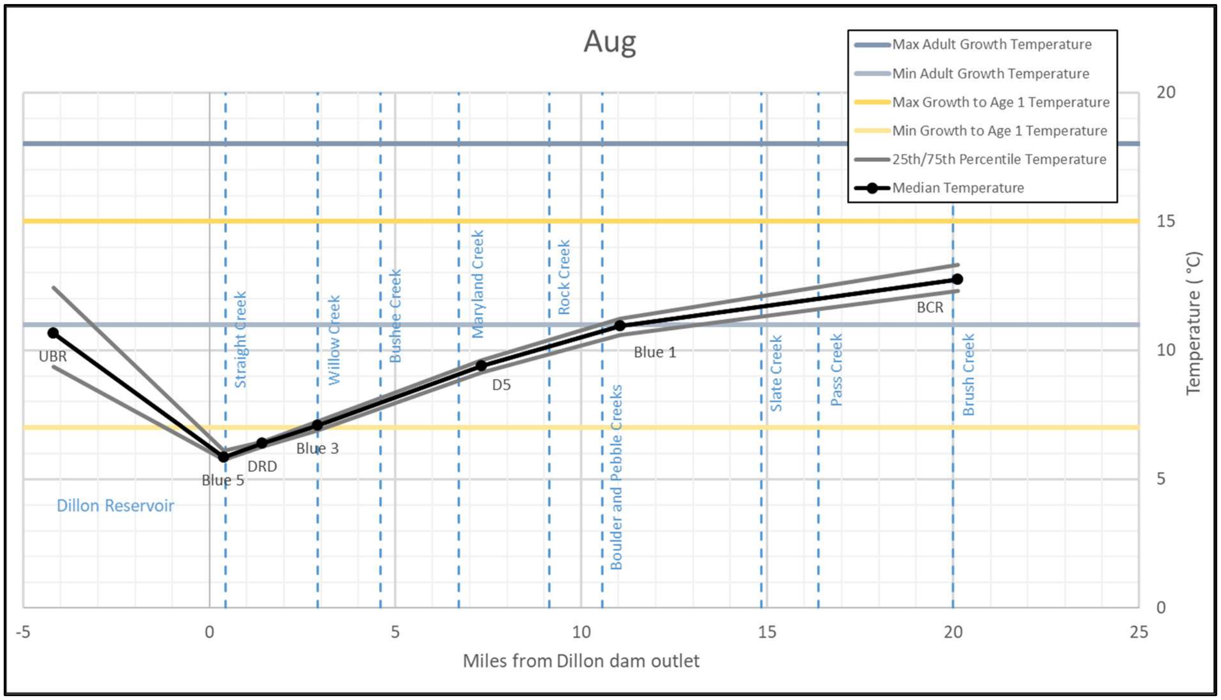


Figure 17. Temperature Profile Plots, August 2020.

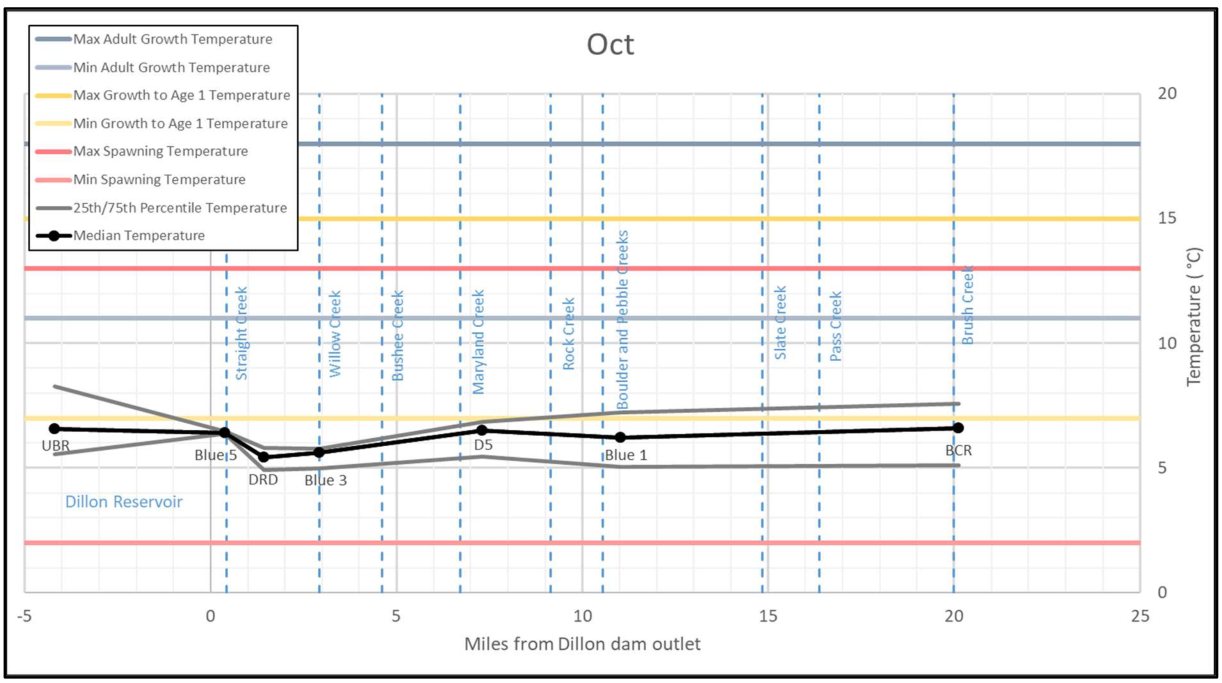


Figure 18. Temperature Profile Plots, October 2020.

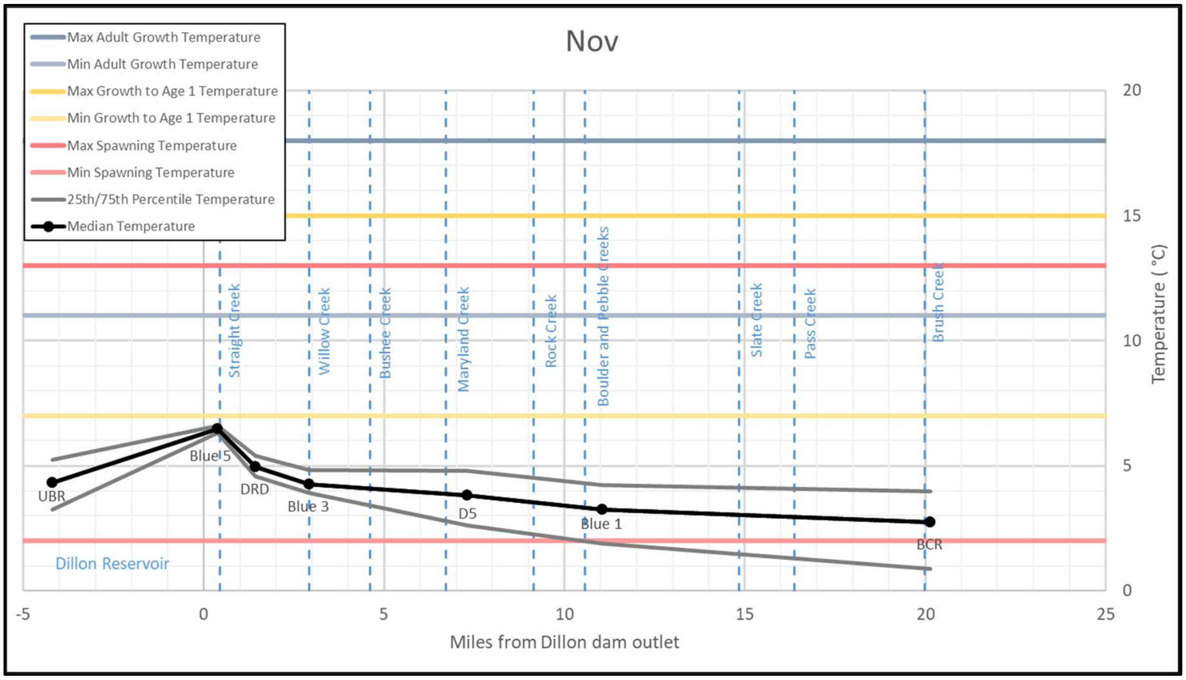


Figure 19. Temperature Profile Plots, November 2020.

Macroinvertebrate Monitoring

In 2020, monitoring and data analysis was conducted by Timberline Aquatics with the results reported in March of 2021, titled "Summary Report, Benthic Macroinvertebrate Biomonitoring/Surveys, Blue River, Colorado, 2020." (Timberline 2021 attached as Appendix D). Seasonal monitoring (spring, summer, and fall) was conducted in 2020 at ten stations and were sampled to evaluate the health of benthic macroinvertebrate communities in the Blue River. Sampling sites included one location upstream from Dillon Reservoir, eight locations between Dillon Reservoir and Green Mountain Reservoir, and one sampling location downstream from Green Mountain Reservoir. Overall, the report indicates the following:

> *A wide range of MMI v4 scores were obtained within the study area during the three seasons in 2020. Results from the MMI v4 consistently indicated that the reference site (UBR) was in 'attainment' for aquatic life use during 2020; however, component metrics from all three seasons suggested that there was likely mild to moderate stress occurring at this location. Results from the MMI v4 and auxiliary metrics indicated that benthic macroinvertebrate communities were 'impaired' at the three study sites downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) in the spring and fall, while a total of five sampling locations generated MMI v4 scores indicating 'impairment' during the summer (Table 5). Farther downstream, improvements in MMI v4 scores were consistently observed near the downstream boundary of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa.* **Figure 20**, **Figure 21**, **Figure 22** *provides plots of the results from the 2020 MMI v4 scores for the 10 study sites.*

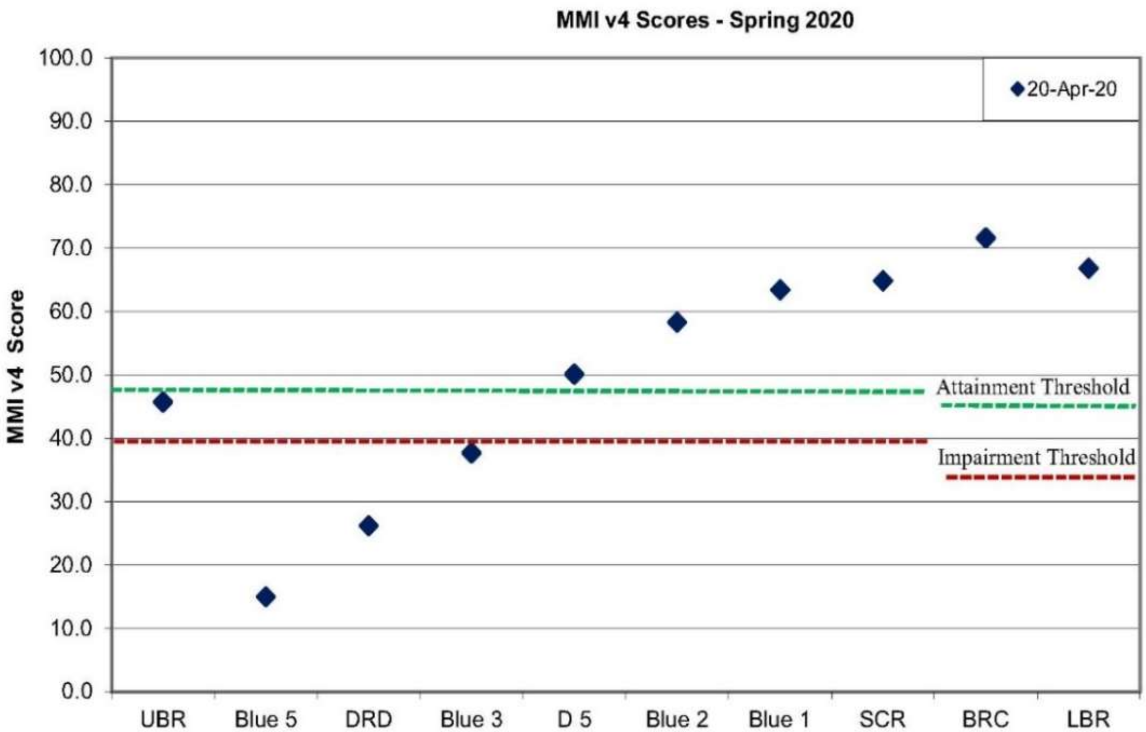


Figure 20. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during April 2020 (Figure 2, Timberline 2021).

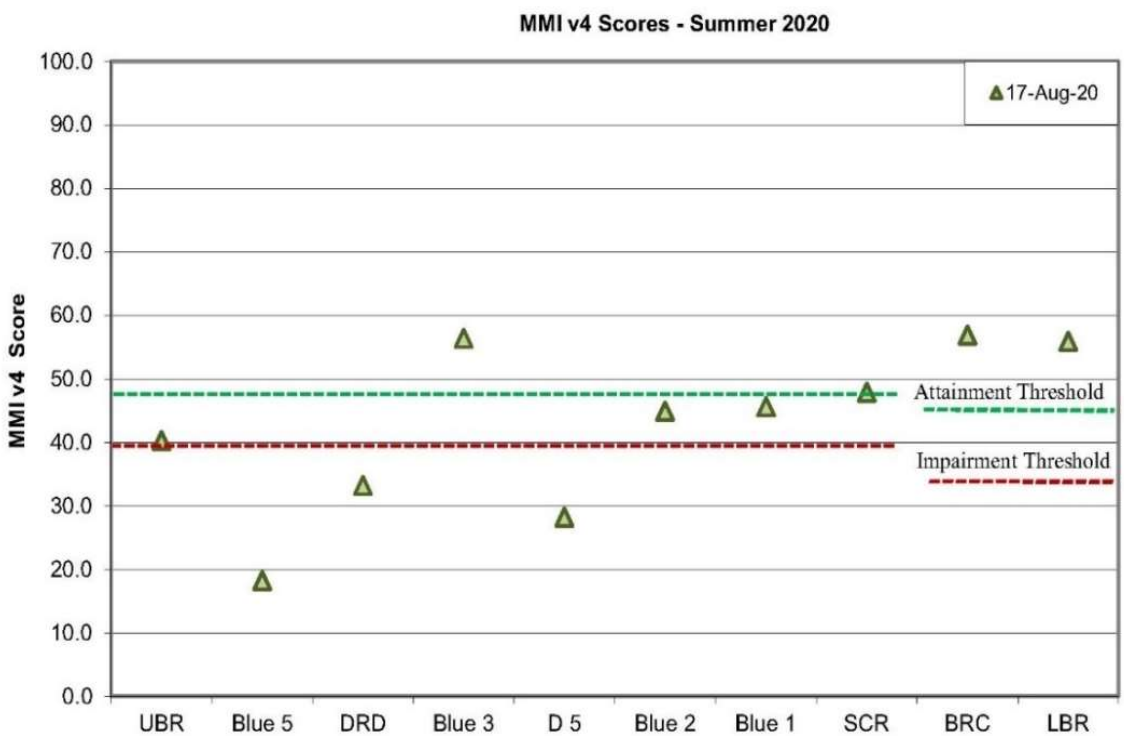


Figure 21. 2020 MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during August 2020 (Figure 3, Timberline, 2021).

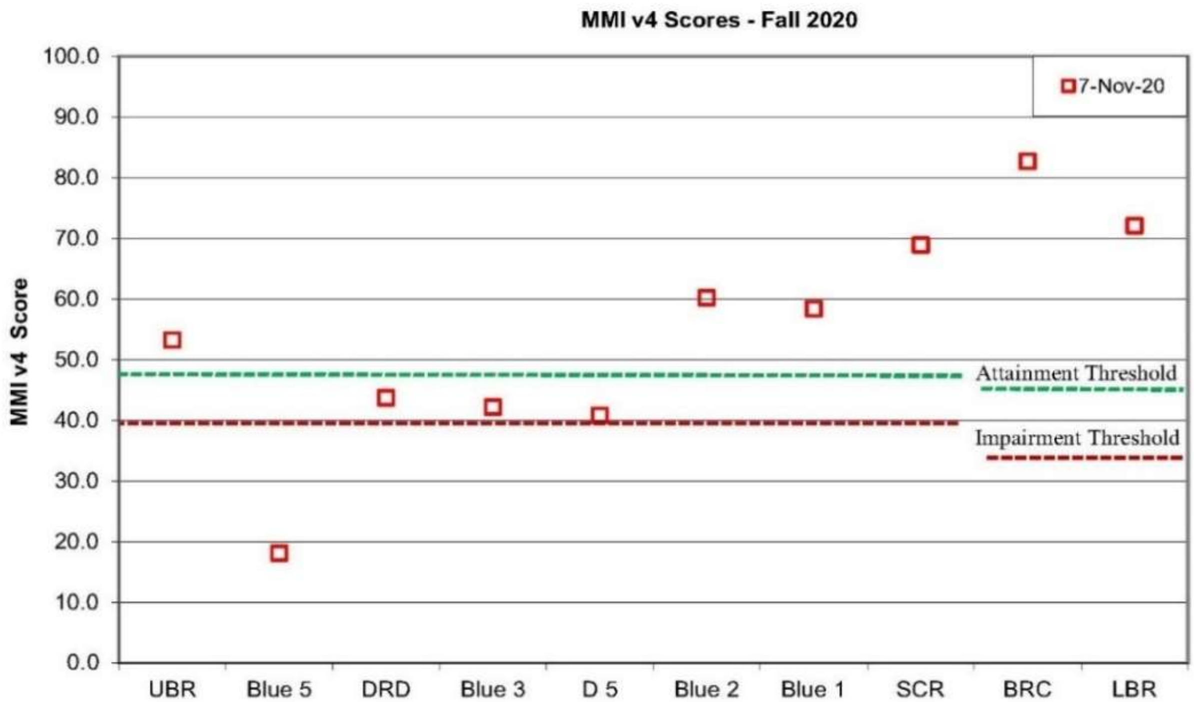


Figure 22. 2020 MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during November 2020 (Figure 4, Timberline 2021).

Periphyton Monitoring

In the summer of 2021, Trout Unlimited completed benthic algae, periphyton, sampling at eight monitoring sites in Reach 2 Blue between Dillon Reservoir and Green Mountain Reservoir. A sampling report was prepared titled "SWQC Fall Periphyton Sampling Report" (TU 2020) (attached as Appendix E). The following conclusions are presented in the report.

> *Because periphyton is the foundation of the Blue River's food web, it has long been surmised that the lack of benthic algae may be limiting invertebrate populations and, subsequently, the fishery. While samples from DRD and BCR indicate that these sites may not provide adequate forage capacity for localized macroinvertebrate populations, there are reaches in the Middle Blue that currently support target macroinvertebrate species. Those sites will continue to command our attention. Practitioners will use monitoring sites that support target biological communities to determine what is fundamentally different about them and how these reference conditions can be replicated at impaired reaches to improve the overall function of the Blue River.*

Blue River Fishery

In 2021, a summary report was prepared by Ksqrdfish Aquatics titled "The Blue River Fishery Status and the Influence of Water Temperature on the Blue River Fishery."(KA 2021 attached as Appendix G) using existing data, studies and information related to the declining fishery in the Blue River below Dillon Reservoir. The purpose of the report is to summarize the data and information to help inform decision makers and provide insight on causes. This report reviewed temperature data collected in 2020, as presented herein, and discussed the influence temperature has on the fishery in the Blue River. The following conclusions are presented in the Summary and Recommendations.

> *Hypolimnetic releases from Dillon Reservoir alter the natural flow and temperature regime downstream in all seasons of the year. Non-winter seasons have colder than normal*

temperatures which do not rebound to temperatures found above the reservoir until approximately 11 miles downstream. This impacts not only fish production in both growth and reproduction, but also has been shown to depress macroinvertebrate health (Rees 2021). Wild brown trout populations below other hypolimnetic release reservoirs in Colorado have not shown the decline in recent years that has been seen on the Blue River. Reservoir productivity, or aging of the upstream reservoir, impacts the downstream fishery (Hansen, CPW, personal communication). In this case all the rivers compared, Blue River, Taylor River, Fryingpan River, all had special regulation management put into place at the same general time in the early 1980s, and all had similar response of expanding trout number and biomass. The Blue River is the only one to show a general decline in the fishery since the early 2000s (see Appendix G). These streams differ in that the upstream reservoirs have different purposes and need for water delivery which could potentially influence downstream river productivity.

Water temperature downstream of Dillon Reservoir is having a negative impact on all life stages of the brown trout fishery. Cold temperatures are limiting growth and reproduction but seems to have the largest impact on the growth of adult brown trout. In 2020, only the Blue River stream reach below Boulder Creek (Blue 1 and BCR) provided water temperatures during the summer in the optimal temperatures for adult brown trout growth. Rapid changes in temperature and flow associated with the reservoir spill may negatively impact both fry and juvenile brown trout. In general, slow changes in temperature or flow within the natural range of variability are needed to avoid negative impact on juvenile salmonids (Brown et al. 2011). If acceptable ramping rates could be developed with the onset and ending of a spill event of Dillon Dam, downstream fisheries would benefit. Given the importance of stream temperature to aquatic organisms (Bear et al. 2007, Ziegler et al. 2013) and the relative ease with which the data can be collected, long-term year-round temperature monitoring seems like a logical way to track conditions in the Blue River.

In addition to altering downstream temperature, reservoirs can alter downstream channel configuration and complexity that was seen prior to reservoir construction. These changes often result in over wide channels and the loss of deep pool habitat with slower velocity water which is important to overwinter habitat. In addition, changes to sediment supply and occurrence of cobble habitat which provides critical fish habitat is common as well. Habitat quality assessments and availability need to be completed to determine if channel alterations could improve the overall fishery of the Blue River.

4.2.7. Reach 2: Summary of Key Issues

- ✓ Flows in Reach 2 are influenced by Dillon Reservoir flow releases. Flows are released primarily through the outlet works consisting of a 15 foot diameter tunnel that releases flows from the bottom of the reservoir.
  - The bottom releases have a capacity up to an estimated 4,000 cfs, however, Denver Water aims to limit, when possible, the outflows to a maximum of 1,800 cfs.
  - The outlet works includes a small power plant which in 2020 generated enough power to be a "net zero" operation.
- ✓ UPCO reports that generally this Reach experiences occasional water supply shortages which will increase under current and future conditions.

- ✓ Most of the agricultural land in Summit County is concentrated in Reach 2. Continued urbanization of agricultural lands could reduce irrigated lands.
- ✓ The agricultural community within the Blue River watershed of Reach 2 indicate challenges with infrastructure and an inability to divert full decrees.
- ✓ Recreation opportunities in this reach include angling, rafting, kayaking, stand up paddle boarding, camping, boating (Green Mountain Reservoir), and wildlife viewing.
    - o Under low-flow conditions, rafting and float-fishing are unlikely to be considered significant uses in Reach 2.
    - o The Town of Silverthorne is currently planning to build a whitewater park located near Dillon Reservoir outlet. The Town has a conditional Recreational In-Channel Diversion water right for the planned kayak park.
    - o Float boating typically occurs when flows are in the 450-700 cfs range.
    - o Due to the varied flow conditions that can support rafts and other crafts, walk-wade fishing is likely the most popular form of recreation on the Blue River in this reach.
    - o In the 2020 TU Angler Survey, 68% of participants indicated being “neutral” or “dissatisfied” with this reach. There is concern among local outfitters about client experience that may impact future visitation.
- ✓ Until 2016, Reach 2 was designated a Gold Medal Fishery by CPW. The designation was removed from the northern City limits of Silverthorne to Green Mountain Reservoir due to failure to meet CPW’s biological criteria (Ewert 2018). CPW has indicated the low productivity may be due to a combination of sub-optimal physical habitat.
    - o Water temperature downstream of Dillon Reservoir is below optimal cold water ranges, likely having a negative impact on all life stages of the brown trout fishery. Cold temperatures are limiting growth and reproduction but seem to have the largest impact on the growth of adult brown trout.
    - o In 2020, only the Blue River stream reach below Boulder Creek (Blue 1 and BCR) provided water temperatures during the summer in the optimal temperatures for adult brown trout growth.
    - o Surface water spills from the reservoir in the month of June appeared to propagate warmer temperatures for the full distance to Green Mountain Reservoir.
    - o November temperatures show a reverse trend with warmer temperatures being released from Dillon Reservoir compared to the downstream reaches.
    - o The rate of changes in temperature and flow associated with the reservoir surface water spills may negatively impact both fry and juvenile brown trout.
    - o Results from the 2020 MMI v4 and auxiliary metrics indicated that benthic macroinvertebrate communities were “impaired” at the three study sites downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) in the spring and fall, while a total of five sampling locations generated MMI v4 scores indicating ”impairment” during the summer.

   - Farther downstream, improvements in MMI v4 scores were consistently observed near the downstream boundary of the study area; however, alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa.
   - Lack of periphyton, or benthic algae, may be limiting invertebrate populations and, subsequently, the fishery. Samples from DRD and BCR indicate that these sites may not provide adequate forage capacity for localized macroinvertebrate populations.

- ✓ In addition to altering downstream temperature, reservoirs can alter downstream channel configuration and complexity that was seen prior to reservoir construction. These changes often result in over width channels and the loss of deep pool habitat with slower velocity water which is important to overwinter habitat.
- ✓ Wild brown trout populations below hypolimnetic release at other reservoirs in Colorado have not shown the decline in recent years that has been seen on the Blue River.

4.2.8. Reach 2: Recommendations and Opportunities

1. Sample and report on 2021 macroinvertebrate and periphyton monitoring as results become available.
2. Incorporate new fish surveys into this reach assessment when they become available. Consider adding dry year sampling using electrofishing with backpack units and perform sampling over multiple years to develop data sets for both wet and dry years. This data will provide a baseline, and, in the future, help inform on the effectiveness of restoration strategies.
3. Establish and implement a monitoring program, in addition to the fish surveys, to document current conditions and to monitor effectiveness of restoration strategies.
4. Continue monitoring water temperatures along the Blue River. Add temperature loggers and monitor several tributaries to inform on temperatures in the region that are not impacted by reservoir releases.
5. Perform stream assessments and map habitat to evaluate aquatic structure and cover, presence of embedded substrate, fish passage barriers, including those from low flows and shallow stream flows, channel morphology, and presence of fine sediments, gravels and algae.
6. Develop restoration strategies reflective of the results of the stream assessments and existing flow regimes. These might potentially include:
   - Channel narrowing
   - Addition of cover and pool habitat
   - Investigate spawning and the potential need for supplemental gravel supplement or creation of side channels and backwater habitats
7. Where there is support from the agricultural community, inspect headgates at diversions and improve as needed to facilitate diversions and minimize channel regrading in the stream bed.
8. Develop a statistically valid angler creel census conducted on the Blue River that would provide baseline conditions for angler use before any projects are completed.

4.3. Reach 3: Blue River- Green Mountain Reservoir Outlet to the confluence with the Colorado River.

The watershed area directly tributary to Reach 3 is about 102 square miles measured at the confluence of the Colorado River (**Figure 23**) representing about 15 % of the total 699 square mile watershed. Most of the land is federal property managed by the BLM and USFS, and agricultural property held in private ownership. Approximately 8 miles of the Blue River is located within the Blue Valley Ranch (BVR), which has implemented a large-scale restoration effort including the installation of grade control structures, bank protection and off-channel wetlands. Other notable private land holdings include the San Toy Land Company located downstream the BVR. There are two privately held parcels along the Blue River downstream of BVR that are under proposal to be exchanged from private to public property as part of a land exchange with the Blue Valley Ranch and BLM[1].

Figure 23. Reach 3: Blue River immediately upstream of the Colorado River confluence, looking south.

Reach 3 is approximately 16 miles long measured along the valley floor with an average channel slope of 0.3% (**Figure 24**). With the exception of the confluence area at the Colorado River, the river plan form is moderately steep with a confined and well-armored channel. Above the channel banks there is generally a relatively flat and wide floodplain bound by steep and high banks. The lower portion of the Blue River is unconfined, sinuous and relatively flat as it is affected by backwater conditions from the Colorado River. On the far upstream end of Reach 3, closer to Green Mountain Reservoir, the Blue River and associated floodplain valley become steeper and narrower, and the channel bed takes on a pool-and-drop planform with large boulder material (**Figure 25, Figure 26**, **Figure 27**). In 2010, the Blue River from the confluence of the Colorado River to the Grand-Summit County line was assessed for the Grand County Stream Management Plan (GCSMP). The analysis and data generated for the GCSMP is presented herein with permission of Grand County. The assessments were performed through a cooperative effort between the BVR, San Toy Land Company, and Grand County.

[1] Available at: https://bluevalleyranch.com/blm-invites-public-comment-on-blue-valley-land-exchange-proposal/

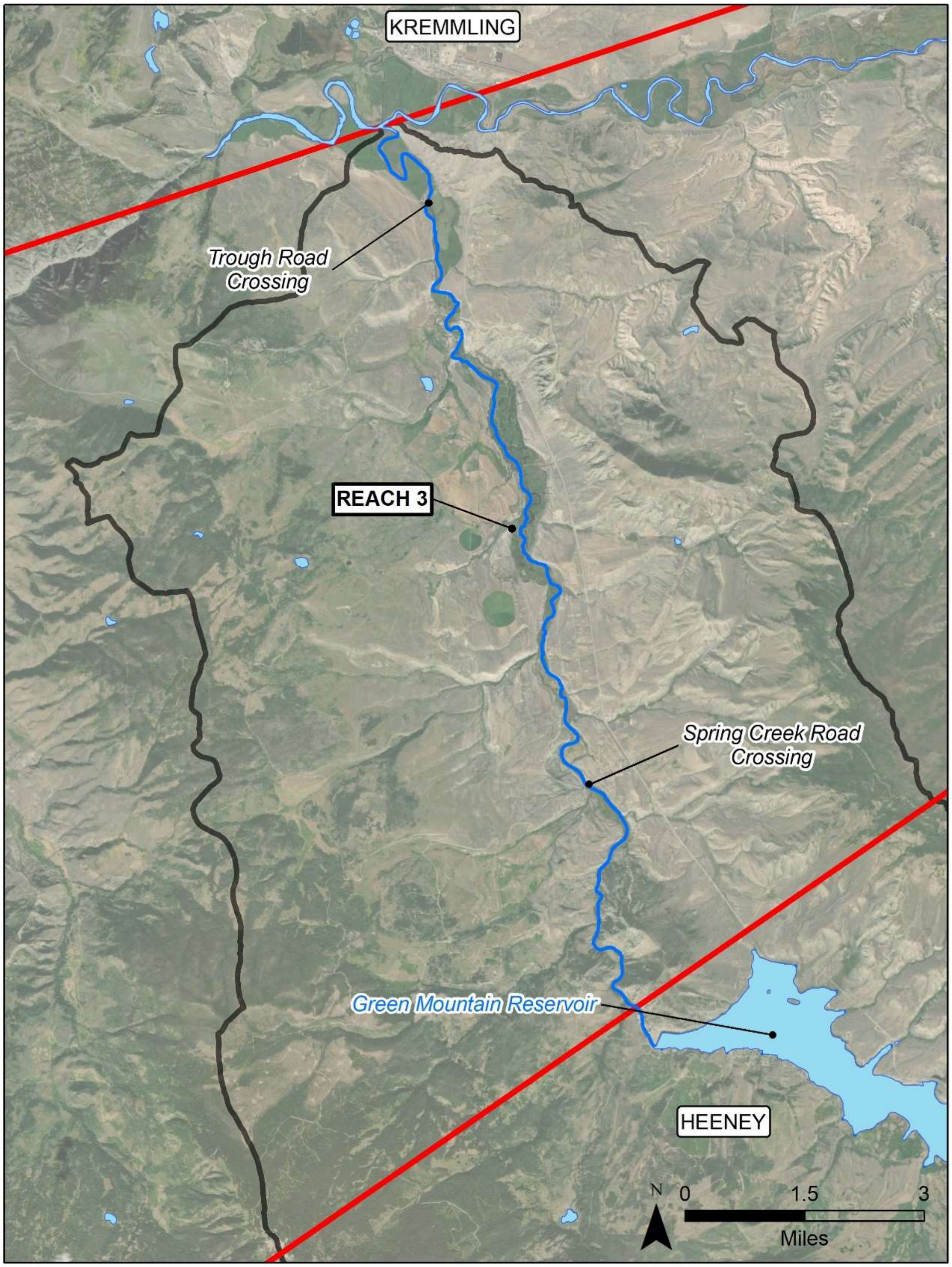


Figure 24. Reach 3.

Figure 25. Reach 3: Blue River below Trough Road at the old railroad crossing, looking upstream. This is the location of the 2008 PHABSIM "spawning site" (GCSMP).

Figure 26. Reach 3: Blue River from overlook on Blue Valley Ranch, looking southeast (GCSMP).

Figure 27 Reach 3: Blue River near the Green Mountain Reservoir outlet.

4.3.1. Water Use

Primary Municipal Water Users

- Green Mountain Reservoir: While Green Mountain Reservoir is physically within Reach 2, the flows released from the reservoir directly impact Reach 3. The reservoir is operated by the U.S. Bureau of Reclamation and its dam is used primarily to store water to compensate the Western Slope for water diverted to cities on the East Slope in Northern Colorado. Hence, flow releases from Green Mountain Reservoir are typically adding water into the River, thereby benefiting conditions downstream. However, timing and ramping of releases may be impacting the habitat as discussed in the following flow recommendations.
- Irrigators, municipalities, and industry: There are four primary irrigation diversions that typically divert up to approximately 130 cfs total in mid to late summer (GCSMP). Most of the diversions are made in the summer for irrigation. There are no major municipal or industrial water diverts in this reach.
- Water Supply Issues: No water supply issues are reported for this reach (UPCO).

Agriculture Operations

There are two major agricultural operations located immediately adjacent to the river in this reach, the largest being the BVR. The San Toy Ranch is located downstream of BVR and adjoins a portion of the Colorado River.

The CWP estimates a future incremental gap for future agriculture needs of 0 to 4 % of baseline demand within the Colorado River basin (CWP).

Recreation

The lower reach extends from the Green Mountain Reservoir Dam to the confluence of the Colorado River. The public access is mainly limited to a three-mile section immediately downstream of the reservoir, a ¼ mile section near Spring Creek Road (BLM), and piecemeal sections near Trough Road and at the confluence of the Colorado River (BLM). The majority of the reach is privately owned with limited-to- no public access. Float fishing and other water-based recreation in this reach is only available to public rafting/kayaking, no commercial outfitters are permitted in this reach. There have been trespassing instances and public/private conflicts within this reach.

There are three boat access points along this reach:

- Furthest upstream: put-in below Green Mountain Reservoir on land leased by Summit County
- Spring Creek Bridge (take-out only)
- Furthest downstream: Confluence River Access Point at confluence of Blue/Colorado Rivers on BLM land.

The boat ramp below the reservoir is very steep and narrow, which creates problems ranging from erosion to user safety. Due to the poor quality of the boat ramp in this section, the lower reach is used less by larger boats (rafts/dorys) than other nearby rivers (e.g., Colorado River below Gore Canyon). However, use is likely to increase based on overall recreation trends in Colorado.

Based on outfitter interviews, wade fishing along the upper canyon reach is best between 200-350 cfs. Above 300 cfs, walking in the river becomes increasingly difficult and dangerous. However, shoreline fishing remains feasible at higher flows.

In 2008, a coalition of land management agencies, private landowners, counties, and nonprofits worked to develop a comprehensive recreation and resource management strategy for the lower Blue River. Titled "Lower Blue River Cooperative Management Plan," the document attempted to convene stakeholders to develop strategies that preserve the outstanding resources within the reach through various recreational management strategies among the different jurisdictions, landowners and users. While it laid out various alternatives and proposed actions, the document was never formalized by the cooperating partners. Since recreational use, conflicts, and pressure on the fishery are continuing to increase, it may be advantageous to reconvene stakeholders to modify the original document and formalize new strategies to protect the resource and mitigate negative impacts. Should the stakeholders choose to reconvene and complete the Lower Blue River Cooperative Management Plan, BRWG is committed to participating providing support from a technical standpoint to advance the plan and develop appropriate management strategies.

Lastly, the Bureau of Land Management, Summit County, and Blue Valley Ranch are in separate negotiations over a proposed land swap agreement. While final details are still unknown at the time of this report, the proposal could potentially improve access at the put-in below Green Mountain Reservoir, as well as increase public access and restore habitat at the confluence with the Colorado River. More information on the land swap agreement will be made public by the BLM in 2021, with expected construction to start in 2022 or 2023.

4.3.2. **Hydrology**

USGS Gage Station 09057500, Blue River below Green Mountain Reservoir, has been in operation since 1938, with flows regulated by the reservoir since 1943. In 1985, reservoir operations changed to meet the demands of agricultural and domestic water users on the Western Slope, the historic user pool, generally resulting in increased releases out of Green Mountain Reservoir, and an unnatural second peak in the months of September and October. Exceedance plots are presented in **Figure 28**. An exceedance hydrograph represents how often the flows have exceeded a level in the past. For example, the 75% exceedance plot, shown below, represents the flows that were equaled or exceeded 75% of the years for each day. Likewise, the 25% exceedance plots represent the flows that were equaled or exceeded 25% of the years for each day. The exceedance plot on Figure 28 indicates that 50% of the time from May to mid-June flows dropped below the summer target flows recommended in the environment flows section, below.

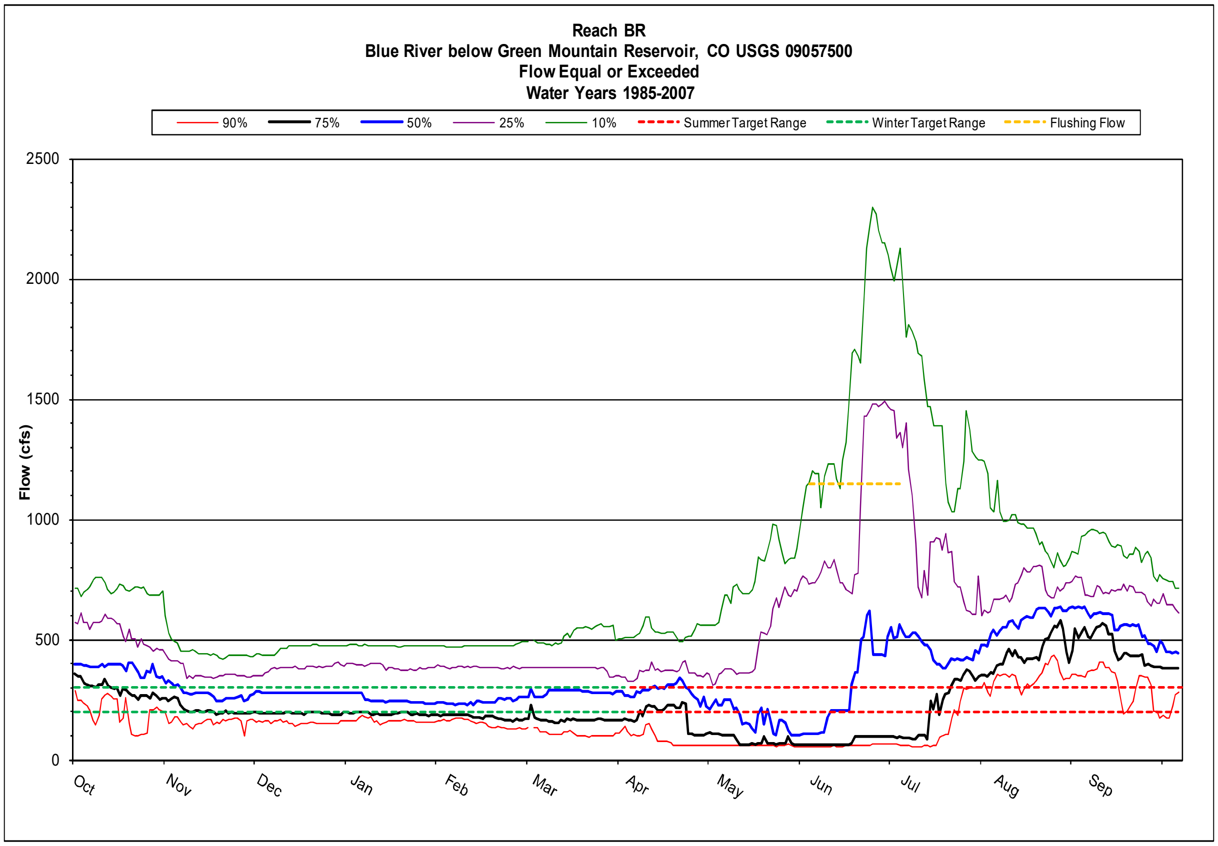


Figure 28. Station 09057500 (Blue River below Green Mountain Reservoir) Exceedance Hydrograph.

Environmental Flows

Recommended environmental flow ranges for two seasons of the year were developed for the Blue River (Reach 3) in the GCSMP. The recommended environmental target flow ranges for each season are flows that provided the maximum or near maximum weighted useable area[2] (WUA) for the target species and life stage as summarized below:

Environmental recommended flow ranges

- 200 to 300 cfs, April 1 through September 30
- 200 to 300 cfs, October 1 through March 31
- Flushing flow - at least 1,150 cfs for a 3-day duration with a frequency of 1 in 2 years during the late May to late June period

[2] Weighted usable area has been traditionally computed as the sum of stream surface area within a study site, weighted by multiplying area by habitat suitability variables (most often velocity, depth, and substrate or cover) which range from 0.0 to 1.0 each, and normalized to square units (either feet or meters) per 1000.

Daily streamflow records, exceedance plots, and an Indicators of Health Analysis (IHA) indicate the recommended flow ranges are commonly present, and often exceeded, within the reach (GCSMP Tetra Tech et al. 2010). See Appendix G, for additional information and support data.

In 1973, the General Assembly authorized the Colorado Water Conservation Board (CWCB) to appropriate water rights for instream flows and natural lake levels to preserve the natural environment to a reasonable degree. Since 1973, CWCB has appropriated instream flow water rights on nearly 1,700 stream segments covering more than 9,700 miles of stream, and natural lake level water rights on 480 natural lakes. Instream flows for the Blue River in Reach 3 are provided below. These instream flows are also shown on the exceedance plots shown on Figure 28 as target flows.

CWCB Instream flows

- 85 cfs summer (05/1 – 07/15)
- 60 cfs winter (07/16 – 04/30)

4.3.3. **Water Quality and Temperature**

Water Quality

The BVR monitors water quality through their property with results indicating low levels of phosphorus. Low levels of phosphorus with a normal level of nitrogen results in a condition that allows didymo to flourish and thereby out compete endemic periphyton. The low production of periphyton, in turn, limits the macroinvertebrate populations and fish biomass. BVR theorizes that reservoirs upstream of Reach 3 trap sediment and reduce flooding, both natural process that would normally carry and deliver nutrients, including phosphorus. The BVR is proposing a nutrient injection study and is in the process of applying for approvals.

Water Temperature

Reach 3 is a Tier I stream reach as designated by CDPHE with a chronic temperature standard of 9 ^{o}C MWAT October through May and 17^{o}C MWAT June through September; and an acute temperature standard of 13.0 ^{o}C and 21.7 ^{o}C DM. The reach is currently listed on the state's 303(d) list for exceeding state temperature standards.

4.3.4. **Aquatic Life**

Fish Surveys

CPW 2006 electrofishing data indicate that brown trout dominate the cold-water fishery, with estimates of 1676 fish/mile > 150 mm, with lesser numbers of rainbow trout, estimate of 138 fish/mile > 150 mm. Quality trout,> 356 mm, are abundant, estimated at 549/mile (Ewert 2008).

Surveys conducted downstream of Trough Road by CPW in the fall of 2018 and spring of 2019 reveal a highly dynamic fish population "heavily used" by brown trout spawning in the fall. Rainbow trout captured were heavily infected by gill lice parasites (Ewert 2020).

Several likely rainbow trout redds (spawning areas) were observed during a float trip through Reach 3 in 2008 in conjunction with the GCSMP field work. Observations of additional spawning activities at that time, were hampered by rising water levels and increasing turbidity. On October 30 and 31, 2008, eight likely brown trout redds were observed at the "spawning site" below Trough Road, while later on October 31, several adult brown trout were observed actively spawning during a float trip through the Blue Valley Ranch. Due to fluctuating conditions over these two days, physical habitat measurements at each redd site could not be made.

Based on observations made by CPW, the unusually high flows in September and October due to releases from Green Mountain Reservoir create a "reverse hydrograph" which may limit brown trout reproduction in some years, especially above Spring Creek bridge. Brown trout spawn prior to November 1 during the higher flow regime. When flow releases are reduced, the water levels in the river drop often, leaving the redds dry (Tetra Tech et al. 2008 and Ewert 2020). The same is likely true for rainbow trout who spawn in late winter and spring, then have their redds dewatered as water levels drop when Green Mountain Reservoir is refilled, starting May 1st on some years. Rapidly rising streamflow could potentially re-locate fish and other aquatic life downstream into less favorable habitats, while rapidly declining flows can strand fish and other aquatic life in temporary habitats ultimately leading to desiccation and death (Reiser et al. 2008 as cited by KA 2021). Also, flow reductions during important life cycle events such as spawning can lead to drying of incubating eggs in redds and immobile fry attempting to emerge from the inter-gravel environment.

Macroinvertebrate Monitoring

Macroinvertebrate sampling was conducted in 2020 on Reach 3 at the LBR site located below Green Mountain Reservoir to serve as a reference reach for Reach 2. The LBR site MMI v4 score was relatively high consistently throughout the three sampling efforts, exceeding attainment threshold, although slightly lower than site BRC in Reach 2 located immediately upstream of Green Mountain Reservoir. Both the BRC and LBR produced higher MMI scores than any of the other sites sampled in 2020 on Reach 2 (Timberline 2021 attached in Appendix D).

4.3.5. **Stream Assessment**

In November 2009 Tetra Tech conducted three assessments at three locations within the Blue Valley Ranch property, and in August 2008 Tetra Tech conducted three assessments at one location downstream of Trough Road at the spawning site. These assessments included Stream Reach Inventory/Channel Stability Evaluation (SRI/CSE), EPA Habitat Quality Assessment (HQA) and a Riffle Stability Index (RSI) evaluation. The SRI/CSE evaluation scored in the “good category” at the upper site and ”fair category” at the other three; the EPA HQA evaluation scored in the ”optimal or high suboptimal category”’ at all four sites and the RSI results indicates this reach tends to have moderate to high bed instability. At the spawning site, conditions tend to be depositional due to reduced channel gradient and occasional backwater conditions caused by the Colorado River. Overall, the stream assessments did not reveal any issues of significant concern. The relatively high degree of riffle bed instability denoted by the RSI scores is likely the result of the magnitude of the 2009 spring peak flow of about 3000 cfs, a flow approaching the 25-year flood event. Results of the assessments are provided in Appendix E. Details and methodology are presented in the GCSMP (Tetra Tech et al. 2010).

4.3.6. **Reach 3: Summary of Key Issues**

- ✓ The recommended environmental flows developed in the GCSMP range from 200 to 300 cfs. These flow ranges are commonly met within the reach, except during refill of Green Mountain Reservoir, which usually starts May 1. The recommended flows exceed the CWCB instream flows of 60 to 85 cfs.
- ✓ No significant concerns were identified from the stream assessments.
- ✓ This reach is listed on the state’s 303(d) list for exceeding state temperature standards.
- ✓ Temperatures and water quality appear supportive of a cold-water fishery.

- ✓ Rapid flow changes particularly in spring and again in late summer and fall are identified as a potential issue for spawning habitat. Further, agricultural water users have indicated concerns over the rapid flow changes which led to unsafe conditions near the river, and difficulty in operating headgates.
- ✓ Flows for recreation are generally adequate, except for safety concerns relative to the rapid fluctuations noted above.
- ✓ Trout habitat availability varied widely between the 2009 study sites, species, life stages and stream flows; although some similar trends were observed. In general, juvenile trout habitat was more abundant than adult habitat, while adult brown trout habitat consistently exceeded rainbow trout habitat. Adult and juvenile habitat tended to be more abundant at the upper site, while spawning habitat varied widely between sites, being about 10 times more abundant at the lower site than at the upper.
- ✓ CPW 2006 electrofishing data indicate that brown trout dominate the cold-water fishery with lesser numbers of rainbow trout. Quality trout are abundant, estimated at 549 per mile.
- ✓ The BVR is proposing a nutrient injection study to determine whether reduced phosphorus levels with a normal level of nitrogen results in a condition that allows didymo to flourish and thereby out compete endemic periphyton. BVR is in the process of applying for approvals.
- ✓ Rapid changes in streamflow, or ramping, has been identified as a possible issue for the Blue River below Green Mountain Reservoir. Such fluctuations could adversely affect aquatic life and pose a human safety risk for recreationists and others along the river corridor.

4.3.7. Reach 3: Recommendations and Opportunities

1. Engage in conversations with the Bureau of Reclamation, state of Colorado, the members of the Historic User Pool regarding flow releases out of Green Mountain Reservoir. To the extent possible, flows should be maintained at a fairly constant rate within the recommended target flow range during the brown trout spawning and incubation period to lessen or prevent the loss of developing trout embryos and be sufficient in quantity to maintain stream temperatures throughout the reach that are below CDPHE's stream temperature criteria. Further, flows for spring and early summer should ascend during the rainbow trout spawning and incubation period and be maintained at a fairly constant rate during the brown trout spawning and incubation period in order to lessen or prevent the loss of spawning reeds and protect developing trout embryos. Additional study, evaluation and discussion of ramping rates for flow releases from Green Mountain Reservoir is recommended. This might include moderate changes to the timing of releases and/or the possibility of assessing operation modifications at other facilities.
2. The 2010 GCSMP recommended bank restoration in Reach 3 along a bank downstream of Trough Road at old the highway bridge crossing. As of 2021, this bank restoration project was completed.
3. Protect and sustain agricultural interests and sufficient water quantity in the Blue River by providing support, as needed, to the agricultural community to find ways, through grant funding, legislative policy, etc. to support irrigation and cattle operations with improvements to infrastructure, channel bank stability, and the riverine habitat adjacent to these fields.

4. Participate as a stakeholder in an advisory role for the advancement of the Lower Blue River Cooperative Management Plan should all the previous stakeholders, including government agencies and private property owners, choose to reconvene and complete the Lower Blue River Cooperative Management Plan.

5. RECOMMENDATIONS AND NEXT STEPS

The BRIWMP is a working document that will be updated in the years to come as recommendations are implemented and projects are developed. The following is an initial list of recommendations for Phase 2 and beyond. Some of these recommendations will be integrated into Phase 2 of the BRIWMP, while others will expand into future phases. These projects have also been included in the Colorado Basin Roundtable projects database, referred to as 'Identified Projects & Processes (IPP)' database. Projects on the IPP list have the Colorado Basin Roundtable support which strengthens the opportunities for funding.

Table 5. Recommendations by Reach

Reach 1 Key Recommendations	
Recommendation 1.1: Evaluate impacts of increasing water use and transbasin diversions on Blue River hydrology.	
1.1.1	Evaluate hydrologic data describing streamflow regimes in the Blue River and, where possible, how that regime has been altered and could potentially be altered due to additional transbasin diversions.
1.2.1	Perform geomorphic assessment(s) in combination with the hydrologic analysis to assess hydrologic flow alterations relative to aquatic habitat. Develop restoration strategies reflective of the results of the stream assessments.
Recommendation 1.2: Understand sources of water quality degradation from hard rock mining and acid rock drainage and monitor the effects of ongoing restoration on constituents of concern including cadmium, copper, iron and zinc, and possibly silver and selenium. Monitor and track efforts by Climax Mining on treatment options.	
1.2.2	Coordinate with and support current and extensive efforts by Summit County, Town of Breckenridge, CPW, TU and other federal and state agencies to continue and/or expand ongoing monitoring to develop baseline information and/or evaluate effects of restoration and remediation.
1.2.3	Work with TU Abandoned Mine Land Program to identify and target future mine site remediation projects.
Recommendation 1.3: Support ongoing efforts by Summit County and Town of Breckenridge to continue and/or expand ongoing restoration efforts from dredge boat mining. Note that this includes the Reach 1 of the Blue River and the Swan River.	
1.3.1	Coordinate with and support current and extensive efforts by Summit County, Town of Breckenridge, CPW, TU and other federal and state to continue and/or expand ongoing monitoring to develop baseline information and/or evaluate effects of restoration efforts.

Recommendation 1.4: Evaluate the causes of the declining fishery and develop action plans for remediation.	
1.4.1	Expand macroinvertebrate monitoring upstream of Dillon Reservoir.
1.4.2	Add water quality monitoring sites to expand the understanding of water quality impacts from French Gulch.

Reach 2 Key Recommendations	
Recommendation 2.1: Continue to sample and survey the aquatic communities.	
2.1.1	Perform macroinvertebrate and periphyton sampling.
2.1.2	Incorporate new fish surveys into this reach assessment when they become available.
2.1.3	Work with CPW to add dry-year (low flow) sampling using electrofishing with backpack units and perform sampling over multiple years to develop data sets for both wet and dry years. This data will provide a baseline, and in the future, help inform on the effectiveness of restoration strategies.
2.1.4	Continue monitoring water temperatures at the 2020 locations and add additional monitoring sites in one or two tributaries such as Boulder and Willow Creeks.
Recommendation 2.2: Perform assessments to develop restoration strategies for the benefit of aquatic habitat.	
2.2.1	Evaluate hydrologic data describing streamflow regimes in the Blue River and, where possible, how that regime has been altered and could potentially be altered due to additional transbasin diversions using a procedure such as Indicators of Hydrologic Alteration (IHA) procedure developed by The Nature Conservancy (TNC).
2.2.2	Map habitat to evaluate aquatic structure and cover, presence of embedded substrate, fish passage barriers (including those from low flows and shallow stream flows), channel morphology, and presence of fine sediments, gravels, and algae.
2.2.3	Perform stream assessments at selected sites to evaluate aquatic structure and cover, presence of embedded substrate, channel morphology, and presence of fine sediments, gravels, and algae.
2.2.4	Develop restoration strategies reflective of the results of the stream assessments, mapping and hydrologic analysis. This may include channel narrowing, addition of cover and pool habitat, enhancement of riparian corridor, and improvements to fish passage barriers.
Recommendation 2.3: Evaluate temperature releases from Dillon Reservoir	
2.3.1	Review Dillon Reservoir temperature profiles to evaluate if releasing flows from higher up in the water column would provide temperature regimes that improve the biological community of the river downstream of the reservoir. Evaluate the potential for alternative release points that would improve water temperatures; assess potential opportunities to also benefit Dillon operations.

Recommendation 2.4: Coordinate with the agricultural community	
2.4.1	Where there is support from the agricultural community and diverters, inspect headgates at diversions and improve as needed to facilitate diversions and minimize channel regrading in the stream bed.
Recommendation 2.5: Establish a monitoring program	
2.5.1	Establish and implement a monitoring program to document current conditions and to monitor effects of restoration strategies.
2.5.2	Develop a statistically valid angler creel census conducted on the Blue River that would provide baseline conditions for angler use before any projects are completed.

Reach 3 Key Recommendations	
Recommendation 3.1: Evaluate current release strategies, including timing and ramping rates to maintain stream temperature and benefit spring and fall trout spawning.	
3.1.1	Study, evaluate and discuss release timing and ramping rates for flow releases from Green Mountain Reservoir. Coordinate with HUP, CWCB, W&S, and others.
Recommendation 3.2: Support opportunities that benefit agricultural operations.	
3.2.1	Support, as needed, to the agricultural community to find ways (grant funding, legislative policy, etc.) to support irrigation diversion and cattle operations with improvements to infrastructure, channel bank stability, and the riverine habitat adjacent to these fields.
Recommendation 3.3: Support nutrient injection study.	
3.3.1	Provide support as needed to BVR should the nutrient injection program move forward. Support might include additional sampling, monitoring and public outreach.
Recommendation 3.4: Participate in the completion of the Lower Blue River Cooperative Management Plan.	
3.4.1	Participate in an advisory role for the advancement of the Lower Blue River Cooperative Management Plan should all the previous stakeholders, including government agencies and private property owners, choose to reconvene and complete the Plan.

6. REFERENCES

Analysis &Technical Update to the Colorado Water Plan, Volume 1 (CWP). Download May 2020. At: https://dnrftp.state.co.us/#/CWCB/Technical%20Update%20to%20Water%20Plan/1.%20Technical%20Update%20Documentation/

Bauch, N.J., Miller, L.D., and Yacob, Sharon. 2014. Analysis of water quality in the Blue River watershed, Colorado, 1984 through 2007: U.S. Geological Survey Scientific Investigations Report 2013–5129, 91 p., http://dx.doi.org/10.3133/sir20135129.

Brown and Caldwell 2004. Engineering Report: Application For Recreational In-Channel Diversion For Blue River At Silverthorne, Colorado. Prepared for the Town of Silverthorne.

Chadwick and Associates 1986. Aquatic Baseline Metropolitan Denver Water Supply Systemwide/Site Specific Environmental Impact Statement.

Coley/Forrest, Inc. 2011. Water and its Relationship to the Economies of the Headwaters Counties. Prepared for Northwest Colorado Council of Governments. December.

Colorado Department of Public Health and Environment, Water Quality Control Commission (WQCC). 2010. 5 CCR 1002-93, Regulation #93, Colorado Section 303(D) List of Impaired Waters and Monitoring and Evaluation List. 2020.

Colorado River Outfitters Association (CROA) 2019. Commercial River Use in the State of Colorado 1988-2019.

Colorado Water Conservation Board (CWCB), Instream Flow Program. 2020. At: https://cwcb.colorado.gov/focus-areas/ecosystem-health/instream-flow-program

Colorado Water Plan Technical Update (CWP). 2019. At: https://cwcb.colorado.gov/colorado-water-plan/technical-update-to-the-plan

Colorado Water Plan, Colorado Basin Roundtable, Basin Implementation Plan (BIP). 2015. At: https://www.coloradobasinroundtable.org/water-planning/colorado-basin-implementation-plan/summit-county/

Colorado Parks and Wildlife (CPW). Download June 2021. At: https://cpw.state.co.us/Documents/Commission/2019/June/Item.15a-POLICY_Wild_Gold_Medal-Katie_Lanter-DNR.pdf

Dean Runyan Associates. 2019. Colorado Travel Impacts 2000-2018p. Prepared for Colorado Tourism Office.

Denver Water. “Recreation - Dillon Reservoir”. Denver Water, 2021. https://www.denverwater.org/recreation/dillon-resevoir Accessed: January 20, 2021.

EcoMetrics, Colorado State University. 2015. FACStream 1.0 (2015) Functional Assessment of Colorado Streams. Prepared for the US EPA.

Elder, N. 2020. Denver Water Letter to Erika Donaghy, Executive Director, Blue River Watershed Group. Denver Water's comments on the Blue River Integrated Water Management Plan (BRIWMP) Progress Draft Report dated June 10, 2020. August 5, 2020.

Elder, N. 2021. Denver Water Email communication to Peggy Bailey regarding Denver Water diversions at Roberts Tunnel. May 27, 2021.

Environmental Protection Agency (EPA). 2021. "Optimization Review: French Gulch/Wellington-Oro Mine Site Water Treatment Plant, Breckenridge, Summit County, Colorado," at: https://www.epa.gov/remedytech/optimization-review-french-gulchwellington-oro-mine-site-water-treatment-plant

Ewert, J. 2008. Aquatic Biologist, Colorado Parks and Wildlife. Personal communication regarding electrofishing data Grand County Colorado.

Ewert, J. 2018. Fishery Management Report, 2010-2017. Colorado Parks and Wildlife.

Ewert, J. 2019. Blue River Above Dillon Reservoir, 2019 Fishery Survey Report. Colorado Parks and Wildlife.

Ewert, J. 2020a. Blue River near Kremmling. Fishery Survey Report. Colorado Parks and Wildlife.

Ewert, J. 2020b. Dillon Reservoir Fishery Management Report. Available: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/DillonReservoir.pdf

Ewert, J. 2020c. Green Mountain Reservoir Fishery Management Report. Available: https://cpw.state.co.us/thingstodo/Fishery%20Survey%20Summaries/GreenMountainReservoir.pdf

Federal Emergency Management Agency (FEMA), Flood Insurance Study, Summit County Colorado and Incorporated Areas, Washington DC, November 16, 2018.

High Country Conservation Center (HCCC). 2019. Climate Action Plan. Available on-line at: https://highcountryconservation.org/climate-change-colorado/

Hydroshere Resource Consultants (HRC). 2003. "Upper Colorado River Basin Study (UPCO), Phase II, Final Report." May 29, 2003.

Johnson, B. M. 2013. Creel Survey Results: Dillon Reservoir, Summer 2012. CSU Fisheries Ecology laboratory. June 20.

Ksqrdfish Aquatics, LLC. (KA). 2021. Summary Report on the Blue River Fishery Status and the Influence of Water Temperature on the Blue River Fishery. Prepared for Tetra Tech Inc.

Lewis W. M., McCutchan, J.H. 2013. Evaluation and Interpretation of the Multi-Metric Index (MMI) Information on Invertebrate Communities of the Blue River below the Dillon Reservoir Dam, Summit: County, Colorado 2012. July 5.

Lower Blue Master Plan. Summit County, Colorado. Retrieved on April 17, 2021 from: https://www.summitcountyco.gov/

McCormick, Ben (Cutthroat Anglers). "RE: Recreation Work". Received by Dan Omasta December 12, 2020. Email Interview.

McMillen, LLC., Tetra Tech. 2013. Blue River Section 206 Aquatic Ecosystem Restoration, Breckenridge, Colorado, Appendix B Engineering Report, April.

Mead, Jordan (Dillon Reservoir Recreation Committee). "RE: DREC Use Analysis". Received by Dan Omasta March 19, 2021. Email Interview.

Northwest Colorado Council of Governments (NWCCOG). 2012. Regional Water Quality Management Plan. At: http://nwccog.org/programs/watershed-services/

Omasta, Dan 2020. Blue River Integrated Water Management Plan, Trout Unlimited Angler Survey Report.

Raleigh, R. F., L. D. Zuckerman, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish Wildlife. Servo Biol. Rep. 82(10.124). 65 pp. [First printed as: FWS/OBS-82/10.71 , September 1984].

Reuter, Jane. "Fish Story". Summit Daily. December 11, 2002. https://www.summitdaily.com/news/fish-story/ Accessed: January 21, 2021.

Richardson, Cory (US Forest Service). "RE: Blue River Watershed Visitation". Received by Greg Hardy February 1, 2021. Email Interview.

Shook Publishing Company, 2013. Blue River Fishing Map and Floating Guide.

Sienkiewicz, Taylor. "Report: Summit County tourism spending exceeds $1 billion, 3rd highest in state". Summit Daily. February 4, 2020. https://www.summitdaily.com/news/report-summit-county-tourism-spending-exceeds-1-billion/ Accessed: January 20, 2021.

Summit County Census of Agriculture (SCCA). 2012. Summit County Profile. Available at: https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/County_Profiles/Colorado/cp08117.pdf

Southwick Associates (SA). 2018. The 2017 Economic Contribution of Outdoor Recreation in Colorado; A regional and county-level analysis. Prepared for Colorado Parks and Wildlife. July 23.

Tetra Tech, HabiTech. Walsh Aquatic, Inc. (Tt et al.). 2010. Draft Report, Stream Management Plan, Phase 3, Grand County Colorado. August 2010

Timberline Aquatics, Inc. (Timberline). 2021. Summary Report, Benthic Macroinvertebrate Biomonitoring/Surveys, Blue River, Colorado, 2020. Prepared for the Blue River Watershed Group and Trout Unlimited. March 10.

Trout Unlimited (TU). 2020. SWQC Fall Periphyton Sampling Report. Prepared by Tanner Banks. December 16.

West, Tim (Breckenridge Outfitters). "RE: IWMP - Fishing Reach 1". Received by Greg Hardy January 11, 2021. Email Interview.

APPENDIX A

Stakeholder Engagement Plan

PLAN DESCRIPTION

This Stakeholder Engagement Plan provides a framework for engaging a diverse range of stakeholders, and the public, in the process to develop the Blue River Integrated Watershed Management Plan. The Stakeholder Engagement Plan addresses the following topics:

- **Objectives** of stakeholder engagement
- **Key messages** about the Plan's process and outcomes
- **Target audiences,** including the Advisory Committee, Stakeholder Groups, and the Public, and the approaches and the participation goals for engaging these audiences
- **Engagement activities and schedule** to be implemented over the course of the planning process
- Recommendations for **continued community involvement** in the Integrated Watershed Management Plan

In addition to guiding the process, this Stakeholder Engagement Plan also serves as a transparency tool, allowing all the stakeholders involved in the process to know what to expect, how and when they can be involved, and what that involvement will entail.

Stakeholder Engagement Objectives

The following re the objectives for stakeholder engagement:

- Build on local knowledge and provide meaningful opportunities for stakeholders and community members to engage throughout the process;
- Understand and address diverse perspectives, interests, and needs;
- Increase education and awareness of issues and opportunities surrounding a healthy Blue River;
- Strengthen partnerships for long-term collaboration and success;
- Create a transparent planning and decision-making process;
- Develop solutions supported by local ownership and buy-in.

Key Messages

By communicating key messages consistently, the project team and Advisory Committee can improve understanding in the community and among stakeholders about the purpose of the project and help to keep it on scope, schedule, and budget. Key messages will expand as the project progresses; current key messages include:

- **Identify and understand current and future water use.** The long-term goal of the IWMP is to enable consumptive and non-consumptive water users to understand and quantify current and future use and integrate those uses for the maximum benefit of all users while protecting the existing water resources.
- **Develop long-term goals and objectives for protecting and improving the health and resiliency of the Blue River Watershed.** The IWMP process will develop and prioritize implementation goals and objectives to improve the health and resiliency of the Blue River Watershed. These goals and objectives will likely include multi-use projects and innovative water management techniques that will be vetted and prioritized through stakeholder participation.

- **Determine the causes for the declining fishery between Dillon and Green Mountain Reservoirs.** Working closely with the Blue River Enhancement Workgroup, the project will include the analysis and integration of previous and ongoing studies of the Blue River, as well as initiating additional studies, to determine the causes and possible remedies for the fishery decline on the main stem of the Blue River from Dillon Reservoir to Green Mountain reservoirs.
- **Community engagement is critical to success.** The Stakeholder Engagement Plan involves the participation of a wide range of stakeholders and the public in the planning process with the objectivesof understanding and addressing diverse interests and developing community-supported solutions. Engagement activities include convening an Advisory Committee, conducting community workshops, developing a webpage, and engaging in other media updates.
- **The process will have sustainability** with long-term community involvement through the Blue River Watershed Group.
- **Multiple sources contributed funding.** The project sponsors have grant funding for the IWMP from the Bureau of Reclamation and the Colorado Water Conservation Board. Cash funding was also received from Blue Valley Ranch, Town of Silverthorne, Summit County, and the Summit County Water Quality Committee.

Target Audiences

The primary audiences for stakeholder engagement include the general public as well as organizations and individuals in the following major stakeholder groups: Agriculture; Recreation and Tourism; Local, State and Federal Governments; Water Managers and Providers; Environmental Groups; and Industry and Land Development.

Advisory Committee

Establish an Advisory Committee with representatives from the major stakeholder groups to guide and inform the identification of concerns and important issues, goals and objectives, analyses and studies, framework for long-term monitoring and the development of a community driven plan.

Participation Goals

- Provide insight into diverse perspectives and interests
- Create connections with and engage other stakeholders and community members
- Increase buy-in and support for outcomes and implementation

Approach

Specific responsibilities of the Advisory Committee include the following:

- Provide expertise, data, reports, and anecdotal information
- Consider and review findings and recommendations from Consultants
- Advise and support stakeholder and community engagement process
- Make final recommendations on goals, objectives, projects and water management techniques
- Assist in evaluating and prioritizing projects for implementation
- Review and provide input on draft documents
- Help communicate plan purpose in wider community

The Advisory Committee will meet six times during the project period. The first Advisory Committee meeting will be organizational. At the second Advisory Committee meeting, the Committee will consider the minutes and reports from the Community Meetings and make recommendations to the Consultant regarding community priorities, issues, concerns, etc. At the third, fourth and fifth Advisory Committee meetings, the Committee will consider and review findings and recommendations from the Consultants as they work on the declining fisheries assessment and watershed data and literature review. At the sixth and final Advisory Committee meeting, the Committee will make final recommendations on goals, objectives, projects and water management techniques that will inform the IWMP Phase 2 Implementation.

Stakeholders

Stakeholders are the groups and individuals affected by the plan and who have a stake or interest in it.

Participation Goals

- Understand interests and perspectives
- Collect best available data and information
- Increase awareness of river health, different interests, and impacts of types of management actions
- Begin to build consensus on opportunities for implementation
- Identify potential funding sources and partners for implementation

STAKEHOLDER GROUPS

1. Agriculture
2. Recreation and Tourism
3. Local, State and Federal Government
4. Water Managers and Providers
5. Environmental Groups
6. Industry and Land Development
7. Individuals/Property Owners

Approach

The project team and Advisory Committee will engage stakeholders through the following outreach methods. The type of outreach depends on the extent to which the stakeholder is affected and their role in implementation.

- **Presentations at Existing Events:** Make a presentation about the IWMP and get feedback on interests, concerns, potential strategies, and other opportunities during a regularly scheduled meeting of a group, such as a board or chapter meeting.
- **Focus Groups**: Invite members of specific interest groups to a meeting that will serve as an opportunity to brief groups about the project purpose and objectives, share interests and concerns, and collect input to inform tasks and final solutions. Some focus groups may have a greater focus on technical expertise of data and standards, while others will provide important social and political context when assessing the feasibility of different management options.
- **Interviews:** Meet one-on-one or in-person with individuals to discuss objectives of project and their interests and involvement.
- **Information Updates:** Send email updates on project milestones and opportunities for involvement to a contact list made up of identified stakeholders and interested parties who sign up on webpage or through other means.

Table 1: Stakeholder Engagement Strategy

Stakeholder outreach was conducted with the goal to recruit representatives from each of the major groups to commit to sering on the Advisory committee. Table 1 identifies the stakeholders list and responses with an X and notations. Rows with no X's and notations indicate a non-response.

Stakeholder	Additional Interests	Advisory Committee	Presentation/ Focus Group		Interview	Keep Informed
Agriculture						
Friends of the Lower Blue		X	X	Board Meeting – 4/22/19		
CSU Extension						
Blue Valley Ranch						
Reeder Creek Ranch						
Recreation and Tourism						
Trout Unlimited		X				
Vail Resorts						
Copper Mountain					X	X
Arapahoe Basin						
Gore Range Anglers		X				
Cutthroat Anglers						
The Colorado Angler						
Mountain Angler						
Trouts Fly Fish						
Breckenridge Outfitters					X	X
Dillon Marina						
Frisco Marina						
Frisco Rowing Club						
Chamber of Commerce			X	Can present at a meeting after becoming a member		
Local, State and Federal Government						
U.S. Bureau of Reclamation						
U.S. Forest Service		X				

Stakeholder	Additional Interests	Advisory Committee	Presentation/ Focus Group		Interview	Keep Informed
U.S. Fish and Wildlife Service						
U.S. Bureau of Land Management						
U.S. Environmental Protection Agency						X
Colorado Parks and Wildlife						
Colorado Department of Transportation						
CO Dept. Public Health & Environment						X
Summit County						
Lake County						X
Grand County					X	X
Town of Frisco						
Town of Dillon						
Town of Silverthorne						
Town of Breckenridge						
Town of Blue River			X	Tarn Talks – 6/6/19		
Northwest CO Council of Governments		X				
Summit Fire and EMS Authority					X	X
Water Managers and Providers						
Colorado River District						X
Summit Water Quality Committee		X			X	
Colorado Water Conservation Board						X
Colorado Division of Water Resources – Division 5						
Denver Water		X			X	
Heeney Water District					X	
East Dillon Water District					X	
Dillon Valley Water District		X			X	
Snake River Water District		X			X	
Colorado Springs Utilities		X			X	
Environmental Groups						

Stakeholder	Additional Interests	Advisory Committee	Presentation/ Focus Group	Interview	Keep Informed
Blue River Watershed Group		X			
Friends of the Dillon Ranger District					
High Country Conservation Center		X		X	
Snake River Task Force					
Forest Health Task Force					
Blue River Enhancement Workgroup		X			
American Whitewater					X
The Nature Conservancy				X	X
Continental Divide Land Trust				X	X
Friends of the Eagles Nest Wilderness		X			
Sustainable Hiker		X			
Industry and Land Development					
Climax Molybdenum				X	X
Peak Materials		X		X	
Individuals/Property Owners					
Richard Strauss	Angler	X			
Hank Wiethake	Angler/Boater Real Estate Developer				X

Public

The **Public** includes citizens of the Blue River basin and community members at large whom it is important to inform and educate about the IWMP process. Members of the public can also provide input on goals and objectives, values, and the types of actions and projects that will be supported by the community.

Participation Goals

- Build trust in the process and support for implementation
- Provide information and get feedback on the types of management strategies being considered
- Improve education and awareness about the Blue River Watershed
- Increase ongoing community engagement and stewardship of the watershed

Approach

Community Outreach Meetings: The project team will host three community outreach meetings, which will be advertised to the public and also targeted to stakeholders. The meetings will be held throughout the basin to incorporate basin-wide community input. There will be one meeting held in Breckenridge (upper Blue), Silverthorne (middle Blue), and Kremmling (lower Blue).

Traditional and Social Media: Keep all interested parties informed of project progress and how they can participate through a dedicated page on the BRWG website; news media, such as the local newspaper; social media; and updates at meetings of elected officials. There will be at least five press releases:
1) Inform about project and process
2) Announce community meeting in Breckenridge
3) Announce community meeting in Silverthorne
4) Announce community meeting in Kremmling
5) Announce findings and recommendations of Advisory Committee

Public Comment and Presentation to Elected Officials
The project team will make final presentations of the report to the Colorado Basin Roundtable.

Activities and Schedule

Outreach Method	Timeframe
Project Webpage	Went live April 11, 2019
Press Releases	Five press releases:
Email Updates	First one sent out April, 14, 2019 To be sent quarterly
Social Media	Update Periodically
Advisory Committee Meetings	1. August 12, 2019 2. October 15, 2019 3. April 28, 2020 (email update) 4. June 24, 2020 (via Zoom webinar) 5. November 10, 2020 with community meeting 6. April 16, 2021 (email update) 7. June 16,2021 (via Zoom)
Stakeholder Presentations	On-going
Stakeholder Focus Groups	On-going (BREW meeting March 14, 2019, Jan 7, 2020)
Document Reviews **1. Draft Phase 1** **2. Final Phase 1**	1. June 2020 2. August 2021
Community Meetings 1. Breckenridge 2. Silverthorne 3. Kremmling	1. TBD 2. TBD 3. TBD
Presentation to the Colorado Basin Roundtable	TBD

Advisory Committee

During the August 12, 2019 meeting attendees were formally asked to confirm their willingness to participate on the Advisory Committee and all present agreed to participate by a show of hands. The Advisory Committee list is provided below.

#	Stakeholder Category	Organization Name	Primary Contact
1	Project Team	Trout Unlimited	Richard Van Gytenbeek
2		Trout Unlimited	Dan Omasta
3		Blue River Watershed Group	Kendra Fuller
4		Blue River Watershed Group	Jay Pansing
5		Tetra Tech	Peggy Baily
6		Keystone Policy Center	Matt Mulica
7	Agriculture	Friends of the Lower Blue	Jonathan Kanopf
8		Reeder Creek Ranch	Paul Bruchez
9	Recreation / Tourism	Trout Unlimited, Abandoned Mines Projects	Lauren Duncan
10		Trout Unlimited, Abandoned Mines Projects	Tanner Banks
11		Gore Range Anglers (TU Chapter)	Greg Hardy
12	Local, State, Fed Gov't	U.S. Bureau of Reclamation	Victor Lee
13		U.S. Forest Service	Bill Jackson
14		U.S. Forest Service	Melvin Woody
15		Town of Dillon	Mark Helman
16		Town of Silverthorne	Tom Daughtery
17		Northwest CO Council of Governments	Lane Wyatt
18	Water Managers / Providers	Denver Water	Alison Witheridge
19		Snake River Water District	Scott Price
20		Colorado Springs Utilities	Tyler Benton
21		Colorado Springs Utilities	Maria Pastore
22	Environmental Groups	High Country Conservation Center	Rachel Zerowin
23		Sustainable Hiker	Tom Koehler
24	Industry/Land Development	Peak Materials	Joanna Hopkins
25	Individuals	Angler	Richard Strauss

APPENDIX B

Hydrology and Water Use

APPENDIX B
HYDROLOGY AND WATER USE

B 1 INTRODUCTION

The purpose of this appendix is to provide background and context to the Blue River hydrology and water use. Section B2 provides a description of the watershed; B3 discusses hydrology and river flows for the Blue River main stem; B4 summaries water supply and demand including a description of transbasin diversions; B5 provides an overview of agricultural uses; B6 addresses recreational uses and B6 and B7 address climate change and current water management and growth related issues.

B 2 BLUE RIVER WATERSHED

The Blue River is located in the central portion of the Rocky Mountains of Colorado just west of the Continental Divide. It is a tributary to the upper Colorado River. The watershed is 680 square miles in size, 65 miles long, and slopes northward, from elevations reaching 14,270 feet in the south, to 7,400 feet where it flows into the Colorado River south of Kremmling (Figure B-1, (NWCOC 2012).

The upper watershed is bounded on the west Tenmile Range and to the east by the Continental Divide. The peak elevations for both typically exceed 13,000 ft, including Quandary Peak at 14,265 feet. The mountains on the eastern side of the Blue River watershed are a mixture of Permian and Pennsylvanian sedimentary formations, Cretaceous and Jurassic sedimentary formations, and Tertiary and Cretaceous intrusives. The mountains above approximately 11,500 ft are vegetated by alpine tundra; below that elevation the terrain is vegetated by subalpine coniferous forest (Elliott, J. R. et al. 2011).

The Blue River watershed encompasses the towns of Dillon, Silverthorne, Frisco, Keystone, Breckenridge, Blue River, Montezuma, and Heeney; four ski areas (Arapahoe, Keystone, Breckenridge, and Copper Mountain); includes 25,365 acres of agricultural land; and five water impound facilities (Green Mountain, Dillon Reservoir, Goose Pasture Tarn, Upper Blue Lake, Clinton Reservoir, and Old Dillon Reservoir).

B 2.1 Impoundments

There are three major impoundments addressed in the BRIWMP. This includes Green Mountain Reservoir, Dillon Reservoir and Goose Pasture Tarn. Green Mountain Reservoir is located between Silverthorne and Kremmling. This reservoir was constructed as part of the Colorado-Big Thompson Project and is operated by the Bureau of Reclamation. The facility has a storage capacity of 154,645 acre-feet and a surface area of 2,100 acres. The reservoir is operated to provide hydroelectric power and to augment water to downstream water users.

Denver Water owns and operates the Dillon Reservoir. Dillon Reservoir has a capacity of 254,304 acre feet and a surface area of 3,233 acres. Flows are diverted in two locations. The first is at the dam outlet into the Blue River immediately upstream of the town of Silverthorne. The second point of diversion is the Roberts tunnel located on the east side and on the bottom of the reservoir. Flows diverted by the Roberts Tunnel are transported under the continental divide and released to the South Platte River on the eastern slope.

Goose Pasture Tarn is a relatively small reservoir, located in the upper portion of the watershed, fed by the upper Blue River and Indiana Gulch. The Goose Pasture Tarn currently serves as the principal domestic water-storage facility for the town of Breckenridge (NWCCG 2012).

Several other impoundments exist within the watershed including Upper Blue Lake Reservoir, Clinton Reservoir and Old Dillon Reservoir.

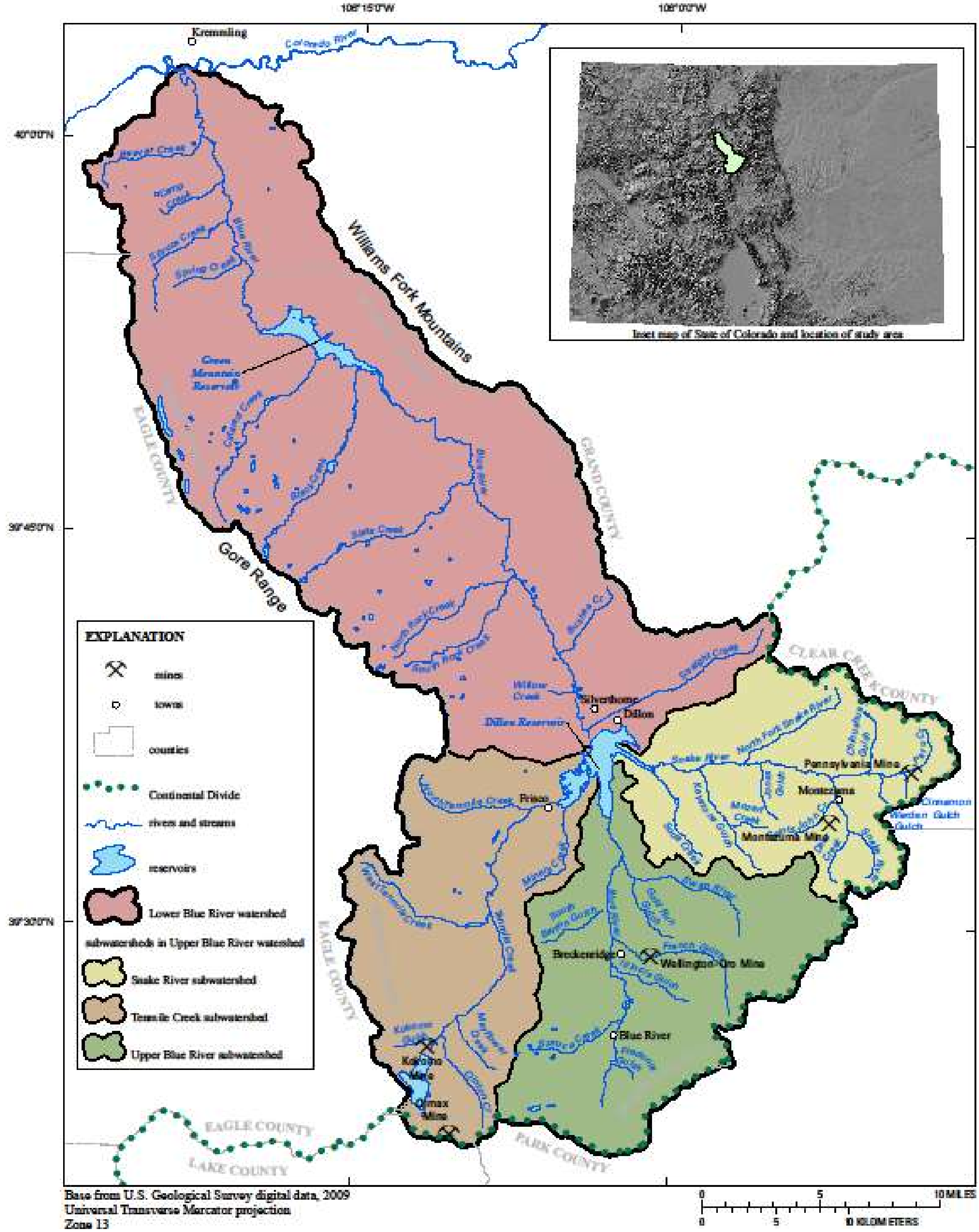


Figure B-1. Blue River watershed map (NWCOC 2012).

B 2.2 Tributaries

There are three major tributaries to the Blue River: the Snake River, a westerly flowing river tributary to Dillon Reservoir with its source originating at Webster Pass on the continental divide; Tenmile Creek, a northeasterly flowing stream tributary to Dillon Reservoir with its source at Fremont Pass on the continental divide; and the Swan River, a westerly flowing river tributary to the Blue River approximately three miles upstream from Dillon Reservoir. In addition to these major tributaries, there are a number of smaller tributaries, most of which had relatively minor hydrologic alterations and are not included in this first phase of assessments.

B 3 HYDROLOGY

B 3.1 Gaged Flows

Based on an assessment conducted by the USGS in 2014 (Bauch 2014), the USGS operated 41 streamflow-gaging stations in the Blue River watershed for different periods between August 1904 and October 2010 (Figure B-2). Real-time streamflow data for active streamflow-gaging stations are also available at https://dwr.state.co.us/Tools/Stations . The USGS report notes the following:

> *Annual streamflow in the Blue River watershed is dominated by spring snowmelt, with increasing flows in April, peak flows in May or June, and decreasing flows in July and August. Thunderstorms in July and August can result in intense but short periods of increased streamflow. Low streamflow generally occurs from October through April and primarily is base flow from groundwater discharge.*

Currently, there are 17 active gage sites in the Blue River watershed reported on the State's website: five on the Blue River, seven on major tributaries, and five gaged diversions. The BRIWMP uses data from four gages located on the main stem of the Blue River (Table B-1). These stations were selected because they have relatively long flow records for use in hydrologic evaluations, have water quality data at or near the gage site , (with the exception of the most upstream gage), and support an overall understanding of the ecological conditions of the Blue River. Stations on the Blue River include *Blue River at Blue River, CO* located upstream of Breckenridge in the headwaters, *Blue River near Dillon, CO* located just upstream of Dillon Reservoir near Highway 9, *Blue River below Dillon, CO* located near its outlet, and *Blue River below Green Mountain Reservoir*, CO located near the outlet of Green Mountain Reservoir.

Daily streamflow exceedance plots are generated directly from data available at the noted USGS website and are presented below and in the **Reach Descriptions** section of the Report for purposes of comparing to instream flows and other water uses. Flood frequency analysis was performed using the Log Pearson Type III method for peak flow.

Table B-1. Gage Data for Blue River Watershed

Site description	Abbrev.	Station ID (USGS)	Data range for anlaysis		Drainage Area, sq mi.	Elevation, ft msl
			Start	End		
Blue River at Blue River, CO	BLUABLCO	09046490	1983	2019	42.3	9835
Blue River near Dillon, CO	BLUNDICO	09046600	1957	2019	123	9020
Blue River below Dillon, CO	BLUDILCO	09050700	1960	2019	334	8760
Blue River below Green Mtn Reservoir, CO	CLUGRECO	09057500	1937	2019	597	7683

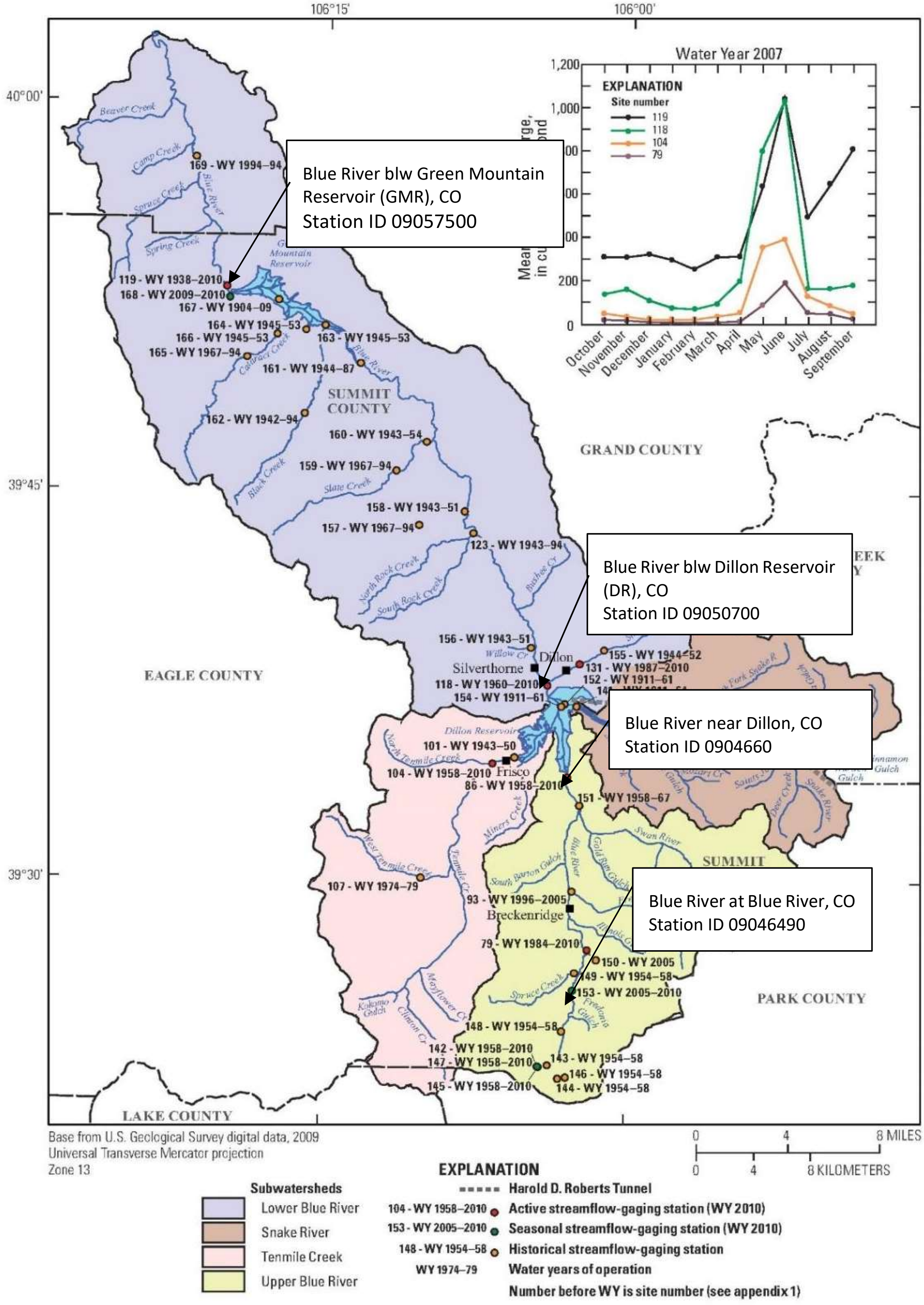


Figure B-2. USGS gaging stations water year 2007, Blue River, Colorado (Bauch, N.J. et al. 2014).

Mean monthly flows are presented for the four Blue River gaged stations for the purpose of comparing flows along the Blue River profile (Figure B-3). As expected, peak springtime flows in the upper watershed tend to occur first, typically in June, whereas the peak below Green Mountain Reservoir occurs typically in July. The plot also shows unusually high flows below Green Mountain Reservoir in late summer and fall, likely due to reservoir operations.

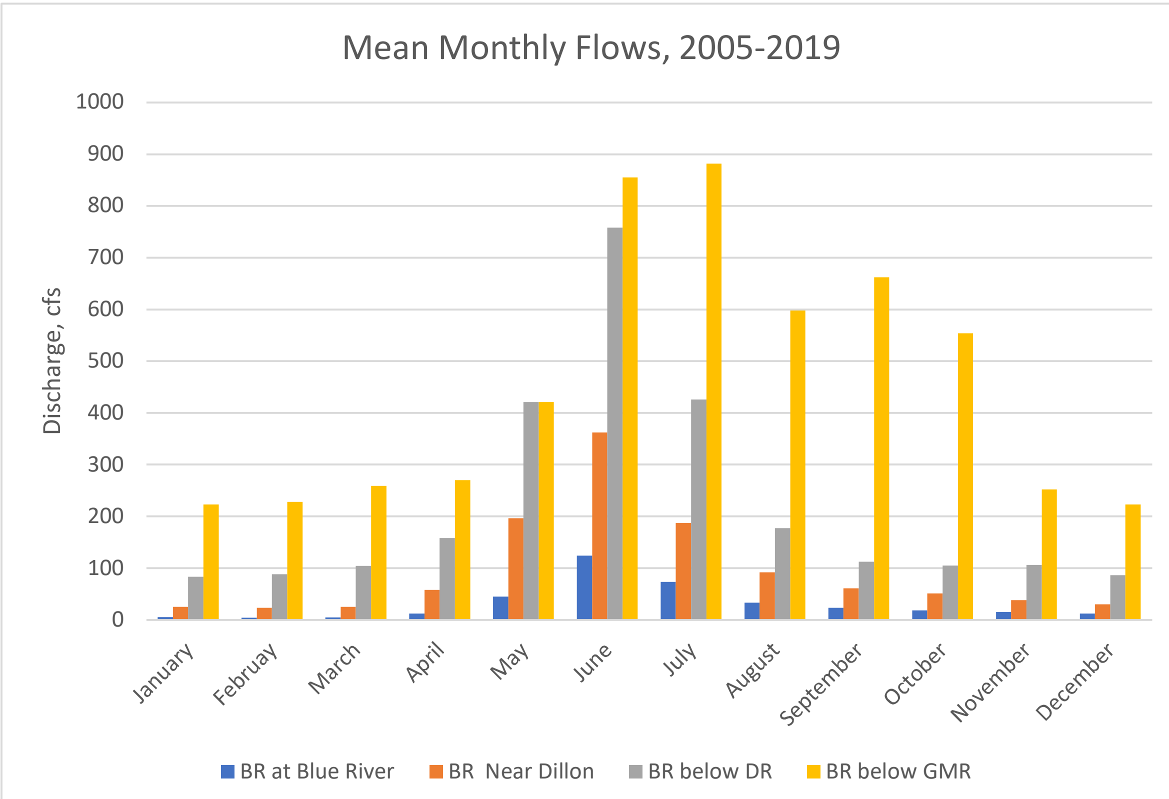
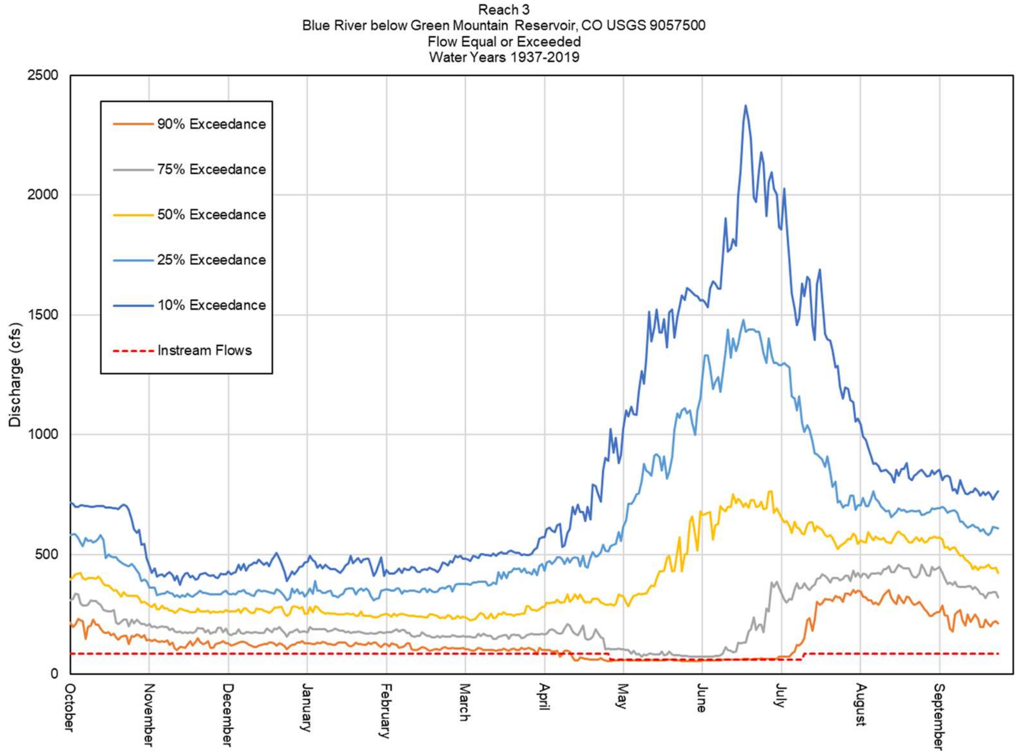


Figure B-3. Mean monthly flows, 2005-2019 at four Blue River gage stations.

Exceedance hydrographs were developed for each day of the available record of mean daily flows for all four gages on the Blue River main stem (Figure B-4). An exceedance hydrograph represents how often the flows will be exceeded for a point in time. For example, the 75% exceedance plot represents the flows that were equaled or exceeded 75% percent of the years for each day. Likewise, the 25% exceedance plot represents the flows that were equaled or exceeded 25% of the years for each day. Looking to the future we can use the exceedance plots to understand how frequently we can expect a certain flow level.

Instream flows are also provided on the plots and further discussed in Section B3.3.



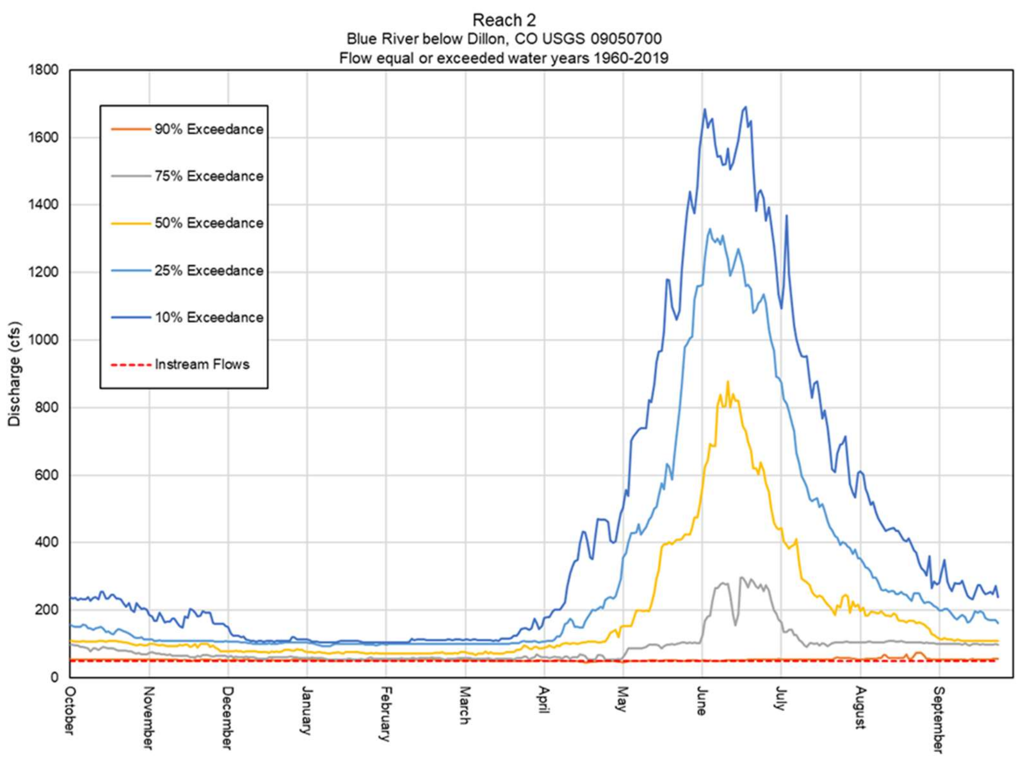
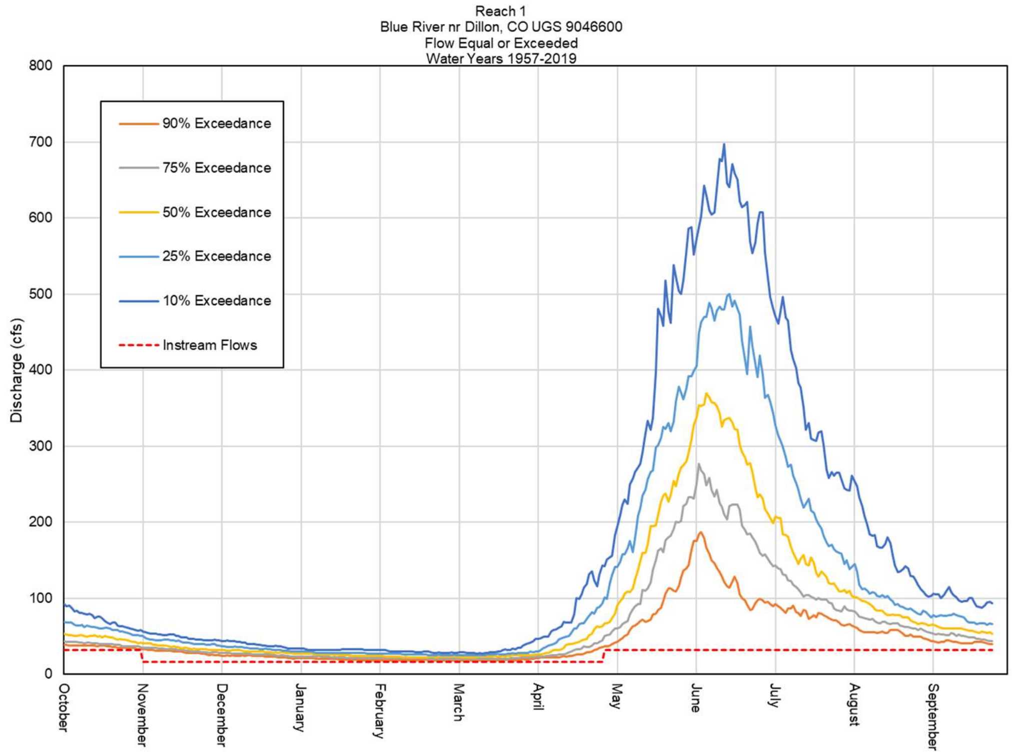


Figure B-4. Exceedance Plots for the Four Blue River Main Stem Gage Sites.



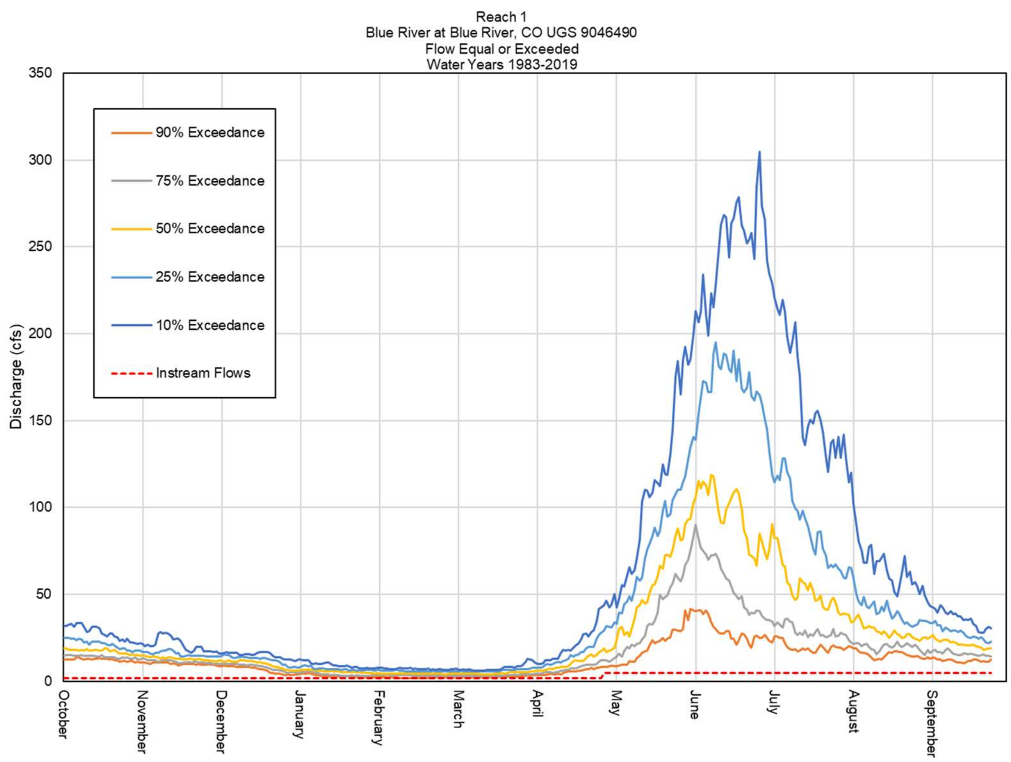


Figure B-4. Exceedance Plots for the Four Blue River Main Stem Gage Sites (cont.).

B 3.2 Flood Flows

The Federal Management Agency recently published its most recent updates to the Summit County Flood Insurance Study (FIS) (FEMA 2018), which includes basin descriptions, hydrologic and hydraulic analysis of peak flows for major storm events, and floodplain mapping of most of the major rivers in the Blue River watershed. A summary of discharges for the 10, 2, 1, and 0.2 Annual Chance Events (ACE) for the Blue River is presented in Table B-2. The ACE represents the probability of a flood event occurring in any given year. For example, the 1% ACE is a flow with a 1% chance of occurring in any given year, which is often referred to as the 100-year flood. Flood profiles and mapping are also available for different reaches in both detailed and approximate levels of study.

Table B-2. Summary of Flood Peak Discharges (FEMA, 2018)

		Peak Discharges cubic feet per second (cfs)			
Flooding Source and Location	**Drainage Area (Square Miles)**	**10 % ACE**	**2 % ACE**	**1 % ACE**	**0.2 % ACE**
Blue River (Reach 2)*					
Just downstream of Dillon Dam	335.0	2,500	3,100	3,350	3,800
Just upstream of Maryland Creek	394.7	2,840	3,550	3,775	4,420
Blue River (Reach 1)*					
Downstream of Broken Lance	43.5	450	850	900	1,200
Just Upstream of Dillon Reservoir	129.0	1,010	1,330	1,540	1,900

* Blue River naming convention from the BRIWMP

B 3.3 Instream Flows

The State of Colorado has to date appropriated instream flow water rights on more than 1,500 stream segments covering more than 8,500 miles of stream and 477 natural lakes. In-stream flow recommendations are based on the minimum flow required to preserve the natural environment to a reasonable degree.

A detailed site-specific water availability analysis that considers both existing water rights and physical flows is used to determine whether water is available for appropriation of the instream flow water right. Water availability typically is assessed using median hydrology. The Colorado Water Conservation Board is authorized by statute to acquire water, water rights, or interests in water for instream flow purposes. In the Blue River watershed, there are instream water rights in 16 reaches of the Blue River (Table B-3).

Table B-3. Blue River Instream Flows

Water Source	Net Absolute water right	Comments
BLUE RIVER	2	CONFLU BEMROSE AND MONTE CRISTO CREEKS TO HWY9 BRIDGE NEAR FREDONIA GULCH, MAY1 THRU SEP30, CONFLU BEMROSE AND MONTE CRISTO CREEKS TO HWY9 BRIDGE NEAR
BLUE RIVER	0	WATER FROM PEABODY CHANGE, THESE AMOUNTS ADMINISTERED FROM SLATE CK TO GMR
BLUE RIVER	125	CONFLU SLATE CR TO GREEN MTN RES INLET, MAY 1 THROUGH SEP 30, CONFLU SLATE CR TO GREEN MTN RES INLET, 90CFS OCT 1 - NOV 30, CONFLU SLATE CR TO GREEN MTN RES
BLUE RIVER	60	FROM GREEN MTN RES OUTLET TO CONFLU W/ COLORADO RIVER, MAY 1 THROUGH JUL 15, FROM GREEN MTN RES OUTLET TO CONFLU COLORADO RIVER - 85CFS JUL 16 - APR 30
BLUE RIVER	5	UPPER HWY9 BRIDGE TO GOOSE PASTURE TARN, MAY 1 THROUGH SEP 30, UPPER HWY9
BLUE RIVER	20	REACH IS FROM SWAN RIVER CONFLUENCE UPSTREAM 1 MILE TO POND, MAY 1 THROUGH OCT 31, REACH IS FROM SWAN RIVER CONFLUENCE UPSTREAM 1 MILE TO POND, 10CFS NOV
BLUE RIVER	32	CONFLU SWAN RIVER TO DILLON RES, MAY 1 THROUGH OCT 31, CONFLU SWAN RIVER TO
BLUE RIVER	50	DILLON RES OUTLET TO CONFLU STRAIGHT CREEK
BLUE RIVER	55	CONFLU STRAIGHT CR TO WILLOW CR, MAY 1 THROUGH JUL 31, CONFLU STRAIGHT CR TO WILLOW CR, 52CFS AUG 1 THROUGH SEP 30, CONFLU STRAIGHT CR TO WILLOW CR, 50CFS OCT
BLUE RIVER	75	CONFLU WILLOW CR TO ROCK CR, APR 1 THROUGH SEP 30, CONFLU WILLOW CR TO ROCK CR,
BLUE RIVER	115	CONFLU ROCK CR TO BOULDER CR, MAY 1 THROUGH AUG 31, CONFLU ROCK CR TO BOULDER CR, 90CFS SEP 1 THROUGH SEP 30, CONFLU ROCK CR TO BOULDER CR, 78CFS OCT 1 THROUGH
BLUE RIVER	0	WATER FROM PEABODY CHANGE, THESE AMOUNTS ADMINISTERED FROM BOULDER CK TO CONFLUENCE W/LUND GULCH, WATER FROM PEABODY CHANGE, THESE AMOUNTS
BLUE RIVER	0	WATER FROM PEABODY CHANGE, THESE AMOUNTS ADMINISTERED FROM BOULDER CK TO
BLUE RIVER	125	CONFLU BOULDER CR TO SLATE CR, MAY 1 THROUGH AUG 31, CONFLU BOULDER CR TO SLATE CR, 90CFS SEP 1 THROUGH OCT 31, CONFLU BOULDER CR TO SLATE CR, 70CFS OV 1 THROUGH
BLUE RIVER	1	HEADWATERS DOWN TO C/W BLUE RIVER
BLUE RIVER	1.5	HEADWATERS DOWN TO C/W DILLON RESERVOIR

B 4 WATER SUPPLY AND DEMAND

The Water Quality Management Plan (WQMP) prepared by the Northwest Colorado Council of Governments (NWCCOG 2012) provides an overview of water supply related issues and characteristics. The WQMP reports that the average annual undepleted (native) flows from the Blue River are approximately 310,000 acre-feet, generated primarily as snowmelt. Review of the Colorado Water Plan and Flow Evaluation Tool (CWP 2019) indicate similar estimates with slightly less than 310,000 acre-feet per year of annual yield under "baseline" conditions. The **Colorado Basin Implementation Plan** concludes that the Blue River watershed will likely be facing a gap of 22,000-48,000 acre-feet per year (ac-ft/yr) between water supplies and demands by 2050 (BIP 2015 as cited in HCCC 2019). Demands on this resource are significant including five transbasin diversions, local municipalities' uses, agricultural uses, and environmental and recreational flows. (Figure B-5).

The population of the Blue River watershed within Summit County has grown from a population of 2,665 in 1970 to a population of 30,367 in 2016. Population is expected to rise to more than 51,000 by 2050 (CO DOLA 2018a as reported in HCCC 2019). As the resident population has grown, so too has population on the Front Range, likely increasing tourism and associated recreational uses that require or impact water use.

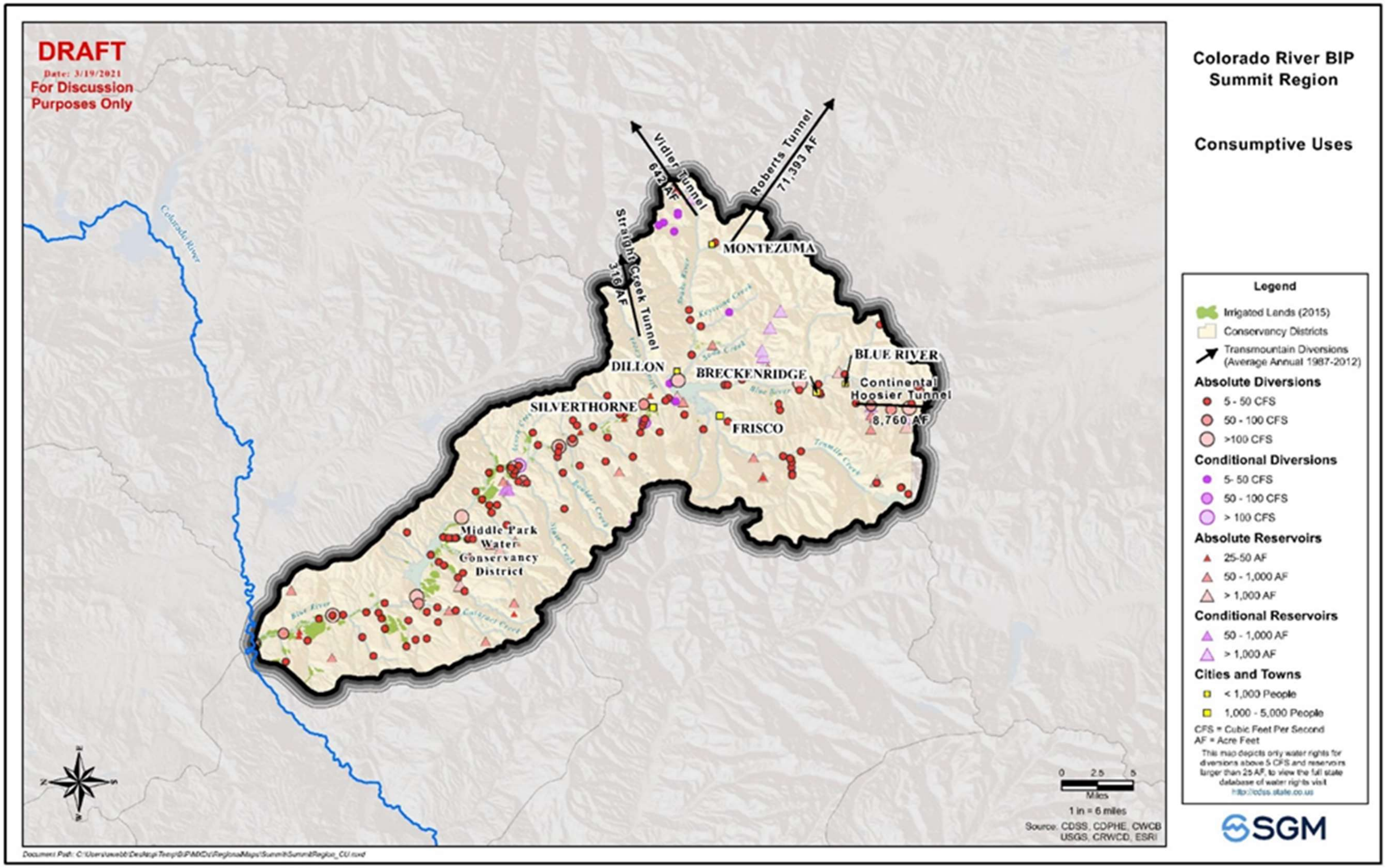


Figure B-5. Water uses in Summit County (BIP 2020).

B 4.1 Summit County Municipal Water Use

Municipal water use for existing water demands, 2000, and future water demands, full build out, in the Blue River watershed in Summit County are reported in the *Upper Colorado River Basin Study, Phase II, Final Report, May 29,* (HRC 2003), herein referred to as the 'UPCO Report' and listed in Table B-4. The UPCO report indicates the annual demand for municipal water use in 2000 was 8,027 ac-ft and under full buildout scenario the future demand will be 17,871 ac-ft. This includes approximately 20% water demand for snowmaking, golf courses, and municipal uses.

Five water use conditions were modeled, all identifying water supply shortages as noted in Table B.5. However, the Colorado Water Plan (CWP 2019) indicates that while municipal demand is projected to increase due to increased population, '*the systemwide demand projections show that pairing of water efficiency drivers can offset population growth and even out the results*." The drivers include efficiencies in growth and development of techniques that may offset climate change impacts. Other local efforts to improve water efficiencies throughout the watershed include measures to reduce outside irrigation primarily in public spaces and use of non-potable water on several golf courses.

The Blue River Watershed Group (BRWG) and Trout Unlimited (TU) queried the local municipalities to update this table, provide input on projected future growth in their respective service areas, and to solicit input on concerns and needs for both current and future conditions. To help this process, a short survey was distributed with several questions along with Table B-5. The following questions were posed:

1. Please provide updates to the values listed (Table B.5) for existing use (2021) and future buildout (2050). These can be approximate.
2. What are your greatest concerns regarding water supply and delivery to your service area?
3. What new and innovative measures are you taking to reduce demands?
4. Do you have water quality issues?
5. Do you anticipate your service area growing? Will this be a 'vertical' growth, or do you anticipate lateral expansion of your service areas?
6. What additional concerns or issues do you have that we should include and document in the BRIWMP?

Table B-4. Study Area Water Demands and Projected Shortages (HRC 2003)

Water Provider	Average Annual Water Demand (AF)		Average Annual Shortages Under Modeled Scenarios (AF)				
	Existing (yr. 2000)	Future Buildout	Existing Demand with Existing Supply	Full Use Demand of Existing Supply	Full Use with New N. System Supply	Full Use with New S. System Supply	Maximum Annual Shortage (AF)
SUMMIT COUNTY							
Arapahoe Basin Snowmaking(5)	0	351	0	133	133	133	330
Keystone-Montezuma Domestic	0	30	0	2	2	2	11
Keystone Snake River Snowmaking(6)	485	1,157	27	207	207	207	668(7)
Keystone Gulch	0	78	0	11	11	11	2
Keystone Golf Course(7)	170	170	0	0	0	0	2
Keystone Ranch(8)	268	274	0	0	0	0	6
Snake River WD	555	1,903	1	35	35	35	239
East Dillon WD	290	623	1	11	11	11	106
Town of Breckenridge	2,062	3,355	0	0	0	0	0
Breckenridge Golf Course	176	365	7	12	12	6	88
Breckenridge Ski Resort	546	685	0	4	4	4	24
Copper Mountain W&SD	381	876	46	101	100	96	282
Copper Mountain Inc (outdoor and snowmaking)	500	689	6	13	12	12	99
Town of Frisco(9)	846	1,976	0	0	0	0	0
Dillon Valley Metro District	333	406	0	0	0	0	7
Town of Dillon	327	878	0	0	0	0	0
Buffalo Mountain / Mesa Cortina	296	755	0	0	0	0	0
Town of Silverthorne	465	2,298	0	0	0	0	0
Eagle's Nest	327	1,002	0	0	0	0	3
Summit Totals	**8,027**	**17,871**	**88**	**529**	**527**	**517**	**1,900**

5) Demands include domestic and snowmaking. Future snowmaking demand is 350 af/year.
6) This shortage can be eliminated by operation of the existing Montezuma shaft pumps
7) PASCM develops historical flows ending in 1991 - golf course irrigation began 1999.
8) Demands for domestic, commercial, golf course and greenbelt.
9) Shortage when the junior right using Dillon exchange cannot operate because Dillon has reached its minimum content in dry years.

Table B-5. Survey Responses

Water Provider	Average Annual Demand, acre feet			Greatest Concern
	Water Demand in 2000	Current Water Demand (2021)	Project Annual Water Demand in 2050	
Snake River WD	555	615	750	Groundwater under the direcct influence of surface water
East Dillon WD	290	300	340	Drought and insufficient water in alluvium to meet demand
Town of Breckenridge	2,062	2333	3,700	Extended drought, wildfire, old infrastructure needing upgrades and replacement, employee shortage
Copper Mountain Consolidated Metropolitan District	381	325-350	752	Drought, wildfires, cybersecurity; potential water degradation from Climax Mine; future development effecting discharge permits
Dillon Valley District	333	325-350	750	Drought and hazardous materials through the I-70 corridor
Town of Dillon	327	313	325	Water quality impacts, trans-mountain diversion impacts, drought impacts
Mesa Cortina Water and Sanitation District	296	20.9	23	Drought

When asked what innovative measures are being taken to reduce demands the following responses were provided:

- Adding automated metering systems
- Install more efficient fixtures and toilets
- Implement annual leak inspection of the distribution system
- Adding water storage
- Raising rates on high water consumers, discouraging outdoor watering
- Performing irrigation audits
- Education/outreach
- Water restrictions
- Water metering
- Tiered rate structure
- Collaboration with neighboring communities
- Rebates and incentives for conservation

Most responses indicate the water providers expect some expansion in their service area primarily through increases in density or "vertical expansion". Most responses indicate good water quality although there is continued concern about hard rock mining impacts in the Snake River watershed. Several issues were also noted that included concerns about inadequate water supply to meet both existing and future water needs.

B 4.2 Transbasin diversions

There are five transbasin diversions from the Blue River Watershed, all located above the Dillon Dam. The WQMP reports that in 2000, the ten-year annual average of water exports from the watershed was 75,109 acre-feet (ac-ft) through the five transbasin diversions. In 2012 the 10-year average annual diversion was 95,004 ac-ft as reported in Table 2.1 of the WQMP (NWCCG 2012), and the 2020 BIP data indicates an average of 81,111 based on an average between 1987 and 2020 (Figure B-5). Diversion records from other sources vary depending on the period of time records are reported as summarized in Table B-6. Overall, the transbasin diversions have been and will continue to withdraw a significant portion of the average annual yield naturally generated within the watershed.

Future transbasin diversions from Denver Water through the Roberts Tunnel will result in decreases in flow from Dillon Reservoir by about 22% on average and Green Mountain Reservoir by about 10%. Additional diversions are being contemplated by Colorado Springs Utilities ~~and Aurora~~ in the upper watershed with impacts that are yet not identified (NWCCG 2012).

Local municipal water uses are estimated to be approximately 12,000 ac-ft of water per year or 4% of the average annual yield, while 81,000 to 95,000 ac-ft of the 310,000 ac-ft or 25% to 30% of the average annual yield is moved out of the watershed through transbasin diversions (NWCOG 2012). Transbasin diversions have no return flows within the basin of origin. Thus, transbasin diversions can have a significant impact on stream flows. Most of the transbasin diversions from the Blue River watershed is delivered primarily to the Colorado Front Range (Coley/Forrest 2011).

Table B-6. Transbasin Diverters and 10-year Average of Diversions

Diversion	Principal owner	Average ac-ft	Future Estimates ac-ft
Roberts Tunnel	Denver Water Board (Elder, 2021)		
	Average since 1960	57,415	
	Future estimates		100,000
Hoosier Tunnel	Colorado Springs (Pastore 2020)		
	Average between 2010 and 2019	7,900	
	Future estimates		TBD
Vidler Tunnel	Vidler Water Company		
	10 year average as of 2012 (NWCCG)	615	
	1987-2020 average (BIP 2020)		642
Straight Creek Tunnel	Golden, CDOT		
	10 year average as of 2012 (NWCCG)	263	
	1987-2020 average (BIP 2020)		316
Boreas Pass Ditch	Englewood		
	10 year average as of 2012 (NWCCG)	138	
	1987-2020 average (BIP 2020)		TBD
Total		**66,331**	**108,996***

*Total future transbasin diversions do not include increases proposed by Colorado Springs or changes to diversions at Boreas Pass Ditch.

B 4.3 Consumption and Nonconsumptive Use

Typically, in-basin water use involves the withdraw of water, the consumption of water, and the return of excess flows that are not consumed or lost in transmission. For domestic, commercial, and recreation uses the consumptive rates are generally around 13% to 34% with 87% to 66% of the diverted flows being returned to the river basin. Agriculture consumptive varies depending on operations, generally ranging from 68% to 78% . Conversely, transbasin diversions are 100% lost from the basin of origin with no water returns (Coley/Forrest, Inc. 2011). Typical consumptive uses and return flows are depicted in Figure B-6 (Coley/Forrest, Inc. 2011) which graphically demonstrates the significant impacts of transbasin diversions.

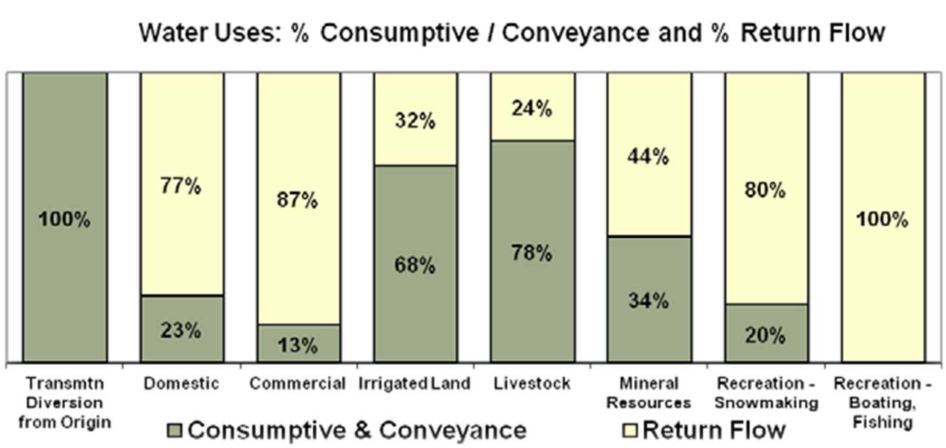


Figure B-6. Typical Consumptive Water Uses (Coley/Forrest, Inc. 2011)

B 5 AGRICULTURE WATER USE

B 5.1 Overview

Most of the agricultural land in Summit County is concentrated in Reach 2 between Dillon and Green Mountain Reservoir. Based on the 2012 Summit County Census of Agriculture (SCCA 2012) there are 38 farms in the County occupying 25,365 acres (Figure B-7), down from 41 farms and 47,818 acres in 2007. Most of the land use in farms is pasturelands. The 2007 market value of agricultural products sold total over $1.1 million dollars. Irrigated lands total to approximately 9,000 acres and are depicted on Figure B-7.

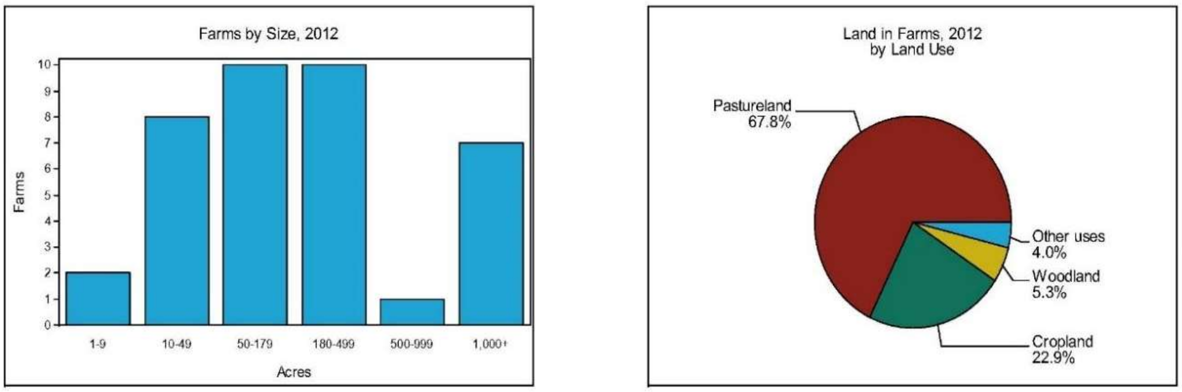


Figure B-7. Farms by size and land use in Summit County, Colorado (SCCA, 2012).

In 2019, the Colorado Cattlemen's Association (CCA(Ag Water NetWORK (CCA 2019) surveyed Colorado agricultural producers to assess their familiarity with the watershed and stream management planning process, and to better understand their needs and priorities related to water. The survey generated 288 responses from agricultural producers in 56 Colorado counties and represented operations of all sizes.

Most producers (63 percent) felt that "preserving and enhancing existing uses (agriculture, etc.)" should be a priority of any watershed management plan. This was followed by irrigation infrastructure improvement and creating a drought contingency plan. Most producers said they were at least "somewhat familiar" with what a watershed management plan is and what it is intended to accomplish. Those familiar with the process indicated a willingness to provide input on watershed management planning activities.

Recommendations from the CCA survey include the following:

- Provide concise, timely information to agricultural producers to help them gain a better understanding of watershed and stream management planning and implementation processes and outcomes. Identify specific purposes and clear, tangible benefits for producers.
- Improve communications so producers can easily stay informed. Keep meetings short, with well-defined goals, and specific timelines for achieving objectives, and avoid meeting during local hunting, calving, irrigation, and harvest seasons. Consider web-based and phone conferencing.
- Reach the project implementation phase sooner to help sustain stakeholder enthusiasm and engagement. Identify funding opportunities for agricultural water projects that improve infrastructure, storage, and efficiency.

Despite the importance of agriculture, increased urbanization of agricultural lands could continue to result in a reduction in irrigated lands, particularly in areas relatively close to the ski resorts and Dillon Reservoir. The CWP anticipates that while irrigated acreage could decrease, the irrigation water requirements will likely increase due to a warmer future climate. Emerging technology, including adoption of higher system efficiencies, may mitigate some climate impacts; however, overall, the CWP estimates the future incremental gap for future agriculture needs will range from 0 to 4 percent of baseline demand (CWP 2015).

B 5.2 Outreach

The agricultural community in the Blue River Watershed is an essential component of the basin, protecting open lands, wildlife habitat, cultural values, and pre-compact water rights. As such, the BRWG project team planned an outreach effort geared towards understanding their water use and helping to ensure their ongoing agricultural practices in the Blue River valley. Working with the DWR District 36 Water Commissioner and the Middle Park Conservation District staff a contact list for all agricultural irrigators diverting water in the basin was developed. In December 2019, an email was sent introducing the project team of BRWG and TU and the IWMP goals and objectives to all producers on that list.

Because opportunities for meeting face to face were limited due to COVID restrictions, a questionnaire was developed and sent to the contact list. Several responses were received, and several onsite meetings conducted following receipt of responses. Coordination with the producers was implemented by Colorado Trout Unlimited. Survey and meeting responses indicate the following:

- Flood irrigation is the primary method of irrigation
- Irrigation occurs from May to October with one hay cutting in late July or early August
- Ditches are operated by ditch companies as opposed to individual owners
- Ditches need repairs
- Water supplies are adequate if the ditch does not leak and is in good condition
- Typically, ditches do not dry-up at the Blue River at headgate, although occasionally water can be challenging to divert
- Irrigators generally support improvements to ditches and headgates because the improvements would improve efficiencies and better use of the decreed amount.

These responses are emblematic of the challenges facing agricultural irrigators throughout the Western Slope of Colorado. The Ruby Ranch and the irrigators off the Independent Blue Ditch noted problems with infrastructure and lack of capital to repair or upgrade it. Head gate issues, transmission losses, lack of measuring devices, and an inability to divert full decrees were all cited. In an effort to protect and sustain these agricultural interests in the Blue River, the community and organizations like TU and BRWG must find methods such as grant funding, legislative policy, etc. to ensure that irrigators can continue irrigating these grass/hay crops and maintain viable cattle operations. Those efforts should further enable and encourage willing producers to increase delivery and application efficiencies, divert less water when possible, and participate in programs like CWCB's agricultural water loans for in-stream flows, recently enacted by HB 20-11567. In the face of increasing water shortages, longer growing seasons, drying streams and rivers, and the larger compact challenges facing water use in the entire Colorado River basin,

The agricultural sector outreach component for the BRIWMP Phase 2 effort will continue as time and project budget allow, to maintain existing relationships and build new contacts based on guidance from the District 36 Water Commissioner during the 2021 field season. To ensure that this effort continues in the near future, the project team has included it as a Colorado Basin Roundtable Identified Process and Project (IPP) in the newly updated Basin Implemented Plan projects list. Inclusion on this list indicates the Roundtable has vetted, approved, and prioritized the effort which greatly improves future funding potential.

B 6 RECREATIONAL WATER USE

Because the local economy and community culture are strongly driven by recreation and tourism, it is critical to gain a better understanding of recreational use within the study area. Snow sports are a major driver of tourism in the valley and water use for snowmaking is discussed in the Reach 1 analysis. The major focus of this appendix is recreation centered around and utilizing the rivers and bodies of water in the spring, summer, and fall seasons. Attention was paid to public and commercial use on the primary reservoirs, Dillon and Green Mountain, and mainstem of the Blue River.

In 2006, Colorado Parks and Wildlife reported $29.7 million in direct spending attributed to hunting and fishing in Summit County, supporting an overall impact of $51.8 million and 708 jobs (BBC Research and Consulting 2008). In that same study, CPW quantified the total economic impact from angling in Summit County to be $36,880,000 .

For the purposes of this report, the BRIWMP team interviewed commercial outfitters on a wide range of issues, conducted targeted surveys to different groups of recreational users and compiled the following information on user impacts. The primary goals for the recreation component of this report are to:

1. Classify and quantify recreational use and impacts
2. Identify user issues (access, pressure, quality of experience, etc.)
3. Propose future projects or studies related to recreation in the Blue River Basin

A study conducted in 2018 by Southwick Associates (SA) for Colorado Parks and Wildlife was prepared to estimate the economic contributions of outdoor recreational activity in Colorado during 2017 (SA 2018). The 2018 investigation updates a similar study completed in 2014 by CPW, both of which are part of a broader CPW effort to characterize outdoor recreation both statewide and regionally for the Colorado Statewide Comprehensive Outdoor Recreation Plan (SCORP). Results are based principally on a 2018 SCORP survey data of Colorado residents. The survey included a set of 30 activities that were grouped into 5 larger categories, including water, winter, and hunting based activities, and divided into7 regions. Summit County and the Blue River watershed lie within the Northwest Region. Note that this survey grouped fishing into the category of wildlife (hunting and fishing), while water-based activities are defined as boating and swimming. The popularity of outdoor recreation by both Colorado residents and non-residents leads to significant consumer spending in the Colorado economy. Outdoor recreationists in Colorado spent over $36.8 million on trips and equipment in 2017. Total estimated spending by activity in the State of Colorado indicates that fishing accounts for 4%, boating 7 %, and skiing 25%, all of which are water-dependent. The Northwest Region included the largest amount of outdoor recreation spending within the State at $10.3 million, accounting for more than one-third of all the outdoor recreation spending within Colorado.

B 6.1 Boating on Dillon Reservoir

Dillon Reservoir is owned and operated by Denver Water. The Dillon Reservoir Recreation Area (DRRA) includes the reservoir's surface and adjacent properties. Popular recreation activities within DRRA include motorized and non-motorized boating, open water and ice fishing, cycling, snowkiting, hiking, running, walking, Nordic skiing and other passive recreational activities. Public access to the reservoir is available via two marinas, located in Frisco and Dillon, as well as six campgrounds and day-use areas on the White River National Forest (SCG 2021). Dillon Marina is usable for most motorized watercraft at reservoir elevation 8,971 ft, while Frisco Bay Marina is usable for most watercraft at reservoir elevation 9,000 ft. Through provisions in the Colorado River Cooperative Agreement, Denver Water has agreed to use best efforts to maintain the water level of Dillon Reservoir at or above 9,012 feet in elevation between June 18 and Labor Day. To date, the development of preferred or required boating flows have not been conducted for support of paddling activities including kayaking, rafting, and stand-up paddleboarding on the Blue River. The Blue River is an important recreational resource for many across the state of Colorado. The Colorado River Outfitters Association (CROA) compiled a study summarizing commercial rafting use which indicates the Blue River accounts for a 1 to 2% of state-wide commercial user days, totaling $1.5 million in direct expenditures and an estimated $3.8 million in economic impacts. Note that this does not capture the economic and social importance of recreational boating for individual private use of not only the local Summit County population, but the extensive statewide and Front Range populations that also tap this resource.

B 6.2 Boating on the Blue River

Boating occurs on the Blue River in all three reaches. One kayak park exists in the town of Breckenridge upstream of Valley Brook Street near the Town's recreational center. The course is 1,800 feet in length and includes 15 water features. Use here is typically May through June. A second facility, the Blue River Whitewater Course, is being planned by the town of Silverthorne to be located downstream of the Dillon Dam. A 100 cfs Recreational In-Channel Diversion (RICD) was established in 2007 to increase recreational use.

Recreational flows for Reach 3 can be found in the Grand County Stream Management Plan (GCSMP) (Tetra Tech, 2010) extending from the Summit/County line downstream of Green Mountain Reservoir, to the confluence with the Colorado River. The GCSMP notes that there is little commercial rafting in this reach due to public access issues and the drop structures, although private rafting and canoeing occur often. Angling is also very popular in this reach for both private and guided fishing. The GCSMP suggests that flows for boating in this reach, while subjective, generally fall in the following ranges: Kayaking: 400-1000 cfs and Rafting: 550-1400 cfs. Information on preferred recreational flows is also available from the Watershed Flow Evaluation Tool (WFET) (Sanderson et. al, 2012) and summarized in Table B-7.

Table B-7. Colorado Basin WFET Recreation Flow Recommendations (Sanderson et. al 2012)

Reach	**Season**	**Flow ranges**
R1: Whitewater Park in Breckenridge: kayaking	May 1-June 30	50 to 200 cfs minimum 90 cfs optimum
R2: Dillon to Green Mountain Reservoir: float fishing, kayaking and rafting	May 1-October 15	400 cfs minimum; no maximum 1000 cfs optimum
R3: Green Mountain Reservoir to confluence with Colorado River: float fishing, kayaking and rafting	April 1-October 31	700 to 900 cfs minimum 1300 to 1500 cfs optimum 2300 maximum

B 6.3 Creel and Angler Surveys

Creel surveys are used to determine the species and number of fish captured in a specific stream, lake, or region over a specified time or season. These surveys rely on anglers to provide information about the amount of time they have been fishing, what species they are fishing for, the species, number, and size of the fish they have caught or released, where they are from, and particular fishing preferences. The information collected through angler surveys gives the CPW an unbiased sample of the angling population that is used in addition to the electrofishing and net assessments to select the best management plans to accommodate the widest variety of anglers.

A creel survey of Dillon Reservoir was performed by Colorado State University during May and August 2012 to provide information on the condition of the fishery and to gather baseline information on the economic impact of sport fishing at Dillon Reservoir and its tailwater. Overall, the creel survey documented a lightly used fishery with low angler effort, catch and harvest, and moderate to poor angler satisfaction. The results of this survey provide baseline information that can be used to evaluate potential changes in fishery management at Dillon Reservoir in the future (Johnson 2013).

In 2020, Colorado Trout Unlimited (CTU) (Omasta 2020) developed and implemented a general angler survey to support recreation outreach as part of this BRIWMP. CTU was directly engaged with recreation stakeholders, outfitters, and the public throughout the process and will continue this effort through the duration of the planning process. The following highlights the results of a Spring 2020 "angler survey" conducted by CTU as part of the engagement process, which is intended to highlight key issues and concerns of anglers in the valley. Results are not intended to be prescriptive, but simply to educate decision-makers and BRIWMP planning staff about important recreation-related issues in the basin.

B 6.3.1 Survey Methodology

CTU, in consultation with the BRIWMP planning team and key stakeholders, developed an online public survey through Google Forms. The survey was advertised through the Blue River Watershed Group, social media, and emails to CTU members in the basin. The survey was also posted to the CTU website and advertised to all members in the State. The survey answer collection period took place March 2020 through June 2020.

The survey broke out the three primary reaches of the Blue River and reservoirs.

- Reach 1 - Blue River above Dillon Reservoir
- Reach 2 - Blue River from Dillon Reservoir Dam to Green Mountain Reservoir
- Reach 3 - Blue River from Green Mountain Reservoir Dam to the Colorado River confluence
- Reservoirs - Dillon and Green Mountain

Participants were asked a series of quantitative and open-ended questions about each reach related to pressure/crowding, environmental concerns, and overall satisfaction with each reach. Participants also provided demographic information, experience on those reaches, and more general responses to the primary issues that the BRIWMP should address.

In total, 41 responses were collected and summarized below. Considering there were 776,472 anglers who purchased licenses in 2017 (Omasta 2020) 41 responses is a low percentage of representation of the Blue River basin and does not fully represent angler values. It is therefore recommended that the results and suggestions included in this survey be used as a "starting point" to identify and address issues on the Blue River.

B 6.3.2 Overall Key Findings

Overall, the survey goals were to identify issues and concerns in the three primary reaches and reservoirs by anglers and TU members that can be used in future stakeholder conversations and BRIWMP assessments; and to provide an opportunity for anglers and TU members to engage in the BRIWMP process. Key findings from the survey are provided below.

- The majority of survey participants indicated that they did not fish any of the reaches more than 10 times per year: Reach 1-90.3%, Reach 2-80.5%, Reach 3-85.4%, Reservoirs-97.6%. These numbers may be driven by a range of factors, including limited access, quality of fishing, pressure/crowding, time available to recreate, even distribution of public access, or survey reach. Some participants noted avoiding certain reaches due to crowding, as well as poor quality of fishing, suggesting that anglers may seek other areas to fish on a more consistent basis, for example Colorado River downstream, Arkansas River, high lakes and creeks, etc.

- Overall, there was a low level of responses indicating that participants were "satisfied" or "very satisfied" with the quality of access on the Blue River:R1-34.2%, R2-39%, R3-11.8%) and significantly more satisfied anglers with the quality of access at the reservoirs-73.3%. Combined with increasing angling pressure in the Basin, this issue has the potential to continually degrade user experience.

- The majority of participants indicated that they were generally "neutral", "dissatisfied", or "very dissatisfied" with the overall quality of fishing and angling experience on the Blue River,R1-65%, R2-68.3%, R3-56.3%, Reservoirs-63%.

- Crowding and angler pressure were noted in the open-ended questions as important issues in all three river reaches,R1-16 of 22 responses, R2-22 of 35 responses, R3- 12 of 22 responses.

- Poor fish quality or "low numbers of fish/macroinvertebrates" was also noted for reaches 1 and 2, R1- 4 of 16 responses, R2-11 of 21 responses.

B 6.3.3 Key Recommendations from Survey

- Continue to work with local stakeholders and management agencies to determine the causes of the declining fishery in the Blue River above Green Mountain Reservoir and support projects that address those issues.

- Work with Colorado Parks and Wildlife, Summit County, and other partners to support a creel survey or similar user count to identify specific areas of high use; as well as potential human impacts to wildlife, habitat, and user experience. Support agencies in the development of strategies and funding to improve and protect riparian areas.

- Continue to work with private landowners and key stakeholders to identify opportunities for public easements or expanded access. In areas where private/public conflict arises, identify opportunities for public education with signage, boundary markers, etc.

Work with public land managers and local stakeholders to identify boat ramps on the middle and lower reach that could be improved to enhance public access.

B 7 CLIMATE DATA

In 2019 the High Country Conservation Center (HCCC 2019) published a Climate Change Action Plan which has since been adopted by the Summit County Board of County Commissioners. Information developed in the Action Plan is summarized below:

- Climate change will bring significant changes to the water cycle. In Colorado, this could cause impacts to a number of industries, including agriculture, tourism, and recreation.
- Most projections for water in Colorado show decreasing annual runoff and less water overall.
- Warmer temperatures are already impacting snowmelt and causing earlier peak runoff and lower late-summer flows. This can impact recreation like rafting and fishing, and declining springtime snowpack could impact winter recreation and tourism.

- Colorado River flow decreases 4 percent for every one degree Fahrenheit increase in temperature.
- Warmer air holds more moisture, and as a result, more water evaporates from soil. This means that more water will be required for irrigating crops and landscaping. This will place increased stress on an already limited water supply.
- Increased frequency and severity of extreme weather events like droughts and floods threaten crops and livestock.

B 8 WATER MANAGEMENT PLANNING

Water use in terms of stream flow management focuses on two issues. The first issue is the physical limitations associated with stream flow that may affect the ability of a local water user to retrieve or use water. The second issue is the flow conditions in the stream relative to maintaining aquatic health. Using the Flow Evaluation Tool from the Colorado Water Plan (Dunavant et.al. 2019) (CWP 2019) and associated Technical Update, current and future impacts on water demands (Figure B-8) can be estimated for a range of economic scenarios with climate adjustments for each scenario. Calculation periods vary by river basin but are generally on the order of 35 years.

Output from the Environmental Flow Tool is available for the *Blue River below Green Mountain Reservoir* located in Reach 3 (Table B-9). The Tool analysis is not available for other segments; however, impacts to flow below Green Mountain Reservoir, Reach 3, are likely good indicators for the other two segments for assessing impacts on the average annual volumes of water (ac-ft).

The Tool indicates that annual flows for baseline or current conditions at the Blue River below Green Mountain gage average 309,812 ac-ft per year (ac-ft/yr), consistent with other reporting of 310,000 ac-ft noted throughout this appendix, and baseline, business as usual, and weak economy all have very similar future projects on water availability in the Blue River.

Annual flow in the Blue River is similar to other headwater conditions which are currently below Naturalized flow conditions. Under future conditions scenarios (Cooperative Growth, Adaptive Innovation, and Hot Growth), annual depletions increase from headwaters to the State Line. While not reflected in this table, the Tool notes that decreases in peak flows (from Naturalized to Baseline) are more pronounced at locations below large reservoirs. This dampening of peak flows is projected to worsen under future conditions scenarios.

Under Baseline conditions, mid- and late-summer flows in the Blue River are subject to transmountain diversions and show decreases compared to the Naturalized conditions from April through July. This pattern worsens under future conditions scenarios. Under the scenarios with climate change factors applied, snowmelt and timing of peak flow shifts earlier in the year, reflecting an increase in winter flows and decreases in spring and summer flows. Tables B-9 and B-10 reflect hydrologic conditions at the Blue River below Green Mountain gage.

Decreased peak flows are prevalent across the Blue River reaches which create risk for riparian/wetland plants and fish habitat. This risk increases under future scenarios. Decreases in mid- and late-summer flows create risk for fish from loss of habitat. Downstream from the reservoirs diminished peak flows create increased risk for riparian/wetland vegetation and fish habitat if sediment is not flushed, while consistent mid- and late-summer flows keep risk to fish low to moderate. Instream flows throughout the basin and recreational instream channel diversions (RICDs) are likely to be regularly unmet if June-August flows decrease as projected under future flow scenarios.

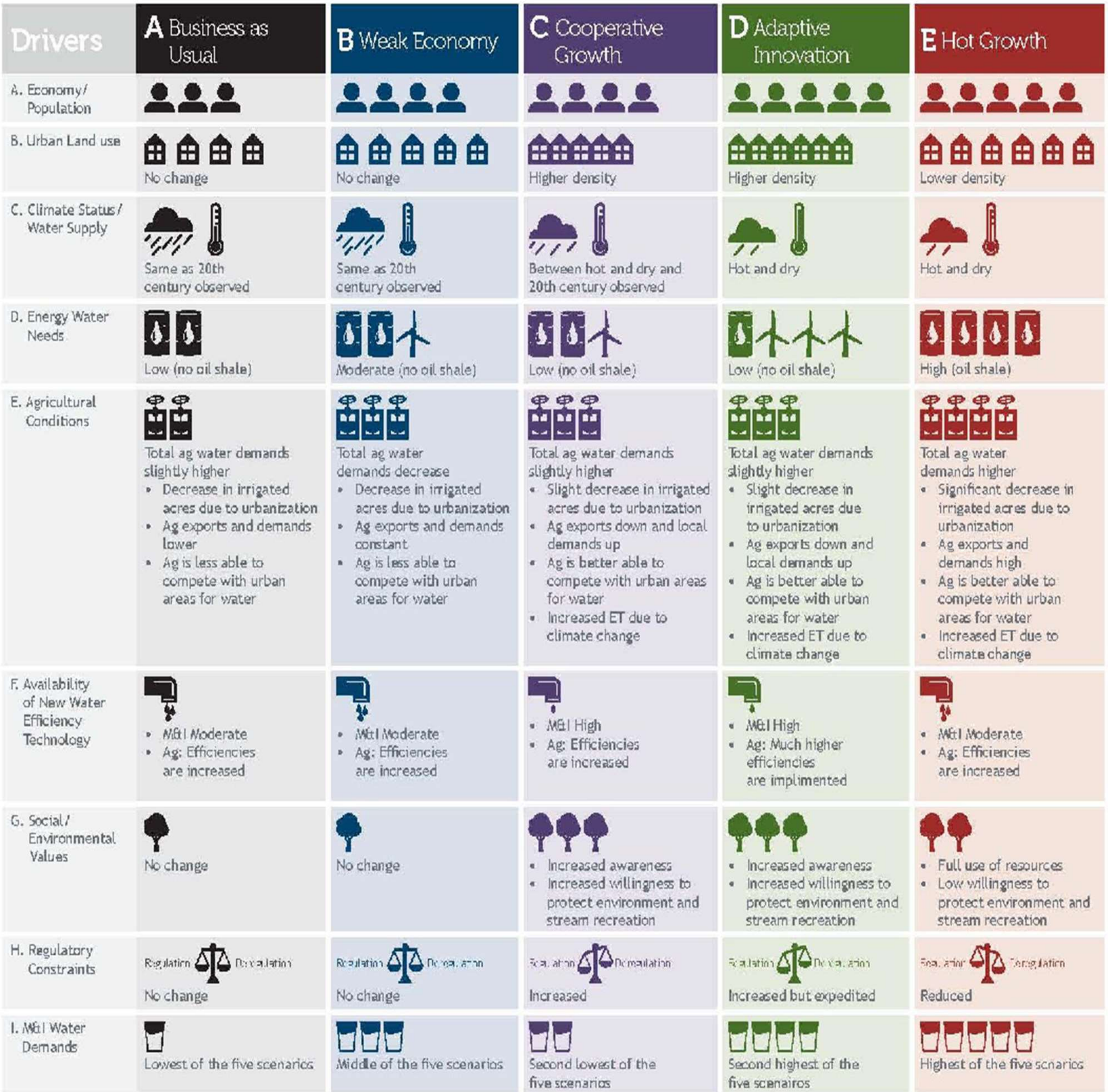


Figure B-8. Flow Evaluation Tool Planning Scenarios (CWP 2019).

Table B-9. Baseline and Future Flow Conditions

Annual Volume of Flow at Blue River below Green Mountain Reservoir, ac-ft/yr					
Hydrologic Classification	Naturalized	Baseline	Cooperative Growth	Adaptive Innovation	Hot Growth
Average	394,018	309,812	273,591	237,847	237,594
Median	375,987	274,287	250,031	223,787	221,697
Minimum	185,153	175,756	174,352	152,179	167,115
Maximum	698,359	676,604	585,774	482,224	472,640

Table B-10. Season Change in Future Flow Conditions

Flow Metric	*Naturalized*	*Baseline*	*Scenario 3: Cooperative Growth*	*Scenario 4: Adaptive Innovation*	*Scenario 5: Hot Growth*
Change in Average January Flow	0%	141%	117%	95%	83%
Change in Average February Flow	0%	153%	130%	109%	95%
Change in Average March Flow	0%	114%	106%	88%	77%
Change in Average April Flow	0%	-72%	-72%	-72%	-72%
Change in Average May Flow	0%	-87%	-70%	-78%	-78%
Change in Average June Flow	0%	-53%	-59%	-67%	-68%
Change in Average July Flow	0%	-23%	-46%	-52%	-51%
Change in Average August Flow	0%	-6%	-35%	-44%	-36%
Change in Average September Flow	0%	56%	39%	26%	37%
Change in Average October Flow	0%	97%	80%	65%	64%
Change in Average November Flow	0%	118%	90%	69%	60%
Change in Average December Flow	0%	133%	108%	86%	76%

Under Baseline existing current flow, issues related to environmental and recreation attributes arise from timing and water delivery issues. Under climate change scenarios, the shift in the timing of peak flow, reductions in total runoff, and increasing demands for consumptive uses contribute to reductions in mid- and late-summer flows. Documentation for the Tool notes that several water management programs implemented in the context of the Upper Colorado Endangered Fish Program (e.g., Coordinated Reservoir Operations Program) have demonstrated that flow timing and magnitude, as well as stream temperature, can be improved through water management that explicitly considers the needs of environmental and recreational attributes.

Table B-11. Environment Flow Tool, Blue River below Green Mountain Reservoir

Flow Metric	*Naturalized*	*Baseline*	*Scenario 3: Cooperative Growth*	*Scenario 4: Adaptive Innovation*	*Scenario 5: Hot Growth*
Cold Water Fish Baseflow Fraction: Aug, Sep					
Change in Peak Flow, for Wetland Plants					
Change in Average Annual Flow					
Change in Average Winter Flow					
Change in Average Late Summer Flow					

Color Key:

- *= low ecological risk*
- *= moderate ecological risk*
- *= less moderate ecological risk (cold water baseflow only)*
- *= high ecological risk*
- *= very high ecological risk*

B 9 REFERENCES

Bauch, N.J., Miller, L.D., and Yacob, Sharon. 2014. (Bauch, N.J. et al, 2014). Analysis of water quality in the Blue River watershed, Colorado, 1984 through 2007: U.S. Geological Survey Scientific Investigations Report 2013–5129, 91 p., *http://dx.doi.org/10.3133/sir20135129*.

Bureau of Reclamation (Reclamation). 2012. Colorado River Basin Water Supply and Demand Study. Technical Report B-Water Supply Assessment.

Coley/Forrest, Inc. 2011. Water and its Relationship to the Economies of the Headwaters Counties. Prepared for Northwest Colorado Council of Governments. December.

Colorado Cattlemen's Association / Partners for Western Conservation Ag Water NetWORK (CCA). 2019. Results of the 2019 Survey of Colorado Agricultural Producers on Watershed and Stream Management Plans.

Colorado Department of Natural Resources. Colorado Water Plan (CWP) Technical Update. 2019. Water Conservation Board. Available at: https://dnrftp.state.co.us/#/CWCB/Technical%20Update%20to%20Water%20Plan/1.%20Technical%20Update%20Documentation/

Colorado Department of Water Resources (CDWR). HydroData Base. Available on-line at: https://www.colorado.gov/pacific/cdss/hydrobase

Colorado River Outfitters Association (CROA). 2019. Commercial River Use in the State of Colorado 1988-2019. On-line at: http://www.croa.org/media.html

Colorado Water Plan, Colorado Basin Roundtable, Basin Implementation Plan (BIP). 2020. At: https://www.coloradobasinroundtable.org/water-planning/colorado-basin-implementation-plan/summit-county/

Dunavant, B., Cox, T., Sanderson,J. and White, M. 2019. Analysis and Technical Update to the Colorado Water Plan, Technical Memorandum for the Colorado Environmental Flow Tool Documentation. Prepared for Colorado Water Conservation Board. August 16.

Elder, Nathan, P. (Denver Water). 2021. Personal communication, email to Peggy Bailey. 2021 May 27.

Elliott, J.G., Flynn, J.L., Bossong, C.R., and Char, S.J., 2011, Estimated probabilities and volumes of postwildfire debris flows, a prewildfire evaluation for the upper Blue River watershed, Summit County, Colorado: U.S. Geological Survey Scientific Investigations Report 2011-5039, 22 p.

Federal Emergency Management Agency (FEMA 2018), *Flood Insurance Study, Summit County Colorado and Incorporated Areas*, Washington DC, November 16, 2018.

High Country Conservation Center (HCCC). 2019. Climate Action Plan. Available on-line at: https://highcountryconservation.org/climate-change-colorado/

Hydroshere Resource Consultants (HRC). 2003. "Upper Colorado River Basin Study, Phase II, Final Report." May 29, 2003.

Johnson, B. M. 2013. Creel Survey Results: Dillon Reservoir, Summer 2012. Fisheries Ecology Laboratory, Department of Fish, Wildlife and Conservation Biology, Colorado State University. June 20.

Northwest Colorado Council of Governments (NWCCOG). 2012. Regional Water Quality Management Plan. At: http://nwccog.org/programs/watershed-services/

Omasta, D. 2020. Blue River Integrated Water Management Plan, Trout Unlimited Angler Survey Report. Prepared by Dan Omasta Colorado Trout Unlimited. December 2020.

Pastore, Maria (Colorado Springs Utilities).2020. Letter to Erika Donaghy (Blue River Watershed Group). 2020 July 17.

Sanderson, J.S., B.P. Bledsoe, N. L. Poff, T. Wilding, and N. Fey (2012). Colorado Basin Roundtable Watershed Flow Evaluation Tool (WFET) Study. Prepared by CDM Smith for North West Council of Governments. March 2012

Southwick Associates (SA). 2018. The 2017 Economic Contribution of Outdoor Recreation in Colorado; A regional and county-level analysis. Prepared for Colorado Parks and Wildlife. July 23.

Summit County Census of Agriculture (SCCA). 2012. Summit County Profile. Available at: https://www.nass.usda.gov/Publications/AgCensus/2012/Online_Resources/County_Profiles/Colorado/cp08117.pdf

Tetra Tech, HabiTech. Walsh Aquatic, Inc. 2010. Draft Report, Stream Management Plan, Phase 3, Grand County Colorado. August 2010.

Summit County Government (SCG) 2021. Available at: https://www.summitcountyco.gov/234/Dillon-Reservoir-Recreation

APPENDIX C

Water Quality and Temperature Report

BLUE RIVER INTEGRATED WATER MANAGEMENT PLAN
June 2021

Appendix C – Water Quality and Temperature Report

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APPENDIX C
WATER QUALITY DATA REVIEW

C 1 EXECUTIVE SUMMARY

The overarching purpose of the Blue River Integrated Water Management Plan (BRIWMP), Project, identified several water quality parameters that serve as important indicators of river health.

This water quality data review evaluated a suite of water quality parameters at six Blue River mainstem locations from a point upstream from the Town of Breckenridge to a location below Green Mountain Reservoir and an additional three tributary sites (Straight Creek, Snake River, and Tenmile Creek) to capture the influence of on the Blue River water quality. The mainstem Blue River sites span a distance of 65 river miles; these sites also had publicly available water quality datasets each containing results that spanned at least one year to provide enough data for analysis of temporal trends.

Table C1. Summary of Water Quality Sites and Parameters Evaluated

	Water Quality Sites Considered	BRIWMP Reach	Exceeding Parameters	Time of Year
Mainstem Sites	Blue River at Blue River	R1.1	pH (upper limit) Temperature	Aug May, July, Oct
	Blue River at Breckenridge Rec Center (below conf. with French Gulch)	R1.3	Cadmium Copper Lead Zinc	Apr, May, Nov, Dec Apr – Sep Apr – Dec Apr – Dec
	Blue River above Swan Mtn Rd.	R1.4	Arsenic (total) Copper Dissolved Oxygen (DO) Iron (total) Lead Selenium Temperature	Mar, Apr, Nov, Dec May – Sep Apr, May (low limit) May, Oct Jan – Mar, May, Jun, Aug – Nov Jun, Jul Jun, Oct
	Blue River at Swan Mtn Rd (above Dillon Reservoir)	R1.4	Cadmium Iron (total) Lead Temperature Zinc	Nov Jun Nov Mar – May, Oct May – Nov
	Blue River below Dillon Reservoir	R2.1	Arsenic (total) Dissolved Oxygen (DO) Silver Temperature	Sep Oct – Nov Sep Oct – Nov
	Blue River below Green Mountain Reservoir	R3.1	Dissolved Oxygen (DO) Temperature	Aug – Sep Aug, Oct, Nov
Tributary Sites	Straight Creek		Arsenic (total) Copper Temperature	Apr-Jul Apr – Aug May
	Snake River below Keystone		Arsenic (total) Cadmium Copper Dissolved Oxygen (DO) Iron (dissolved)	Jan – Mar, Nov Jan – Dec Jan, Jun – Nov Feb, Apr, Oct May

	Water Quality Sites Considered	BRIWMP Reach	Exceeding Parameters	Time of Year
			Lead pH (lower limit) Selenium Zinc	Jan – Mar, May, Aug – Dec Jan – Jun, Aug, Dec Feb – Mar, Jul Jan – Dec
	Tenmile Creek below conf. with N. Tenmile Creek		Cadmium Copper Dissolved Oxygen (DO) Temperature Zinc	Nov Jul Dec May, Oct Nov

C 2 PURPOSE

SGM reviewed publicly available water quality (WQ) data for the Study Area and summarized that information in this document. The data review focused primarily on the sample sites along the mainstem of Blue River and those located at or near the confluence of tributaries which contribute substantial flow to the Blue River and/or which drain from areas with significant anthropogenic disturbances, most notably mining. These tributaries include French Gulch, Swan River, Snake River, Tenmile Creek and Straight Creek (**Figure C1**).

This data reviewed herein was limited to publicly available data from federal and state agencies: namely the United States (US) Geological Survey (USGS), US Environmental Protection Agency (EPA), Colorado Department of Transportation (CDOT), and Colorado River Watch (CORIVWCH). It should be noted that Colorado River Watch is a volunteer-based program overseen by Colorado Parks and Wildlife (CPW), where volunteers from the community sample river conditions and water quality. Duplication errors (i.e., repeating sample results for same parameters on same day and time) in the datasets were ignored.

The sites identified in **Table C1** contained publicly available water quality datasets each containing results that span at least one year to provide enough data for analysis of temporal trends. EPA data spanned only one day but is co-located with a USGS site and thus was used to supplement the USGS data. Not all datasets contain sample results for the same water quality parameters, nor do all datasets contain paired flow measurements with water quality measurements, but enough data was present to compute table-value standards (TVS) when required based on stream segment WQ standards based on the Colorado Department of Public Health and Environment (CDPHE) Water Quality Control Commission's (WQCC) regulatory requirements, specifically Regulations 31 (§5 CCR 1002-31)[1]and 33 (§5 CCR 1002-33)[2].

Table C2 lists the sample site description, identification number and the CDPHE-WQCCs water segment alphanumeric code (identification number) as listed in Regulation No. 33.

[1] Regulation No. 31. The Basic Standards and Classifications for Surface Water. 5 CCR 1002-31 (Regulation No. 31)

[2] Regulation No. 33. Classifications and Numeric Standards for Upper Colorado River Basin and North Platte River (Planning Region 12). 5 CCR 1002-33 (Regulation No. 33)

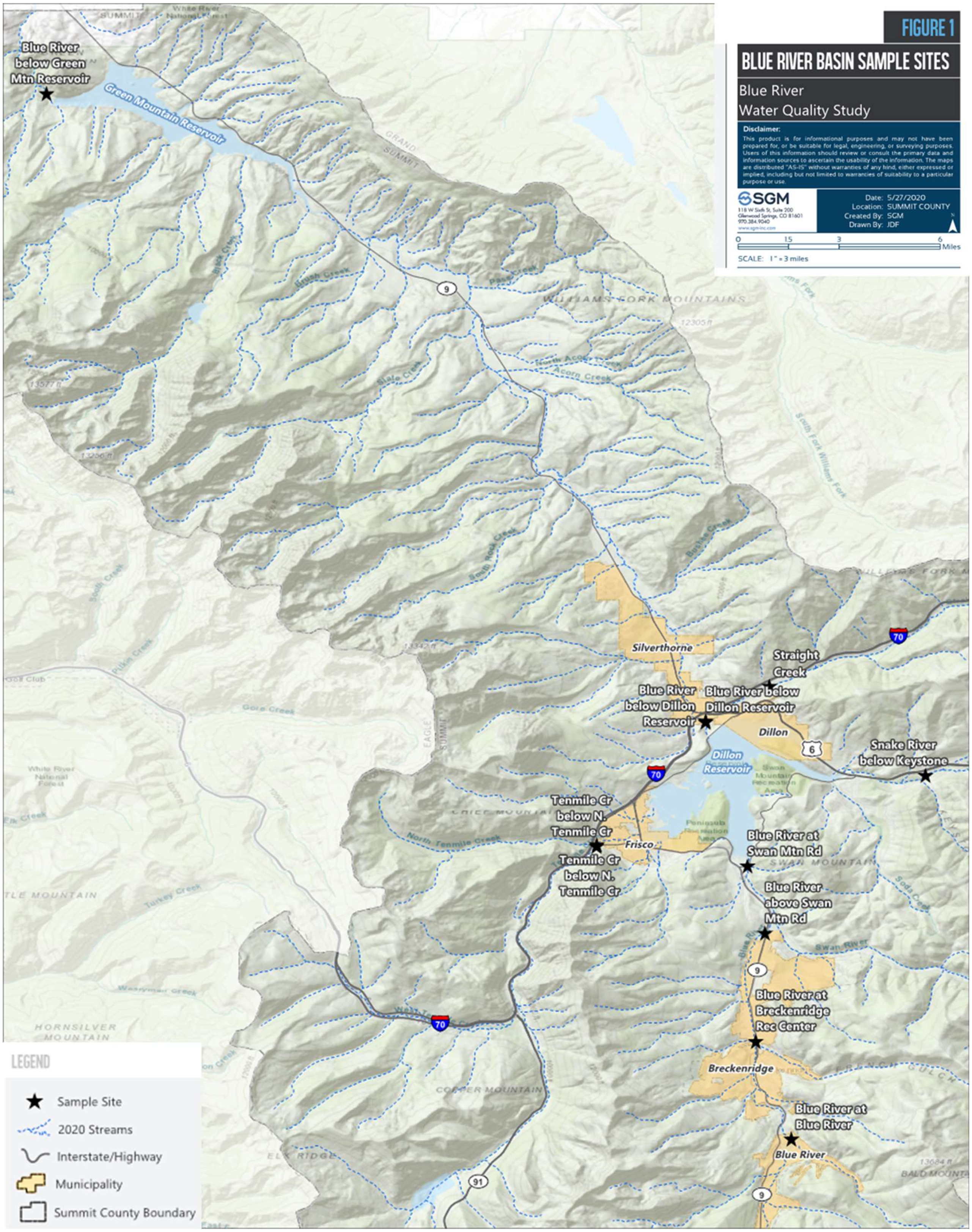

Figure C1 Map of sample sites with available water quality data within the Study Area (Not to Scale)

Table C2 Sample Site Information

Site Description	BRIMWO Reach	Source Agency Site ID	Reg. No. 33 Segment ID
Mainstem Sites			
Blue River at Blue River	R1.1	USGS 09046490	COUCBL01
Blue River at Breckenridge Rec Center (below conf. with French Gulch)	R1.3	CORIVWCH 656	COUCBL02A
Blue River above Swan Mtn Rd.	R1.4	CORIVWCH 657	COUCBL02B
Blue River at Swan Mtn Rd. (above Dillon Reservoir)	R1.4	USGS 09046600	COUCBL02C
Blue River below Dillon Reservoir	R2.1	EPA 12304D USGS 09050700	COUCBL17
Blue River below Green Mountain Reservoir	R3.1	USGS 09057500	COUCBL17
Tributary Sites			
Straight Creek		CDOT SC-2	COUCBL04A
Snake River below Keystone		CORIVWCH 51	COUCBL06A
Tenmile Creek below conf. with N. Tenmile Creek		CORIVWCH 197 USGS 09050100	COUCBL14

C 3 Water Quality Regulations

C 3.1 Regulation No. 33

Regulation No. 33 establishes the classifications and numeric standards for the Colorado River, the Yampa River, and the North Platte River, including all tributaries and standing bodies of water as indicated in Section 33.6. The classifications identify the actual beneficial uses of the water. The numeric standards are assigned to determine the allowable concentrations of various parameters. Discharge permits are issued by the Water Quality Control Division (WQCD) to comply with basic, narrative, and numeric standards and control regulations so that all discharges to waters of the state protect the classified uses (CDPHE-WQCC, Regulation No. 33, 2020). Regulation No. 33 also assigns a unique water segment ID for each stream segment which specifies the geographic and hydrologic areas to which the water quality standard(s) apply(ies). The Blue River is in the Colorado River Basin (CO), in the Upper Colorado reach (UC), and given the stream identifier BL with an alphanumeric code specifying a segment of the river, counting upwards from the headwaters of the stream. For example, the USGS gage site number 09046490 (Blue River at Blue River) has the segment ID COUCBL01 (see **Table C2**). Tributaries to the stream are also given segment IDs.

C 3.2 Regulation No. 93

Regulation No. 93[3] includes Colorado's Lists of Impaired Waters. These waters include water-quality-limited segments requiring Total Maximum Daily Loads (TMDLs), impaired water bodies with approved

[3] Regulation No. 93. Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List. 5 CCR 1002-93 (Regulation No. 93)

TMDLs and 4b plans, and Colorado's Monitoring and Evaluation (M&E) List. A brief description of these waters is provided.

- The list of water-quality-limited segments requiring TMDLs fulfills requirements of section 303(d) of the federal Clean Water Act which requires that states submit to the EPA a list of those waters for which technology-based effluent limitations and other required controls are not stringent enough to implement water quality standards. These segments are included in Section 93.3 with parameters included in the Clean Water Act Section 303(d) impairment column.
- Colorado's Monitoring and Evaluation List identifies water bodies where there is reason to suspect water quality problems, but there is also uncertainty regarding one or more factors, such as the representative nature of the data. The Monitoring and Evaluation list is a state-only document that is not subject to EPA approval. These segments are included in Section 93.3 with parameters included in the Colorado's Monitoring and Evaluation column.
- The list of water-quality-limited segments not requiring a TMDL identified segments where data is available that indicates that at least one classified use is not being supported, but a TMDL is not needed. These segments and parameters are included in Section 93.4.

Only those segments where a Clean Water Act Section 303(d) impairment has been determined require TMDLs. Segments within the Study Area are included in **Table C3**.

Table C3 Regulation No. 93 Information for the Study Area

Stream Segment ID	Stream Segment Description	Affected Use	Analyte	Category/List	Priority
COUCBL01	Mainstem of the Blue River from the source to the confluence of French Gulch	Aquatic Life Use	Macroinvertebrates (provisional)	5. 303(d)	L
		Water Supply Use	Arsenic (Total)	5. 303(d)	L
COUCBL02a_A	Mainstem of the Blue River from South Barton Gulch to a point one half mile below Summit County Road 3	Aquatic Life Use	Cadmium (Dissolved)	3b. – M&E List	NA
		Water Supply Use	Manganese (Dissolved)	5. 303(d)	L
		Water Supply Use	Cadmium (Dissolved)	5. 303(d)	L
		Aquatic Life Use	Nitrite	5. 303(d)	H
COUCBL02a_B	Blue River from the confluence with French Gulch to the South Barton Gulch	Water Supply Use	Manganese (Dissolved)	5. 303(d)	L
		Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	H
COUCBL02b_A	Mainstem of the Blue River from a point one half mile below Summit County Road 3 to the confluence with the Swan River	Aquatic Life Use	Macroinvertebrates (provisional)	5. 303(d)	L
COUCBL02c_A	Mainstem of the Blue River from above the confluence with the Swan River to Dillon Reservoir	Aquatic Life Use	Macroinvertebrates (provisional)	5. 303(d)	L
		Water Supply Use	Arsenic (Total)	5. 303(d)	L
		Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	H
COUCBL04a_B	Gold Run Gulch below Jessie Mine	Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	H
		Water Supply Use	Arsenic (Total)	5. 303(d)	L
COUCBL04a_C	Meadow Creek and its tributaries not in the wilderness	Aquatic Life Use	Silver (Dissolved)	3b. – M&E List	NA
		Aquatic Life Use	Copper (Dissolved)	5. 303(d)	H
COUCBL04a_D	Mainstem of Soda Creek from the source to Dillon Reservoir	Water Supply Use	Arsenic (Total)	3b. – M&E List	NA
		Aquatic Life Use	Macroinvertebrates (provisional)	5. 303(d)	L
COUCBL06a_B	Mainstem of the Snake River from the source to Dillon Reservoir, including Saint John Creek	Aquatic Life Use	Macroinvertebrates	3b. – M&E List	NA
		Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	H
COUCBL06a_C	All tributaries and wetlands of the Snake River from the source to Dillon Reservoir, except for specific listings in Segments 6b, 7, 8, 9, and Saint John Creek	Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	M
COUCBL07_A	Mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listings in Segment 8	Aquatic Life Use	Iron (Total)	3b. – M&E List	NA
COUCBL12_B	Mainstem of Illinois Gulch from its source to their confluence with the Blue River	Aquatic Life Use	Copper (Dissolved)	3b. – M&E List	NA
		Water Supply Use	Manganese (Dissolved)	3b. – M&E List	NA
		Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	M
		Water Supply Use	Arsenic (Total)	5. 303(d)	L
		Aquatic Life Use	Macroinvertebrates	5. 303(d)	M

Stream Segment ID	Stream Segment Description	Affected Use	Analyte	Category/List	Priority
COUCBL12_C	Mainstem of Fredonia Gulch from its source to their confluence with the Blue River	Aquatic Life Use	Copper (Dissolved)	3b. – M&E List	NA
		Water Supply Use	Manganese (Dissolved)	3b. – M&E List	NA
		Water Supply Use	Arsenic (Total)	3b. – M&E List	NA
		Aquatic Life Use	Zinc (Dissolved)	5. 303(d)	M
COUCBL17_A	Blue River from outlet of Dillon Reservoir to Green Mountain Reservoir	Aquatic Life Use	Macroinvertebrates	3b. – M&E List	NA
		Water Supply Use	Arsenic (Total)	3b. – M&E List	NA
COUCBL17_B	Blue River from Green Mountain Reservoir to confluence with Colorado River	Aquatic Life Use	Macroinvertebrates	3b. – M&E List	NA
		Water Supply Use	Arsenic (Total)	5. 303(d)	L
		Aquatic Life Use	Temperature	5. 303(d)	H
COUCBL18_B	Straight Creek	Aquatic Life Use	Macroinvertebrates (provisional)	5. 303(d)	H
COUCBL20_B	Spruce Creek and tributaries	Water Supply Use	Arsenic (Total)	5. 303(d)	H

Priority: H=High; M=Medium; L=Low

C 4 Water Quality Classifications

Waters are classified according to the uses for which they are presently suitable or intended to become suitable. In addition to the classifications, one or more of the qualifying designations described in Regulation No. 31, Section 31.13(2)[4], may be appended. Classifications may be established for any state surface waters, except that water in ditches and other manmade conveyance structures shall not be classified.

The water segments within the Study Area are all assigned the following classifications, which drive the water quality standards and aim to protect the uses of the streams:

- Agriculture
  - These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.
- Aquatic Life Cold 1 – Cold Water Aquatic Life
  - These are waters that (1) currently can sustain a wide variety of cold-water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of the abundance and diversity of species.
- Recreation E – Existing Primary Contact Use
  - These surface waters are used for primary contact recreation or have been used for such activities since November 28, 1975.
- Water Supply
  - These surface waters are suitable or intended to become suitable for potable water supplies. After receiving standard treatment (defined as coagulation, flocculation, sedimentation, filtration, and disinfection with chlorine or its equivalent) these waters will meet Colorado drinking water regulations and any revision, amendments, or supplements hereto.

C 5 Water Quality Data Review for the Blue River Integrated Water Management Plan

C 5.1 Purpose and Approach

The overarching purpose of the Blue River Integrated Water Management Plan (BRIWMP), Project, identified several water quality parameters that serve as important indicators of river health; hence this data review used the water quality standards set forth in Regulation No. 33 to evaluate the conditions in the Study Area. Publicly available digital data from USGS, Colorado Data Sharing Network (CDSN), EPA, CDOT, CORIVWCH, and the Summit Water Quality Committee (SWQC) were used for this evaluation [1]. Also, data and observations from a 2014 USGS report of water quality in the Blue River Watershed were also reviewed and considered [2]. All water quality data were compiled by month and compared to chronic water standards to gain perspective on general trends as opposed to specific weeks in which a parameter may exceed these standards. **Appendix C** includes the water quality standards unique to the water segment listed in **Table C2**.

When both acute and chronic standards applied to a parameter, the chronic standard was used to evaluate potentially problematic water quality issues, as it is the more restrictive of the two standards. A synopsis of the results for each parameter are presented in the following sections of this document.

[4] Regulation No. 31. The Basic Standards and Methodologies for Surface Water. 5 CCR 1002-31 (Regulation No. 31)

The following sections summarize the water quality standards that are most important for purposes of the BRIWMP project.

C 5.2 Temperature

Temperature data for the Study Area were reviewed against the specific water segment temperature standards. These standards are established to protect the aquatic community from the harmful effects of high, and in some instances, low-water temperatures, based on the thermal requirements of fish species found in the Blue River and its tributaries.

The chronic standard, measured as the Maximum Weekly Average Temperature (MWAT), is the largest mathematical mean of multiple, equally spaced daily temperatures over a seven-day consecutive period with a minimum of three data points spaced equally throughout the day. All temperature data were compiled and compared to the chronic standards in Regulation No. 33 to develop monthly and seasonal historical trends.

Cold water temperatures are also a concern for the Blue River and its tributaries. For purposes of this assessment, cold water temperature ranges are assessed using US Fish and Wildlife Service (USFWS) standards noted below, although narrative standards developed by USFWS indicate these could be too cold for eggs to hatch. See **Appendix E** for further discussion related to temperature and aquatic habitat. Temperature standards applied for this project are summarized in **Table C4**.

Table C 4 Temperature Standards applied to the Project

Temperature Tier	Standards	Species Expected to be Present	Applicable Months	Temperature Standard (°C)	
				MWAT or Temperature Range	DM
Cold Stream Tier I[5]	WQCC	Brook trout, cutthroat trout	June-Sept	17.0	21.7
	WQCC		Oct-May	9.0	13.0
Varies by Stage of Growth	USFWS		Not applicable	7 – 15 up to 1 year	Not applicable
			Not applicable	11 – 19 adults	
			October only	2 -7 spawning	

DM - daily maximum

C 5.2.1 Temperature Trends

An attempt was made to correlate stream temperatures with several other parameters at several of the sites. This exercise is presented only to show examples for possible future data collection efforts, as there

[5] Mountain whitefish-based summer temperature criteria [16.9 (ch), 21.2 (ac)] apply when and where spawning and sensitive early life stages of this species are known to occur.

was limited data available. Factors potentially contributing to stream temperature include, but are not limited to, discharges, source of flows such as reservoir releases versus rainfall, influence of snow melt, and/or air temperature. In addition, spatial and temporal trends were reviewed and discussed to present as an example of how future monitoring efforts could help with management strategies.

C 5.2.1.1 Temperature Trends - Spatial and Temporal

Temperature data were analyzed for temporal and spatial trends. Data from three sites (Town of Blue River, at Swan Mountain Rd, and below Dillon Reservoir) were selected to depict spatial and temporal trends in temperature moving downstream along the Blue River. There is greater variability in temperature upstream at the Town of Blue River than at the outlet of Dillon Reservoir. In the month of May, the water temperature in the Town of Blue River could be as low as $2°C$ and as high as $15°C$ each year, whereas the range of temperatures at the outlet of Dillon Reservoir are narrower, between $3°C\ and$ $8°C$. The monthly temperature distributions for these three sites (**Figure C2**Error! Reference source not found.) are flatter moving from the Town of Blue River toward the outlet of Dillon Reservoir.

There is substantial seasonal variation in the Blue River, with summer months from June to September showing higher temperatures than the long winter season from October to May. Exceedances of temperature standards have occurred at various sites, particularly at the Town of Blue River in May and at all three sites in October. High temperatures could have a negative impact on fisheries. Extremely cold temperatures could also have an impact and the next section highlights the cold temperature limits for growth and health of fisheries.

The US Forest Service (USFS) also conducted a temperature spatial analysis by compiling temperature data at various sites along the Blue River, from above Dillon Reservoir (UBR) to downstream below Dillon Reservoir (B5) and downstream of Dillon Reservoir (B3, D5 and B1) for the period 2007-2017. The data were analyzed and compared spatially to reveal a drop in temperature from above to below Dillon Reservoir and then a general upward trend in temperature moving downstream away from Dillon Reservoir, shown in the box-and-whisker plot in **Figure C3**. This is consistent with the finding presented in Appendix F, where temperature variability in Reach 2 is further assessed using daily temperature data from six new loggers located along the Blue River from the Town of Silverthorne to Green Mountain Reservoir . **See Appendix F**.

For the box-and-whisker plots in **Figure C3**, the median temperatures are depicted by the horizontal red line and the upper and lower quartiles (75^{th} and 25^{th} percentiles, respectively) form the edges of the box. The difference between the upper and lower quartile is the interquartile range (IQR). The whiskers extend out a computed value that is $1.5 \times IQR$. Data points shown as "**+**" are values between $1.5 \times IQR$ and $3.0 \times IQR$, and data points shown as "**o**" are outliers (those values outside of $3.0 \times IQR$).

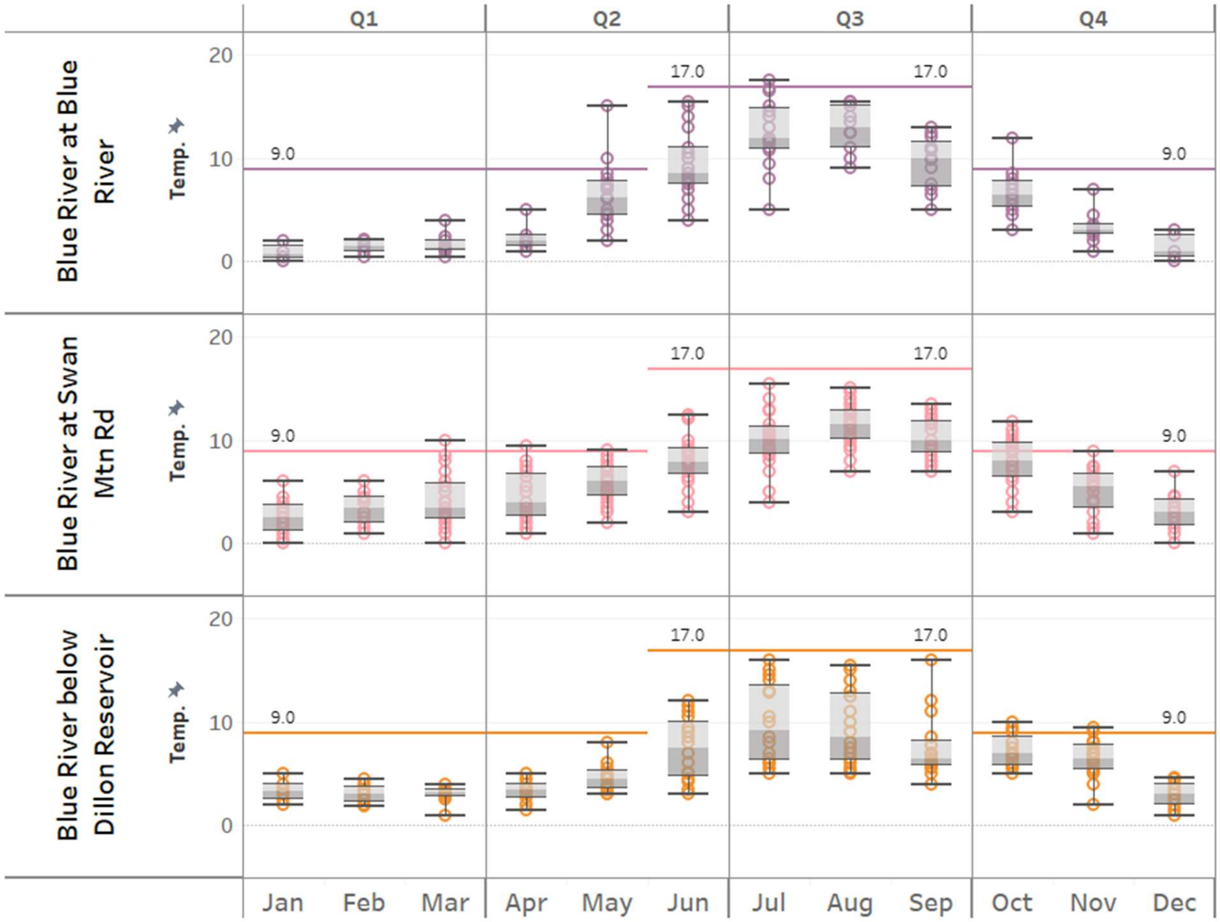

Figure C2 Spatial-temporal trends in Temperature (°C) for three selected sites along Blue River (the MWAT values, Table 2, are shown for the various seasons).

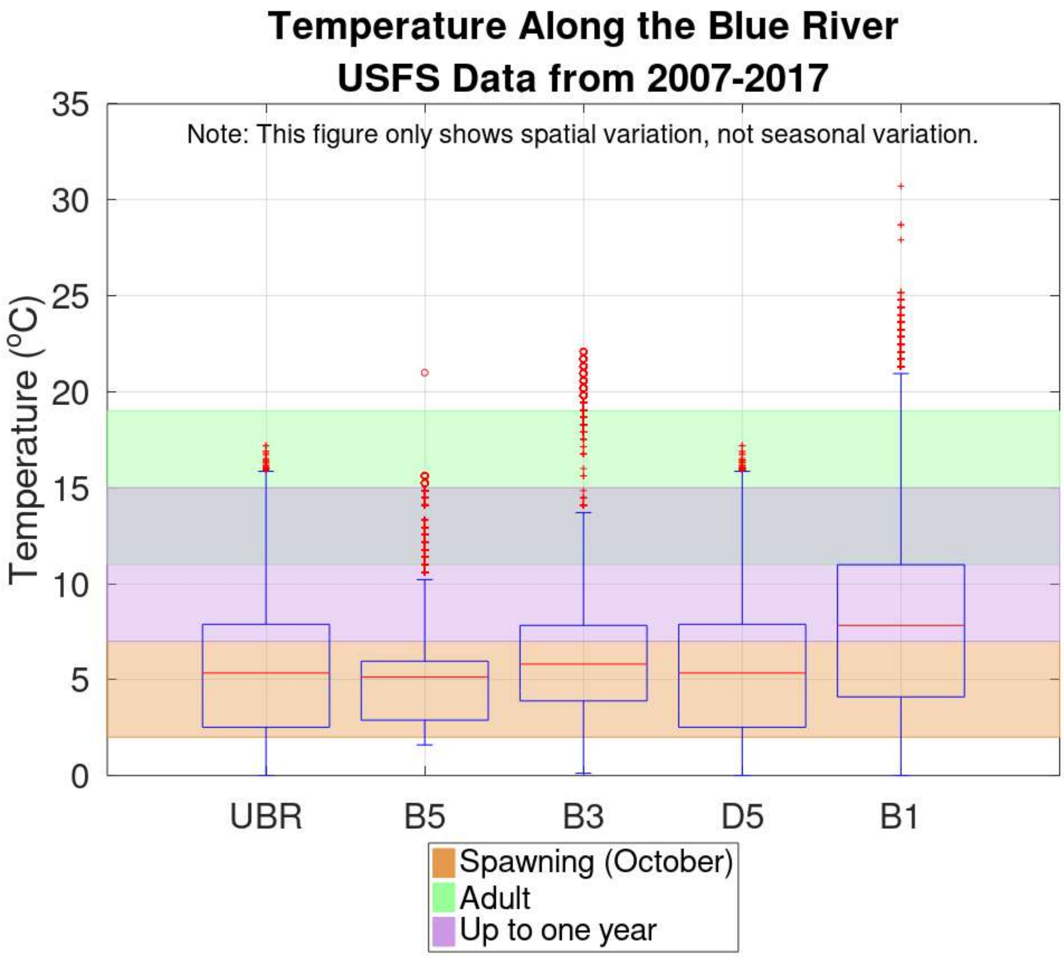

Figure C3 Box and whisker plot of USFS Temperature (°C), data from their 2007-2017 temperature study along the Blue River. Optimal growth temperature ranges are shown, which vary seasonally and depending upon the life-stage of Brown Trout [3]. *For spawning fish, the optimal temperature range is between 2-13 °C during the month of October. For fish up to one year, the optimal growth temperature range is 7-15 °C. For adult fish, the optimal growth temperature range is 11-19 °C. This is the only figure where you use UBR, B5, etc. Need to include these cross-references to the table, perhaps.*

It is important to reiterate that the temperature data in **Figure C3** is plotted based on spatial location along the river and seasonal variation in temperature is not depicted, only a comparison of the spatial variation of all temperature data available.

Figure C4 depicts the spatial variability of temperature along the Blue River from just upstream from Swan Mountain Rd to Green Mountain Reservoir. The trends are like the trend shown in **Figure C3** with slightly upward trending temperatures moving downstream and colder temperatures in the middle reaches of the Blue River. **Figure C5** depicts the temperatures for Tenmile Creek, Snake Creek, and Straight Creek.

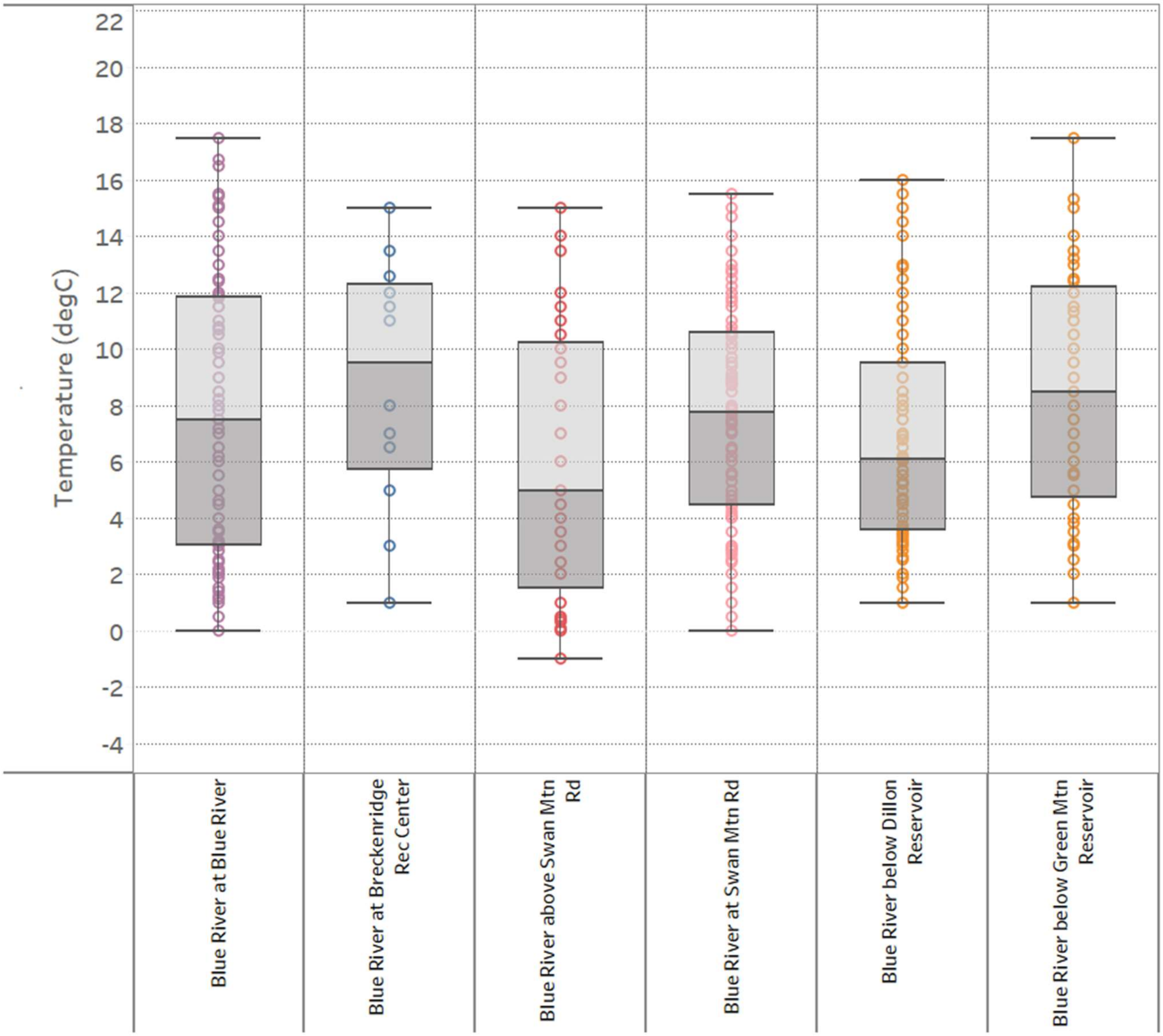

Figure C4 Spatial variation of Temperature (°C) data along Blue River from just upstream of Swan Mountain Road to Green Mountain Reservoir.

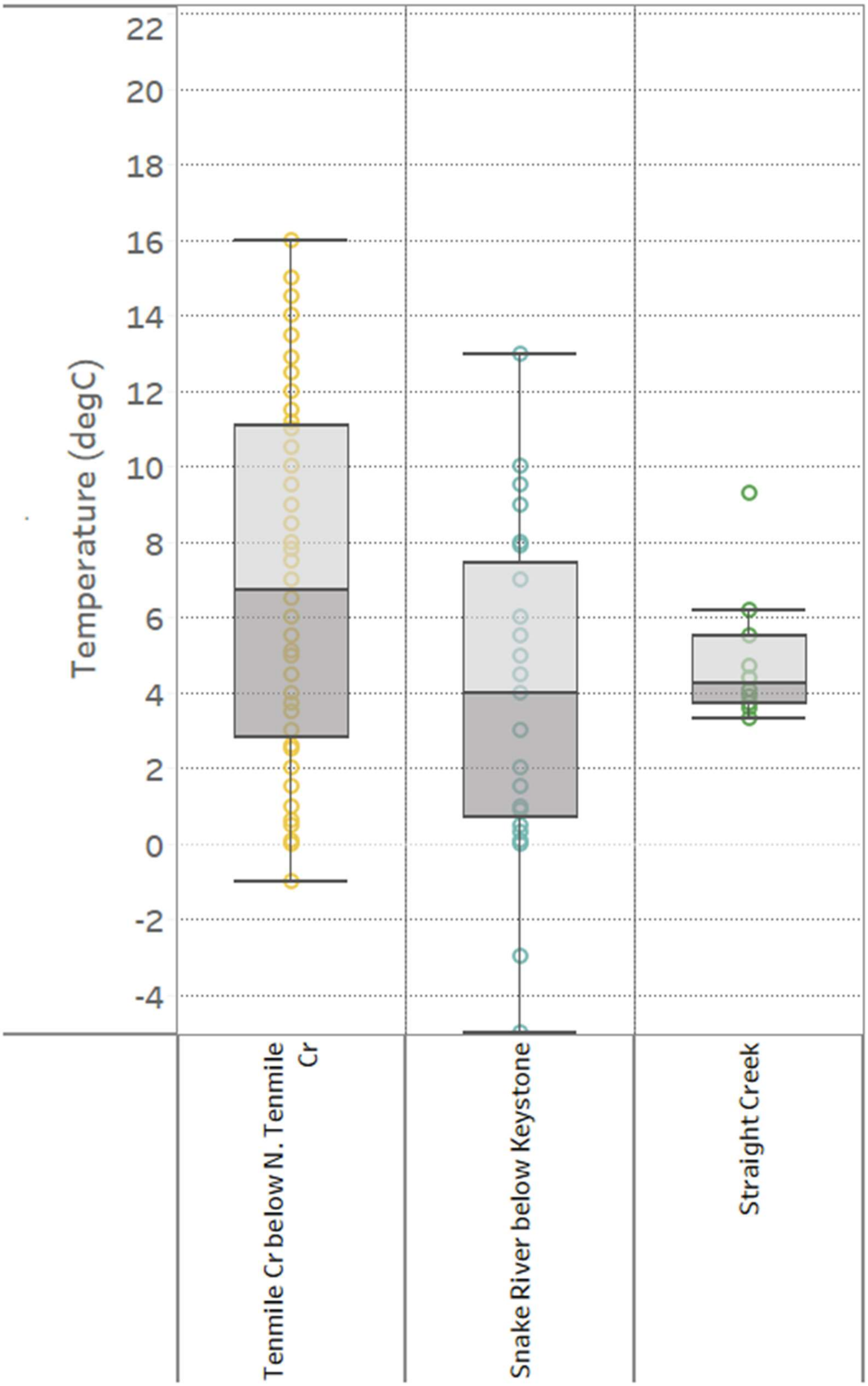

Figure C5 Comparison of Blue River tributary Temperature (°C) data. Size of the image is different.

C 5.3 Dissolved Oxygen

Dissolved oxygen (DO) is present in all surface water and required for many organisms that live in the river. Extremely low or high DO values could be harmful for aquatic organisms. The level of DO in the water depends on temperature, water velocity and turbulence, and the activity of existing organisms in the water, such as algae. An abundance of nutrients could result in algae blooms which could produce a "diurnal" effect in streams and impact DO levels. DO levels decrease at night due to respiration of aquatic vegetation or decaying material, but then increase dramatically during sunlight hours due to photosynthesis. This is a natural process in surface water but could negatively affect the health of a stream and its' fishery when DO levels fall too low.

Expected levels in a healthy river ecosystem may range from 6.0 milligrams per liter (mg/L) to 12.0 mg/L [4]. For Brown trout, the minimum concentration of dissolved oxygen required for survival is approximately 5.0 mg/L [5]. In this analysis, a minimum of 7.0 mg/L is used to review data for indications of DO deficiency, which is the DO minimum standard for spawning fish and is the most restrictive standard.

Along the mainstem of the Blue River, there are sites where DO levels have fallen below the Regulation No. 33 standard for spawning, though DO levels are generally adequate throughout the year. At segments of the Blue River closer to the headwaters, the DO levels have not shown any levels below the standard, but closer to Dillon Reservoir, there are measurements showing DO levels below the standard. **Figure C6** compares DO and temperature levels throughout the year at the Town of Blue River and at the Colorado River Watch site above Swan Mountain Rd, which is closer to the inlet of Dillon Reservoir. Though rare, low DO levels have been measured and could have a negative impact on the fisheries near Dillon Reservoir.

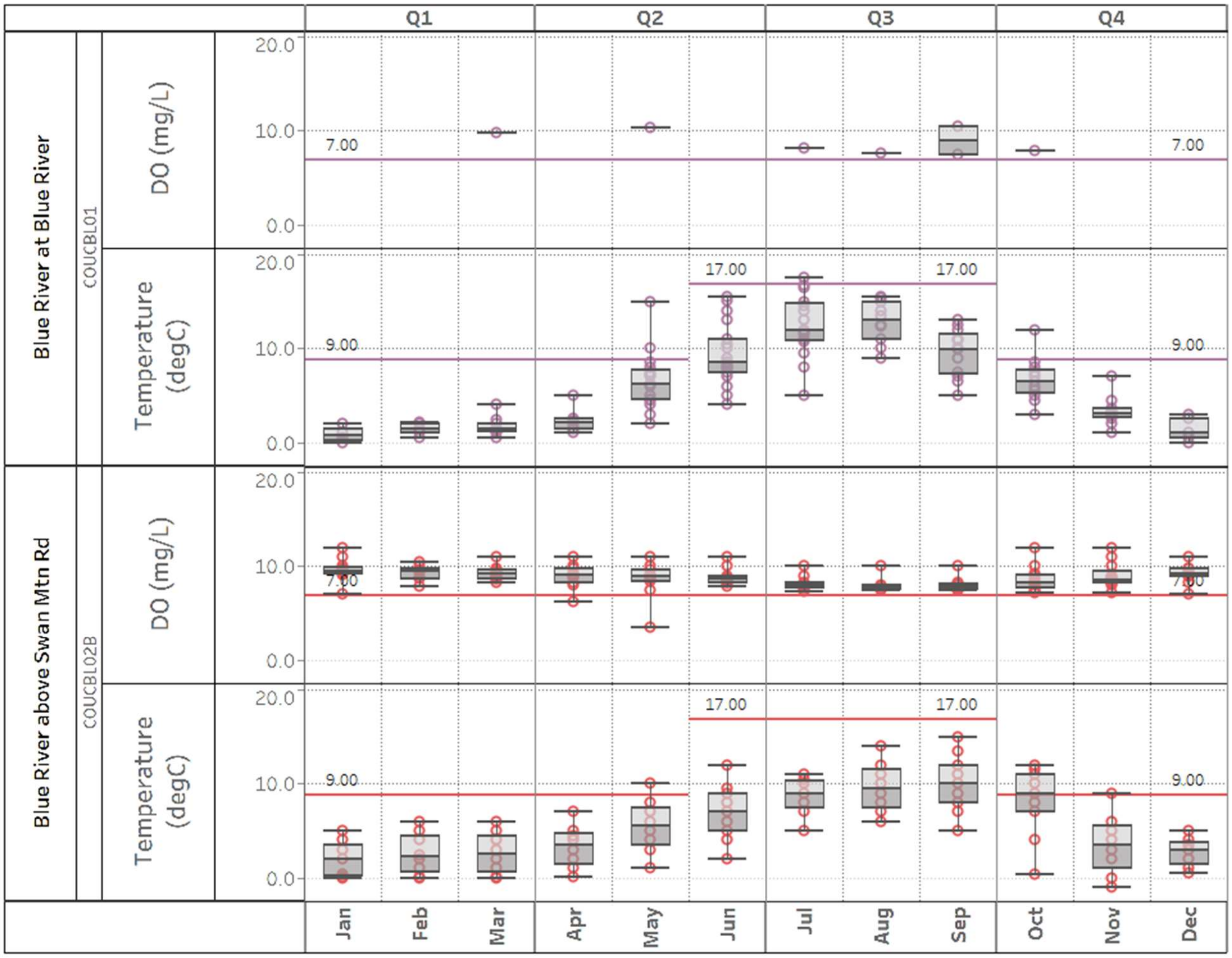

Figure C6 DO (mg/L) and Temperature (°C) values at the Town of Blue River and at Swan Mountain Rd. The colors denote different Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

There is a possible trend of decreasing DO levels with increasing temperatures above and below Dillon Reservoir from July to December, as highlighted by **Figure C7**. Algae decay is more likely to occur in a reservoir in fall and winter months than a relatively faster moving stream, which could account for the decrease in DO levels along the Blue River mainstem. **Figure C8** compares DO and temperature levels at sites below Dillon Reservoir and below Green Mountain Reservoir, where seasonal trends are similar. It is also noteworthy that DO levels below the reservoirs trend with seasonal water temperatures, whereas sites along the river mainstem do not show as strong of a seasonal correlation. More data and analysis would be needed to determine if the impacts to DO in the Blue River are from reservoir dynamics or other influences. Low levels of DO could be negatively impacting the fisheries between Dillon Reservoir and Green Mountain Reservoir.

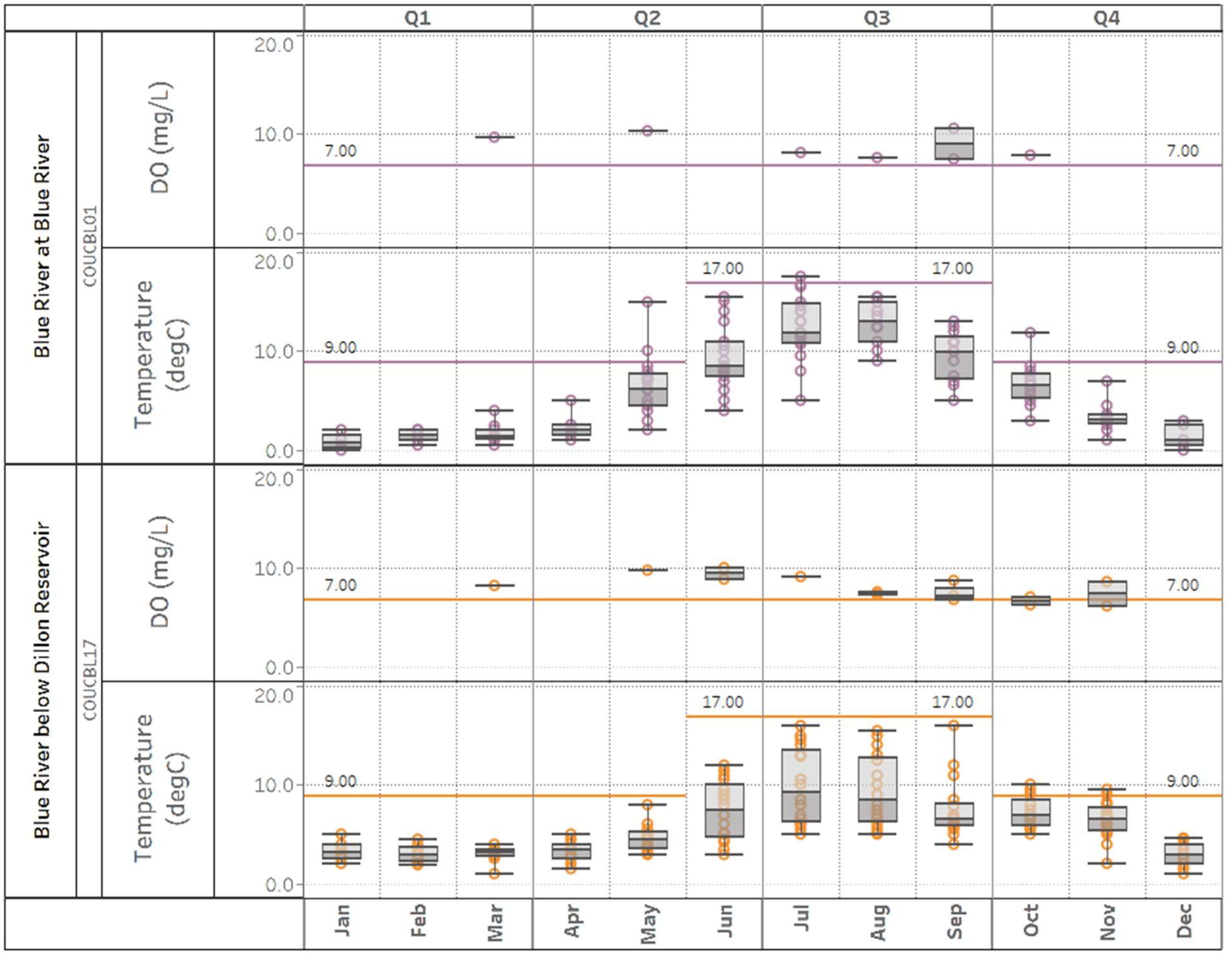

Figure C7 DO (mg/L) and Temperature (°C) values at Blue River above Swan Mtn Rd and Below Dillon Reservoir. The colors denote different Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

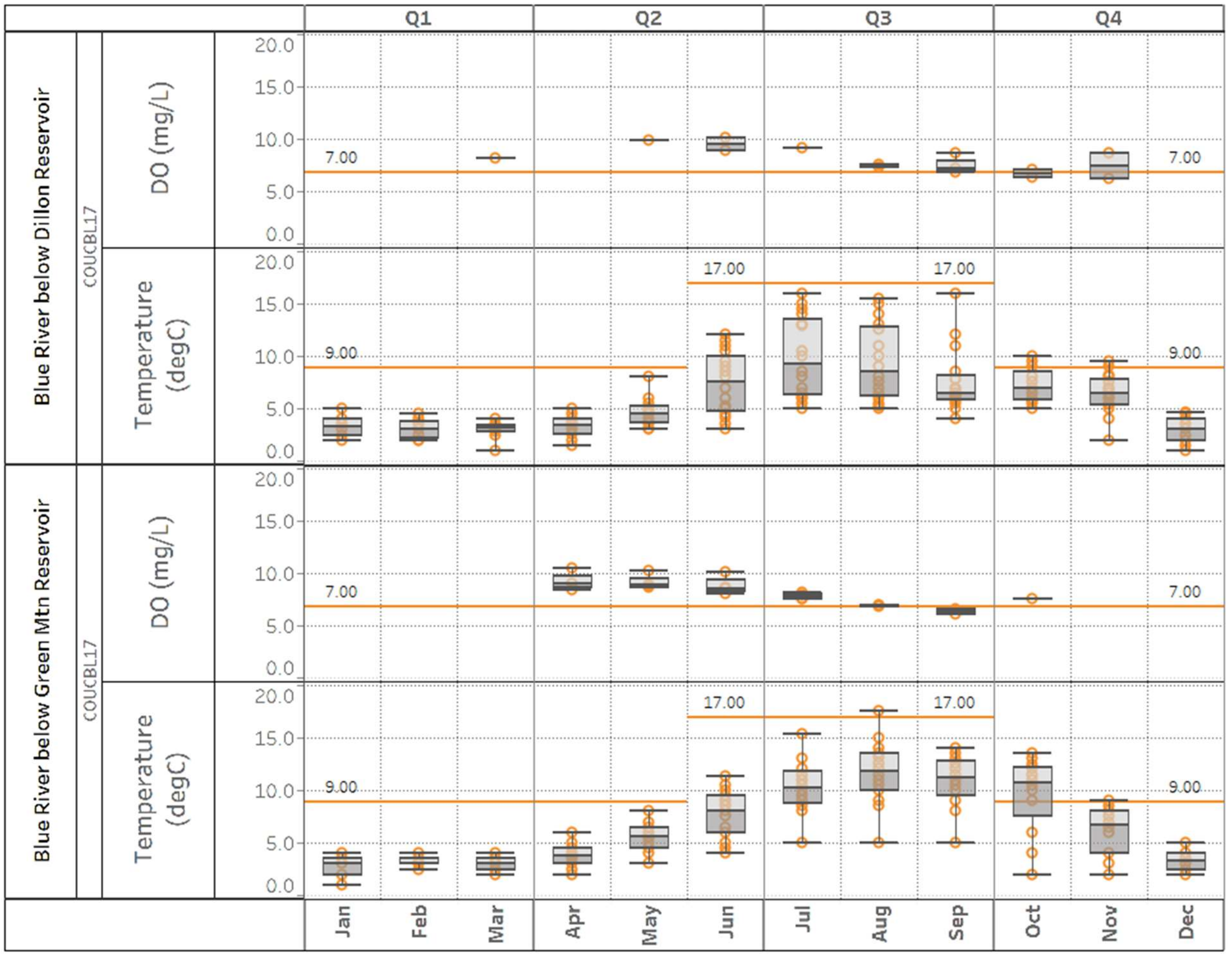

Figure C8 DO (mg/L) and Temperature (°C) values at sites below Dillon Reservoir and below Green Mountain Reservoir. The color denotes the sites Regulation No. 33 segment ID. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

Tributaries of the Blue River also show low levels of DO with higher temperatures, though not consistently throughout the year. **Figure C9** shows DO levels in the Snake River below Keystone Ski Resort that do not strongly follow seasonal temperature variations. Tenmile Creek does not show any DO exceedances and there is no DO data available for Straight Creek.

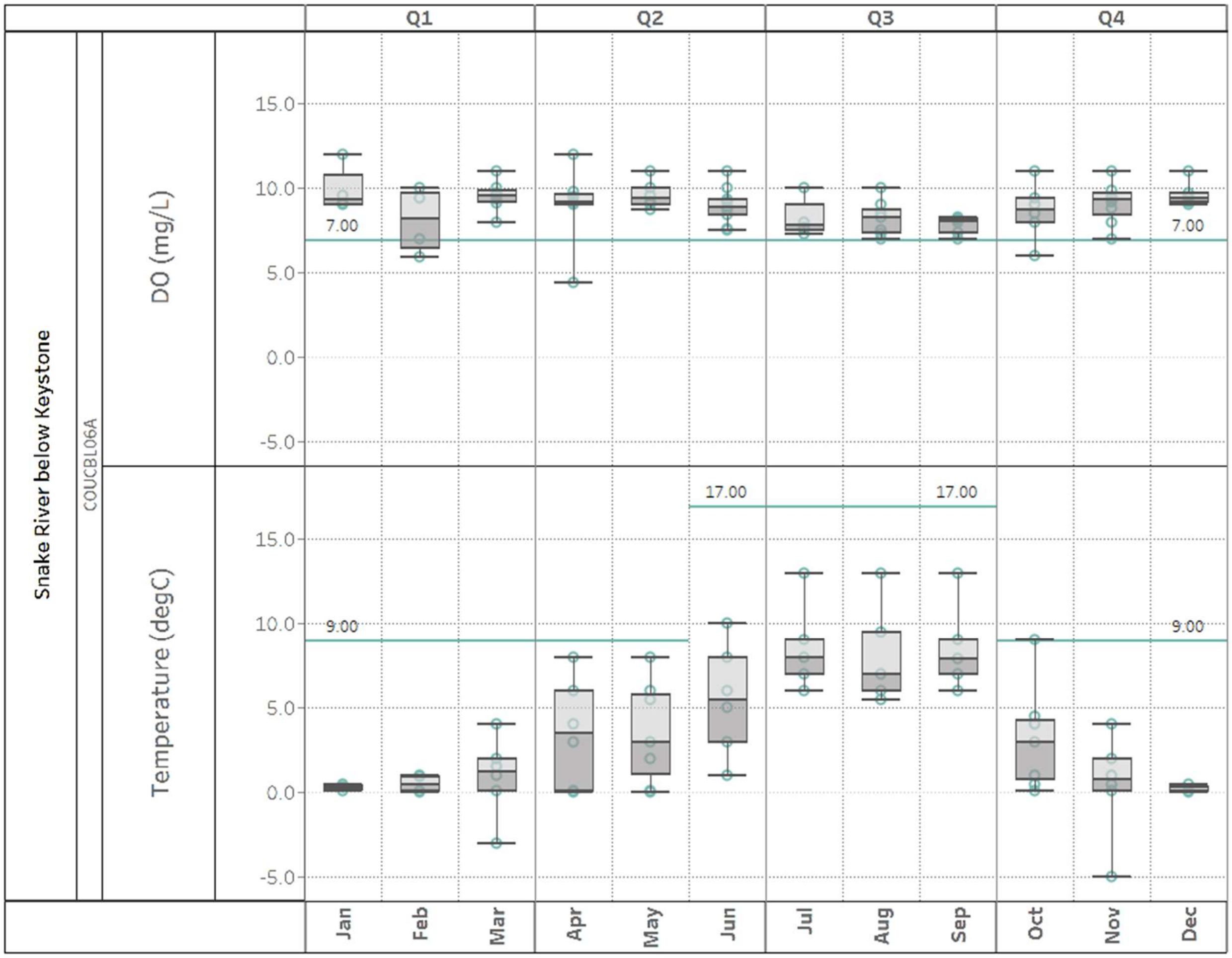

Figure C9 DO (mg/L) and Temperature (°C) values at Snake River below Keystone. The color denotes the sites Regulation No. 33 segment ID. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 5.4 pH

pH is used to describe the acidity or alkalinity of the river or stream. Both low and high pH values could drastically affect the sustainability of a river ecosystem. Reduced pH is especially harmful to aquatic life, as it could boost the toxicity of pollutants such as ammonia. Runoff from surface soils with low or high pH could also directly affect the river acidity and alkalinity. Young fish and larvae are especially sensitive to low pH, although extremes on either end may affect them. Considering the Regulation No. 33 standards, guidelines for pH of natural, healthy river systems may vary from 6.5 to 9.0.

Typically, the Blue River's pH values have remained within the Regulation No. 33 standards at all sites, except for at the Town of Blue River and the tributary Snake River below Keystone. As depicted in **Figure C10**, pH has exceeded the upper standard threshold of 9 in the Town of Blue River.

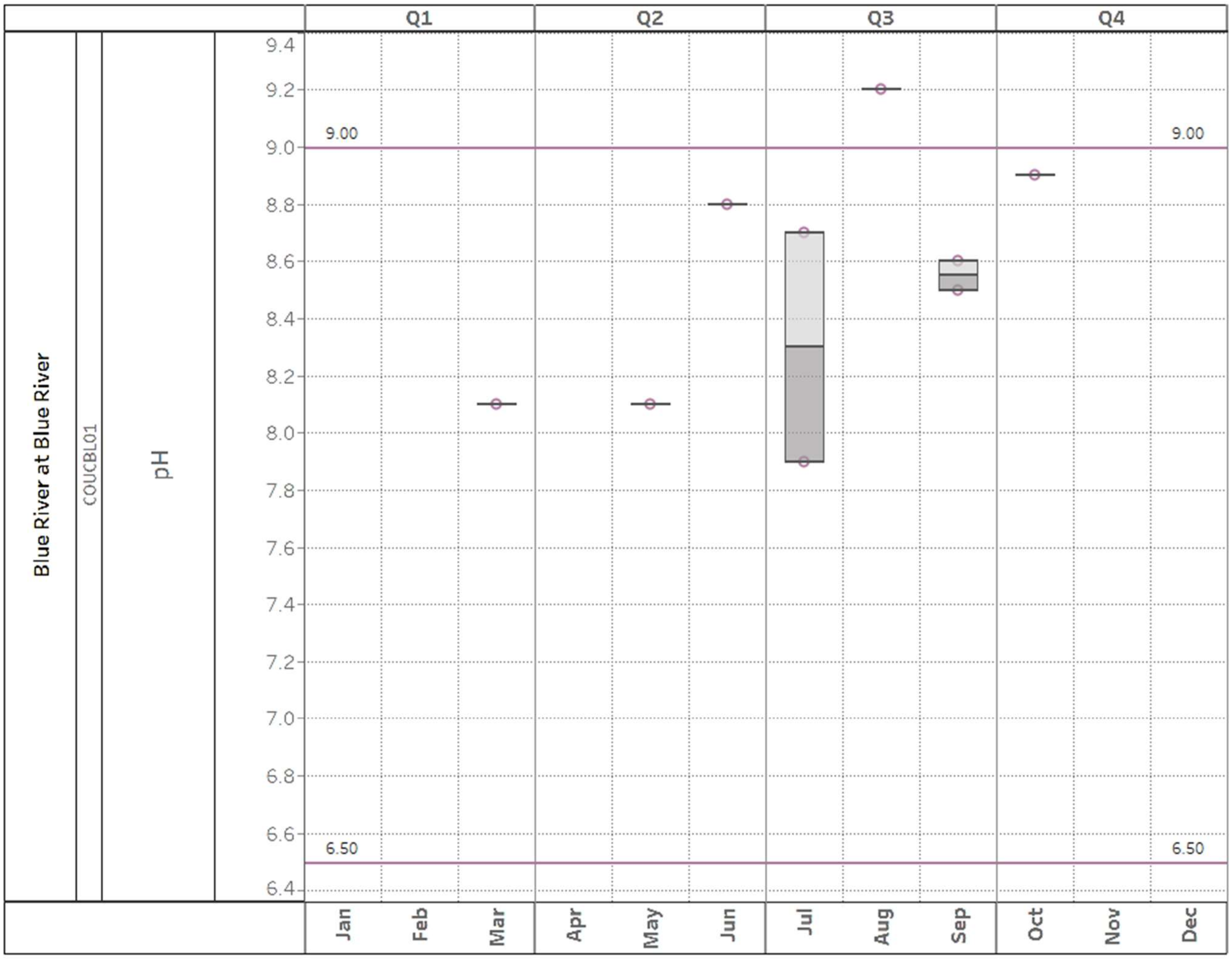

Figure C10 pH at Blue River. The color denotes the sites Regulation No. 33 segment ID. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

In the Snake River below Keystone (**Figure C11**), pH values in the stream trended much lower and at times fell below the lower standard threshold of 6.

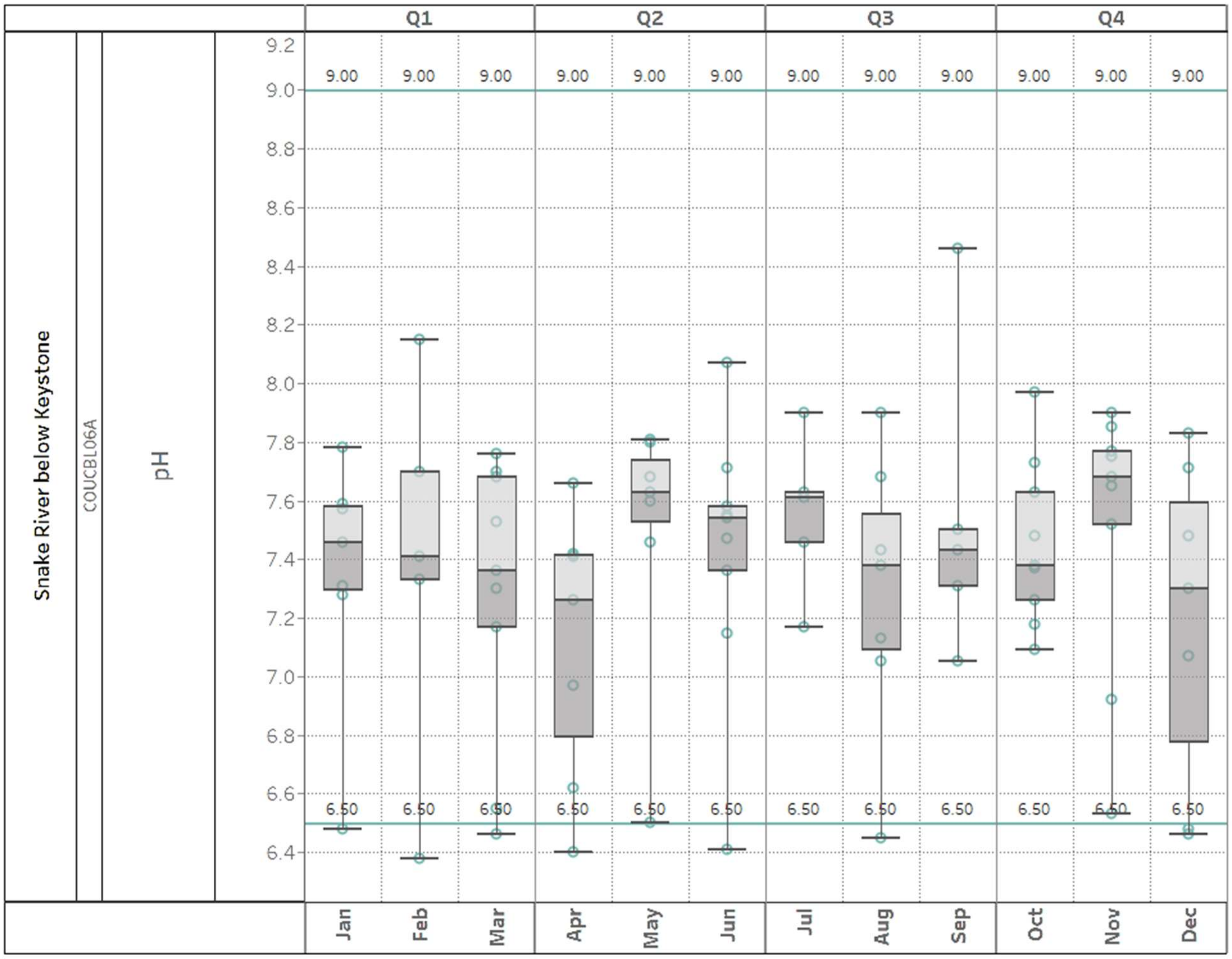

Figure C11 pH at Snake River below Keystone. The color denotes the sites Regulation No. 33 segment ID. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

In general, moving downstream from the Town of Blue River to the outlet of Dillon Reservoir, pH decreases, as shown in **Figure C12.** This effect may be caused by several factors but given the extensive mining history and numerous abandoned claims, the downward trending pH is likely due to the contribution of acidic mine drainage in the tributary basins of French Gulch, Swan River, and Snake River.

The areas surrounding the Snake River, Swan River, and Blue River have a colorful mining history and drainage from these abandoned mine sites may be contributing to the lower pH values observed in the stream [6]. More analysis at sites along the upper reach of the Blue River should be conducted to verify and track pH in the watershed.

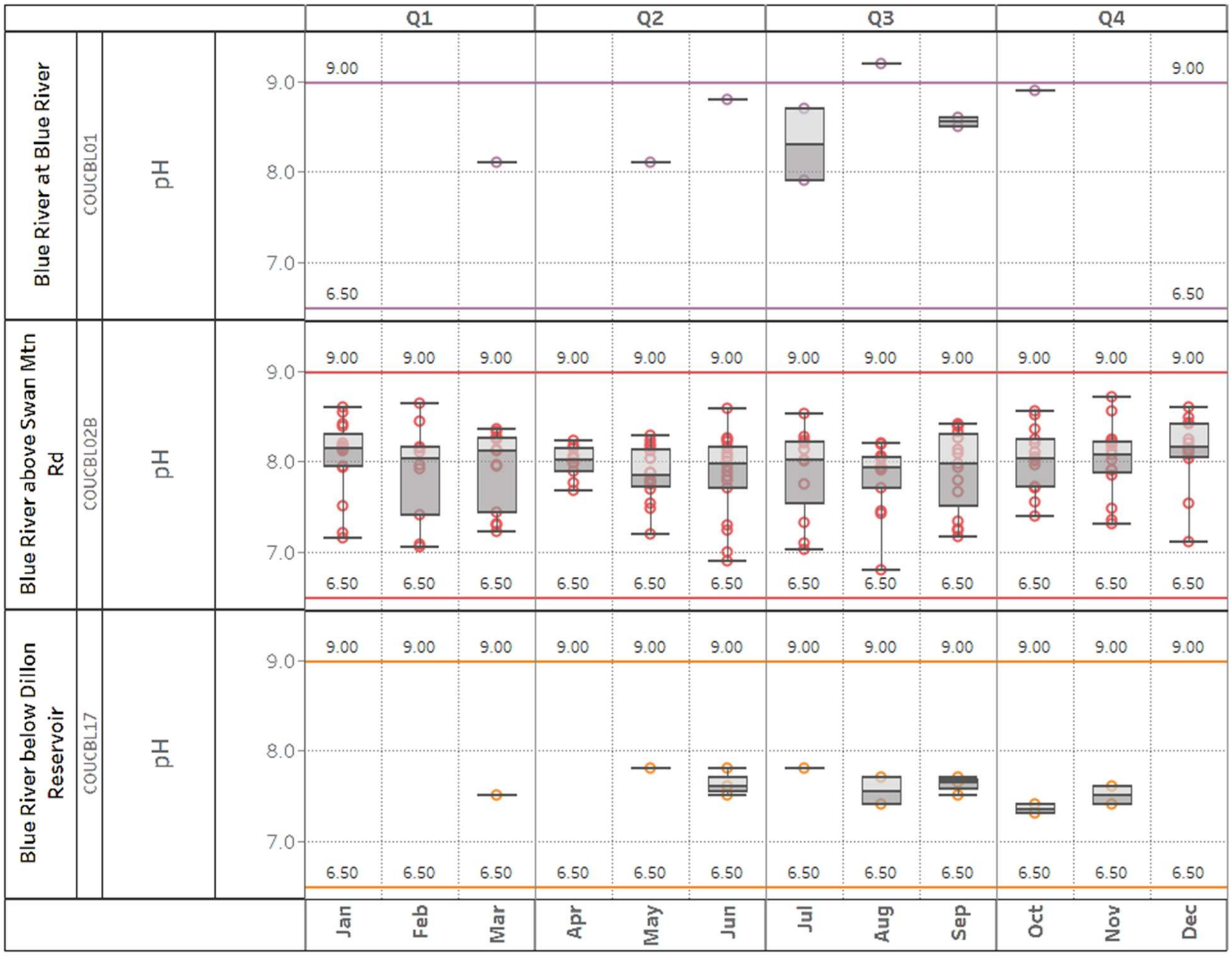

Figure C 12 pH values at the Blue River site, Blue River at Swan Mountain Rd, and below Dillon Reservoir. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 5.5 Turbidity

Total suspended solids (TSS) is a parameter that is correlated to turbidity levels in waterbodies, specifically during turbulent flow conditions when solids stay in suspension and could add to the receiving stream's turbidity. While in suspension, the solids could affect trout in two ways. First, as trout are sight-feeders, their ability to find food could be impaired. Second, in high enough concentrations, gill damage could occur. Once the material deposits out, which it could do in very tranquil pools, it could also add to substrate embeddedness and perhaps limit habitat for quality insects such as mayflies, stoneflies and caddisflies. Also, clay beds could serve as good rooting material for rooted aquatic vegetation, which could be either good or bad, depending on the stream and circumstances. The clay deposits could also smother trout eggs deposited in the spillway at the downstream end of the pool just as the flow breaks into the next riffle [7].

The publicly available datasets included either no turbidity or lacked a sufficient amount of data to analyze. Turbidity data, correlated to TSS, should be collected in the Blue River watershed to establish a robust dataset for future analysis.

C 6 Nitrates

Nitrogen is another important nutrient in rivers, essential for life and sustainability, but destructive in large quantities. If there is not enough nitrogen in a river system, macroinvertrate production would be reduced resulting in less food for fish. In large quantities, nitrogen becomes food for masses of cyanobacteria, or blue-green algae. When overpopulated, algae typically die off, asphyxiating the river. Nitrogen may be found in several forms: ammonia, nitrate, or nitrite, to name a few, and sources may range from natural organic matter to human sewage and fertilizers. nitrogen, in addition to phosphorus, may be used as an indicator of human impacts on the land and river ecosystem.

Review of the available nitrogen data indicates that most readings fall within the range of guidelines for total nitrogen (TN).

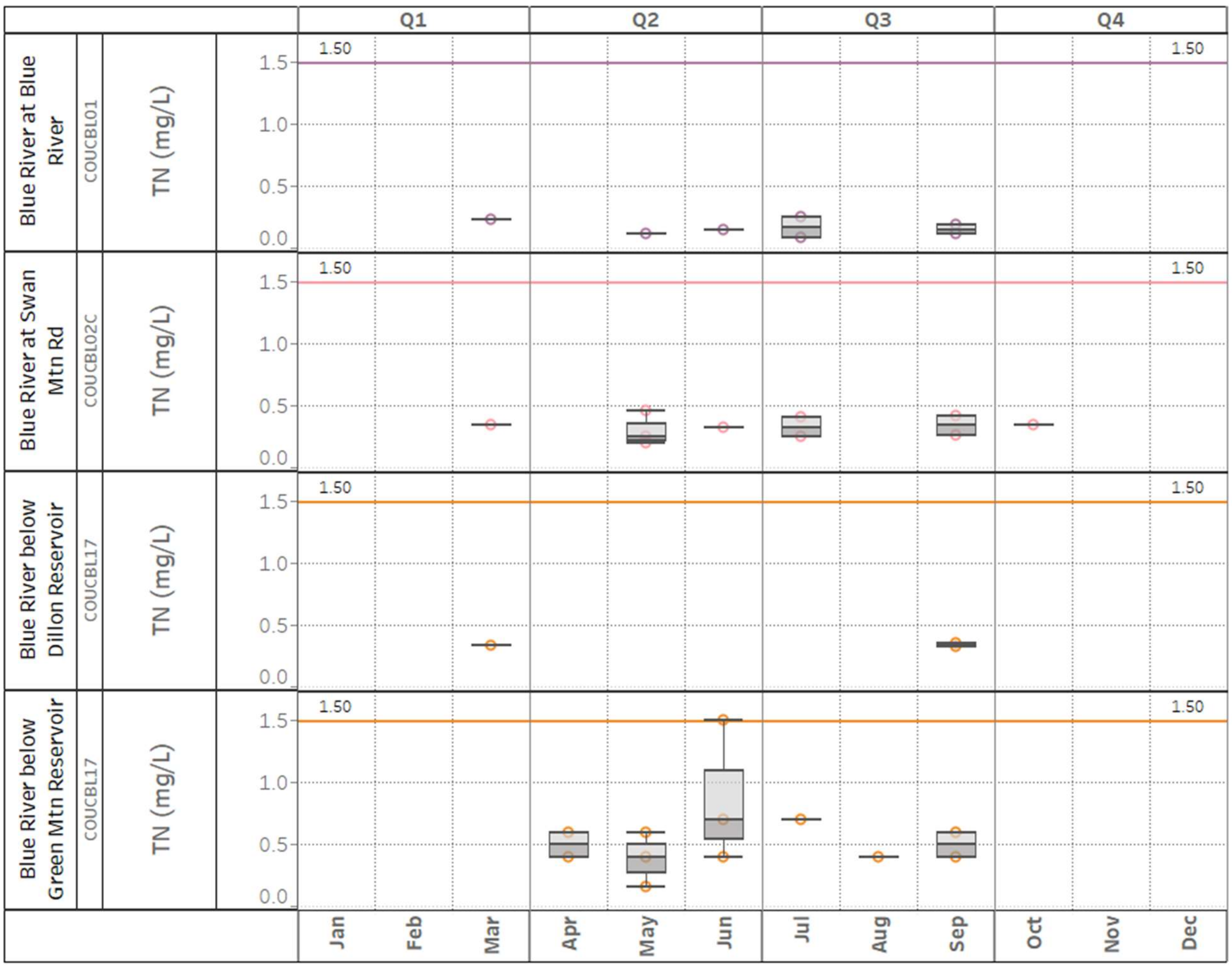

Figure C 13 Total Nitrogen (TN) values at the Blue River site, Blue River at Swan Mountain Rd, below Dillon Reservoir, and below Green Mountain Reservoir. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

In general, there are limited total nitrogen data for sites within the Blue River watershed and this parameter should be measured and included in a more robust dataset for future analysis.

C 7 Phosphorus

Phosphorus and inorganic phosphorus in the form of phosphate play a major role in the structural framework of aquatic life forms. Phosphorus is a limiting factor in most ecosystems, controlling the rate of growth. However, excess phosphorus is problematic, allowing out-of-control growth, and is one of the major causes of excessive algae. Phosphorus could be generated from non-point surface runoff and is present in fertilizers and sometime in municipal wastewater effluent, a result of the use of detergent and soap.

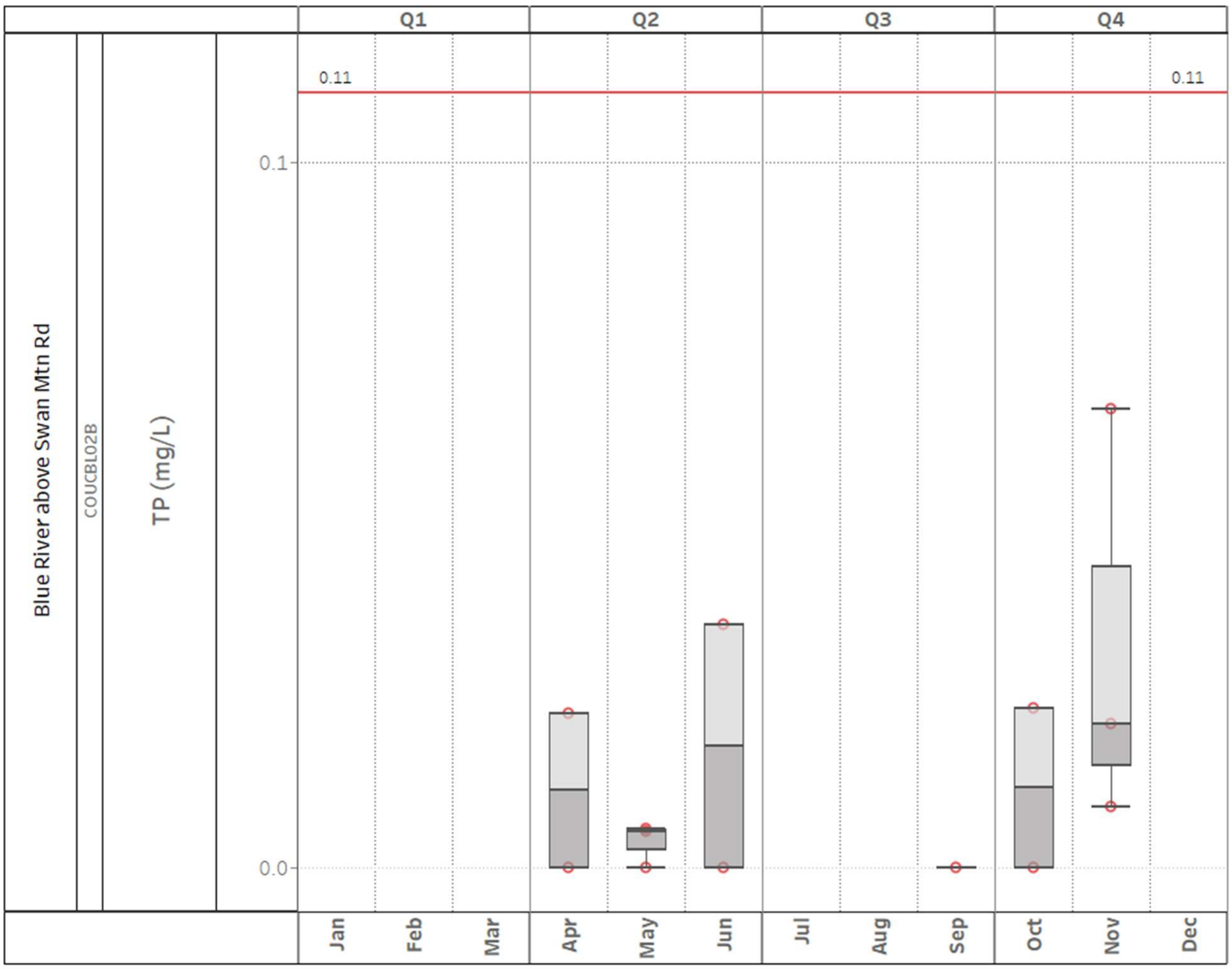

Figure C 14 Total Phosphorus (TP) values at the Blue River above Swan Mountain Rd site. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

Review of the available phosphorus data indicates that most sites do not have any phosphorus measurements. However, at the Blue River above Swan Mtn Rd site, readings fall within the range of guidelines for phosphorous as P.

This general lack of data suggest that more phosphorous data should be collected along the Blue River and throughout the watershed in order to build a robust dataset for future analysis.

C 8 METALS

Metals could potentially impact the trout fishery through physiological stress, reproductive impairment/failure, increased mortality, an indirectly through toxicity to aquatic invertebrates. Some metals of concern are highlighted below. All metal concentration units are reported in µg/L (1x10^{-3} mg/L).

C 8.1 Arsenic

Arsenic may be present in the Blue River above and below Dillon Reservoir. Though data is limited for arsenic measurements at sites along the Blue River, exceedances have been measured at the Blue River above Swan Mtn Rd (CORIVWCH Site 657) and at EPA sites below Dillon Reservoir (EPA Site 12304D). The water quality standard for arsenic within all segments of the Blue River is $0.02\ \mu g/L$.

Arsenic measurements were not captured at higher reaches of the Blue River, such as in the Town of Blue River, but more frequent measurement of arsenic at sites near the headwaters, just above Dillon Reservoir, and just below Dillon Reservoir could help identify the sources and accumulation of arsenic in the Blue River.

Based on the limited data set available, levels have still exceeded the water quality standard in the past (**Figure C15**).

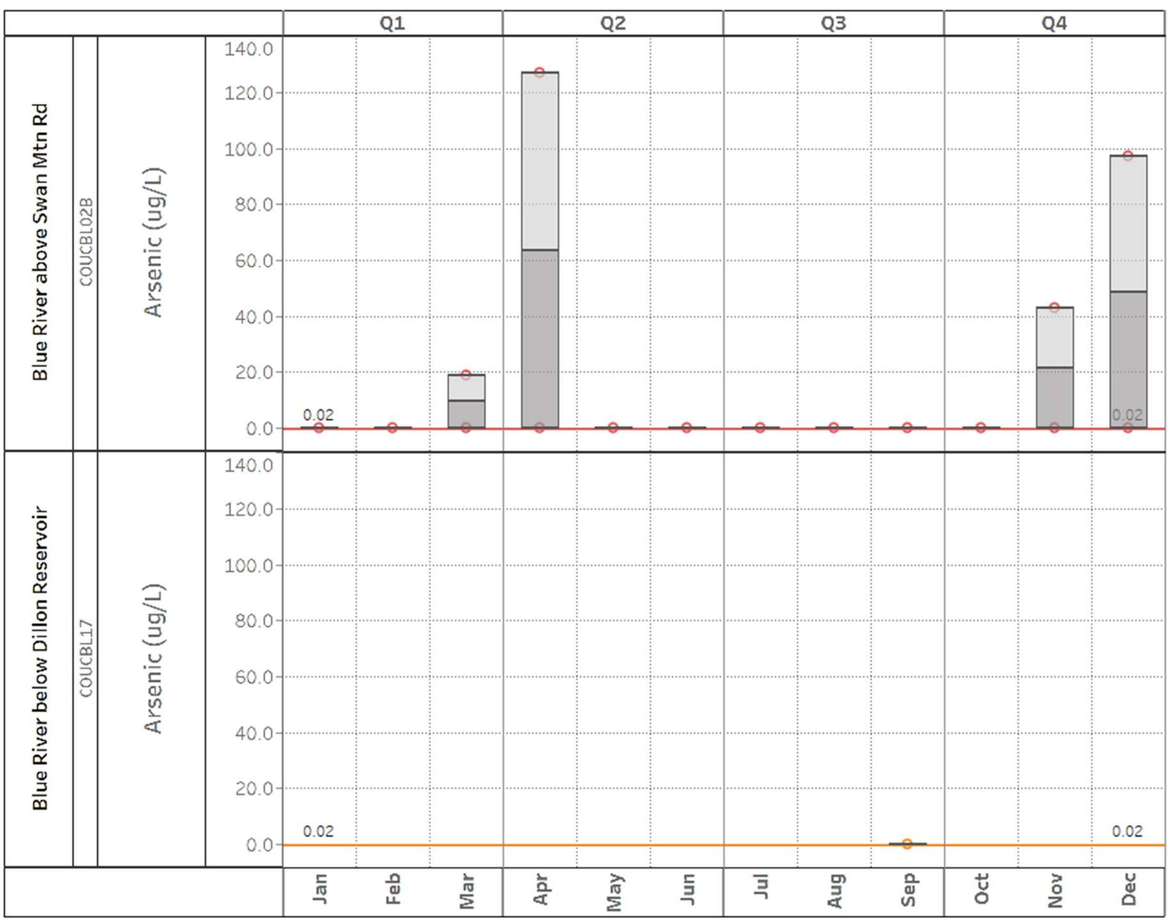

Figure C15 Monthly averaged Arsenic (total, µg/L) levels above and below Dillon Reservoir. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 8.2 Cadmium

Cadmium is present in the Blue River, particularly below the confluence with French Gulch, which has been a heavily active mining area outside the Town of Breckenridge. Cadmium in surface water could be found in areas that are downstream from acid-mining drainage discharge points, especially historic mines that were not regulated during operation. The cadmium water quality standards vary by segment in the Blue River but as seen in **Figure C16** cadmium concentrations exceed standards at higher reaches and below Dillon Reservoir.

Cadmium concentrations and water quality standards vary along different segments of the Blue River. cadmium concentrations measured at the Breckenridge Rec Center (CORIVWCH Sites 656) tend to be higher than those measured at the outlet of Dillon Reservoir (EPA 12304D and USGS 0905700). It appears that concentrations are high near the confluence with French Gulch (Breckenridge Rec Center) and decrease downstream. The mechanism for the observed decrease in cadmium concentrations near Swan Mtn Rd (roughly 4 miles downstream from Breckenridge Rec Center) could be due to dilution or the dissolved metal coming out of solution.

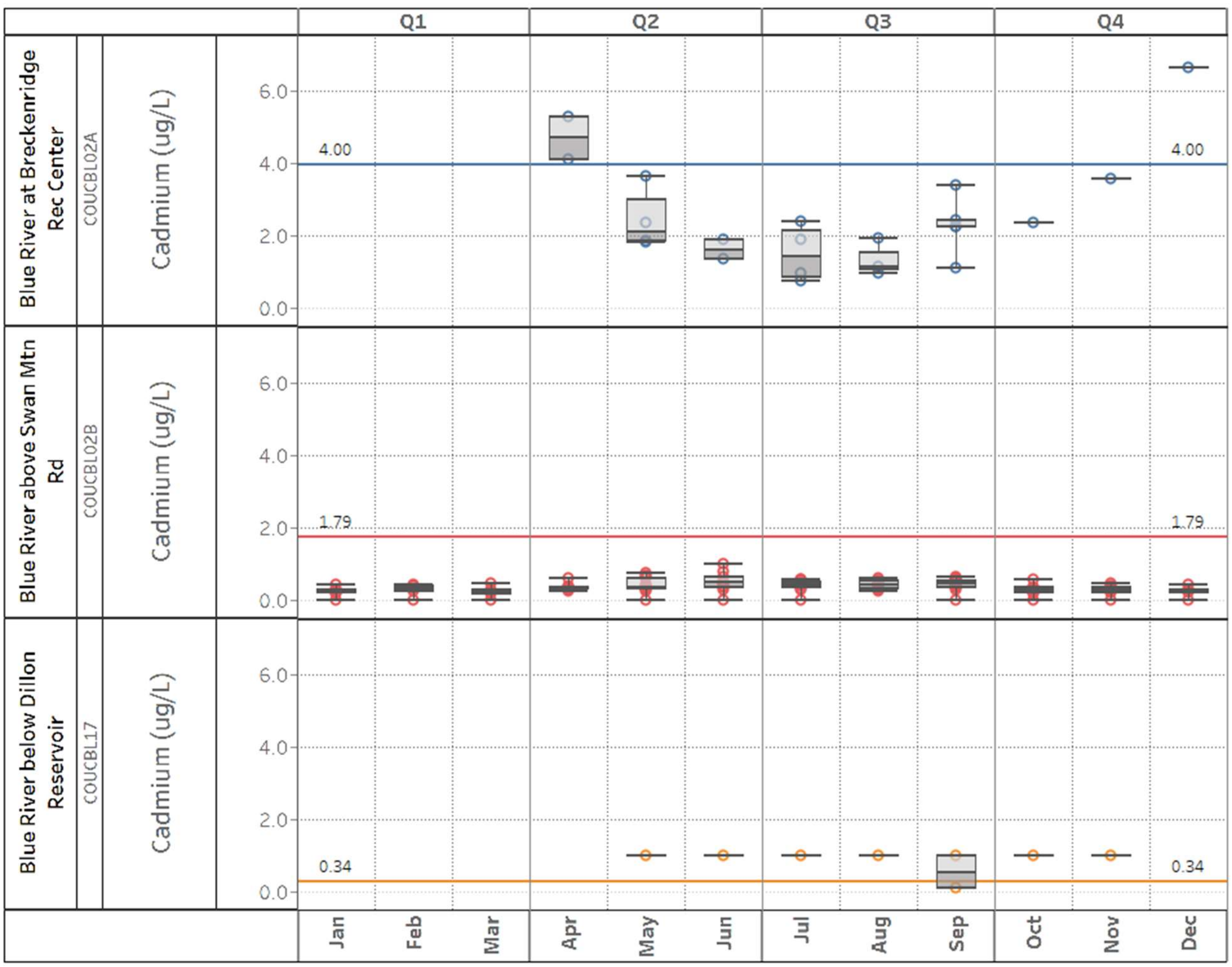

Figure C16 Cadmium (µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

Increased cadmium monitoring at the outlet of Dillon Reservoir and continued monitoring at the other sites shown below would be beneficial for tracking cadmium trends both spatially and temporally and to understand different mechanisms for dilution, absorption / consumption, etc. of the metal in the river.

C 8.3 Copper

Copper is present in the Blue River, particularly above Dillon Reservoir at the Breckenridge Rec Center (CORIVWCH 656) and above Swan Mtn Rd (CORIVWCH 657). Water quality standards vary along different segments of the Blue River, but typically range between $7.07 - 7.44\ \mu g/L$. Exceedances have been measured at both the Rec Center and Above Swan Mtn Rd, particularly in Spring and Summer (Q2 and Q3, respectively) (**Figure C17**).

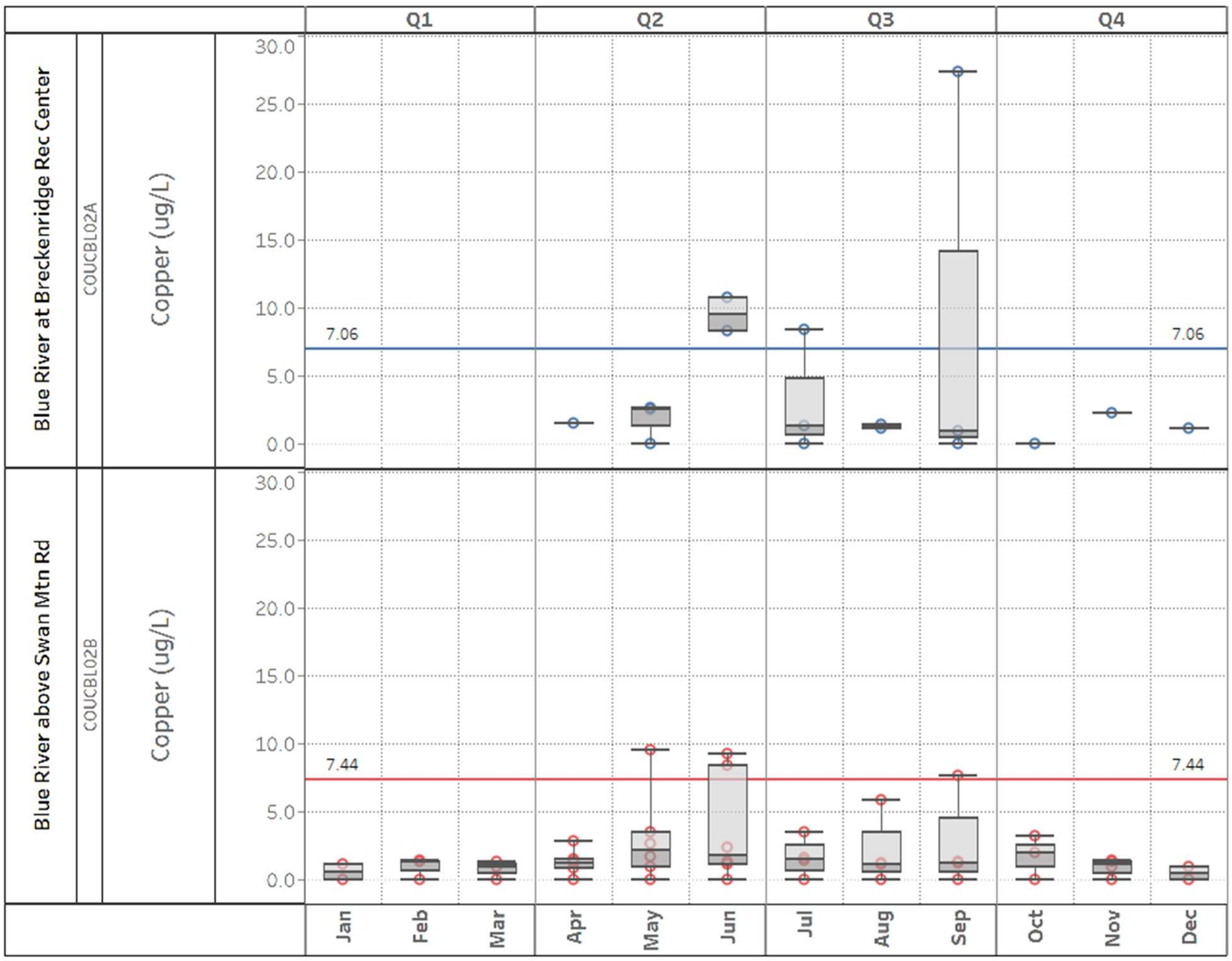

Figure C17 Copper (µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

Continued monitoring of copper at sites above Dillon Reservoir is recommended to improve understand trends both spatially and temporally in the river. Increased monitoring at the outlet of Dillon Reservoir would benefit the understanding of mechanisms that may be removing copper from the Blue River.

C 8.4 Iron (total recoverable)

Iron is present in the Blue River within several segments. The water quality standard for total recoverable iron is $1000\ \mu g/L$ for all segments.

Exceedances have been observed at the Rec Center (CORIVWCH 656), Above Swan Mtn Rd (CORIVWCH 657), and At Swan Mtn Rd (USGS 09046600). The data may contain outliers but continued monitoring at all sites highlighted **Figure C18** would be beneficial. Increased monitoring at the outlet of Dillon Reservoir would benefit understanding of the trends and mechanisms for removal of total recoverable iron from the Blue River (**Figure C18**).

An extensive dataset from CDPHE/EPA exists for total recoverable iron but these data were not considered in this report but are targeted for analysis in the future studies of water quality data in the Blue River watershed.

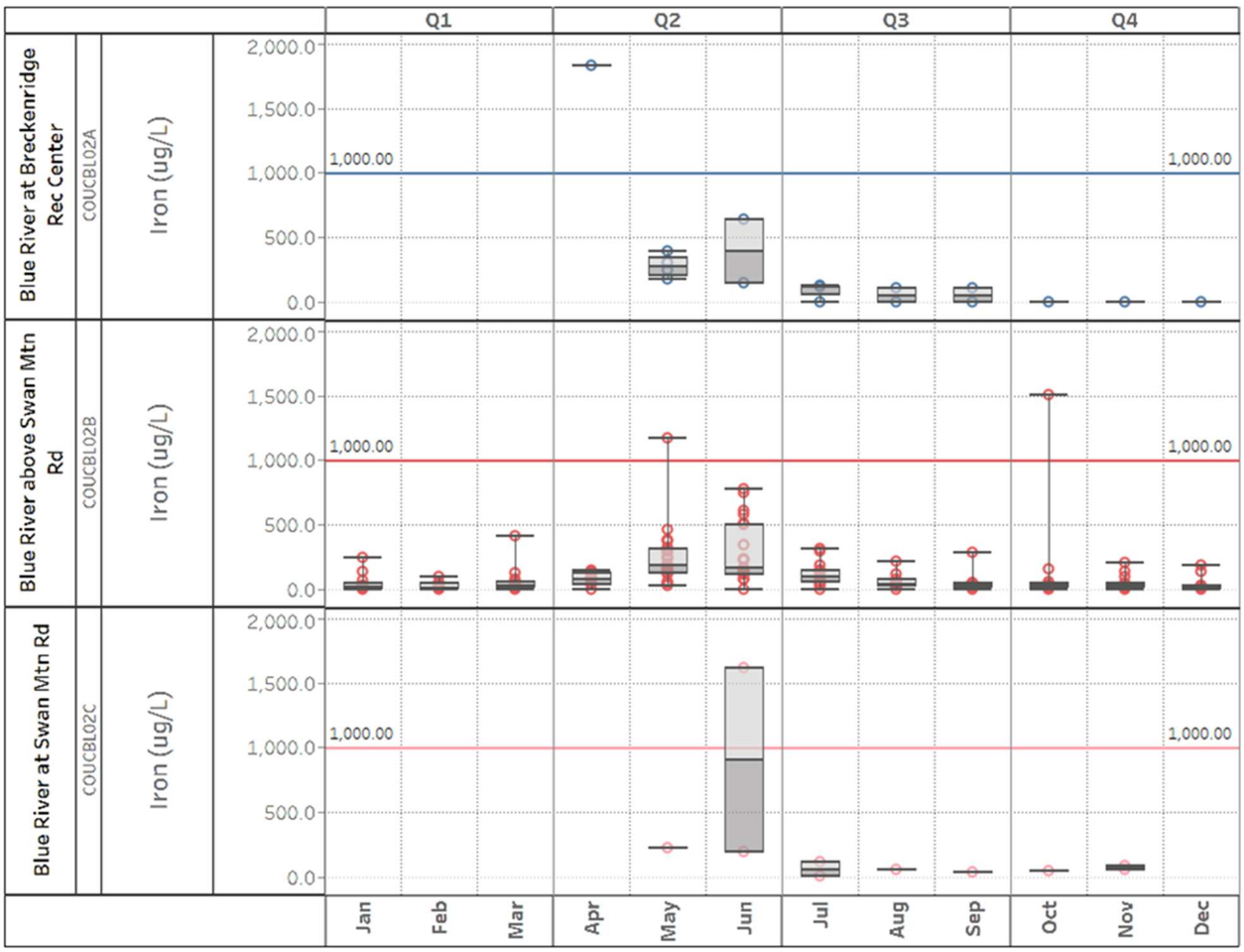

Figure C18 Iron (total recoverable, µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 8.5 Lead

Lead is present in the Blue River, particularly near the confluence with French Gulch. Exceedances are common at the Rec Center and Above Swan Mtn Rd based on the available data (**Figure C19**).

Continued monitoring at sites near French Gulch will be beneficial for understanding trends of lead concentrations in the river. Increased monitoring at the outlet of Dillon Reservoir would be beneficial to understanding the reservoirs role as a "sink" and how or if lead concentrations may be affected at sites lower in the Blue River.

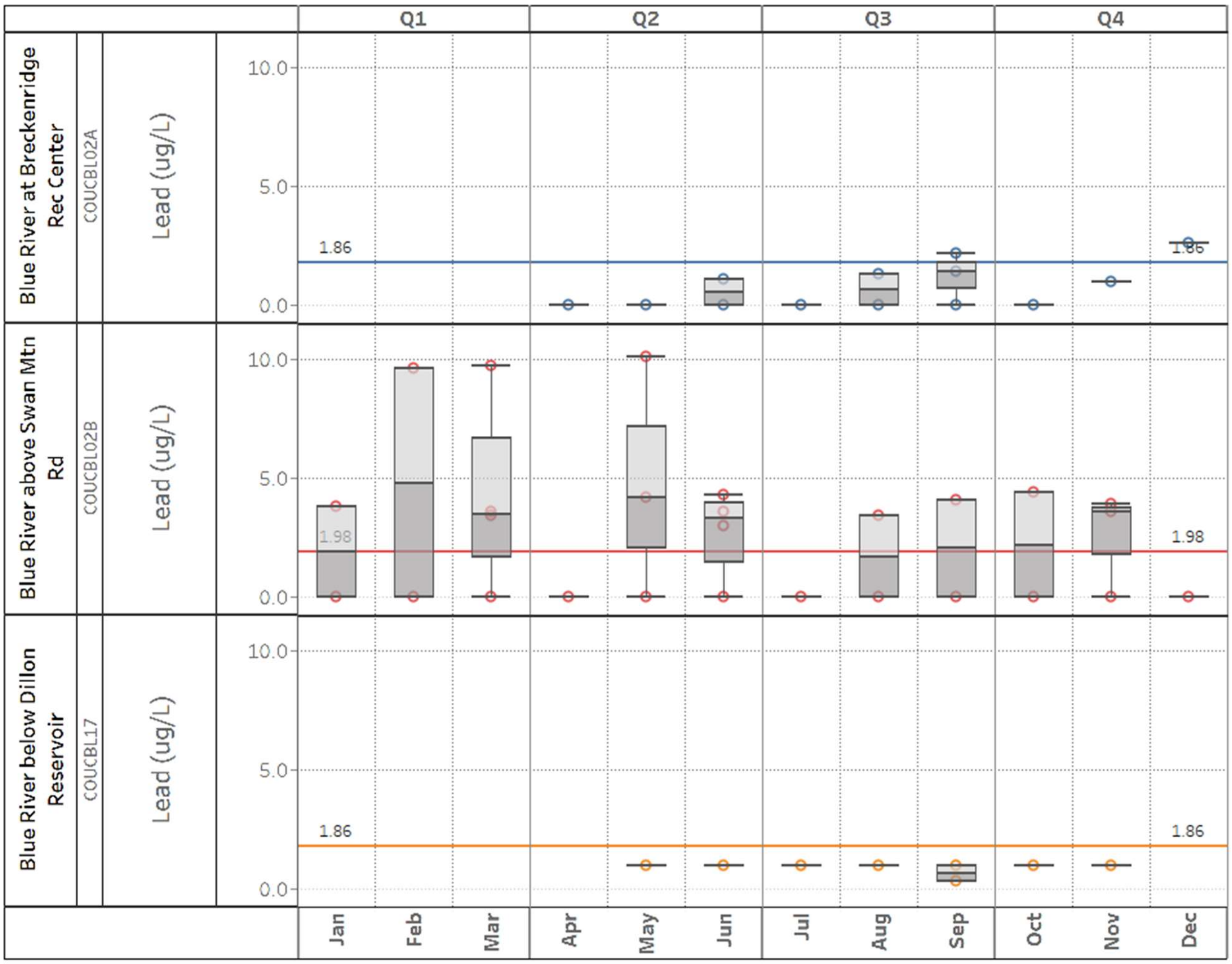

Figure C19 Lead (µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 8.6 Selenium

Selenium is a priority contaminant of concern for many reaches of the Colorado River and data indicate there may be selenium present in the Blue River. Selenium sources are typically from groundwater and agricultural activity as the surface is disturbed during tilling, planting, etc., and selenium is dissolved in storm water and runoff. There is a lack of data for selenium and future monitoring efforts should aim to capture the spatial and temporal trends of concentrations throughout the Blue River basin.

There have been exceedances of the water quality standard Above Swan Mtn Rd (CORIVWCH 657) though most of the measurements are zero in the existing dataset. (**Figure C20**).

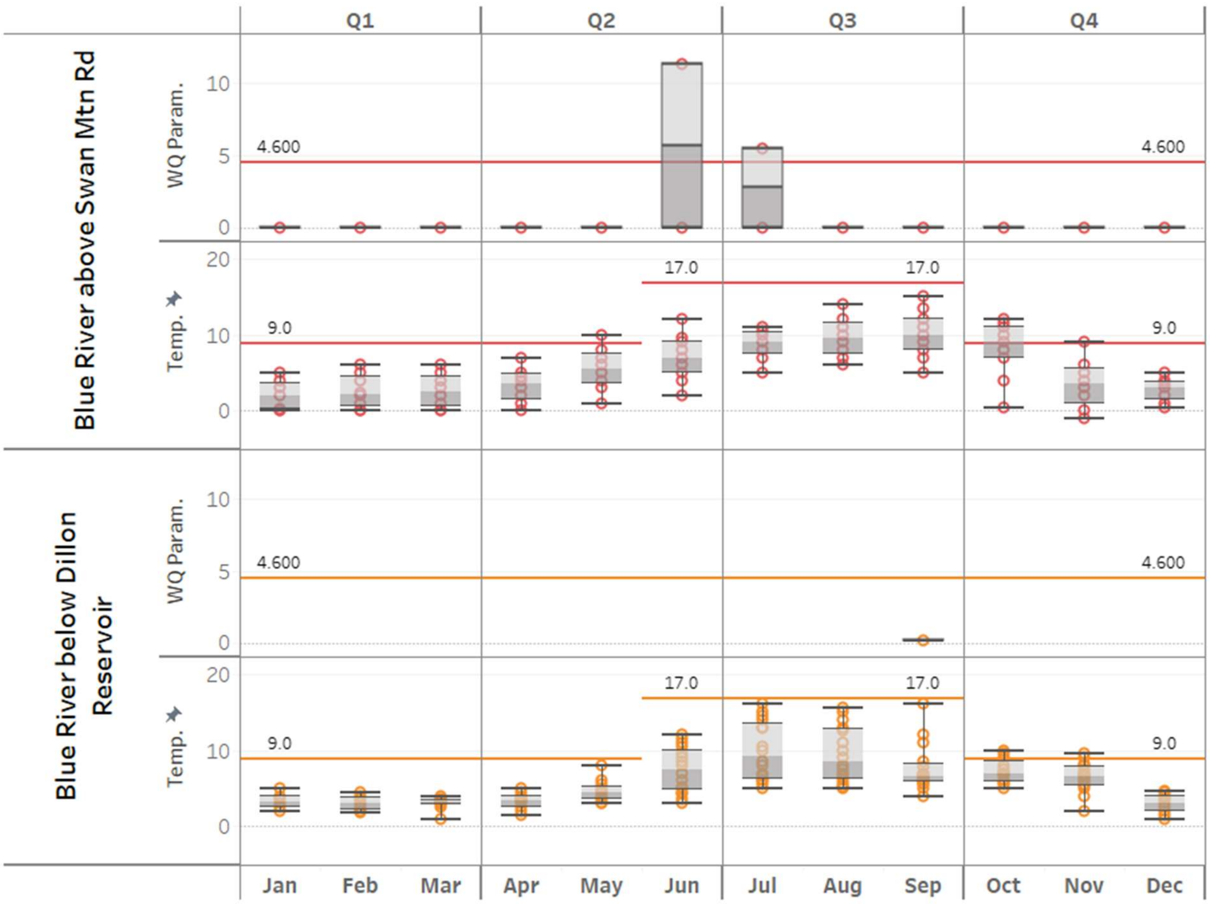

Figure C20 Selenium (µg/L) levels at two sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 8.7 Silver

Silver may be present in the Blue River, both above and below Dillon Reservoir. Silver could negatively impact fish navigation and reducing concentrations could benefit the fishery. The data for this pollutant is very limited and more data should be collected for this constituent in order to better assess the typical concentrations present in the river and how best to mitigate for the benefit of the fisheries (**Figure C21**).

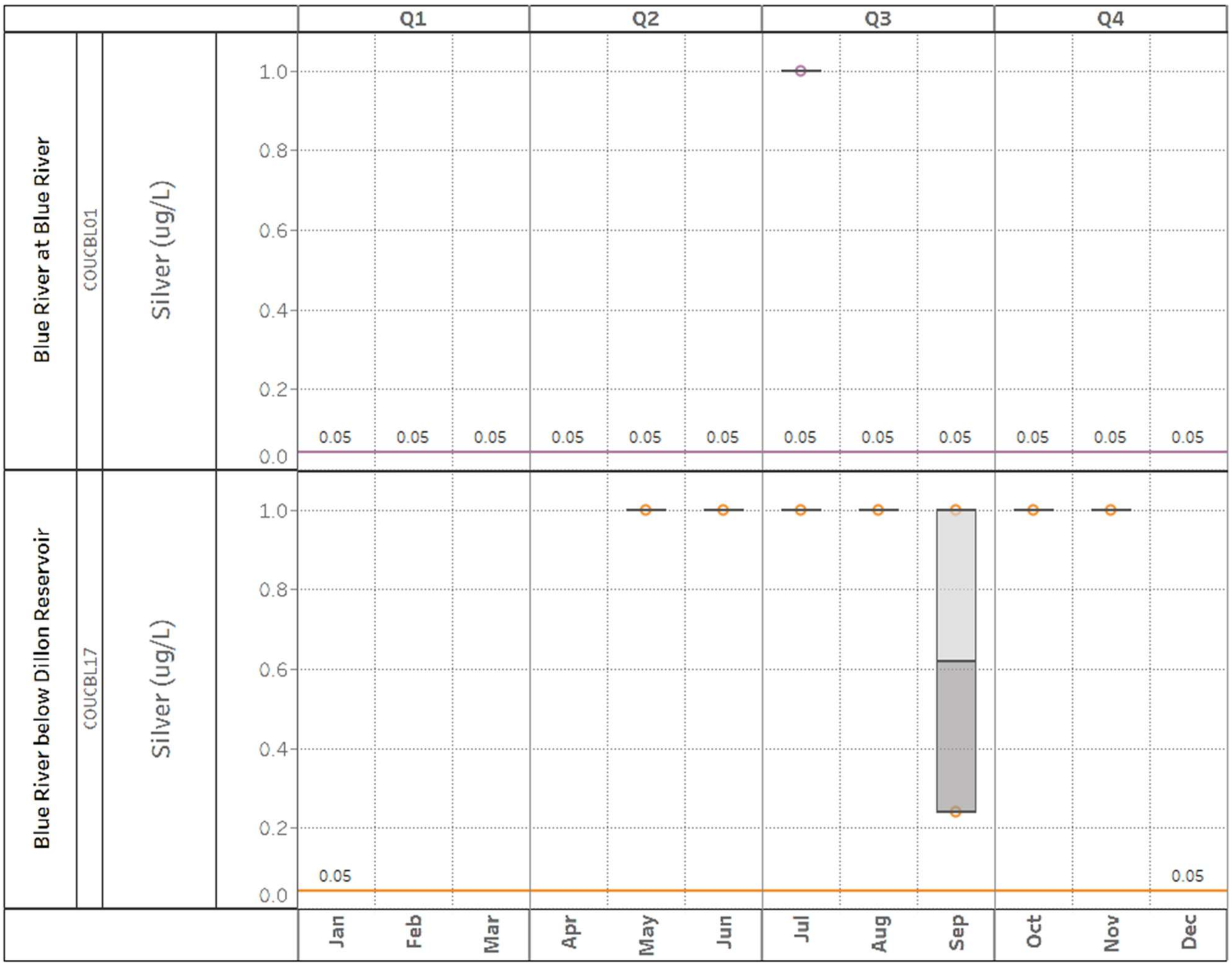

Figure C21 Silver (µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

C 8.8 Zinc

Zinc is present in the Blue River and concentrations at various sites and often exceeds the water quality standard for several segments. The water quality standard varies by segment and, in general, decreases from the headwaters to Green Mtn Reservoir.

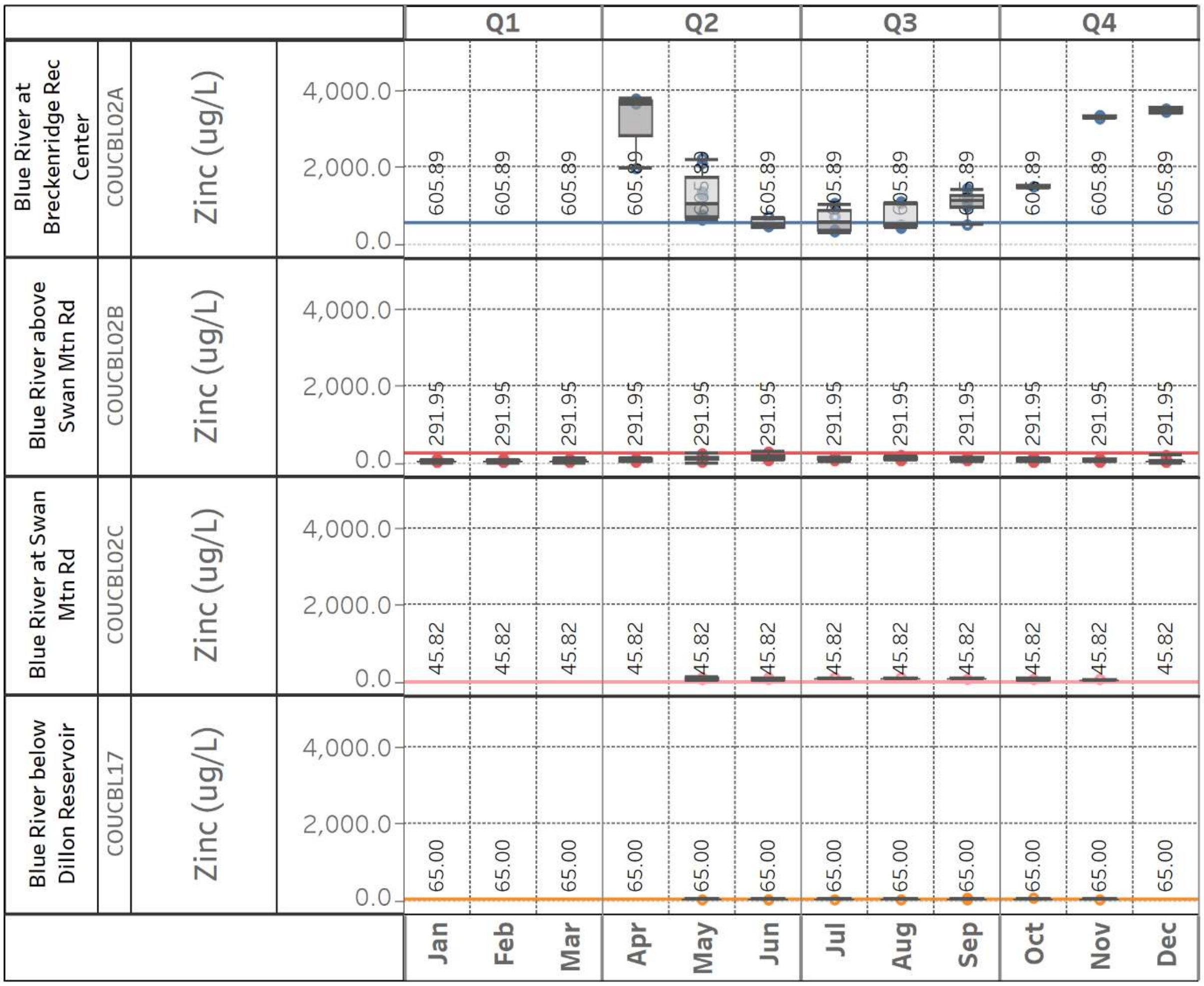

Figure C 22 Zinc (µg/L) levels at three sites along the Blue River. The colors denote the sites' Regulation No. 33 segment IDs. Relevant water quality standards are also overlaid in the plot. The box & whisker diagrams in the plot highlight statistics of the dataset. The box spans the 25th to 75th percentile and the median is shown as a dark bar in the box. The whiskers extend to the minimum and maximum values in the dataset.

Zinc concentrations at the Rec Center exceed the water quality standard for that segment ($605.89\ \mu g/L$) during much of the year. Further downstream Above Swan Mtn Rd (CORIVWCH 657), the concentrations do not tend to exceed the water quality standard. However, shortly downstream at Swan Mtn Rd (USGS 09046600) concentrations again exceed the water quality standard nearly year-round, partly due to the significantly lower standard concentration at this site near the inlet of Dillon Reservoir.

At the outlet of Dillon Reservoir, the water quality standards are not exceeded, and concentrations decrease significantly from those observed at the Rec Center.

C 9 Algae

Algae could be a "nuisance", due to aesthetics, and clogging of pump intakes. Algae could also contribute to fish stress or even mortality as warm, still, or slow-moving water with high nutrient content (N and P) contribute to low dissolved oxygen content [8], [9]. Both the WQCD/WQCC and the EPA suggest that soluble nutrient levels could be related to algal biomass. The EPA Clean Water Act Section 304(a) criteria set levels for N, P, Chlorophyll *a*, and clarity (turbidity / transparency). However, there are WQCC interim TP, TN, and Chlorophyll a criterion that should be used when assessing water quality conditions for this project. Currently, there are only Interim Values for Chlorophyll a, TP, and TN in streams (cold water and warm water), as there are for lakes. The WQCC Regulation No. 31 (Section 31.17, Nutrients) lists the Interim values for these parameters as:

- Chlorophyll *a* (max for July 1-September 30) - for cold and warm rivers and streams = 150 mg/m^2
- TP – for cold rivers and streams = 110 ug/L (annual median TP, allowable exceedance frequency 1-in-5 years)
- TP – for warm rivers and streams = 170 ug/L (annual median TP, allowable exceedance frequency 1-in-5 years)
- TN – for cold rivers and streams = 1,250 ug/L (annual median TN, allowable exceedance frequency 1-in-5 years)
- TN – for warm rivers and streams = 2,010 ug/L (annual median TN, allowable exceedance frequency 1-in-5 years)

Section C.6 and C.7 discuss the TN and TP data available for the project area, which is limited. No Chlorophyll *a* data exists for this project area.

REFERENCES/CITATIONS

[1] Colorado Data Sharing Network (CDSN), “CDSN Monitoring Location & Exceedance Application,” 2020. http://www.coloradowaterdata.org/exceedanceappcdsn.html.

[2] N. J. Bauch, L. D. Miller, and S. Yacob, “Analysis of water quality in the Blue River watershed, Colorado, 1984 through 2007,” Reston, VA, 2014. doi: 10.3133/sir20135129.

[3] R. . Raleigh, L. D. Zuckerman, and P. C. Nelson, “Habitat suitability index models and instream flow suitability curves: Brown trout, revised.,” *U.S. Fish Wildl. Servo Biol. Rep.*, vol. 82, no. 10.124, p. 65, 1986.

[4] “RiverWach Institute of Alberta,” 2021. https://www.riverwatch.ca/chemistry/ (accessed Jul. 07, 2021).

[5] A. G. Eklöv, L. A. Greenberg, C. Brönmark, P. Larsson, and O. Berglund, “Influence of water quality, habitat and species richness on brown trout populations,” *J. Fish Biol.*, vol. 54, no. 1, pp. 33–43, Jan. 1999, doi: https://doi.org/10.1111/j.1095-8649.1999.tb00610.x.

[6] N. F. Gray, “Field assessment of acid mine drainage contamination in surface and ground water,” *Environ. Geol.*, vol. 21, pp. 358–361, 1996, [Online]. Available: https://link.springer.com/content/pdf/10.1007/BF00766705.pdf.

[7] D. L. Ward, R. Morton-Starner, and B. Vaage, “Effects of Turbidity on Predation Vulnerability of Juvenile Humpback Chub to Rainbow Trout and Brown Trout,” *J. Fish Wildl. Manag.*, vol. 7, no. 1, pp. 205–212, Mar. 2016, doi: 10.3996/102015-JFWM-101.

[8] K. Klose, S. D. Cooper, A. D. Leydecker, and J. Kreitler, “Relationships among catchment land use and concentrations of nutrients, algae, and dissolved oxygen in a southern California river,” *Freshw. Sci.*, vol. 31, no. 3, pp. 908–927, Sep. 2012, doi: 10.1899/11-155.1.

[9] M. S. Pollock, L. M. J. Clarke, and M. G. Dubé, “The effects of hypoxia on fishes: from ecological relevance to physiological effects,” *Environ. Rev.*, vol. 15, no. NA, pp. 1–14, Feb. 2007, doi: 10.1139/a06-006.

APPENDIX D

D-1 Historical Data Review

Benthic Macroinvertebrate Biomonitoring/Surveys

Timberline Aquatics, Inc.

Memo

To: Blue River Watershed Group and Trout Unlimited

From: David E. Rees, Timberline Aquatics, Inc.

Date: 3/12/2021

Subject: Results from historical benthic macroinvertebrate sampling on the Blue River, Colorado.

Historical biological data with the benefit of long-term ecological research is essential in understanding the effects and alterations of human-caused and natural stochastic disturbances in ecological systems. Long-term historical data can provide valuable insight into natural biological, chemical, and hydrological processes which allows for a clearer understanding of current regional water quality issues and current and future anthropogenic stressors. The following evaluation of benthic macroinvertebrate community structure is based on a compilation of available macroinvertebrate data from the Blue River study area in Summit County, Colorado (a segment ranging from immediately upstream from Dillon Reservoir to 7.24 km downstream from Green Mountain Reservoir).

Initial benthic macroinvertebrate collections from the Blue River were taken in the fall of 1985, and subsequent monitoring was conducted by the U.S. Forest Service from the fall of 2016 through the fall of 2019. It is our understanding that quantitative benthic macroinvertebrate samples (Surber samples) were collected by the U.S. Forest Service, then these samples were composited and processed using a 300-count subsampling methodology. This provided semi-quantitative data that was extrapolated to determine an approximate number of individuals/m^2. For the samples taken between 2016 and 2018, Timberline Aquatics, Inc. received the extrapolated data (number of individuals /m^2), while in 2019, the raw data (from 300-count subsamples) were provided. All data were evaluated using the Multi-Metric Index (MMI v4) developed by Water Quality Control Division (WQCD) for the Colorado Department of Public Health and Environment. Since the data from 2016-2018 had been extrapolated to number/m^2, these data required a rarefication process (to approximately 300 individuals) to use the MMI program. This may have resulted in some negative bias in MMI v4 scores from 2016 to 2018. The raw 300-count data from the fall of 2019 was directly used to provide MMI v4 scores. Since many aspects of the of the historical data collection and sample processing are unknown, the results from data analysis should be interpreted with some caution. However, this historical data

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still provides valuable information on the natural and anthropogenic processes which help us to understand natural variability and human-caused impacts.

The historical fall data reflected similar benthic macroinvertebrate community patterns to those that are typically found downstream from a deep release reservoir. During all of the years, site Blue 1, located the farthest downstream from Dillon Dam, scored the highest in EPT Taxa (Ephemeroptera [mayflies]/Plecoptera [stoneflies]/Trichoptera [caddisflies]); Clinger Taxa; Intolerant Taxa; Predator Taxa; and MMI v4 scores (Tables 1-10, Figures 1-4). Site Blue 5, located immediately below the dam, scored the lowest EPT Taxa; Clinger Taxa; Total Taxa; Intolerant Taxa; % Increasers, Mountains; and MMI v4 scores in all of the historical data provided (Tables 1-10, Figures 1-4). Data collected in 1985 also indicated that site BR1, the historical site closest to the current site Blue-1, produced high scores from the EPT Taxa, % EPT, Clinger Taxa, and MMI v4 (Table 1). Site BR2, located near present day LBR (below Green Mountain Reservoir), scored a slightly lower MMI v4, but still maintained a relatively healthy macroinvertebrate community (Table 1). The historical data collected between the years 2016 and 2019 also shows general patterns of increasing Taxa Richness, % EPT, Number of Intolerant Taxa, and MMI v4 scores and a general decrease in Percentage Chironomids, % Tolerant Taxa, and HBI moving from site Blue-5 downstream to site Blue-1 (Tables 2-5). The historical data clearly shows the well-known pattern of benthic macroinvertebrate community recovery downstream from a deep release reservoir; however, other information (such as biomass) was lacking.

Table 1. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from the Blue River during November 1985. Data obtained from the Two Forks EIS.

Metric	**Station ID**	
	BR1 (near Blue 1)	**BR2 (near LBR)**
EPT Taxa	77.6	66.7
% EPT, no Baetidae	100.0	69.7
Clinger Taxa	85.0	81.7
Total Taxa	71.4	--
Intolerant Taxa	95.2	--
% Increasers, Mountains	100.0	--
Predator Taxa	76.9	--
% Scraper individuals	4.2	--
% Non-Insect individuals	--	98.6
% Coleoptera individuals	--	14.6
% Intolerant Taxa	--	87.4
% Increasers, Mid-Elev.	--	97.2
Predator/Shredder taxa	--	78.6
MMI	**76.3**	**74.3**
	Auxiliary Metrics	
Diversity	2.55	3.75
HBI	0.69	3.16
TIV (Sediment Region 1)	3.57	NA

Table 2. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from the Blue River during the fall (13-14 September) of 2016. All metric scores based on extrapolated data (#/m^2) provided by the USFS.

Metric	Station ID						
	UBR	**Blue 5**	**Blue 4**	**Blue 3**	**D 5**	**Blue 2**	**Blue 1**
EPT Taxa	20.4	16.3	24.5	40.8	32.7	36.7	44.9
% EPT, no Baetidae	7.5	3.9	13.8	29.6	59.9	37.1	50.0
Clinger Taxa	30.0	15.0	25.0	50.0	40.0	40.0	70.0
Total Taxa	40.5	38.1	40.5	57.1	57.1	61.9	81.0
Intolerant Taxa	28.6	19.0	28.6	47.6	47.6	52.4	66.7
% Increasers, Mountains	24.2	5.1	33.7	49.8	35.1	41.5	56.1
Predator Taxa	7.7	15.4	30.8	23.1	15.4	38.5	46.2
% Scraper individuals	5.7	3.5	3.4	10.3	7.3	4.0	10.2
MMI v4	**20.6**	**14.5**	**25.0**	**38.5**	**36.9**	**39.0**	**53.1**
	Auxiliary Metrics						
Diversity	2.66	2.75	2.95	3.13	3.21	3.63	3.85
HBI	5.24	3.96	3.31	4.11	3.27	3.90	3.53
TIV (Sediment Region 1)	5.85	5.70	4.72	5.53	3.82	4.88	4.18

Table 3. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from the Blue River during the fall (6-7 September) of 2017. All metric scores based on extrapolated data (#/m^2) provided by the USFS.

Metric	Station ID						
	UBR	**Blue 5**	**Blue 4**	**Blue 3**	**D 5**	**Blue 2**	**Blue 1**
EPT Taxa	24.6	12.3	28.7	41.2	37.0	45.3	70.0
% EPT, no Baetidae	5.3	0.8	15.1	28.7	49.0	55.4	48.6
Clinger Taxa	40.0	15.0	30.0	45.0	40.0	50.0	90.0
Total Taxa	47.6	35.7	47.6	57.1	59.5	69.0	95.2
Intolerant Taxa	33.3	14.3	33.3	47.6	38.1	52.4	90.5
% Increasers, Mountains	46.7	2.7	21.5	66.0	34.7	64.4	50.3
Predator Taxa	15.4	15.4	30.8	23.1	15.4	23.1	61.5
% Scraper individuals	5.5	5.2	21.0	25.7	2.1	13.4	9.0
MMI v4	**27.3**	**12.7**	**28.5**	**41.8**	**34.5**	**46.6**	**64.4**
	Auxiliary Metrics						
Diversity	3.11	2.47	3.05	3.32	3.51	3.52	4.10
HBI	4.68	4.33	3.30	3.88	3.13	3.15	3.69
TIV (Sediment Region 1)	6.28	6.27	6.42	5.04	4.66	4.06	4.66

Table 4. Individual metrics and MMI v4 scores from benthic macroinvertebrate samples collected from the Blue River during the fall (12, 13, and 17 September) of 2018. All metric scores based on extrapolated data (#/m^2) provided by the USFS.

Metric	Station ID						
	UBR	**Blue 5**	**Blue 4**	**Blue 3**	**D 5**	**Blue 2**	**Blue 1**
EPT Taxa	24.5	16.3	28.6	28.6	32.7	36.7	49.0
% EPT, no Baetidae	36.0	1.9	6.5	17.2	45.6	28.0	45.3
Clinger Taxa	35.0	15.0	35.0	30.0	45.0	45.0	60.0
Total Taxa	47.6	33.3	45.2	47.6	69.0	57.1	66.7
Intolerant Taxa	28.6	23.8	38.1	33.3	57.1	47.6	66.7
% Increasers, Mountains	32.9	1.6	11.1	34.9	19.3	25.6	33.9
Predator Taxa	23.1	23.1	46.2	15.4	38.5	23.1	53.8
% Scraper individuals	9.4	15.3	2.2	3.4	6.9	23.4	18.9
MMI v4	**29.6**	**16.3**	**26.6**	**26.3**	**39.3**	**35.8**	**49.3**
	Auxiliary Metrics						
Diversity	3.30	2.46	1.90	2.80	3.35	3.84	3.76
HBI	3.87	4.71	4.62	4.22	4.29	4.70	4.12
TIV (Sediment Region 1)	4.52	5.69	4.57	4.86	5.12	5.83	4.90

Table 5. Individual metrics and MMI scores from benthic macroinvertebrate samples collected from the Blue River during the fall (16-18 September) of 2019. All metric scores based on raw data (300 count subsamples) provided by the USFS.

Metric	Station ID						
	UBR	**Blue 5**	**Blue 4**	**Blue 3**	**D 5**	**Blue 2**	**Blue 1**
EPT Taxa	32.7	8.2	24.5	40.8	28.6	36.7	53.1
% EPT, no Baetidae	32.2	0.4	6.7	14.2	80.1	33.6	38.4
Clinger Taxa	35.0	10.0	25.0	50.0	40.0	40.0	65.0
Total Taxa	57.1	28.6	47.6	52.4	42.9	54.8	71.4
Intolerant Taxa	38.1	14.0	28.6	52.4	33.3	57.1	66.7
% Increasers, Mountains	45.1	0.0	11.3	37.4	15.6	19.9	32.8
Predator Taxa	30.8	23.1	30.8	46.2	23.1	46.2	53.8
% Scraper individuals	14.7	2.3	15.3	8.3	3.9	11.9	12.3
MMI	**35.7**	**10.9**	**23.7**	**37.7**	**33.4**	**37.5**	**49.2**
	Auxiliary Metrics						
Diversity	3.55	1.44	3.07	2.90	2.54	3.77	3.67
HBI	3.96	5.37	3.79	3.62	2.04	3.56	3.85
TIV (Sediment Region 1)	5.41	6.98	6.72	5.81	3.75	5.29	4.49

Figure 1. MMI v4 scores from study sites on the Blue River during the fall of 1985. Data obtained from the Two Forks EIS.

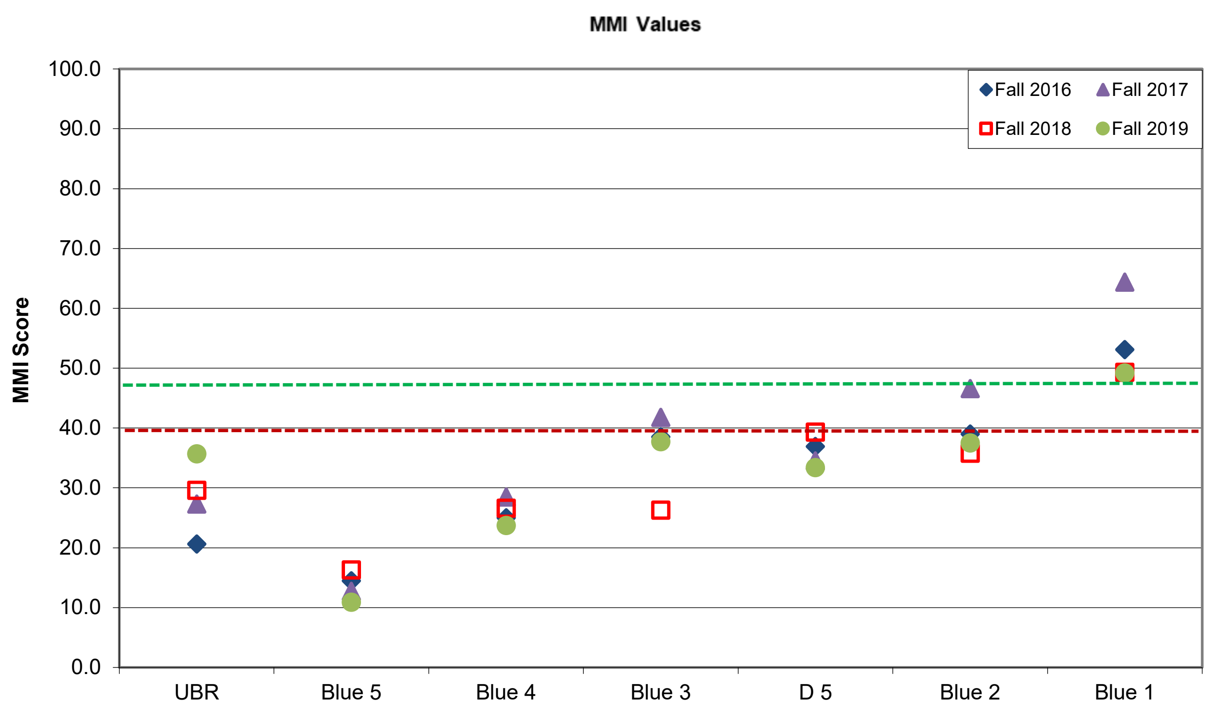

Figure 2. MMI v4 scores from study sites on the Blue River during fall of 2016, 2017, 2018, and 2019. Data provided by the USFS.

Table 6. Additional metrics and comparative values for macroinvertebrate samples collected from the Blue River in fall 1985. Data obtained from the Two Forks EIS.

Metric	BR1 (near Blue 1)	BR2 (near LBR)
EPT Taxa	**19**	**17**
Taxa Richness	**30**	**31**
Percent EPT	**94.48%**	**52.82%**

Table 7. Additional metrics and comparative values for macroinvertebrate samples collected from the Blue River in the fall (13-14 September) of 2016. All metric scores based on extrapolated data (#/m²) provided by the USFS.2016.

Metric	UBR	Blue 5	Blue 4	Blue 3	D 5	Blue 2	Blue 1
EPT Taxa	**5**	**5**	**8**	**11**	**9**	**11**	**13**
Taxa Richness	**17**	**17**	**19**	**25**	**25**	**28**	**36**
Percent EPT	**28.77%**	**40.83%**	**42.07%**	**32.04%**	**68.15%**	**45.65%**	**53.58%**

Table 8. Additional metrics and comparative values for macroinvertebrate samples collected from the Blue River in the fall (6-7 September) of 2017. All metric scores based on extrapolated data (#/m²) provided by the USFS.

Metric	UBR	Blue 5	Blue 4	Blue 3	D 5	Blue 2	Blue 1
EPT Taxa	**6**	**3**	**7**	**13**	**9**	**13**	**18**
Taxa Richness	**20**	**15**	**20**	**27**	**25**	**31**	**41**
Percent EPT	**4.99%**	**35.73%**	**27.49%**	**45.48%**	**49.05%**	**61.71%**	**54.29%**

Table 9. Additional metrics and comparative values for macroinvertebrate samples collected from the Blue River in the fall (12, 13, and 17 September) of 2018. All metric scores based on extrapolated data (#/m^2) provided by the USFS.

Metric	UBR	Blue 5	Blue 4	Blue 3	D 5	Blue 2	Blue 1
EPT Taxa	**6**	**4**	**8**	**7**	**9**	**9**	**13**
Taxa Richness	**20**	**14**	**20**	**20**	**30**	**24**	**29**
Percent EPT	**36.41%**	**50.82%**	**74.36%**	**61.68%**	**38.92%**	**34.11%**	**49.33%**

Table 10. Additional metrics and comparative values for macroinvertebrate samples collected from the Blue River in the fall (16-18 September) of 2019. All metric scores based on raw data (300 count subsamples) provided by the USFS.

Metric	UBR	Blue 5	Blue 4	Blue 3	D 5	Blue 2	Blue 1
EPT Taxa	**8**	**2**	**6**	**10**	**7**	**10**	**15**
Taxa Richness	**24**	**12**	**20**	**22**	**19**	**25**	**32**
Percent EPT	**32.01%**	**7.44%**	**20.85%**	**42.82%**	**73.14%**	**42.32%**	**61.23%**

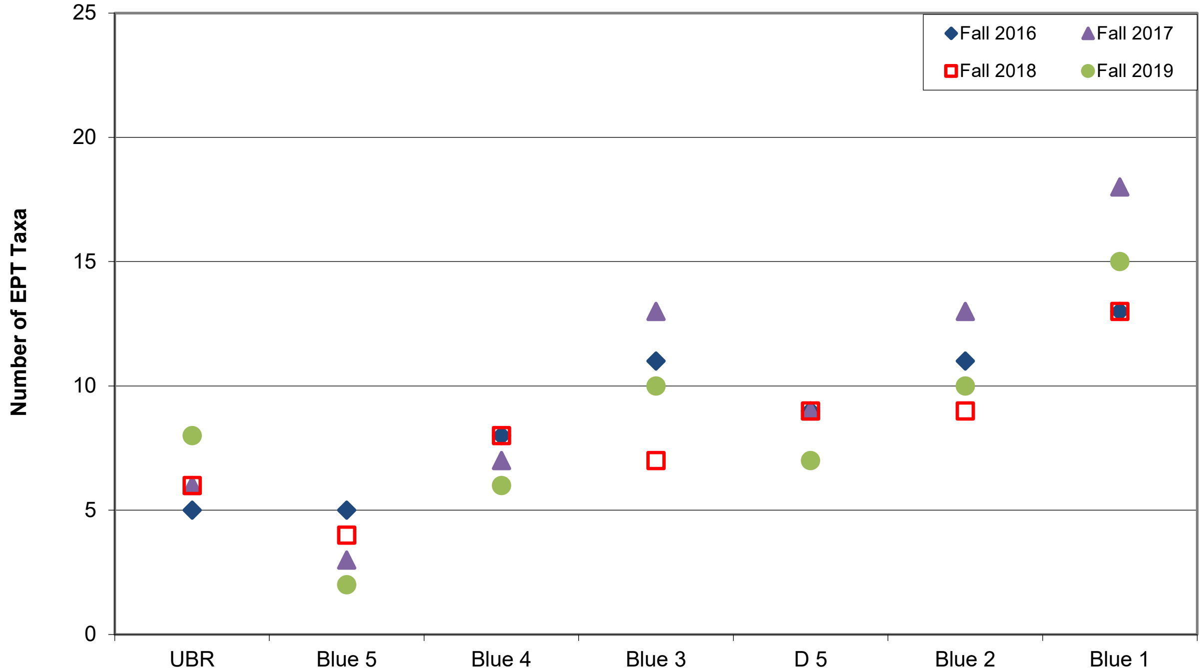

Figure 3. Number of EPT Taxa from study sites on the Blue River during the fall of 2016, 2017, 2018, and 2019. Data provided by USFS.

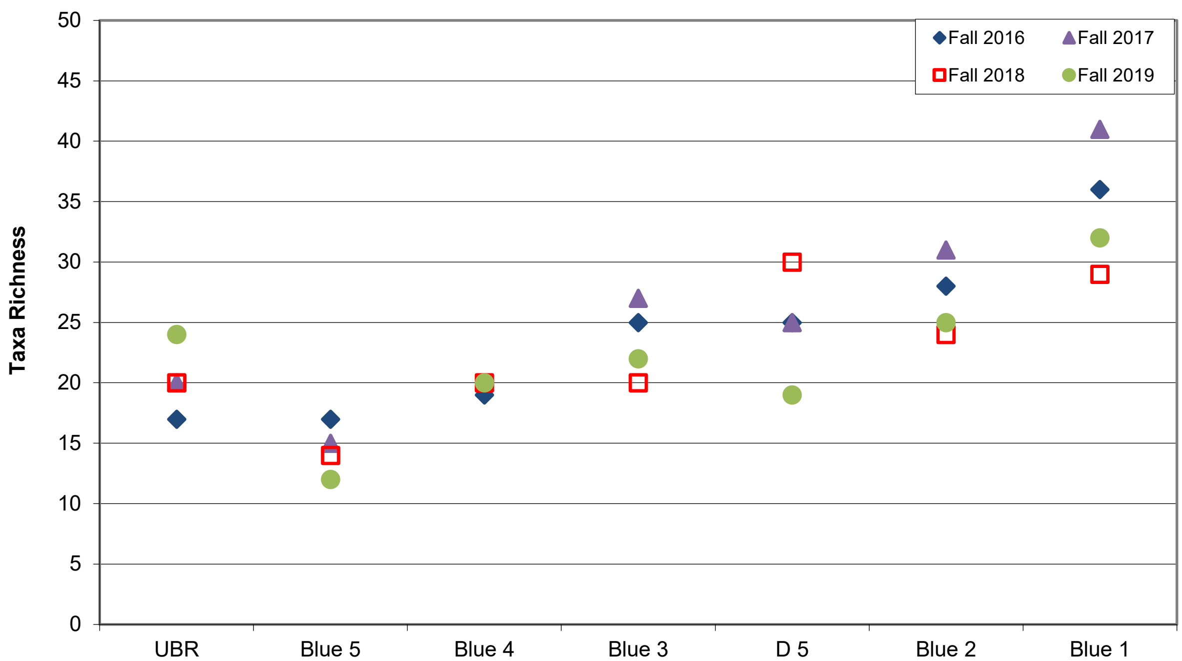

Figure 4. Taxa Richness from study sites on the Blue River during the fall of 2016, 2017, 2018, and 2019. Data provided by USFS.

APPENDIX D
D-2 Blue River Benthic Macroinvertebrate Report 2020

Benthic Macroinvertebrate Biomonitoring/Surveys

Summary Report

Benthic Macroinvertebrate Biomonitoring/Surveys Blue River, Colorado

2020

Prepared for:

The Blue River Watershed Group
and Trout Unlimited

Prepared by:

David E. Rees
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Fort Collins, Colorado 80526

10 March 2021

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10 March 2021

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Introduction

The environmental effects of dams and impoundments that modify a wide range of abiotic and biotic factors downstream have been relatively well-documented and reviewed (Ward 1976, 1982, Baxter 1977, Ward and Stanford 1979, 1983, Schmidt and Wilcock 2008, Ellis and Jones 2013, White et al. 2016, Krajenbrink et al. 2019). The above published studies have shown that major downstream impacts of dams include changes in flow patterns, riverine thermal regimes (depending if dam releases are from the surface, bottom, or mixed), increased or decreased sedimentation, changes in water chemistry, and alterations to the structure and function of benthic macroinvertebrate communities. Usually, two recovery gradients occur in these regulated rivers (Ellis and Jones 2013), (1) a longer thermal gradient often taking more than 30 kilometers to ameliorate and (2) a shorter resource subsidy gradient within 1-4 km downstream of the impoundment. These two gradients are expected to influence the structure of macroinvertebrate communities in regard to presence or absence of taxa, abundance, trophic ecology, and life histories. Decreases in macroinvertebrate taxa richness and abundances below dams have also been attributed to changes in the predominant substrate composition, a change from course to fine particle size (Wang et al. 2020). It has also been shown that intolerant macroinvertebrate taxa generally decrease in relative abundance, whereas more tolerant taxa remain the same or increase (Santucci et al. 2003). For example, Ephemeroptera (mayflies) and Plecoptera (stoneflies) abundance decreased downstream from an impoundment (Bredenhand and Samways 2009, Gillespie et al. 2014, White et al. 2016), while Diptera (true flies) abundance and richness increased or remained relatively constant (Bredenhand and Samways 2009, Santucci et al., 2003). Detailed studies on specific aquatic insect orders such as Ephemeroptera and Trichoptera (caddisflies) have supported the above conclusions (Ward 1987, Brittain 1989, Voelz and Ward 1996). Stanford et al. (1996) suggested that mitigative protocols may be necessary to restore the ecological integrity of rivers regulated by dams, especially pertaining to macroinvertebrate community structure and function.

Colorado, like much of the western U.S., is well-known for its numerous impoundments on rivers and streams of various sizes. Several detailed studies document the downstream impacts of regulated Colorado rivers on benthic macroinvertebrate communities (Stanford and Ward 1984, Zimmerman and Ward 1984, Rader and Ward 1988, Voelz and Ward 1991, Collier et al. 1996). These studies support the concept that changes in flow patterns and riverine thermal regimes below dams clearly impact the structure and function of macroinvertebrate communities for many kilometers downstream. Previous studies on the Blue River below Dillon Reservoir by Voelz and Ward (1989, 1990) determined that a sequential macroinvertebrate community gradient occurred within the first 20 km below the impoundment. An incremental improvement in benthic macroinvertebrate species diversity in a downstream direction was attributed (in part) to the recovery of a more natural thermal regime. Other probable variables influencing macroinvertebrate community distributional patterns included a shift in food resources, from filamentous algae below the dam to diatoms and detritus farther downstream.

In summary, downstream effects of impoundments can be characterized as dampening or completely shifting seasonal patterns in macroinvertebrate community structure and function. Although some of the most profound abiotic and biotic alterations occur within 1-4 km downstream of the impoundment, there are often detectable impacts for more than 30 kilometers below a deep-release impoundment.

Study Area

During seasonal monitoring (spring, summer, and fall) in 2020, a total of ten (10) stations were sampled to evaluate the health of benthic macroinvertebrate communities in the Blue River (Table 1, Figure 1). Sampling sites included one location upstream from Dillon Reservoir, eight locations between Dillon Reservoir and Green Mountain Reservoir, and one sampling location downstream from Green Mountain Reservoir. Study sites were generally selected to assess impacts and recovery from regulated flows and the altered thermal regime downstream from impoundments. Study sites upstream from reservoirs were used to provide reference information. Sampling locations between Dillon Reservoir and Green Mountain Reservoir were strategically positioned in areas where there was historical data and/or potential influences to the temperature and flow regime from physical stream attributes or tributaries. A comparison of metric values obtained from each study site provided information regarding changes in the structure and health of benthic macroinvertebrate communities found throughout the study area.

Table 1. Coordinates and elevations of sample sites on Blue River in 2020.

	Latitude	Longitude	Elevation (m)
UBR	39.56651	-106.04884	2773
Blue 5	39.62601	-106.06658	2684
DRD	39.63651	-106.07419	2675
Blue 3	39.65595	-106.07685	2647
D 5	39.70545	-106.11062	2596
Blue 2	39.72713	-106.1321	2574
Blue 1	39.74336	-106.13196	2558
SCR	39.78217	-106.16035	2502
BRC	39.8217	-106.20584	2443
LBR	39.92729	-106.3528	2296

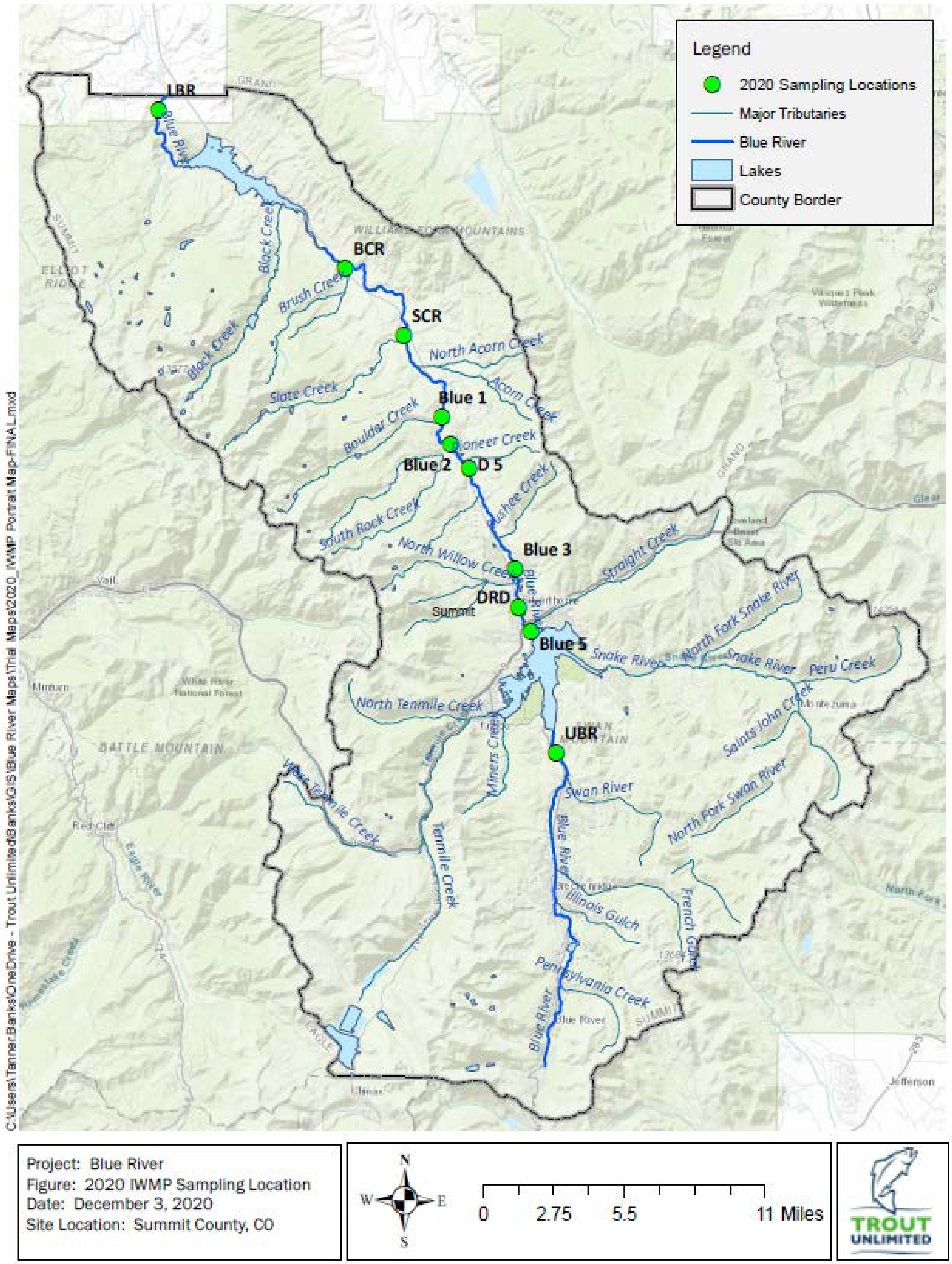

Figure 1. Map of study sites used for Blue River benthic macroinvertebrate monitoring in 2020.

Methods

The purpose of this biomonitoring study was to assess seasonal variability in benthic macroinvertebrate communities at specific locations along the Blue River where releases from Dillon Reservoir and/or other anthropogenic stressors (e.g., urban runoff, etc.) may be influencing the health of aquatic life. The objective of this study required that three (3) quantitative replicate Hess samples were taken from similar habitat at each study site. Several biotic analysis tools (metrics) were included in this study to account for different types of responses to various stressors. This approach was designed to identify the spatial distribution of disturbances as well as any seasonal variability.

Three replicate, quantitative samples were collected from ten study sites on the Blue River during April, August, and November (spring, summer, and fall) of 2020. All samples were collected from similar habitat (riffle habitat) to provide benthic macroinvertebrate data that was representative and comparable throughout the study area. Substrate within each sample was thoroughly agitated and individual rocks were scrubbed by hand to dislodge benthic organisms. All macroinvertebrates were rinsed into sample jars and preserved in 80% ethanol solution. Each sample jar was labeled with date, location, and sample ID number on the outside and inside of each container. All samples were transported to the lab at Timberline Aquatics, Inc. where benthic macroinvertebrates were sorted, identified, and enumerated. The sorting and identification process was conducted for each entire sample to avoid any potential problems or controversy associated with subsampling.

The sorting process involved separating macroinvertebrates from debris in each sample. All macroinvertebrates were removed from each sample and placed into vials containing coarse taxonomic groups. Benthic macroinvertebrates were then identified to a taxonomic level consistent with the Operational Taxonomic Unit (OTU) established by the Water Quality Control Division (WQCD) for the Colorado Department of Public Health and Environment (CDPHE). This level of identification was typically genus or species for mayflies, stoneflies, caddisflies, and many dipterans. Members of the family Chironomidae were also identified to the genus level. Specimens were identified using a variety of taxonomic keys including Ward et al. (2002) and Merritt et al. (2008). As part of the quality control protocols at Timberline Aquatics, Inc., all sorted macroinvertebrate samples were checked by a qualified taxonomist, and 10% of identifications were checked for accuracy at Colorado State University.

Population densities and species lists were developed for each sampling event during 2020 and a variety analysis tools were used to provide information regarding aquatic conditions. All macroinvertebrate data were analyzed using the MMI v4 and an assortment of individual metrics. The following section provides a brief description of each tool that was used to assess the health of aquatic communities in this study.

Multi-Metric Index (MMI v4)

In the fall of 2010, the WQCD developed a Multi-Metric Index (MMI) to assist in the evaluation of benthic macroinvertebrate data from across the State of Colorado (Colorado Department of Public Health and Environment 2010). In 2017, the MMI was recalibrated and updated to produce a new analysis tool (the MMI v4) that relies on specific methods and protocols for sample processing and analysis (Colorado Department of Public Health and Environment 2017). This most recent version of the MMI provides a single index score based on eight equally weighted metrics. The MMI v4 was applied to quantitative macroinvertebrate data collected from the Blue River in 2020 using the guidelines established in the WQCD Listing Methodology, 2020 Listing Cycle (Colorado Department of Public Health and Environment 2019).

The group of metrics used in MMI v4 calculations depends on the sampling location and corresponding Biotype (Mountains, Transitional, or Plains). In the Blue River study area, the eight most upstream study sites were located in Biotype 2 (Mountains), while sites BRC and LBR were located within Biotype 1 (the Transition Zone), which includes lower mountain areas in the State of Colorado. Each of the individual metrics used in the analysis produces a score that is adjusted to a scale from 1 to 100 based on the range of metric scores found at "reference sites". In Biotype 1, these metrics include: EPT Taxa, % Non-Insect Individuals, % EPT Individuals (no Baetidae), % Coleoptera Individuals, % Intolerant Taxa, % Increaser Individuals (Mid-Elevation), Clinger Taxa, and Predator/Shredder Taxa. In Biotype 2, these metrics include: EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, Total Taxa, Intolerant Taxa, % Increasers (Mountains), Predator Taxa, and % Scraper Individuals. A detailed description of the component metrics and methods used to calculate MMI v4 scores can be found in the *Aquatic Life Use Attainment: Methodology to Determine Use Attainment for Rivers and Streams*, *Policy 10-1* and Appendix D in the *Section 303(d) Listing Methodology 2020 Listing Cycle* (Colorado Department of Public Health and Environment 2017 and 2019). The MMI v4 was developed using macroinvertebrate data that was mostly collected during the late summer or fall; therefore, it is expected to be most accurate when applied during those seasons. Thresholds for the MMI v4 in Biotypes 1 and 2 are as follows:

Biotype	Attainment Threshold	Impairment Threshold
Transitional (Biotype 1)	45.2	33.7
Mountains (Biotype 2)	47.5	39.8

MMI v4 scores that fall between the thresholds for attainment and impairment (the 'Grey Zone') require further evaluation using additional metrics to determine an aquatic life use designation. The additional metrics include Shannon Diversity (Diversity) and the Hilsenhoff Biotic Index (HBI). The specific thresholds for the auxiliary metrics in Biotypes 1 and 2 are listed below, followed by descriptions of each metric:

Biotype	HBI	Diversity
Transitional (Biotype 1)	5.8	2.1
Mountains (Biotype 2)	4.9	3.2

Shannon Diversity (Diversity): Diversity was used as an auxiliary metric for the MMI v4 and as an independent metric in this study to evaluate changes in macroinvertebrate community structure by providing a measure of community balance. In unpolluted waters, Diversity values typically range from near 3.0 to 4.0. In polluted waters, this value is generally less than 1.0 (Ward et al. 2002).

Hilsenhoff Biotic Index (HBI): The HBI is another auxiliary metric used for the MMI v4; however, it is also valuable as an independent metric and has been widely used and/or recommended in numerous regional biomonitoring studies (Paul et al. 2005). Most of the value from this metric lies in the detection of organic pollution, but it is also used to evaluate aquatic conditions in a variety of other circumstances. The HBI was originally developed using macroinvertebrate taxa from streams in Wisconsin; therefore, it may require regional modifications (Hilsenhoff 1988). Tolerance values for taxa occurring in this study area were taken from a list provided by the CDPHE, which was derived from a variety of regional sources. Although HBI values may naturally vary among regions, a comparison of the values produced within the same river system should provide information regarding locations impacted by nutrient-enrichment and/or other aquatic disturbances. Values for the HBI range from 0.0 to 10.0, and increase as water quality decreases.

Additional Metrics Used in this Study

In addition to the MMI v4 and associated auxiliary metrics, several other individual metrics were applied in the analysis of macroinvertebrate data from sites in the Blue River study area in order to provide a more thorough evaluation of macroinvertebrate community structure and function. The following section provides a description of each individual metric used in this study:

Richness measures:

Ephemeroptera Plecoptera Trichoptera (EPT Taxa): The effectiveness of this metric is based on the assumption that the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) are generally more sensitive to pollution/perturbations than other benthic macroinvertebrate orders (Lenat 1988). The EPT metric is currently an important and widely used metric in many regions of the United States (Barbour et al. 1999). The EPT Taxa value is simply given as the total number of distinguishable taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera found at each sampling location. For the purpose of this study, each major component (insect order) used in this metric was viewed separately in addition to the total EPT Taxa value. Results from this metric are expected to naturally vary among river systems, but this tool can be an excellent indicator of disturbances within a specific drainage. The EPT value is expected to decrease in response to a variety of stressors including nutrients (Wang et al. 2007).

Taxa Richness: The Taxa Richness (or Total Taxa) metric is reported as the total number of identifiable taxa collected from each sampling location. Total Taxa has become one of the most widely used metrics to evaluate stream health, as it provides a general indication of community health and stability (Courtemanch 1996). Total Taxa values are expected to decrease with increased perturbations to the aquatic environment (Resh and Jackson 1993).

Number of Clinger Taxa: This metric requires the reorganization of macroinvertebrates into groups based on their habits or modes of locomotion. The Number of Clinger Taxa metric includes those macroinvertebrates which are adapted to attach to relatively clean benthic substrate. Perturbations such as excessive sedimentation, rapid changes in discharge, or excessive algal growth can cause a reduction in this metric value (Hughes and Brossett 2009).

***Composition measures*:**

Percent Clinger Taxa: The Percent Clinger Taxa metric generally relies on the assumption that changes in preferred habitat will result in negative impacts to benthic macroinvertebrates with specific habitat adaptations. The above list of perturbations (sedimentation, rapid changes in discharge, and excessive algal growth) should not only reduce the richness of clinger taxa, but these types of impacts should also cause a decline in the proportion of these specialized macroinvertebrates.

Percent Scrapers and Shredders: Scrapers and shredders are often considered sensitive to disturbances because they are specialized feeders (Barbour et al. 1999). Consequently, these sensitive feeding groups are expected to be well-represented in healthy streams. Much of the value in this type of analysis comes from a comparison of sites within a specific study area.

Percent Chironomidae: The midge family Chironomidae is generally considered to be fairly tolerant of environmental stress compared to other aquatic insect families (Plafkin et al. 1989). The Percent Chironomidae metric relies on the assumption that the proportion of representatives from this family will increase with increasing stress or pollution. Streams that are undisturbed often have a relatively even distribution of Ephemeroptera, Plecoptera, Trichoptera, and Chironomidae (Mandaville 2002); while the family Chironomidae often dominates (75% or more of the macroinvertebrate density) at sites degraded by metals or other pollutants (Barton and Metcalf-Smith 1992). Most species in the family Chironomidae tend to have a relatively short life-cycle which enables them to continually re-colonize unstable or polluted habitats, making their abundance a relatively reliable indicator of environmental stress (Lenat 1983).

Percent EPT: As previously stated, most taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera are expected to be sensitive to environmental perturbations or pollution. Therefore, the percentage of individuals from EPT orders provides a measure of benthic macroinvertebrates (at each sampling location) that are expected to be sensitive to anthropogenic stressors or pollution. To improve accuracy and provide context to the Biomass analysis, each component of the Percent EPT metric (Ephemeroptera, Plecoptera, and Trichoptera) was calculated separately. A decrease in the Percent EPT value suggests that the benthic macroinvertebrate community consists of a higher proportion of tolerant taxa.

***Abundance measures*:**

Density: Macroinvertebrate abundance (Density) was reported as the mean number of macroinvertebrates per m^2 found at each study site. The Density metric provides a means of measuring and comparing standing crop at each site. This metric can be useful when compared among sites or paired with other individual metrics used in this study.

Biomass: Biomass was reported as the mean dry weight of benthic macroinvertebrates per m^2 at each site. Biomass values were obtained by drying macroinvertebrates from each sample in a scientific drying oven at 100° C for 24 hours or until all water content had evaporated (no decrease in weight could be detected). Biomass values provided production-related information in terms of weight of macroinvertebrates produced at each site. Density and Biomass values offered a means of measuring standing crop, which provided an indication of productivity for the macroinvertebrate portion of the food web at each sampling location.

***Trophic measures*:**

Functional Feeding Groups: Most of the previously described metrics use macroinvertebrate information that is based upon community structure; however, macroinvertebrate taxa were also separated into functional guilds based on methods of food acquisition to provide a measure of ecological function. All specimens were categorized according to feeding strategy to determine the relative proportion of various groups. Some representation of each feeding group usually indicates healthy aquatic conditions; however, it is normal for certain groups (such as collector-gatherers) to be more abundant than others (Ward et al. 2002). Scrapers and shredders are often considered sensitive to disturbance because they are specialized feeders (Barbour et al. 1999). Consequently, these sensitive groups are expected to be well-represented in healthy streams. Much of the value in this type of analysis comes from the comparison of sites within a specific drainage. Changes in the proportion of functional feeding groups can provide insight into various types of stress in river systems (Ward et al. 2002).

Results/Discussion

Quantitative benthic samples were collected from ten (10) study sites on the Blue River during the spring (20 April), summer (17 August), and fall (6-7 November) of 2020 to evaluate the health (structure and function) of benthic macroinvertebrate communities. After samples were collected, they were transported to the lab at Timberline Aquatics, Inc. where specimens were sorted, identified, and enumerated (Appendix A; Tables A1-A10, Appendix B; Tables B1-B10, Appendix C; Tables C1-C10). The previously described metrics and analysis tools (including the MMI v4) were applied to the macroinvertebrate data to provide a comprehensive assessment of macroinvertebrate community health in the study area.

In general, results from 2020 demonstrated considerable variability in the structure, function, and health of benthic macroinvertebrate communities among sites on the Blue River. Despite the variability observed among study sites, certain sampling locations showed consistent evidence of stress, while other sites tended to support relatively healthy aquatic communities, regardless of the season. The presence of impoundments and other anthropogenic activities appeared to have a substantial influence on the health of macroinvertebrate communities within the study area.

The MMI v4

In the spring, summer, and fall of 2020, a comprehensive evaluation of benthic macroinvertebrate community health in the Blue River was provided by the MMI v4. All samples were processed according to the guidelines provided in Appendix D of the *Section 303(d) Listing Methodology 2020 Listing Cycle* (WQCD 2019). Changes in macroinvertebrate community health from upstream to downstream were demonstrated by MMI v4 and the individual (component) metrics used in MMI v4 calculations (Tables 2-4). A comparison of MMI v4 scores among seasons showed some spatial consistencies in the health of aquatic communities; however, certain study sites showed greater variability in macroinvertebrate community structure and function.

Study sites on the Blue River were distributed between two Biotypes in the State of Colorado (based on State classifications). The eight most upstream sampling sites were located in mountain habitat (Biotype 2), while the remaining two study sites (BRC and LBR) were located in a transitional area (Biotype 1) between the mountains and plains. In order to correctly utilize the MMI v4, all specimens were identified to the Operational Taxonomic Unit (OTU) that was established by the WQCD. For each Biotype, the MMI v4 was calculated using the appropriate set of component metrics, and final scores were evaluated using the corresponding thresholds for ‘attainment’ and ‘impairment’. While it is not always appropriate to compare MMI v4 scores between Biotypes, some of the component metrics or individual metrics in the following section provided an opportunity to make comparisons throughout the study area.

During the spring season (20 April 2020), the MMI v4 indicated that the greatest stress to benthic macroinvertebrate communities occurred immediately downstream from Dillon Reservoir, with gradual improvements generally detected in a downstream direction (Table 2, Figure 2). Scores from the MMI v4 in Biotype 2 ranged from 15.0 at site Blue 5 to 64.8 at site SCR. Farther downstream, the two study sites located in Biotype 1 (BRC and LBR) generated relatively high MMI v4 scores (71.6 and 66.8, respectively) both upstream and downstream from Green Mountain Reservoir (Table 2). Components of the MMI v4 suggested that much of the stress to aquatic life downstream from Dillon Reservoir could be attributed to the loss of sensitive and specialized macroinvertebrates (based on the EPT Taxa, % EPT Individuals [no Baetidae], and % Scraper Individuals scores). As the richness of sensitive taxa and relative abundance of sensitive and specialized individuals increased, MMI v4 scores responded by indicating consistent improvements in macroinvertebrate community health with distance downstream from the impoundment (Figure 2). During the spring of 2020, the only study site that produced a MMI v4 score in the 'Grey Zone' (the range of scores between the 'attainment' and 'impairment' thresholds) was the 'reference site' (UBR). Although this site provided reference information related to reservoir influences, it is likely that this location was also impacted by other anthropogenic stressors (including runoff from an adjacent highway). The three consecutive study sites immediately downstream from Dillon Reservoir were the only sampling locations that produced MMI v4 scores below the 'impairment' threshold, while data from remaining study sites generated scores above the 'attainment' threshold. The auxiliary metrics (Diversity and HBI) followed a similar pattern showing general improvements (with distance) downstream from the reservoir (Table 2). The results provided by the MMI v4 (and auxiliary metrics) in the spring of 2020 provided strong evidence suggesting that most of the stress to benthic macroinvertebrate communities in the study area was likely associated with the existence and operations of Dillon Reservoir. The health of macroinvertebrate communities gradually improved for more than 12 kilometers downstream from this impoundment.

During the summer (17 August) of 2020, the MMI v4 continued to detect impacts to aquatic life downstream from Dillon Reservoir, with some recovery near the downstream boundary of the study area (Table 3). Once again, the reference site (UBR) produced a MMI v4 score in the 'Grey Zone', and auxiliary metrics indicated that this sampling location remained in 'attainment' for aquatic life use. Downstream from the Dillon Reservoir, relatively severe impacts to aquatic life were observed at site Blue 5, followed by rapid recovery at site Blue 3. A second decline in MMI v4 scores was observed at site D 5 followed by slow recovery in a downstream direction (Figure 3). Detectable impacts downstream from the impoundment could mostly be attributed to a reduction in the proportion of sensitive and specialized individuals (based on % EPT Individuals [no Baetidae] and % Scraper Individuals, respectively), and an increase in the proportion of taxa that are resistant to environmental stressors or pollution (% Increasers, Mountain Trn). MMI v4 scores in Biotype 2 ranged from 18.2 at site Blue 5 to 56.4 at site Blue 3 (Table 3). Downstream from site D 5, improvements in the overall health of communities were gradual, with site SCR generating one of the few MMI v4 scores that was above the ‘attainment’ threshold for Biotype 2. Both sites in Biotype 1 (BRC and LBR) produced similar MMI v4 scores during August 2020, indicating ‘attainment’ for aquatic life use at those locations (Figure 3). While the influences of releases from Dillon Reservoir continued to be the most likely source of disturbance to macroinvertebrate communities in the summer season, the low MMI v4 score at site D 5 and slow rate of recovery in a downstream direction suggested that there may be other sources of anthropogenic stress (e.g., urban runoff, etc.) in this study area (Table 3).

Benthic macroinvertebrate sampling continued on 6-7 November, 2020 at the same ten study sites that were sampled during the spring and summer seasons. Results from the MMI v4 (and associated metrics) generally displayed a longitudinal pattern of change during the fall season that was similar to the pattern observed during the spring (Figures 2 and 4). Scores generated by the MMI v4 in Biotype 2 ranged from 18.1 (site Blue 5) to 68.9 (site SCR), while the two study sites in Biotype 1 (BRC and LBR) generated relatively high MMI v4 scores (82.7 and 72.1, respectively) both upstream and downstream from Green Mountain Reservoir (Table 4). The component metrics for the MMI v4 that detected the greatest stress downstream from Dillon Reservoir included the % EPT Individuals (no Baetidae), Clinger Taxa, % Increasers (Mountain Trn), and % Scraper Individuals. These metrics suggested that the macroinvertebrate community below the reservoir consisted of high proportions of tolerant taxa that were less specialized in their habits and habitat requirements. Many component metric scores improved rapidly between sites Blue 5 and DRD; however, MMI v4 scores remained relatively stable from site DRD to site D 5 (Table 4, Figure 4). It is possible that the potential for continued recovery in this stream segment was somewhat inhibited by other sources of anthropogenic stress. Eventually, improvements in most component metrics led to considerably higher MMI v4 scores in the downstream portion of the study area (Table 4). Based on the results provided by the MMI v4, the presence of Green Mountain Reservoir had much less of a negative influence on the benthic macroinvertebrate community at site LBR during the fall (and other seasons) in 2020 (Figures 2-4).

Over the course of seasonal sampling, several study sites produced MMI v4 scores that fell into the ‘Grey Zone’ (the range of scores between the ‘attainment’ and ‘impairment’ thresholds). Auxiliary metrics (HBI and Diversity) were applied to all macroinvertebrate data collected in 2020 to determine the status of MMI v4 scores that were in the ‘Grey Zone’, and to assist in the evaluation of macroinvertebrate data throughout the study area (Figures 5 and 6).

During all seasons, the majority of HBI values remained relatively low and showed little variability in the proportions of nutrient-tolerant individuals among study sites (Figure 5). In most cases, HBI values were below the threshold set by the WQCD, and the only exceedances were found at site Blue 5 (in Biotype 2) during the spring and summer (Tables 2 and 3). It is possible that the altered thermal regime immediately downstream from Dillon Reservoir was at least partially responsible for elevated HBI values during these two seasons. Overall, results from the HBI exhibited some spatial and seasonal variability, but most values remained below the State’s threshold, suggesting that nutrient-enrichment was probably not a substantial cause for stress within the study area (Figure 5). It is important to note that the elevated HBI values produced for site Blue 5 had no influence on the aquatic life use designations, because MMI v4 scores for these sampling events were already below the 'impairment' threshold.

The Diversity metric was also calculated (as part of the MMI v4 tool) using macroinvertebrate data from all three seasons. In 2020, several study sites produced values that were below the State's 'impairment' threshold (3.2) in Biotype 2, indicating that community balance may have been adversely affected by reservoir operations or other anthropogenic activities (Figure 6). Alternatively, Diversity values from the two sites in Biotype 1 were among the highest in the study area and well-above the threshold of 2.1 (Figure 6). During the spring season, only one site (UBR) produced an MMI v4 score in the 'Grey Zone', and data from this site generated HBI and Diversity values indicating that it was in 'attainment' for aquatic life use (Table 2). During the summer, low Diversity values were responsible for 'impairment' designations for two study sites (Blue 2 and Blue 1) that generated MMI v4 scores in the 'grey zone', and in the fall, sites DRD and Blue 3 were also determined to be 'impaired' based on low Diversity values (Tables 3 and 4). In general, macroinvertebrate community balance appeared to be consistently impacted immediately downstream from Dillon Reservoir, and the somewhat inconsistent pattern of recovery that followed in a downstream direction supported the possibility of influences from other seasonal anthropogenic stressors.

In summary, a wide range of MMI v4 scores were obtained within the study area during the three seasons in 2020. Results from the MMI v4 consistently indicated that the reference site (UBR) was in 'attainment' for aquatic life use during 2020; however, component metrics from all three seasons suggested that there was likely mild to moderate stress occurring at this location. Results from the MMI v4 and auxiliary metrics indicated that benthic macroinvertebrate communities were 'impaired' at the three study sites downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) in the spring and fall, while a total of five sampling locations generated MMI v4 scores indicating 'impairment' during the summer (Table 5). Farther downstream, improvements in MMI v4 scores were consistently observed near the downstream boundary of the study area. Alterations from the natural flow and temperature regime imposed by reservoir operations were likely responsible for a decline in the richness and abundance of sensitive and specialized taxa. Several components of the MMI v4 that consistently detected these types of impacts included the EPT Taxa, % EPT Individuals (no Baetidae), Clinger Taxa, % Increasers (Mountain Trn), and % Scraper Individuals. Seasonal and spatial variability in the pattern of recovery with distance downstream from the reservoir suggested that there may be other factors (such as gradient, substrate, tributaries, and/or other sources of anthropogenic stress) influencing the health and recovery of benthic macroinvertebrate communities. In addition to the MMI v4, a variety of other metrics and analysis tools were used to further describe the overall health (structure and function) of benthic macroinvertebrate communities in this study area.

Table 2. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 20 April 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	65.7	21.9	51.1	73.1	73.1	87.7	95.0	80.4	62.5	70.8
% EPT individuals, no Baetidae	32.3	0.8	5.2	10.6	59.2	44.8	53.9	62.4	100.0	42.1
Clinger Taxa	45.0	15.0	30.0	45.0	50.0	55.0	55.0	50.0	72.1	81.7
Total Taxa	57.1	28.6	42.9	54.8	64.3	59.5	57.1	64.3	--	--
Intolerant Taxa	52.4	19.0	38.1	47.6	57.1	66.7	61.9	61.9	--	--
% Increasers, Mountain Trn	34.5	0.5	6.2	14.4	22.0	41.6	51.9	67.6	--	--
Predator Taxa	53.8	23.1	30.8	38.5	46.2	38.5	53.8	46.2	--	--
% Scraper individuals	24.5	11.2	5.5	17.5	29.0	73.0	78.7	85.5	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	92.4	94.2
% Coleoptera individuals	--	--	--	--	--	--	--	--	3.5	3.3
% Intolerant Taxa	--	--	--	--	--	--	--	--	82.0	84.8
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	95.8	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	64.3	57.1
MMI Score	**45.7**	**15.0**	**26.2**	**37.7**	**50.1**	**58.3**	**63.4**	**64.8**	**71.6**	**66.8**
Auxiliary Metrics										
Shannon Diversity	3.69	2.70	1.49	2.76	3.31	3.59	3.60	3.82	3.59	3.77
HBI	4.29	5.13	4.80	4.82	2.73	3.80	3.43	3.59	2.65	3.86
TIV (Sediment Region 1)	4.84	6.06	4.34	5.00	4.31	5.00	4.63	4.50	NA	NA

Table 3. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 17 August 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	48.2	21.9	48.2	65.7	35.0	52.5	61.3	52.5	54.2	54.2
% EPT individuals, no Baetidae	41.5	3.5	16.4	52.9	29.4	27.6	30.3	44.3	27.5	24.1
Clinger Taxa	50.0	30.0	45.0	70.0	35.0	55.0	60.0	50	52.9	38.5
Total Taxa	57.1	33.3	47.6	61.9	45.2	64.3	61.9	71.4	--	--
Intolerant Taxa	42.9	28.6	52.4	71.4	42.9	61.9	61.9	66.7	--	--
% Increasers, Mountain Trn	42.5	3.8	15.3	54.6	4.1	12.8	15.0	28.0	--	--
Predator Taxa	38.5	23.1	30.8	46.2	30.8	76.9	69.2	61.5	--	--
% Scraper individuals	2.1	1.3	9.8	28.9	3.3	8.1	5.4	8.8	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	92.2	99.3
% Coleoptera individuals	--	--	--	--	--	--	--	--	9.0	2.6
% Intolerant Taxa	--	--	--	--	--	--	--	--	67.8	78.7
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	94.8	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	57.1	50.0
MMI Score	**40.3**	**18.2**	**33.2**	**56.4**	**28.2**	**44.9**	**45.6**	**47.9**	**56.9**	**55.9**
Auxiliary Metrics										
Shannon Diversity	3.21	0.98	2.02	3.21	1.98	2.86	2.72	4.00	3.33	3.73
HBI	3.49	4.91	4.52	3.37	4.61	4.57	4.60	3.35	4.51	3.83
TIV (Sediment Region 1)	4.21	4.33	4.38	3.97	5.55	5.24	5.02	4.74	NA	NA

Table 4. MMI v4 scores from composited replicate Hess samples collected from ten study sites on the Blue River on 6-7 November 2020. Scores indicating 'impairment' are provided in red.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
	Biotype 2								Biotype 1	
EPT Taxa	36.7	20.4	49.0	40.8	44.9	49.0	53.1	57.1	79.2	66.7
% EPT individuals, no Baetidae	70.5	4.6	45.7	36.7	50.8	54.9	54.0	76.2	100.0	66.0
Clinger Taxa	45.0	15.0	50.0	50.0	45.0	65.0	60.0	70.0	96.2	72.1
Total Taxa	42.9	33.3	52.4	50.0	50.0	66.7	59.5	71.4	--	--
Intolerant Taxa	47.6	28.6	57.1	52.4	61.9	66.7	76.2	81.0	--	--
% Increasers, Mountain Trn	67.4	4.6	54.0	58.4	29.7	46.1	49.2	57.0	--	--
Predator Taxa	30.8	30.8	38.5	38.5	30.8	61.5	53.8	69.2	--	--
% Scraper individuals	84.3	7.5	2.7	11.1	13.1	71.9	61.5	69.2	--	--
% Non-Insect individuals	--	--	--	--	--	--	--	--	96.4	86.7
% Coleoptera individuals	--	--	--	--	--	--	--	--	4.5	21.2
% Intolerant Taxa	--	--	--	--	--	--	--	--	100.0	100.0
% Increasers, Mid-Elevation	--	--	--	--	--	--	--	--	100.0	100.0
Predator/Shredder taxa	--	--	--	--	--	--	--	--	85.7	64.3
MMI Score	**53.2**	**18.1**	**43.7**	**42.2**	**40.8**	**60.2**	**58.4**	**68.9**	**82.7**	**72.1**
Auxiliary Metrics										
Shannon Diversity	2.78	2.81	2.81	3.03	3.35	3.55	3.13	3.88	3.96	3.45
HBI	3.10	2.97	3.27	3.76	2.75	3.31	3.65	2.67	2.42	3.11
TIV (Sediment Region 1)	3.49	4.87	3.75	4.31	4.09	4.41	3.84	4.02	NA	NA

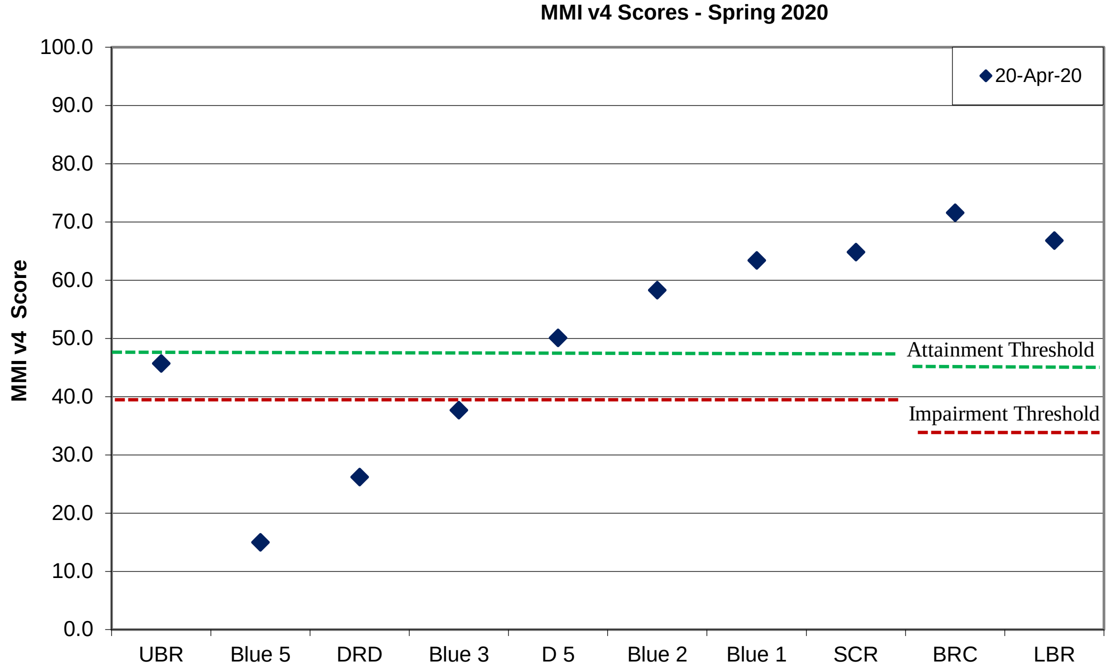

Figure 2. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during April 2020.

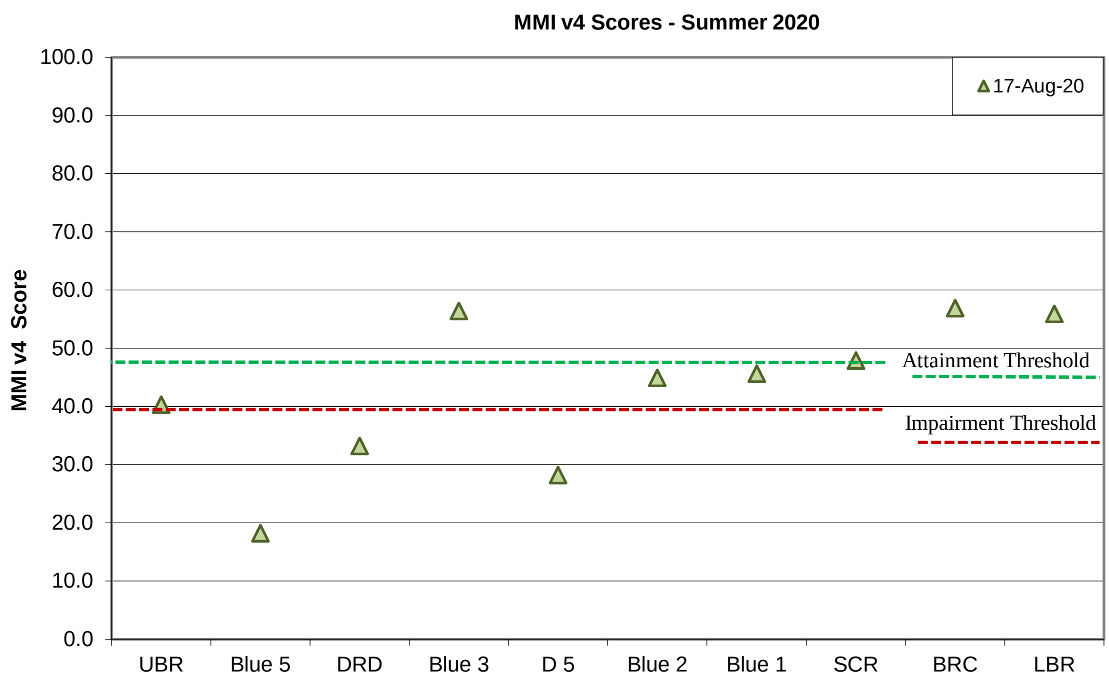

Figure 3. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during August 2020.

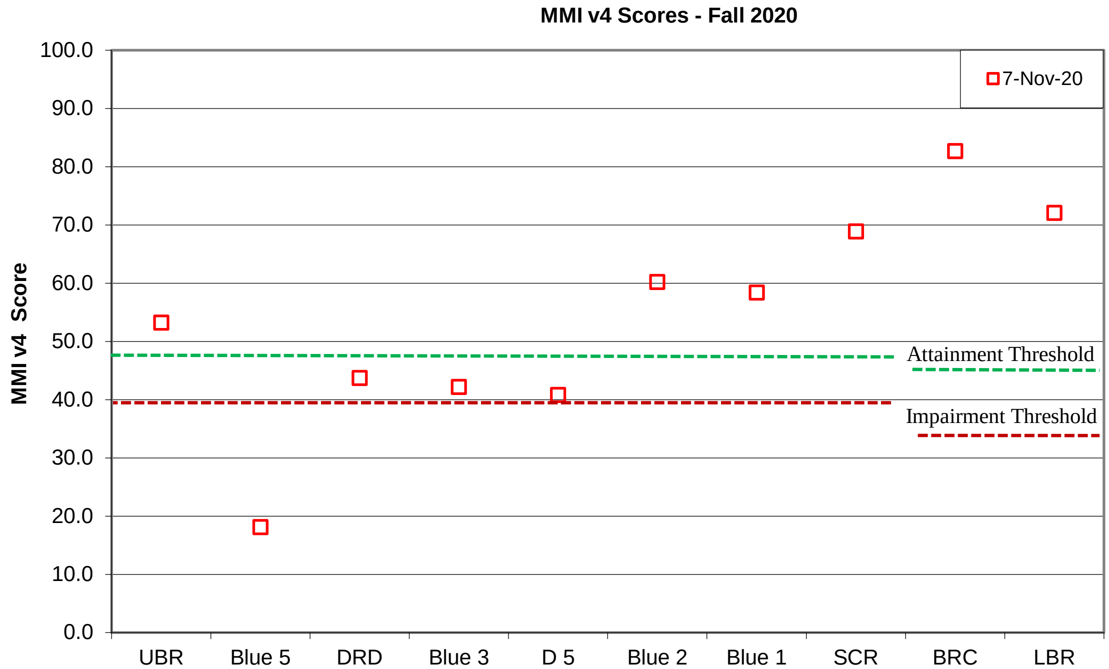

Figure 4. MMI v4 scores from composited quantitative (Hess) samples at study sites on the Blue River during November 2020.

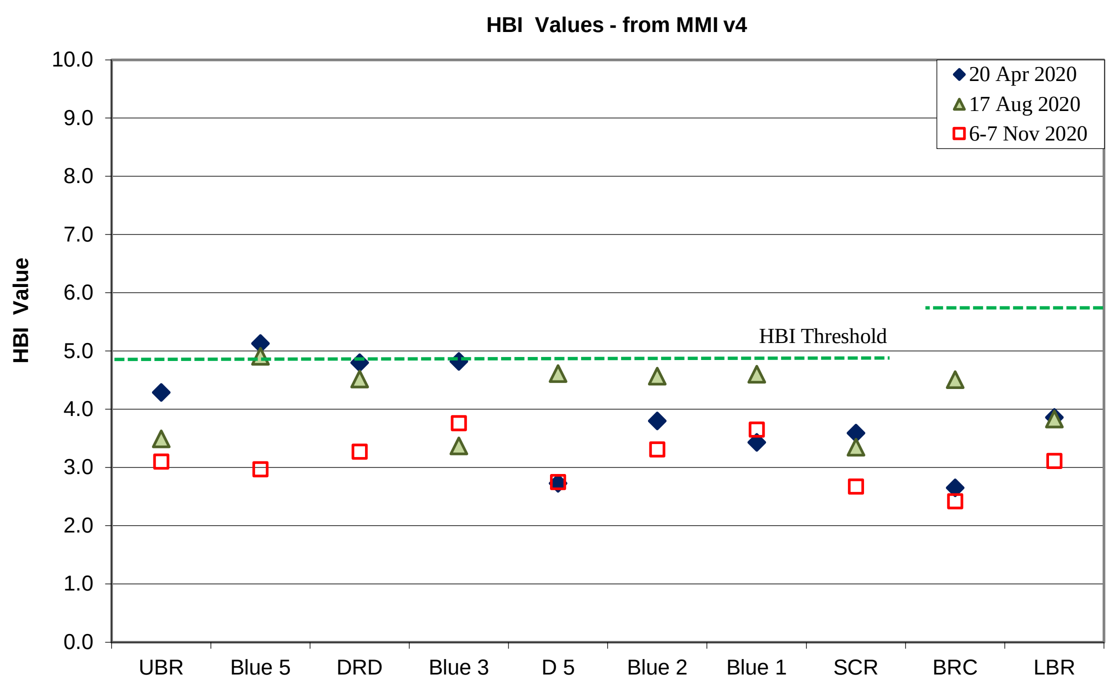

Figure 5. HBI values from composited quantitative (Hess) samples at study sites on the Blue River during April, August and November of 2020.

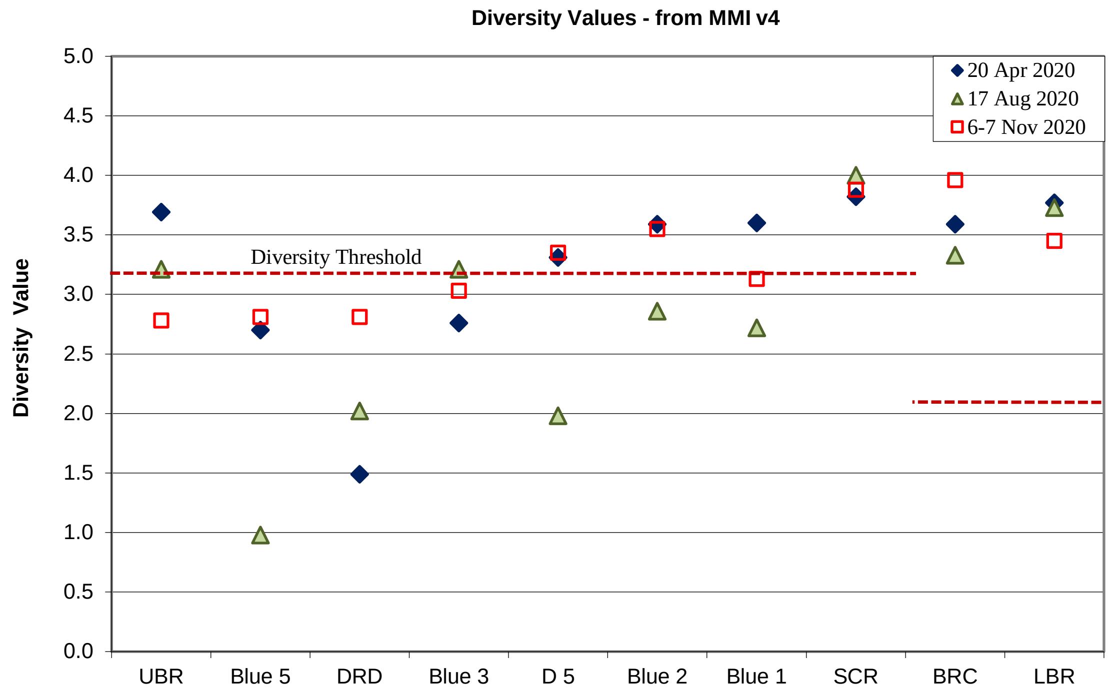

Figure 6. Shannon Diversity values from composited quantitative (Hess) samples at study sites on the Blue River during April, August and November 2020.

Table 5. Aquatic life use designations based on MMI v4 scores from quantitative (Hess) samples at sites in the Blue River study area, 2020.

Aquatic Life Use Designations in 2020 based on MMI (v4)			
Site	**Spring 2020**	**Summer 2020**	**Fall 2020**
UBR	Attainment	Attainment	Attainment
Blue 5	Impairment	Impairment	Impairment
DRD	Impairment	Impairment	Impairment
Blue 3	Impairment	Attainment	Impairment
D 5	Attainment	Impairment	Attainment
Blue 2	Attainment	Impairment	Attainment
Blue 1	Attainment	Impairment	Attainment
SCR	Attainment	Attainment	Attainment
BRC	Attainment	Attainment	Attainment
LBR	Attainment	Attainment	Attainment

Additional Evaluation (Individual Metrics)

In the previous section, results from the MMI v4 (and associated metrics) were based on a subset of specimens (approximately 300) from composited Hess samples. This rarefication process is built into the MMI v4 program to ensure that a consistent allotment of data can be compared when using different sampling techniques throughout the State of Colorado. It should be noted that some bias may occur during this rarefication process, and inevitably some taxa may be excluded or poorly represented. Therefore, the following data analysis was conducted using all specimens from each quantitative sample (Tables 6-11). This was done to provide a more replicable and accurate examination of community composition, structure, balance, and function during each season in 2020.

On 20 April 2020, results from most of the additional applied metrics identified an area of stressed aquatic conditions immediately below Dillon Reservoir followed by apparent recovery of macroinvertebrate structure and function with distance downstream. It is likely that the hypolimnetic releases had a substantial impact directly below the dam on the most environmentally sensitive taxa (EPT Taxa), but minimal deleterious effects on these taxa farther downstream (Table 6). The summation of these sensitive macroinvertebrate taxa ranged from a low of 4 at site Blue 5 (directly below Dillon Reservoir) to a high of 17 EPT taxa at two study sites farther downstream (Table 6). As has been previously reported in similar studies (see Introduction), relatively few taxa comprised the macroinvertebrate community at site Blue 5 (the site closest to the dam). In the spring of 2020, ninety-three percent of the macroinvertebrate community at Blue 5 was numerically dominated by the geographically widespread and resilient baetid mayfly, *Baetis tricaudatus* (33% of the total abundance), chironomid midges (38% of the total abundance), and black flies of the genus *Simulium* (22% of the total abundance) (Appendix A, Table A2). Whereas, farther downstream at site Blue 1, 32 different taxa were collected including 17 EPT taxa (Appendix A, Table A7).

Generally, stoneflies and caddisflies are considered the most sensitive groups of aquatic insects in regulated streams. Directly below the dam, at site Blue 5, only two species of stoneflies occurred, the tolerant widespread western species, *Isoperla fulva*, and an unidentified chloroperlid. Only one caddisfly species, *Brachycentrus americanus,* another geographically wide spread and common North American taxon was collected (Appendix A, Table A2). At site Blue 1, six stonefly taxa and seven caddisfly taxa were collected (Appendix A, Table A7), reflecting a more typical healthy southern Rocky Mountain assemblage of macroinvertebrate taxa. This increase in EPT taxa downstream may have been enhanced by select taxa drifting and recolonizing downstream from the numerous tributaries along the Blue River.

Other individual metrics (including Taxa Richness, Clinger Taxa, % Shredders and Scrapers, and % EPT individuals) also detected a reduction in sensitive and specialized macroinvertebrates directly below the dam (Table 6 and 7). A comparison of Density values to Dry Weight values suggested that while aquatic organisms remained abundant immediately downstream from Dillon Reservoir, they were typically smaller in body size during the spring of 2020. Again, improvements were detected farther downstream.

Table 6. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 20 April 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	4	1	3	3	3	4	4	4	5	7
# Plecoptera Taxa	4	2	3	7	3	3	6	3	4	2
# Trichoptera Taxa	2	1	2	4	4	5	7	4	7	8
Total EPT Taxa	**10**	**4**	**8**	**14**	**10**	**12**	**17**	**11**	**16**	**17**
Taxa Richness	26	13	20	29	30	28	32	28	33	33
Clinger Taxa	13	4	11	15	14	15	19	15	19	17
Hydropsychidae Density (estimated #/m²)	63	0	8	16	78	32	105	55	79	431
% Clingers	60.86%	23.26%	5.59%	13.24%	44.83%	38.58%	47.77%	55.85%	57.71%	43.75%
% Shredders and Scrapers	12.95%	0.00%	2.51%	7.84%	13.24%	28.44%	31.97%	38.13%	64.86%	8.85%
% Chironomidae	17.34%	38.00%	10.06%	29.51%	30.83%	31.24%	27.74%	20.89%	15.10%	28.65%

Table 7. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 20 April 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	29.11%	32.94%	83.10%	59.80%	29.79%	40.45%	48.22%	51.11%	41.97%	40.24%
% Plecoptera individuals	9.22%	0.37%	0.98%	4.41%	4.51%	3.20%	4.97%	8.86%	3.34%	0.21%
% Trichoptera individuals	12.22%	0.06%	0.42%	0.69%	26.85%	10.55%	5.64%	6.33%	34.82%	16.78%
% EPT individuals	**50.55%**	**33.37%**	**84.50%**	**64.90%**	**61.15%**	**54.21%**	**58.83%**	**66.30%**	**80.13%**	**57.23%**
Ephemeroptera (estimated #/m²)	1544	2070	2308	2366	2435	1176	2521	1253	1025	2224
Plecoptera (estimated #/m²)	490	24	28	177	370	95	262	218	83	12
Trichoptera (estimated #/m²)	649	4	12	28	2196	309	297	158	853	930
Other (estimated #/m²)	2629	4190	434	1394	3183	1336	2158	832	491	2368
Total Density (estimated #/m²)	**5,312**	**6,288**	**2,782**	**3,965**	**8,184**	**2,916**	**5,238**	**2,461**	**2,452**	**5,534**
Ephemeroptera Dry Wt (estimated g/m²)	0.3977	0.3298	0.3318	0.3054	0.9012	0.2488	0.5950	0.2814	0.1833	0.6880
Plecoptera Dry Wt (estimated g/m²)	0.4085	0.0783	0.0205	0.1105	0.5682	0.1031	0.5357	0.3353	0.6240	0.0802
Trichoptera Dry Wt (estimated g/m²)	0.7647	0.0016	0.0922	0.1721	5.4578	0.1733	0.7322	0.2845	0.2872	0.6140
Other Dry Wt (estimated g/m²)	0.5721	0.8213	0.0477	0.1438	0.9783	0.2074	0.3213	0.2008	0.0395	0.3120
Total Dry Wt (estimated g/m²)	**2.1430**	**1.2310**	**0.4922**	**0.7318**	**7.9054**	**0.7326**	**2.1841**	**1.1019**	**1.1341**	**1.6942**

Benthic macroinvertebrate sampling and analysis continued in the summer (17 August) of 2020 to provide a seasonal perspective on longitudinal patterns of community structure and function. The most likely sources of stress during the summer months continued to include hypolimnetic releases from Dillon Reservoir and runoff from urban development (adjacent to the Blue River) within the Town of Silverthorne. Results from data analysis generally detected evidence of stressed conditions at sites Blue 5 and D 5 with robust recovery gradients downstream from these locations (Tables 8 and 9). There were also differences in terms of community structure and taxa richness when site UBR (the "reference" site) was compared to most of the study sites downstream from Dillon Reservoir.

The summation of sensitive macroinvertebrate taxa (EPT Taxa) ranged from a low of 5 at the site directly below Dillon Reservoir (Blue 5) to a high of 18 at sites Blue 2 and Blue 1, indicating a substantial increase in sensitive taxa with distance downstream from the dam (Table 8). Generally, stoneflies and caddisflies are considered the most sensitive groups of macroinvertebrates, usually demonstrating significant reductions in regulated streams. The average number of EPT Taxa reported in healthy Colorado mountain streams typically ranges between 21-30+ (Ward et al. 2002). The increase in EPT taxa at the downstream sampling locations was likely enhanced by contributions (drifting or aerial colonization) from numerous tributaries along the Blue River study segment. Interestingly, the site below Green Mountain Reservoir, site LBR, consisted of a more diverse macroinvertebrate community, including 14 EPT taxa (Appendix B, Table B10), whereas, at site Blue 5, only five EPT were collected (Appendix B, Table B2). It was also important to note that the EPT Taxa metric (and several other individual metrics) detected greater stress at the "reference site" (UBR) compared to most sampling locations in the lower portion of the Blue River study area.

Overall, other individual metrics used in this assessment (Taxa Richness, Clinger Taxa, Hydropsychidae Density, % Clingers, and % Shredders and Scrapers) were consistent in detecting increased stress immediately downstream from Dillon Reservoir, while improvements in metric values often varied throughout the remainder of the study area (Table 8). The % Chironomidae and % EPT individuals metrics were the only two analysis tools that did not detect additional stress at site Blue 5 (Tables 8 and 9), but both of these metrics were greatly influenced by the dominance of the relatively tolerant mayfly, *Baetis tricaudatus*, (Appendix B, Table B2). Total density (estimated #/m^2) values ranged from a low of 989 individuals/m^2 at site DRD (1.9 km below the dam) to a high of 24,589 individuals/m^2 at site D 5 (11.7 km downstream from the dam). Total Dry Weight generally reflected Total Density estimates except at site Blue 5 where the ratio of Total Density to Total Dry Weight clearly showed that the majority of specimens exhibited a smaller body size (Table 9). Almost the entire macroinvertebrate community at site Blue 5 was numerically composed of the geographically widespread and resilient baetid mayfly, *Baetis tricaudatus* and a few dipterans (primarily chironomid midges and black flies) (Appendix B, Table B2). Many of the taxa that were found at downstream sampling locations exhibited a larger body size, increasing the ratio of Total Dry Weight to Total Density. Again, much of the variability in metric values in the middle reaches of the study area may have been influenced by additional impacts from other anthropogenic sources (urban and agricultural runoff) and tributaries. The influence of Dillon Reservoir and other anthropogenic stressors in this study area appeared to be offset by improvements in aquatic conditions and additional faunal contributions downstream from tributaries.

Table 8. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 17 August 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	4	2	4	5	4	5	8	6	4	8
# Plecoptera Taxa	4	2	5	5	2	6	5	4	3	4
# Trichoptera Taxa	5	1	3	5	3	7	5	5	7	2
Total EPT Taxa	**13**	**5**	**12**	**15**	**9**	**18**	**18**	**15**	**14**	**14**
Taxa Richness	**26**	**14**	**21**	**26**	**26**	**34**	**36**	**38**	**31**	**28**
Clinger Taxa	**13**	**6**	**12**	**17**	**12**	**19**	**19**	**16**	**16**	**11**
Hydropsychidae Density (estimated #/m²)	**109**	**0**	**4**	**12**	**249**	**566**	**586**	**225**	**187**	**55**
% Clingers	**49.44%**	**7.22%**	**13.83%**	**48.89%**	**83.41%**	**59.15%**	**58.53%**	**31.64%**	**63.58%**	**17.46%**
% Shredders and Scrapers	**1.75%**	**0.28%**	**3.56%**	**13.06%**	**0.69%**	**3.83%**	**6.12%**	**13.74%**	**7.36%**	**10.05%**
% Chironomidae	**9.57%**	**4.44%**	**12.25%**	**6.94%**	**4.21%**	**10.54%**	**8.43%**	**28.04%**	**22.08%**	**33.94%**

Table 9. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 17 August 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	33.17%	86.11%	73.91%	46.94%	9.86%	23.52%	24.72%	26.58%	11.55%	53.38%
% Plecoptera individuals	11.64%	2.50%	6.72%	14.17%	2.21%	6.24%	6.57%	9.37%	3.43%	0.82%
% Trichoptera individuals	22.65%	0.28%	3.16%	15.28%	20.31%	12.65%	13.54%	21.30%	14.97%	9.06%
% EPT individuals	**67.46%**	**88.89%**	**83.79%**	**76.39%**	**32.38%**	**42.41%**	**44.83%**	**57.25%**	**29.95%**	**63.26%**
Ephemeroptera (estimated #/m²)	809	1202	727	657	2423	2502	1914	1486	355	1258
Plecoptera (estimated #/m²)	284	36	68	200	544	665	509	525	106	20
Trichoptera (estimated #/m²)	552	4	32	214	4994	1347	1048	1192	460	214
Other (estimated #/m²)	796	158	162	333	16628	6128	4271	2396	2148	872
Total Density (estimated #/m²)	**2,441**	**1,400**	**989**	**1,404**	**24,589**	**10,642**	**7,742**	**5,599**	**3,069**	**2,364**
Ephemeroptera Dry Wt (estimated g/m²)	0.0461	0.0795	0.0864	0.1070	0.3081	0.2105	0.2054	0.1384	0.0446	0.2996
Plecoptera Dry Wt (estimated g/m²)	0.0446	0.0043	0.0198	0.0267	0.0624	0.0895	0.0864	0.1240	0.1147	0.0008
Trichoptera Dry Wt (estimated g/m²)	0.2535	0.0039	0.0264	0.0043	0.5101	0.2388	0.6120	0.1500	0.2492	0.0306
Other Dry Wt (estimated g/m²)	0.1380	0.0074	0.0085	0.0318	2.0194	0.7477	0.5473	0.3868	0.4167	0.0845
Total Dry Wt (estimated g/m²)	**0.4822**	**0.0950**	**0.1411**	**0.1698**	**2.9000**	**1.2864**	**1.4512**	**0.7992**	**0.8252**	**0.4155**

Seasonal benthic macroinvertebrate monitoring continued on the Blue River during the fall (6-7 November) of 2020 with the same individual metrics that were utilized during previous sampling events (spring and summer). Results from data analysis were used to assess changes in macroinvertebrate community health and ultimately provide insight into the overall ecological integrity of the aquatic system. In general, results from November of 2020 reflected a strong recovery gradient of macroinvertebrate structure and function downstream from Dillon Dam to the lower portion of the study area (Tables 10 and 11). While the sampling location upstream from Dillon Reservoir (UBR) supported a benthic macroinvertebrate community that was generally healthier than the site immediately downstream from the reservoir (Blue 5), results from most metrics suggested that the most optimum community parameters (in terms of community structure and taxa richness) occurred in the lower half of the study area (Tables 10 and 11). Interestingly, site LBR (located approximately 7.2 km downstream from Green Mountain Reservoir) did not show the same evidence of stress that was observed at sites downstream from Dillon Reservoir.

The summation of the most sensitive macroinvertebrate taxa, EPT Taxa, ranged from a low of only five taxa at the site directly below Dillon Dam (Blue 5) to a high of 21 EPT Taxa at site BRC (immediately upstream from Green Mountain Reservoir). A review of EPT values generally showed a substantial positive increase in these sensitive taxa in a downstream direction (Table 10). At site Blue 5, only one species of stonefly was collected, whereas eight species of stoneflies were collected at site BRC, including the sensitive and uncommon Colorado perlodidine taxon, *Diura knowltoni* (Appendix C, Table C9). Surprisingly, the site below Green Mountain Reservoir (LBR), also supported a much more diverse macroinvertebrate community than site Blue 5, with 20 EPT taxa (Table 10).

In November of 2020, most of the individual metrics detected relatively rapid improvements in macroinvertebrate community health with distance downstream from Dillon Reservoir. Sites Blue 2, Blue 1, and SCR exhibited diverse macroinvertebrate communities (Appendix C, Tables C6-C8), including relatively high values from the following metrics: EPT Taxa, Taxa Richness, Clinger Taxa, and % Shredders and Scrapers (Table 10). Metric values generally improved from site Blue 5 to site Blue 2 before becoming somewhat stable between sites Blue 2 and LBR (Table 10). At site BRC, mayflies and caddisflies composed 47% and 34% respectively, of the benthic community (Table 11), which could be considered "healthy" for a southern Rocky Mountain riverine macroinvertebrate community. Again, the high number of taxa (and repopulation of sensitive taxa) found in the middle reaches of this study area likely reflected faunal contributions from the numerous tributaries along the sampled reach of the Blue River.

Total Density estimates varied from a low of 953 individuals/m^2 at site Blue 3 to a high at site Blue 1 of 9,074 individuals/m^2, while Total Dry Weight ranged from 0.1450 g/m^2 at site Blue 5 to 3.1163 g/m^2 at site SCR (Table 11). Interestingly, the ratio of Total Density to Total Dry Weight indicated that the macroinvertebrate specimens with the smallest body size occurred at sites Blue 5, DRD, and Blue 3. Farther downstream at site BRC, the average Dry Weight of individual specimens was more than 7 times greater than those found at site Blue 5. These results suggested that the feeding habits and energy expenditures of fish below Dillon Dam (sites Blue 5, DRD, and Blue 3) were potentially limited by the small body size (and biomass) of the available benthic macroinvertebrates during the fall of 2020.

Table 10. Individual metrics and comparative values for quantitative benthic macroinvertebrate samples collected from the Blue River, 6-7 November 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
# Ephemeroptera Taxa	3	2	3	3	5	5	5	4	6	7
# Plecoptera Taxa	4	1	6	5	4	7	6	6	8	6
# Trichoptera Taxa	4	2	4	3	4	5	8	7	7	7
Total EPT Taxa	**11**	**5**	**13**	**11**	**13**	**17**	**19**	**17**	**21**	**20**
Taxa Richness	**21**	**14**	**23**	**22**	**28**	**38**	**36**	**38**	**33**	**35**
Clinger Taxa	**13**	**4**	**9**	**12**	**14**	**19**	**20**	**21**	**23**	**21**
Hydropsychidae Density (estimated #/m²)	**202**	**0**	**4**	**39**	**299**	**206**	**411**	**291**	**268**	**1,207**
% Clingers	**64.14%**	**7.32%**	**9.56%**	**32.79%**	**37.64%**	**39.17%**	**43.03%**	**48.48%**	**77.94%**	**52.67%**
% Shredders and Scrapers	**34.34%**	**0.00%**	**2.39%**	**3.69%**	**9.04%**	**29.90%**	**38.24%**	**34.33%**	**53.78%**	**27.63%**
% Chironomidae	**1.52%**	**33.06%**	**12.35%**	**11.48%**	**19.87%**	**19.30%**	**9.67%**	**20.31%**	**7.14%**	**6.43%**

Table 11. Additional metrics and comparative values for quantitative benthic macroinvertebrate samples collected on the Blue River, 6-7 November 2020.

Metric	UBR	Blue 5	DRD	Blue 3	D 5	Blue 2	Blue 1	SCR	BRC	LBR
% Ephemeroptera individuals	63.64%	17.62%	37.45%	37.30%	32.14%	50.16%	67.32%	44.58%	47.48%	32.63%
% Plecoptera individuals	4.88%	3.25%	33.86%	20.90%	11.31%	8.38%	5.00%	7.66%	5.46%	1.78%
% Trichoptera individuals	18.01%	0.54%	1.99%	5.74%	27.77%	12.95%	11.72%	21.41%	34.24%	40.70%
% EPT individuals	**86.53%**	**21.41%**	**73.31%**	**63.93%**	**71.21%**	**71.49%**	**84.05%**	**73.65%**	**87.18%**	**75.10%**
Ephemeroptera (estimated #/m²)	1467	253	365	354	2083	3063	6102	2665	880	1851
Plecoptera (estimated #/m²)	114	47	331	199	733	513	455	460	103	103
Trichoptera (estimated #/m²)	416	8	20	55	1800	793	1065	1282	635	2310
Other (estimated #/m²)	314	1129	264	345	1871	1748	1452	1581	241	1418
Total Density (estimated #/m²)	**2,311**	**1,437**	**980**	**953**	**6,487**	**6,117**	**9,074**	**5,988**	**1,859**	**5,682**
Ephemeroptera Dry Wt (estimated g/m²)	0.0640	0.0209	0.0229	0.0182	0.1500	0.1678	0.4035	0.8725	0.2236	0.2961
Plecoptera Dry Wt (estimated g/m²)	0.0345	0.0233	0.1302	0.0721	0.3740	0.2791	0.2605	0.2519	0.2109	0.0457
Trichoptera Dry Wt (estimated g/m²)	0.3678	0.0035	0.0035	0.0271	1.7895	1.0810	1.1833	1.6864	0.9422	1.6523
Other Dry Wt (estimated g/m²)	0.0829	0.0973	0.0306	0.0698	0.5167	0.6376	0.5116	0.3054	0.0271	0.2302
Total Dry Wt (estimated g/m²)	**0.5492**	**0.1450**	**0.1872**	**0.1872**	**2.8302**	**2.1655**	**2.3589**	**3.1163**	**1.4039**	**2.2244**

When comparing results from select metrics during all three sampling periods, 20 April (Spring), 17 August (Summer), and 6-7 November (Fall) of 2020, there were certain measures of macroinvertebrate community structure and function that appeared to respond similarly to spatial changes in aquatic conditions while other individual metrics detected more variable responses depending on site location and/or season (Figures 7-14).

The EPT Taxa, Taxa Richness, Clinger Taxa, and Percent Shredders and Scrapers metrics demonstrated considerable spatial similarity among seasons, due to low values from these metrics found at site Blue 5 followed by a general recovery in a downstream direction (Figures 7-10). During each sampling event (April, August, and November), these metrics showed that higher numbers of sensitive and specialized taxa were present in the downstream portion of the study area, providing a typical pattern of impact and recovery that is expected downstream from a hypolimnetic release reservoir. EPT Taxa and Taxa Richness values were reduced at site Blue 5 (immediately downstream from Dillon Reservoir) and increased to substantially higher values at sites Blue 2 and Blue 1 during all seasons (Figures 7 and 8). Clinger Taxa values also improved in a downstream direction with consistently higher numbers (19-20) found at site Blue 1 (Figure 9). While many representatives from the Clinger Taxa metric may be adversely impacted by an unnatural shift in the thermal regime, these taxa also respond poorly to rapid changes in discharge (often associated with regulated streams) because they are typically poor swimmers. It should be noted that the Clinger Taxa metric also showed a slight decline downstream from Green Mountain Reservoir (site LBR) during each season (Figure 9).

The pattern of Percent Scrapers and Shredders suggested that these specialized feeding guilds had the greatest capacity for recovery downstream from Dillon Reservoir during April and November of 2020; however, both feeding groups were consistently absent (or nearly so) at site Blue 5 (Figure 10). The coarse particulate organic material that provides a food resource for shredders is expected to be poorly represented immediately downstream from reservoirs. Improvements in percent composition of Scrapers and Shredders in a downstream direction could likely be attributed to changes in periphyton community composition and/or increased riparian habitat along the length of the Blue River and its tributaries.

While most metrics detected a pattern of impact followed by recovery downstream of Dillon Reservoir, the Percent EPT, Density, and Dry Weight measures exhibited greater variability among sampling locations and seasons (Figures 11-14). The lowest Percent EPT values were found at site Blue 5 during April and November; however, low Percent EPT values were observed at sites D 5, Blue 2, Blue 1 and BRC in August (Figure 11). The highest Total Density value occurred at site D 5 during August of 2020 where black flies of the genus *Simulium* sp. and the humpless casemaking caddisfly, *Brachycentrus occidentalis* comprised more than 81% of the density (Figure 12, Appendix B; Table B5). Both black flies and *Brachycentrus* are collector-filterers, indicating a probable abundance of fine particulate organic matter at this sampling location.

Measures of macroinvertebrate dry weight (estimated g/m^2 and mg/individual) detected a large increase in biomass at site D 5 in April, with seasonal variability throughout the remainder of the study area in 2020 (Figures 13 and 14). At site D 5 in the spring, both of these measures were positively influenced by a high proportion of mature caddisflies (*Brachycentrus occidentalis*), while macroinvertebrate densities and site-specific species composition likely influenced the overall dry weights of macroinvertebrates at other sites during other seasons. During all sampling events, the total Dry Weight (g/m^2) of the benthic macroinvertebrate portion of the food-web appeared to be relatively limited at sites Blue 5, DRD, and Blue 3 (Figure 13). This was particularly evident in the summer and fall when the production of macroinvertebrates (in terms of g/m^2) at these sites was the lowest in the study area. The average body size (individual dry weight) of macroinvertebrate specimens was also lowest at sites Blue 5, DRD, and Blue 3 in the spring and fall, but showed substantial improvement in the downstream portion of the study area (Figure 14). In general, the sampling locations in the lower half of the study area tended to support individuals of slightly larger size/mass, and during most sampling events these sites supported a greater biomass (in terms of g/m^2) of benthic macroinvertebrates. This evaluation provided some insight into possible limitations in food resources for fish populations in the segment of the Blue River from Dillon Reservoir downstream for at least 4.7 km.

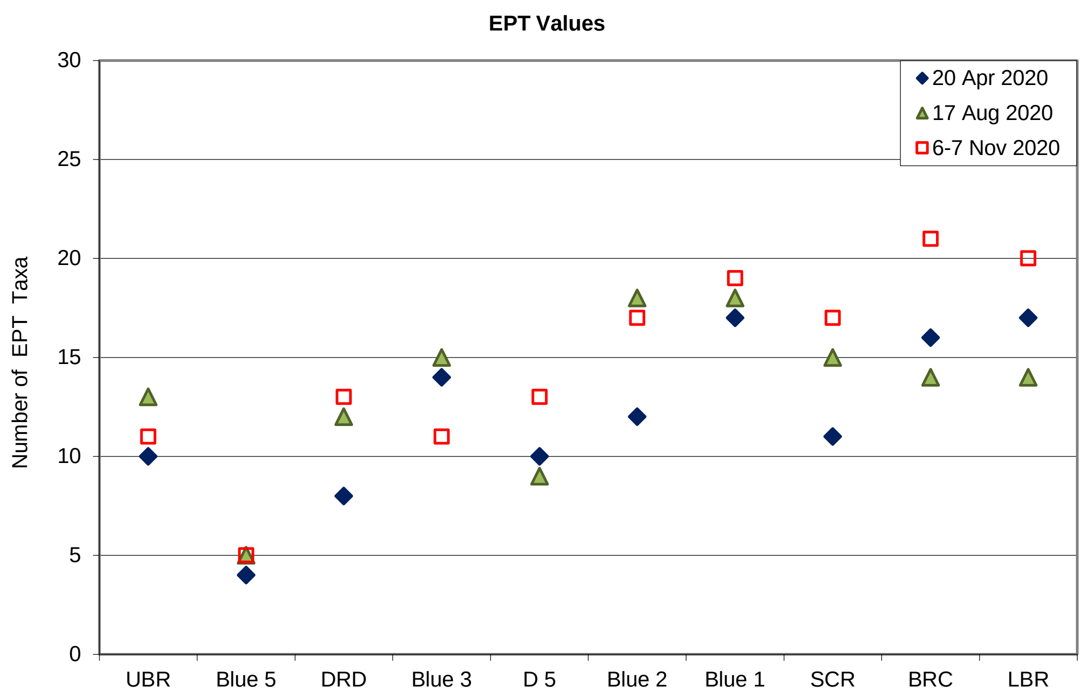

Figure 7. EPT Taxa values from spring, summer, and fall sampling on the Blue River during 2020.

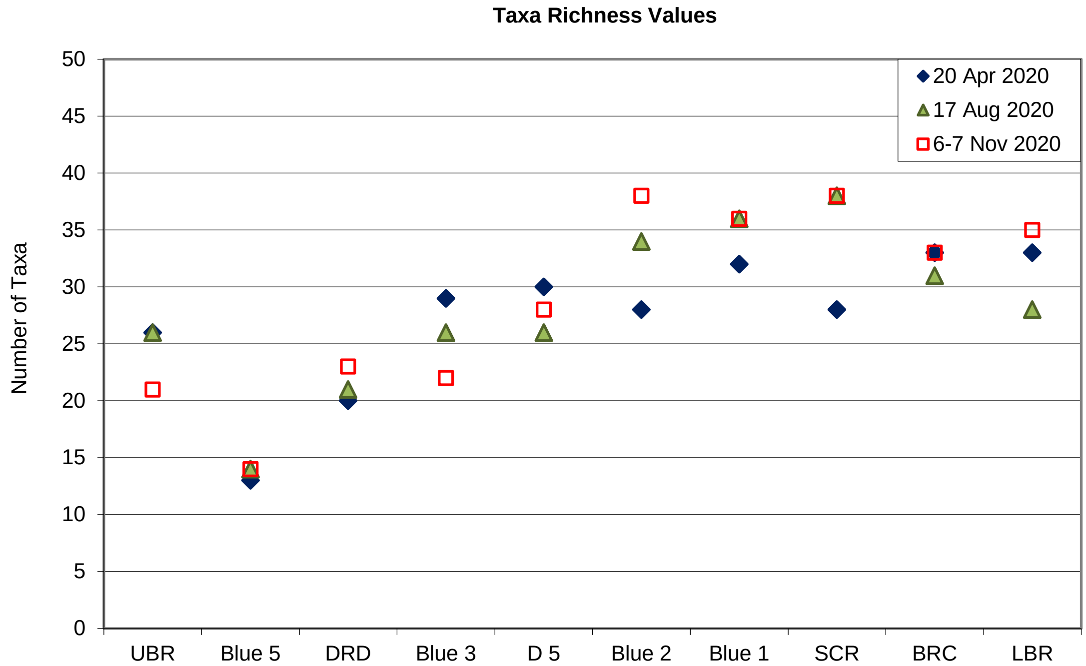

Figure 8. Taxa Richness values from spring, summer, and fall sampling on the Blue River during 2020.

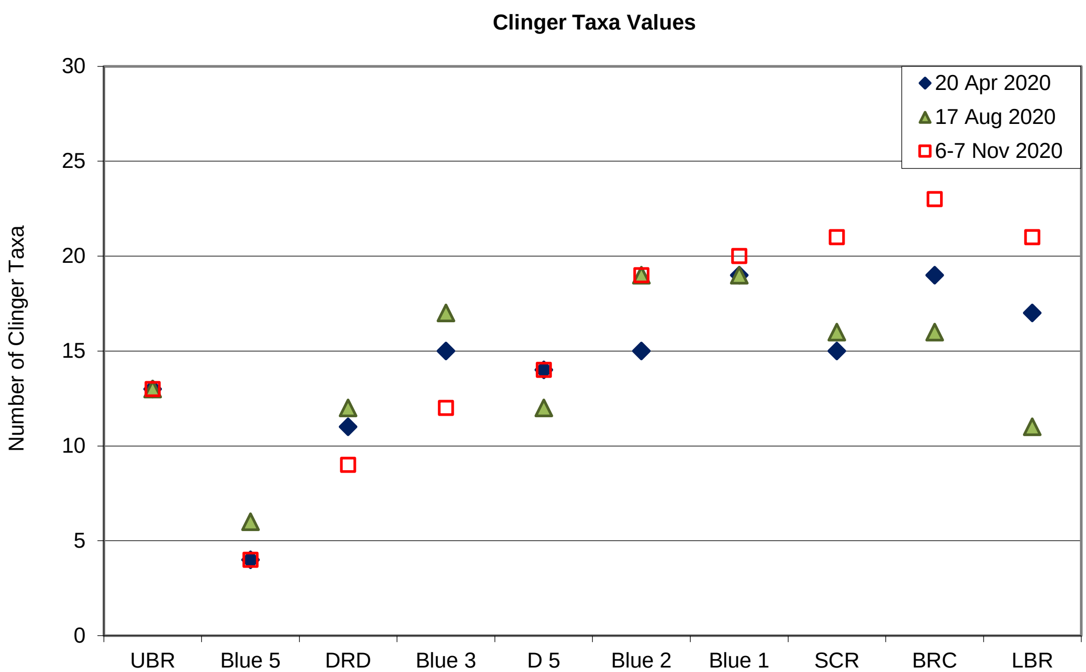

Figure 9. Clinger Taxa values from spring, summer, and fall sampling on the Blue River during 2020.

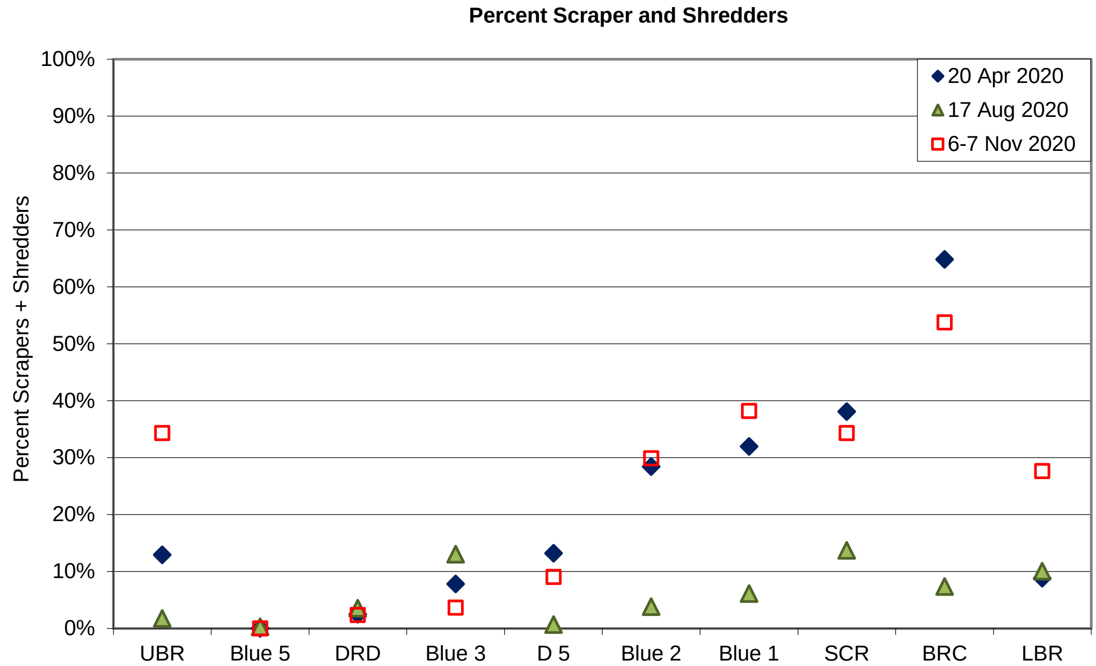

Figure 10. Percent Scrapers and Shredders from spring, summer, and fall sampling on the Blue River during 2020.

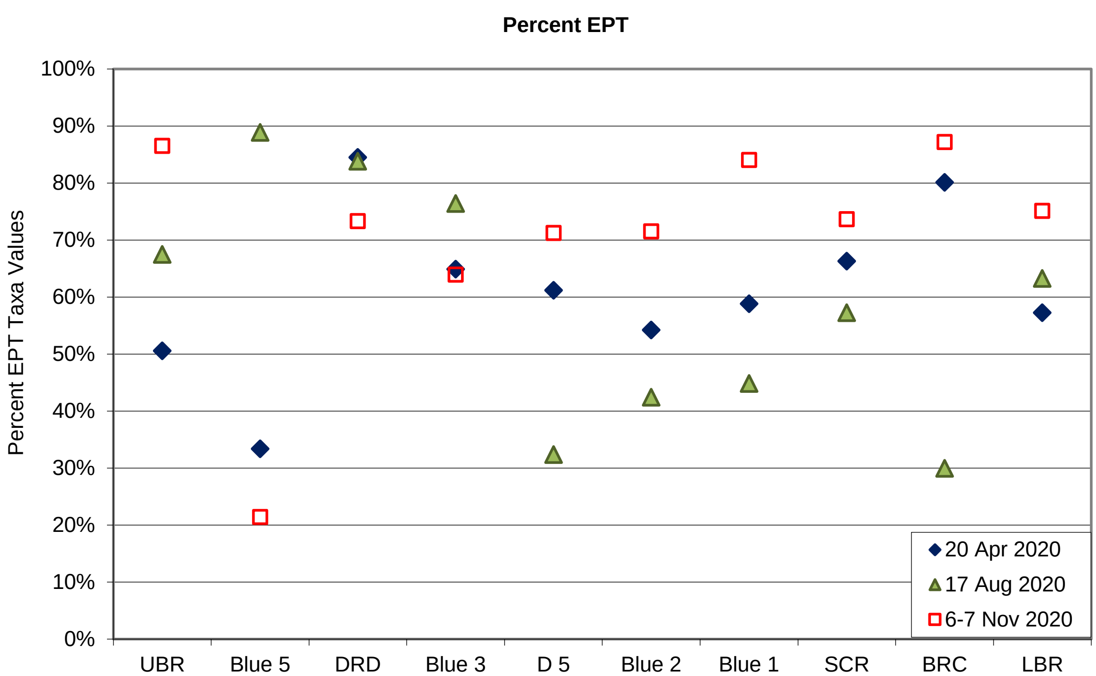

Figure 11. Percent EPT values from spring, summer and fall sampling on the Blue River during 2020.

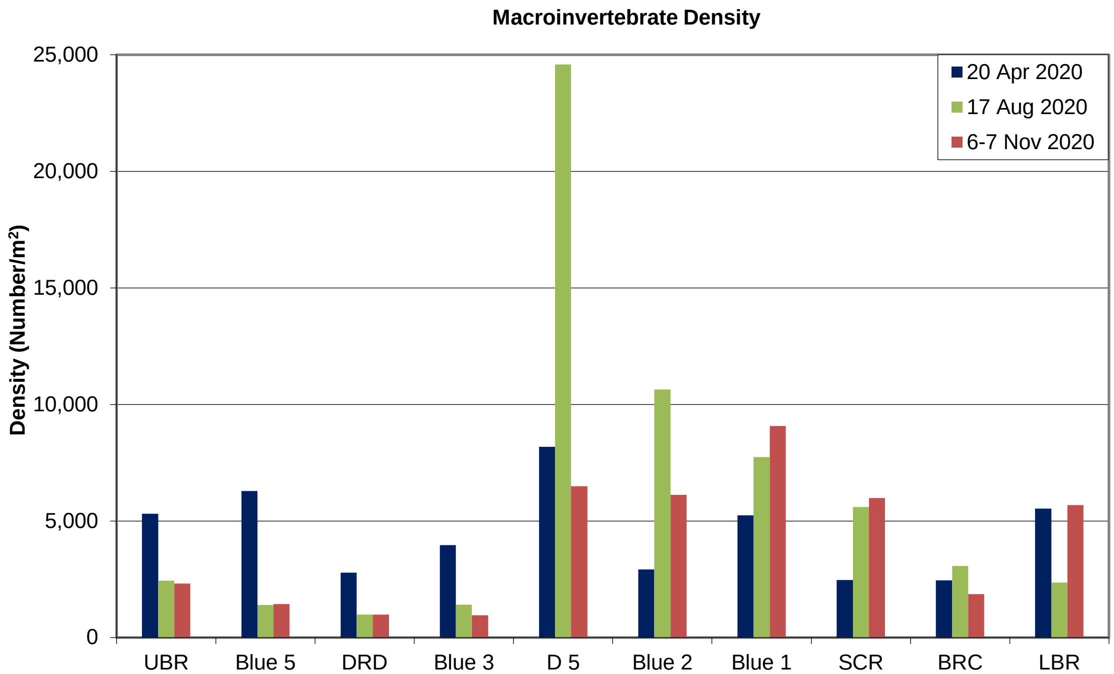

Figure 12. Estimated Density values (number/m2) from spring, summer and fall sampling on the Blue River, 2020.

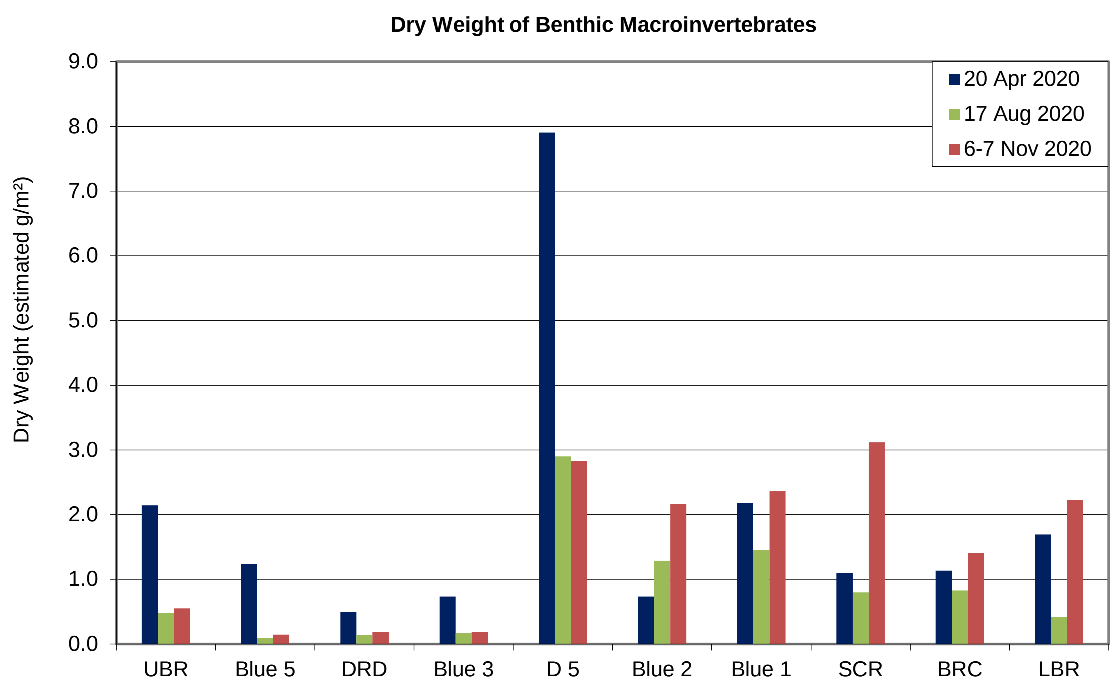

Figure 13. Estimated dry weight (g/m2) of benthic macroinvertebrates during spring, summer, and fall sampling on the Blue River, 2020.

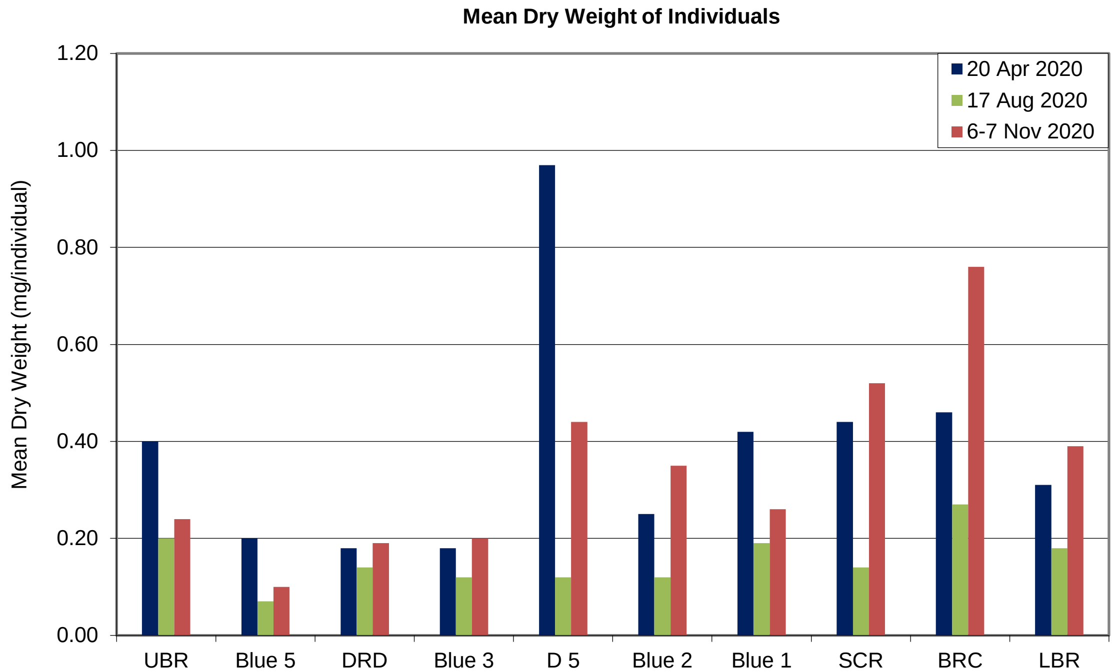

Figure 14. Mean dry weight (mg/individual) for benthic macroinvertebrate specimens during spring, summer, and fall of 2020.

Functional Feeding Groups

In order to provide an assessment of ecological function at each sampling location, benthic macroinvertebrates were classified according to their method of food acquisition (Tables 12-14, Figures 15-17). In healthy streams, all feeding groups should be adequately represented; however, it is common for certain groups (collector-gatherers) to be slightly dominant. An evaluation of functional guilds in the Blue River study area during the spring, summer, and fall of 2020 showed evidence of spatial and seasonal changes in community function (Figures 15-17). In general, the most tolerant group (collector-gatherers) was consistently abundant (and often dominated) at the three study sites below Dillon Reservoir (Blue 5, DRD, and Blue 3), while the most sensitive feeding groups (shredders and scrapers) were often absent or poorly represented at these locations (Tables 12-14). Farther downstream there were improvements in the representation of various feeding guilds; however, a reduction of specialized feeding groups was again observed at site LBR in the spring and summer, suggesting probable impacts from Green Mountain Reservoir (Figures 15 and 16). The large proportion of collector-gatherers at study sites below Dillon Reservoir was primarily due to one mayfly (*Baetis tricaudatus*) and chironomid midges. Improvements downstream were likely dependent on the stability of diverse food resources which may have also been tied to influences from tributaries.

Table 12. Relative abundance of functional feeding groups on 20 April 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	49.16%	30.29%	6.66%	6.29%	5.05%	2.56%
Blue 5	70.94%	22.89%	0.00%	0.00%	0.49%	5.68%
DRD	92.32%	1.54%	0.42%	2.09%	1.12%	2.51%
Blue 3	88.33%	0.88%	3.24%	4.61%	2.16%	0.78%
D 5	49.95%	28.89%	1.14%	12.10%	5.36%	2.56%
Blue 2	53.54%	9.75%	6.14%	22.30%	4.14%	4.14%
Blue 1	47.63%	7.86%	2.67%	29.30%	7.42%	5.12%
SCR	39.87%	6.96%	2.85%	35.28%	11.87%	3.16%
BRC	20.83%	6.52%	25.28%	39.59%	7.15%	0.64%
LBR	65.45%	20.51%	2.04%	6.81%	0.77%	4.42%

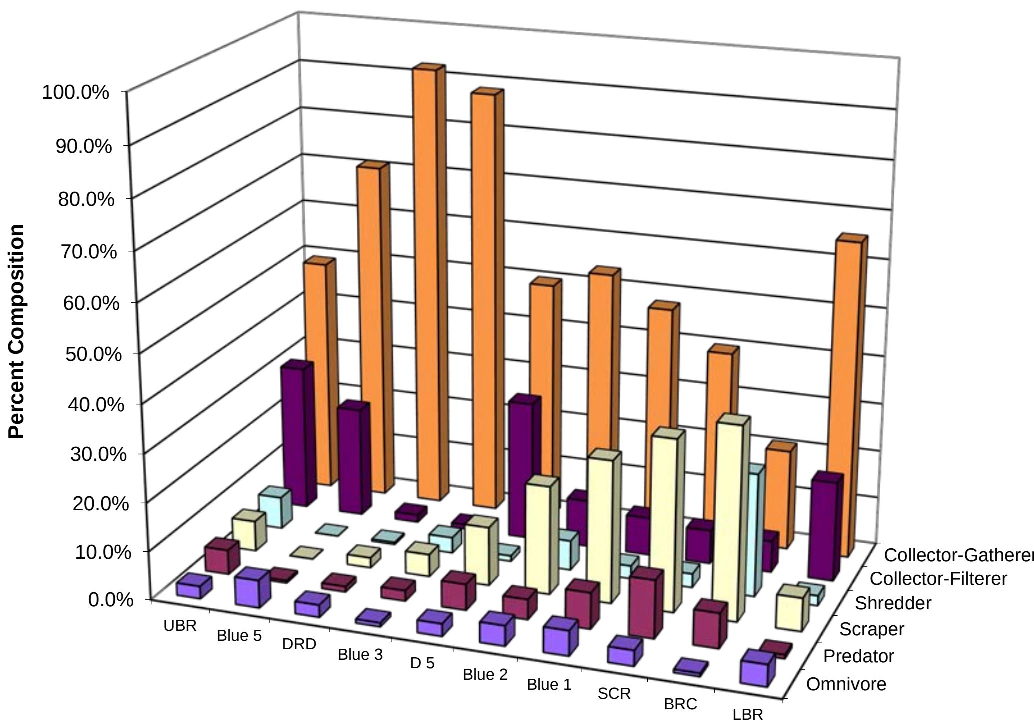

Figure 15. Functional feeding group composition for study sites in the Blue River study area, 20 April 2020.

Table 13. Relative abundance of functional feeding groups on 17 August 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	59.97%	22.81%	0.32%	1.44%	15.47%	0.00%
Blue 5	90.83%	6.11%	0.28%	0.00%	2.78%	0.00%
DRD	84.19%	5.53%	0.40%	3.16%	6.72%	0.00%
Blue 3	54.44%	18.06%	0.28%	12.78%	14.44%	0.00%
D 5	14.08%	82.40%	0.65%	0.05%	2.82%	0.00%
Blue 2	33.33%	54.96%	2.15%	1.68%	7.88%	0.00%
Blue 1	33.25%	51.86%	5.07%	1.05%	8.78%	0.00%
SCR	49.13%	22.69%	10.20%	3.54%	14.43%	0.00%
BRC	29.06%	56.22%	2.41%	4.95%	7.36%	0.00%
LBR	81.71%	3.62%	6.92%	3.13%	4.61%	0.00%

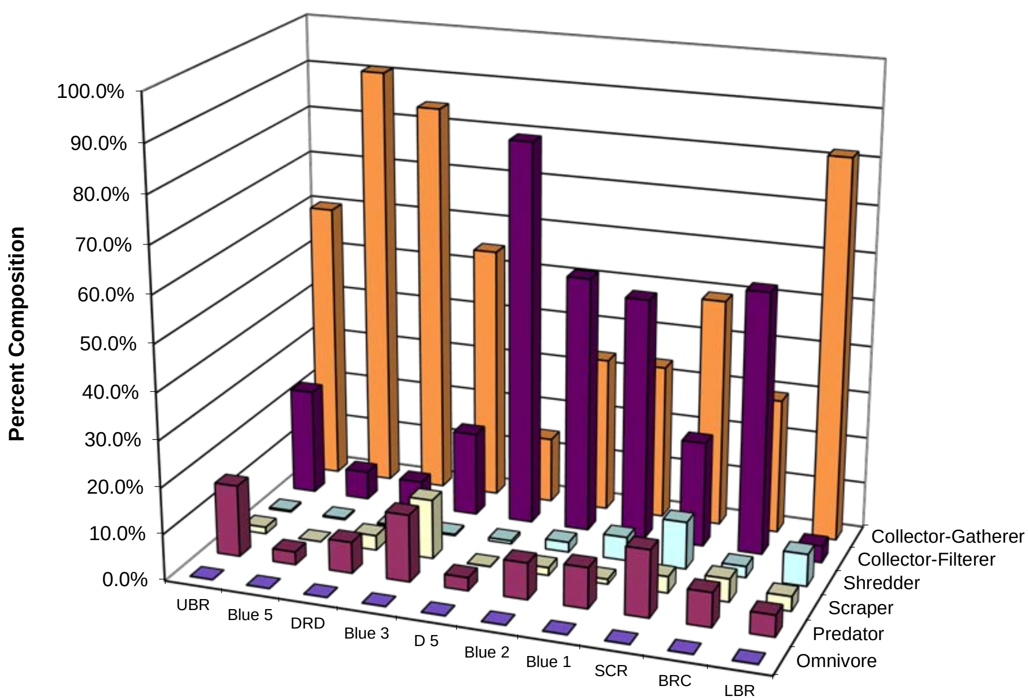

Figure 16. Functional feeding group composition for study sites in the Blue River study area, 17 August 2020.

Table 14. Relative abundance of functional feeding groups on 6-7 November 2020 at sampling locations in the Blue River study area.

Site	Functional Feeding Group					
	Collector-Gatherer	Collector-Filterer	Shredder	Scraper	Predator	Omnivore
UBR	41.08%	18.35%	1.18%	33.16%	4.88%	1.35%
Blue 5	50.68%	6.50%	0.00%	0.00%	4.07%	38.75%
DRD	54.58%	1.99%	1.99%	0.40%	33.47%	7.57%
Blue 3	66.80%	5.74%	1.23%	2.46%	22.54%	1.23%
D 5	50.57%	24.96%	1.86%	7.18%	12.51%	2.93%
Blue 2	51.94%	7.43%	4.76%	25.14%	8.89%	1.84%
Blue 1	48.93%	5.99%	6.54%	31.69%	5.47%	1.37%
SCR	40.49%	15.38%	7.46%	26.87%	8.89%	0.91%
BRC	19.96%	18.91%	7.77%	46.01%	6.93%	0.42%
LBR	36.53%	23.46%	3.42%	24.21%	2.74%	9.64%

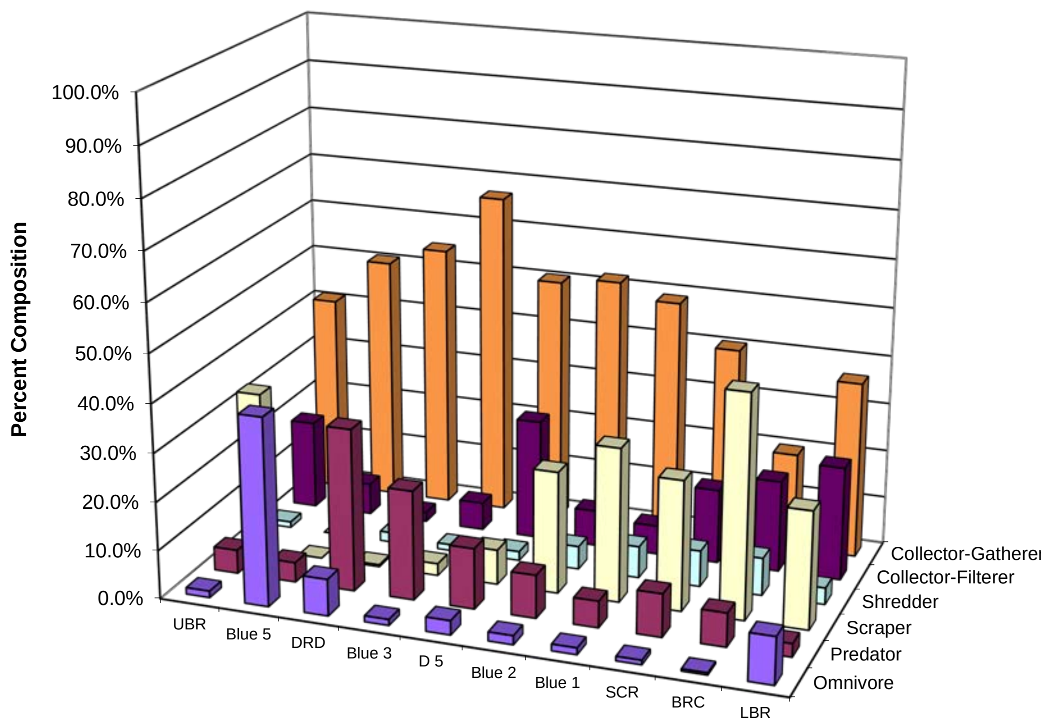

Figure 17. Functional feeding group composition for study sites in the Blue River study area, 6-7 November 2020.

Conclusion

In conclusion, the 2020 study of macroinvertebrate community structure and function in the Blue River indicated: 1) the “reference site” (UBR) consistently showed evidence of minor to moderate stress, despite supporting a benthic macroinvertebrate community that was considered in ‘attainment’ for aquatic life use, 2) the three study sites immediately downstream from Dillon Reservoir (Blue 5, DRD, and Blue 3) were consistently ‘impaired’ based on MMI v4 scores, and these results were supported by additional analysis tools, 3) recovery occurred in a downstream direction with some seasonal variability, and 4) impacts to benthic macroinvertebrate communities that are normally expected downstream from impoundments appeared to be less severe below Green Mountain Reservoir (at site LBR).

A fairly predictable recovery gradient of macroinvertebrate structure and function occurred downstream from Dillon Reservoir from site Blue 5 to site BRC during 2020. It is not known (currently) how biotic and abiotic factors may have collectively influenced the health of macroinvertebrate communities or how these influences may change seasonally. It is likely that the hypolimnetic releases altered the river temperature regime below the dam negatively impacting community structure and function, while the numerous tributaries ameliorated the natural thermal regime in the downstream portion of the study area. Additionally, the hydrology of the Blue River below Dillon Reservoir may also impact the structure and function of benthic macroinvertebrate communities. Research has shown that changes in timing, magnitude, and frequency of low and high flows can affect the abundance and diversity of macroinvertebrate communities (Ward and Stanford 1979, Stanford and Ward 2001). It is recommended that additional physical, chemical and biological factors be measured, such as water chemistry, water temperature, discharge, substrate, periphyton, and sedimentary detritus to ascertain how these factors may impact various longitudinal macroinvertebrate community patterns in the section of the Blue River between Dillon and Green Mountain reservoirs. Additional study sites may also be needed on tributaries along the Blue River to accurately assess the contributions from these additional water sources.

The results of this study, when compared with previous research conducted on the Blue River and other Colorado montane impounded rivers, indicated that there is a predictability in longitudinal patterns and recovery potential of macroinvertebrate structure and function in regulated Colorado streams. In the Blue River, the most rapid change in a sequential macroinvertebrate gradient occurred within the first 11.0 km below the impoundment. This and other studies indicated that the stretch of the river directly below the impoundment had depressed macroinvertebrate community health. While negative impacts to the abundance (Density) of individuals were less consistent below the dam, Dry Weight measurements indicated that most individuals were smaller in body size. Reductions in the Density and Dry Weight of benthic macroinvertebrates below Dillon Reservoir may impose food-web limitations, particularly when supporting the desired fish populations. Additional research may be needed to determine if the results from this seasonal benthic macroinvertebrate assessment can be extrapolated to other years and other seasons.

Literature Cited

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Barton, D.R. and J.L. Metcalfe-Smith. 1992. A comparison of sampling techniques and summary indices for assessment of water quality in Yamaska River, Quebec, based on benthic macroinvertebrates. Environmental Monitoring and Assessment 21: 225-244.

Baxter, R. M. 1977. Environmental effects of dams and impoundments. Annual Review of Ecology and Systematics 8: 255-283.

Bredenhand, E. and M. J. Samways. 2009. Impact of a dam on benthic macroinvertebrates in a small river in a biodiversity hotspot: Cape Floristic Region, South Africa. Journal of Insect Conservation 13: 297-307.

Brittain, J. E. 1989. The review of the effects of river regulation on mayflies (Ephemeroptera). Regulated Rivers: Research and Management 3: 191-204.

Collier, M., R. H. Webb, and J. C. Schmidt. 1996. Dams and rivers: A primer on downstream effects of dams. U.S. Geological Survey 1126.

Colorado Department of Public Health and Environment. 2010. Aquatic life use attainment: Methodology to determine use attainment for rivers and streams. Policy Statement 2010-1.

Colorado Department of Public Health and Environment. 2017. Aquatic life use attainment: Methodology to determine use attainment for rivers and streams. Policy Statement 10-1.

Colorado Department of Public Health and Environment. 2019. Section 303(d) Listing Methodology 2020 Listing Cycle.

Courtemanch, D.L. 1996. Commentary on the Subsampling Procedures Used for Rapid Bioassessments. Journal of the North American Benthological Society 15: 381-385.

Ellis, L. E. and N. E. Jones. 2013. Longitudinal trends in regulated river: A review and synthesis within the context of the serial discontinuity concept. Environmental Review. NRC Research Press. Pp. 136-148.

Gillespie, B.R., Brown, L.E., and P. Kay. 2014. Effects of impoundment on macroinvertebrate community assemblages in upland streams. River Research and Applications 31: 953-963.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family level biotic index. Journal of the North American Benthological Society 7(1): 65-68.

Hughes, D.L. and M.O. Brossett. 2009. Rapid Bioassessment of Stream Health. CRC Press, Taylor & Francis Group. Boca Raton, FL.

Krajenbrink, H., J. Acreman, M., Dunbar, M. J., Hannah, D.M., Laize, C. L. R., and P. J. Wood. 2019. Macroinvertebrate community responses to river impoundment at multiple spatial scales. Science of the Total Environment 650: 2648-2656.

Lenat, D.R. 1983. Chironomid Taxa Richness: Natural Variation and Use in Pollution Assessment. Freshwater Invertebrate Biology 2: 192-198.

Lenat, D.R. 1988. Water quality assessment of streams using a qualitative collection method for benthic macroinvertebrates. Journal of the North American Benthological Society 7: 222-33.

Mandaville, S.M. 2002. Benthic macroinvertebrates in freshwaters-taxa tolerance values, metrics, and protocols. Project H-1. Soil and Water Conservation Society of Metro Halifax,.xviii. 48. Pp., Appendices A-B 120pp.

Merritt, R. W., K. W. Cummins, and M. B. Berg. 2008. An Introduction to the Aquatic Insects of North America. Fourth Edition, Kendall/Hunt. Dubuque, Iowa.

Paul, M. J., J. Gerritsen, C. Hawkins, and E. Leppo. 2005. Draft. Development of biological assessment tools for Colorado. Colorado Department of Public Health and Environment, Water Quality Control Division – Monitoring Unit. Denver, Colorado.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. EPA/444/4-89/001.

Rader, R. B. and J. V. Ward. 1988. Influence of regulation on environmental conditions and macroinvertebrate community in the upper Colorado River. Regulated Rivers 2:597-628.

Resh, V.H. and J.K. Jackson. 1993. Rapid assessment approaches in biomonitoring using benthic macroinvertebrates. In Rosenberg, D.M, V.H. Resh. (Editors). Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, New York: 195-223.

Stanford, J. A. and J. V. Ward. 1984. The effects of regulation on the limnology of the Gunnison River: A North American case history. Pp. 467-480. *In* Regulated Rivers. Lillehammer, A. and S. J. Salveit (eds.) Oslo University Press, Oslo, Norway.

Stanford, J. A. and J. V. Ward. 2001. Revisiting the Serial Discontinuity Concept. Regulated Rivers: Research and Management 17: 303-310.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williamd, and J. A. Lichatowich and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management 12: 391-413.

Santucci, Jr., V. J., Gephard S. R., and S. M. Pescitelli. 2003. Effects of multiple low-head dams on fish, macroinvertebrates, habitat, and water quality in the Fox River, Illinois. North American Journal of Fisheries Management 25: 975-992.

Schmidt, J. C. and P. R. Wilcock. 2008. Metrics for assessing the downstream effects of dams. Water Resources Research 44(4):doi10.1029/2006WR005092.

Voelz, N. J. and J. V. Ward. 1989. Biotic and abiotic gradients in a regulated high elevation Rocky Mountain river. Regulated Rivers 3: 143-152.

Voelz, N. J. and J. V. Ward. 1990. Macroinvertebrate responses along a complex regulated stream environmental gradient. Regulated Rivers: Research and Management 5:365-374.

Voelz, N. J. and J. V. Ward. 1991. Biotic responses along the recovery gradient of a regulated stream. Canadian Journal of Fisheries and Aquatic Sciences 48: 2477-2490.

Voelz, N. J. and J. V. Ward. 1996. Microdistributions of filter-feeding caddisflies (Insecta: Trichoptera) in a regulated Rocky Mountain river. Canadian Journal of Zoology 74: 654-666.

Wang, L., D. M. Robertson, and P. J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. Environmental Management 39: 194-212.

Wang, J., C. Ding, J. Heino, X. Jiang, J. Tao, L. Ding, W. Su, M. Huang, and D. He. 2020. What explains variation in dam impacts on riverine macroinvertebrates? A global quantitative synthesis. Environmental Research Letters 15:124028

Ward, J. V. 1976. Effects of flow patterns below large dams on stream benthos: A review. Instream Flow Needs. American Fisheries Society. Pp. 235-253.

Ward, J. V. 1982. Ecological aspects of stream regulation: Responses in downstream reaches. Water Pollution Management. Reviews 2: 1-26.

Ward, J. V. 1987. Trichoptera of regulated Rocky Mountain streams. Pp. 375-380. *In* Bournaud, M. and H. Tachet (eds.). Proceedings of the 5th International Symposium of Trichoptera. Dr, W. Junk Publications, Dordrecht, the Netherlands.

Ward, J. V. and J. A. Stanford (eds.). 1979. The ecology of regulated rivers. Plenum Press, New York. 398 pp.

Ward, J. V. and J. A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pp. 29-42. *In* Fontaine, T. D. and S. M. Bartell (eds.). Dynamics of Lotic Ecosystems. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Ward, J. V., B. C. Kondratieff, and R. E. Zuellig. 2002. An Illustrated Guide to the Mountain Stream Insects of Colorado. Second Edition. University Press of Colorado. Boulder, Colorado.

White, J. C., D. M. Hannah, A. House, S. J. V. Beatson, A. Martin and P. J. Wood. 2016. Macroinvertebrate responses to flow and stream temperature variability across regulated and non-regulated rivers. Ecohydrology 10: e1773.

Zimmermann, H. J. and J. V. Ward. 1984. A survey of regulated streams in the Rocky Mountains of Colorado, U.S.A. Pp. 251-262. *In* Regulated rivers. Lillehammer, A. and S. J. Salveit (eds.) Oslo University Press, Oslo, Norway.

Appendix A

Benthic Macroinvertebrate Data – Spring 2020

Table A1. Macroinvertebrate data collected from site UBR on 20 April 2020.

Blue River				
UBR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	193	59	56	**1194**
Diphetor hageni	3	1		**16**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	4	9	6	**74**
Epeorus longimanus	22	27	18	**260**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	4	11	5	**78**
Prostoia besametsa	49	15	27	**353**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	3	5	1	**35**
Kogotus modestus	4	2		**24**
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	67	48	36	**586**
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis	12	1	3	**63**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	3	3	1	**28**
Diamesa sp.	3	3	1	**28**
Eukiefferiella sp.	17	5	10	**125**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	19	22	15	**218**
Microtendipes sp.				
Pagastia sp.	14	7	10	**121**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	9	73	10	**357**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group		1		**4**
Tvetenia sp.	5	3	3	**43**

Table A1. cont. Macroinvertebrate data collected from site UBR on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	221	9	17	**958**
Antocha sp.	15	8	13	**140**
Dicranota sp.	1			**4**
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	22	13	31	**256**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	12	9	5	**101**
Protzia sp.				
Sperchon sp.	4	2		**24**
Crangonyx sp.				
Polycelis coronata	19	9	7	**136**
Enchytraeidae		3	19	**86**
Nematoda				
Totals	**725**	**348**	**294**	**5312**
Shannon Weaver Diversity				**3.69**
Calculated Evenness				**0.784**
EPT				**10**
% EPT				**50.55%**
Density				**5312**
% Non-Insect				**6.51%**
% Shredder/Scraper				**12.95%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**29.11%**
% Plectopera individuals				**9.22%**
% Trichoptera individuals				**12.22%**
Percent Chironomidae				**17.34%**
Percent Tolerant Organisms				**10.39%**
# Intolerant Taxa				**11**

Table A2. Macroinvertebrate data collected from site Blue 5 on 20 April 2020.

Blue River				
Blue 5		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	221	161	152	**2070**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae			2	**8**
Sweltsa sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	2	2		**16**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	29	30	7	**256**
Diamesa sp.	1	1	1	**12**
Eukiefferiella sp.	33	25	4	**241**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	43	23	44	**427**
Microtendipes sp.				
Pagastia sp.	29	28	25	**318**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	201	68	24	**1136**

Table A2. cont. Macroinvertebrate data collected from site Blue 5 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons		1	1	**8**
Simulium sp.	168	150	52	**1435**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Crangonyx sp.				
Polycelis coronata	43	11	38	**357**
Enchytraeidae				
Nematoda				
Totals	**771**	**500**	**350**	**6288**
Shannon Weaver Diversity				**2.61**
Calculated Evenness				**0.706**
EPT				**4**
% EPT				**33.37%**
Density				**6,288**
% Non-Insect				**5.68%**
% Shredder/Scraper				**0.00%**
Taxa Richness				**13**
# Ephemeroptera Taxa				**1**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**1**
% Ephemeroptera individuals				**32.94%**
% Plectopera individuals				**0.37%**
% Trichoptera individuals				**0.06%**
Percent Chironomidae				**38.00%**
Percent Tolerant Organisms				**10.61%**
# Intolerant Taxa				**5**

Table A3. Macroinvertebrate data collected from site DRD on 20 April 2020.

Blue River				
DRD		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	120	199	261	**2249**
Diphetor hageni				
Drunella doddsii			1	**4**
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus longimanus	6	3	5	**55**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae	1		1	**8**
Sweltsa sp.		1	1	**8**
Prostoia besametsa		3		**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva				
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis				
Glossosoma sp.				
Arctopsyche grandis	1	1		**8**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea				
Rhyacophila coloradensis	1			**4**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	6	17	4	**105**
Diamesa sp.				
Eukiefferiella sp.	2	1	1	**16**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	5	3	3	**43**
Microtendipes sp.				
Pagastia sp.	5	3	3	**43**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.			2	**8**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	3	4	10	**66**

Table A3. cont. Macroinvertebrate data collected from site DRD on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	8		1	**35**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	1	1	1	**12**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1			**4**
Protzia sp.				
Sperchon sp.		2		**8**
Crangonyx sp.				
Polycelis coronata	3	13	2	**70**
Enchytraeidae	2	4		**24**
Nematoda				
Totals	**165**	**255**	**296**	**2782**
Shannon Weaver Diversity				**1.39**
Calculated Evenness				**0.321**
EPT				**8**
% EPT				**84.50%**
Density				**2,782**
% Non-Insect				**3.77%**
% Shredder/Scraper				**2.51%**
Taxa Richness				**20**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**83.10%**
% Plectopera individuals				**0.98%**
% Trichoptera individuals				**0.42%**
Percent Chironomidae				**10.06%**
Percent Tolerant Organisms				**3.35%**
# Intolerant Taxa				**9**

Table A4. Macroinvertebrate data collected from site Blue 3 on 20 April 2020.

Blue River				
Blue 3		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	200	238	126	**2187**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	2	5	2	**35**
Epeorus longimanus	19	12	6	**144**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae	4		1	**20**
Sweltsa sp.	5	1	1	**28**
Prostoia besametsa	7	11		**70**
Zapada cinctipes	1			**4**
Zapada oregonensis group	10	1		**43**
Claassenia sabulosa				
Isoperla fulva	1	1		**8**
Kogotus modestus				
Megarcys signata	1			**4**
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	1			**4**
Glossosoma sp.				
Arctopsyche grandis	2	2		**16**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.				
Rhyacophila brunnea	1			**4**
Rhyacophila coloradensis	1			**4**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.	3			**12**
Cricotopus/*Orthocladius* sp.	28	22	23	**283**
Diamesa sp.				
Eukiefferiella sp.	16	15	11	**163**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	24	4		**109**
Microtendipes sp.				
Pagastia sp.	46	27	14	**338**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	16	6	1	**90**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	26	14	4	**171**

Table A4. cont. Macroinvertebrate data collected from site Blue 3 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	2	1	1	**16**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	10	13	2	**97**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1	1	**8**
Protzia sp.				
Sperchon sp.	1	1		**8**
Crangonyx sp.				
Polycelis coronata	5	3		**32**
Enchytraeidae	10	5		**59**
Nematoda				
Totals	**442**	**385**	**193**	**3965**
Shannon Weaver Diversity				**2.68**
Calculated Evenness				**0.551**
EPT				**14**
% EPT				**64.90%**
Density				**3,965**
% Non-Insect				**2.65%**
% Shredder/Scraper				**7.84%**
Taxa Richness				**29**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**7**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**59.80%**
% Plectopera individuals				**4.41%**
% Trichoptera individuals				**0.69%**
Percent Chironomidae				**29.51%**
Percent Tolerant Organisms				**8.82%**
# Intolerant Taxa				**14**

Table A5. Macroinvertebrate data collected from site D 5 on 20 April 2020.

Blue River				
D 5		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	111	181	87	**1469**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	10	16	26	**202**
Epeorus longimanus	89	55	53	**764**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	27	25	19	**276**
Prostoia besametsa	6	3	2	**43**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	3	1	9	**51**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	202	188	141	**2059**
Glossosoma sp.	3			**12**
Arctopsyche grandis	9	8	3	**78**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	1	3	8	**47**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.		1		**4**
Cricotopus/Orthocladius sp.	105	208	99	**1597**
Diamesa sp.	8	5	6	**74**
Eukiefferiella sp.	13	23	4	**156**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	14	3	70	**338**
Microtendipes sp.				
Pagastia sp.	14	17	46	**299**
Parametriocnemus sp.	2			**8**
Pseudorthocladius sp.				
Rheocricotopus sp.		1	6	**28**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group	1			**4**
Tvetenia sp.		3		**12**

Table A5. cont. Macroinvertebrate data collected from site D 5 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.	1	1		**8**
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	32	26		**225**
Antocha sp.			5	**20**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	7	7	7	**82**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	4	2	10	**63**
Protzia sp.				
Sperchon sp.	2	1	6	**35**
Crangonyx sp.	1			**4**
Polycelis coronata	10	12	32	**210**
Enchytraeidae				
Nematoda	1	2		**12**
Totals	**676**	**793**	**639**	**8184**
Shannon Weaver Diversity				**3.31**
Calculated Evenness				**0.674**
EPT				**10**
% EPT				**61.15%**
Density				**8,184**
% Non-Insect				**3.94%**
% Shredder/Scraper				**13.24%**
Taxa Richness				**30**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**29.79%**
% Plectopera individuals				**4.51%**
% Trichoptera individuals				**26.85%**
Percent Chironomidae				**30.83%**
Percent Tolerant Organisms				**7.26%**
# Intolerant Taxa				**12**

Table A6. Macroinvertebrate data collected from site Blue 2 on 20 April 2020.

Blue River				
Blue 2		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	45	69	25	**539**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	10	16	8	**132**
Epeorus longimanus	47	43	38	**497**
Rhithrogena sp.			2	**8**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	6	8	2	**63**
Prostoia besametsa	1	1	1	**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	4		1	**20**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	11	8	5	**94**
Glossosoma sp.	2		1	**12**
Arctopsyche grandis	4	4		**32**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	10	25	8	**167**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group		1		**4**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	20	109	7	**528**
Diamesa sp.		1		**4**
Eukiefferiella sp.	12	40	6	**225**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	3	3	1	**28**
Microtendipes sp.				
Pagastia sp.	3	18	1	**86**
Parametriocnemus sp.		2	2	**16**
Pseudorthocladius sp.				
Rheocricotopus sp.		4	1	**20**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		1		**4**

Table A6. cont. Macroinvertebrate data collected from site Blue 2 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	9	19	13	**159**
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.		1		**4**
Coleoptera				
Heterlimnius corpulentus	10	11	6	**105**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	4		**20**
Protzia sp.				
Sperchon sp.	1	1		**8**
Crangonyx sp.				
Polycelis coronata	6	20	5	**121**
Enchytraeidae				
Nematoda				
Totals	**206**	**410**	**133**	**2916**
Shannon Weaver Diversity				**3.58**
Calculated Evenness				**0.745**
EPT				**12**
% EPT				**54.21%**
Density				**2,916**
% Non-Insect				**5.07%**
% Shredder/Scraper				**28.44%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**40.45%**
% Plectopera individuals				**3.20%**
% Trichoptera individuals				**10.55%**
Percent Chironomidae				**31.24%**
Percent Tolerant Organisms				**9.61%**
# Intolerant Taxa				**14**

Table A7. Macroinvertebrate data collected from site Blue 1 on 20 April 2020.

Blue River				
Blue 1		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	79	93	83	**989**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens	2			**8**
Cinygmula sp.	24	19	27	**272**
Epeorus longimanus	75	99	149	**1252**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae		1	6	**28**
Sweltsa sp.	4	2	11	**66**
Prostoia besametsa	2	4	1	**28**
Zapada cinctipes				
Zapada oregonensis group			1	**4**
Claassenia sabulosa				
Isoperla fulva	16	7	11	**132**
Kogotus modestus				
Megarcys signata			1	**4**
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	5	4	4	**51**
Glossosoma sp.	1			**4**
Arctopsyche grandis	7	6	14	**105**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	10	11	7	**109**
Rhyacophila brunnea				
Rhyacophila coloradensis			4	**16**
Rhyacophila sibirica group	1	1		**8**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	61	73	52	**721**
Diamesa sp.	1	2		**12**
Eukiefferiella sp.	16	20	20	**218**
Hydrobaenus sp.			1	**4**
Micropsectra/Tanytarsus sp.	8	3	17	**109**
Microtendipes sp.			1	**4**
Pagastia sp.	20	15	22	**221**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	13	6	21	**156**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2			**8**

Table A7. cont. Macroinvertebrate data collected from site Blue 1 on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae		1		**4**
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	5	49	10	**249**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	4	3	6	**51**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	12	6	12	**117**
Protzia sp.				
Sperchon sp.	2	1	1	**16**
Crangonyx sp.				
Polycelis coronata	22	18	29	**268**
Enchytraeidae				
Nematoda				
Totals	**393**	**444**	**511**	**5238**
Shannon Weaver Diversity				**3.58**
Calculated Evenness				**0.716**
EPT				**17**
% EPT				**58.83%**
Density				**5,238**
% Non-Insect				**7.64%**
% Shredder/Scraper				**31.97%**
Taxa Richness				**32**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**48.22%**
% Plectopera individuals				**4.97%**
% Trichoptera individuals				**5.64%**
Percent Chironomidae				**27.74%**
Percent Tolerant Organisms				**8.83%**
# Intolerant Taxa				**17**

Table A8. Macroinvertebrate data collected from site SCR on 20 April 2020.

Blue River				
SCR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	27	36	38	**392**
Diphetor hageni				
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	22	23	36	**314**
Epeorus longimanus	51	43	46	**543**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Sweltsa sp.	10	4	11	**97**
Prostoia besametsa	2			**8**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	15	6	8	**113**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	2			**8**
Brachycentrus occidentalis	2	1	5	**32**
Glossosoma sp.				
Arctopsyche grandis	1	6	7	**55**
Hydropsyche cockerelli				
Hydropsyche oslari				
Lepidostoma sp.	5	4	7	**63**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	4	9	7	**78**
Diamesa sp.				
Eukiefferiella sp.	6	8	11	**97**
Hydrobaenus sp.		1		**4**
Micropsectra/Tanytarsus sp.	7	9	15	**121**
Microtendipes sp.		1		**4**
Pagastia sp.	8	11	6	**97**
Parametriocnemus sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.	11	4	4	**74**
Stempellinella sp.				
Synorthocladius sp.				
Thienemannimyia genus group	3	3	2	**32**
Tvetenia sp.			2	**8**

Table A8. cont. Macroinvertebrate data collected from site SCR on 20 April 2020.

Other Diptera				
Atherix pachypus		1	2	**12**
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.	1		1	**8**
Clinocera sp.				
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	1	6	12	**74**
Antocha sp.		1	1	**8**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	10	8	9	**105**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.			2	**8**
Protzia sp.				
Sperchon sp.	2	1	3	**24**
Crangonyx sp.				
Polycelis coronata	2	4	14	**78**
Enchytraeidae				
Nematoda				
Totals	**193**	**190**	**249**	**2461**
Shannon Weaver Diversity				**3.79**
Calculated Evenness				**0.788**
EPT				**11**
% EPT				**66.30%**
Density				**2,461**
% Non-Insect				**4.43%**
% Shredder/Scraper				**38.13%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**51.11%**
% Plectopera individuals				**8.86%**
% Trichoptera individuals				**6.33%**
Percent Chironomidae				**20.89%**
Percent Tolerant Organisms				**10.28%**
# Intolerant Taxa				**13**

Table A9. Macroinvertebrate data collected from site BRC on 20 April 2020.

Blue River				
BRC		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	8	6	4	**70**
Diphetor hageni				
Drunella doddsii				
Drunella grandis	1			**4**
Ephemerella dorothea infrequens	4	10	5	**74**
Cinygmula sp.	12	18	17	**183**
Epeorus longimanus	30	94	55	**694**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae		1		**4**
Sweltsa sp.		2		**8**
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	4	3	1	**32**
Isoperla fulva	5	1	4	**39**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia				
Trichoptera				
Brachycentrus americanus	2	10		**47**
Brachycentrus occidentalis	2	3	1	**24**
Glossosoma sp.	1	13	6	**78**
Arctopsyche grandis	7	3	6	**63**
Hydropsyche cockerelli	3	1		**16**
Hydropsyche oslari				
Lepidostoma sp.	21	113	25	**617**
Rhyacophila brunnea				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Oligophlebodes sp.		2		**8**
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	2	4	9	**59**
Diamesa sp.				
Eukiefferiella sp.	7	6	9	**86**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	9	10	1	**78**
Microtendipes sp.				
Pagastia sp.	5	2	2	**35**
Parametriocnemus sp.				
Pseudorthocladius sp.		1		**4**
Rheocricotopus sp.		11	3	**55**
Stempellinella sp.		1		**4**
Synorthocladius sp.				
Thienemannimyia genus group	2	5	2	**35**
Tvetenia sp.	1	1	2	**16**

Table A9. cont. Macroinvertebrate data collected from site BRC on 20 April 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.		1		**4**
Wiedemannia sp.				
Lispoides aequifrons				
Simulium sp.	1	1		**8**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		9		**35**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	3		**16**
Protzia sp.	1			**4**
Sperchon sp.	3	4	1	**32**
Crangonyx sp.				
Polycelis coronata		1	3	**16**
Enchytraeidae				
Nematoda				
Totals	**133**	**340**	**156**	**2452**
Shannon Weaver Diversity				**3.53**
Calculated Evenness				**0.699**
EPT				**16**
% EPT				**80.13%**
Density				**2,452**
% Non-Insect				**2.70%**
% Shredder/Scraper				**64.86%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**41.97%**
% Plectopera individuals				**3.34%**
% Trichoptera individuals				**34.82%**
Percent Chironomidae				**15.10%**
Percent Tolerant Organisms				**8.74%**
# Intolerant Taxa				**16**

Table A10. Macroinvertebrate data collected from site LBR on 20 April 2020.

Blue River				
LBR		Sample		
20 April 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Baetis tricaudatus	112	124	131	**1423**
Diphetor hageni	1			**4**
Drunella doddsii				
Drunella grandis	5	2	4	**43**
Ephemerella dorothea infrequens	81	43	11	**524**
Cinygmula sp.	1		1	**8**
Epeorus longimanus	20	9	6	**136**
Rhithrogena sp.				
Paraleptophlebia sp.	16	6		**86**
Plecoptera				
Chloroperlidae				
Sweltsa sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Isoperla fulva	1		1	**8**
Kogotus modestus				
Megarcys signata				
Pteronarcella badia	1			**4**
Trichoptera				
Brachycentrus americanus	21	15	10	**179**
Brachycentrus occidentalis	6	4	4	**55**
Glossosoma sp.	7	23	7	**144**
Arctopsyche grandis	7	9	3	**74**
Hydropsyche cockerelli	32	29	12	**283**
Hydropsyche oslari	14	3	2	**74**
Lepidostoma sp.	18	7	3	**109**
Rhyacophila brunnea				
Rhyacophila coloradensis	1	2		**12**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	80	90	47	**842**
Diamesa sp.	1	4		**20**
Eukiefferiella sp.	9	19	10	**148**
Hydrobaenus sp.				
Micropsectra/Tanytarsus sp.	12	1		**51**
Microtendipes sp.				
Pagastia sp.	19	8	5	**125**
Parametriocnemus sp.	1			**4**
Pseudorthocladius sp.				
Rheocricotopus sp.	75	11	4	**349**
Stempellinella sp.				
Synorthocladius sp.	1			**4**
Thienemannimyia genus group	4			**16**
Tvetenia sp.	1	6		**28**

Table A10. cont. Macroinvertebrate data collected from site LBR on 20 April 2020.

Other Diptera				
Atherix pachypus	1			**4**
Bibiocephala sp.				
Ceratopogoninae				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Wiedemannia sp.		1		**4**
Lispoides aequifrons				
Simulium sp.	16	45	60	**469**
Antocha sp.		3		**12**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.	6	5	1	**47**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Crangonyx sp.				
Polycelis coronata	46	16	1	**245**
Enchytraeidae				
Nematoda				
Totals	**616**	**485**	**323**	**5534**
Shannon Weaver Diversity				**3.71**
Calculated Evenness				**0.736**
EPT				**17**
% EPT				**57.23%**
Density				**5,534**
% Non-Insect				**4.42%**
% Shredder/Scraper				**8.85%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**7**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**8**
% Ephemeroptera individuals				**40.24%**
% Plectopera individuals				**0.21%**
% Trichoptera individuals				**16.78%**
Percent Chironomidae				**28.65%**
Percent Tolerant Organisms				**3.58%**
# Intolerant Taxa				**17**

Appendix B

Benthic Macroinvertebrate Data – Summer 2020

Table B1. Macroinvertebrate data collected from site UBR on 17 August 2020.

Blue River				
UBR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	7	7	1	**59**
Baetis flavistriga		2		**8**
Baetis tricaudatus	77	44	64	**718**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	3		3	**24**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1		2	**12**
Sweltsa sp.	33	16	9	**225**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	4	1	4	**35**
Diura knowltoni		2	1	**12**
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	59	21	30	**427**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	14	2	11	**105**
Hydropsyche oslari	1			**4**
Hydroptila sp.				
Ochrotrichia sp.		2		**8**
Lepidostoma sp.	2			**8**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	4	15	3	**86**
Diamesa sp.				
Eukiefferiella sp.	1	2	1	**16**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	1			**4**
Odontomesa sp.				
Pagastia sp.	7	4	10	**82**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	4	5	2	**43**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.			1	**4**

Table B1. cont. Macroinvertebrate data collected from site UBR on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.	1			**4**
Simulium sp.		1	4	**20**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	46	33	29	**419**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	7	4	5	**63**
Protzia sp.				
Sperchon sp.	1	4	4	**35**
Torrenticola sp.				
Enchytraeidae			4	**16**
Nematoda				
Totals	**274**	**165**	**188**	**2441**
Shannon Weaver Diversity				**3.23**
Calculated Evenness				**0.686**
EPT				**13**
% EPT				**67.46%**
Density				**2,441**
% Non-Insect				**4.63%**
% Shredder/Scraper				**1.75%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**33.17%**
% Plectopera individuals				**11.64%**
% Trichoptera individuals				**22.65%**
Percent Chironomidae				**9.57%**
Percent Tolerant Organisms				**5.42%**
# Intolerant Taxa				**9**

Table B2. Macroinvertebrate data collected from site Blue 5 on 17 August 2020.

Blue River				
Blue 5		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.		1		**4**
Baetis flavistriga				
Baetis tricaudatus	81	129	99	**1198**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		1		**4**
Sweltsa sp.	3	1	4	**32**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.				
Diamesa sp.				
Eukiefferiella sp.		2		**8**
Heleniella sp.				
Micropsectra/Tanytarsus sp.		1	1	**8**
Odontomesa sp.				
Pagastia sp.	1	2	3	**24**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.		1		**4**
Rheocricotopus sp.				
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		4	1	**20**

Table B2. cont. Macroinvertebrate data collected from site Blue 5 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	1	17	3	**82**
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus		1		**4**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.		1		**4**
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**88**	**161**	**111**	**1400**
Shannon Weaver Diversity				**0.98**
Calculated Evenness				**0.258**
EPT				**5**
% EPT				**88.89%**
Density				**1,400**
% Non-Insect				**0.28%**
% Shredder/Scraper				**0.28%**
Taxa Richness				**14**
# Ephemeroptera Taxa				**2**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**1**
% Ephemeroptera individuals				**86.11%**
% Plectopera individuals				**2.50%**
% Trichoptera individuals				**0.28%**
Percent Chironomidae				**4.44%**
Percent Tolerant Organisms				**1.39%**
# Intolerant Taxa				**5**

Table B3. Macroinvertebrate data collected from site DRD on 17 August 2020.

Blue River				
DRD		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	1		1	**8**
Baetis flavistriga				
Baetis tricaudatus	51	68	58	**687**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus	2	3	2	**28**
Epeorus longimanus		1		**4**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1			**4**
Sweltsa sp.	6	2		**32**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae		3		**12**
Diura knowltoni				
Isoperla sp.				
Megarcys signata	2			**8**
Skwala americana		3		**12**
Trichoptera				
Brachycentrus americanus		2		**8**
Brachycentrus occidentalis	3	2		**20**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	1			**4**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.		1		**4**
Diamesa sp.				
Eukiefferiella sp.		3		**12**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	2	1		**12**
Odontomesa sp.				
Pagastia sp.	1	3	1	**20**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.			1	**4**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2	14	2	**70**

Table B3. cont. Macroinvertebrate data collected from site DRD on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	2	4		**24**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.	1			**4**
Coleoptera				
Heterlimnius corpulentus	3			**12**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**78**	**110**	**65**	**989**
Shannon Weaver Diversity				**2.02**
Calculated Evenness				**0.460**
EPT				**12**
% EPT				**83.79%**
Density				**989**
% Non-Insect				**0.00%**
% Shredder/Scraper				**3.56%**
Taxa Richness				**21**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**73.91%**
% Plectopera individuals				**6.72%**
% Trichoptera individuals				**3.16%**
Percent Chironomidae				**12.25%**
Percent Tolerant Organisms				**2.37%**
# Intolerant Taxa				**11**

Table B4. Macroinvertebrate data collected from site Blue 3 on 17 August 2020.

Blue River				
Blue 3		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	2		2	**16**
Baetis flavistriga				
Baetis tricaudatus	67	30	23	**466**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis				
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus	8	16	9	**128**
Epeorus longimanus	8	1	2	**43**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		1	2	**12**
Sweltsa sp.	15	2	21	**148**
Zapada cinctipes				
Zapada oregonensis group		1		**4**
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata		2	2	**16**
Skwala americana		3	2	**20**
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	7	41	2	**194**
Micrasema bactro				
Glossosoma sp.		1		**4**
Arctopsyche grandis			1	**4**
Hydropsyche oslari	2			**8**
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.				
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.		1		**4**
Cricotopus/Orthocladius sp.			1	**4**
Diamesa sp.				
Eukiefferiella sp.				
Heleniella sp.				
Micropsectra/Tanytarsus sp.	3	1	5	**35**
Odontomesa sp.				
Pagastia sp.	2	3	1	**24**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	1	1	2	**16**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.		4		**16**

Table B4. cont. Macroinvertebrate data collected from site Blue 3 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	10	1		**43**
Antocha sp.		1		**4**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	28	8	10	**179**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	1			**4**
Protzia sp.				
Sperchon sp.	1			**4**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**157**	**118**	**85**	**1404**
Shannon Weaver Diversity				**3.21**
Calculated Evenness				**0.683**
EPT				**15**
% EPT				**76.39%**
Density				**1,404**
% Non-Insect				**0.56%**
% Shredder/Scraper				**13.06%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**46.94%**
% Plectopera individuals				**14.17%**
% Trichoptera individuals				**15.28%**
Percent Chironomidae				**6.94%**
Percent Tolerant Organisms				**3.33%**
# Intolerant Taxa				**14**

Table B5. Macroinvertebrate data collected from site D 5 on 17 August 2020.

Blue River				
D 5		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	5	19	9	**128**
Baetis flavistriga				
Baetis tricaudatus	102	290	197	**2283**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis		1		**4**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	1	1		**8**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.	1	2	1	**16**
Sweltsa sp.	24	66	46	**528**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae				
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	83	699	401	**4586**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	11	32	21	**249**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.		28	13	**159**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	1	7	3	**43**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	1	27	10	**148**
Diamesa sp.				
Eukiefferiella sp.	10	49	6	**252**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	3	2	1	**24**
Odontomesa sp.				
Pagastia sp.	4	76	22	**396**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	3	9	3	**59**
Stempellinella sp.	1		1	**8**
Sublettea sp.				
Synorthocladius sp.			2	**8**
Thienemannimyia genus group		11	3	**55**
Tvetenia sp.	2	8	2	**47**

Table B5. cont. Macroinvertebrate data collected from site D 5 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	355	3104	517	**15411**
Antocha sp.		1	2	**12**
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	9	7	11	**105**
Optioservus sp.				
Zaitzevia parvula		1		**4**
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.		6	1	**28**
Protzia sp.				
Sperchon sp.	1	3	2	**24**
Torrenticola sp.				
Enchytraeidae				
Nematoda		1		**4**
Totals	**617**	**4450**	**1274**	**24589**
Shannon Weaver Diversity				**1.84**
Calculated Evenness				**0.391**
EPT				**9**
% EPT				**32.38%**
Density				**24,589**
% Non-Insect				**0.22%**
% Shredder/Scraper				**0.69%**
Taxa Richness				**26**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**2**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**9.86%**
% Plectopera individuals				**2.21%**
% Trichoptera individuals				**20.31%**
Percent Chironomidae				**4.21%**
Percent Tolerant Organisms				**1.32%**
# Intolerant Taxa				**10**

Table B6. Macroinvertebrate data collected from site Blue 2 on 17 August 2020.

Blue River				
Blue 2		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	2		2	**16**
Baetis flavistriga				
Baetis tricaudatus	153	305	176	**2458**
Diphetor hageni				
Drunella coloradensis		1		**4**
Drunella grandis	1		1	**8**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	1	2	1	**16**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.		3	2	**20**
Sweltsa sp.	30	75	54	**617**
Zapada cinctipes	1			**4**
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	3			**12**
Diura knowltoni				
Isoperla sp.			1	**4**
Megarcys signata		1	1	**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	61	19	21	**392**
Micrasema bactro	1			**4**
Glossosoma sp.	30	6	3	**152**
Arctopsyche grandis	96	31	19	**566**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	12	30	15	**221**
Rhyacophila sibirica group	1	1		**8**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	6	1	2	**35**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	6	11	5	**86**
Diamesa sp.				
Eukiefferiella sp.	21	15	6	**163**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	8	21	2	**121**
Odontomesa sp.				
Pagastia sp.	26	18	13	**221**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.	11	14	2	**105**
Stempellinella sp.	5	32	8	**175**
Sublettea sp.				
Synorthocladius sp.				
Thienemannimyia genus group	3	4	1	**32**
Tvetenia sp.	40	7	1	**187**

Table B6. cont. Macroinvertebrate data collected from site Blue 2 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	739	218	257	**4706**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.		1	1	**8**
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	17	19	13	**190**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	3	7	4	**55**
Protzia sp.		2		**8**
Sperchon sp.	6	2		**32**
Torrenticola sp.				
Enchytraeidae				
Nematoda	1			**4**
Totals	**1285**	**846**	**611**	**10642**
Shannon Weaver Diversity				**2.79**
Calculated Evenness				**0.549**
EPT				**18**
% EPT				**42.41%**
Density				**10,642**
% Non-Insect				**0.91%**
% Shredder/Scraper				**3.83%**
Taxa Richness				**34**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**23.52%**
% Plectopera individuals				**6.24%**
% Trichoptera individuals				**12.65%**
Percent Chironomidae				**10.54%**
Percent Tolerant Organisms				**3.54%**
# Intolerant Taxa				**18**

Table B7. Macroinvertebrate data collected from site Blue 1 on 17 August 2020.

Blue River				
Blue 1		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	1	1	1	**12**
Baetis flavistriga	1			**4**
Baetis tricaudatus	202	158	106	**1807**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis	2	1		**12**
Ephemerella dorothea infrequens	1			**4**
Serratella sp.	1	1		**8**
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	9	2	5	**63**
Rhithrogena sp.	1			**4**
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae			1	**4**
Suwallia sp.	1	1		**8**
Sweltsa sp.	39	59	15	**438**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae	5	3	3	**43**
Diura knowltoni				
Isoperla sp.				
Megarcys signata	1	3		**16**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	10	4	3	**66**
Micrasema bactro				
Glossosoma sp.	1			**4**
Arctopsyche grandis	68	50	33	**586**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	51	36	13	**388**
Rhyacophila sibirica group		1		**4**
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.	4	2	1	**28**
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	9	11	2	**86**
Diamesa sp.				
Eukiefferiella sp.	13	7	5	**97**
Heleniella sp.			1	**4**
Micropsectra/Tanytarsus sp.	11	11	1	**90**
Odontomesa sp.				
Pagastia sp.	13	8	3	**94**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.		1		**4**
Rheocricotopus sp.	11	14		**97**
Stempellinella sp.	1	1	1	**12**
Sublettea sp.				
Synorthocladius sp.		1		**4**
Thienemannimyia genus group	3	2		**20**
Tvetenia sp.	19	11	1	**121**

Table B7. cont. Macroinvertebrate data collected from site Blue 1 on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.	1			**4**
Clinocera sp.				
Simulium sp.	415	137	311	**3345**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	15	14	9	**148**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.	1			**4**
Lebertia sp.	8	6	4	**70**
Protzia sp.				
Sperchon sp.	4	5	2	**43**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**922**	**551**	**521**	**7742**
Shannon Weaver Diversity				**2.78**
Calculated Evenness				**0.538**
EPT				**18**
% EPT				**44.83%**
Density				**7,742**
% Non-Insect				**1.50%**
% Shredder/Scraper				**6.12%**
Taxa Richness				**36**
# Ephemeroptera Taxa				**8**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**24.72%**
% Plectopera individuals				**6.57%**
% Trichoptera individuals				**13.54%**
Percent Chironomidae				**8.43%**
Percent Tolerant Organisms				**3.91%**
# Intolerant Taxa				**17**

Table B8. Macroinvertebrate data collected from site SCR on 17 August 2020.

Blue River				
SCR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.		1		**4**
Acentrella sp.	4	4	1	**35**
Baetis flavistriga				
Baetis tricaudatus	80	134	109	**1252**
Diphetor hageni				
Drunella coloradensis				
Drunella grandis		17	20	**144**
Ephemerella dorothea infrequens				
Serratella sp.		1		**4**
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus	4	5	3	**47**
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.			1	**4**
Sweltsa sp.	29	36	60	**485**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa			1	**4**
Perlodidae	4	3	1	**32**
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus			3	**12**
Brachycentrus occidentalis	14	31	54	**384**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	4	25	29	**225**
Hydropsyche oslari				
Hydroptila sp.		1	1	**8**
Ochrotrichia sp.				
Lepidostoma sp.	35	43	67	**563**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.			1	**4**
Cardiocladius sp.				
Cladotanytarsus sp.		2		**8**
Cricotopus/Orthocladius sp.	22	45	68	**524**
Diamesa sp.	1			**4**
Eukiefferiella sp.	8	2	11	**82**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	11	13	6	**117**
Odontomesa sp.				
Pagastia sp.	15	15	29	**229**
Parametriocnemus sp.	1	4	2	**28**
Phaenopsectra sp.				
Polypedilum sp.			1	**4**
Rheocricotopus sp.		37	5	**163**
Stempellinella sp.	16	14	11	**159**
Sublettea sp.				
Synorthocladius sp.	5	11	1	**66**
Thienemannimyia genus group	2	8	14	**94**
Tvetenia sp.		9	14	**90**

Table B8. cont. Macroinvertebrate data collected from site SCR on 17 August 2020.

Other Diptera				
Atherix pachypus			1	**4**
Chelifera/Neoplasta sp.	8	3	6	**66**
Clinocera sp.				
Simulium sp.	4	39	83	**489**
Antocha sp.				
Dicranota sp.			1	**4**
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus	9	19	9	**144**
Optioservus sp.				
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.	2	7	9	**70**
Protzia sp.			1	**4**
Sperchon sp.	3	4	3	**39**
Torrenticola sp.				
Enchytraeidae				
Nematoda		1		**4**
Totals	**281**	**534**	**626**	**5599**
Shannon Weaver Diversity				**3.94**
Calculated Evenness				**0.751**
EPT				**15**
% EPT				**57.25%**
Density				**5,599**
% Non-Insect				**2.08%**
% Shredder/Scraper				**13.74%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**6**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**26.58%**
% Plectopera individuals				**9.37%**
% Trichoptera individuals				**21.30%**
Percent Chironomidae				**28.04%**
Percent Tolerant Organisms				**5.69%**
# Intolerant Taxa				**16**

Table B9. Macroinvertebrate data collected from site BRC on 17 August 2020.

Blue River				
BRC		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	3	7	3	**51**
Baetis flavistriga				
Baetis tricaudatus	21	21	18	**233**
Diphetor hageni	1		1	**8**
Drunella coloradensis				
Drunella grandis	3	7	6	**63**
Ephemerella dorothea infrequens				
Serratella sp.				
Epeorus sp.				
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Chloroperlidae				
Suwallia sp.				
Sweltsa sp.	1	14	4	**74**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	2		1	**12**
Perlodidae				
Diura knowltoni				
Isoperla sp.		5		**20**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus		2		**8**
Brachycentrus occidentalis	2	31	9	**163**
Micrasema bactro				
Glossosoma sp.		1		**4**
Arctopsyche grandis	15	19	14	**187**
Hydropsyche oslari				
Hydroptila sp.		3	2	**20**
Ochrotrichia sp.				
Lepidostoma sp.		12	7	**74**
Rhyacophila sibirica group				
Oligophlebodes sp.		1		**4**
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	17	49	28	**365**
Diamesa sp.				
Eukiefferiella sp.	7	4	3	**55**
Heleniella sp.				
Micropsectra/Tanytarsus sp.		2	1	**12**
Odontomesa sp.				
Pagastia sp.	5	14	8	**105**
Parametriocnemus sp.				
Phaenopsectra sp.				
Polypedilum sp.				
Rheocricotopus sp.		1	2	**12**
Stempellinella sp.		14	4	**70**
Sublettea sp.		1		**4**
Synorthocladius sp.		6		**24**
Thienemannimyia genus group		5	2	**28**
Tvetenia sp.	1			**4**

Table B9. cont. Macroinvertebrate data collected from site BRC on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.			3	**12**
Clinocera sp.				
Simulium sp.	243	42	47	**1287**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus		3	3	**24**
Optioservus sp.	2	8	6	**63**
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.			5	**20**
Protzia sp.				
Sperchon sp.		3	9	**47**
Torrenticola sp.	1	3		**16**
Enchytraeidae				
Nematoda				
Totals	**324**	**278**	**186**	**3069**
Shannon Weaver Diversity				**3.28**
Calculated Evenness				**0.662**
EPT				**14**
% EPT				**29.95%**
Density				**3,069**
% Non-Insect				**2.66%**
% Shredder/Scraper				**7.36%**
Taxa Richness				**31**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**3**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**11.55%**
% Plectopera individuals				**3.43%**
% Trichoptera individuals				**14.97%**
Percent Chironomidae				**22.08%**
Percent Tolerant Organisms				**4.82%**
# Intolerant Taxa				**12**

Table B10. Macroinvertebrate data collected from site LBR on 17 August 2020.

Blue River				
LBR		Sample		
17 August 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Ameletus sp.				
Acentrella sp.	24	18	27	**268**
Baetis flavistriga			25	**97**
Baetis tricaudatus	39	89	20	**574**
Diphetor hageni	5	20	9	**132**
Drunella coloradensis				
Drunella grandis	1	5	3	**35**
Ephemerella dorothea infrequens		17	11	**109**
Serratella sp.				
Epeorus sp.		1	1	**8**
Epeorus deceptivus				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.	1	6	2	**35**
Plecoptera				
Chloroperlidae		1		**4**
Suwallia sp.				
Sweltsa sp.		2		**8**
Zapada cinctipes		1		**4**
Zapada oregonensis group				
Claassenia sabulosa				
Perlodidae			1	**4**
Diura knowltoni				
Isoperla sp.				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis		10	4	**55**
Hydropsyche oslari				
Hydroptila sp.				
Ochrotrichia sp.				
Lepidostoma sp.	4	20	17	**159**
Rhyacophila sibirica group				
Oligophlebodes sp.				
Diptera				
Chironomidae				
Brillia sp.				
Cardiocladius sp.				
Cladotanytarsus sp.				
Cricotopus/Orthocladius sp.	6	5	4	**59**
Diamesa sp.				
Eukiefferiella sp.			3	**12**
Heleniella sp.				
Micropsectra/Tanytarsus sp.	30	4	5	**152**
Odontomesa sp.	1			**4**
Pagastia sp.	33	11	33	**299**
Parametriocnemus sp.	3	2		**20**
Phaenopsectra sp.	2			**8**
Polypedilum sp.				
Rheocricotopus sp.	22	2	8	**125**
Stempellinella sp.				
Sublettea sp.				
Synorthocladius sp.	3	4	3	**39**
Thienemannimyia genus group	7	11	3	**82**
Tvetenia sp.		1		**4**

Table B10. cont. Macroinvertebrate data collected from site LBR on 17 August 2020.

Other Diptera				
Atherix pachypus				
Chelifera/Neoplasta sp.				
Clinocera sp.				
Simulium sp.	1	5	2	**32**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Tipula sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.	1	3	2	**24**
Zaitzevia parvula				
Miscellaneous (Non-insects)				
Hygrobates sp.				
Lebertia sp.				
Protzia sp.				
Sperchon sp.		2	1	**12**
Torrenticola sp.				
Enchytraeidae				
Nematoda				
Totals	**183**	**240**	**184**	**2364**
Shannon Weaver Diversity				**3.74**
Calculated Evenness				**0.778**
EPT				**14**
% EPT				**63.26%**
Density				**2,364**
% Non-Insect				**0.49%**
% Shredder/Scraper				**10.05%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**8**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**53.38%**
% Plectopera individuals				**0.82%**
% Trichoptera individuals				**9.06%**
Percent Chironomidae				**33.94%**
Percent Tolerant Organisms				**7.74%**
# Intolerant Taxa				**12**

Appendix C

Benthic Macroinvertebrate Data – Fall 2020

Table C1. Macroinvertebrate data collected from site UBR on 7 November 2020.

Blue River				
UBR		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	73	22	86	**702**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.	5		2	**28**
Epeorus sp.	72	44	74	**737**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.		6	3	**35**
Paraleuctra sp.				
Prostoia besametsa	1	2	3	**24**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae	4	3	5	**47**
Diura knowltoni				
Isoperla fulva		1	1	**8**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	13	15	24	**202**
Brachycentrus occidentalis				
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	12	17	23	**202**
Hydropsyche cockerelli				
Lepidostoma sp.			1	**4**
Rhyacophila coloradensis		1	1	**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.				
Diamesa sp.				
Eukiefferiella sp.			1	**4**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	2	2	4	**32**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.				

Table C1. cont. Macroinvertebrate data collected from site UBR on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.		1	4	**20**
Antocha sp.	2	7	9	**70**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	4	10	19	**128**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1		**4**
Protzia sp.				
Sperchon sp.			1	**4**
Torrenticola sp.				
Polycelis coronata	3	1	4	**32**
Enchytraeidae			3	**12**
Nematoda	1		1	**8**
Totals	**192**	**133**	**269**	**2311**
Shannon Weaver Diversity				**2.80**
Calculated Evenness				**0.639**
EPT				**11**
% EPT				**86.53%**
Density				**2,311**
% Non-Insect				**2.53%**
% Shredder/Scraper				**34.34%**
Taxa Richness				**21**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**63.64%**
% Plectopera individuals				**4.88%**
% Trichoptera individuals				**18.01%**
Percent Chironomidae				**1.52%**
Percent Tolerant Organisms				**1.01%**
# Intolerant Taxa				**12**

Table C2. Macroinvertebrate data collected from site Blue 5 on 7 November 2020.

Blue River				
Blue 5		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.		2	1	**12**
Baetis tricaudatus	18	15	29	**241**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.				
Epeorus sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	3	5	4	**47**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva				
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis		1		**4**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis				
Hydropsyche cockerelli				
Lepidostoma sp.				
Rhyacophila coloradensis			1	**4**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	8	4	12	**94**
Diamesa sp.	3	8	12	**90**
Eukiefferiella sp.	1	8	3	**47**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	1	1		**8**
Microtendipes sp.				
Pagastia sp.	1	5	22	**109**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	4	15	14	**128**

Table C2. cont. Macroinvertebrate data collected from site Blue 5 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	9	3	11	**90**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus				
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	2			**8**
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	46	33	64	**555**
Enchytraeidae				
Nematoda				
Totals	**96**	**100**	**173**	**1437**
Shannon Weaver Diversity				**2.82**
Calculated Evenness				**0.740**
EPT				**5**
% EPT				**21.41%**
Density				**1,437**
% Non-Insect				**39.30%**
% Shredder/Scraper				**0.00%**
Taxa Richness				**14**
# Ephemeroptera Taxa				**2**
# Plecoptera Taxa				**1**
# Trichoptera Taxa				**2**
% Ephemeroptera individuals				**17.62%**
% Plectopera individuals				**3.25%**
% Trichoptera individuals				**0.54%**
Percent Chironomidae				**33.06%**
Percent Tolerant Organisms				**4.34%**
# Intolerant Taxa				**5**

Table C3. Macroinvertebrate data collected from site DRD on 7 November 2020.

Blue River				
DRD		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.			1	**4**
Baetis tricaudatus	19	46	27	**357**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.		1		**4**
Epeorus sp.				
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	11	52	13	**295**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes		1		**4**
Zapada oregonensis group		1	1	**8**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae		1	1	**8**
Diura knowltoni				
Isoperla fulva			1	**4**
Megarcys signata		3		**12**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	1			**4**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis		1		**4**
Hydropsyche cockerelli				
Lepidostoma sp.			1	**4**
Rhyacophila coloradensis	2			**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.		1		**4**
Cricotopus/*Orthocladius* sp.	2	2	1	**20**
Diamesa sp.	2	4	1	**28**
Eukiefferiella sp.	2			**8**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	2		2	**16**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.	2	8	2	**47**

Table C3. cont. Macroinvertebrate data collected from site DRD on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	2	1		**12**
Antocha sp.				
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	3	3	4	**39**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	5	12	2	**74**
Enchytraeidae		2	2	**16**
Nematoda				
Totals	**53**	**139**	**59**	**980**
Shannon Weaver Diversity				**2.81**
Calculated Evenness				**0.620**
EPT				**13**
% EPT				**73.31%**
Density				**980**
% Non-Insect				**9.16%**
% Shredder/Scraper				**2.39%**
Taxa Richness				**23**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**37.45%**
% Plectopera individuals				**33.86%**
% Trichoptera individuals				**1.99%**
Percent Chironomidae				**12.35%**
Percent Tolerant Organisms				**2.39%**
# Intolerant Taxa				**12**

Table C4. Macroinvertebrate data collected from site Blue 3 on 7 November 2020.

Blue River				
Blue 3		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	9	45	31	**330**
Drunella doddsii				
Drunella grandis				
Ephemerella dorothea infrequens				
Cinygmula sp.		1	1	**8**
Epeorus sp.		1	3	**16**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	12	11	18	**159**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes				
Zapada oregonensis group		3		**12**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae		2	2	**16**
Diura knowltoni				
Isoperla fulva		1		**4**
Megarcys signata	2			**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus		1		**4**
Brachycentrus occidentalis		1	2	**12**
Micrasema bactro				
Glossosoma sp.				
Arctopsyche grandis	3	3	4	**39**
Hydropsyche cockerelli				
Lepidostoma sp.				
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	3	10	5	**70**
Diamesa sp.				
Eukiefferiella sp.	2	2	2	**24**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		1		**4**
Microtendipes sp.				
Pagastia sp.	3			**12**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group				
Tvetenia sp.				

Table C4. cont. Macroinvertebrate data collected from site Blue 3 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.		1		**4**
Wiedemannia sp.				
Simulium sp.				
Antocha sp.	1			**4**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	13	19	14	**179**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.		1	1	**8**
Protzia sp.				
Sperchon sp.	1	1	2	**16**
Torrenticola sp.				
Polycelis coronata	1	2		**12**
Enchytraeidae	2	1		**12**
Nematoda				
Totals	**52**	**107**	**85**	**953**
Shannon Weaver Diversity				**3.03**
Calculated Evenness				**0.679**
EPT				**11**
% EPT				**63.93%**
Density				**953**
% Non-Insect				**4.92%**
% Shredder/Scraper				**3.69%**
Taxa Richness				**22**
# Ephemeroptera Taxa				**3**
# Plecoptera Taxa				**5**
# Trichoptera Taxa				**3**
% Ephemeroptera individuals				**37.30%**
% Plectopera individuals				**20.90%**
% Trichoptera individuals				**5.74%**
Percent Chironomidae				**11.48%**
Percent Tolerant Organisms				**6.56%**
# Intolerant Taxa				**12**

Table C5. Macroinvertebrate data collected from site D 5 on 7 November 2020.

Blue River				
D 5		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.		1		**4**
Baetis tricaudatus	183	113	138	**1683**
Drunella doddsii				
Drunella grandis		2		**8**
Ephemerella dorothea infrequens				
Cinygmula sp.	53		4	**221**
Epeorus sp.	32	5	6	**167**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.	114	60	12	**721**
Paraleuctra sp.				
Prostoia besametsa		1		**4**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	1			**4**
Megarcys signata	1			**4**
Skwala americana				
Trichoptera				
Brachycentrus americanus				
Brachycentrus occidentalis	64	173	102	**1314**
Micrasema bactro				
Glossosoma sp.	7	6	5	**70**
Arctopsyche grandis	29	32	16	**299**
Hydropsyche cockerelli				
Lepidostoma sp.	5	23	2	**117**
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	41	32	25	**380**
Diamesa sp.	17	10	10	**144**
Eukiefferiella sp.	5	9		**55**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	2			**8**
Microtendipes sp.				
Pagastia sp.	71	63	41	**679**
Polypedilum sp.				
Pseudorthocladius sp.		2		**8**
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group		4		**16**
Tvetenia sp.				

Table C5. cont. Macroinvertebrate data collected from site D 5 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.	1	2		**12**
Wiedemannia sp.				
Simulium sp.			1	**4**
Antocha sp.	9	19	2	**117**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	33	11	8	**202**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.	2	2	1	**20**
Sperchon sp.	1	1		**8**
Torrenticola sp.				
Polycelis coronata	28	20	1	**190**
Enchytraeidae				
Nematoda	2	3	2	**28**
Totals	**701**	**594**	**376**	**6487**
Shannon Weaver Diversity				**3.35**
Calculated Evenness				**0.697**
EPT				**13**
% EPT				**71.21%**
Density				**6,487**
% Non-Insect				**3.77%**
% Shredder/Scraper				**9.04%**
Taxa Richness				**28**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**4**
# Trichoptera Taxa				**4**
% Ephemeroptera individuals				**32.14%**
% Plectopera individuals				**11.31%**
% Trichoptera individuals				**27.77%**
Percent Chironomidae				**19.87%**
Percent Tolerant Organisms				**1.38%**
# Intolerant Taxa				**14**

Table C6. Macroinvertebrate data collected from site Blue 2 on 7 November 2020.

Blue River				
Blue 2		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	180	107	175	**1791**
Drunella doddsii			1	**4**
Drunella grandis			2	**8**
Ephemerella dorothea infrequens				
Cinygmula sp.	28	22	31	**314**
Epeorus sp.	96	65	83	**946**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.	1	1		**8**
Chloroperlidae				
Sweltsa sp.	45	27	41	**438**
Paraleuctra sp.	1			**4**
Prostoia besametsa	2	4	4	**39**
Zapada cinctipes				
Zapada oregonensis group	1			**4**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	2	1		**12**
Megarcys signata	1	1		**8**
Skwala americana				
Trichoptera				
Brachycentrus americanus			1	**4**
Brachycentrus occidentalis	11	9	19	**152**
Micrasema bactro				
Glossosoma sp.	30	38		**264**
Arctopsyche grandis	14	27	12	**206**
Hydropsyche cockerelli				
Lepidostoma sp.	6	6	31	**167**
Rhyacophila coloradensis				
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.	27	9	25	**237**
Diamesa sp.	23	6	5	**132**
Eukiefferiella sp.	32	39	18	**345**
Heterotrissocladius sp.			1	**4**
Micropsectra/Tanytarsus sp.	4	2		**24**
Microtendipes sp.		1		**4**
Pagastia sp.	34	27	28	**345**
Polypedilum sp.	9	1	8	**70**
Pseudorthocladius sp.		1	1	**8**
Rheocricotopus sp.		1	1	**8**
Synorthocladius sp.				
Thienemannimyia genus group	1			**4**
Tvetenia sp.				

Table C6. cont. Macroinvertebrate data collected from site Blue2 on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.			1	**4**
Wiedemannia sp.				
Simulium sp.	13	10		**90**
Antocha sp.	3	2	5	**39**
Dicranota sp.				
Hexatoma sp.	1		1	**8**
Coleoptera				
Heterlimnius corpulentus	20	11	31	**241**
Optioservus sp.				
Miscellaneous (Non-insects)				
Lebertia sp.	1	1	3	**20**
Protzia sp.	1	1	1	**12**
Sperchon sp.	1	4	2	**28**
Torrenticola sp.				
Polycelis coronata	11	13	5	**113**
Enchytraeidae				
Nematoda	1	2		**12**
Totals	**600**	**439**	**536**	**6117**
Shannon Weaver Diversity				**3.65**
Calculated Evenness				**0.695**
EPT				**17**
% EPT				**71.49%**
Density				**6,117**
% Non-Insect				**2.98%**
% Shredder/Scraper				**29.90%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**7**
# Trichoptera Taxa				**5**
% Ephemeroptera individuals				**50.16%**
% Plectopera individuals				**8.38%**
% Trichoptera individuals				**12.95%**
Percent Chironomidae				**19.30%**
Percent Tolerant Organisms				**6.98%**
# Intolerant Taxa				**21**

Table C7. Macroinvertebrate data collected from site Blue 1 on 7 November 2020.

Blue River				
Blue 1		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.	1			**4**
Baetis tricaudatus	306	307	226	**3252**
Drunella doddsii				
Drunella grandis		4	5	**35**
Ephemerella dorothea infrequens				
Cinygmula sp.	60	77	127	**1024**
Epeorus sp.	129	159	173	**1787**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.	2		2	**16**
Chloroperlidae				
Sweltsa sp.	25	22	43	**349**
Paraleuctra sp.				
Prostoia besametsa	4	3	2	**35**
Zapada cinctipes				
Zapada oregonensis group			2	**8**
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	4	3	4	**43**
Megarcys signata				
Skwala americana			1	**4**
Trichoptera				
Brachycentrus americanus	1			**4**
Brachycentrus occidentalis	7	6	9	**86**
Micrasema bactro	1			**4**
Glossosoma sp.	1		2	**12**
Arctopsyche grandis	58	27	21	**411**
Hydropsyche cockerelli				
Lepidostoma sp.	40	37	56	**516**
Rhyacophila coloradensis	4	1	1	**24**
Rhyacophila sibirica group	1	1		**8**
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	16	27	35	**303**
Diamesa sp.	17	13	12	**163**
Eukiefferiella sp.	39	12	14	**252**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.				
Microtendipes sp.				
Pagastia sp.	15	6	15	**140**
Polypedilum sp.	3		1	**16**
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group			1	**4**
Tvetenia sp.				

Table C7. cont. Macroinvertebrate data collected from site Blue 1 on 7 November 2020.

Other Diptera				
Atherix pachypus			2	**8**
Bibiocephala grandis		3		**12**
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.	4	6	1	**43**
Antocha sp.	1		3	**16**
Dicranota sp.		1		**4**
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	24	15	40	**307**
Optioservus sp.			1	**4**
Miscellaneous (Non-insects)				
Lebertia sp.	2		1	**12**
Protzia sp.	3	1	5	**35**
Sperchon sp.				
Torrenticola sp.				
Polycelis coronata	7	11	14	**125**
Enchytraeidae				
Nematoda		2		**8**
Totals	**775**	**744**	**819**	**9074**
Shannon Weaver Diversity				**3.12**
Calculated Evenness				**0.604**
EPT				**19**
% EPT				**84.05%**
Density				**9,074**
% Non-Insect				**1.97%**
% Shredder/Scraper				**38.24%**
Taxa Richness				**36**
# Ephemeroptera Taxa				**5**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**8**
% Ephemeroptera individuals				**67.32%**
% Plectopera individuals				**5.00%**
% Trichoptera individuals				**11.72%**
Percent Chironomidae				**9.67%**
Percent Tolerant Organisms				**3.29%**
# Intolerant Taxa				**22**

Table C8. Macroinvertebrate data collected from site SCR on 6 November 2020.

Blue River				
SCR		Sample		
6 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	79	69	129	**1074**
Drunella doddsii				
Drunella grandis	8	22	19	**190**
Ephemerella dorothea infrequens				
Cinygmula sp.	17	27	28	**280**
Epeorus sp.	84	78	127	**1121**
Epeorus longimanus				
Rhithrogena sp.				
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.		1		**4**
Chloroperlidae		3		**12**
Sweltsa sp.	13	28	43	**326**
Paraleuctra sp.				
Prostoia besametsa	3	4		**28**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa				
Hesperoperla pacifica				
Perlodidae				
Diura knowltoni				
Isoperla fulva	2	7	12	**82**
Megarcys signata				
Skwala americana	1	1		**8**
Trichoptera				
Brachycentrus americanus	1	1	5	**28**
Brachycentrus occidentalis	60	39	42	**547**
Micrasema bactro				
Glossosoma sp.	2	1		**12**
Arctopsyche grandis	17	16	41	**287**
Hydropsyche cockerelli		1		**4**
Lepidostoma sp.	16	51	34	**392**
Rhyacophila coloradensis	1		2	**12**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	51	15	47	**438**
Diamesa sp.	22	3	13	**148**
Eukiefferiella sp.	10	7	37	**210**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.	1			**4**
Microtendipes sp.		1		**4**
Pagastia sp.	25	27	38	**349**
Polypedilum sp.		1	5	**24**
Pseudorthocladius sp.	3	2		**20**
Rheocricotopus sp.		1		**4**
Synorthocladius sp.				
Thienemannimyia genus group	1	1	2	**16**
Tvetenia sp.				

Table C8. cont. Macroinvertebrate data collected from site SCR on 6 November 2020.

Other Diptera				
Atherix pachypus		1	2	**12**
Bibiocephala grandis				
Chelifera/Neoplasta sp.		1		**4**
Wiedemannia sp.			1	**4**
Simulium sp.	9	3	1	**51**
Antocha sp.	4	10	5	**74**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus	7	14	5	**101**
Optioservus sp.	1			**4**
Miscellaneous (Non-insects)				
Lebertia sp.	1	2	1	**16**
Protzia sp.				
Sperchon sp.	4	4	2	**39**
Torrenticola sp.				
Polycelis coronata	5	5	4	**55**
Enchytraeidae				
Nematoda			1	**4**
Totals	**448**	**447**	**646**	**5988**
Shannon Weaver Diversity				**3.84**
Calculated Evenness				**0.731**
EPT				**17**
% EPT				**73.65%**
Density				**5,988**
% Non-Insect				**1.88%**
% Shredder/Scraper				**34.33%**
Taxa Richness				**38**
# Ephemeroptera Taxa				**4**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**44.58%**
% Plectopera individuals				**7.66%**
% Trichoptera individuals				**21.41%**
Percent Chironomidae				**20.31%**
Percent Tolerant Organisms				**4.48%**
# Intolerant Taxa				**19**

Table C9. Macroinvertebrate data collected from site BRC on 7 November 2020.

Blue River				
BRC		Sample		
7 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.				
Baetis tricaudatus	11	6	7	**94**
Drunella doddsii				
Drunella grandis	2	4	9	**59**
Ephemerella dorothea infrequens	10	9	10	**113**
Cinygmula sp.	9	1	9	**74**
Epeorus sp.				
Epeorus longimanus	43	66	27	**528**
Rhithrogena sp.		3		**12**
Paraleptophlebia sp.				
Plecoptera				
Capnia sp.				
Chloroperlidae			1	**4**
Sweltsa sp.	9		3	**47**
Paraleuctra sp.				
Prostoia besametsa	1		2	**12**
Zapada cinctipes				
Zapada oregonensis group				
Claassenia sabulosa	1		1	**8**
Hesperoperla pacifica				
Perlodidae	1		1	**8**
Diura knowltoni	1		1	**8**
Isoperla fulva	1	1	1	**12**
Megarcys signata				
Skwala americana	1			**4**
Trichoptera				
Brachycentrus americanus	2	2		**16**
Brachycentrus occidentalis	4	6	5	**59**
Micrasema bactro				
Glossosoma sp.	11	18	12	**159**
Arctopsyche grandis	21	9	21	**198**
Hydropsyche cockerelli	9	5	4	**70**
Lepidostoma sp.	16	9	7	**125**
Rhyacophila coloradensis	1		1	**8**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/Orthocladius sp.				
Diamesa sp.				
Eukiefferiella sp.	5	5	9	**74**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		1	1	**8**
Microtendipes sp.				
Pagastia sp.		3	6	**35**
Polypedilum sp.	1		1	**8**
Pseudorthocladius sp.				
Rheocricotopus sp.				
Synorthocladius sp.				
Thienemannimyia genus group	2			**8**
Tvetenia sp.				

Table C9. cont. Macroinvertebrate data collected from site BRC on 7 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.	1			**4**
Simulium sp.	1		1	**8**
Antocha sp.	5	1		**24**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		1	5	**24**
Optioservus sp.	2	1		**12**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.	3	3	1	**28**
Torrenticola sp.				
Polycelis coronata	1		1	**8**
Enchytraeidae				
Nematoda				
Totals	**175**	**154**	**147**	**1859**
Shannon Weaver Diversity				**3.84**
Calculated Evenness				**0.762**
EPT				**21**
% EPT				**87.18%**
Density				**1,859**
% Non-Insect				**1.89%**
% Shredder/Scraper				**53.78%**
Taxa Richness				**33**
# Ephemeroptera Taxa				**6**
# Plecoptera Taxa				**8**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**47.48%**
% Plectopera individuals				**5.46%**
% Trichoptera individuals				**34.24%**
Percent Chironomidae				**7.14%**
Percent Tolerant Organisms				**5.88%**
# Intolerant Taxa				**21**

Table C10. Macroinvertebrate data collected from site LBR on 6 November 2020.

Blue River				
LBR		Sample		
6 November 2020	1	2	3	**Estimated #/m²**
Ephemeroptera				
Acentrella sp.	1			**4**
Baetis tricaudatus	90	153	131	**1450**
Drunella doddsii				
Drunella grandis	7	8	10	**97**
Ephemerella dorothea infrequens	4	10	15	**113**
Cinygmula sp.				
Epeorus sp.				
Epeorus longimanus	5	3	3	**43**
Rhithrogena sp.	1		2	**12**
Paraleptophlebia sp.	3	2	29	**132**
Plecoptera				
Capnia sp.				
Chloroperlidae				
Sweltsa sp.			1	**4**
Paraleuctra sp.				
Prostoia besametsa				
Zapada cinctipes	1	1	3	**20**
Zapada oregonensis group				
Claassenia sabulosa			1	**4**
Hesperoperla pacifica	1			**4**
Perlodidae			2	**8**
Diura knowltoni				
Isoperla fulva	3	7	6	**63**
Megarcys signata				
Skwala americana				
Trichoptera				
Brachycentrus americanus	7	5	14	**101**
Brachycentrus occidentalis				
Micrasema bactro	1			**4**
Glossosoma sp.	22	17	167	**799**
Arctopsyche grandis	24	40	55	**462**
Hydropsyche cockerelli	37	48	107	**745**
Lepidostoma sp.	7	11	26	**171**
Rhyacophila coloradensis		4	3	**28**
Rhyacophila sibirica group				
Diptera				
Chironomidae				
Brillia sp.				
Cricotopus/*Orthocladius* sp.	8	3	5	**63**
Diamesa sp.				
Eukiefferiella sp.	2	4	12	**70**
Heterotrissocladius sp.				
Micropsectra/Tanytarsus sp.		2	5	**28**
Microtendipes sp.				
Pagastia sp.	5	16	22	**167**
Polypedilum sp.				
Pseudorthocladius sp.				
Rheocricotopus sp.			2	**8**
Synorthocladius sp.			1	**4**
Thienemannimyia genus group	1	1	4	**24**
Tvetenia sp.	1			**4**

Table C10. cont. Macroinvertebrate data collected from site LBR on 6 November 2020.

Other Diptera				
Atherix pachypus				
Bibiocephala grandis				
Chelifera/Neoplasta sp.				
Wiedemannia sp.				
Simulium sp.		4	2	**24**
Antocha sp.	1	3	2	**24**
Dicranota sp.				
Hexatoma sp.				
Coleoptera				
Heterlimnius corpulentus		2		**8**
Optioservus sp.	34	29	46	**423**
Miscellaneous (Non-insects)				
Lebertia sp.				
Protzia sp.				
Sperchon sp.			5	**20**
Torrenticola sp.			1	**4**
Polycelis coronata	24	42	75	**547**
Enchytraeidae				
Nematoda				
Totals	**290**	**415**	**757**	**5682**
Shannon Weaver Diversity				**3.55**
Calculated Evenness				**0.691**
EPT				**20**
% EPT				**75.10%**
Density				**5,682**
% Non-Insect				**10.05%**
% Shredder/Scraper				**27.63%**
Taxa Richness				**35**
# Ephemeroptera Taxa				**7**
# Plecoptera Taxa				**6**
# Trichoptera Taxa				**7**
% Ephemeroptera individuals				**32.63%**
% Plectopera individuals				**1.78%**
% Trichoptera individuals				**40.70%**
Percent Chironomidae				**6.43%**
Percent Tolerant Organisms				**2.12%**
# Intolerant Taxa				**21**

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APPENDIX E

Periphyton Sampling

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SWQC Fall Periphyton Sampling Report

Submitted: December 16, 2020
Amended for BR-IWMP: August 2, 2021

Submitted by:
Tanner Banks, Project Manager | Trout Unlimited

Background

Discussions about the root cause for a declining gold medal fishery, and ultimately, the deterioration of ecological function of the Blue River have been ongoing since 2015. To identify the cause for such declines, an initial phase of an Integrated Water Management Plan (IWMP) would collate historic data and fund field sampling according to metrics agreed upon by IWMP managers and stakeholder groups. Due to unforeseen costs to complete Phase 1 objectives, periphyton sampling was postponed until more funding could be pursued. At the request of Summit Water Quality Committee (SWQC), Trout Unlimited completed an initial round of periphyton sampling at all but one IWMP study site. This report summarizes the results from that sampling event.

With Blue Valley Ranch (BVR) recently proposing a nutrient enhancement study downstream of Green Mountain Reservoir (IWMP Reach LBR), it was an opportune time to collect periphyton at the Upper Blue and Middle Blue sites (IWMP Reach 1 and 2). Even in the event the BVR proposed study is not undertaken, the data collected by BVR since 2019 provide valuable background information that can be used to inform comparisons with periphyton collected this October in the Middle Blue River. The BVR study is focused on understanding the effect of phosphorus on benthic algae (periphyton), and more specifically *Didymosphenia geminata* (Didymo), a filamentous diatom that can invade and alter the ecological function of lotic ecosystems (Rost & Fritsen 2014). One concern of practitioners is that these invasive Didymo algae blooms often take place in oligotrophic streams, and particularly, in streams that lack dissolved phosphorus. This deficiency in phosphorus may be part of what's causing the occurrence of Didymo below Green Mountain Reservoir. Comparatively, the Middle Blue is also oligotrophic, but colonization's of Didymo are much less severe and therefore may serve as control reach should the BVR study commence.

Ultimately, benthic algae samples will identify differences and similarities between the two Blue River reaches that can be used to inform future management decisions. Data collation in conjunction with the BVR nutrient study will provide quantified data for whether nutrient enhancement could be useful on the Middle Blue (Reach 2), and if so, whether it would be an effective management tool for restoring ecological function. This periphyton sampling was also intended to serve as continued foundational data to be used in determining root causes for the decline of Blue River ecological function.

Sampling

This benthic algae field sampling did not adhere to WQCD stream chlorophyll sampling protocols. Instead, a more rigorous sampling approach was used to coincide with the methods set forth by BVR. This alternative sampling methodology is comparable to the WQCD approach but is tailored for repeatability. The quantitative strength of this sampling was not compromised, rather its use provides for more direct comparisons with ongoing sampling on the Blue River downstream of Green Mountain Reservoir. Importantly, the Blue River IWMP macroinvertebrate sample site locations were used in this study to enable a better understanding of all potential factors affecting the Middle Blue River stream ecology.

Upon approval by the SWQC, Trout Unlimited completed the periphyton sampling on October 6th, 2020. Eight Middle Blue and one Upper Blue IWMP study sites (Figure 1) were sampled according to the agreement between SWQC and Trout Unlimited. This task was completed with the assistance of the BVR staff to ensure comparability of results from the two field sampling initiatives and so field work could be completed in a single day. Immediately following the completion of field work, samples were shipped overnight to EnviroScience in Stow, Ohio for laboratory analysis.

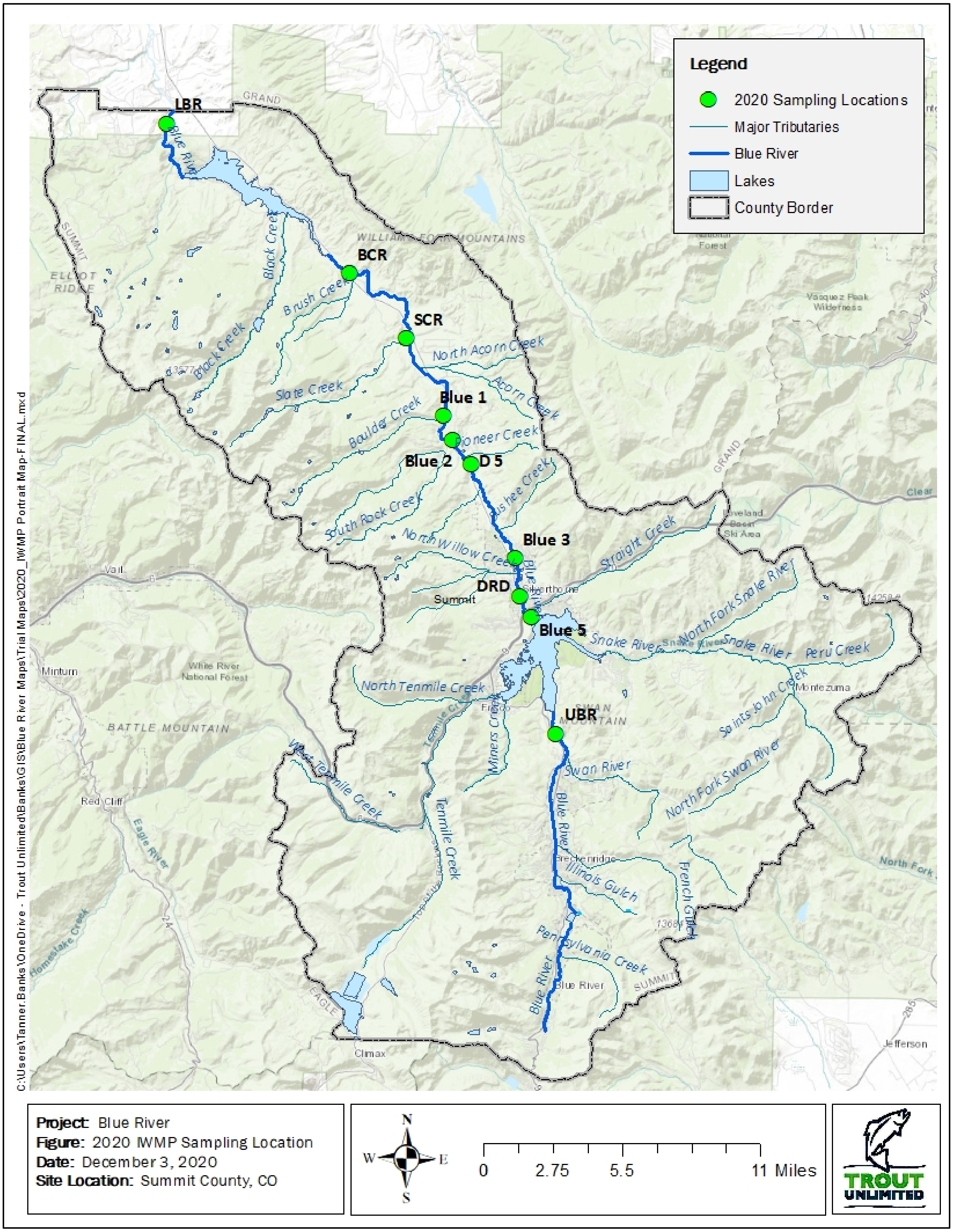
Methods

At each site, a total of eight small to large cobble with an estimated range of 60 - 180 mm were collected from a single riffle/run segment. Of the eight sample rocks, four were collected as replicates to quantify spatial variability. The section of the rock exposed to surface water and to be scraped for benthic algae is referred to as the "standing crop". Over a small plastic tub, the standing crop margin is scraped and brushed to dislodge benthic algae and organic matter. The organic-laden stream water is then consolidated within the small tub, bottled and labeled for lab analysis. Following the scrapes, aluminum foil was placed over the top each rock and cut to fit the total area scraped; the foil is used to determine surface area to quantify the mass per unit area of each subsample.

EnviroScience received the periphyton samples on October 7th, and subsequently completed the lab analysis for Ash-free dry weight (AFDW) and chlorophyll a (Chl-*a*). The AFDW is a general quantification of the total organic mass using oxidation methods for total organic mass of a sample; AFDW does not differentiate the type of organics. Chl-*a* is commonly measured using spectrophotometry, which is a pigment analysis that identifies the abundance of benthic algae (Steinman et. al 2006). The advantage of a pigment analysis compared to AFDW is its ability to differentiate algal biomass from organics such as detritus or fungi (Steinman et al. 2006). The results of the top rock scrapes and subsequent lab results are presented in Table 1.

At site *Blue-5*, only two rocks at the upstream and downstream locations were used to due to the abundant biomass of aquatic algae and mosses. Chain of custody paperwork was completed for each sample to catalogue and verify collection parameters and field sampling notes, which is attached as *Appendix 1*.

Figure 1. 2020 site locations according the Blue River IWMP.



Data

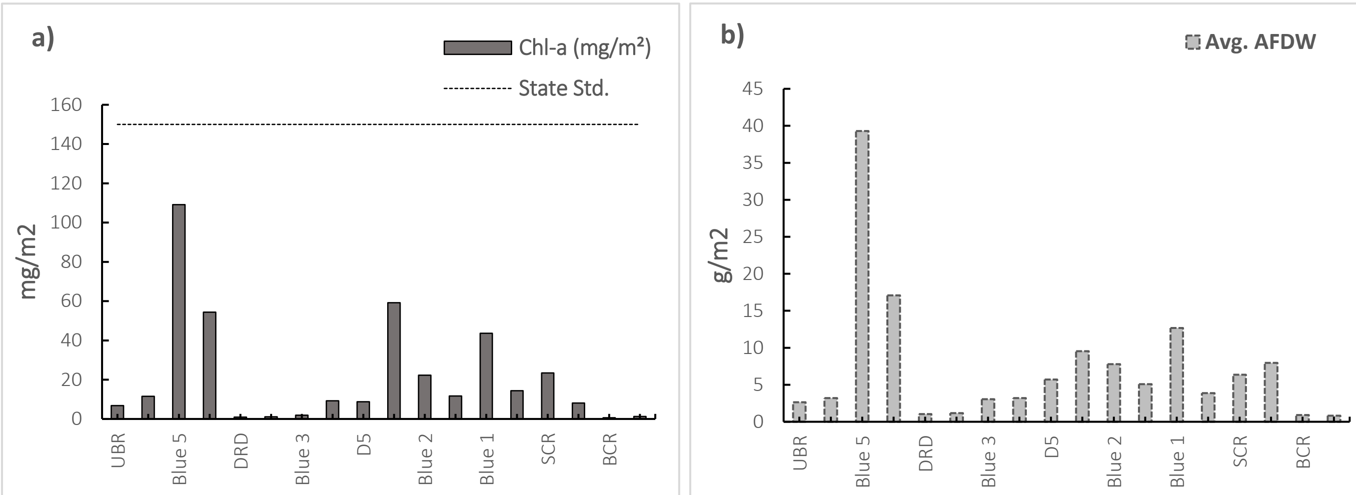
During the periphyton field sampling, several sites displayed healthy colonization's of periphyton, while other sites appeared relatively void of any primary productivity. After completing the field work, it was apparent at that time that the longitudinal distribution of periphyton communities in the Blue River are spatially, highly variable. Each of the IWMP sample sites is represented by two periphyton subsamples; an upstream (US) and a downstream (DS) site, the DS is considered the subsample control.

Table 1. Shows all sites according to the IWMP nomenclature with lab results by site and subsample. Chlorophyll *a* concentrations are reported as milligrams of Chl-a per square meter (mg/m^2) and ash-free dry mass are reported as grams of AFDW per square meter (g/m^2).

IWMP Site Name	Site Notes	Lat , Long	Sample ID	AVG AFDW (mg/L)	AVG AFDW (g/m^2)	Initial Sample Volume (mL)
UBR	Historic FS Site - Above Swan Mtn Rd	39.56627, -106.04929	TR-UBR_US	331	2.6339	438
			TR-UBR_DS	501	3.1970	373
Blue 5	Historic FS Site - Above Straight Cr	39.62604, -106.06712	TR-Blue-5_US	1240	39.2885	565
			TR-Blue-5_DS	1320	17.0766	780
DRD	Dillon Ranger Station	39.63626, -106.07526	TR-DRD-US	237	1.0419	270
			TR-DRD-DS	246	1.1692	245
Blue 3	Historic FS Site - Below Willow Cr	39.65606, -106.07747	TR-Blue-3_US	295	3.0611	315
			TR-Blue-3_DS	473	3.2044	432
D5	Historic FS Site - Pioneer Cr	39.70523, -106.11146	TR-D5_US	493	5.7019	474
			TR-D5_DS	639	9.5370	579
Blue 2	Historic FS Site - Campground	39.72716, -106.13264	TR-Blue-2_US	516	7.7812	804
			TR-Blue-2_DS	367	5.0858	480
Blue 1	Historic FS Site - Below Boulder Cr	39.74358, -106.13282	TR-Blue-1_US	504	12.6698	542
			TR-Blue-1_DS	425	3.8766	497
SCR	Above Slate Cr	39.78226, -106.16085	TR-SCR_US	541	6.3688	503
			TR-SCR_DS	408	7.9604	743
BCR	Below Brush Cr	39.82165, -106.20679	TR-BCR_US	111	0.9069	430
			TR-BCR_DS	80	0.8132	411

Table 1 and Figures 2a-b support the field observations described above. The highest algal biomass measured as Chl-a was located at Blue 5 at 109.13 mg/m^2, compared to the least abundant sample, BCR at 0.653 mg/m^2. AFDW mass per unit area results are similar to Chl-a concentrations with the most abundance observed at Blue 5 (39.28 g/m^2) and least at the BCR control site (0.813 g/m^2). Lewis and McCutchin (2016) explain, annual abundances of Chl-a is affected by several factors including but limited to runoff and anchor ice, which can lead to spatial and temporal variability. These factors are important because it may help explain some of the variability presented in this report. While abiotic factors likely have a more significant impact on biota in high alpine environments, data from grab samples lack spatial and temporal representation and therefore may not allow for this generalization in this specific context. Annual sampling events throughout all seasons should continue to provide a more statistically confident representation of abiotic and biotic interactions.

Figure 2a. Depicts Chlorophyll-a concentrations at each IWMP sample site compared to the current State Chl-a threshold for cold water rivers and streams. **Figure 2b.** Depicts the average ash free dry weight (AFDW), which is the total biomass of benthic algae scraped from the upstream and downstream locations at each site.



Based on the results illustrated in Figure 2a – b, site Blue 5 displayed significantly higher concentrations of Chl-a and AFDW than all other 2020 sample sites. This finding has been documented from data collected and presented by in Lewis et. al (2012, 2016) in SWQC annual reports. Neither the 2016 or 2012 Lewis and McCutchan reports explicitly recognize high concentrations of Chl-a or the causation, but rather explains the unlikelihood of exceedances of the Chl-a standard at any site in the Blue River Watershed. Based on the 2020 data, concentrations of Chl-a at Blue-5 approach State Chl-a thresholds, but do not exceed them. Field observations at the time of collection noted the increase in biomass of benthic algae, filamentous algae, and aquatic mosses.

The 2016 and 2020 sampling events carried out by Lewis et. al, as well as this Trout Unlimited study reveal that Chl-a concentrations immediately downstream of Dillon Dam are significantly higher than those observed in the Upper Blue River before the inlet into Dillon Reservoir (Figure 3). The 2020 results also reveal that Chl-a concentrations at sites north of Silverthorne down to SCR have reasonable concentrations of Chl-a. Referencing Figure 2b, the total algal biomass is more consistent and can be interpreted that the abundance of forage for benthic macroinvertebrates increases as you move downstream from site DRD.

Figure 3. Compares Chlorophyll a concentrations from 2012, 2016, and 2020 below Dillon Dam (DD) and above Dillon Reservoir (DR). The sampling locations are not identical across all years, but GPS locations confirm that during all years, samples collected from the DR site are taken upstream of the water treatment plant and the DD site is within 0.30 miles of the Dillon Dam tailrace.

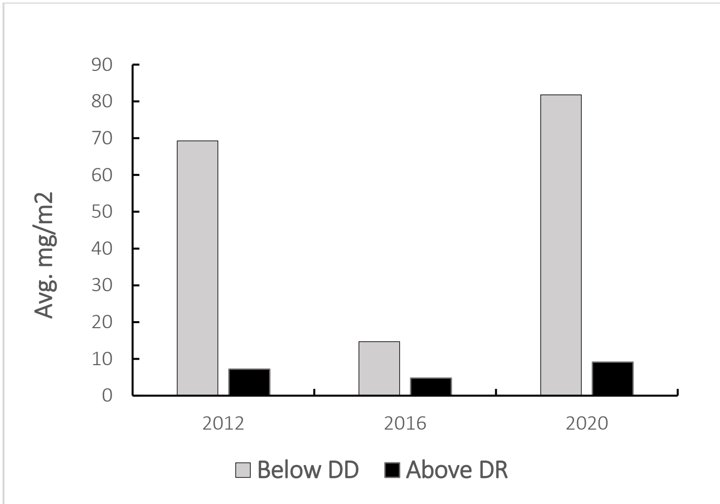
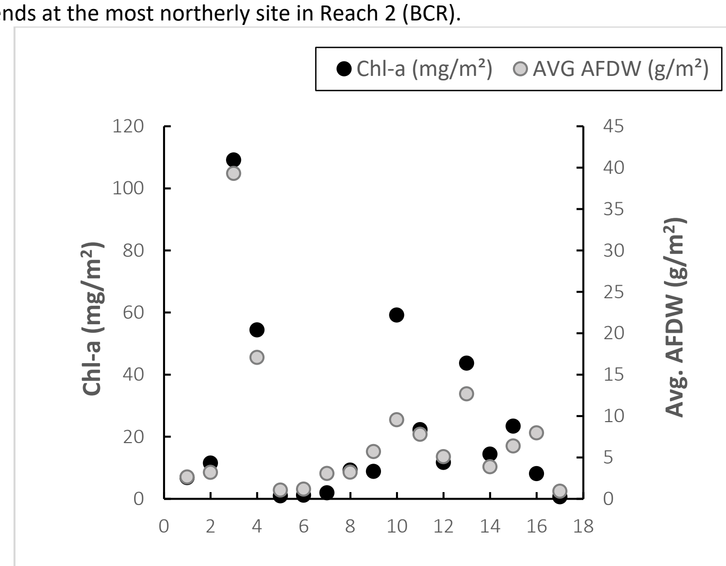


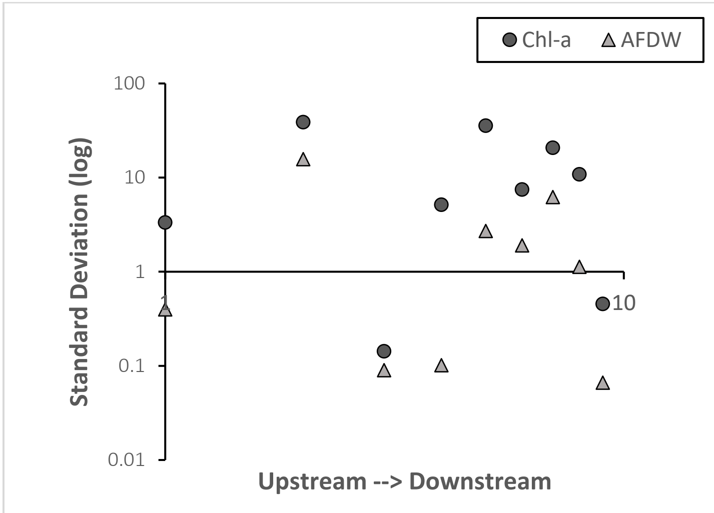
Figure 4. Illustrates periphyton abundance as chlorophyll-a in mg/m^2 as the primary y-axis compared to the average ash-free dry weight (AFDW) in g/m^2 as the secondary axis. The x-axis is represented by the sample number, which starts at the most southerly site (UBR) and ends at the most northerly site in Reach 2 (BCR).



X-axis: 1-2 (UBR); 3-4 (Blue 5); 5-6 (DRD); 7-8 (Blue 3); 9-10 (D5); 11-12 (Blue 2); 13-14 (Blue-1); 15-16 (SCR); 16-17 (BCR)

The similarity between Chl-a and AFDW that is illustrated in Figure 4 reveals that there is not a large amount of fungi, bacteria, or detritus in the Blue River. This relationship can be partially explained in the sampling methods and the removal of clung particulates and caddis retreats from the standing crop area prior to scraping. This removal may have inadvertently removed biological communities that colonize woody particulates and/or caddis retreats symbiotically. This field sampling is worth noting, but it is not believed that the step to remove such debris and detritus altered results in a significant manner. Figure 5 illustrates that that longitudinally, Chl-a and AFDW are closely correlated and the samples were not comprised of significant amounts of detritus or non-pigment producing plant matter; D5 appearing to be the only site that does not reflect that pattern (Figure 4 & 5).

Figure 5. Denotes the standard variation between all the upstream and downstream top rock samples at each site across all nine IWMP sample sites on a logarithmic scale. It does not represent differences found between sites. The figure represents the variability found between top rock samples (y-axis) at each of the respective sites (x-axis).



Conclusions and Recommendations

The lack of regional precipitation from late winter through typical monsoonal months is a potential variable impacting the results of this seasonal study. Due to the draught-like conditions throughout the Blue River and Upper Colorado watersheds, drinking water impoundments such as Dillon Reservoir and Green Mountain Reservoir maximized their water storage resulting in less than typical reservoir releases. Future sampling events should seek to increase the frequency of sampling to explain seasonal variability that is often observed below each reservoir.

The fall sampling effort was extremely useful in that it provided practitioners and stakeholders with more baseline data for Reach 2. Although the sampling was not identical to the original proposal by TU to BREW and IWMP members, this sampling does provide useful data on Reach 2. For a one-time grab sample, September through October is the most meaningful time to represent one growing season (WQCD). For a more comprehensive representation of the potential shifts in benthic algae assemblages, more frequent sampling events should be considered.

Most importantly, the results of this study should be combined with chemical and biological data collected prior to, or as part of the IWMP. Historic water chemistry data from the Blue River should be referenced in conjunction with benthic algae samples as well as all relevant species assemblages of benthic macroinvertebrates. Any future benthic algae study plans should include methods to quantify temporal variability as well as determine whether spatial variability of the 2020 samples was a stochastic event. The temporal component should be accounted for by completing seasonal top rock scrapes along with the benthic macroinvertebrate samplings (spring, summer, fall). Site Blue 5 should be resampled according to the sampling protocols set forth in 2020 to determine whether this site consistently supports increased primary productivity, and more specifically, what factors may be causing the current conditions. Should continued empirical studies takes place on the Blue River, an emphasis should be given on the necessity to continue this work through several consecutive years. As seen in this dataset, there may be several abiotic and biotic variables impacting individual grab samples, making annual replication paramount for well-informed management actions.

Literature Cited

Andy L. Rost & Christian H. Fritsen (2014) Influence of a tributary stream on benthic communities in Didymosphenia geminata impacted stream in the Sierra Nevada, USA, Diatom Research, 29:3, 249-257, DOI: 10.1080/0269249X.2014.929029.

Steinman et al. (2006) Biomass and Pigments of Benthic Algae. Methods of Stream Ecology: Second Edition, Edited by F. Richard Hauer and Gary A. Lamberti, Ch. 17, 357-368.

Colorado Water Quality Control Division (WQCD), Standard Operating Procedures for the Collection of Streams Periphyton Samples.

William M. Lewis and James H. McCutchan (2012), Evaluation and Interpretation of Multi-Metric Index (MMI) Information on Invertebrate Communities of the Blur River below the Dillon Reservoir Dam, Summit County, Colorado, Rpt. 337.

William M. Lewis and James H McCutchan (2013), Results of a Field Survey of Benthic Chlorophyll Abundance and its Possible Relationship to Nutrient Concentrations for Streams within and Just Below the Lake Dillon Watershed, Rpt. 328.

William M. Lewis and James H McCutchan and Jennifer Roberson (2016), Chlorophyll and Nutrient Concentrations for Selected Sites in the Lake Dillon Watershed, Rpt. 378.

Appendix 1. Blue River Chlorophyll *a* and ash-free dry weight EnviroScience chain of custody (CoC) forms.

EnviroScience
Excellence in Any Environment

SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

5070 Stow Road Stow, OH 44224
Phone: 330-688-0111 Ext. 282
Fax: 330-688-3858
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Purchase Order Number:

Project ID #:

Report to:	Tanner Banks	Invoice to:	Tanner Banks
Company:	Trout Unlimited	Company:	Trout Unlimited
Address:	620 Main St, STE 9	Address:	620 Main St, STE 9
	Frisco, CO 80443		Frisco, CO 80443
Phone:	970.390.9492	Phone:	970.390.9492
Email:	tanner.banks@tu.org	Email:	tanner.banks@tu.org

(Leave blank if same as reporting)

Client:	Blue Valley Ranch
Contact:	Brian Rose
Email:	brian.rose@[illegible].com
Phone:	970.531.6223

(Leave blank if same as reporting)

Requested Analyses

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	HAB Screening	Algal Toxin Analysis	Algae Test 1	Algae Test 2	Algae Test 3	Ash-Free Dry Weight	ATP Analysis	Diatom Analysis	Chl. a	Volume of Container	Number of Containers
	TR-BLR-01	Middle Blue	11/6/20	9:00											
	TR-BLR-Control			" "											
	TR-SLR-01			11:30											
	TR-SLR-Control			" "											
	TR-BlueL-01			10:15											
	TR-BlueL-Control			" "											

Expedited turnaround analysis (Tiefel [illegible] if required):

Total Number of Containers:

Preservative(s) Used:

On ice at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only

Sample Receipt Evaluation

Received Time:	Lab Received:
Lab Verified:	Approved Condition:
Sample Temperature:	°C

(If preserved by cooling on ice at 4°C)

Condition of Container(s)

Relinquished by	Received by	Date	Time	Shipping Information	
Tanner Banks				Date Shipped	11/6/20
	[illegible signature]	10/7/[illegible]		Method Shipped	Overnight (UPS)

Sample collector signature: [signature]

EnviroScience
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5070 Stow Road, Stow, OH 44224
Phone: [illegible]
Fax: [illegible]
Email: [illegible]

SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

Purchase Order Number:

Project ID #:

Report to:	Tanner Banks	Invoice to:	Tanner Banks	Client:	Blue Valley Ranch
Company:	Trout Unlimited	Company:	Trout Unlimited	Contact:	Brian Rose
Address:	620 Main St, STE 9	Address:	620 Main st, STE 9	Email:	brian.rose@insgrp.com
	Frisco, CO 80443		Frisco, CO 80443	Phone:	970-531-6229
Phone:	970-390-9492	Phone:	970-390-9492		
Email:	tanner.banks@TU.org	Email:	tanner.banks@TU.org		

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	HAB Screening	Algal Toxin Analysis	Algae level 1	Algae level 2	Algae level 3	Ash-Free Dry Weight	ATP Analysis	Diatom Analysis	Chl-a	Volume of Containers	Number of Containers
	TR-Blue-2_01	middle Blue	10/6/20	11:22											
	TR-Blue-2_Control	↓	↓												
	TR-D-5_01			11:56											
	TR-D-5_Control														

Requested turnaround time to analyze (if [illegible] is required):

Total Number of Containers:

Preservative(s) Used:	
Chilled at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only	
Sample Receipt Evaluation	
[illegible]	[illegible]
[illegible]	[illegible]
Sample Temperature:	
(If preserved by cooling on ice at 4°C)	
Condition of Container(s)	

Relinquished by	Received by	Date	Time	Shipping Information		Sample collector signature:
Tanner Banks				Date Shipped	10/6/20	[signature]
	[signature]	10/7/20		Method Shipped	UPS overnight	

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SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

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Phone: 330 688-0111 Ext. 282
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Purchase Order Number:
Project ID #:

Report to:	Tanner Banks
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	Frisco, CO 80443
Phone:	970-390-5492
Email:	tanner.banks@TU.org

Invoice to:	Tanner Banks
Company:	Trout Unlimited
Address:	" "
Phone:	
Email:	

Client:	Blue Valley Ranch
Contact:	Brian Pope
Email:	brian.pope@jasgrp.com
Phone:	970-531-6223

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	HAB Screening	Algal Toxin Analysis	Algae Test 1	Algae Test 2	Algae Test 3	Ash-free Dry Weight	ATP Analysis	Coliform Analysis	Chl. a	Volume of Containers	Number of Containers
	TR-Blue3_01	Middle Blue	10/6/20	12:25											
	TR-Blue3_Control			" "											
	TR-DRD_01			12:57											
	TR-DRD_Control														

Requested toxins to analyze (if algal toxin analysis is required):

Total Number of Containers:

Preservative(s) Used:
On ice at 4°C:
Glutaraldehyde:
Formalin:
Other:

EnviroScience Use Only
Sample Receipt Evaluation
Sample Temperature: °C
(If preserved by cooling on ice, 4°C)
Condition of Container(s)

Relinquished by	Received by	Date	Time	Shipping Information	
Tanner Banks				Date Shipped	10/6/20
	[illegible]	[illegible]		Method Shipped	UPS OVERNIGHT

Sample collector signature: [signature]

EnviroScience
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5070 Stow Road, Stow, OH 44224
Phone: 330-688-0111 Ext. 222
Fax: 330-688-3256
Email: [illegible]

SAMPLE SUBMISSION AND CHAIN OF CUSTODY FORM

Purchase Order Number:
Project ID #:

Report to:	Tanner Banks
Company:	Trent Unlimited
Address:	620 Main St, STE 9
	Frisco, CO 80443
Phone:	970-390-9492
Email:	TannerBanks@[illegible].org

Invoice to:	Tanner Banks
Company:	Trent Unlimited
Address:	"
Phone:	
Email:	

(Leave blank if same as reporting)

Client:	Blue Valley Ranch
Contact:	Brian Rose
Email:	[illegible]
Phone:	970-531-6823

(Leave blank if same as reporting)

Laboratory No. (Lab Use Only)	Sample ID	Site ID	Date	Time	Requested Analyses: [illegible]	Algal Toxin Analysis	Algae Test 1	Algae Test 2	Algae Test 3	Ash-Free Dry Weight	[illegible] Analysis	Diatom Analysis	Chl-a	Volume of Container	Number of Containers
	TR-Blue5_01	(Middle Blue)	10/6/20	1:21											
	TR-Blue5_Control														
	TR-UBR_01	(Upper Blue)		2:03											
	TR-UBR_Control														

Requested toxins to analyze (if algal toxin analysis is required):

Total Number of Containers:

Preservative(s) Used:	
On ice at 4°C:	
Glutaraldehyde:	
Formalin:	
Other:	

EnviroScience Use Only

Sample Receipt Evaluation	
Date/Time Rec'd:	Lab Acct #:
Invoice Acct:	Approved:
Sample Temperature:	°C
(If preserved by cooling on ice at 4°C)	
Condition of Container(s)	

Relinquished by	Received by	Date	Time	Shipping Information	
Tanner Banks				Date Shipped	10/6/20
	[signature]	[illegible]		Method Shipped	UPS OVERNIGHT

Sample collector signature: [signature]

APPENDIX F

Blue River Fishery

Summary Report on the

The Blue River Fishery Status and the Influence of Water Temperature on the Blue River Fishery

August 2021

Prepared For:
Tetra Tech Inc.

Prepared By:
Ken Kehmeier
Ksqrdfish Aquatics LLC
1718 Silvergate Rd.
Fort Collins, Colorado 80526

Executive Summary

The Blue River fishery below Dillon Reservoir has been under special regulation management since 1983. These regulations were implemented to increase both numbers and biomass of fish in the Blue River. By the late 1980's the fishery had reached it maximum production of quality fish, and since then has shown a downward trend and currently the fishery is at than 50% or less of what was seen after the implementation of the regulations. Most recent estimates show the Blue River supports approximately 1000 fish per mile which is significantly less than reference streams like the Taylor River (5000 fish/mile) and the Fryingpan (8000 fish/mile). The Blue River has been shown to have the slowest growth rates of studied rivers in Colorado. A 4+ year old brown trout in the Blue River is more than and inch smaller than fish of similar age in other Colorado Rivers.

Cold water temperatures coming out of Dillon Reservoir contributes to the declining fishery by limiting growth, reproduction and recruitment of brown trout. Cold temperatures also have been found to limit aquatic invertebrates which are the main food source for the fish in the Blue River. Temperatures for optimal growth of brown trout (11-18^0 C) were only seen in 2020 in the lower few miles above Green Mountain Reservoir and only in late summer.

Blue River fish populations also seems to fluctuate more than other rivers in Colorado. Habitat availability at different flow levels has been found to impact year class strength on the Blue River. This may be due to stream channel changes due to years of altered flows and the lack of lateral connection to critical habitat at higher flows. In 2020 the reservoir spill created an increase in stream temperatures of 6.6^0 C (4.8^0-11.4^0 C), in 48 hours, which is considerable when compared to conditions on the Blue River above Dillon which changed 1.2^0 C (7.7^0-8.9^{0}C) over the same time period. Rapid increases temperature during the spill events may create temperature shock as well as limit habitat for brown trout fry and invertebrates.

Future work on the Blue River fishery should include continued year-round monitoring of water temperature in both the mainstem Blue River and a few select tributaries. Habitat assessment to determine the need for restoration projects to improve lateral connectivity and overall habitat for all life stages at anticipated flows. And all projects should be measured for success by standardized fish sampling and creel census, with the goal of returning the Blue River to the Gold Medal Status it once had.

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Introduction

In 2016 Colorado Parks and Wildlife's designation of Gold Medal status was removed from the portion of the Blue River between Hamilton Creek Road and Green Mountain Reservoir . A Gold Medal fishery must be able to produce a minimum of 12 "quality trout" (14+ inches) per acre and 60 pounds of trout standing stock per acre. However, this portion of the Blue River has not met Gold Medal criteria for many years prior. The purpose of this summary report is to inform decision makers on existing data, studies and information that provide insight on the declining fishery in the Blue River below Dillon Reservoir. This report will also review the temperature data collected in 2020 and review how temperature continues to influence the fishery in the Blue River.

Review of Data on Blue River Fish Populations

Fisheries data from Colorado Parks and Wildlife databases were reviewed along with older documents associated with the environmental review for Two Fork (Chadwick and Associates 1986). The majority of these historical data sets are for the Blue River between Dillon Reservoir and Green Mountain Reservoir, and for the purpose of this document will be the focus of the following discussion.

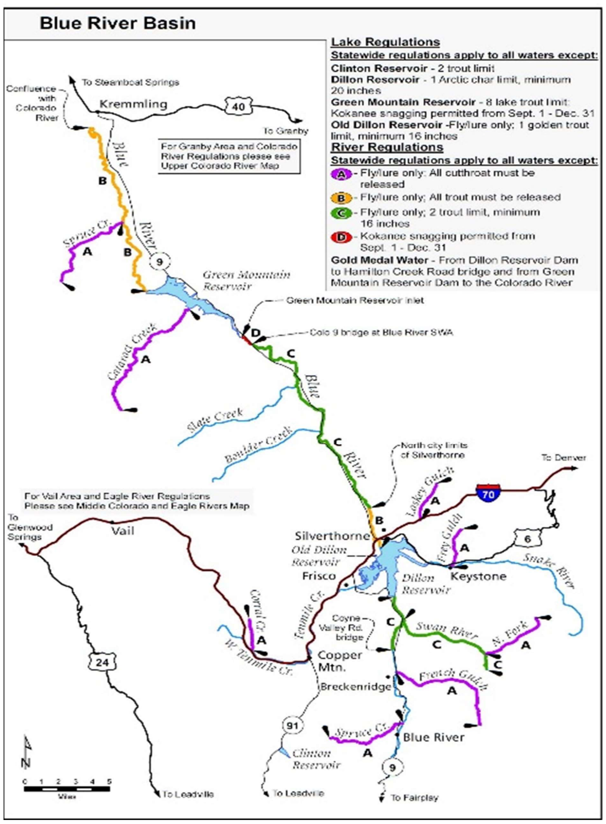

Figure 1. Current fishing regulation map for the Blue River Drainage (CPW 2020 Regulation Brochure).

Beginning in 1983 the Blue River between Dillon and Green Mountain Reservoirs was placed under a 2-trout creel limit with a catch and release restriction on all brown trout under 35cm (14 in). These regulations were implemented initially to increase the trout biomass and fish quality (Nehring 1987). Nehring postulated that angler activity removed the younger, faster growing fish under standard regulations and so the protections to a larger size kept those faster growing fish in the river longer. Current fishing regulations (Figure 2) include catch and release fishing from Dillon Reservoir downstream within the city limits of Silverthorne and downstream of Green Mountain Reservoir to the Colorado River. Two additional areas, downstream of Silverthorne to Green Mountain Reservoir and upstream of Dillon Reservoir to Summit County Road 3 (Coyne Valley Bridge) and the Swan River are managed with a fly and lure, 2 trout over 16-inch regulation.

Rainbow trout in the Blue River are maintained by stocking on most years with both catchable trout (>9 inches) and sub-catchable (<9 inches) sized fish. A stocking strategy has been difficult to determine for the biologist because survival and recruitment have been erratic and unpredictable. Sub-catchable rainbows stocked have not shown consistent survival between years. It is felt this is due to heavy predations by brown trout or mortality due to the fish not thriving after stocking due to cold water and fluctuating flows (Ewert, personal communication). Recent years excess brood fish (>14 inches) have been utilized for stocking and success has been limited. During low flows, brood fish that are stocked do not disperse throughout the river. They appear to remain in, or close to, the locations that they were stocked for the entire season (Ewert, personal communication), Nehring (1991) found similar sedentary nature of stocked rainbow trout on the Fryingpan River. This increases their vulnerability to angler and lessens the probability of survival long term. From 1992 to 1999 no rainbow trout were stocked into the Blue River due to hatchery rainbow trout availability because of whirling disease. Little fish sampling was completed during this time period, so no results are available to know the impact to the fishery.

Brown trout are managed as a wild trout fishery and make up the majority of the numbers and biomass of trout throughout the Blue River. Nehring (1987) found implementation of special regulations in 1983, increased population biomass and numbers of brown trout over 30 and 35 cm (12 and 15 inches). He felt after 4 years of special regulations the Blue River had reached maximum production of quality trout, and that 35 cm (14 inches) was about the maximum size that most brown trout could achieve in the Blue River. Nehring cited cold water temperatures in the Blue River due to hypolimnion releases from Dillon Dam led to slow growth rates for brown trout. However strong year classes were seen in years of drought with increased growth rates of young of the year brown trout. Nehring (1987) found that the larger average sizes in the first year of life carried through in subsequent years for that cohort's life span in the stream. This is evident after the drought of 2002-2003 where lower fish per mile created higher biomass of brown trout (Figure 3), or higher biomass was created by bigger fish from the 2003-year class.

Following the initial success of special regulations in the late 1980's brown trout numbers per acre and biomass have trended down and currently are at or less than 50% of the numbers per acre and biomass what was seen after the implementation of the special regulations (Figure 2 and 3). Recent surveys of trout populations in reach 2 of the Blue River between Lake Dillon and Green Mountain Reservoir have continued to show low growth rates and lower body condition that was documented in the fishery inventories which began in the mid-1980's (Nehring 1987).

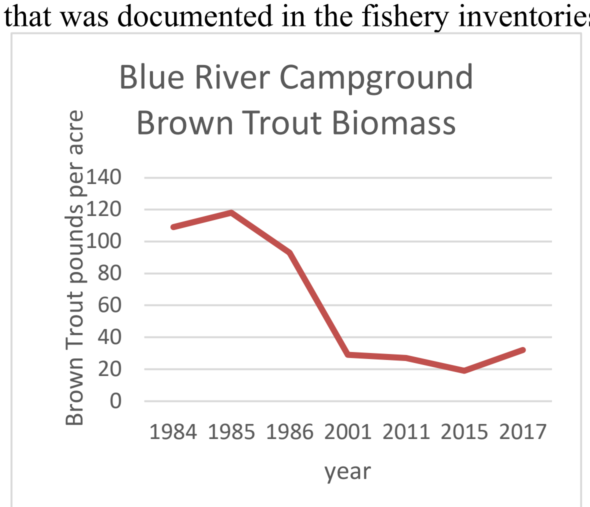

Figure 2.Brown Trout Biomass (lb./A) at Blue Campground 1984-2017

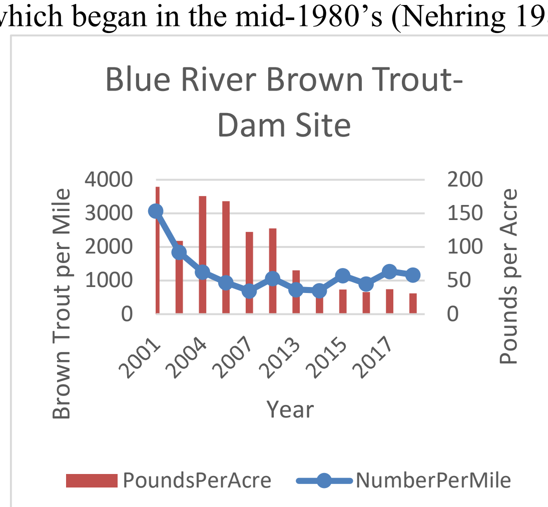

Figure 3.Brown trout per mile and Biomass downstream of Dillon Dam.

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Conditions in the Blue River, 1.5 miles downstream of the reservoir, at the Forest Service Ranger Station did not meet Gold medal standards in recent surveys, however there was a relatively consistent brown trout biomass seen in four occasions, sampled in 2004, 2005, 2008 and 2014. Rainbow estimates have been more variable; however, the differences can be directly attributed to stocking strategies in effect at the time.

The Blue River adjacent to the USFS Blue River Campground has been surveyed multiple times over the past decade and since 2011 this segment has not met the biological criteria for a Gold Medal designation. Reasons for the lack of productivity on this reach of the Blue are not fully understood. There are some areas with obvious physical habitat shortcomings particularly when Dillon releases are less than 100 cfs, but it is likely not the only limiting factor given the extremely slow trout growth in the surveyed populations here, which suggests aquatic invertebrate productivity limitations (Rees 2021).

Chadwick and Associates (1986) found that a positive tailwater effect on the fishery was not seen below the Dillon Reservoir, as no increase in bio-productivity was evident. Some of the most productive fisheries are in tailwaters below dams due to constant temperatures and ample food supply from macro invertebrates and items like amphipods (scuds) coming out of the associated reservoir. These factors allow faster growth, superior fish condition and overall survival.

Comparison to Other Colorado River Systems

Additional analysis was completed comparing the Blue River fishery over time to similar rivers in Colorado that are regulated by large reservoirs upstream which have hypolimnetic releases and similar fisheries management and regulations. Rivers which were utilized were the Fryingpan River below Reudi Reservoir, and the Taylor River below Taylor Reservoir. Both these rivers have wild brown trout populations with rainbow populations which are dependent on stocking.

All these rivers have been stocked with catchable and sub-catchable size rainbow trout since 1980 (Table 1). Statewide stocking rainbow trout in tailrace fisheries is quite common, due to factors limiting rainbow trout reproduction and recruitment. In addition to the Blue River, Fryingpan River and Taylor River other tailrace fisheries like the Dream Stream (below Spinney Mtn Res.) and Cheeseman Canyon on the South Platte are stocked with fingerling rainbow trout because seasonal flows and/or cold-water temperatures hinder successful rainbow spawning. Unlike the Blue River these other tailrace rivers have developed rainbow trout fisheries by stocking subcatchable fish. Whirling disease limited statewide stocking of rainbows in the 1990's.

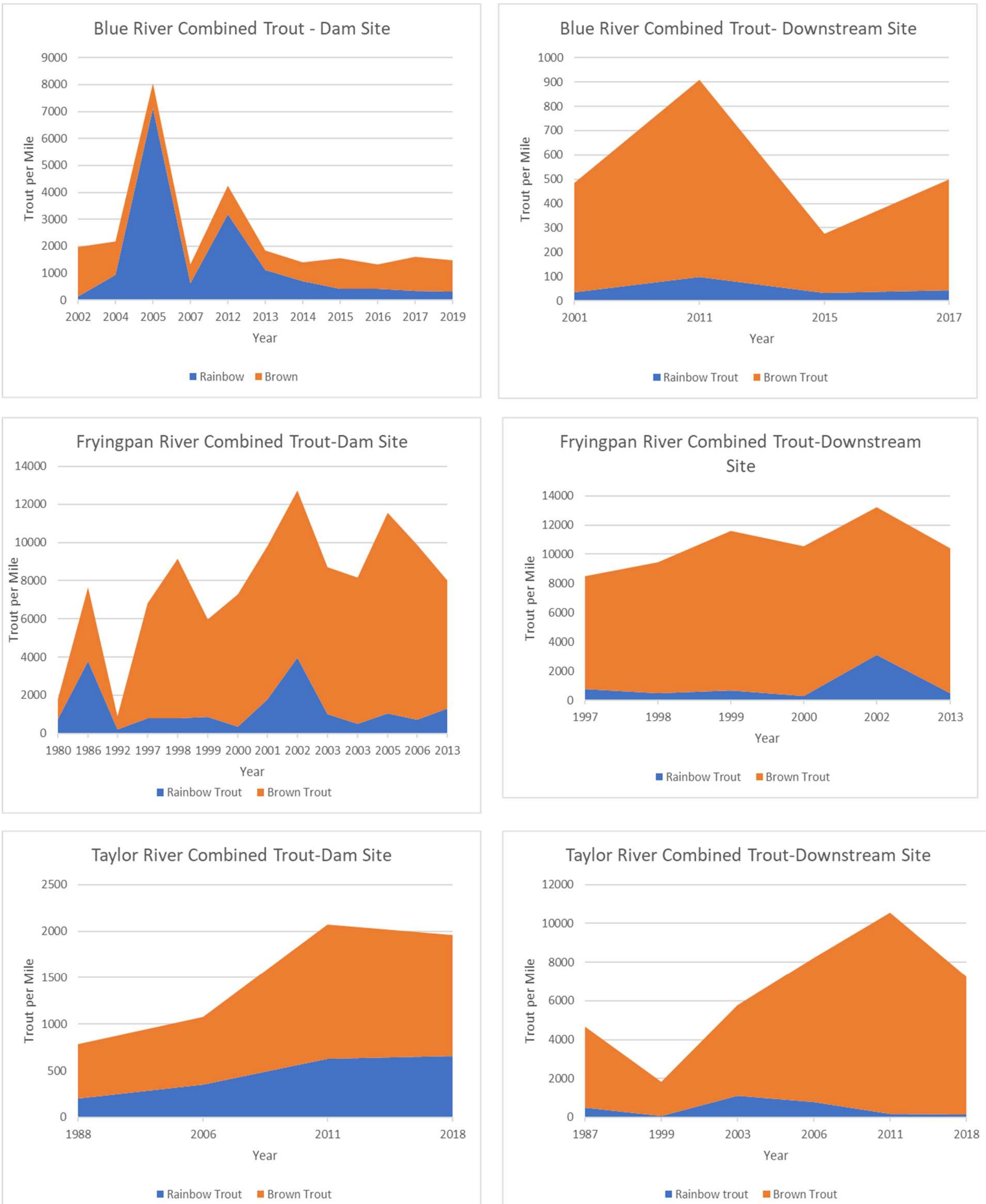
Sampling of these rivers over the past nearly 40 years has been completed for many different objectives. These include standardized population sampling, stocking evaluations, research on whirling disease and water development projects. The sampling approach is not always the same and sampling technique and data collected differs between rivers and biologists. Different data collection approach can limit the comparisons but trends in fish populations provide some insight into what is occurring in the fishery.

Table 1. Stocking summary for the Blue River, Fryingpan River, Taylor River for the period of 1980-2019

River				
		Blue	**Fryingpan**	**Taylor**
Catchables	**Years Stocked**	**26**	**8**	**25**
	Total Stocked	**130,159**	**12,224**	**179,851**
	Average/Year	**5,006**	**1528**	**7,419**
	Maximum	**30,767**	**5999**	**25,899**
	Minimum	**507**	**22**	**1,800**
		Blue	**Fryingpan**	**Taylor**
Sub-catchable				
	Years Stocked	**25**	**32**	**32**
	Total Stocked	**814,151**	**736,481**	**220,218**
	Average/ Year	**32,556**	**24,549**	**7,274**
	Maximum	**61,815**	**48,061**	**27,630**
	Minimum	**1,564**	**5,005**	**833**

Fisheries data was filtered for sampling dates that reported results for fish-per-mile and biomass. Sites that were directly associated with the dam and a site downstream a few miles were utilized for comparison. Looking at trends for fish-per-mile and biomass are more insightful than comparing individual results between rivers. In all three rivers brown trout make up the majority of the numbers and biomass in each river. The Blue River has significantly fewer trout per mile than the Fryingpan or Taylor Rivers at both the dam sites and downstream sites (Figure 4). Population trends on both the Fryingpan and Taylor show an upward trend in fish-per-mile over the last twenty years, whereas the Blue River shows a static to slightly decreasing trend for the number of fish (Figure 4). Brown trout populations on the Blue River do not appear to have the recruitment and survival of fish, the other river seem to have evidenced by the lower fish per mile. Altered flows below reservoirs have been shown to narrow natural channels and decrease connectivity with the lateral flood plain which can limit habitat for all life stages in peak flow events or other times of year (Schmutz and Moog 2018). Chadwick and Associates (1986) showed in the Blue River brown trout adults, juvenile and fry have approximately 40-50% loss of available habitat during the summer peak flows. Downstream sites on the Blue River available juvenile and adult habitat decreases by about 40% during high flow periods. Fry habitat seems to be the limiting habitat type during the peak summer flows or spill events from Dillon Reservoir.

Figure 4.Fish-per-mile for the Blue, Fryingpan and Taylor Rivers for approximately the last twenty years. Information is for sampling locations associated with respective upstream dams and sites less than 10 miles downstream. (CPW Aquatic Database)



Fish populations numbers on the Blue River fluctuate more than is what has been evident in the Fryingpan and Taylor Rivers. Cold water release temperatures and fluctuation in flows from Dillon Reservoir limits not only growth but also limits spawning success and recruitment of trout (Nehring 1987, Ewert, CPW personal communication) Nehring (1987) found in May when Dillon Reservoir releases are held below 500 cfs year class strength for age 2+ fish is much stronger when compared against same age cohorts when flows exceed 1000 cfs, correlating to habitat availability at different flows. Growth of the Brown Trout in the Blue River was found to be some of the slowest among rivers in Colorado. Nehring (1987) found that age 4+ brown trout in the Blue River averages 28 cm (10 in.) which was more than an inch smaller than Brown Trout from other rivers (Table 2).

Table 2. Back-calculated size of age 4+ Brown Trout from select rivers in Colorado studied by Nehring in 1987.

River	**Size at Age 4+**
Blue River	28 cm (10 in)
Fryingpan River	32 cm (12.7 in)
Colorado River	37 cm (15 in)
Gunnison R / Almont	32 cm (12.6 in)

When compared directly to the Fryingpan River in 1986, Brown Trout in the Blue River were consistently smaller in size than the same age Brown Trout in the Fryingpan River. Growth rate differences increased each year of age and by age 5+ was found to be 7 cm (2.8 in) (Table 3) (Nehring 1987). This difference could be influenced by river elevation and habitat availability.

Table 3. Back calculated lengths (cm) of trout from Blue and Fryingpan Rivers (Table 4, Nehring, 1987).

Table 4. Back calculated lengths (cm) of trout from Blue and Fryingpan Rivers , 1986 (Nehring 1987)

Year Class	N	Age Class	L_C	S.E.	L_1	S.E.	L_2	S.E.	L_3	S.E.	L_4	S.E.	L_5	S.E.	L_6	S.E.	L_6
Blue River browns - November 1986																	
1985	40	1+	15.3	0.39	7.44	0.33											
1984	20	2+	21.2	0.40	6.47	0.40	14.6	0.49									
1983	30	3+	26.8	0.10	6.66	0.30	13.4	0.53	20.9	0.63							
1982	24	4+	31.8	0.55	6.86	0.28	14.6	0.56	21.5	0.68	27.9	0.54					
1981	15	5+	35.1	0.83	8.46	0.61	16.3	0.99	22.5	1.15	28.0	1.02	32.6	0.89			
1980	9	6+	36.6	0.44	6.84	0.39	13.7	0.72	21.4	0.87	27.2	0.98	30.9	0.83	34.2	0.65	
1979	1	7+	39.0		8.82		19.1		24.3		28.0		31.0		34.8		36.7

Year Class	N	Age Class	L_C	S.E.	L_1	S.E.	L_2	S.E.	L_3	S.E.	L_4	S.E.	L_5	S.E.	L_6	S.E.	L_6
Fryingpan River brown - Fall 1986																	
1985	27	1+	14.8	0.35	7.23	0.30											
1984	37	2+	20.9	0.47	6.85	0.26	14.2	0.36									
1983	41	3+	28.6	0.57	8.03	0.29	15.8	0.39	23.2	0.45							
1982	36	4+	35.1	0.61	8.02	0.26	16.7	0.52	24.3	0.61	30.8	0.54					
1981	15	5+	40.6	0.97	7.74	0.38	16.6	0.69	24.7	0.82	31.6	1.05	37.6	0.96			
1980	4	6+	45.8	3.82	8.12	1.42	19.2	1.51	28.8	2.57	34.6	2.34	39.7	3.60	43.1	3.82	

L_c • Length at time of collection L_1 • back-calculated length at year y_1

The Fryingpan and Taylor Rivers also have the addition of *Mysis* shrimp entrained through the outlet structures into the river. Nehring (1991) found that when pluses of mysids are entrained through the outlets and into the Fryingpan and Taylor Rivers, growth rates and body conditions of the downstream trout populations appeared to increase dramatically with the addition of this new food source within the first mile below the dam. Mysids were abundant in collections made in Dillon Reservoir from 1981-1984. Anecdotal information is that mysids were entrained to the outlet and were utilized by fish in the Blue River in the mid 1980's but have not continued as has been seen in the Fryingpan and Taylor Rivers. This may be due to o Mysis density within each reservoir and the operational release patterns and flows creating entrainment from the reservoirs. Dillon Reservoir's mysid population appears to be decreasing due to an aging reservoir and the introduction of Arctic Char (Hansen, CPW, personal communication).

Influence of Temperature on the Fishery in the Blue River

Water temperature essentially influences ecosystem function and aquatic diversity, because all life stages of fish and aquatic invertebrates are intricately linked to the thermal regime of a given environment. Water temperature is perhaps the single most important environmental parameter for fish (Magnusen et al 1979). Ambient water temperature drives fish survival (Brinkman et al 2013), behavior (Cook and Bergersen 1988, Rogers 1998), growth (Selong et al. 2001, Bear et al. 2007, Brinkman et al. 2013) and also is known to define the range a fish can occupy (Dunham et al. 2003, de la Hoz Franco and Budy 2005) Recently most temperature research has been associated with rising temperatures and the potential impact to river dwelling fish (Ficke et al. 2007, Wenger et al. 2011, Zeigler et al. 2019, Roberts et al. 2013), with less research on the impacts of cold water on fish habitat and fish populations (Coleman and Fausch 2007a, Coleman and Fausch 2007b, Mullner and Hubert 2005, Simpkins and Hubert 2000, Brown et al 2011). Temperature requirements of different life stages of brown trout have been studied by numerous researchers. (Raleigh et. al 1986, Elliot and Hurley 1999, Elliot and Elliot 2010).

Study Area

In 2020 temperature loggers were monitored at 8 locations between Dillon and Green Mountain Reservoir. These temperature monitoring stations are a combination of temperature loggers installed by Trout Unlimited (TU) in 2020 and loggers previously installed by the US Forest Service (USFS). Sites were selected based on a combination of factors including locations relative to tributaries, access and previous USFS temperature monitoring sites. Sampling sites also included one location upstream from Dillon Reservoir, and one sampling location downstream from Green Mountain Reservoir. The upstream site was selected as a reference location not impacted by Dillon Reservoir (DR.). For the purpose of this report the upstream site and six sites between Dillon and Green Mountain Reservoirs were used for analysis (Table 4). All sites sampled for various purposes is shown in Figure 5. temperature logger data for Sites SCR and Blue 2, were not used in this report due to data availability or sampling dates.

Table 4. Coordinates and elevation for temperature sampling sites 2020.

Site	Description	Latitude	Longitude	Elevation (m)	Miles from Dillon Dam
UBR	Immediately upstream of DR	39.56651	-106.04884	2773	-
Blue 5	Immediately downstream of DR	39.62601	-106.06658	2684	0.4
DRD	At Dillon Ranger District in Silverthorne	39.63651	-106.07419	2675	1.4
Blue 3	Downstream of Bald Eagle Drive	39.65595	-106.07685	2647	2.9
D5	Upstream of County Road 1870	39.70545	-106.11062	2596	7.3
Blue 2	Downstream of Blue River Campground	39.72713	-106.1321	2575	9.6
Blue 1	Downstream of Boulder Creek	39.74336	-10613196	2558	11.0
BCR	Upstream of GMR at Blue River State Wildlife Area	39.8217	-106.20584	2443	20.1

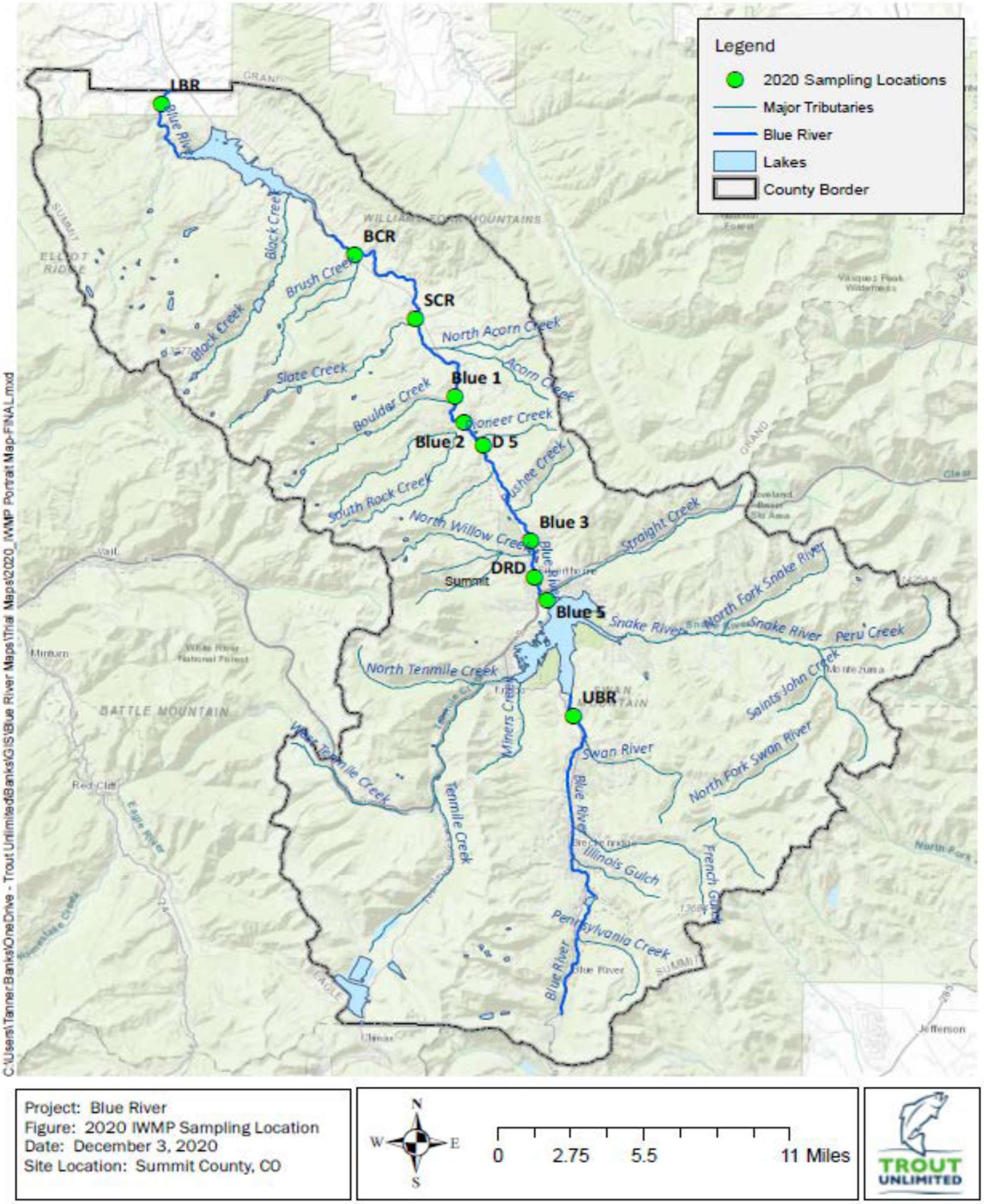


Figure 5. Map of the study sites used for temperature, macroinvertebrates and periphyton in 2020.

Methods

Onset HOBO Water Temperature Pro v2 (Onset Corporation, Bourne, MA, USA) data loggers were deployed at samplings sites in the spring of 2020. The data loggers were set to record water temperature every hour and data loggers were downloaded in late fall, and the information exported to files that could be analyzed by WaTSS 3.0 a water summary software developed by Colorado Parks and Wildlife. (Rogers K. B. 2015).

Hourly temperatures were analyzed into several temperature statistics. Daily temperature metrics were calculated from hourly daily temperatures. Monthly, growing season (May 1 to Oct 31) and comparative annual statistics (when available) were all calculated from daily metrics. Further analysis and graphics were completed in Microsoft Excel (2021). Several temperature metrics were calculated in consideration of aquatic biota. The 30-day average temperature (M30AT)was calculated as a measurement of potential fish production. The maximum weekly temperature (MWMT) was calculated as a prediction of fish population persistence, survival of brown trout is expected when maximum weekly temperature is <29^0 C. Degree day increases for each station was calculated for each site for the growing season of May 1 to October 31, providing insight into both emergence and growth. A Daily Temperature Unit is equal to 1^0F above freezing (32^0F) for a 24 period. For example, if the average daily water temperature for the first day of incubation 49^0F, it would equal to 17 DTU (49^0-32^0) (Piper 1983) Optimal growth range for adult brown trout was found to occur between 11^0 C and 19^0 C, with spawning occurring in the fall as day length shortens and temperatures decrease to <9^0 C (Range 2-13^0 C) and growth to 1-year from 7^0 to 15^0 C (Raleigh et.al 1986).

Results for the 2020 Temperature Sampling Season

Temperature varied between sites and seasons. Overall, in 2020 average hourly water temperatures ranged from an absolute minimum of -0.10^0 C (site B1) in January to an absolute maximum of 15.4^0 C (site B5) in July. Reservoir spill events are the only flow change to the Blue River that had any impact on downstream temperature. For example, at Blue 5 2020 hourly water temperature changes occurred June 17-19 with an increase of 13.5^0 C (0.56^0 C/ hour) and again on July 4-10 with a decrease of 19.9^0 C (-0.28^0 C/hour), coinciding with the increasing and decreasing discharge associated with the surface releases from Dillon Reservoir. The surface release associated with a spill event increased overall maximum water temperature as well as daily average water temperature at all sites, diminishing downstream (Table 5).

Mean average water temperature from May through October increased with distance downstream from Dillon Reservoir (Table 5). The influence of the bottom release reservoir can be seen throughout the May-October time frame, outside the spill event, at all sites down to Site Blue 1. All show a loss in stream temperature after the spill event. Only Site BCR appears to maintain an increased temperature post spill event (Figure 6). Temperatures downstream of Dillon Reservoir do not recover to the temperature seen above the reservoir at the reference site until Site B1 which is over 11 miles downstream of the reservoir (Table 5, Figure 6).

Average rates of warming in the Blue River, downstream of Dillon Reservoir, were 0.18^0 C/mile in the growing season of 2020 ranging from 0.04 and $0{,}32^0$ C, and 0.04^0 C/mile across a year for the river segment from Blue 3 to Blue 1 (Table 6).

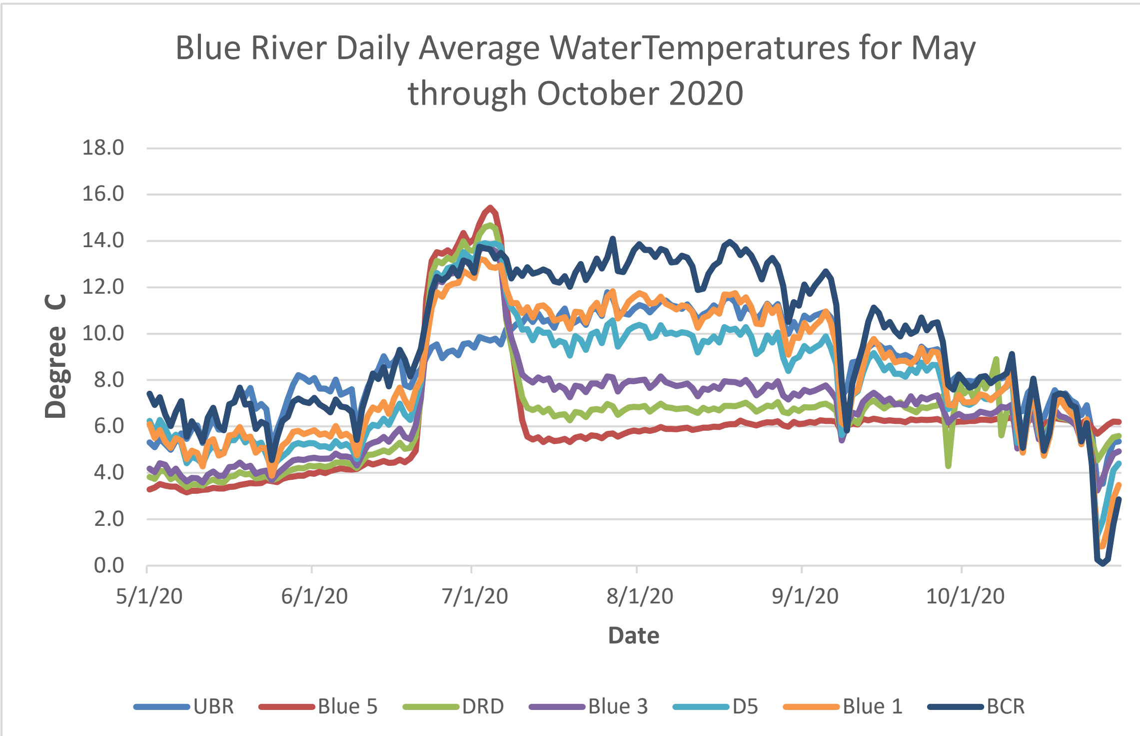
Table 5. Mean and maximum water temperatures (^{0}C) for May to October 2020, by site for the Blue River.

Site	Mean Temperature (±95%CI)	Maximum Temperature
UBR	8.7 (0.28)	11.8
Blue 5	6.1 (0.38)	15.4
DRD	6.5 (0.36)	14.7
Blue 3	6.9 (0.34)	13.8
D5	8.0 (0.37)	13.9
Blue 1	8.4 (0.40)	13.2
BCR	9.6 (0.46)	14.1

Table 6. Comparison of change in temperature per mile between sites on the Blue River during the designated growing season May through October.

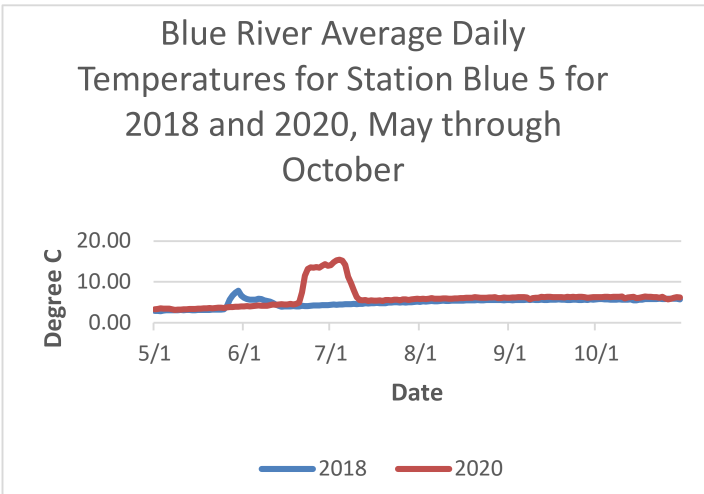
Location	Reach Length (mile)	Δ C^{0}/Mile ±95% confidence limits Growing Season May through October	Year 11/19 to 10/20
Blue 5 to DRD	1.1	0.04 ±0.01	
DRD to Blue 3	1.5	0.21 ±0.07	
Blue 3 to D5	4.4	0.26 ±0.03	
D5 to Blue 1	3.7	0.11 ±0.03	
Blue 1 to BCR	9.1	0.32 ±0.03	
Blue 5 to BCR	19.8	0.18 ±0.02	
Blue 3 to Blue 1	8.1		0.04 ±0.02

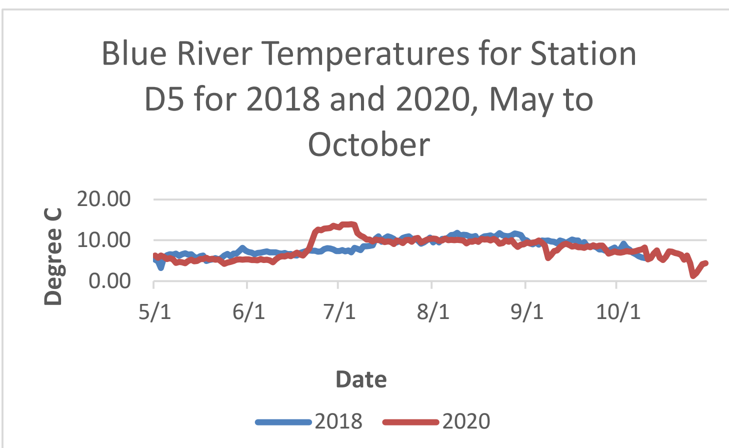
Figure 6. Blue River daily average water temperatures for May through October 2020 by site.

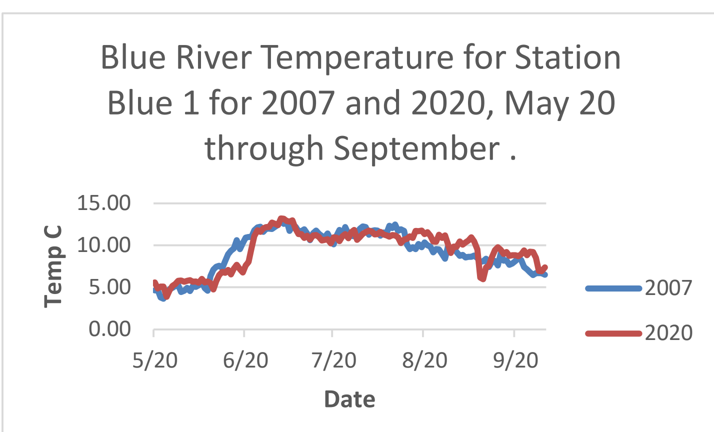


Water temperatures did not differ notably between years at any one site (Figure 7), for data available. What was observed is that average daily temperature does show more variation, moving downstream, with apparent ice formation in late October or early November at all sites. This is most likely due to solar warming and addition of tributary streams entering the Blue River. Tributary streams could also buffer loss of temperature as the river cooled after a spill event from the reservoir (Figure 6). Only the most downstream site maintained similar temperature readings seen during the remainder of the summer.

Figure 7. Comparison of daily average temperatures for three Blue River sites May through October, from different years.

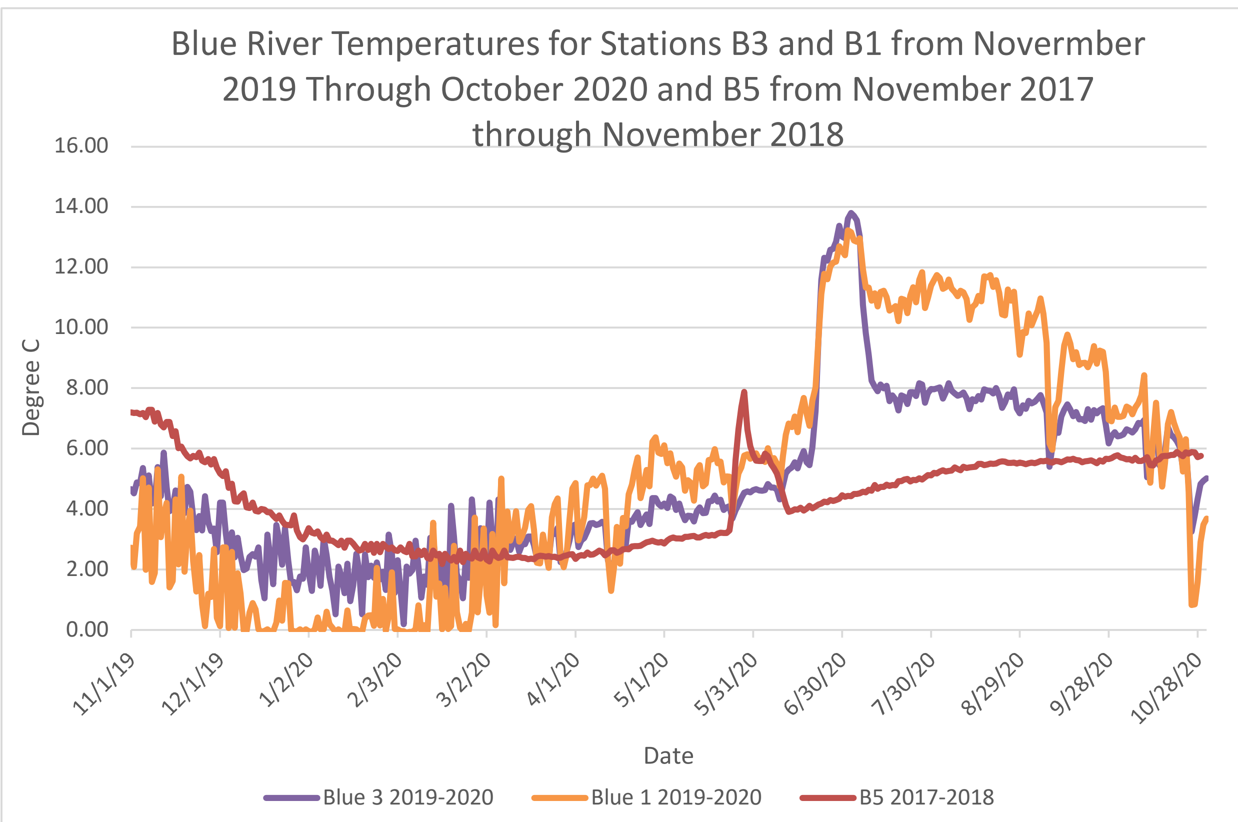






Hypolimnetic release reservoirs, like Dillon Reservoir, alter the natural temperature regimes downstream resulting in warmer-than-natural winter water temperatures (Figure 8). Warmer winter water extends downstream approximately 3 miles (Blue 3) below the reservoir, however the reverse is true in the remainder of the year, where you see colder temperatures due to the influence of the hypolimnetic release (Figure 8).

***Figure 8. Yearlong daily average water temperature for Sites B5, B3 and B1, showing the warmer than natural winter flow and colder than normal summer flows below Dillon Reservoir due to the hypolimnetic release*.**



Biological Temperature Metrics

Figure 9 shows 2020 Blue River average daily temperatures with highlighted optimal adult growth range, growth during the first year of life and spawning range for brown trout. Temperatures seen in the Blue River in 2020 meet the criteria for adult growth in the Upper Blue River (UBR) and the lower two stations (Blue 1 and BCR) from approximately July-August and showed better temperatures for successful hatching and recruitment of browns in the Blue River. Stream temperatures in 2020 seem to potentially limit growth of brown trout in the Blue River.

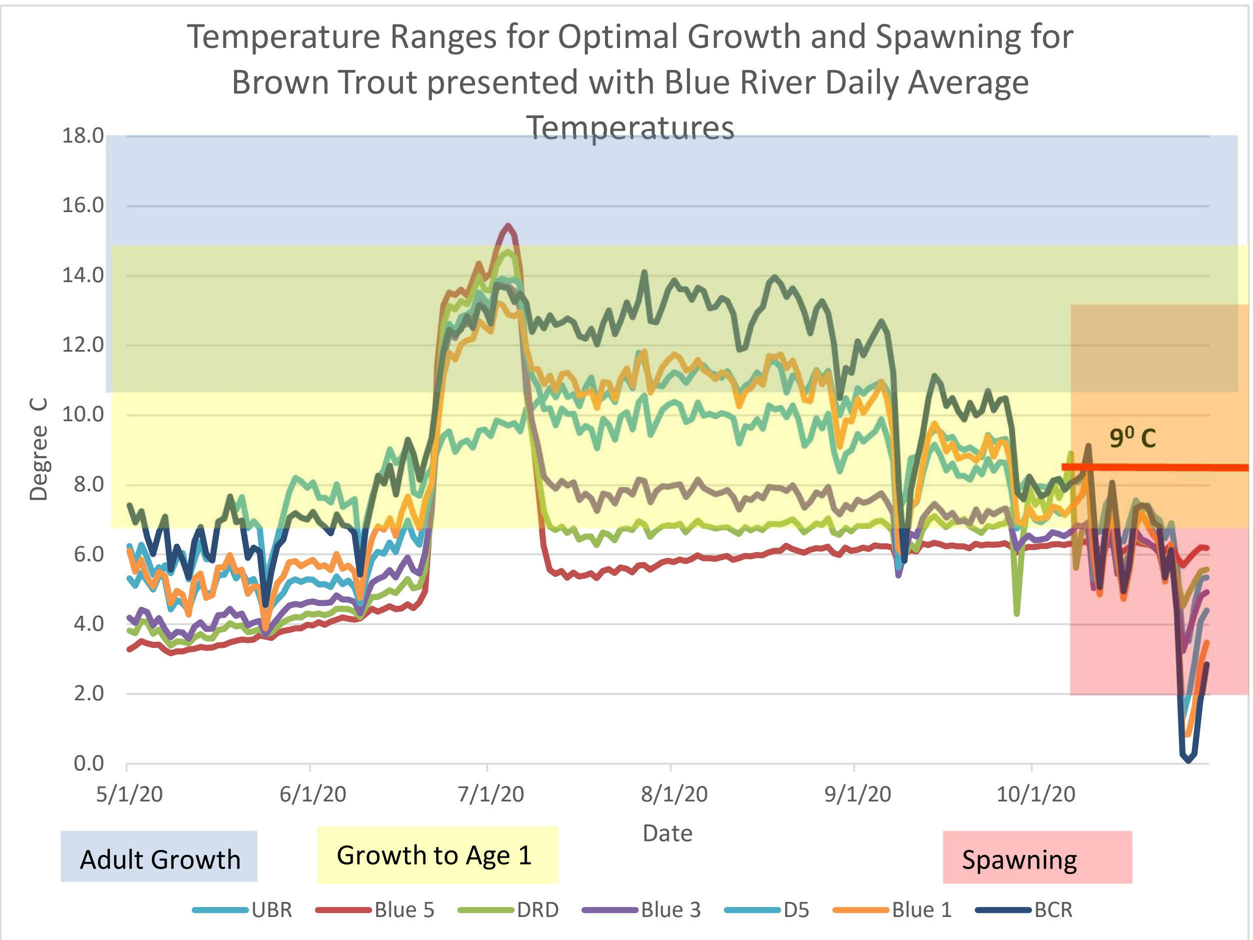


Figure 9. Blue River average daily temperature with growth and spawning temperature requirements and known range of dates those temperatures are needed for adult growth, growth to age 1 and spawning. Temperature ranges from Raleigh et. al 1986.

The M30AT tended to increase downstream, but the MWAT showed a general decrease moving downstream showing the influence of the reservoir spill (Table 8). M30AT ranged from 10.2^0 C to 13.2^0 C, and MWMT ranged from 14.8^0 C and 17.3^0 C. Temperatures never approach critical levels (27^{0}C) with respect to survival for brown trout. Other than the Upper Blue River (UBR) these values are influenced by the spill event from Dillon Reservoir in 2020. The increase in temperature caused by the release of surface water from Dillon Reservoir influences these temperature metrics to increase over what would be seen in years without a reservoir spill.

Table 7 Summary of the fish-temperature metrics for the Blue River. (M30AT = maximum 30-day average temperature, MWMT = maximum weekly mean maximum temperature). Accumulated Degree Day values include the influence of the Dillon Reservoir spill seen in 2020. All values summarize May 1 to October 31, 2020. *not influenced by reservoir spill

	Temperature Metric		
Site	**MWMT**	**M30AT**	**Degree Days**
UBR	14.8	11.1	1606*
Blue 5	15.7	10.2	1128
DRD	15.7	10.4	1209
Blue 3	15.5	10.5	1260
D5	16.8	11.5	1462
Blue 1	16.2	11.6	1546
BCR	17.3	13.2	1766

Degree days increased moving downstream from Dillon Dam. The hypolimnetic releases have an impact on degree days values down to below Blue 1. If the degree day production during the spill event is accounted for at each site, on average a reduction 259-degree days would be reduced at all sites downstream of Dillon Reservoir. With Site BCR maintaining stream temperature after the spill event the increase to Degree Days is less than would be seen at upstream sites. At the CPW Mount Shavano Hatchery brown trout eggs hatch at 760-degree days, but fry do not swim up from hatching until approximately they have gained 1440-degree days (Bryan Johnson, CPW, personal communication). Showing that in portions of the Blue River recruitment of brown trout fry could be limited due to temperature (Table 7).

Summary and Recommendations

After special regulation management was instituted on the Blue River in 1983, limiting harvest and tackle restrictions, the brown trout population expanded in both number and biomass until

1987, when it was shown to have reached the maximum production potential of quality size fish (35 cm,14-in). The Blue River was also shown to have the slowest growth rates when compared to other Colorado Rivers where wild fish populations were being studied. Overtime quality size fish numbers decreased until the Gold Medal fishery designation was removed in 2016.

The hypolimnetic releases from Dillon Reservoir alter the natural flow and temperature regime downstream in all seasons of the year. Non winter seasons have colder than normal temperatures which do not rebound to temperatures found above the reservoir until approximately 11 miles downstream. This impacts not only fish production in both growth and reproduction, but also has been shown to depress macroinvertebrate health (Reese, 2021). Wild brown trout populations below other hypolimnetic release reservoirs in Colorado have not shown the decline in recent years that has been seen on the Blue River. Reservoir productivity of the upstream reservoir impacts the downstream fishery. In this case all the rivers compared, (Blue River, Taylor River, Fryingpan River) all had special regulation management put into place at the same general time (early 1980's) and all had similar response of expanding trout number and biomass. The Blue River is the only one to show a general decline in the fishery since the early 2000's. These streams differ in that the upstream reservoirs have different purposes and need for water delivery which could potentially influence downstream river productivity. Both the Taylor and the Fryingpan only deliver water to downstream users, whereas Dillon Reservoir delivers water to East Slope (Denver) via the Roberts Tunnel in addition to the Blue River.

Water temperature downstream of Dillon Reservoir are having a negative impact all life stages of the brown trout fishery. Cold temperatures are limiting growth and reproduction but seems to have the largest impact on the growth of adult brown trout. In 2020,only the Blue River stream reach below Boulder Creek (Blue 1 and BCR) provided water temperatures during the summer in the optimal temperatures for adult brown trout growth. Rapid changes in temperature and flow associated with the reservoir spill may negatively impact both fry and juvenile brown trout. In general, slow changes in temperature or flow within the natural range of variability are needed to avoid negative impact on juvenile salmonids (Brown et al, 2011) . If acceptable ramping rates could be developed with the onset and ending of a spill event of Dillon Dam, downstream fisheries would benefit. Given the importance of stream temperature to aquatic organisms (Bear et al. 2007, Ziegler et al. 2013) and the relative ease with which the data can be collected, long-term year-round temperature monitoring seems like a logical way to track conditions in the Blue River. Monitoring the yearlong temperatures in some key tributaries will be useful to determine the influence of tributary temperature on the Blue River between Dillon and Green Mountain Reservoirs.

In addition to altering downstream temperature, reservoirs can alter downstream channel configuration and complexity that was seen prior to reservoir construction. These changes often result in over width channels and the loss of deep pool habitat, nursery areas and overall habitat for all life stages in various time of the year. In addition, changes to sediment supply and occurrence of cobble habitat which provides critical fish habitat is altered below reservoirs. Habitat quality assessments and availability need to be completed to determine if channel alterations could improve the overall fishery of the Blue River.

To determine if projects or changes to the Blue River system have and effect on the quality of the fishery some measurement tool must be used to measure success. Statistically valid creel census should be completed both before and after changes are made to measure the success of a project.

If the goal is to return the Blue River to Gold Medal Fishery status, then angler satisfaction as well as standard fish population sampling must be completed to verify success.

REFERENCES

Bear, E. A., T. E. McMahon, and A. V. Zale. 2007. Comparative thermal requirements of Westslope Cutthroat Trout and Rainbow Trout: implications for species interactions and development of thermal protection standards. Transactions of the American Fisheries Society 136:1113–121.

Brinkman Stephen F. , Harry J. Crockett & Kevin B. Rogers 2013. Upper Thermal Tolerance of Mountain Whitefish Eggs and Fry, Transactions of the American Fisheries Society, 142:3, 824-831

Brown, Richard S., Hubert, Wayne A., Daly, Steven F. 2011. A Primer on Winter, Ice, and Fish: What Fisheries Biologists Should Know about Winter Ice Processes and Stream-dwelling Fish. Fisheries 36:1.

Chadwick and Associates 1986. Aquatic Baseline Metropolitan Denver Water Supply Systemwide/Site Specific Environmental Impact Statement.

Coleman, M and K. Fausch 2007a. Cold Summer Temperature Regimes Cause a Recruitment Bottleneck in Age-0 Colorado River Cutthroat Trout Reared in Laboratory Streams . TAFS 136:639–654.

Coleman, M and K. Fausch 2007b. Cold summer temperature limits recruitment of age-0 cutthroat trout in high-elevation Colorado streams. TAFS 136:1231–1244.

Cook, M. F., and E. P. Bergersen. 1988. Movements, habitat selection, and activity periods of northern pike in Eleven Mile Reservoir, Colorado. Transactions of the American Fisheries Society 117:495-502Colorado Parks and Wildlife. 2020. Fishing Regulations Brochure. Colorado Parks and Wildlife.

de la Hoz Franco, E. A. and P. Budy 2005. Effects of biotic and abiotic factors on the distribution of trout and salmon along a longitudinal stream gradient. Environmental Biology of Fishes 72; 379-391.

Dunham, J., R. Schroeter, and B. Rieman. 2003. Influence of maximum water temperature on occurrence of Lahontan Cutthroat Trout within streams. North American Journal of Fisheries Management 23:1042–1049

Elliott, J. M., and J. A. Elliott. 2010. Temperature requirements of Atlantic Salmon Salmo salar, Brown Trout Salmo trutta, and Arctic Charr Salvelinus alpinus: predicting the effects of climate change. Journal of Fish Biology. 77:1793–1817.

Elliott, J. M., and M. A. Hurley. 1999. A new energetics model for Brown Trout, *Salmo trutta*. Freshwater Biology 42:235–246.

Ewert, J. 2018. Fishery Management Report, 2010-2017. Colorado Parks and Wildlife.

Ewert, J. 2019. 2019 Fishery Survey Report. Colorado Parks and Wildlife.

Ficke, A. D., C. A. Myrick, and L. J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17:581–613.

Magnuson, J. J., L. B. Crowder, and P. A. Medvick. 1979. Temperature as an ecological resource. American Zoologist 19:331-343.

Mullner, Scott A and Wayne A. Hubert 2005. Low Summer Water Temperatures Influence Occurrence of Naturalized Salmonids across a Mountain Watershed. NAJFM 25:1034–1040.

Nehring R. B. 1987. Stream Fisheries Investigations. Fed. Aid Study F-51. Colorado Division of Wildlife, Ft. Collins, CO.

Nehring R. B. 1991. Effects of Reservoir Escapement of Mysids on Two Colorado Tailrace Trout Fisheries. American Fisheries Society Symposium 9:134-143, 1991.

Piper, R.G., McElwain, I.B., Orme, L.E., McCraren, J.P., Fowler, L.G. and Leonard, J.R. (1982) Fish Hatchery Management. 2nd Printing, U.S. Fish and Wildlife Service, Washington, DC.

Raleigh, R. F., L. D. Zuckerman, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Brown trout, revised. U.S. Fish Wildl. Servo Biol. Rep. 82(10.124). 65 pp. [First printed as: FWS/OBS-82/10.71 , September 1984].

Rees, David E., 2021. Summary Report Benthic Macroinvertebrate Biomonitoring/Surveys Blue River, Colorado 2020. Prepared for the Blue River Watershed Group and Trout Unlimited

Roberts, J. J., K. D. Fausch, D. P. Peterson, and M. B. Hooten. 2013. Fragmentation and thermal risks from climate change interact to affect persistence of native trout in the Colorado River basin. Global Change Biology 19:1383-1398

Rogers, K. B. 1998. Habitat use by largemouth bass and northern pike on the Rocky Mountain Arsenal, Colorado. Doctoral dissertation. Colorado State University, Fort Collins.

Rogers, K. B. 2015. User manual for WaTSS 3.0 (Water temperature summary software). Colorado Parks and Wildlife, Fort Collins. Available online at: http://cpw.state.co.us/ learn/Pages/ResearchAquaticSoftware.aspx

Selong, J. H., T. E. McMahon, A. V. Zale, and F. T. Barrows. 2001. Effect of temperature on growth and survival of Bull Trout, with application of an improved method for determining thermal tolerance in fishes. Transactions of the American Fisheries Society 130:1026–1037.

Simpkins, Darin G., and Wayne A. Hubert 2000. Drifting Invertebrates, Stomach Contents, and Body Conditions of Juvenile Rainbow Trout from Fall through Winter in a Wyoming Tailwater. Transactions of the American Fisheries Society 129:1187–1195.

Schmutz, Stefan and Otto Mood 2018. Chapter 6 Dams: Ecologic Impacts and Management in

Riverine Ecosystem Management, Science for Governing Towards a Sustainable Future ed. by Stefan Schmutz and Jan Sendzimir. Pages 111-128.

Wenger, S. J., D. J. Isaak, C. H. Luce, H. M. Neville, K. D. Fausch, J. B. Dunham, D. C. Dauwalter, M. K. Young, M. M. Elsner, B. E. Rieman, A. F. Hamlet, and J. E.Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change.Proceedings of the National Academy of Sciences of the USA 108:14175–14180.

Zeigler, Matthew P., Kevin B. Rogers, James J. Roberts, Andrew S. Todd, Kurt D Fausch 2019. Predicting Persistence of Rio Grande Cutthroat Trout Populations in an Uncertain Future North American Journal of Fisheries Management.

APPENDIX G

Stream Assessments

APPENDIX G

BLUE RIVER STREAM ASSESSMENT

G.1. PURPOSE

A preliminary stream assessment for the Blue River in Summit County, Colorado was conducted for the purpose of rating functional ecological conditions of the river to develop a basis for understanding the key physical characteristics of the river and associated aquatic health. This information will support the formulation of restoration opportunities and/or needs for further study and create a baseline for future assessments and evaluations. Several studies and assessments concurrently underway or proposed for subsequent phases of the BRIWMP will be folded into this assessment in future phases. It is anticipated that this assessment may be updated in conjunction with these additional assessments, possibly resulting in modified ratings or scores.

Section G2 presents the assessment methodology and defines the variables used to perform the assessment. Section G3 summarizes the assessments by reach and section G4 provides an assessment summary by variables. Section G5 provides a summary of data sources.

G.2. METHODOLOGY

This assessment utilizes the framework outlined in the Functional Assessment of Colorado Streams (FACStream) version 1.0 (Beardsley et al. 2015). FACStream is a reach-scale functional assessment tool that rates functional conditions of a stream using the level of departure from a reference reach. A reference reach is defined as a river segment that represents a stable channel within a particular valley morphology, generally in an unimpacted condition. FACStream uses ten ecological variables and can be employed as a reconnaissance (Level 1), routine (Level 2), or intensive (Level 3) effort.

- Level 1 relies on the documentation of observable factors
- Level 2 routine assessment includes observable factors and review of existing information
- Level 3 includes observable factors, review of existing information, and the use of predictive models to further document the degree of impairment and loss of function

The Blue River Stream Assessment can generally be categorized as a Level ”1 to 2” assessment utilizing observable factors and to the extent practical, existing available reports and data.

A desktop analysis of existing available information collected and/or developed for the draft BRIWMP, including hydrologic analysis, aerial imagery, channel profile information, water quality, land use, watershed conditions (including pine beetle impacts), presence of channel obstructions and hydraulic controls, was conducted to inform this evaluation.

Field assessments were conducted in the fall of 2020. Observations and assessments generally follow the guidance outlined in FACStream to qualitatively assess the ten stream health variables summarized in Table G-1**.**

Table G-1. FACStream Variables

Scale	Variable		Metrics
Watershed	V_{hyd}	Flow Regime	Peak flow, base flow, rate of change
	V_{sed}	Sediment Regime	Land and channel erosion; transport through the reach
	V_{chem}	Water Quality	Temperature, nutrients, metals, others
Riparian	V_{con}	Floodplain Connectivity	Extent of lateral flooding and duration
	V_{veg}	Riparian Vegetation	Vegetation banks and overbanks, diversity, connectivity
	V_{deb}	Debris	Large wood, soil and duff, organic matter
Stream	V_{morph}	Stream Morphology	channel planform/dimensions, profile
	V_{stab}	Stability	channel stability and ability to recover
	V_{str}	Physical Structure	Bank and bed structures (rock and wood) supporting aquatic life
	V_{bio}	Biotic Structure	Macroinvertebrates, fishery

These ten variables are assessed and rated on a report card grading scale relative to the degree of functional impairment or deviation from the reference standard (Table G-2). Details on the scoring guidelines can be found in the FACStream 1.0 (Beardsley et al. 2015).

Table G-2. FACStream Scoring: Degree of Deviation from Reference Reach

Scores	
A	Negligible
B	Mild
C	Significant
D	Severe
F	Profound or unsustainable

FACStream indicates the reference standard should be thought of as "the river in its state of natural dynamic equilibrium or 'optimal' functioning river system, likely present prior to settlement in or around the 1800s." The use of a reference standard establishes a consistent benchmark against which to measure the different FACStream scores and provides a consistent definition of reference standard to enable universal scoring guidelines. FACStream utilizes three stream classification systems: Rosgen Stream Classification, Stream Evolution Model Classification, and Montgomery-Buffington Classification.

> *Selecting the appropriate reference standard when doing a FACStream assessment begins with defining the reference morphological type of the assessment reach. On many reaches, the stream type may have been altered either by direct human manipulation or by channel evolution following some anthropogenic disturbance. Because of these changes, selecting the appropriate reference stream type requires some knowledge about local history and general trends in stream evolution. FACStream provides some basic guidance following the principle that certain stream types naturally occur in certain process domains (Beardsley et al. 2015).*

For purposes of conducting this stream assessment, the use of the term "reference reach" will be limited to a general understanding of what undisturbed conditions might be for the Blue River. Based on guidance outlined in FACStream, and a general understanding and familiarity of the watershed. An overall reference standard could generally be described as a meandering single thread channel with wide floodplains, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a relatively moderate to dense riparian vegetated corridor. This reference standard diverges in the upstream headwater region of Reach 1 where the river begins as a steep, cobble, and confined single thread channel that follows the centerline of the valley bottom, into a flatter, braided channel with a wetlands complex and beaver habitat. These reference reaches would have no local water use, transbasin diversions or water impoundments.

G.3. REACHES

The project reach is defined as the main stem of the Blue River from the headwaters region at Hoosier Pass to the confluence with the Colorado River, estimated to be approximately 60 miles of river corridor. Assessments are conducted in each of the three main project reaches shown in Figure G-1. The major reaches are further divided into subreaches as documented in the assessment and defined in the following sections of this appendix. Tributaries are not assessed in this phase of the BRIWMP, but may be added at a later time.

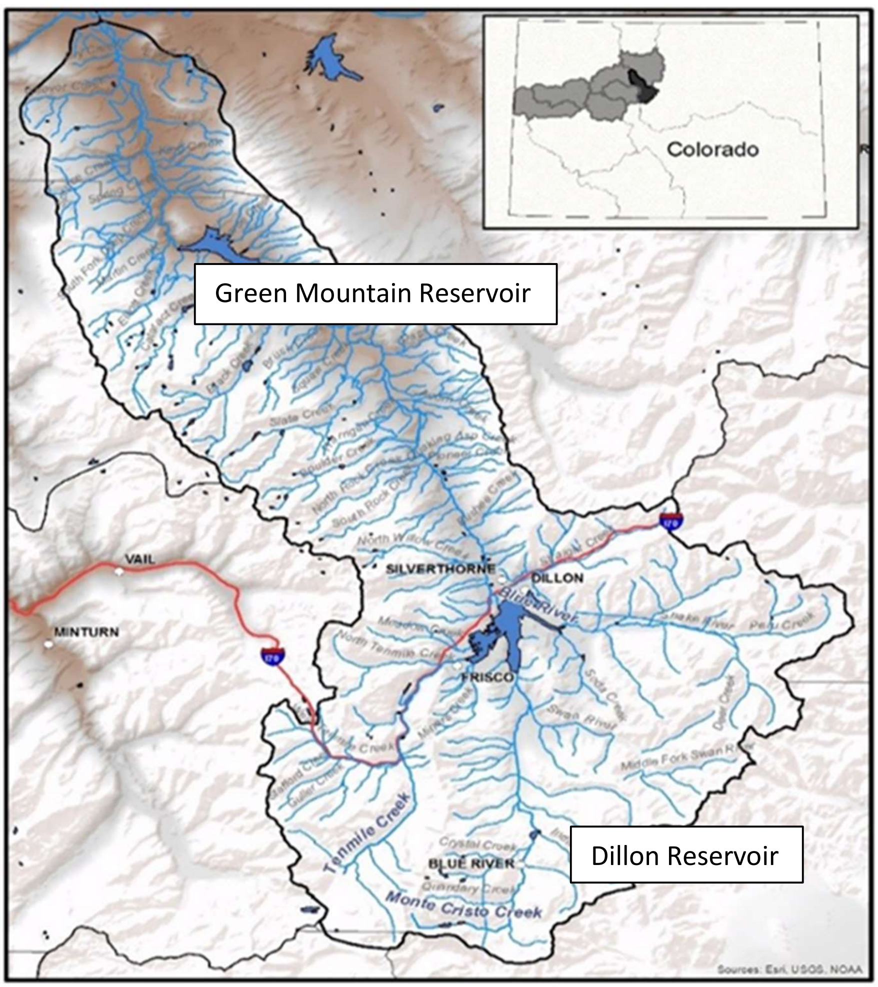


Figure G-1. Blue River Watershed.

Reach 1

Reach 1 is approximately 16.6 miles long and extends from Hoosier Pass on the Continental Divide to Dillon Reservoir. For purposes of this assessment, Reach 1 is further subdivided into four subreaches to represent the changing morphology and starkly different settings, in terms of river form, urban development, and historic disturbance from mining activities which have been significant in this Reach (Figure G-2). The assessment does not include Dillon Reservoir, nor tributaries to the reservoir or main stem of the Blue River.

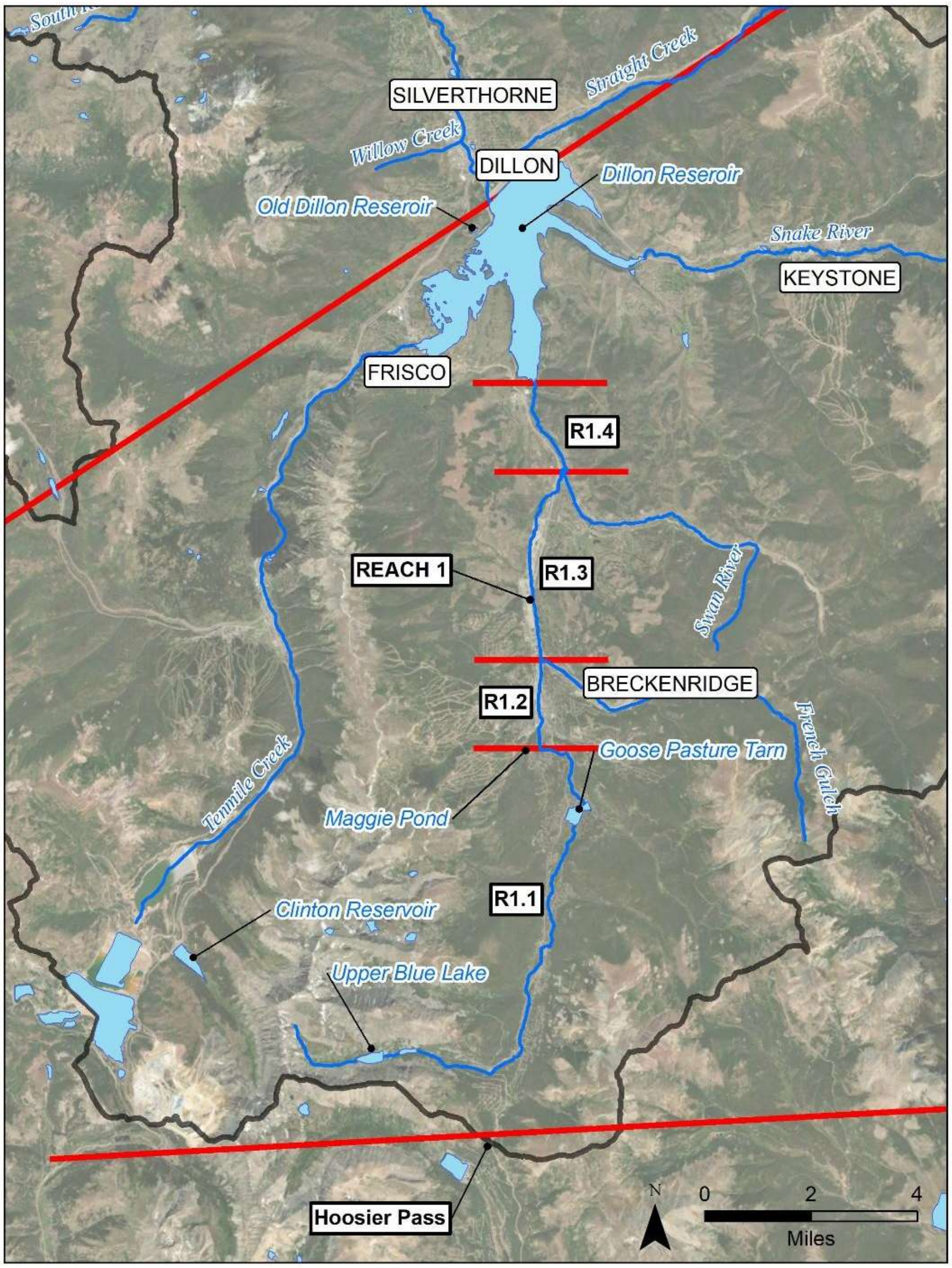


Figure G-2. Reach 1 Subreaches.

Blue River Reach 1.1-Headwaters to Maggie Pond in Breckenridge

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B	Mild	Reach R1.1 begins at the Continental Divide. The Continental-Hoosier transbasin diversion is located in this reach. Transbasin diversions and local mmunicpal uses may affect flow. Increases to transbasin diversions are anticipated. There are several small mine sites. This reach is listed on the 303(d) list for macroinvertebrates and arsenic, both with a low priority. Impacts from winter maintenance (sanding) along US Hwy 9 were observed.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	A	Negligible	There are three significant wetland areas located along this reach. There is some encroachment but overall the wetlands are relatively undisturbed and have signs of beaver activity; bank overtopping and saturation of overbanks appear to be frequent as evident by extensive footprint of wetlands. Goose Pasture Tarn, an online dam likely creates additional backwater, sustaining a wetlands upstream of the reservoir. Wood is present.
	V_{veg}	Riparian Vegetation	A	Negligible	
	V_{deb}	Debris	A-	Negligible/mild	
Stream	V_{morph}	Stream Morphology	A-	Negligible/mild	Some encroachment along the river, more notably near Breckenridge. There are several stream crossings and one online dam and reservoir serving the Town of Breckenridge (Goose Pasture Tarn).
	V_{stab}	Stability	A	Negligible	
	V_{str}	Physical Structure	A-	Negligible/mild	
	V_{bio}	Biotic Structure	B+	Mild/negligible	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Overall Reach 1.1 has hydrologic impacts from transbasin diversions and winter maintenance activities along the highway, one online dam and encroachment from rural development, however, overall impacts are relatively minor, particularly compared to downstream reaches.
0.80			A-	Negligible/mild	


Blue River Reach 1.2-Maggie Pond in Breckenridge to French Gulch Confluence

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	Transbasin diversions impact hydrology in this reach, and increases are anticipated; snowmaking and naturally occurring late season flows result in low flows in early winter. This reach is on the 303(d) list for macroinvertebrates, zinc, aquatic life, arsenic, manganese and zinc, all with a low priority. Water quality vaults in the Town of Breckenridge collect and reduce sediment within Town. Illinois Gulch, a tributary along this subreach includes several mines that likely contribute inorganic contaminants; urban environment encroaches on riparian corridor.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	B-	Mild/significant	
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	Restoration has been implemented through the urban corridor by Town of Breckenridge in phases over the past 20 years. Corridor is urbanized with landscaping along the banks that includes plantings, trails and multiple river crossings. Some crossings are likely impediments to fish passage.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	C-	Significant/severe	
Stream	V_{morph}	Stream Morphology	C+	Significant/mild	This subreach is highly urbanized, with encroachments and channel alterations in an urban-park setting. Much of this reach has walkways and pedestrian crossings and is very popular with tourists. Channel appears stable and well armored.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B-	Mild/significant	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.2 was significantly impacted by mining and more recently reconstructed and urbanized. Generally this is a relatively straight reach within a confined urban setting. Flows regimes are affected by transbasin diversions and local municipal uses.
0.62			B-	Mild/significant	

Blue River Reach 1.3-French Gulch Confluence to Swan River Confluence

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B	Mild	Transbasin diversions and local municipal uses affect flows in this reach and increases are anticipated. Pump back at new water treatment plant may improve base flows in the river. Reach currently on the 303(d) list for cadmium, manganese, nitrite, zinc , arsenic, with highest levels detected between French Gulch and County Road 3; likely source is Wellington Oro mine where work is being undertaken to improve water quality in a cooperative effort with EPA, County, Town of Breck and land developer.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	C	Significant	
Riparian	V_{con}	Floodplain Connectivity	C+	Significant/mild	This reach was significantly impacted by dredge boat mining, with excavations to depths up to 60 feet and widths up to 1,200 feet to the river and floodplain. Restoration has been or is being implemented in phases by various parties (Town of Breck, Summit County, private landowners) beginning in the 1980's; some are currently in progress. Swan River, a major tributary to the Blue River was also heavily impacted by dredge boat mining and is also in various stages of restoration.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	D	Severe	
Stream	V_{morph}	Stream Morphology	C	Significant	As noted extensive restoration has been implemented ; Step pools and a kayak park downstream of French Gulch may be creating fish passage barriers. Physical structure and biotic structure should improve with time but are not anticipated to be optimal for many decades. CPW fish surveys indicate a healthy fishery in the lower reaches, a poor fishery in the upstream reach and an overall trend showing a decline for the entire reach. Reach is listed provisional for macroinvertebrates.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	C	Significant	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.3 is undergoing significant restoration efforts for both riverine and aquatic habitat as well as water quality improvements. Without these restoration efforts this reach would be rated as 'F or Profound.'
0.56			C+	Significant/mild	

Blue River Reach 1.4-Swan River Confluence to Dillon Reservoir

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	B-	Mild/significant	Transbasin diversions and local municipal uses affect flows in this reach and increases are anticipated. Flows from Swan River, a major tributary located at the upstream end of this reach, ameliorate flow conditions. This reach is currently on 303(d) list for zinc (H) and arsenic (L), and macroinvertebrates.
	V_{sed}	Sediment Regime	A-	Negligible/mild	
	V_{chem}	Water Quality	C	Significant	
Riparian	V_{con}	Floodplain Connectivity	B-	Mild/significant	This reach was not impacted by dredge boat mining and landownership is large acreage, privately owned. Consequently there has been minor to moderate disturbance to floodplain overbanks. Riparian corridor is present, although somewhat disturbed from urban encroachment.
	V_{veg}	Riparian Vegetation	B-	Mild/significant	
	V_{deb}	Debris	C+	Significant/mild	
Stream	V_{morph}	Stream Morphology	B-	Mild/significant	Overall channel morphology has some impacts from development and channel alterations and crossings. Fish surveys conducted by CPW show decline in fishery since 2011 (CPW 2018). Sampling in 2020 indicate MMI scores between 'attainment' and 'impairment.' Water temperature trends indicate an unexpected drop in surface water temperatures between Swan River confluence and Dillon Reservoir.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 1.4 is located below the confluence with the Swan River which likely ameliorates low flow conditions. This reach was also not disturbed by dredge boat mining and a riparian corridor is present. Fishery is in decline and MMI scores are between 'attainment' and 'impairment.'
0.64			B-	Mild/significant	


Reach 2

Reach 2 is approximately 27.5 miles long from the outlet at Dillon Reservoir to the inlet of Green Mountain Reservoir. Three subreaches are used to characterize Reach 2 representing the urbanized area immediately downstream of Dillon Reservoir in Silverthorne, the confined valley area of the Blue River to approximately mid-way to Green Mountain Reservoir, and the lower half of the valley near Green Mountain Reservoir (Figure G-3). This assessment does not include Green Mountain Reservoir, nor tributaries to the reservoir or main stem of the Blue River.

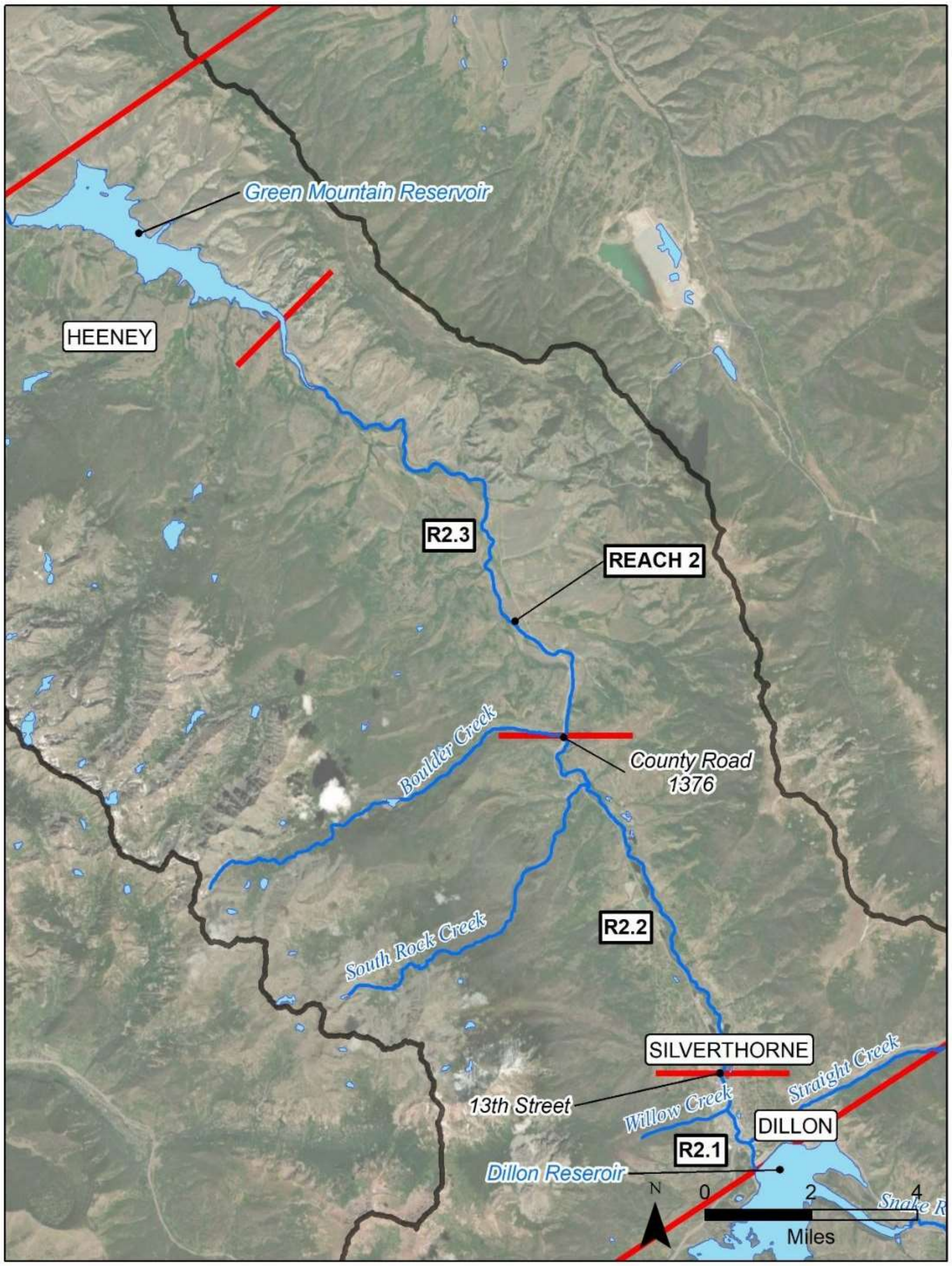


Figure G-3. Reach 2 Subreaches.

Blue River Reach 2.1-Dillon Reservoir (DR) outlet to 13th Street in Silverthorne

FACStream Summary					Notes
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	C	Significant	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases reducing overall volumes and spring time peaks; transbasin diversion are anticipated to increase. Monitoring of surface water indicate average monthly temperatures below narrative standards recommended by USFWS for adult brown trout and 'growth to age 1' brown trout for all months monitored (April through October). In 2020 the Town of Silverthorne initiated a water quality sampling program to assess stormwater/snowmelt runoff.
	V_{sed}	Sediment Regime	C	Significant	
	V_{chem}	Water Quality	C-	Significant/severe	
Riparian	V_{con}	Floodplain Connectivity	C	Significant	Review of 1954 aerial mapping indicates this channel alignment and adjacent riparian fringe has not changed significantly in spite of the significant urban encroachment and development adjacent to the river. Flow alterations may be dimensioning habitat availability in the side channels and floodplain overbanks thereby not optimal for supporting aquatic life and other natural functions.
	V_{veg}	Riparian Vegetation	B	Mild	
	V_{deb}	Debris	C-	Significant/severe	
Stream	V_{morph}	Stream Morphology	B	Mild	Overall channel morphology is impacted by development and encroachment, channel alterations and crossings. The overbanks along the first mile are heavily developed with commercial land uses. Flow alterations are likely diminishing habitat availability in the overbanks. Portions of the channel has retained a narrow band of riparian and forested growth.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B-	Mild/significant	
	V_{bio}	Biotic Structure	D	Severe	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.1 spans the first 2 miles below Dillon Reservoir and includes sample sites Blue 5 and DRD. Average monthly water temperatures at these sites were suboptimal from April through October; MMI scores for 2020 macroinvertebrate failed to reach attainment in spring, summer and fall; and fish surveys conducted by CPW report slow growth in the brown trout fishery. Overall channel morphology has some impacts from development, encroachment, channel alterations and crossings and flow alterations are likely diminishing habitat availability.
0.54			C	Significant	

Blue River Reach 2.2-13th Street in Silverthorne to Boulder Creek at County Road 1376

FACStream Summary					Notes
Scale	**Variable**		**Grade**	**Degree of Impairment**	
Watershed	V_{hyd}	Flow Regime	C+	Significant/mild	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases, although some amelioration may be occurring from tributaries. Transbasin diversion are anticipated to increase. Average monthly water temperatures were below narrative standards recommended by USFWS for adult brown trout for all months monitored (April through October) and for 'growth to age 1' for April through July.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely due to lower flows since 1954 with the construction of DR. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions.
	V_{veg}	Riparian Vegetation	B	Mild	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely do to lower flows since 1954 with the construction of DR. Overbank floodplain impacts exist from gravel mining. MMI scores for 2020 macroinvertebrate varied with sample site Blue 3 consistently impaired while D5 between impaired and attainment. Fish surveys conducted by CPW report slow growth in the brown trout fishery. Flow alterations are likely diminishing habitat availability.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	C	Significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.2 spans miles 2 to 11 below Dillon Reservoir to the confluence with Boulder and Pebble Creek and includes sample sites Blue 3 and D5. Average monthly water temperatures at these sites were suboptimal from April through October; MMI scores for 2020 macroinvertebrate varied with sample site Blue 3 consistently impaired while D5 between impaired and attainment. Fish surveys conducted by CPW report slow growth in the brown trout fishery. Flow alterations are likely diminishing habitat availability.
0.66			B	Mild	

Blue River Reach 2.3-Boulder Creek at County Road 1376 to Green Mountain Reservoir					
FACStream Summary					**Notes**
Scale	**Variable**		**Grade**	**Degree of Impairment**	
Watershed	V_{hyd}	Flow Regime	B	Mild	Transbasin diversion and flow operations from Dillon Reservoir impact flow releases, with some amelioration from tributaries. Transbasin diversion are anticipated to increase. Average monthly water temperatures were below narrative standards recommended by USFWS for adult brown trout and for 'growth to age 1' for April through June.
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B+	Mild/negligible	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	There is evidence of land use encroachment from agriculture, resulting in a lower sinuosity, loss of side channels and a reduction in riparian vegetation density and lateral extent. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions. Diversions for irrigiation are present which may impact fish passage.
	V_{veg}	Riparian Vegetation	C	Significant	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Review of 1954 aerial mapping indicates this channel alignment is relatively stable and has not changed significantly, although there is evidence of vegetation encroachment likely do to lower flows since 1954 with the construction of DR. Flow alterations may be diminishing habitat conditions and not optimal for supporting aquatic life and other natural functions. MMI scores for 2020 macroinvertebrate sampling generally indicate attainment to slightly impaired in spring, summer and fall.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 2.3 spans the downstream half of the reach between Dillon and Green Mountain Reservoir and generally depicts a downstream recovery in both temperatures and macroinvertebrates. Average monthly water temperatures show a general increase but remain suboptimal from April through June; MMI scores for 2020 macroinvertebrate generally show attainment. Development is outside of the historically active floodplain, although there is agricultural impacts including loss of riparian vegetation and the presence of fish passage impediments.
0.70			B	Mild	

Reach 3

Reach 3 is approximately 16 miles long and extends from the Green Mountain Reservoir outlet to the confluence with the Colorado River (Figure G-4). Much of this reach is in private ownership, held by Blue Valley Ranch (BVR) and extensively managed for aquatic habitat and agricultural land use. Most of this reach is in Grand County and was studied in preparation of the Grand County Stream Management Plan (GCSMP) which is referenced and relied on, along with updated data from BVR, for information used in this stream assessment.

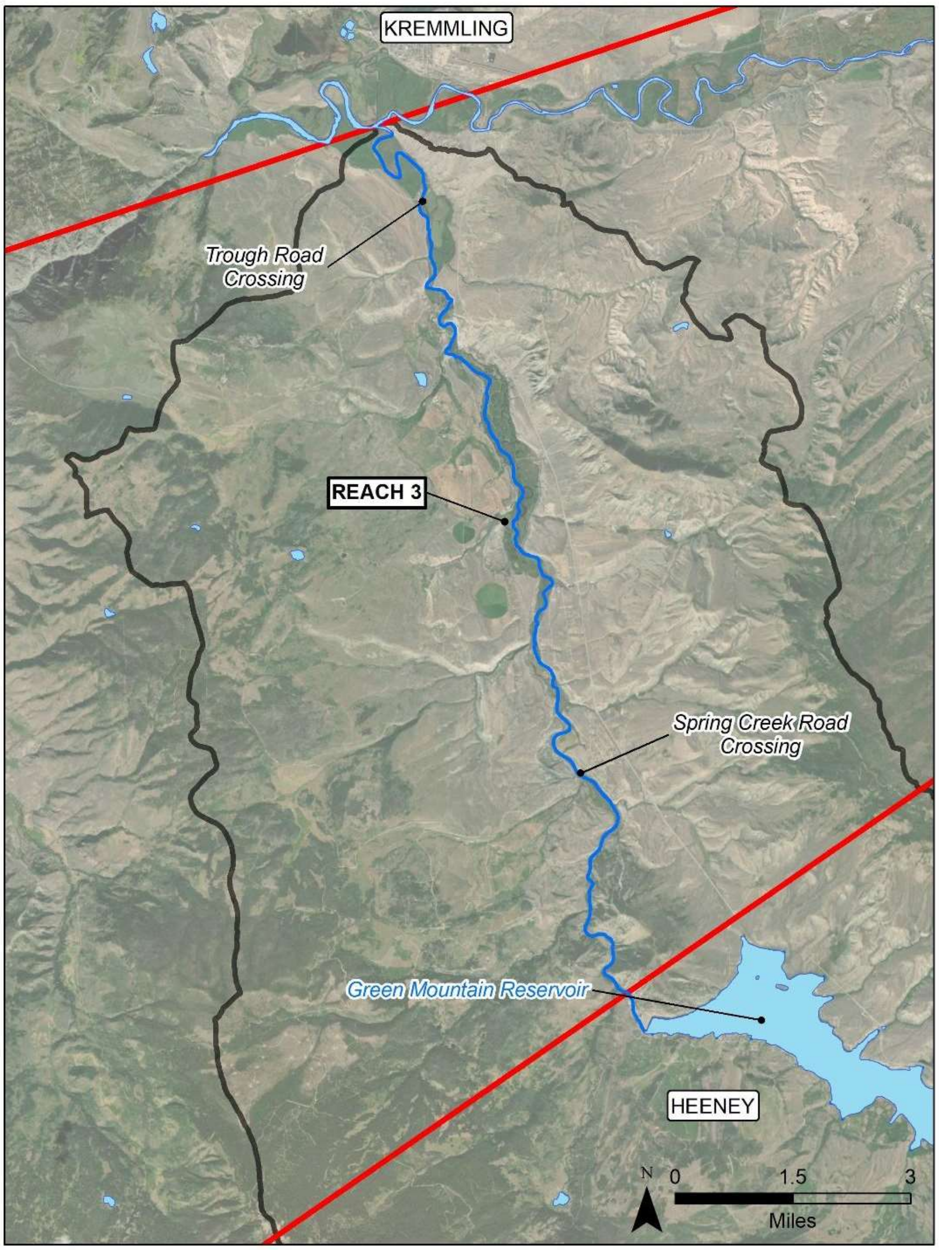


Figure G-4. Reach 3 Subreach.

Blue River Reach 3-Green Mountain Reservoir to confluence with Blue River					
FACStream Summary					**Notes**
Scale	Variable		Grade	Degree of Impairment	
Watershed	V_{hyd}	Flow Regime	C	Significant	Rapid flow changes from GMR particularly in the late fall have impacted spawning habitat with high flows in early fall support create spawning habitat in side channels and along the banks of the main channel, but later left dry due to rapid and significant flow reductions (GCSMP 2010).
	V_{sed}	Sediment Regime	B	Mild	
	V_{chem}	Water Quality	B	Mild	
Riparian	V_{con}	Floodplain Connectivity	B	Mild	Generally riparian corridor appears well vegetated along banks with well established cottonwood galleries. Overbanks are in agricultural production with some areas managed for wildlife habitat. There is a lack of debris (wood) in the lower portions of this reach.
	V_{veg}	Riparian Vegetation	A	Negligible	
	V_{deb}	Debris	B	Mild	
Stream	V_{morph}	Stream Morphology	B	Mild	Below GMR and above Trough Road there appears to be many structures in the river (v-shaped weirs, deflectors, jetties) likely installed to stabilize the river and support irrigation diversions. These may impede fish passage.
	V_{stab}	Stability	B	Mild	
	V_{str}	Physical Structure	B	Mild	
	V_{bio}	Biotic Structure	B-	Mild/significant	
Overall FCI			Reach Condition	Degree of Impairment of Reach	Reach 3 is located between GMR and the Colorado River. While this reach is the benefactor of ample flow releases from GMR, the timing and rate of flow changes may be hampering the aquatic life in this reach.
0.64			B	Mild	

G.4. SUMMARY OF RESULTS BY VARIABLE

Much of the information, data, and reporting referenced in this Stream Assessment report is derived from the studies cited in the main body of the report and appended documents. This includes CPW fish surveys (cited), macroinvertebrate sampling by Timberline (Appendix D), Periphyton sampling by TU (Appendix E) Blue River Fishery Review by Ksqrdfish Aquatics (Appendix F) and water quality and temperature (Appendix C). Additional data sources are also identified in the following descriptions and Section G.5. of the appendix.

Flow Regime

The Blue River is generally a snowmelt driven system, with peak flows typically occurring in late spring and early summer and often lasting for multiple days or weeks. Snowmelt runoff will typically dominate flows until early summer as river flows begin to drop off. Changes to total annual volume and peak flows, including bankfull discharge and floods, are most relevant to channel stability, riparian vegetation, and floodplain functions. Impacts to base flows are most relevant to stream habitat and water quality. Alterations to natural patterns of flow variability, including the frequency and timing of peaks, fluctuations, and rates of change, are particularly important to fish, insects and other biota that have life history strategies tied to predictable flow rates at specific times of the season (Beardsley et al. 2015).

The Blue River watershed is impacted by transbasin diversions which occur in several locations, including a diversion in the headwaters of Reach 1 and in Dillon Reservoir at the upstream end of Reach 2. These diversions often occur during peak runoff but can affect both peak flows and base flows. Current estimates indicate annual flow depletions from transbasin diversions can be significant. In the 2012 Blue River Water Quality Management Plan prepared by the Northwest Colorado Council of Governments (NWCCOG) they note:

> *In 2009, 71,436.5 acre-feet of water were diverted to the eastern slope from the Blue River watershed [2009 Annual Report, Division 5 Water Resources]. To put this in perspective, in the 2000 water year 150,576 acre-feet of water flowed past the USGS gage 0.3 miles below Green Mountain dam [USGS 2000 Water Resources Data, Colorado Volume 2]. The trans-basin water diversions, therefore account for approximately 40% of the total stream flow in the Blue River watershed. (NWCCOG 2012).*

Changes in flow regime in Reach 3 is impacted by releases from Green Mountain Reservoir, which makes releases for downstream water uses late in the summer or fall resulting in an unnaturally high flow regime in the fall. Based on the scoring guidelines provided in FACStream, these factors can result in a rating of a severe impairment for total volume of flow and high to very high ecological risks to the Blue River.

Information developed through the Flow Evaluation Tool and Analysis & Technical Update provided by the Colorado Water Plan (CWP 2019) indicates future water demands, combined with climate-impacted conditions, will likely result in peak flows moving earlier in the year, with April through August flows decreasing and possible mis-matches between peak flow timing and species' needs. The *Cooperative Growth*, *Adaptive Innovation*, and *Hot Growth* scenarios developed in the Flow Evaluation Tool indicate that mid- and late-summer flows may be reduced by 60 to 70 percent, creating high risk to fish from loss of habitat. In addition, downstream from major reservoirs, diminished peak flows could create risk for riparian/wetland vegetation and fish habitat if sediment is not flushed (CWP 2019).

Additional information will be collected in subsequent phases of analysis to assess habitat suitability for selected fish species and age groups, likely brown trout, including quantitative analysis and prediction of suitable physical habitat for chosen species and life stages under different river flow scenarios. This assessment will be based on field measurements, hydraulic calibration, and species physical habitat preferences (depth, velocity, and substrate).

Sediment Regime

Overall, the sediment regime in the main stem of the Blue River scored in the negligible to mild range of impairment, indicating little observable or documented modifications from reference standards. There are two exceptions. The first is in Reach 2.1 downstream of the Dillon Reservoir dam where a lack of fine material as well as lack of small gravels and cobbles in the channel is observed and likely a result of the impoundment from the dam. The second is in Reach 1.3 located between the Swan River confluence and French Gulch where dredge boat mining has resulted in a reduction in fine sediment, gravel, and small cobble within the channel and adjacent floodplain. In Reach 1.1, there is some evidence of sand accumulation south of Breckenridge, possibly indicating impacts from the placement of traction sand on Highway 9 in the winter. Data collection in Phase 2, particularly for habitat suitability and associated field observations, will provide an opportunity to further the understanding of sediment regime in all three reaches. Excess sediment was not observed in the other reaches.

Water Quality and Temperature

Review of water quality data indicate a presence of inorganics and toxins in all reaches, with some exceedances in Reach 1, likely the result of underlying geology, as well as historic hard rock mining along several of the tributaries.

Temperature regime is a critical abiotic habitat factor that often limits what types of organisms inhabit a reach. It is a direct determinant of biotic structure and physicochemical processes such as metabolic rates. Impacts typically manifest at the extremes (high temperatures in summer or extended freezing in winter) (Beardsley et al. 2015).

Review of temperature data indicate the Blue River has little to no warm temperature standard exceedances but can often be very cold, dropping below narrative standards established by the USFWS for support of brown trout (Raleigh et al, 1986). In the summer of 2020, continuous temperature loggers were installed along the Blue River to complement the temperature loggers already in place and being monitored by the USFS. The data indicate values below cold water narrative standards. See Appendix B for further discussion on cold water narrative standards and impacts on the fishery.

Floodplain Connectivity

Floodplain connectivity describes the degree to which water accesses and hydrates the floodplain. Reach 1.1 upstream of the town of Breckenridge, has the lowest degree of impairment ,impairment, with increasing impairment moving downstream. Reach 1.1 has minor development encroaching on the floodplain and several wetland complexes where access and hydration are abundant. Floodplain connectivity in Reaches 1.2 and 1.3 is rated with a significant impairment due to urban development and the historic dredge boat mining. Dredge boat mining destroyed the original river channel and surrounding floodplain as the dredge boats extracted the alluvium and sifted through the material for gold. What remained of the river was a straight, trapezoidal channel which only conveyed flow during snowmelt run-off. Additionally, the dredge tailings, devoid of vegetation, fine sediment and boulders, were highly mobile resulting in very unstable riverbed and banks. Restoration has been in progress since the mid-1980s including the urban corridors through Breckenridge (McMillen et. al. 2013). By necessity due to dense development in the town of Breckenridge, the urban corridors have reduced floodplain connectivity (Figure G-5). Reach 1.3 is also in the process of being restored to improve this and other riparian and stream functions and conditions. Without the restoration efforts, the impacts to floodplain connectivity in Reaches 1.2 and 1.3 would be rated as "Profound." Reach 1.4 has mild impairments due to large acreage residential development.

Reach 2 has had fewer floodplain connectivity impacts from mining, but instead has impairment due to reduced flow regimes. This is evident by the change in riparian vegetation density, which has increased over the past 60 years, likely due to lack of overbank flows since the time Dillon Reservoir was constructed in 1963 (Figure G-6).

Figure G-5. Urban Development along the Blue River, Breckenridge (top photo) and photo of dredge boat in operation immediately north of Breckenridge (1938) (bottom photo).

Figure G-6. 1954 aerial photo (left) and 2020 aerial photo (right) showing increases in vegetation density on channel banks and bars.

Reach 3, downstream of Green Mountain Reservoir, is located within a largely rural agricultural setting. Land ownership includes several privately held properties, ranches, and the USFS. Floodplain encroachment is typically limited to agricultural impacts; however, floodplain connectivity is likely reduced due to reservoir operations.

Riparian Vegetation

The degree of impairment for riparian vegetation in Reach 1 generally follows the same pattern as the floodplain connectivity, with negligible impairments in the upper watershed (Reach 1.1) and profound impacts in the urban corridor (Reach 1.2) and where dredge boat mining has occurred (Reach 1.3). Ratings reflect ongoing restoration efforts. Within Reach 2 and outside of the urbanized areas (Reach 2.1), the riparian vegetation impairment is rated as ”mild;“ however, in this case, the vegetation has become heavier along the channel corridor, likely due to the reduction of overbank flows which would have, in a unaltered system, scoured and mobilized the material in the overbanks thereby maintaining a less dense riparian corridor. In portions of Reach 2.3, impacts to the riparian corridor are rated as ”significant” due primarily to agricultural land use that includes the removal of riparian vegetation along the channel corridor. Reach 3, downstream of Green Mountain Reservoir, is located within a largely rural agricultural setting with relatively minor impacts . Land ownership includes several privately held properties and ranches which are managed to maintain and improve riparian vegetation. The portion of the Blue River within USFS land is near the outlet of Green Mountain Reservoir and is heavily wooded, steep, and relatively undisturbed except for changes in flow regime from reservoir operations. The riparian vegetation and cottonwood galleries are abundant.

Stream Morphology

Stream morphology rates the degree of departure from the reference condition, which includes planform, channel dimensions, and longitudinal profile. Based on guidance outlined in FACStream, and a broad understanding and familiarity with the watershed, an overall reference standard could generally be described as a meandering single thread channel with wide floodplains, unconfined or partially confined valleys, pool-riffle bed formation consisting primarily of cobble and gravels, and a relatively dense riparian vegetated corridor. The reference reach would have no local water use, transbasin diversions or water impoundments.

This variable is affected by anthropogenic impacts and flows. Here again, Reach 1.2 and 1.3 scored a significantly higher departure from the reference reach due to anthropogenic impacts (urbanization and dredge boat mining) while the other reaches rated as having a ”mild” degree of impairment as a result of anthropogenic impacts. Changes in flow regime due to transbasin diversions have occurred in all three reaches.

Stability

Stability evaluates the probability that the stream will maintain its geomorphic structure over time based on the dynamic balance between sediment supply and transport. This measurement also encompasses the ability of the system to recover after a large disturbance such as a large flood, wildfire, or mass erosion event. Primary factors include its ability to move and adjust as well as the potential for riparian vegetation communities to recover. For the Blue River mainstem, all reaches rated as having a ”mild” departure from the reference reach, indicating that despite the changes that have occurred in the recent past, the mainstem has retained its resiliency and ability to rebound from disturbance in most locations with the exception of Reaches 1.2 and 1.3 which were significantly impacted by dredge boat mining.

Physical Structure

Physical Structure rates the degree to which characteristic patterns of structural heterogeneity are altered as depicted by the processes of erosion, scour, and deposition that shape the form of bed, banks, and substrate. Biological drivers such as riparian vegetation, wood, and beavers may have an impact on physical structure and diversity. For the Blue River mainstem reaches 1.4, all of 2, and all of 3, are rated as having a ”mild” departure from the reference reach. Reaches 1.2 and 1.3 are rated as “mild” to “significant” departure reflecting the urbanization and dredge boat mining impacts. Restoration of these reaches have typically been linear, with little sinuosity or channel meandering due to existing and proposed encroachments including such things as the downtown corridor of Breckenridge, urban encroachment, and Highway 9.

Biotic Structure

Biotic structure is the biological component of the natural infrastructure of a stream, and the main subject of stream ecology. As noted in FACStream, this variable is difficult to assess accurately in routine assessments because few simple, rapid indicators exist. For purposes of this assessment the biotic structure included consideration of CPW fish surveys and 2020 macroinvertebrate monitoring. The CPW fish surveys indicate a healthy but declining fishery in Reach 1, and a poor and declining fishery in Reach 2. Macroinvertebrate monitoring results in the form of MMI scores indicate less than optimal conditions in Reach 1, impairment in the upstream section of Reach 2, and attainment in the lower reaches of Reach 2 and all of Reach 3.

Channel Habitat Assessment, Reach 3

In 2010, the Blue River from the confluence of the Colorado River to the Grand-Summit County line was assessed for the Grand County Stream Management Plan (GCSMP) (Reach 3). The analysis and data generated for the GCSMP is presented herein with permission of Grand County and reported on for the purposes of the BRIWMP this Stream Assessment. (Tetra Tech et al. 2010).

Flow recommendations developed in the GCSMP and adopted for Reach 3 were developed using the PHABSIM (Physical Habitat Simulation) system (Bovee 1997; USGS 2001). Spawning habitat availability was also evaluated using water depth and velocity suitability curves for brown and rainbow trout, assuming a substrate preference for gravel (less than 3.0-inch diameter).

Five sites were selected for analysis as described below.

1. One site was established downstream of County Road 10 in 2007. This site is within the upstream reaches of the Blue Valley Ranch property.
2. One site was established in 2008 downstream of Trough Road at the old highway bridge on San Toy Land Company property. The site is referred to in this report as the ”spawning site.”
3. Three additional sites were established in 2009, all within the Blue Valley Ranch property and are referred to as the upper, middle, and lower sites.

Flow recommendations developed from this analysis are as follows:

- 200 to 300 cubic feet per second (cfs), April 1 through September 30
- 200 to 300 cfs, October 1 through March 31
- Flushing flow - at least 1150 cfs for a 3-day duration with a frequency of 1 in 2 years during the late May to late June period.

Note that current instream flows for this reach are 60 cfs from May 1-July 15 and 85 cfs for the remainder of the year. These values are closer to the values assessed for the Two Forks Aquatic Baseline and in the

Nehring Federal Reports state PHABSIM recommendations are for a minimum of 50 and optimum of 100. Further analysis and assessment may be required to review the differing results.

Both the 1985 Chadwick and Associates report and the GCSMP note that rapid changes in streamflow (ramping) could adversely affect aquatic life, including fish. Rapidly rising streamflows could potentially re-locate fish and other aquatic life downstream into less favorable habitats, while rapidly declining flows can strand fish and other aquatic life in temporary habitats ultimately leading to desiccation and death (Reiser et al. 2008). Also, flow reductions during important life cycle events such as spawning can lead to drying of incubating eggs in redds and immobile fry attempting to emerge from the inter-gravel environment. The latter problem was observed on the Blue River through the BVR and downstream below the Trough Road. While the magnitude of the effects of rapid streamflow fluctuations on the Blue River trout population and other aquatic life is not well defined, additional study, evaluation, and discussion of this potential issue is recommended. To the extent possible, flows should be maintained at a fairly constant rate within the recommended target flow range during the trout spawning and incubation period to lessen or prevent the loss of developing trout embryos. This includes the late summer and early fall seasons of September through October during which flows from Green Mountain Reservoir have often been used to supplement downstream water requirements.

G.5. DATA SOURCES AND EXISTING STUDIES

The following is a brief summary of several existing studies referenced in preparation of the stream assessments.

G.5.1. Channel Habitat Assessments Upstream of Dillon Reservoir

A cursory review of existing studies and assessments for the establishment of instream flows upstream of Dillon Reservoir was conducted by Bill Miller of Miller Ecological on behalf of Summit County in 2019/2020. It is our understanding that Mr. Miller located several R2Cross studies conducted in the 1980s to establish the minimum instream flows in the Blue River upstream of Dillon Reservoir; two additional hydraulic simulations completed in the reach downstream of the Swan River; and an R2Cross model upstream of the confluence with the Swan River and upstream of the highway bridge. Minimum flows specified by CWCB for each section of the river are based on the R2Cross model results in combination with a water availability analysis. The supportive data for each minimum flow appropriation includes the R2Cross data sets and model output, and hydrologic analysis. The R2Cross data and hydrologic analysis appeared to be used in combination to set the minimum flow recommendations used by the Colorado Water Conservation Board to establish instream flows.

R2Cross does not inform on seasonal flow requirements, flushing flows for habitat maintenance, nor are the data sets helpful for assessing impacts of restoration projects, operational changes, and/or changes in trans-basin diversions. For this level of assessment, a more robust study and assessment is required. A summary of current instream flows for the study reach is provided in Table G3.

Table G-3. CWCB Instream Flows

Blue River Minimum Instream Flows		Minimum Flows, cfs									
Reach	Segment description	summer cfs	date	fall/winter cfs	date	fall/winter cfs	date	fall/winter cfs	date	fall/winter cfs	date
1	To Hwy 9 near Fredonia	2	all year								
1	Hwy 9 near Fredonia to Goose Pasture Tarn	5	5/1-9/30	3	10/1-4/30						
1	Swan River confluence upstream 1 mile to pond	20	5/1-10/31	10	11/1-4/30						
1	Swan River to Dillon Reservoir inlet	32	5/1-10/31	16	11/1-4/30						
2	Dillon Reservoir outlet to Straight Creek	50	all year								
2	Straight Creek to Willow Creek	55	5/1-7/31	52	8/1-9/30	50	10/1-4/30				
2	Willow Creek to Rock Creek	75	4/1-9/30	58	10/1-3/31						
2	Rock Creek to Boulder Creek	115	5/1-8/31	90	9/1-9/30	78	10/1-10/31	67	11/1-3/31	90	4/1-4/30
2	Boulder Creek to Slate Creek	125	5/1-8/31	90	9/1-10/31	70	11/1-2/29	78	3/1-3/31	90	4/1-4/30
2	Slate Creek to GMR inlet	125	5/1-9/30	90	10/1-4/30	85	12/1-2/29	90	3/1-4/29		
3	GMR outlet to Colorado River	60	5/1-7/15	85	7/16-4/29						

G.5.2. Channel Habitat Assessment Metropolitan Denver Water Supply Systemwide/Site-Specific Environmental Impact Statement (1986)

Instream Flow Incremental Methodology (IFIM) is a method for determining the relationship between stream flows and fish habitat. An IFIM was completed in association with the Aquatic Baseline Metropolitan Denver Water Supply Systemwide/Site-Specific Environmental Impact Statement in 1986 (Chadwick and Associates). Four IFIM sites (Table G-4) were assessed, three by Chadwick and Associates (1985) and one by the Colorado Division of Wildlife (1983). Two sites were located downstream of Dillon Reservoir and two were completed downstream of Green Mountain Reservoir.

Table G-4. IFIM Sites

Station	Sampled By	Latitude	Longitude
Blue River I	Chadwick 1985	39° 42'10"	106° 06' 23"
Blue River II	CDOW 1983	39° 45' 14"	106° 07' 51"
Blue River III	Chadwick 1985	39° 45' 23"	106° 20' 39"
Blue River IV	Chadwick 1985	39° 58' 05"	106° 23' 25"

The four segments used for the IFIM analysis were selected based on a combination of discharge, slope, and geomorphology (Chadwick and Associates 1986).

River segments are presented below:

Blue River I extends from the base of Dillon Reservoir to the confluence with Rock Creek and represents 10.4 km (6.5 mi). This coincides with the BRIWMP Reach 1 and portions of Reach 2.

Blue River II extends from Rock Creek to the inlet of Green Mountain Reservoir and represents 21.6 km (13.5 mi) This overlaps with the BRIWMP Reach 2 and all of Reach 3.

Blue River III extends from the base of Green Mountain Reservoir to the confluence of Spring Creek and represents 6.1 km (3.8 mi). This coincides with the BRIWMP Reach 3.

Blue River IV extends from Spring Creek to the confluences of the Colorado River and represents 17.6 km (11.0 mi). This site was completed before the channel restoration efforts on the Blue Valley Ranch were implemented. This coincides with the BRIWMP Reach 3.

In the IFIM study, brown trout was the species of interest in the Blue River. The suitability of use curves were from Raleigh et al. (1984b). The brown trout spawning criteria was modified using data collected in the fall of 1985.

G.5.3. Other Data Sources

Colorado Department of Natural Resources. Colorado Water Plan Technical Update (CWP). 2019. Water Conservation Board. Available at: https://dnrftp.state.co.us/#/CWCB/Technical%20Update%20to%20Water%20Plan/1.%20Technical%20Update%20Documentation/

Colorado Parks and Wildlife. 2020. Fishing Regulations Brochure. Colorado Parks and Wildlife.

Northwest Colorado Council of Governments (NWCCOG). 2012. Regional Water Quality Management Plan. At: http://nwccog.org/programs/watershed-services/

McMillen, LLC, Tetra Tech. 2013. Blue River Section 206 Aquatic Ecosystem Restoration, Breckenridge, Colorado. Appendix B. Engineering Report.

Tetra Tech, HabiTech, Inc. and Walsh Aquatics, Inc., 2010. Draft report, Stream Management Plan, Phase 3, Grand County, Colorado. Prepared for Grand County, CO with support from Denver Water and Northern Colorado Water Conservancy District. Hot Sulphur Springs, CO. August.

Site assessments were conducted in the fall of 2020 which included photo documentation and pebble counts.

Google earth was utilized to estimate valley lengths, slopes.

1954 aerial imagery was utilized to compare riparian conditions with current conditions in Reach 2 (Grand County, CO, Bureau of Land Management, Esri, HERE, Garmin, INCREMENT P, Intermap, USGS, METI/NASA, EPA, USDA | USGS The National Map: Imagery | Trout Unlimited).