City of Golden

City of Golden
Clear Creek Aquatic Health Management Plan

August 2022

ERO

Consultants in Natural Resources and the Environment

Clear Creek Aquatic Health Management Plan
Golden, Colorado

Prepared for—

City of Golden
1445 10th Street
Golden, Colorado 80401

Prepared by—

ERO Resources Corporation
1842 Clarkson Street
Denver, Colorado 80218
(303) 830-1188
ERO Project #22-114

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Executive Summary

The reach of Clear Creek within City of Golden (City), Colorado limits has become an attraction for anglers, tubers, kayakers, and other recreational users. In recent years, impacts on the health of fisheries and aquatic resources from impacts of recreational use have received more focus. The City has developed this Aquatic Health Management Plan (Plan) for the approximately 1-mile reach of Clear Creek that flows within the City limits. This Plan is intended to assist the City in decision making with regard to recreational use of Clear Creek within City limits and impacts that recreational use may have on aquatic populations in Clear Creek.

High water temperatures, low dissolved oxygen concentrations, and low stream flows are all interrelated factors that can potentially affect aquatic resources during the summer months in Clear Creek. Of these three factors, stream temperatures are often the focus as they are easily measured; in addition, the effects of temperature on aquatic organisms have been studied extensively. Aquatic organisms all have limits above or below which temperatures cause stress to that organism or even become lethal. Lethal temperatures and preferred temperature ranges differ by species, with some "sensitive" species having narrower optimal ranges and/or lethal limits that occur at lower temperatures compared to more "tolerant" species. The City determined that management activities would be triggered when stream temperature based on an instantaneous reading reached 19°C (66°F) or greater, as temperatures less than 19°C (66°F) are preferable for brown trout and native longnose suckers (the two most abundant species in this section of Clear Creek).

Recreational activities that occur in and around Clear Creek also affect aquatic health through disturbance of riparian vegetation and stream substrates, water pollution (e.g., soap and sunscreen), and effects of instream structures.

This Plan concludes with aquatic health management recommendations to ensure protection of aquatic resources while still allowing responsible use by recreational users. The City may choose to implement one or a combination of options and potentially monitor the success of these options to determine measures that are the most effective and least disruptive to recreational use, in general. Aquatic health management recommendations for the City include the following:

1. Limit or prohibit angling, tubing, and kayaking when stream temperatures based on instantaneous readings approach 19°C (66°F).
2. Encourage anglers and other users who use this reach of Clear Creek to carry a handheld thermometer and check stream temperatures. If stream temperatures exceed the 19°C (66°F) threshold, users would be advised to cease fishing for the day or to go to another location.
3. Publish recorded temperatures daily from the City's gage to advise recreational users as to when to avoid Clear Creek due to the likelihood of adverse effects on trout exposed to angling pressure or large numbers of recreational users.
4. Advise anglers and other recreational users to visit the following website that lists closure conditions statewide: https://cpw.state.co.us/thingstodo/Pages/StatewideFishingConditions.aspx.

5. Encourage anglers and other recreational users to use Clear Creek for these activities only during the morning and cooler parts of the day in July and August, ceasing activities in the afternoon.
6. In July and August, encourage anglers to fish for warmwater species more tolerant of higher temperatures in other stream reaches that support such assemblages, such as bass or carp.
7. Encourage whitewater and angling guide companies or outfitters to book trips for morning hours during July and August and book trips in the afternoon for later in the year when temperatures are lower.
8. Encourage the use of appropriate fishing techniques to reduce stress on fish, even when stream temperatures do not exceed 19°C (66°F).

Clear Creek Aquatic Health Management Plan
Golden, Colorado

August 5, 2022

1.0 Summary

The City of Golden, Colorado (City) retained ERO Resources Corporation (ERO) to provide an Aquatic Health Management Plan (Plan) for the reach of Clear Creek that runs within the City limits. As a subconsultant to ERO, GEI Consultants, Inc. (GEI) is assisting with the Plan as specialists in fisheries and aquatic resources. This report is intended to assist the City in decision making with regard to recreational use of Clear Creek within City limits and impacts that recreational use may have on aquatic populations in Clear Creek.

2.0 Introduction and Background

Clear Creek, with its headwaters at the foot of the Continental Divide, flows east through the towns of Georgetown and Idaho Springs and eventually into the South Platte River. From Georgetown downstream to Golden, Clear Creek provides good fishing for wild brown trout (Winkle 2021). Between Georgetown and State Highway 40, the stream lies mostly on private property. There is good public access from Highway 40 downstream to Golden, with land owned by Clear Creek Open Space and Jefferson County Open Space.

The reach of Clear Creek within City limits has become an attraction for anglers, tubers, kayakers, and other recreational users. The Clear Creek Whitewater Park (whitewater park) in Golden was dedicated in 1998 and was initially a 0.25-mile stretch of Clear Creek built for recreational canoeing and kayaking. Additional drop structures were added further downstream in 2002 (Figure 1), with the length extended to approximately 1 mile of Clear Creek. In recent years, impacts on the health of fisheries and aquatic resources from the features constructed in whitewater parks have received more focus, in addition to the other impacts of recreational use on aquatic populations.

Figure 1. Drop structure associated with the whitewater park, April 2022.

In the summer of 2022, City officials anticipate activity levels that may exceed the norm for summertime in Golden (City 2022). After many months of limited activities, interactions, and events due to the COVID-19 pandemic, people will likely seek to get out and participate in the outdoor recreation activities that they have missed - especially along and in the popular Clear Creek.

2.1 City Council Clear Creek Subcommittee

As described on the Guiding Golden webpage, (*Clear Creek Management Strategies* (City 2022)), in 2021 the City Manager formed the City Council Clear Creek Subcommittee (Clear Creek Subcommittee) to review management practices in the Clear Creek corridor. This working group - representing Golden residents, civic organizations, the Golden Visitor's Center, local businesses, outdoor recreation industry representatives, and equipment rental companies– discussed issues, challenges, and potential strategies to address the growing popularity of Clear Creek (City 2022) and provided City staff and Council valuable feedback regarding the communities' priorities and desires. The group focused on water use and safety, trail use, traffic and parking, communications, enforcement of rules and regulations, and environmental concerns.

This Plan is intended to assist City staff and Council with identifying and moving forward with aquatic health management practices for Clear Creek. The Plan includes the following elements: (1) a data summary and explanation of aquatic populations, temperature regimes, and stream flows in Clear Creek; (2) a discussion of how recreational use of Clear Creek, particularly in summer, may exacerbate challenges to maintaining healthy aquatic ecosystems; and (3) long-term management recommendations for the protection of aquatic resources and the health and resiliency of Clear Creek.

3.0 Project Area

The project area for this Plan includes the approximately 1-mile segment of Clear Creek that runs through City limits from west to east (Figure 2). The easternmost point is the water intake at the Church Ditch and headgate, where stream and aquatic species data are collected.

Figure 2. Project Area

4.0 Consistency with Other Plans

This Plan was developed using existing monitoring data for Clear Creek (described in the sections that follow), existing studies on temperature and stream flow, information developed by the Clear Creek Subcommittee, and similar plans developed by other municipalities and agencies. In addition, the Plan is consistent with previous documentation and recommendations developed by the Clear Creek Subcommittee and is consistent with other City planning documents and management plans, including the following:

- *2011 Clear Creek Corridor Master Plan* (available at: https://www.cityofgolden.net/media/clearcreekplan.pdf).
- *2013 Clear Creek Ecosystem Health Riparian and Aquatic Assessment Report* (available at: https://www.cityofgolden.net/media/ClearCreekHealthAssessmentReport.pdf)
- *2020 City of Golden Sustainability Strategic Plan* (available at: https://www.cityofgolden.net/media/2020SustainabilityStrategicPlan.pdf).

- *2014 Clear Creek Management Plan* (available at: https://www.cityofgolden.net/media/ClearCreekManagementPlan.pdf).

4.1 Climate Change Considerations

It should be noted that climate change considerations will continue to change terrestrial and aquatic conditions within this corridor in the coming years and will need to be incorporated into this effort as new information becomes available. Warmer temperatures and changes in the amount and timing of snow may drastically change the landscape in this corridor. Snow is melting earlier in the spring, and as temperatures rise, surface waters and the plants and animals that depend upon them are particularly vulnerable to changes in temperature and moisture. Ever-changing climatic conditions may limit the ability for the City to use resource data beyond a specified period (i.e., a "shelf life" for data) and predicting resource trends will be increasingly challenging. As climate change multiplies impacts across resources, data used to predict future conditions may become increasingly more uncertain. The City will need to consider the effects climate change has on the resources in the Clear Creek corridor as well as the effects the City's actions contribute to climate change and continue to adapt methodologies and frequency of data collection.

5.0 Existing Conditions/Clear Creek Health Assessment

5.1 Status of the Aquatic Communities

The reach of Clear Creek that flows through the City, including the reach that functions as the whitewater park, is in Segment 11 of the Clear Creek Basin (5 Code of Colorado Regulations [CCR] 1002-38-Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin). As delineated by the Colorado Department of Public Health and Environment (CDPHE), this segment extends approximately 20 miles in total length, stretching from the Argo Tunnel near Idaho Springs, Colorado to the Farmers Highline Canal diversion near the Molson Coors facility. The whitewater park area is near the downstream boundary of this segment (Figure 6. This segment is classified as a Cold Water Aquatic Life Class 1 stream reach, which is defined by the CDPHE as either currently capable of sustaining a wide variety of cold water biota, including sensitive species, or could sustain such biota but for correctable water quality conditions (CDPHE 2021).

Since 2000, more than 80 fish surveys have been conducted in Segment 11 of the Clear Creek Basin by Colorado Parks and Wildlife (CPW) biologists and other entities, including GEI (Figure 3). Results of these surveys indicated that brown trout (*Salmo trutta*) are the most abundant fish species in this reach of Clear Creek (Figure 4). Their presence makes this reach popular with anglers. Brown trout are not native to Colorado, but this population is naturally reproducing in Clear Creek, as evidenced by the presence of small young-of-year trout (trout born within the past year) in addition to larger juvenile and adult trout.

Other species present in multiple surveys conducted in this reach of Clear Creek include longnose suckers (*Catostomus catostomus*), rainbow trout (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*). Similar to brown trout, the size distribution of native longnose suckers collected during

surveys of Clear Creek suggest that this species is maintaining the population through natural reproduction. Rainbow trout resistant to whirling disease (a disease that can cause high rates of mortality in young-of-the-year fish) have been stocked annually since 2009 according to the CPW (Winkle 2021). Rainbow trout are substantially less abundant than brown trout in this segment of Clear Creek. While the occasional presence of smaller rainbow trout in this segment indicates that limited natural reproduction may be occurring for this species, likely few of the stocked fish survive from year to year. Fetherman et al. (2014) noted similar results on the Colorado River; survival of stocked rainbow trout resistant to whirling disease was low, but some reproduction did occur. Fetherman et al. (2021) suggested that resistance to whirling disease is a heritable trait.

Figure 3. GEI field crew surveying fish populations in Clear Creek upstream of the Ford Street bridge in April 2022.

Figure 4. Brown trout are the dominant trout species in Clear Creek.

Young-of-year brook trout were observed occasionally in addition to older fish. A very small number of cutthroat trout x rainbow trout hybrids (cuttbows, *O. clarkii x O. mykiss*), longnose dace (*Rhinichthys cataractae*), and white suckers (*C. commersonii*) have also been seen in this reach occasionally in surveys, but the low numbers and infrequent sightings of these species and hybrids suggests that they do not typically reside in this reach of Clear Creek, even though longnose dace and white suckers are native to the basin. These species may be prohibited from moving upstream into this reach from further downstream in Clear Creek by the multiple fish barriers including drop structures present on Clear Creek.

In addition to serving as a food resource for trout and other species, the macroinvertebrate assemblages in streams are good indicators of the overall biological integrity of aquatic communities. Macroinvertebrate assemblages can typically assimilate to the effects of stressors over time (CDPHE 2020); these effects can be "seen" or inferred by the species that are present in the assemblage. As with fish sampling, macroinvertebrate sampling has also been conducted in Segment 11 of Clear Creek in more than 20 different surveys. Macroinvertebrate populations in this reach of Clear Creek frequently consist of groups such as mayflies, stoneflies, beetles, caddisflies, true flies, and water mites. Most of the samples collected from this reach indicate that the macroinvertebrate assemblages are diverse and healthy, and contain multiple *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisfly) taxa, collectively referred to as EPT taxa. The EPT taxa are generally considered sensitive to disturbance and pollution. Often baetid mayflies or hydropsychid caddisflies (Figure 5) were the most abundant organisms in each sample; these insects tend to be moderately tolerant of environmental disturbance. The CDPHE assesses the ability of stream reaches to support healthy aquatic populations through use of the Colorado bioassessment tool, the Macroinvertebrate Multi-Metric Index (MMI; CDPHE 2020). Most, but not all, MMI samples collected in Segment 11 indicated healthy and diverse macroinvertebrate populations were present.

Figure 5. Hydropsychid caddisfly and baetid mayfly larvae are abundant in Clear Creek.

5.2 Thermal Regime in Clear Creek

Stream temperatures and fluctuations are extremely important in determining the aquatic life a stream will support as fish and macroinvertebrate species all have preferred temperature ranges. Sensitivities between species differ, with some organisms able to tolerate greater ranges of stream temperatures than others. Stream temperatures are also interrelated with other aspects of stream conditions that can affect aquatic life, mostly notably stream flows and concentrations of dissolved oxygen in the water column.

Stream temperatures were continuously monitored at two locations by Molson Coors (M. Koch, personal communication, April 11, 2022) and the City in Clear Creek near the whitewater park and recreation area in 2021 (Figure 6). At the location on Clear Creek near the Ford Street bridge crossing and immediately downstream of the whitewater park, stream temperatures were measured and recorded every 15 minutes throughout 2021 by Molson Coors (unpublished data). The second location at which temperatures were measured by the City, designated as Site CC59, is upstream of the whitewater park reach. Stream temperatures were recorded every 15 minutes at this site from mid-June through mid-August 2021. There is a third location between these two sites in the whitewater park area, designated as Site CC2, at which a weekly temperature reading is taken. Stream temperatures have also been measured in previous years at this site; however, the data from 2021 were the focus of the analysis since data were recent and available from all three locations in that year.

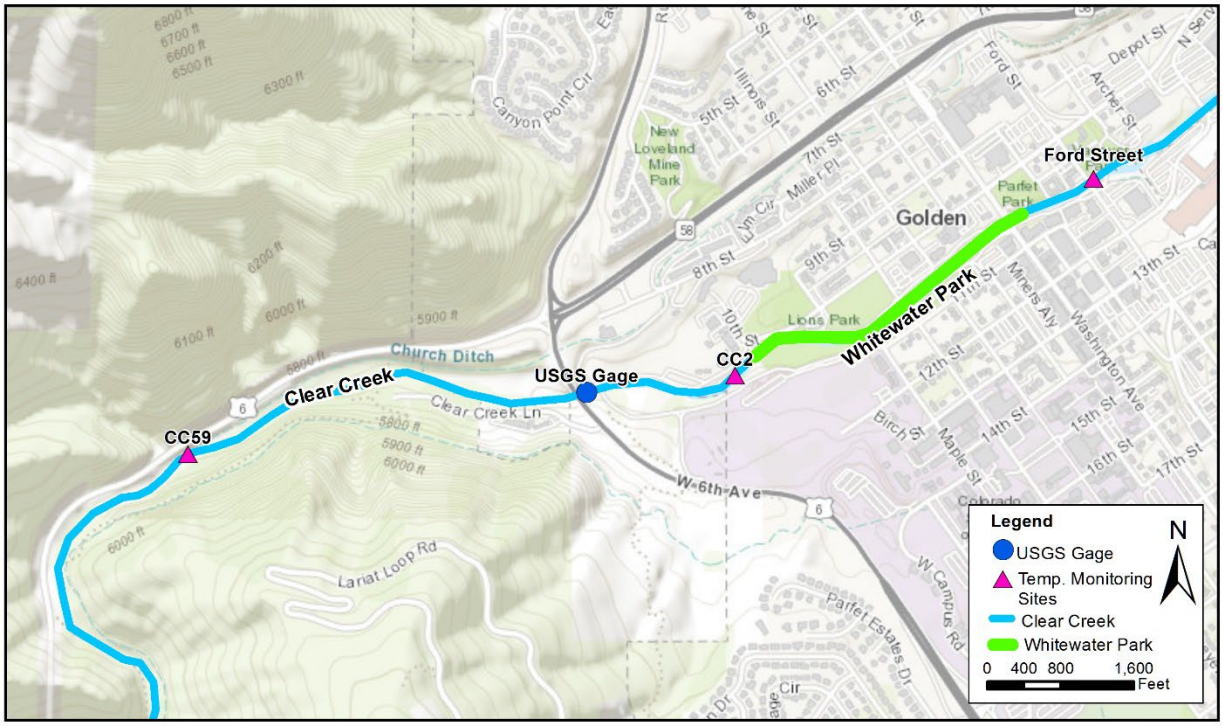

Figure 6. Locations of whitewater recreation area, U.S. Geological Survey (USGS) gage 06719505, and stream temperature and dissolved oxygen sampling locations on Clear Creek.

The same patterns were observed in the temperature data from sites CC59 and Ford Street; daily average temperatures varied by 0.35 degrees Celsius (°C) or less between the two stations (Figure 7). Likely, the stream temperatures observed at the Ford Street site are representative of the stream reach throughout the whitewater park. Temperature data at Site CC2 varied much more from average daily temperatures than at site CC59 and Ford Street, but this was a result of only a single temperature measurement being taken about once a week. Likely these weekly measurements were often taken relatively early in the cooler part of the day.

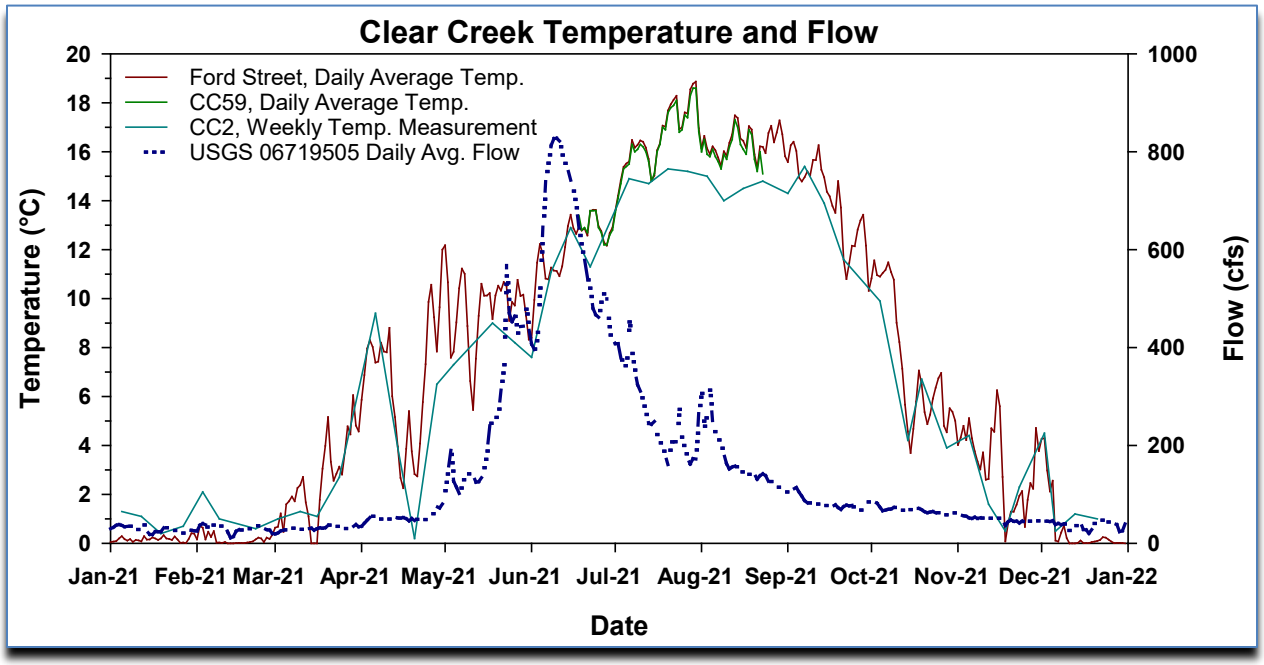

Figure 7. Daily average stream temperature (°C) and flow (cubic feet per second (cfs)) in Clear Creek in the vicinity of the whitewater recreation area in 2021.

While only daily average temperatures from 2021 are shown on Figure 7, patterns across the seasons are evident. At the Ford Street site in the vicinity of the whitewater park, average daily stream temperatures were above 14°C (57°Fahrenheit (F)) from early July through mid-September, with the highest average daily temperature of almost 19°C (66°F) measured on July 30, 2021. There was one extended period with daily average stream temperatures above 17°C (63°F) from July 18 through July 30, 2021, and a few days in mid- and late-August also had daily average stream temperatures that exceeded 17°C.

When evaluating the highest instantaneous stream temperature that occurred each day in the 15-minute data from Ford Street rather than the average daily values, maximum daily stream temperatures at Ford Street were almost always greater than 19°C (66°F) and ranged up to 22°C (71°F) from mid-July through the end of the month, as well as during some days in mid- and late-August 2021.

The maximum temperatures that occur over the summer months are important to aquatic life in addition to the fluctuations that occur daily. During some days in 2021, these fluctuations were

substantial in a 24-hour period (Figure 8). Assessing the magnitude of the differences between the minimum and maximum values that occurred each day in 2021 at the Ford Street site indicated that daily temperature values varied by more than 9°C (16°F) in mid-April. Fluctuations were not quite as extreme in the summer months when temperatures would be expected to be the warmest, but daily minimum and maximum stream temperatures fluctuated by up to 6°C (11°F) for one day in late August. Average daily temperatures were more stable but also varied from day to subsequent day by as much as 2°C (4°F) from June through the end of September in 2021.

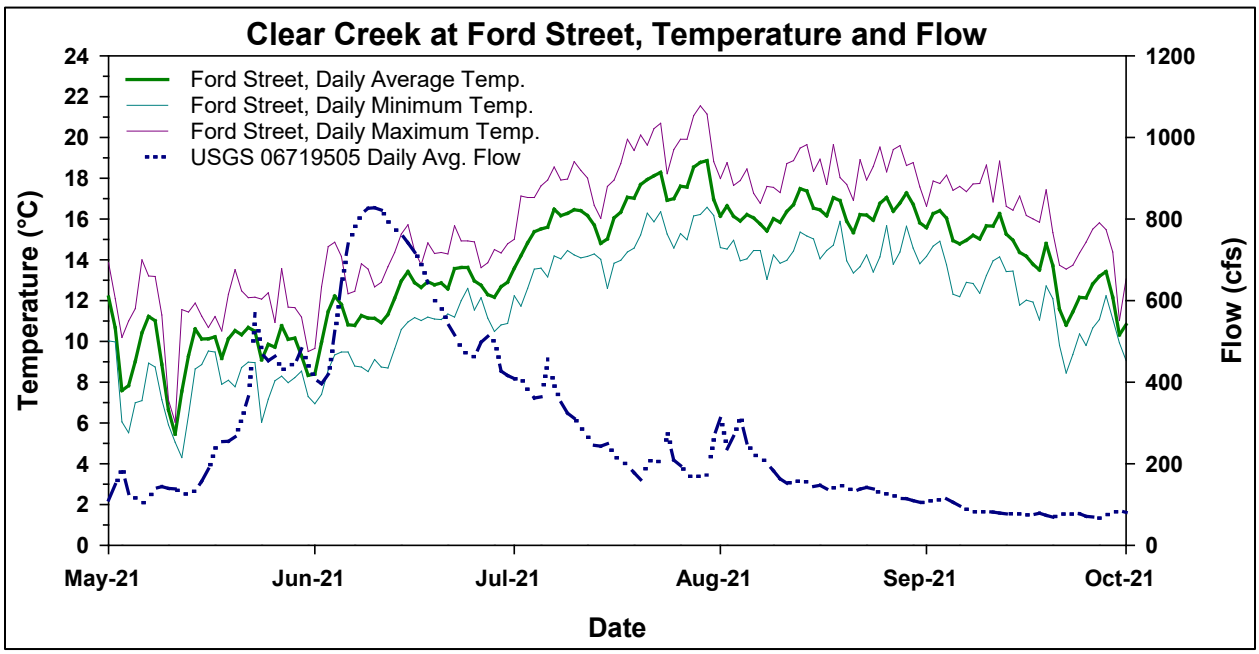

Figure 8. Daily minimum, maximum, and average stream temperature (°C) and daily average flow (cfs) in Clear Creek in the vicinity of the whitewater recreation area in 2021 at Ford Street.

5.3 Flow Regime in Clear Creek

Stream flows can also affect aquatic life and, as discussed further below, is interrelated with stream temperatures. A USGS gage (#06719505) measures flow in Clear Creek in the whitewater park reach of Clear Creek (Figure 6). As with stream temperature, Figure 7 and Figure 8 only display data from 2021 but provide information on seasonal flow variations. Flows on Clear Creek in 2021 rose rapidly starting in early May, then peaked in early to mid-June, before decreasing quickly by late July. Flows continued to decrease throughout August and the rest of the year in 2021. During the two warmest months of July and August, recorded flows in Clear Creek were highest on July 6 at 457 cfs and lowest on August 31 at 105 cfs. Flows during this period generally decreased steadily with subsequent decreases each day from the beginning of July to the end of 2021 with a few large precipitation events that caused notable storm peaks in July and August. This hydrograph (Figure 8) demonstrates a spring peak in flow followed by steadily decreasing flows punctuated occasionally by increases related to summer thunderstorms typical of a Colorado foothills stream.

5.4 Dissolved Oxygen Concentrations in Clear Creek

Dissolved oxygen concentrations in water characterize the amount of oxygen available to living aquatic organisms in streams, rivers, lakes, and ponds. Dissolved oxygen concentrations were measured approximately weekly at Site CC2 in 2021, concurrent with the temperature measurements (Figure 9). Weekly measurements do not provide information on fluctuations throughout the day, which can be significant as discussed below; however, dissolved oxygen concentrations in 2021, as measured weekly, suggested that concentrations remained relatively stable throughout 2021, varying from 7.92 to 12.3 milligrams/Liter (mg/L). Dissolved oxygen concentrations were lowest when stream temperatures were high from mid-June through mid-September when it ranged from 7.92 to 8.71 mg/L.

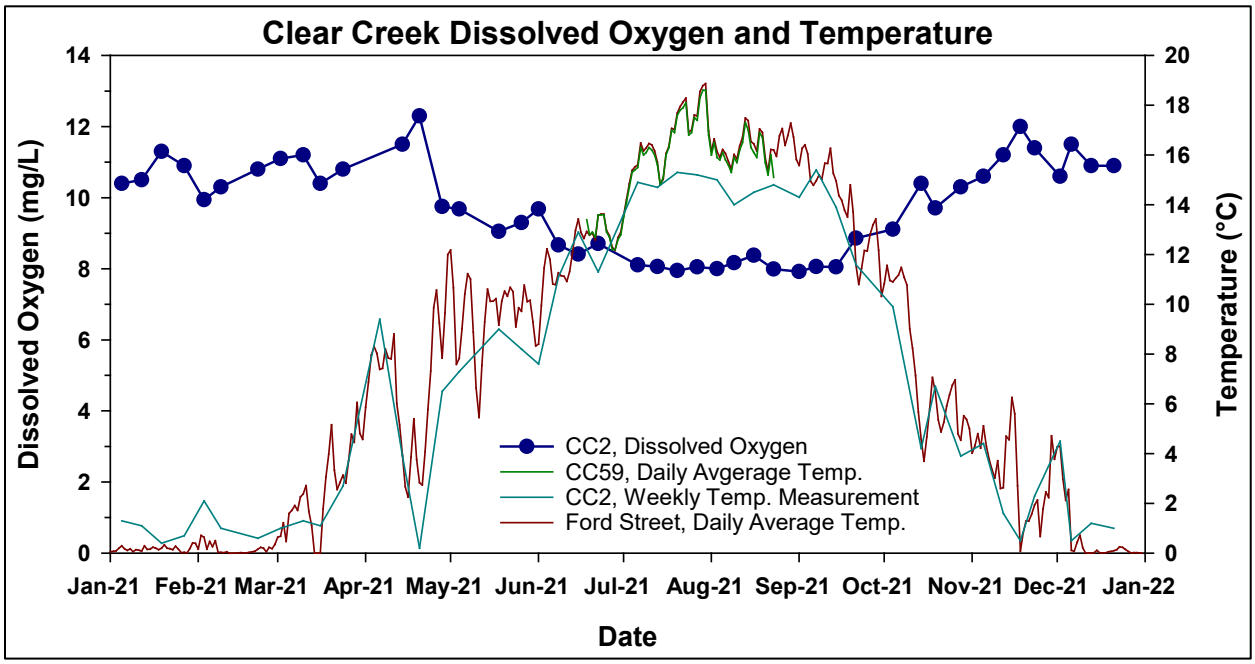

Figure 9. Dissolved oxygen concentration (mg/L) and daily average or weekly stream temperature (°C) in Clear Creek in 2021.

6.0 Interrelationships Between Stream Temperatures, Flows, and Dissolved Oxygen

The data collected from Clear Creek in 2021 (Figure 7, Figure 8, and Figure 9) indicate the relationship between each of these three factors. Low streamflow can be a factor contributing to relatively large changes in daily average stream temperature and daily maximum temperature. This results because air temperature alters stream temperature more easily at low-flow conditions than during higher flow conditions. The maximum variance in average daily stream temperature in 2021 on Clear Creek at the Ford Street site was greatest in the months of March and April, at 8.92°C and 9.26°C, respectively (Table 1). In 2021, average daily flow was relatively low during this period with the overall lowest monthly average daily flow of 31.4 cfs in March. Flows during the warmest months in July and August 2021 were

relatively high, which assisted in moderating the daily variance in stream temperature to equal or less than 5.63°C (Table 1).

Table 1. Average daily temperature, maximum daily temperature, and maximum daily temperature variance, at Ford Street and average daily flow at USGS gage #06719505 for each month in 2021.

Month	Average Daily Temperature (°C)	Maximum Daily Temperature (°C)	Maximum Daily Temperature Variance (°C)	Average Daily Flow (cfs)
January	0.17	2.10	2.11	32.5
February	0.17	2.93	2.93	32.6
March	2.49	10.3	8.92	31.4
April	6.65	16.18	9.26	53.3
May	9.60	14.00	7.27	260.2
June	12.10	15.72	6.06	610.9
July	16.56	21.56	5.53	265.8
August	16.38	19.65	5.63	168.5
September	14.05	18.84	5.42	83.0
October	7.38	13.59	4.34	68.1
November	3.15	7.39	4.21	48.6
December	0.61	5.85	3.12	37.6

Just as stream temperatures can increase as stream flows decrease in summer months, dissolved oxygen concentrations also decrease as stream temperatures increase, as is demonstrated in Clear Creek on Figure 9. Oxygen is more soluble in cold water, meaning that colder water holds higher concentrations of dissolved oxygen than warmer waters. As water temperatures fluctuate seasonally and daily as discussed above, so do dissolved oxygen concentrations, with concentrations tending to decrease as water temperatures increase (U.S. Environmental Protection Agency [EPA] 2017). This is one of the mechanisms by which warmer temperatures stress fish and other aquatic life. Fish and macroinvertebrates that respire through their gills have a harder time breathing in warmer water with lower dissolved oxygen concentrations. Increased water temperatures and lower dissolved oxygen concentrations interact to create conditions stressful to aquatic life during the summer months.

Other factors also affect dissolved oxygen concentrations in streams. One of the ways in which oxygen enters water is through absorption from the atmosphere; this absorption is enhanced by turbulence (EPA 2017). Based on this, dissolved oxygen concentrations are increased in turbulent fast-moving water such as in riffles. The second mechanism by which dissolved oxygen enters water is through production by aquatic plants, and algae-oxygen is a byproduct of photosynthesis. Oxygen entering the water in this way is subject to daily fluctuations because sunlight is necessary for photosynthesis. Plants and algae photosynthesize during the day, releasing oxygen into the water; conversely, plants consume oxygen during nighttime hours. The result of this cycle is that the lowest dissolved oxygen concentrations in waterbodies often occur in the early morning in streams where aquatic plants and algae are present. Decomposition of plant and algal detritus in the stream also uses oxygen, leading to decreased levels in streams with abundant decaying vegetation. Algal and plant abundance in streams is affected by the availability of necessary nutrients and other factors, but in streams in which algae or macrophytes are dense, dissolved oxygen fluctuations can be extreme and reach levels low enough to be stressful or lethal to aquatic life.

7.0 Impacts on Clear Creek Aquatic Species

7.1 How Do Stream Temperature, Stream Flows, and Dissolved Oxygen Affect Fish and Aquatic Life?

7.1.1 Effects of Stream Temperatures on Aquatic Life

As discussed above, stream temperature, streamflow, and dissolved oxygen concentrations are all interrelated; thus, the cumulative effects on aquatic life must be considered. To begin with stream temperatures, aquatic organisms all have limits above (or below) which temperatures become lethal. Organisms also have a preferred temperature range at which feeding, metabolism, reproduction, growth, and survival can optimally occur without temperatures being stressful to the organism. Lethal temperatures and preferred temperature ranges differ by species, with some "sensitive" species having narrower optimal ranges and/or lethal limits that occur at lower temperatures compared to more "tolerant" species.

Segment 11 of Clear Creek where the whitewater park is located is categorized as a Cold Stream Tier 1 stream based on the expectation that cutthroat trout and brook trout would be expected to occur there. For these streams, the acute (short-term, instantaneous) and chronic (longer term, weekly) temperature standards that apply from June through September are 21.7 and 17.0°C (71.1 and 62.6°F), respectively. The acute temperature criterion provides protection against lethal effects that elevated temperatures can cause, while the chronic temperature criterion is intended to protect against sublethal effects on behavior, metabolism, growth, and reproduction, including protection of sensitive life stages such as eggs and fry and critical activities such as migration and spawning (CDPHE 2011).

Laboratory and field experiments on brown trout and rainbow trout have provided insight into the stream temperatures that are lethal to these species compared to the preferred temperature range for these trout. Studies of both species suggest that temperatures greater than 24°C (75°F) may be tolerated in the short term, but these temperatures are increasingly lethal if sustained for periods of hours or days (Kaya 1978; Myrick and Cech 2000; Ineno et al. 2005; Wehrly et al. 2007). As stream temperatures approach these lethal limits, decreased feeding occurs, combined with an increase in energy demands, which can lead to eventual starvation (Kitchell et al. 1977; Taniguchi et al. 1998). Optimal temperatures for growth and survival of brown trout and rainbow trout were substantially lower than 24°C, ranging from 14 to 20°C (57 to 68°F; Myrick and Cech 2000; Forseth et al. 2009). Even as stream temperatures approach 20°C, an increase in food demand can occur, coupled with increased stress responses and disease susceptibility (Elliot 1975a, 1975b; Schisler et al. 1999; Myrick and Cech 2000; Hiner and Moffitt 2001; Kocan et al. 2009).

Laboratory and field experiments have shown that trout are generally more susceptible to infection as temperatures increase. Rainbow trout exposed to a bacterial pathogen show increased disease severity and shorter time to mortality at 20°C than at 10°C (Kocan et al. 2009). Infection severity and mortality rates in brown trout exposed to a number of bacterial diseases also increase over a similar range of temperatures (reviewed in Jonsson and Jonsson 2009). Field experiments have also demonstrated that

the infection severity of whirling disease in rainbow trout is positively correlated with water temperature (Hiner and Moffitt 2001). Coldwater fish that encounter high temperatures experience physiological stress (Wood and McDonald 1997) that can increase the probability of angling or disease-related mortality. Based on this research, temperatures that do not exceed 19°C would be optimal for the brown trout and rainbow trout populations that inhabit Clear Creek in the vicinity of the whitewater park.

Less data were readily available to document temperature preferences of the most common native fish in Clear Creek, the longnose sucker; however, Mandeville et al. (2019) and the U.S. Department of Agriculture (USDA; 1986) indicated that the daily maximum temperature tolerated by this species was approximately 25 to 28°C (77 to 82°F). USDA (1986) further noted that the preferred temperature range for adult longnose suckers was 10 to 15°C (50 to 59°F), with summer temperatures in streams and lakes at which they were found ranging from 11 to 19°C (52 to 66°F), dependent on where they were present in their range. Data were not available specific to streams in similar geographic locations or elevations as Clear Creek.

Macroinvertebrate communities are also affected by stream temperatures, with macroinvertebrate taxa also having specific thermal requirements that vary by species (CDPHE 2011). Specific temperature requirements of every macroinvertebrate species in Clear Creek are not available. However, some macroinvertebrate species are known coldwater stenotherms, meaning that they can only tolerate a narrow range of temperatures. A list of such species is provided in Grafe et al. (2002); a few of the mayfly and stonefly species included on that list have been collected in Clear Creek in the vicinity of the whitewater park but were only observed in low numbers.

Based on the determination that stream temperatures of less than 19°C are preferable for brown trout and native longnose suckers (the two most abundant species in this section of Clear Creek), the 2021 stream temperature data should be evaluated to determine if and how often stream temperatures in 2021 approached this upper limit. Average daily values in Clear Creek in 2021 did not exceed 19°C (Figure 9); however, values were near this threshold for much of mid to late July. If the 15-minute data are examined more closely, stream temperatures did reach or exceed 19°C for hours at a time almost every day from mid-July through the end of July, as well as during multiple days in August. During most days, these exceedances began occurring around 3 or 4 p.m. and remained above that threshold up until midnight on some days. The in-depth analysis was limited to assessing the stream temperature data from 2021; however, some data from 2020 were also available for the Ford Street site from Molson Coors. A similar pattern was evident in 2020, although in this year the exceedances routinely occurred from mid- to late-August, as well as occasionally in September. Likely all years have such periods of summer high temperatures.

7.2 Effects of Low Stream Flows on Aquatic Life

During low-flow periods, most stream habitat types and overall stream size are reduced and changes in water quality can occur (Bradford and Heinonen 2008; Harvey et al. 2006). These changes can be harmful to fish and aquatic macroinvertebrate populations even over short periods. Abrupt decreases in

flow may not allow for aquatic macroinvertebrates to move into flowing water habitat and they may become stranded in dewatered areas. As flows decrease, fewer deep pools or shady areas are available for shelter and thermal refuge for fish (Hunt 2022) and additional bank-associated habitat, such as undercut bank habitat, is reduced or eliminated. When deep water habitat areas are scarce, trout and other fish can group in the remaining areas in high densities, becoming easy targets for predators and anglers. In years with high summer flows, habitat quality is improved, reducing fish predation risk and increasing foraging success (Harvey et al. 2006).

Trout forage is highly dependent on benthic macroinvertebrates, representing the vast majority of trout prey (Huryn 1996). Riffle habitat provides ideal habitat for the majority of benthic macroinvertebrate species found in cold-water streams. This habitat provides oxygen-rich water, preferred food resources, coarse substrate for cover, and fast flowing water that certain species require for foraging on drifting particulate matter (Bradford and Heinonen 2008). Riffle habitat is most notably affected by reduction in flows, which reduces overall riffle habitat available for aquatic macroinvertebrates and fish and alters the physical attributes of riffle habitat (Harvey et al. 2006). Small-bodied fish and juvenile fish that prefer shallow water habitat would likely be most negatively affected by decreases in flow and reductions in riffle habitat. Decreases in riffle habitat can lead to decreases in salmonid forage efficiency (Harvey et al. 2006) and decreased fish condition, and make fish more vulnerable to predation as competition between fish and fish species increases due to smaller areas of available habitat. Additionally, decreases in stream flow can lead to negative impacts on juvenile fish (Nislow and Sepulveda 2004) and individual fish growth, and may cause long-term effects on fish population dynamics (Harvey et al. 2006). Significant reductions in populations of juvenile fish in a single year can lead to reduced and potentially absent adult age classes in the future, resulting in overall poor fish recruitment and therefore additional impacts on the fish community.

7.3 Effects of Low Dissolved Oxygen Concentrations on Aquatic Life

In Colorado, a protective level of 6.0 mg/L is the standard set for coldwater stream segments such as the reach of Clear Creek in the vicinity of the whitewater park to ensure sufficient oxygen is present to support aquatic life (5 CCR 1002-38-Classifications and Numeric Standards for South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin). This level is increased to 7.0 mg/L to protect spawning fish during times of the year when they are present. For the fish species consistently present in the segment of Clear Creek in the vicinity of the whitewater park, the two fall spawning fish species, brown trout and brook trout, have spawning periods extending from September through January and September through October, respectively (CDPHE 2011). For the species that spawn earlier in the year, rainbow trout spawn from March through June, while longnose suckers spawn from March through July.

While some fish and macroinvertebrate species are more tolerant of low dissolved oxygen concentrations, if dissolved oxygen concentrations fall below the 6.0 mg/L standard, there is a risk of adverse effects on aquatic life, including fish kills, with larger fish often affected disproportionately (EPA 2017). Fish may be observed gulping air. Reduced growth can occur as fish become lethargic as feeding rates decrease and their metabolic demand continues to increase, and reduced survival of eggs and

larval fish can also occur. Even tolerant fish species can generally only persist if the dissolved oxygen concentrations stay above 4 mg/L. Salmonids are also sensitive to dissolved oxygen levels, requiring high levels of oxygen. Within the macroinvertebrate communities, sensitive species such as many of the mayflies, stoneflies, caddisflies, and beetles will be replaced by more tolerant groups such as true flies and aquatic worms if dissolved oxygen concentrations are consistently low. Such changes in the macroinvertebrate assemblages can affect the available food resources for fish.

Evaluating the data collected in 2021 (Figure 9), dissolved oxygen concentrations did not fall below 6.0 mg/L in 2021. However, in late July, late August, and early September, the concentrations did approach this level, with multiple measurements between 7 and 8 mg/L. Of note, these measurements were collected only once a week. In addition, the measurements were collected during morning hours; the measurements were not taken during the time when dissolved oxygen would have been at the most minimal concentrations. Without continuous data loggers measuring dissolved oxygen, levels could have potentially been below the 6.0 mg/L target during the warmer parts of the day.

8.0 Effects of Recreation on Aquatic Life

Recreational activities such as fishing, tubing, wading, kayaking, and rafting can affect trout and other aquatic life through multiple avenues. These effects are addressed specifically below, but the residential and commercial development in general has substantially altered Clear Creek in the reach that flows through the City through disturbance and habitat alteration, as well as water pollution.

8.1 Disturbance of Riparian Vegetation and Stream Substrates

Riparian vegetation is a very important component of stream ecology that enables increased diversity of niches for wildlife to exploit (USDA 1999), attenuates high-flow events, provides refuge habitat during flood events for fish and other wildlife, and helps maintain substrate dynamics. Recreation in stream corridors can destroy vegetation along stream margins as users access the stream; this enables bank erosion, decreases riparian habitat, reduces fish and macroinvertebrate cover, increases sedimentation, and increases turbidity. Disturbing riparian vegetation may also reduce overall vegetation cover, height, and biomass; lead to changes in species composition; and introduce and spread nonnative plant species (Marion et al. 2016).

Recreation activity in Clear Creek may disturb settled substrate as recreational users access and use the stream channel. This can lead to turbidity and nutrient increases, and reduce levels of dissolved oxygen (Marion and Sober 1987). These effects may also harm aquatic vegetation and macroinvertebrates, and facilitate algal blooms (Marion and Carr 2009).

8.2 Water Pollution

Clear Creek may also see pollution impacts from soap, sunscreen, food particles, human and animal waste, and litter (Ursem et al. 2009; Venohr et al. 2018; GEI personnel observations). The release of chemicals such as oxybenzone and titanium dioxide common in sunscreen has been studied and addressed in Clear Creek through research conducted in part by the Colorado School of Mines in Golden. While the levels of concern for these two chemicals observed are not known, oxybenzone

concentrations peaked between the hours of noon and 7 p.m. (Reed et al. 2017; J. Ranville, pers. communication, April 26, 2022). Titanium increases were theorized to result from resuspended sediment when recreational users moved about the stream channel, kicking up sediment and increasing turbidity.

8.3 Changes to Fish Behavior

Fish behavior may be altered from recreation in Clear Creek due to direct contact, sound, and sight, which could stimulate anti-predator behaviors (Lewin et al. 2006). These effects can result in decreased fish fitness and condition by altering feeding behaviors and increasing susceptibility to predation by forcing fish into suboptimal foraging habitat (McNamara and Houston 1987). This in turn has the potential to alter fish species assemblages (Venohr et al. 2018). Different life stages of fish may be differentially affected by recreation disturbance depending on areas frequented by recreators since juvenile fish prefer shallower habitat along stream margins, while adult fish prefer deeper water habitat. Such impacts could negatively affect brown trout populations in Clear Creek through these mechanisms. In addition, coldwater fish that encounter high temperatures experience physiological stress (Wood and McDonald 1997) that can increase the probability of angling or disease-related mortality.

Additionally, disturbance and stress on the fish community during summer months when Clear Creek is experiencing maximum water temperatures can lead to negative impacts on the fish community. As noted previously, temperatures greater than 19°C (66°F) may affect food demand, stress response, and disease susceptibility. Even at temperatures well below the lethal limit for brown trout, survival can be affected in recreational catch-and-release fisheries. At water temperatures greater than 23°C (73°F) there was an increase of 16 percent and 4 percent in mortality over a three-day period (72 hours) for rainbow trout and brown trout, respectively, compared to fish caught and released at 20°C. Mortality of fish caught and released between 20 and 23°C was 9 percent for rainbow trout and 0 percent for brown trout. No mortality was observed for either species for fish caught and released at temperatures below 20°C (Boyd et al. 2010). Angling likely presents the most severe form of stress to the fish community during the summer months on Clear Creek when temperatures are at their maximum, and a high degree of human recreation activity in the creek during this period may alter fish behavior as such to induce stress-related physiological harm. Fish can avoid or reduce temperature-related stress through selecting cooler areas of the stream, such as deep pools or shaded areas; however, if the stream is experiencing heavy recreational use, fish could be excluded from these areas because these habitats are also attractive to waders, anglers, and boaters.

8.4 Effects of Instream Structures

Many of Colorado's recreational instream structures were designed for boaters, but not for fish. As a result, these structures have the potential to disrupt fish life cycles. Many fisheries professionals once thought that freshwater fish lived their entire lives in a relatively small section of stream. However, new fish tagging techniques and a growing number of studies have provided a better understanding of fish movement, and demonstrate that fish movement is greater than previously thought. Whether for spawning, access to food, or in search of refuge from harsh summer or winter conditions, movement is essential for fish to fulfill their life cycles. Whitewater parks can inhibit movement of adult trout, due to

high water velocities in the boat chutes. Data are limited for smaller trout and for native species such as longnose sucker, white sucker, and longnose dace, but movement of these individuals is probably more restricted by whitewater parks because these fish do not swim as quickly as adult trout.

Deep pools associated with whitewater parks are essential to boater safety, but again, the pools were designed for boaters, not for fish. High turbulence and a surging of the high-velocity "jet" of water entering the pool from the boat chute are likely reasons why many fish avoid whitewater park pools; conditions are not as predictable or stable as they are in natural pools. Because whitewater parks can inhibit fish migration, and because they create conditions that are not attractive to fish (Dawson 2020; CPW undated), an unintended result of whitewater park construction in some streams has been a lower number of fish living in and moving through the portion of the stream that contains the park.

9.0 Policies in Colorado and Other States

In Clear Creek and other Colorado streams a balance between recreational use and ensuring the health of the fisheries in the stream is needed. In the summer of 2018, CPW began recommending voluntary fishing closures statewide (Foster 2019) and encouraged anglers to be aware of the impacts on fishing for trout in warm, dry weather when flows were low. CPW provided some recommendations for minimizing effects, which have been adapted for Clear Creek.

In 2021 (Hunt 2022; CPW 2022), multiple stream reaches were placed under voluntary closures to fishing either for the full day or afternoon, including a reach of the Dolores River, Tomichi Creek, Fish Creek, Elk River, Roaring Fork River, and Fryingpan River, as well as multiple reaches of the Colorado, Eagle, and Yampa Rivers. Most voluntary closures were initiated in June or July 2021 and extended for various periods from August through November 2021. Voluntary closures included requesting that recreational users including tubers to anglers stay off the water. In addition, a reach of the Yampa River downstream of Stagecoach Reservoir was mandatorily closed on May 24, 2021 to protect stressed fish; restrictions were removed on November 1, 2021. CPW again enacted an emergency fishing closure on 0.6 mile of the Yampa River downstream of Stagecoach Reservoir on June 1, 2021 due to critically low flows caused by dry conditions and minimal snowpack. In the closure notice by CPW, the agency noted that other river reaches in the area might be subject to additional closures that year as well to proactively protect the fisheries.

While CPW has requested voluntary fishing closures in most cases compared to mandatory closures, the agency does have the authority to enforce closure under Title 33 of the Colorado Revised Statutes (Foster 2019). This authority includes the ability to mandate specific dates and times for fishing and enact water-specific or emergency closures for up to a nine-month period to protect endangered and threatened species and spawning habitat, as well as the integrity of native and sport fisheries. Of note, specific conditions under which CPW has power to prohibit fishing include when water temperatures exceed 23°C (74°F), the temperature slightly below the 24°C (75°F) threshold above which temperatures become lethal quickly, or when the daily average temperature exceeds 21.7°C (71°F), the daily maximum temperature standard (CPW 2022). In addition, CPW can close fisheries when measured stream flows are less than 50 percent or less of the daily average flow, fish condition is deteriorating

such that fungus or other visible signs of deterioration are present, daily minimum levels of dissolved oxygen decrease below 6 parts per million (approximately 6 mg/L), or a natural or man-made event such as wildfires, mudslides, oil spills, or similar experiences are affecting waters (Foster 2019). If a closure is in place, violators can be fined, can lose their fishing license or be prohibited from purchases of a license in the future, or face criminal charges. In addition, if the closure is voluntary, violators can result in the CPW considering mandatory closures. CPW has published a fishing closure decision tree to clarify their decisions at https://cpw.state.co.us/Documents/Fishing/Fishing_Closure_Decision_Tree.pdf.

Other states have also initiated voluntary or mandatory closures of waters determined to be stressed by the combination of high temperatures, low dissolved oxygen concentrations, and/or low flows. The Wyoming Department of Game and Fish (WDGF) publishes warnings in the form of recommendations for anglers as well as restrictions (WGFD 2020). Fishing is prohibited at certain times of the year after 2 p.m. in Yellowstone National Park and other hotter, lower elevation parts of the state, and biologists recommend that anglers both fish in the early hours of the day and take care, particularly with catch and release fishing, to minimize stress to trout (Peterson 2021). WDGF does not prohibit fishing but does send out email blasts to ask anglers to consider the effects of fishing on trout populations.

The Montana Department of Fish and Wildlife (MDFW) was the first to issue “Hoot Owl Restrictions” for fishing, named after restrictions on logging activities based on wildfire risk that shifted activities to cool, dewy mornings when hoot owls were actively calling (MDFW 2022; Ausable River Association 2022). As with some of the Colorado and Wyoming restrictions, these are temporary or permanent afternoon closures on trout fishing in specific waters from 2 p.m. to 12 a.m. These “Hoot Owl” restrictions have been in place through much of Montana since 2013 and have gained popularity in other states such as Idaho, Connecticut, Massachusetts, and New York, in addition to Colorado.

10.0 Management Opportunities

10.1 Recommendations for Managing Recreational Use of Clear Creek

After outlining the challenges that aquatic life face in Clear Creek when summer temperatures rise and flows decrease, the City should consider the management actions described below to ensure protection of aquatic resources while still allowing responsible use by recreational users. While it may not be reasonable or feasible to implement all of the recommendations listed, the City may choose to implement one or a combination of options and potentially monitor the success of these options to determine measures which are the most effective and least disruptive to recreational use, in general.

As stream temperatures can be easily measured, these recommendations largely focus on limiting or prohibiting activities when stream temperatures are high rather than addressing limiting recreation when dissolved oxygen levels or streamflow are low. Another factor to consider when adopting these recommendations is that increased effects on aquatic life should be expected based on the number of people recreating in Clear Creek each day and the intensity of the various recreational activities. While impacts on individual fish that are caught may occur from angling, impacts on aquatic life overall are expected to be less from a few anglers maintaining an appropriate distance from one another and

fishing from the bank or shallow wadeable areas near the banks. In contrast, large groups of tubers traveling together through the deeper portions of the channel could be more disruptive to the fish within the reach.

Clear Creek aquatic health management recommendations for the City include the following:

1. Limit or prohibit angling, tubing, and kayaking when stream temperatures based on instantaneous readings approach 19°C (66°F), as trout have very limited thermal refuge available to them during the hours of peak recreational activity (which likely coincides with peak temperatures during each day).
2. Encourage anglers and other users who use this reach of Clear Creek to carry a handheld thermometer and check stream temperatures. If stream temperatures based on instantaneous readings exceed the 19°C (66°F) threshold, users would be advised to cease fishing for the day or to go to another location at a higher elevation where stream temperatures would likely be cooler. While not present on Clear Creek itself, the tailwater section of streams downstream of reservoirs could also be a destination due to the coldwater releases.
3. Publish recorded temperatures daily from their gage to advise recreational users as to when to avoid Clear Creek due to the likelihood of adverse effects on trout exposed to angling pressure or large numbers of recreational users. The City had already suggested a color-coded water safety protocol to warn recreational users of potentially dangerous high flows; the color coding could be extended to warn anglers and other recreational users when stream temperatures are high enough to potentially adversely affect fish.
4. Advise anglers and other recreational users to visit the following website that lists closure conditions statewide: https://cpw.state.co.us/thingstodo/Pages/StatewideFishingConditions.aspx.
5. Encourage anglers and other recreational users to use Clear Creek for these activities only during the morning and cooler parts of the day in July and August, ceasing activities in the afternoon. Stream temperatures were highest in these months usually by 3:00 or 4:00 p.m.
6. In July and August, encourage anglers to fish for warmwater species more tolerant of higher temperatures in other stream reaches that support such assemblages, such as fishing for bass or carp (Aguirre 2018; Hunt 2022; Craig Press Staff Report 2020). These species are not present in the reach of Clear Creek in which the whitewater park is located but warmwater fish are present further downstream and in the South Platte River.
7. Encourage whitewater or angling guide companies or outfitters to book trips for morning hours during July and August and book trips in the afternoon for later in the year when temperatures are lower.
8. Encourage the use of appropriate fishing techniques to reduce stress on fish, even when stream temperatures do not exceed 19°C (66°F). Such precautions could include using heavier tippet and line to ensure anglers can quickly reel in and release fish (Craig Press Staff Report 2020), keeping fish submerged while unhooking and releasing them, minimizing or avoiding taking fish out of the water for photos, and fishing with barbless hooks.

Other more long-term strategies could be investigated and put into place if sufficient funding and/or incentives were in place, including:

1. Identify, restore, or enhance areas of thermal refuge such as deeper pools and provide more shading, and increase habitat complexity. In Clear Creek, stream habitat throughout much of the reach through the City is homogenous and channelized, with little undercut bank habitat. Restoring greater habitat complexity would benefit the fishery in this reach.
2. Enhance and restore riparian vegetation to increase bank stability, reduce erosion, and increase bank habitat for aquatic life. Access to the stream could be limited to certain areas along the banks with other stretches of the bank excluding access and allowing dense riparian vegetation.
3. In recent years, there has been increased focus on designing "fish friendlier" whitewater parks. For example, many of the newer whitewater parks contain a fish bypass in addition to the boat chute so that fish can successfully move upstream past individual whitewater park structures. Most of Colorado's newer whitewater parks contain these bypasses, and this design is being used in other states as well. An assessment of the whitewater park could be completed to determine if the potential for such a bypass exists in Clear Creek. Preliminary assessment of the drop structures associated with the park indicated upstream fish passage would be impeded by the structures in some flow regimes, specifically for suckers or small trout.

11.0 Community Engagement and Stewardship

On the Guiding Golden webpage (City 2022), the City has added the *Clear Creek Management Strategies* page. This page provides the following information:

- Background on the Clear Creek Subcommittee process and Work Plan
- A schedule for management activities
- Public comment opportunities
- Related documents such as summaries of public comments to date

The City will continue to communicate with the public through this webpage and will identify other means to communicate management strategies to the public including but not limited to:

- Public and stakeholder meetings to provide science-based information on Clear Creek aquatic resource impacts and how individual actions can help mitigate impacts
- City Council meetings; Mobility and Transportation Advisory Board meetings; and Parks, Recreation and Museum Advisory Board meetings
- Weekly City e-newsletter and monthly *Golden Informer* distribution
- Social media (Facebook, Twitter, etc.)
- Information dissemination by City representatives at local events
- Information dissemination at local angling and other recreational businesses (e.g., flyers)
- Signage along Clear Creek to communicate voluntary measures and/or temporary restrictions
- Presence of Park Rangers to communicate voluntary measures and/or temporary restrictions, enforce rule violations, and answer questions

The City will coordinate with interested stakeholders to include but not be limited to kayaking groups, tubing outfitters, and fly fishing groups. The city will continue to identify and engage interested stakeholders throughout the process.

Community engagement activities should be held on an annual basis, at the end of spring/beginning of summer, at a minimum. As new information and monitoring data are collected each year, this information would be presented to the public to encourage collaboration and stewardship of the resources in and along Clear Creek.

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