2020 SURVEY OF COLORADO RIVER CUTTHROAT TROUT IN THE ESCALANTE AND FREMONT RIVER DRAINAGES, UTAH

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INTRODUCTION

The Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*) (CRCT) is one of only three subspecies of trout native to Utah. As with other subspecies of cutthroat trout throughout the Intermountain West, habitat alterations and introductions of nonnative trout from the late 1880s until the 1970s caused large-scale losses of this native fish (Young 2008). Active management of CRCT began in southern Utah after the Endangered Species Act was passed in 1973 (Hepworth et al. 2002). By the 1990s, cooperative interagency efforts to conserve, protect, and expand populations of CRCT led to the development of a formal management strategy for the state of Utah (Lentsch and Converse 1997), as well as a strategy and agreement (CRCT Task Force 2001) for range-wide conservation in the states of Colorado, Utah, and Wyoming. The range-wide conservation strategy and agreement have been revised and reissued several times, most recently in 2020 (CRCT Conservation Team 2020, CRCT Coordination Team 2020), while the Utah CRCT strategy was also updated in 2020 (Utah CRCT Team 2020). CRCT conservation was identified as a primary objective for the Escalante River drainage (Hydrologic Unit Code [HUC] 14070005) and Fremont River drainage (HUC 14070003) by the Utah Division of Wildlife Resources (UDWR) (Ottenbacher and Hepworth 2003a, b). These drainages, along with the Muddy Creek drainage, make up the Lower Colorado River Geographic Management Unit (GMU). CRCT conservation efforts in the GMU are coordinated and completed by a cooperative interagency team, with representatives from UDWR, Dixie National Forest (DNF), Fishlake National Forest (FNF), Bureau of Land Management (BLM), and Trout Unlimited (TU). This team acts as a subset of the range-wide CRCT Conservation Team.

A principal component of native cutthroat trout management is the monitoring of populations to evaluate their current status, assess trends in population dynamics and the factors that influence them, evaluate past land management actions, and help guide future population and land management actions. Range-wide status reviews of CRCT were completed in 2005 (Hirsch et al. 2006), 2010 (Hirsch et al. 2013), and 2015 (Albeke 2020). CRCT in the Escalante and Fremont River drainages were previously surveyed in the late 1990s (Hepworth et al. 2001), 2006-07 (Hadley et al. 2008), and 2013 (Hadley et al. 2014). The UM Creek population was also extensively studied from 1999 to 2009 (Hepworth et al. 2010). This report presents results of surveys of CRCT in the Escalante and Fremont River drainages conducted in 2020, as well as comparisons with results from previous surveys.

STUDY AREA DESCRIPTION

The Fremont and Escalante rivers drain part of the southwestern portion of the Colorado River basin in south central Utah (Figure 1, 2). Perennial tributaries begin at 8,000-11,000 feet (2,400-3,400 m) on the Fish Lake Plateau, Thousand Lake Mountain, and Aquarius Plateau (Boulder Mountain), while both rivers meet the Colorado River at Lake Powell (the Fremont River as the Dirty Devil River). Most of the CRCT-bearing streams in these drainages are found within the FNF and DNF, while some reaches cross private land or land administered by the BLM. Habitat fragmentation is common due to naturally marginal conditions for trout persistence in main stem rivers, natural barriers, and diversion of water for irrigation or hydropower use in the lower reaches of many tributaries. Thermal and water quality conditions also restrict trout persistence and movement in lower tributary reaches.

HISTORY

The historic distribution of CRCT in the Lower Colorado River GMU may never be fully described because sub drainages of the lower Colorado River basin with suitable trout habitat were more fragmented than those found in the northern reaches of the basin, may have experienced population losses in isolated habitat, and were stocked with nonnative trout early during European settlement. CRCT were known to occur naturally in Fish Lake (Hazzard 1935) in the headwaters of the Fremont River, but those fish eventually disappeared due the continued stocking and introduction of nonnative fish. Colorful cutthroat trout consistent with CRCT were reported from the upper UM Creek forks during the early 1990s, but they were assumed to be hybridized with nonnative trout due to the lack of fish barriers in the drainage and were not evaluated further. No reports of native trout from the Escalante River drainage were made before the 1980s, as sampling sufficient for detecting their presence had been limited. Occasional observations of cutthroat trout in the Escalante drainage were not evaluated for native potential because it was assumed that the historic range of CRCT extended down the Colorado River only as far as the Fremont River drainage (Behnke and Benson 1980).

CRCT were first discovered in the Escalante River drainage in the mid-1980s, when a number of colorful cutthroat trout were observed in a headwater meadow of the East Fork of Boulder Creek. Because the phenotypic appearance of these fish was so distinct, Regional Aquatics Manager Dale Hepworth sent a sample of fish to Dr. Robert Behnke at Colorado State University for review. Behnke determined through meristic analysis that the fish were CRCT (Behnke 1992).

Additional meristic (Thron and Miller 2002) and genetic (Shiozawa et al. 1993, Shiozawa and Evans 2011) analyses confirmed the population's identity. The discovery in East Fork Boulder Creek prompted extensive searches for CRCT throughout the Escalante River drainage (Hepworth et al. 2001, 2002). Between 1990 and 2000, five more remnant populations of CRCT were confirmed in West Fork Boulder Creek (Shiozawa and Evans 1994, Hudson and Davis 2000, University of Montana 2003 unpublished data, Shiozawa and Evans 2011), Pine Creek (Evans and Shiozawa 2005), West Branch Pine Creek (Toline et al. 1999a, Evans et al. 2013), White Creek (University of Montana 2001 unpublished data, Evans et al. 2013), and Water Canyon (Toline et al 1999a, b; Evans and Shiozawa 2008). An additional remnant population was discovered in Hall Creek in 2011 (Evans et al. 2012). Most of these populations persisted because they were isolated from invasions of nonnative trout by natural waterfall barriers (Pine Creek, White Creek), a man-made dam (West Fork Boulder Creek), or miles of intermittent flow and inadequate fish habitat (Water Canyon, Hall Creek). Brook trout (*Salvelinus fontinalis*) had failed to establish in the headwater meadow of East Fork Boulder Creek despite a lack of any physical barrier to invasion, while CRCT were being gradually displaced by brown trout (*Salmo trutta*) in West Branch Pine Creek at the time of their discovery.

By 1995, southern Utah fisheries managers were well versed in native cutthroat trout conservation, thanks to extensive work in restoring Bonneville cutthroat trout in the southern Bonneville basin during the 1980s. The discovery of remnant CRCT populations in the Escalante River drainage prompted a concerted restoration effort across the Lower Colorado River GMU throughout the late 1990s and early 2000s. Restoration projects included both expansion and introduction efforts. CRCT from West Fork Boulder Creek were transferred to Sand Creek – a small, fishless stream on Thousand Lake Mountain (Fremont drainage) – in 1995. The populations in West Fork Boulder Creek, Pine Creek, West Branch Pine Creek, and White Creek were expanded downstream by constructing new fish passage barriers and removing nonnative fish. CRCT were transferred from the forks of Boulder Creek to Dougherty Basin Lake (North Creek headwaters, Escalante drainage) from 1997 to 1999 to establish a brood population to supply fish for population founding and sport fish stocking. This brood facilitated introduction of CRCT to UM Creek and Pine Creek in the Fremont River drainage, as well as Twitchell Creek in the Escalante River drainage. Nonnative trout were also removed from these streams and fish passage barriers were installed prior to CRCT introduction. Restoration of CRCT in UM Creek was conducted as part of a research project that evaluated the potential for native trout restoration in a system infected by *Myxobolus cerebralis*, the pathogen that causes whirling disease (Hepworth et al. 2010). The restoration of CRCT in Pine Creek and Twitchell Creek was made possible by a project designed to improve sport fishing opportunities on Boulder Mountain by removing fertile brook trout from headwater lakes (Hadley and Hepworth 2013).

Genetic analyses of cutthroat trout populations in Colorado (Metcalf et al. 2007, Rogers 2010, Metcalf et al. 2012) eventually described two distinct genetic lineages among populations throughout the accepted historic range of CRCT. These included the "CR" (Rogers 2010), or "Blue" (Metcalf et al. 2012), lineage most closely associated with traditional CRCT taxonomical assignments. The "GB" (Rogers 2010), or "Green" (Metcalf et al. 2012) lineage represented haplotypes found in fish that were previously assumed to be greenback cutthroat trout. (Color designations became more widely used than Rogers' names by the CRCT Conservation Team during the ensuing years.) The blue lineage was identified as predominant in the Green River drainages of the northern Colorado River basin, while the green lineage dominated some of the southern reaches of the basin, including the upper Colorado and Delores river drainages. (A third lineage native to the San Juan River drainage was presumed extinct at the time, though remnant populations have been discovered since that time.) Due to basin connectivity and theorized historic invasion patterns, researchers thought that cutthroat trout in the Lower Colorado River GMU would fall in the green lineage. However, Shiozawa and Evans (2011) determined that cutthroat trout in the east and west forks of Boulder Creek expressed haplotypes consistent with the blue lineage. Additional analyses confirmed blue lineage CRCT in Pine Creek (Escalante) (Bestgen et al. 2013), West Branch Pine Creek (Evans et al. 2013), White Creek (Evans et al. 2013), Hall Creek (Evans et al. 2012), and Right Fork UM Creek (founded by Boulder Creek remnants) (Bestgen et al. 2013).

Additional survey and restoration efforts succeeded in expanding CRCT occupation in the Lower Colorado River GMU from just 3.8 km (2.4 mi) of known stream habitat in 1994 to 84.4 km (52.4 mi) in 2007 (Table 1, 2). The bulk of this increase occurred between 1998 and 2007, when the CRCT-occupied habitat increased six-fold. Not all efforts yielded success, however, as a planned restoration in West Deer Creek (Escalante drainage) was abandoned after one rotenone treatment because the project met with local opposition due to a perceived loss of sport fishing opportunity and because the stream was deemed excessively complex to treat effectively.

The next step in CRCT conservation in the GMU was anticipated to be expansion through the remainder of East Fork Boulder Creek – the site of the first remnant CRCT discovery – during the late 2000s. Not only would this project have expanded CRCT through the largest stream (by flow) in the Escalante River drainage, but it also would have facilitated the establishment of a more productive brood population in the East Garkane Impoundment (King's Pasture Reservoir). Hadley et al. (2014) detailed the challenges that delayed the project from 2009 to 2013, which included opposition by local residents to the use of pesticides, as well as a lawsuit filed by the Boulder Irrigation Company against Garkane Energy for the release of water from the East Impoundment (a mitigation measure required by Garkane's renewed license from the Federal Energy Regulatory Commission [FERC]). Since that time, the project was continually postponed by ongoing local opposition, as well as the re-negotiation of mitigation measures for Garkane's FERC license. While the license was successfully amended, UDWR decided in 2019 to delay the East Fork Boulder Creek restoration while other, less controversial restoration projects could be conducted in the GMU.

CRCT restoration slowed significantly in southern Utah between 2007 and 2013 due to the stalemate in East Fork Boulder Creek (Hadley et al. 2014). The expansion of the Twitchell Creek population and the discovery of the Hall Creek remnant amounted to just 6.1 km (3.8 mi) of additional habitat and were tempered by the loss of the Sand Creek population to drought or flooding (Table 1, 2). In addition, CRCT recruitment in UM Creek was limited by whirling disease and infection spread past the fish passage barrier into the upper right fork. Periodic supplemental stocking of CRCT has been conducted in UM Creek in response to these challenges. In addition, CRCT were transferred from Pine Creek (Escalante drainage) to Sand Creek in 2014, with the intent of attempting establishment a second time.

The other prominent challenge to CRCT conservation in southern Utah from 2013 to 2020 was the unsatisfactory performance of the Dougherty Basin brood population. While the majority of the brood production supports annual sport fish stocking in Boulder and Thousand Lake mountain lakes, it is also a vital source for establishing new conservation populations and continued stocking in UM Creek. In addition, several Boulder Mountain lakes where CRCT are stocked are connected to stream conservation populations, so sport fish stocking with native CRCT is vital to securing these populations. The annual need for CRCT production is 40,000 fish (mostly fingerlings), though the Dougherty Basin brood has never been able to produce even half of this total. The reasons for this underperformance are varied and were detailed in recent brood production reports (Hadley 2018, 2019). For many years, the shortfall in sport fish need was filled by excess production of Bonneville cutthroat trout from the Manning Meadow brood. Unfortunately, the stocking of nonnative cutthroat trout in sport fisheries in the Lower Colorado GMU may have hindered acceptance of native cutthroat trout by anglers (Hadley and Hepworth 2013).

Numerous adjustments have been employed to improve the success of the Dougherty Basin brood, including altering practices during CRCT brood fish collection and holding, egg take, egg transportation, incubation, and fry rearing (Hadley 2019). Concern over potential inbreeding stresses were addressed by introduction of CRCT from other remnants not previously represented in the population: White Creek in 2014 and Pine Creek in 2014, 2017, 2018, and 2020. While these efforts have resulted in some improvements in egg survival and development, poor fry survival during rearing continues to hamper production. In addition, recruitment of stocked CRCT fry to the Dougherty Basin brood pool has decreased in recent years, leading to reduced egg production. In light of these ongoing challenges, UDWR has been working to establish a captive brood since 2017. While this effort has faced its own share of stumbling blocks, it is hoped that the captive brood will succeed in filling CRCT stocking needs within the near future and that efforts and resources can be redirected from the Dougherty Basin brood to other CRCT conservation needs.

While most CRCT conservation effort since 2013 was directed at the Dougherty Basin brood, some limited expansion efforts were also attempted. In addition to the reintroduction to Sand Creek, an experimental introduction of White Creek fish was made to the fishless headwaters of North Creek (Escalante drainage) in 2014. This introduction was made in preparation for future restoration throughout North Creek. Additionally, CRCT were salvaged from a reach of Pine Creek (Fremont drainage) that was chemically treated in 2013 to remove brook trout that had reinvaded. These salvaged fish were transferred to the isolated reach upstream of Pine Creek Reservoir, where no fish had been stocked since nonnative trout were removed in 2003. The results of these expansion efforts were evaluated during the 2020 survey.

METHODS

All known populations of CRCT in the Escalante and Fremont river drainages were sampled during 2020 using backpack electrofishing units (Smith-Root models 12-B, LR-20B, and/or LR-24; Halltech HT-2000) (Fig. 3). UDWR, DNF, FNF, and BLM personnel conducted surveys when stream conditions allowed for effective sampling. Surveys were generally conducted at a similar time of year as previous surveys (Appendix A). A minimum of two stations were electrofished in each second or higher order stream, while at least one station was surveyed in first order tributaries. The target length of each station was 100 m, though the exact length was modified as needed to fit available habitat and allow for effective sampling. Fish populations were sampled in each station using the multiple-pass removal method (Zippin 1958). We attempted to collect all trout except young-of-the-year, though relative abundance of age-0 fish was documented. (In general, young-of-the-year measured less than 70 mm in total length.) Total length (TL) (mm) and weight (g) were recorded for all trout collected. Presence and/or relative abundance of other native fish species was also recorded.

Mean wetted stream width (m) was determined by measuring ten random transects within each survey station. Population estimates were calculated by the program MicroFish 3.0 (Demo Version) (Van Deventer 1989). Stream dimensions were combined with population estimates and mean trout weight to calculate trout density (fish/km, fish/hectare) and biomass (kg/ha). Upstream and downstream ranges of CRCT were determined in each surveyed stream through electrofishing, ocular observation, or professional judgment. Range locations and stream distances were determined with a global positioning system (GPS) unit, US Geological Survey topographical maps, and ArcGIS® software (by Esri). Reaches currently occupied by CRCT were classified as occupied habitat. Trout biomass and distribution were compared to results from previous surveys. Trends were classified as increasing, decreasing, or stable, depending if current values differed by more than 10% from previous surveys.

RESULTS

Survey results were compiled by stream, with tables listing CRCT abundance and biomass at specific stations, along with maps showing the distribution of native trout (Appendix A). CRCT were observed in all 14 streams surveyed, in 27 of 28 stations. (No fish were observed in West Fork Boulder Creek Station 1.) Native mottled sculpin (*Cottus bairdii*) were abundant at all stations in UM Creek. Brook trout were documented in both stations in East Fork Boulder Creek. Sterile, hybrid tiger trout were collected in East Fork Boulder Creek, UM Creek, and Left Fork UM Creek. Sterile, hybrid splake trout were observed at the lowest UM Creek station. (Tiger and splake trout are stocked for sport fishing purposes, either in the stream – e.g. tiger trout in UM Creek – or in connected lakes and reservoirs.) Although CRCT were the only species detected in

Pine Creek (Fremont), brook trout are known to occur in an on-channel beaver bond below Pine Creek Reservoir, and a limited number of tiger trout have been stocked in the reservoir. Tiger trout are also stocked in the headwater lakes of Twitchell Creek, but were not observed in the stream. No hybridizing species (i.e. rainbow trout, nonnative cutthroat trout) were observed during the surveys.

Occupied Stream Length

Comparisons of current results with previous surveys showed that stream length occupied by CRCT increased or maintained in all streams in the Lower Colorado River GMU (Table 3, 4). Increases included 4.9 km (3.0 mi) in East Fork Boulder Creek, where CRCT numbers increased downstream of the headwater meadow despite persistent occupation by a high density of brook trout. The 2014 experimental introduction of CRCT in the North Creek headwaters was found to be successful, with a self-sustaining population established in 0.8 km (0.5 mi) of stream. CRCT found upstream of Pine Creek Reservoir added 1.7 km (1.1 mi) in Pine Creek (Fremont), while the reestablishment of the Sand Creek population yielded another 2.6 km (1.6 mi). The total known stream length occupied by CRCT in the Escalante River drainage increased from 40.1 km (24.9 mi) in 2013 to 45.8 km (28.4 mi) in 2020 (Table 1). Occupied habitat in the Fremont River drainage increased from 49.4 km (30.7 mi) to 53.7 km (33.3 mi) over the same time period (Table 2). Altogether, CRCT occupied 10.0 km (6.2 mi) more stream habitat in the GMU in 2020, compared to the previous survey in 2013. In 2020, CRCT occupied 100% of currently available trout habitat in six of the nine Escalante streams and in all five of the Fremont streams.

CRCT Biomass

CRCT biomass increased since 2014 in seven of the fourteen streams sampled, while it decreased in the other seven (Table 3, 4). Reasons for the changes varied and will be discussed by individual stream in the next section, though some general trends were observed among multiple streams. Decreases resulted from impacts of drought, flooding, and infection by whirling disease, but also occurred when new sampling stations were surveyed in reaches where CRCT were still expanding. Increases were generally attributed to new/restored populations or the presence of a large age-1 cohort spawned in 2019. The historic snowpack in the winter of 2018-2019 increased flow in streams throughout southern Utah and relieved impacts from years of severe drought. The age-1 cohort was abundant in many of the streams surveyed in 2020, though the high density of small fish was not always sufficient to make up for previous loss of biomass to drought or flooding.

DISCUSSION

During 2019 and 2020, UDWR developed a new strategy for CRCT conservation in Utah (Utah CRCT Team 2020). This strategy was patterned after the range wide Conservation Strategy and Agreement for Bonneville cutthroat trout finalized in 2018 (Bonneville Cutthroat Trout Conservation Team 2018) and will help direct future conservation focus within the Lower Colorado River GMU. The strategies adopt Trout Unlimited's Conservation Portfolio approach to securing range wide, long-term persistence by spreading risk of loss from various factors (e.g. invasive species, environmental change, etc.) across a variety of habitats, populations, and management approaches (Haak et al. 2011). Within this approach, range-wide subspecies security is achieved through promotion of genetic integrity, life history diversity, and geographic (or ecological) diversity, backed by large patches of interconnected habitat for resiliency. The Portfolio recommends Shafer and Stein's (2000) "3-R" conservation principles as an adaptable framework to guide development of goals and objectives for CRCT conservation within each GMU that help achieve this strength through diversity. These principles include **representation** (preserving existing elements of diversity), **resiliency** (having sufficiently large populations and intact habitats to facilitate recovery from large disturbances), and **redundancy** (preserving enough different populations so that some can be lost without jeopardizing the subspecies). The 3-R framework will be considered, where applicable, in discussions of current and future CRCT conservation actions within the Escalante and Fremont river drainages.

Boulder Creek Forks

As has been the case since CRCT were first discovered over 30 years ago, brook trout continued to dominate all but the upper 0.5 km (0.3 mi) of East Fork Boulder Creek in 2020. Even after one rotenone treatment was conducted downstream of the headwater meadow in 2009, brook trout quickly reestablished and outpaced CRCT. Only two CRCT were observed at Station 1 in 2013 (Hadley et al. 2014), likely representing a population sink situation. CRCT numbers increased at this station in 2020 and, although they remained low in comparison to brook trout, the population was distributed over multiple age classes. This distribution is more reflective of a self-sustaining population rather than downstream migration of more than 2.0 km (1.2 mi) from the headwater meadow. The addition of Station 1 to the mean CRCT biomass calculated for the east fork led, in part, to the overall decline in that measure from 2013 (Table 3), when only the meadow population was considered "sustainable" and only the biomass figure from Station 2 was reported.

Because the 4.9 km (3.0 mi) of stream below the meadow are similar in habitat characteristics, it was assumed that trout population composition should be similar enough to identify the entire reach as occupied by CRCT in 2020 (Table 1). This occupation is hindered, however, by the relatively low CRCT density. While the establishment and increase of CRCT following rapid brook trout recolonization is encouraging, this population still lacks long-term resiliency due to the threat of competitive dominance by brook trout.

While the 2020 decrease in mean CRCT biomass in East Fork Boulder Creek can be partly attributed to the addition of the Station 1 population, biomass also decreased at Station 2, from 240 kg/ha in 2013 to 165 kg/ha in 2020. Rather than a decrease in the population, however, this reduction may more likely be a reflection of survey station placement. Trout habitat is typically distributed evenly within a reach in southern Utah streams, so UDWR typically focuses repetition of station placement within a locally representative section on the same general reach, and station location may vary slightly between surveys. Trout habitat is not distributed evenly in the east fork headwater meadow, however. Station 2 was shifted approximately 30 m downstream in 2020 and included a wide, shallow section with poor habitat and no CRCT, while excluding a deep pool with undercut banks that was surveyed in 2013. This minor, inadvertent shift meant that the resultant catch, density, and biomass were just 60-70% of those measures observed in 2013. Mean CRCT size, condition, and size distribution were similar, however, suggesting less actual change between the surveys. Future surveys should attempt to replicate more exactly the survey reach to avoid influence of habitat distribution on catch. Increasing the station length or subsampling several stretches of this headwater stream reach may also improve the accuracy of representation of the overall habitat and population in the meadow, as opposed to surveying just the “best” 100 m in the reach.

Brook trout have been periodically observed in small numbers in the east fork headwater meadow (two were collected at Station 2 in 2020), though they have never been able to establish a self-sustaining population in that reach. Research conducted in northern Utah’s Logan River found that high-elevation streams provide refugia for native trout because low winter stream temperature extends egg incubation time for fall-spawning, nonnative trout (Wood and Budy 2009). This extended incubation results in loss of eggs or newly hatched fry during spring runoff, precluding recruitment of nonnative trout even when adults are able to invade the area and compete with native trout for food and habitat. This mechanism may help explain the lack of historic brook trout establishment in the East Fork Boulder Creek headwater meadow. However, brook trout density increases markedly just a short distance downstream of the meadow, representing a persistent threat to CRCT due the lack of a physical fish passage barrier. Any change in stream temperature or flow could tip the balance in favor of brook trout invasion in the meadow reach, resulting in a potential rapid loss of that small CRCT population. (2020 survey results indicated that the meadow sustains less than 500 CRCT.) Climate change projections generally predict increases in stream temperature throughout southern Utah in the next 20-60 years (https://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST/ModeledStreamTemperatureScenarioMaps.shtml). While replications of this population have helped secure its representation on the landscape (i.e. redundancy), the resiliency of the East Fork Boulder Creek CRCT remnant will continue to be threatened until brook trout can be completely eradicated from the drainage. This removal has been postponed at the present time but securing and expanding the East Fork Boulder Creek CRCT population remains a critical component to future CRCT conservation in the Lower Colorado River GMU.

West Fork Boulder Creek experienced a large flood in June 2019 following a rain-on-snow precipitation event. Shortly after, DNF staff observed significant damage to the lowest reach of the stream, including loss of the Forest Road culvert. Both fish passage barriers were compromised by loss of boulders and sediment deposition (Fig. 4). The barriers and road culvert were repaired in fall 2019. Additional infrastructure damage occurred at the West Garkane Impoundment, which filled with sediment. Garkane Energy was still working to repair the pipeline diversion works in summer 2020. Survey staff also observed extensive flood evidence (channel erosion, sediment deposition, habitat damage, and loss of riparian cover) throughout the length of the west fork during August 2020 (Fig. 5).

The 2019 flood also impacted the CRCT population in West Fork Boulder Creek. No fish were observed in Station 1 in 2020 or the reaches immediately above and below. CRCT density was severely reduced at Station 3, where only eight adult fish were observed. In contrast, Station 2 showed a four-fold increase in CRCT density over the previous survey, though this density was dominated by age-1 fish (88% of the sample). DNF conducted informal sampling in the west fork in early July 2019 – shortly after the flood – and found few fish in the Station 2 reach. It is hypothesized that improved stream flow in spring 2019 – resulting from a high snowpack – supported high spawning success and a large cohort of young-of-the-year. This cohort was subsequently washed downstream to the low gradient reach near the West Garkane Impoundment (Station 2) by continued elevated flow throughout the early summer. Overall, the 2019 flood caused a 70% decrease in mean CRCT biomass in the west fork, though the population was functionally eradicated in the lowest reach. (DNF found some CRCT in isolated pools below the reservoir in July 2019, though these few survivors were not sufficient to recolonize the lower reach in the short term.) Two hundred CRCT were transferred from Pine Creek (Escalante) to the west fork in October 2020 and stocked at Station 1 in an effort to reestablish that population. (This lower reach is isolated from remnant populations in the headwaters of both Boulder Creek forks by the West and East Garkane impoundments.)

While West Fork Boulder Creek was significantly impacted by the 2019 flood, the CRCT population persisted because the stream exhibited sufficient resiliency. 9.5 km (6.0 mi) of stream provided adequate refugia opportunities (e.g. West Garkane Impoundment) for displaced fish. The CRCT remnant in this stream also survived a previous large flood event when the Spectacle Lake dam, located above the west fork on the Boulder Top, failed in 1938. Thanks to several redundant populations in the Escalante River drainage, repopulation of CRCT in the lower reaches of the west fork was also made possible in 2020.

Birch Creek Subdrainage

The CRCT remnant populations in Hall Creek and Water Canyon are mostly confined to headwater reaches and only loosely connected through Birch Creek. Reduced stream flow and poor habitat limit CRCT to only seasonal occupation in Birch Creek and the lower reaches of the tributaries. These remnants have successfully persisted despite marginal conditions in such small streams, in contrast to many widely accepted tenets of population viability, stability, and resiliency that suggest larger, more connected systems are necessary. Both streams experienced increases in CRCT biomass in 2020 (Table 3) thanks to the large age-1 cohort. Native cutthroat trout abundance in southern Utah has often been shown to be highly influenced by annual snowpack and stream flow – especially in small, first order streams like these – and the 2019 snowpack clearly had a positive effect on several of the streams surveyed in 2020.

Due to limited abundance, neither of the CRCT remnants in Hall Creek and Water Canyon has been replicated to date, so conservation of these populations relies on activities that promote resiliency. Several projects have been completed in recent years with this goal in mind: Impassable culverts were removed from Hall Creek at the Forest Highway 17 crossing in 2013 and the upper

DNF administrative road in 2019, and replaced with new passable structures (Fig. 6). Log-drop grade control structures in lower Water Canyon were replaced with fish-passable rock vanes in 2012. A vegetation control treatment was also conducted in Water Canyon during the same year to remove conifers encroaching in the riparian zone. While thinning conifers certainly benefits riparian vegetation health, CRCT would have benefited even more if the cut woody debris had been placed in the active stream channel, rather than left perched on the upper terrace. The reach downstream of Station 2 is lacking in trout habitat and has clearly been impacted by a flood-prone drainage that enters Water Canyon from the north, just east of the upper survey station. Adding woody debris would help stabilize the stream bed and banks, as well as increase the total habitat available to CRCT.

Even though the primary physical barriers to CRCT movement have been addressed in Hall Creek and Water Canyon, connectivity between these streams remains limited. The combined flow of the two tributaries should be sufficient to sustain fish in Birch Creek; however, both streams lose flow in their lower reaches. Habitat is also marginal and riparian vegetation variable in Birch Creek, especially in the reaches downstream of Water Canyon, where the Corn Creek Fire burned in 2008. In theory, stream flow could possibly be regained in these reaches through riparian and stream restoration. However, active restoration work required to achieve appreciable improvement may be extensive, could be complicated by private property, and would be considered low priority compared to other potential conservation projects in the GMU. Ultimately, flow reduction may simply be a natural condition in this drainage and mitigation may be difficult, though an attempt at passive restoration, like the introduction of beavers, may provide an effective and economical approach to improving riparian habitat and recovering stream flow in Birch Creek and the lower reaches of Water Canyon and Hall Creek. Woody riparian species density is variable throughout all these systems and could be improved with better grazing management; however, it may be dense enough in certain areas to provide for a small population of beavers. Beaver activity could, in theory, fill the incision and restore the stream to its historic flood plain, providing for more consistent base flow in late summer and early fall, as well as potentially expanding the area available for riparian species colonization. Private property and nearby infrastructure (roads, bridges, and culverts) present complicating factors and would have to be considered prior to any introduction.

North Creek Subdrainage

Twitchell Creek experienced periodic flooding, poor water quality, and fine sediment deposition during the past decade. The 2020 survey observed reduced abundance of adult CRCT in comparison to the previous survey, reflecting negative effects of these conditions; however, the population benefited from stream flow in 2019, as evidenced by a high catch of age-1 CRCT. While CRCT density was higher at both stations than that observed in 2013, lower average size prevented biomass from matching previous values. Silt load was noticeably reduced in 2020, indicating that problematic erosional processes may have naturally subsided, or that increased 2019 flows flushed sediment downstream. The robust 2019 CRCT cohort should help the population to continue to strengthen in the coming years.

CRCT experienced increases in abundance and biomass in White Creek in 2020, though all size classes contributed to the growth, not just the age-1 cohort. The largest increase occurred at Station 1, where biomass improved from 76 kg/ha in 2013 to 102 kg/ha in 2020. CRCT abundance has continuously increased in this lowest reach since the population was expanded downstream of the natural barrier in 2001.

The experimental introduction of CRCT to the North Creek headwaters in 2014 was successful in establishing a population, though abundance is somewhat limited by low water temperature. Natural barriers restrict access to an additional 1.0 km (0.6 mi) of suitable habitat upstream of the current distribution. More natural barriers and dense brook trout downstream of the inflow from the Barker reservoirs further restrict CRCT establishment lower in the drainage. North Creek provides another 11.7 km (7.3 mi) of trout habitat downstream to North Creek Reservoir and sustains rainbow and nonnative cutthroat trout, in addition to brook trout. DNF has also observed small congregations of CRCT in North Creek near the confluences with Twitchell and White creeks, though these groups are considered sink populations due to competition and potential hybridization with nonnative trout.

With suspension of restoration efforts in the Boulder Creek drainage, North Creek has been identified as the highest priority candidate for CRCT restoration in the Lower Colorado River GMU. CRCT already occur in North Creek's two largest tributaries (Twitchell and White creeks) and the North Creek Reservoir dam provides an existing fish passage barrier. In addition, sport fish stocking in the basin's headwater lakes was converted to either CRCT or sterile (hybrid or triploid) trout during the last decade. Self-sustaining populations of brook trout were removed from two more lakes in 2019 and 2020. Further sampling to determine if fertile brook trout still persist in any headwater lakes is planned for 2021, with nonnative fish removal tentatively scheduled for North Creek in 2022-23. Once CRCT restoration is complete, the North Creek drainage will sustain the largest CRCT population (21.8 km; 13.5 mi) in the Escalante River drainage.

Pine Creek (Escalante)

Similar to Twitchell Creek, West Branch Pine Creek experienced flooding since 2013 that reduced adult CRCT. The strong 2019 cohort supported a high total CRCT density in 2020, but this could not yet make up for the loss of adult biomass. Biomass is expected to continue increasing in the coming years with the growth of the 2019 cohort. Pine Creek, however, did see increased biomass at all stations. Age-1 CRCT were very high at Stations 1 and 2, while all cohorts increased at Station 3 in 2020. The robust Pine Creek population supported transfers to both Dougherty Basin Lake and West Fork Boulder Creek in fall 2020.

Pine Creek represents one of the highest quality opportunities for CRCT expansion in the Escalante River drainage. An additional 20 km (12.4 mi) of trout habitat are found downstream of the current distribution, extending through The Box-Death Hollow Wilderness Area. Some of this reach may also provide the opportunity to restore other native fish species, including bluehead sucker (*Catostomus discobolus*). Restoration will require removal of nonnative brown trout and construction of fish passage barriers to prevent reinvasion. Most pesticide applications are designated as actions under state authority by U.S. Forest Service (USFS) direction (USDA Forest Service Manual 2610, Intermountain Region Supplement 2611.11) and a 2013 agreement between UDWR and USFS Intermountain Region (Hadley et al. 2014). A large portion of this part of Pine Creek lies in a federally designated Wilderness Area, so additional review is needed to ensure that there are no extraordinary circumstances that would elevate the project to requiring either an Environmental Assessment (EA) or Environmental Impact Statement (EIS), rather than the current pesticide use waiver determination process. Staff at the DNF Escalante Ranger District have expressed interest in the potential project and support for initiating the NEPA review process in the future, though such review will not commence until after the completion of CRCT restoration in North Creek.

Pine Creek (Fremont)

The 2013 introduction of CRCT to the reach upstream of Pine Creek Reservoir added 1.7 km (1.1 mi) of occupied habitat to Pine Creek (Table 2). The addition of a new survey station in this reach, where the population is still expanding, contributed to the decrease in mean CRCT biomass between 2013 and 2020. Biomass also showed decreases at the other three stations, though the declines at Stations 2 and 3 were minimal and biomass remained at or near 200 kg/ha. CRCT biomass decreased from 102 kg/ha in 2013 at Station 1 to 85kg/ha in 2020. Conversely, CRCT density was higher at Stations 1 and 2 in 2020, while density at Station 3 was similar in 2013 and 2020. Similar to previously discussed streams, the changes in biomass values in Pine Creek in 2020 can be attributed to lower mean size and the presence of a strong age-1 cohort spawned in 2019. Reasons for a reduction in abundance of older cohorts are not clear, though drought conditions may have had an impact.

CRCT are subject to two other challenges in Pine Creek. Brook trout were observed in a large beaver pond between Station 3 and Pine Creek Reservoir beginning in 2011. Two rotenone treatments were conducted in the reach between the pond and the Forest Road crossing (just upstream of Station 3) in 2013. While it was assumed that brook trout were successfully eradicated by the 2013 treatments, they reappeared in the pond during the subsequent years. It is unknown whether the brook trout in the pond persisted through multiple pesticide applications in 2002, 2003, and 2013, or have been illegally reintroduced. Despite that persistence, brook trout have not been observed outside the beaver pond during multiple reconnaissance and monitoring surveys in 2012, 2013, and 2020, nor during treatment and salvage activities in 2013. Consequently, brook trout have not yet exerted any direct impact on the Pine Creek CRCT population, though their presence represents an enduring potential threat.

M. cerebralis was detected in Pine Creek Reservoir CRCT in 2016, though evidence of strong recent recruitment indicates that whirling disease has yet to exert any influence on the Pine Creek CRCT population. Because the effects of whirling disease infection are exacerbated by habitat conditions (see UM Creek discussion), conservation efforts in Pine Creek must continue to focus on promoting land management actions that reduce sedimentation, maintain or improve stream bank stability, strengthen riparian integrity, and avoid increases in water temperature.

Sand Creek

CRCT persisted in low numbers in Sand Creek from introduction in 1995 to sometime after 2007, despite what was generally considered naturally marginal habitat subject to flash flooding. The failure to detect CRCT in the 2013 survey, however, seemed to support this description of the stream as marginal habitat (Hadley et al. 2014). The opportunity for a second introduction arose in 2014 with the certification of CRCT in Pine Creek (Escalante) for transfer to other waters. The abundance of CRCT in that stream allowed for transfer to both the Dougherty Basin brood, as well as Sand Creek. Seventy CRCT were introduced to the upper reach of Sand Creek (near Station 1) in October 2014, while thirty-four were placed in the lower reach between the falls and the Hells Hole confluence. This reach below the falls had also received a stocking of about 100 age-0 CRCT (produced by Dougherty Basin brood) in October 2001, though cursory electroshocking surveys conducted after that plant failed to document CRCT persistence and survival below the falls. The 2020 survey found that the 2014 introduction was successful in establishing a new self-sustaining CRCT population in Sand Creek. This new population was more robust than that observed in 2007 (Hadley et al. 2008), as evidenced by 42% more CRCT biomass (Table 4), 85% greater density, and the presence of abundant young-of-the-year. In addition, CRCT were observed downstream as far as the Hells Hole confluence, though in limited numbers. (Sand Creek below this point is severely impacted by flash floods from Hells Hole and habitat is not sufficient to sustain CRCT.)

While the CRCT population appears to be flourishing currently, Sand Creek still has a high potential for flash floods, meaning that long-term population resiliency is uncertain. Similar cases have been observed in streams of the Pine Valley Mountains (Upper Virgin River drainage), where Bonneville cutthroat trout have been able to persist only after active refounding following disturbances (Hadley and Golden 2019). Like Sand Creek, those streams contain numerous natural barriers that restrict recolonization by native trout after population-impacting events like floods or drought. Despite the presence of sufficient flow and habitat, it was determined that some Pine Valley streams could not support resilient populations of native trout in the long term and active management for BCT in those streams was abandoned. In addition, Sand Creek has had alterations to its natural base flow due to management of headwater springs. Spring flow from the headwaters and adjacent drainage headwaters has been diverted into Sand Creek in the past by the town of Torrey, but recently authorized spring developments will be diverting some or much of this flow into a pipeline instead. Spring management likely did not affect peak flows in the past, but may have increased base flow. The new changes may decrease Sand Creek's base flow in the future to near natural conditions or even below what the stream historically experienced. The cumulative effects of these water management actions have been difficult to understand and quantify, particularly on the CRCT-occupied habitat over a mile downstream of the springs. The next GMU-wide CRCT survey, tentatively scheduled for 2027, will help to determine whether the population is able to persist in Sand Creek without regular stocking.

UM Creek Drainage

Whirling disease infection, along with all the factors that contribute to it, continues to present the greatest challenge to CRCT establishment and persistence in UM Creek and its forks. While self-sustaining populations have established previously in the right and left forks, natural recruitment has been limited and infrequent in main stem UM Creek (Hepworth et al. 2010) and only periodic stocking has maintained CRCT presence there. Habitat quality has been shown to affect *M. cerebralis* density, whirling disease infection potential, and survival rates by infected fish (Schisler and Bergersen 2000; Hiner and Moffitt 2001; Sandell et al. 2001; de la Hoz Franco and Budy 2004).

Habitat conditions contribute to elevated impacts of whirling disease in the UM Creek main stem, in comparison to the headwater forks. Sedimentation and elevated water temperature are two of the primary factors that influence whirling disease effects on a trout population and are common occurrences in UM Creek thanks to both natural and human caused conditions. UM Creek in the upper drainage flows through wide, mature valleys whose beds contain a high mass of fine sediment. These fine-grained soils are easily eroded and, when introduced into the stream, settle in beaver ponds, pools, and slow-velocity areas, providing excellent habitat for the oligochaete worms that act as the secondary host for *M. cerebralis*. Both livestock grazing and vehicle traffic have increased erosion and sedimentation in these meadow reaches. Lower drainage canyon reaches are more confined, rocky, and protected, but still contain fine sediment banks. Thick stands of riparian shrubs and trees protect many banks in the canyon reach, but small openings frequently have severely eroded banks due to livestock use which, when coupled with erosion in the upper drainage, create extensive fine sediment deposits that normally would be infrequent in this stream type.

Stream shading is limited in meadows and some other headwater reaches of UM Creek because the riparian vegetative community in these reaches is dominated by grasses and sedges, with limited willows providing only localized cover. Stream temperature in these reaches is also affected by stream morphology. The heavily grazed meadows and headwater reaches of UM Creek have tended to be overly wide and shallow, with reduced willow coverage. Summer daytime stream temperatures in these reaches have been documented at over 20° C (68° F) even in high elevations (Hepworth et al. 2010). In contrast, stream reaches protected within grazing exclosures have narrowed significantly, so that even tall, ungrazed grass on the streambanks provides considerable stream shade. In addition, willows have begun to pioneer into most of the exclosures, even in areas where some felt that they could not, or would not, establish. Groundwater recharge from underbank gravel vanes has also been noted to provide a cooling influence to the stream in protected exclosures. In contrast, heavily grazed riparian areas with compacted soils outside of these exclosures lack these cooling inflows. Elevated stream temperature has been shown to increase whirling disease infection potential in cutthroat trout (de la Hoz Franco and Budy 2004) and increased stress also compounds the effects of the disease on infected fish (Schisler and Bergersen 2000).

After the UM Creek CRCT restoration project illuminated the severity of habitat concerns in the drainage, FNF began implementing management actions beginning in 2003 to mitigate habitat degradation and alleviate stressors on CRCT. Hepworth et al. (2010) noted that livestock exclosures and improved grazing management were successful in reducing stream bank erosion, narrowing stream channel width, and increasing riparian vegetation, stream shading, and undercut bank habitat. However, they also noted some lapses in exclosure maintenance or commitment to grazing prescriptions, which have continued periodically in the 10 years since that project review. Grazing impacts on UM Creek seem dependent on yearly snowpack and summer monsoon rain conditions: adequate forage is available in upland areas away from the stream during good water years, while livestock use is congregated along streams and impacts are more severe during dry years. This variability means that grazing practices that have little impact on riparian habitat one year may be devastating the next. A lack of adaptive grazing management has the potential to slow habitat improvement – which is critical to lessening the effects of whirling disease and allowing UM Creek to sustain CRCT – and illustrates the need for diligence in continually reviewing management practices.

All previous and present population evaluations have noted that habitat and CRCT in the UM Creek forks were significantly benefited by improved grazing management. The left fork showed particular improvement, from limited CRCT occupation in the late 1990s and early 2000s, to population establishment by 2013 (Hadley et al. 2014), to sustaining the most robust population in the drainage in 2020 (Table 4). In the early 2000s excessive streambank damage in key areas of left fork led to stream sedimentation so severe that CRCT planted in the spring moved downstream out of the tributary and could not be relocated in late summer. Fencing these most vulnerable areas has considerably reduced sedimentation. Topography in the left fork is also more open and rolling, which helped distribute livestock throughout the unit once these most vulnerable areas were protected. The stream has narrowed in the exclosures, allowing for decreased water temperature and cleaner spawning gravels. The situation in the left fork exemplifies the potential for CRCT persistence, in spite of whirling disease, through continued efforts to mitigate impacts to stream habitat.

While CRCT biomass has increased in the left fork over the years despite whirling disease infection, it has decreased in the right fork since infection was detected in 2006. Livestock impact on stream banks seems to be intensified in the right fork due to a few factors. The topography is more confined than that of the left fork and a greater area of the stream is confined to exclosures or by a reach of extensive willows. While stream reaches in exclosures have improved and appear to be near peak natural condition, the previously mentioned factors have concentrated livestock use on the limited available stream banks outside exclosures, which may be exacerbated by grazing prescriptions. Deterioration of these reaches may be limiting the ability of exclosures to support a robust CRCT population. While the right fork population has certainly declined due to increased whirling disease prevalence, sampling conditions in 2020 may have also overstated the decline. Station 1 has continued to be pushed downstream by beaver activity and had to be relocated again in 2020, which resulted in the lower half of the station lying in a split channel, with generally poorer habitat and less cover. Improved station placement in the future may yield population metrics that are less dire than what was observed in 2020.

Vehicle access improvement projects (Fig. 7) in recent years have also targeted reducing travel impacts to the UM Creek forks by re-routing roads and trails away from the streams, more effectively restricting unauthorized vehicle access, and replacing the Black Flat crossing of the right fork with a bridge (Fig. 8). Unfortunately, the bridge was installed far too late to prevent the spread of whirling disease to the upper right fork by vehicle traffic. (The right fork fish passage barrier was removed concurrently with the Black Flat project in order to improve stream connectivity.)

UM Creek faces additional challenges from future land management actions. FNF has an active prescribed fire program and, in 2019, the Porcupine fuels project was approved to treat 4,804 acres, or 19% of the watershed, of mixed conifer and aspen between Water Flat and Danish

Meadows on the east side of UM Creek. To protect CRCT, stream function, and watershed health, a design feature was included to limit burn treatments to 10% of the watershed, or 2,700 acres, at one time. A similar sized area was burned by wildfires in 2002 and 2003 on the western edge of the watershed, but the greater distance to the stream limited sediment input in that case. The 2002-2003 wildfires were beneficial in helping aspen restore in burned areas and likely were a factor in increased aspen regeneration throughout the watershed by redistributing wild ungulates and, to a lesser extent, livestock. The Porcupine fuels project is immediately adjacent to the stream, however, and will likely increase sedimentation impacts to UM Creek in the short to moderate term.

Timber harvest was proposed in the headwaters of the left and right forks of UM Creek to allow harvest of spruce stands for wood products, salvage dead and dying timber, and improve stand composition. The proposed harvest would have increased truck traffic considerably on the road which parallels the right fork. In the left fork, harvest of some proposed areas would have involved crossing the stream or skidding logs across the stream. Through the planning process, the right fork harvest zone was eliminated and the left fork harvest zone was reduced to only west of the stream (with access only from the west), as documented in the signed Decision Notice dated November 2020. The final treatment prescriptions requested that all equipment avoid entering the left fork, though some springs and seeps in the treatment zone do flow into the stream. Forest fisheries and hydrology personnel will need to pay attention to these water sources if or when implementation of the project occurs. Harvests in the left fork would likely slightly increase stream sedimentation in the short term, but there is a chance that the timber sales will not find buyers and the harvest will not occur.

The 2020 water year (including both snowpack and summer monsoons) was the driest on record, which increased grazing impacts on UM Creek outside of exclosures. In addition, unauthorized ATV use seems to be an increasing problem again. Due to all these concerns, it may be appropriate for FNF to increase land use and project monitoring, aquatic habitat surveys, and sediment monitoring in the future to assess impacts and better inform land management actions which will, hopefully, lead to improved and more timely management.

Future Conservation

The first twenty years of CRCT conservation in the Lower Colorado River GMU focused on identifying remnant populations, expanding some of those remnants, and restoring CRCT in stream systems of varying scales. Unfortunately, efforts during the subsequent 10 years were mired by the stalemate surrounding the Boulder Creek project. In addition, GMU staff took advantage of numerous opportunities to accelerate Bonneville cutthroat trout restoration in the Southern Bonneville GMU, diverting time and resources away from possible CRCT restoration. CRCT conservation and expansion will need to be prioritized again during the 2020s so that security in the Lower Colorado GMU can catch up to what is being achieved in the Bonneville Basin.

The "3-R" conservation model employed in the new Utah CRCT Strategy provides a framework for prioritizing conservation actions during the coming years. Identification of remnant populations (i.e. representation) has likely been completed as most stream systems in the Lower Colorado GMU have already been surveyed. While the possibility of finding new remnants should not be entirely discounted, efforts to search them out should be assigned the lowest priority.

Population expansion was employed and/or attempted multiple times in the past in order to improve resiliency of CRCT remnants though, admittedly, the small scale of these projects achieved only limited gains in resiliency. Opportunities for creating larger metapopulations are limited in southern Utah by both natural habitat conditions in mainstem rivers and lower tributary reaches, as well as manmade diversions and anthropogenic habitat degradation. UM Creek provided one of the best opportunities for creating a metapopulation in the GMU, though whirling disease impacts and habitat conditions have greatly compromised that system's ability to sustain CRCT and attain resiliency. GMU staff will continue to work diligently to promote and prescribe land management activities that will improve habitat stability and reduce the compounding of habitat on disease effects. Even with habitat improvement, regular stocking of CRCT may be necessary to sustain a recreational population in UM Creek. Consistent stocking will be dependent, however, on current efforts to establish a captive CRCT brood. (This development is detailed in Hadley 2019.) The Sevenmile Creek drainage (Fremont) was also considered as a potential site for creating a metapopulation, though this was abandoned when whirling disease spread to the system in the late 2000s.

Pine Creek (Fremont drainage) represents the next largest current CRCT population (15.3 km; 9.5 mi), though it has also been infected with whirling disease. CRCT have withstood the infection well to date, though only time will tell if the population will gain resistance to the disease or suffer a loss in resiliency. Habitat condition in Pine Creek is currently superior to that of UM Creek – thanks to harder banks overall and fewer fine-grained soils – providing hope that this population has a greater chance of sustaining itself in the long term. Maintenance of that habitat will be critical, however, in assuring resiliency of CRCT in Pine Creek. All land management actions in the drainage must consider and prioritize stream health and CRCT persistence.

Improving CRCT resiliency in the Lower Colorado River GMU will continue with restoration in the North Creek drainage (Escalante) during the early 2020s and was discussed in detail earlier. Pine Creek (Escalante) provides the other most significant opportunity for creating a large population in the GMU. Total trout habitat available in that drainage extends up to 34 km (21 mi), a near three-fold increase over the current population. Due to the substantial potential of this population, NEPA review should be pursued as soon as is feasible. The Boulder Creek forks represent the other best opportunity for a resilient, connected population. Although opposition by a limited number of local residents has temporarily postponed this project, CRCT restoration in East Fork Boulder Creek continues to be a high priority and will be pursued again in the future.

Beyond these large-scale projects, other opportunities for increasing redundancy of remnant CRCT will also be evaluated and developed. Pleasant Creek and Oak Creek on the east slope of Boulder Mountain (Fig. 9) provide the best chances to increase occupied habitat in the Fremont River drainage. Natural waterfall barriers can be found in the lower reaches of each stream, though sport fisheries and water diversion present complications to restoration. The outflow of Lower Bowns Reservoir – where fertile rainbow trout are stocked – connects to Oak Creek upstream of the waterfalls, so barriers would have to be constructed above this confluence. Potential barrier sites were identified and construction feasibility was reviewed in 2019. CRCT restoration in Oak Creek would be dependent, however, on removal of fertile brook trout from Oak Creek (Upper Bowns) Reservoir at the stream's head. Such removal – and replacement with sterile brook trout – coincides with goals for the reservoir's sport fishery and is prescribed by the Boulder Mountain Sport Fish Management Plan (Boulder Mountain Sport Fish Advisory Committee 2014). This management plan was the driving force for considering opportunistic CRCT restoration in Oak Creek. However, fertile brook trout removal has met with opposition from some anglers due to temporary fishery losses after a piscicide application, as well as a newly gained value in the high harvest of brook trout allowed in the reservoir since enactment of the management plan in 2014. This opposition will likely preclude removal of fertile brook trout until the reservoir population reaches a critical stage of overabundance, where sport fish value decreases precipitously. Pleasant Creek, therefore, provides a more feasible option for restoring CRCT in the near future. Some Pleasant Creek flow is diverted to Lower Bowns Reservoir, so identification or construction of barriers in the diversion ditch will be necessary. Barrier reconnaissance in both the ditch and main stem of Pleasant Creek will be conducted in 2021 or 2022.

Calf Creek (Escalante drainage) (Fig. 1) represents a valuable opportunity for restoration of CRCT in a highly visible location. Calf Creek's canyon and waterfalls are the focal point of the Grand Staircase-Escalante National Monument, hosting thousands of visitors each year from across the globe. UDWR and BLM fisheries staff met with monument management in spring 2020 to discuss common management goals and mutual interest in restoring CRCT, bluehead suckers, and speckled dace (*Rhinichthys osculus*) to Calf Creek. In the coming years, BLM will initiate NEPA review of barrier construction and chemical removal of nonnative trout. It is expected that the project will meet with some opposition from the local Boulder community; however, UDWR and BLM staff have expressed a willingness to address any concerns that arise during the review process. While the addition of 11 km (7 mi) of occupied habitat pales in comparison to other potential projects, restoring a native fish assemblage in such a well-visited area provides the opportunity to further conservation outreach efforts far beyond what has been previously achieved.

While future restoration is being planned and implemented in the Lower Colorado GMU, landscape scale watershed management activities have also been planned to improve riparian and terrestrial vegetation communities and ground cover, as well as reduce the risk of uncharacteristically large and severe fires. Over the past 20 years wildfires, managed natural fires, and escaped prescribed fires, along with the flooding and debris flows that follow them, have had the largest negative impact on native trout conservation and recovery in southern Utah (Hepworth et al. 2003, Hadley et al. 2010, Hadley et al. 2011a, Hadley et al. 2011b, Hadley and Golden 2016, Hadley et al. 2017, Hadley and Golden 2019, Hadley et al. 2020). To date these impacts have been confined to drainages in the southern Bonneville Basin; however, conditions conducive to large, severe wildfires (dense continuous stands of late successional vegetation – particularly conifer-invaded aspen and pinyon/juniper-invaded mountain brush stands, high dead and down fuel loads, and copious ladder fuels) are also common in the watersheds surrounding CRCT conservation populations in the Lower Colorado GMU. While planning efforts have begun in an attempt to address these concerns in some areas (North Creek, Pine Creek-Escalante, Pine Creek-Fremont), the planning and implementation of watershed improvement and fuel reduction projects should be expedited and prioritized so that current and future CRCT populations and their habitats can be sustained.

CONCLUSION

Previous restoration efforts have established a solid foundation for CRCT conservation in the Lower Colorado River GMU. Future collaborative projects will build off this foundation, attempting to increase occupation and improve resiliency. The new Utah CRCT conservation strategy presents the first attempt to identify a point of "recovery" for the subspecies, finalize major restoration efforts, and move on to maintenance and enhancement of previously restored populations. Restoration efforts in the Lower Colorado GMU have not yet produced the level of security desired for CRCT. However, the projected shift in management focus prioritizes identifying an end point to major restoration and will provide an impetus for completing most or all of the proposed projects. As conservation progresses from restoration to maintenance and enhancement, responsible management of various land uses such as fire, vegetation, grazing, roads, and recreation will be essential to sustaining watershed health and CRCT population persistence. Watershed improvement projects represent key opportunities to implement landscape-scale enhancement of both terrestrial and aquatic habitats. Such projects have been designed and implemented, at varying scales, in recent years on Monroe Mountain, the Pine Valley Mountains, and the west slope of Boulder Mountain in the East Fork Sevier River drainage. The Forest Service will soon be initiating a similar landscape project intended to address, among other issues, dangerous fire fuel loads across much of Boulder Mountain. Planning for the project will be collaborative and include input from UDWR and other interested entities. This type of collaboration among cooperating agencies, as well as among specialized personnel within those agencies, provides a vital opportunity to achieve successful fish and landscape conservation. These activities will aid in ensuring that CRCT persist in the Lower Colorado River GMU.

STATEMENT OF EQUAL OPPORTUNITY

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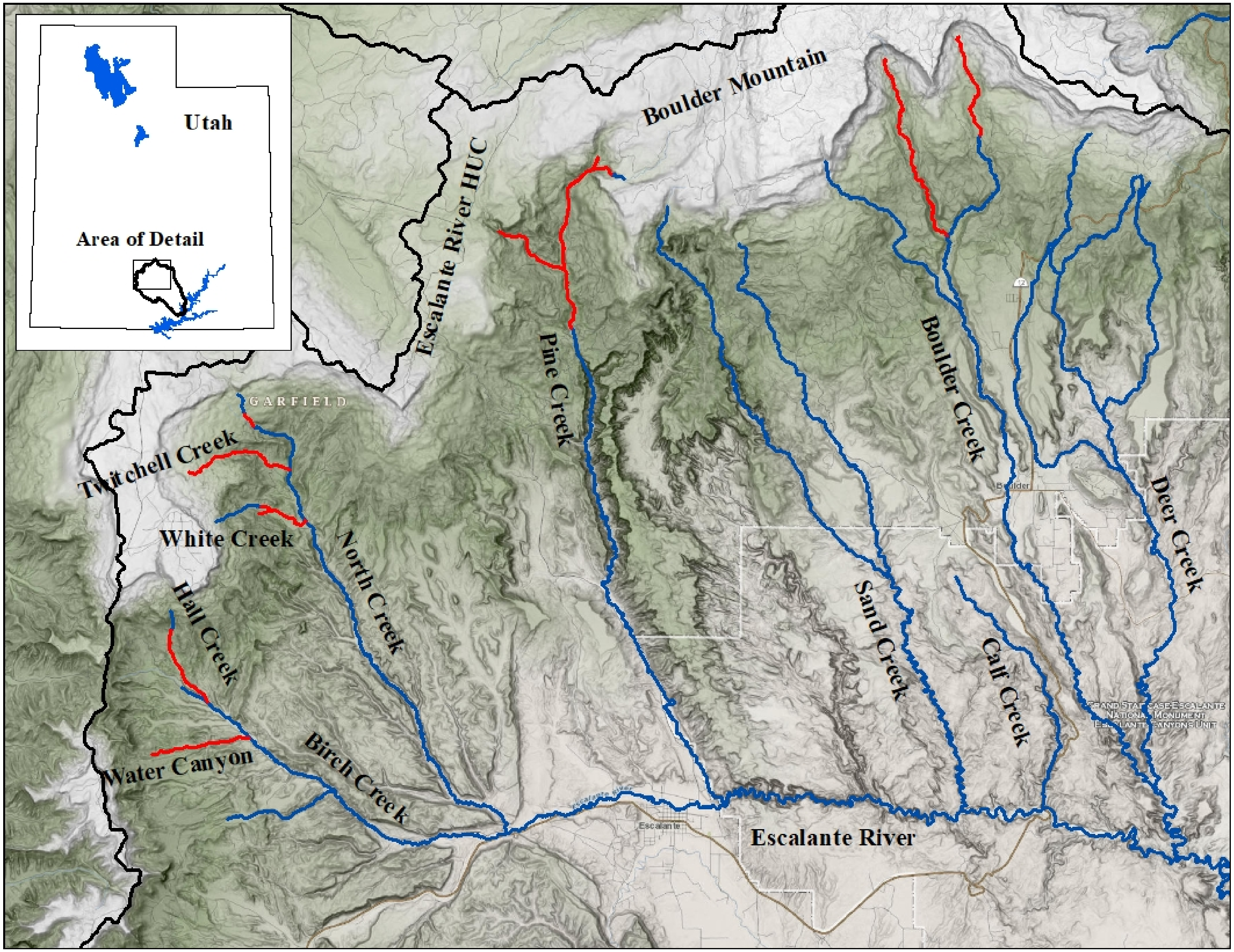

Figure 1. The Escalante River drainage (HUC 14070005) of south central Utah. Current (2020) CRCT distribution highlighted in red.

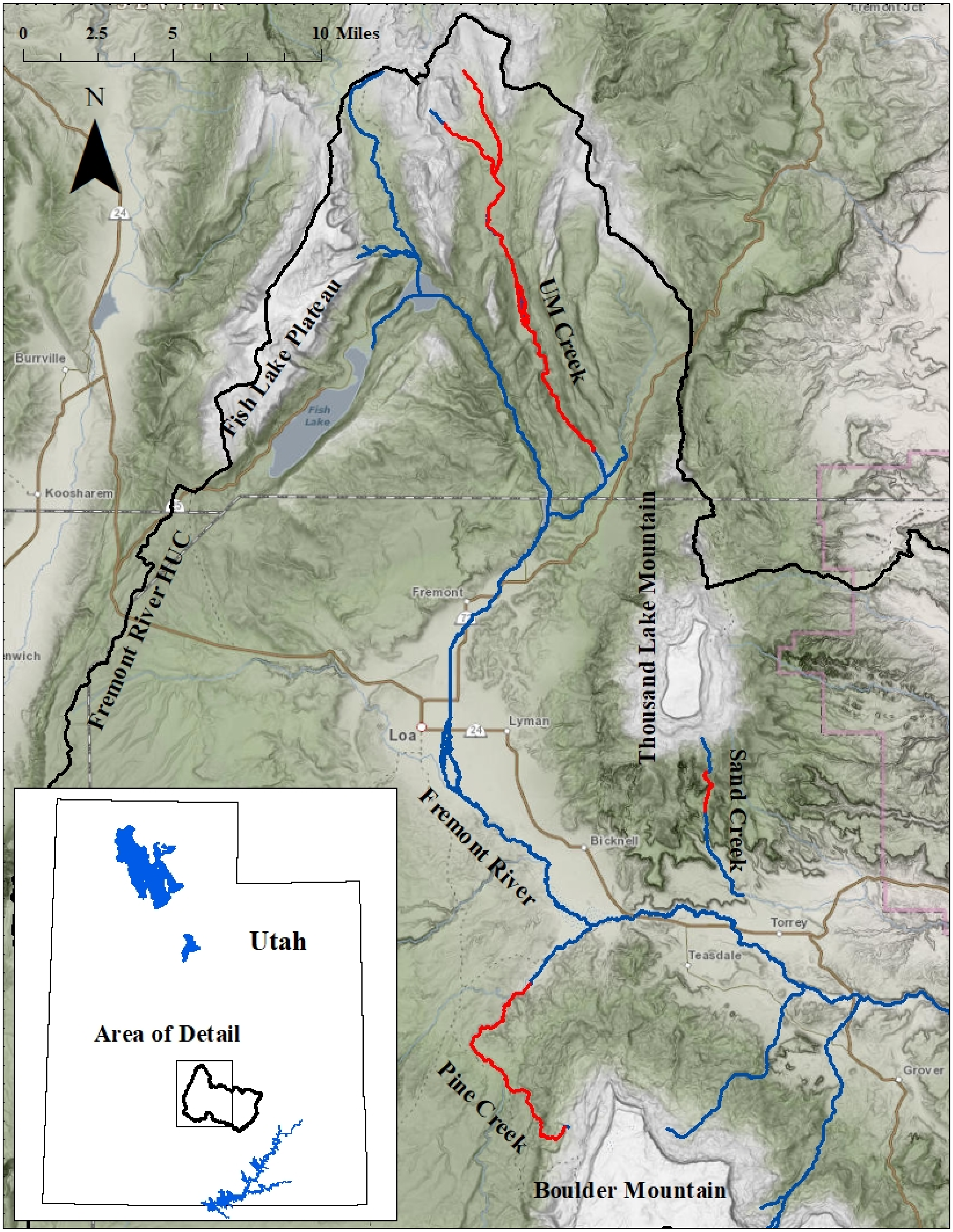

Figure 2. The northwest portion of the Fremont River drainage (HUC 14070003) of south central Utah. Current (2020) CRCT distribution highlighted in red.

Figure 3. Personnel conduct an electrofishing survey in UM Creek.

Figure 4. Flood damage observed at West Fork Boulder Creek upper barrier in June 2019.

Figure 5. Flood damage observed in August 2020 in lower (top) and upper (bottom) West Fork Boulder Creek.

Figure 6. Fish-passable culvert (top) and timber crib bridge (bottom) that replaced previously impassable culverts in Hall Creek at Forest Highway 17 and the upper administrative road, respectively.

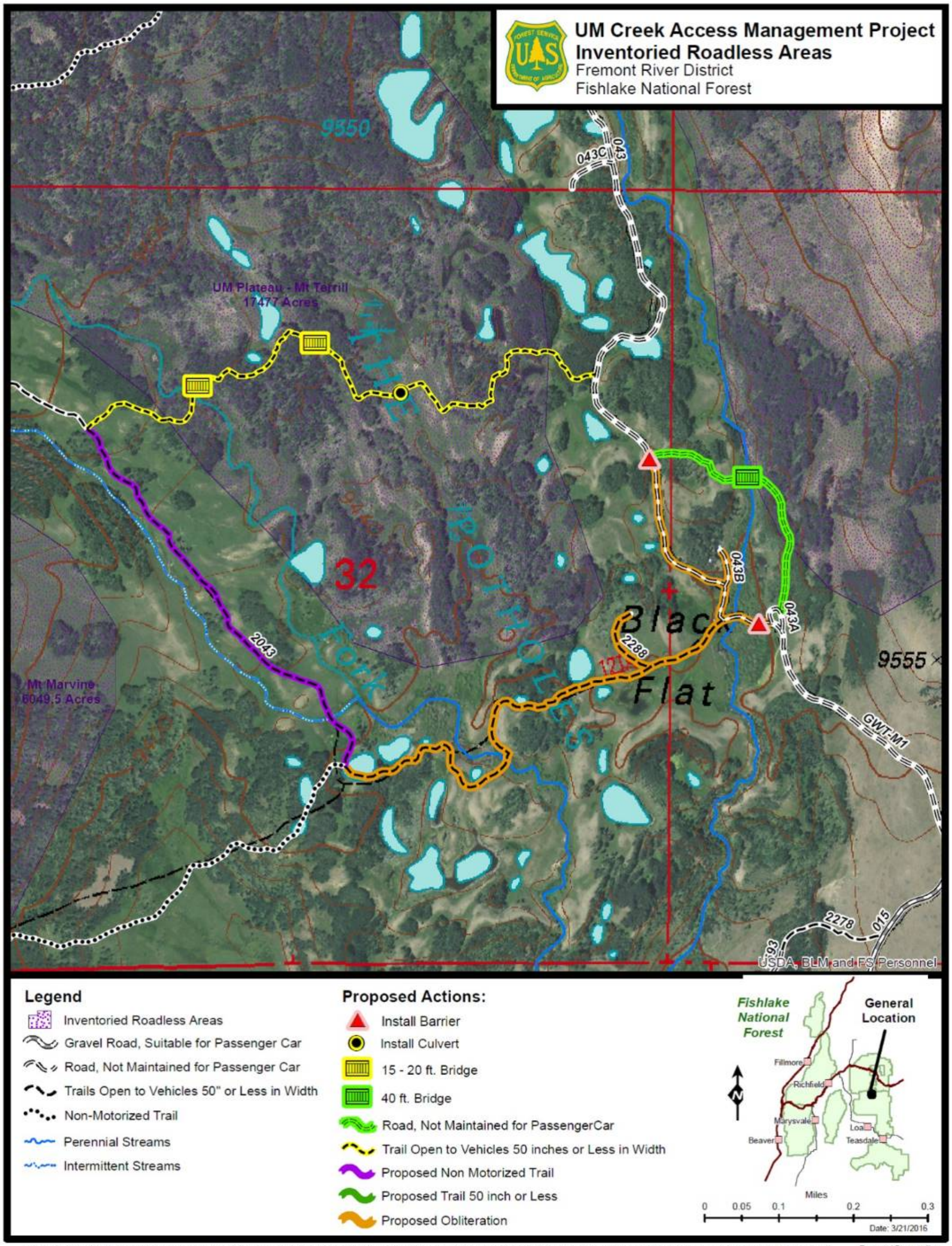

Figure 7. Map detailing the UM Creek Access Management Project.

Figure 8. Bridge installed in 2019 to replace the ford crossing of Right Fork UM Creek at Black Flat.

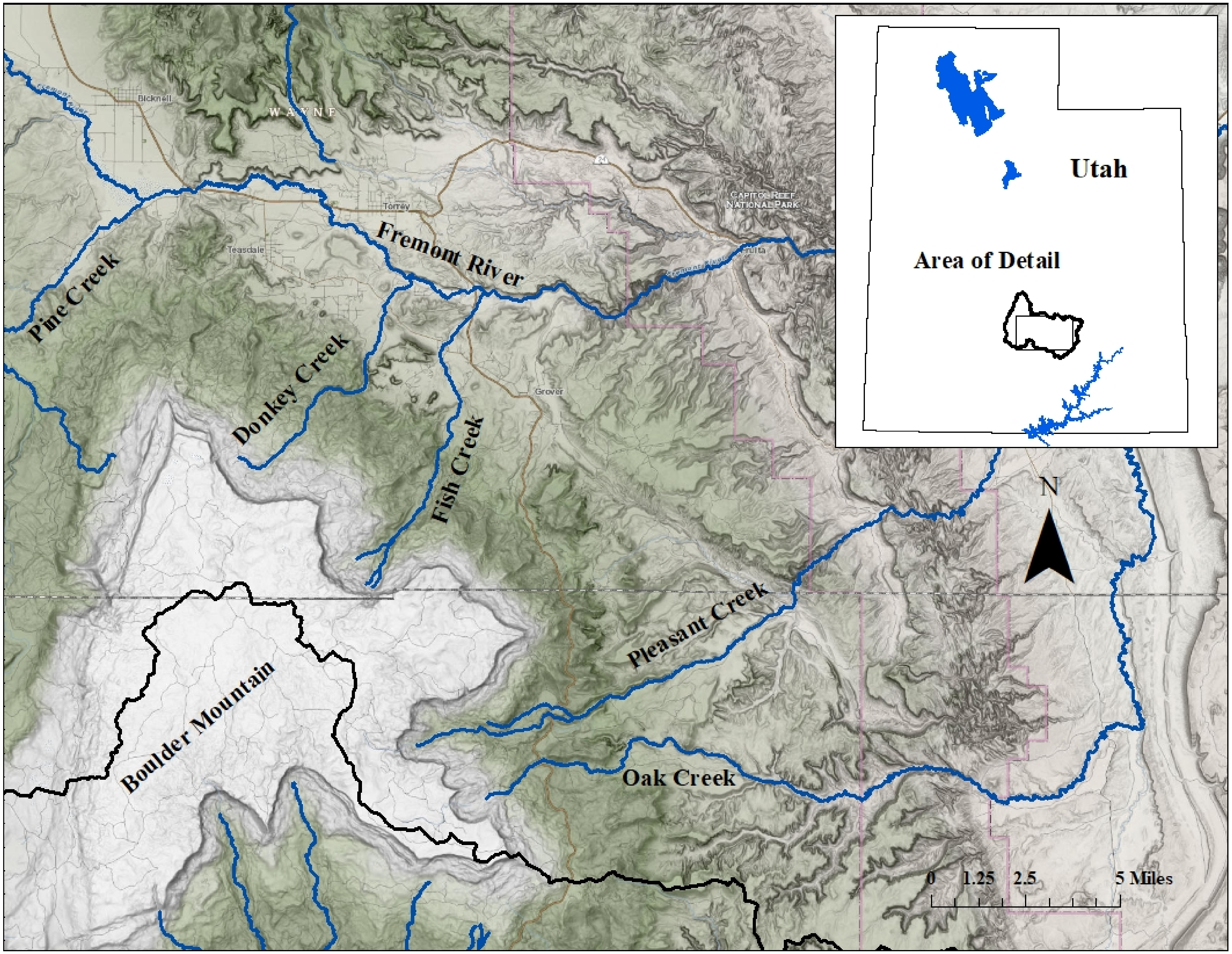

Figure 9. The southeast portion of the Fremont River drainage.

Table 1. Comparison of stream length (km) occupied by Colorado River cutthroat trout in the Escalante River drainage, 1994 to 2020. *Italics* denote stream length occupied by remnant populations, normal text denotes stream length occupied by restored and/or expanded populations, and **bold** text denotes totals for the year (remnant plus restored). (Results from historic surveys [1994-2013] were corrected by more accurate mapping employed in 2020.)

Sampling Years	Known Occupied Stream Length	Change
1994	*3.8 km* **3.8 km**	*+0.5 km (EF Boulder Cr)* *+3.3 km (WF Boulder Cr)*
1998	*9.4 km* **9.4 km**	*+2.3 km (White Cr)* *+2.5 km (WB Pine Cr)* *+0.8 (Water Cyn)* **Total: +5.6 km**
2006-2007	*16.6 km* 17.4 km **34.0 km**	*+3.7 (Water Cyn)* *+3.5 (Pine Cr)* +6.2 km (WF Boulder Cr) +0.7 km (White Cr) +1.2 km (WB Pine Cr) +6.1 km (Pine Cr) +3.2 (Twitchell Cr) **Total: +24.6 km**
2013	*20.5 km* 19.6 km **40.1 km**	*+3.9 km (Hall Cr)* +2.2 km (Twitchell Cr) **Total: +6.1 km**
2020	*20.5 km* 25.3 km **45.8 km**	+4.9 km (EF Boulder Cr) +0.8 km (North Cr) **Total: +5.7 km**

Table 2. Comparison of stream length (km) occupied by Colorado River cutthroat trout in the Fremont River drainage, 1998 to 2020. All populations in the drainage are restored. (Results from historic surveys [1998-2013] were corrected by more accurate mapping employed in 2020.)

Sampling Years	Known Occupied Stream Length	Change
1998	3.9 km	+2.9 km (RF UM Cr) +1.0 km (Sand Cr)
2006-2007	50.4 km	+4.2 km (RF UM Cr) +5.1 km (LF UM Cr) +23.6 km (UM Cr) +13.6 km (Pine Cr) **Total: +46.5 km**
2013	49.4 km	-1.0 km (Sand Cr) **Total: -1.0 km**
2020	53.7 km	+2.6 km (Sand Cr) +1.7 km (Pine Cr) **Total: +4.3 km**

Table 3. Comparison of Colorado River cutthroat trout population status in the Escalante River drainage by individual stream, 1994-2020. Trends noted as an increase (↑) or decrease (↓) if values changed by more than 10%; >0 indicates that trout were present but biomass or range was not measured. Biomass presented is a mean of all sampling stations where CRCT were detected.

State water identification number	Stream/tributary (indentation denotes tributaries)		Occupied Habitat		Biomass		
		Year	km	Trend	kg/ha	Trend	Comments
I AJ 110C	Boulder Creek, EF	1994	0.5	--	>0	--	Remnant population
		1998	0.5	↔	69	↑	Remnant population
		2006	0.5	↔	102	↑	Expansion planned
		2013	0.5	↔	240	↑	Expansion delayed
		2020	5.4	↑	91[1]	↓	Increasing below headwater meadow
I AJ 110D	Boulder Creek, WF	1994	3.3	--	22	--	Remnant population
		1998	3.3	↔	100	↑	Remnant population
		2006	9.5	↑	100	↔	Expanded 2001
		2013	9.5	↔	140	↑	Increasing population
		2020	9.5[2]	↔	41	↓	Impacted by 2019 flood
I AJ 170C	Hall Creek	2006	>0	--	>0	--	Unknown remnant
		2013	3.9	↑	45	↑	Population discovered 2011
		2020	3.9[2]	↔	79	↑	Benefited by 2019 snowpack
I AJ 160	North Creek	2013	--	--	--	--	Headwaters fishless
		2020	0.8	↑	27	↑	Experimental introduction 2014
I AJ 160F	Twitchell Creek	1998	--	--	--	--	Non native trout
		2007	3.2	↑	76	↑	CRCT restored 2001, 2006
		2013	5.4	↑	98	↑	Population increasing
		2020	5.4[2]	↔	74	↓	Impacted by flooding[3]
I AJ 160E	White Creek	1994	>0	--	>0	--	Unknown remnant
		1998	2.3	↑	43	↑	Population discovered 1997
		2007	3.0	↔	96	↑	Expanded 2001
		2013	3.0	↔	80	↓	Natural variability
		2020	3.0[2]	↔	96	↑	Natural variability
I AJ 150	Pine Creek	1998	>0	--	>0	--	Population discovered 2000
		2006	9.6	↑	38	↑	Expanded 2002
		2013	9.6	↔	79	↑	Population increasing
		2020	9.6	↔	118	↑	Benefited by 2019 snowpack
I AJ 150C	Pine Creek, West Branch	1994	>0	--	>0	--	Unknown remnant
		1998	2.5	↑	18	↑	Population discovered 1997
		2006	3.7	↑	50	↑	Non native trout removed 2002
		2013	3.7	↔	124	↑	Population expanding
		2020	3.7[2]	↔	94	↓	Impacted by flooding[3]
I AJ 170B	Water Canyon	1994	>0	--	>0	--	Unknown remnant
		1998	0.8	↑	26	↑	Population discovered 1998
		2007	4.5	↑	33	↑	Source population identified
		2013	4.5	↔	32	↔	Population mostly stable
		2020	4.5[2]	↔	69	↑	Benefited by 2019 snowpack

[1] – Mean biomass decreased due to inclusion of reaches below headwater meadow.

[2] – 100% of currently available habitat.

[3] –Population impacted by flooding after 2013. Density rebounded in 2020 but dominated by 2019 cohort, so biomass is still reduced.

Table 4. Comparison of Colorado River cutthroat trout population status in the Fremont River drainage by individual stream, 1994-2020. Trends noted as an increase (↑) or decrease (↓) if values changed by more than 10%; >0 indicates that trout were present but biomass or range was not measured. Biomass presented is a mean of all sampling stations where CRCT were detected.

State water identification number	Stream/tributary (indentation denotes tributaries)	Year	Occupied Habitat km	Occupied Habitat Trend	Biomass kg/ha	Biomass Trend	Comments
I AZ 130U	Pine Creek	1998	--	--	--	--	Non native trout
		2006	13.6	↑	42	↑	CRCT restored 2003
		2013	13.6	↔	176	↑	Population increasing
		2020	15.3[1]	↑	128	↓[2]	Expanded above reservoir 2013
I AZ 130M 01	Sand Creek	1994	--	--	--	--	Fishless
		1998	1.0	↑	>0	↑	CRCT introduced 1995
		2007	1.0	↔	50	↑	Limited persistence
		2013	0	↓	0	↓	Population lost
		2020	2.6[1]	↑	71	↑	CRCT re-introduced 2014
I AZ 130Z	UM Creek	1998	--	--	--	--	Non native trout removed 1991-96
		2007	23.6	↑	18	↑	CRCT introduced 2000-01
		2013	23.6	↔	20	↔	Supplemental stocking needed[3]
		2020	23.6[1]	↔	35	↑	Supplemental stocking needed[3]
I AZ 130Z 02	UM Creek, LF	1998	--	--	--	--	Non native trout removed 1991
		2007	5.1	↑	>0	↑	CRCT introduced 2000
		2013	5.1	↔	155	↑	Population increasing
		2020	5.1[1]	↔	122	↓	Natural variability
I AZ 130Z 03	UM Creek, RF	1994	--	--	--	--	Non native trout removed 1991
		1998	2.9	↑	60	↑	CRCT introduced 1996-97
		2007	7.1	↑	148	↑	Population increasing
		2013	7.1	↔	125	↓	Impacted by whirling disease
		2020	7.1[1]	↔	56	↓	Impacted by whirling disease

[1] – 100% of potential habitat.
[2] – Decrease attributed to addition of Station 4, where CRCT are still expanding.
[3] – Recruitment limited by whirling disease.

APPENDIX A

Survey results and maps for individual streams (coordinates are presented in NAD83 datum)—contained in the following pages as outlined below by drainage, stream, and tributary:

East Fork Boulder Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 12, 2020** Biologist: **M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **East Fork Boulder Creek, I AJ 110C, 02, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Upper end of headwater meadow—120459420E 4214764N**
   Downstream range of native trout (general description and GPS): **East Garkane Impoundment**
   Location (GPS) and description of barriers: **East Garkane Impoundment dam—120460305E 4210220N**
   Stream Length—Occupied habitat: **5.4 km (3.4 mi)** Available habitat: **11.7 km (7.3 mi)**[1]
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **3.0 km upstream of East Garkane Impoundment (King's Pasture)—120460054E 4212921N**
   Station 2: **Headwater meadow—120459437E 4214554N**

Parameter	**Station 1**	**Station 2**
Station length (m)	100 m	100 m
Mean stream width (m) (n)	7.14 m (10)	5.13 m (10)
Station area (hectares)	0.0714 ha	0.0513 ha
CRCT		
Removal Pattern	12 0	42 8
Population estimate (95 % CI)	12 (NA)	51 (±3)
Capture probability	1.000	0.833
Mean length (mm) (n)	197 (12)	228 (50)
Mean weight (g) (n)	96 (12)	166 (50)
Mean KTL (n)	1.16 (12)	1.20 (50)
Number fish per km (95 % CI)	120 (NA)	510 (±30)
Number fish per ha (95 % CI)	168 (NA)	995 (±59)
Biomass (kg per ha) (95 % CI)	16 (NA)	165 (±10)

4. Comments:

[1] – Includes 6.3 km from West Fork confluence to East Garkane Impoundment.

Additional Species Observed

	Brook Trout		**Tiger Trout**	
Station(s)	1	2	1	2
Fish per km	1,260	20	60	---
Fish per ha	1,764	39	84	---
Biomass (kg per ha)	96	4	12	---

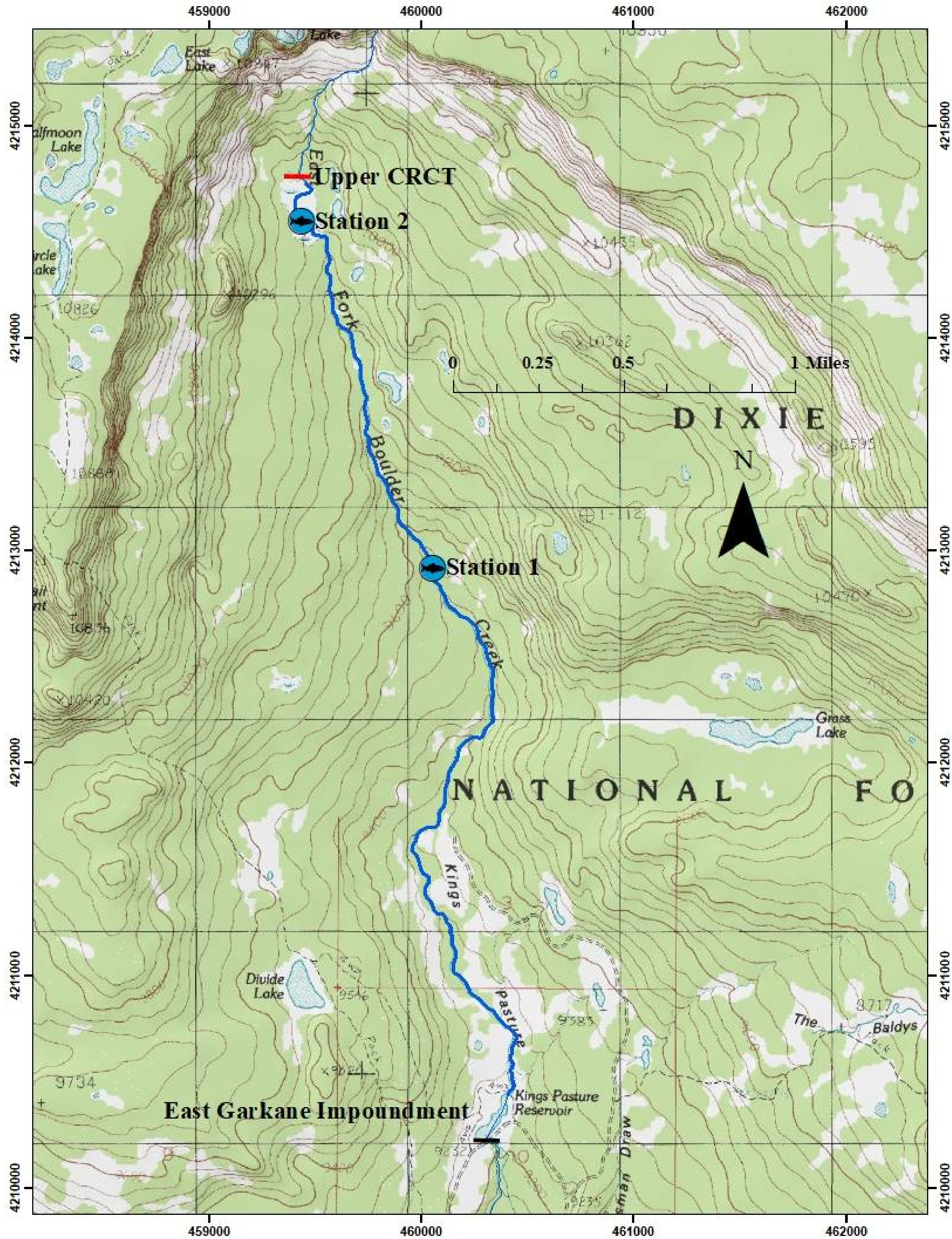

Figure A1. Locations of survey stations, barriers, and CRCT distribution in East Fork Boulder Creek.

West Fork Boulder Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 11 & 13, 2020** Biologist: **M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **West Fork Boulder Creek, I AJ 110D, 01 & 02, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Base of Boulder Top rim—120456260E 4213724N**
   Downstream range of native trout (general description and GPS): **East Fork confluence**
   Location (GPS) and description of barriers: **West Garkane Impoundment dam—120456893E 4210913N; upper constructed barrier[1]—120458511E 4206297N; lower constructed barrier—120458778E 4206223N**
   Stream Length—Occupied habitat: **9.5 km (5.9 mi)** Available habitat: **9.5 km (5.9 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **100 m upstream of upper constructed barrier—120458452E 4206402N**
   Station 2: **300 m upstream of West Garkane Impounment—120456917E 4211225N**
   Station 3: **1.8 km m upstream of West Garkane Impounment—120456667E 4212592N**

Parameter	**Station 1**	**Station 2**	**Station 3**
Station length (m)	200 m	100 m	100 m
Mean stream width (m) (n)	2.20 m (10)	2.59 m (10)	3.10 m (10)
Station area (hectares)	0.0441 ha	0.0259 ha	0.0310 ha
CRCT			
Removal Pattern	0	84 14	8 0
Population estimate (95 % CI)	0 (NA)[2]	100 (±4)	8 (NA)
Capture probability	NA	0.845	1.000
Mean length (mm) (n)	NA	101 (98)[3]	212 (8)
Mean weight (g) (n)	NA	21 (27)	166 (8)
Mean KTL (n)	NA	0.98 (27)	1.18 (8)
Number fish per km (95 % CI)	0 (NA)	1,000 (±40)	80 (NA)
Number fish per ha (95 % CI)	0 (NA)	3,868 (±155)	258 (NA)
Biomass (kg per ha) (95 % CI)	0 (NA)	80 (±3)	43 (NA)

4. Comments: Stream and CRCT population severely impacted by Spring 2019 flood (rain on snow event).

[1] – Upper barrier buried and damaged by flood. Rebuilt fall 2019.
[2] – 200 CRCT transferred from Pine Creek (Escalante drainage) to Station 1 in Oct 2020.
[3] – Strong 2019 year class (age 1 in 2020) appears to have been washed down to Station 2 reach.

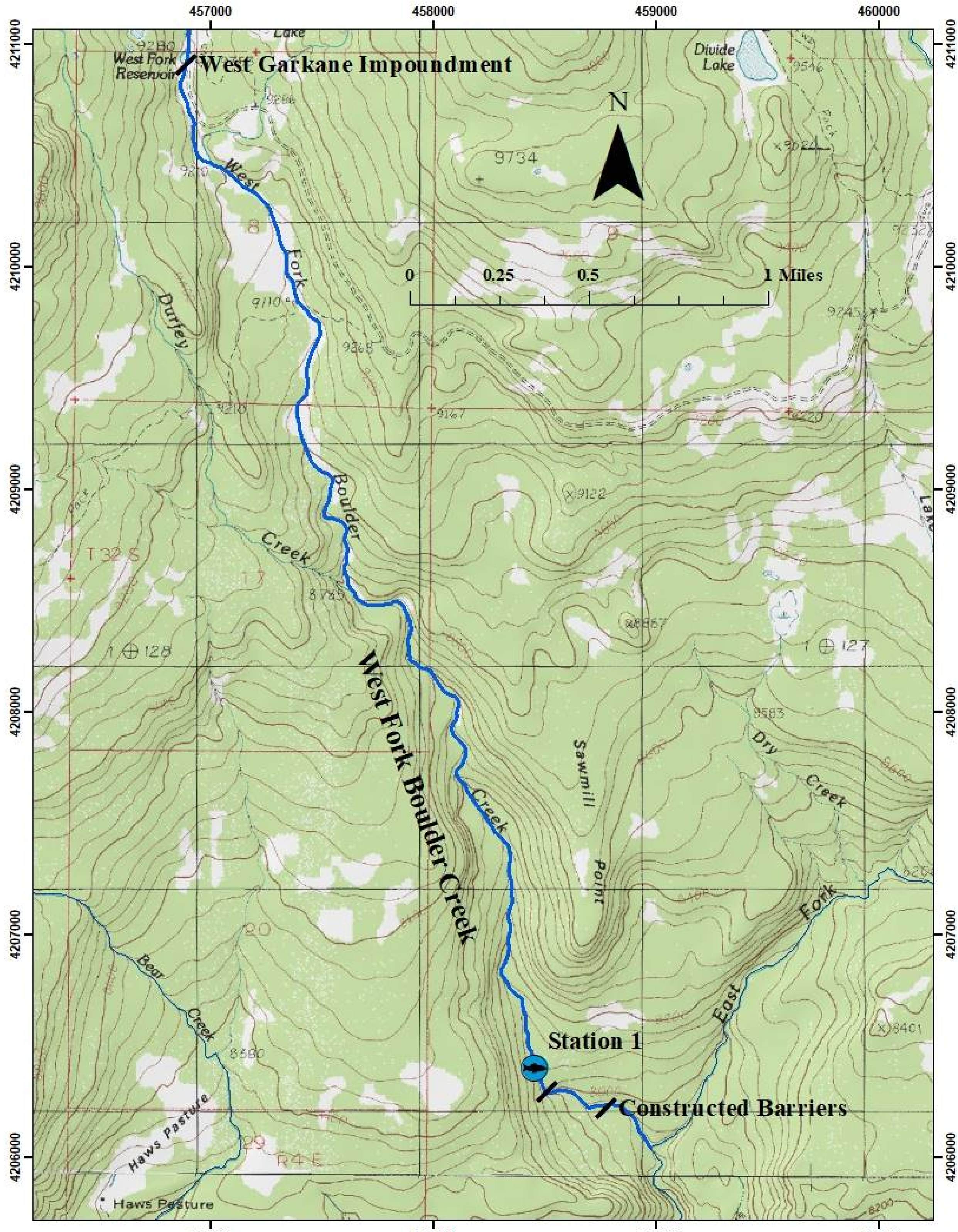

Figure A2. Locations of survey stations, barriers, and CRCT distribution in lower West Fork Boulder Creek.

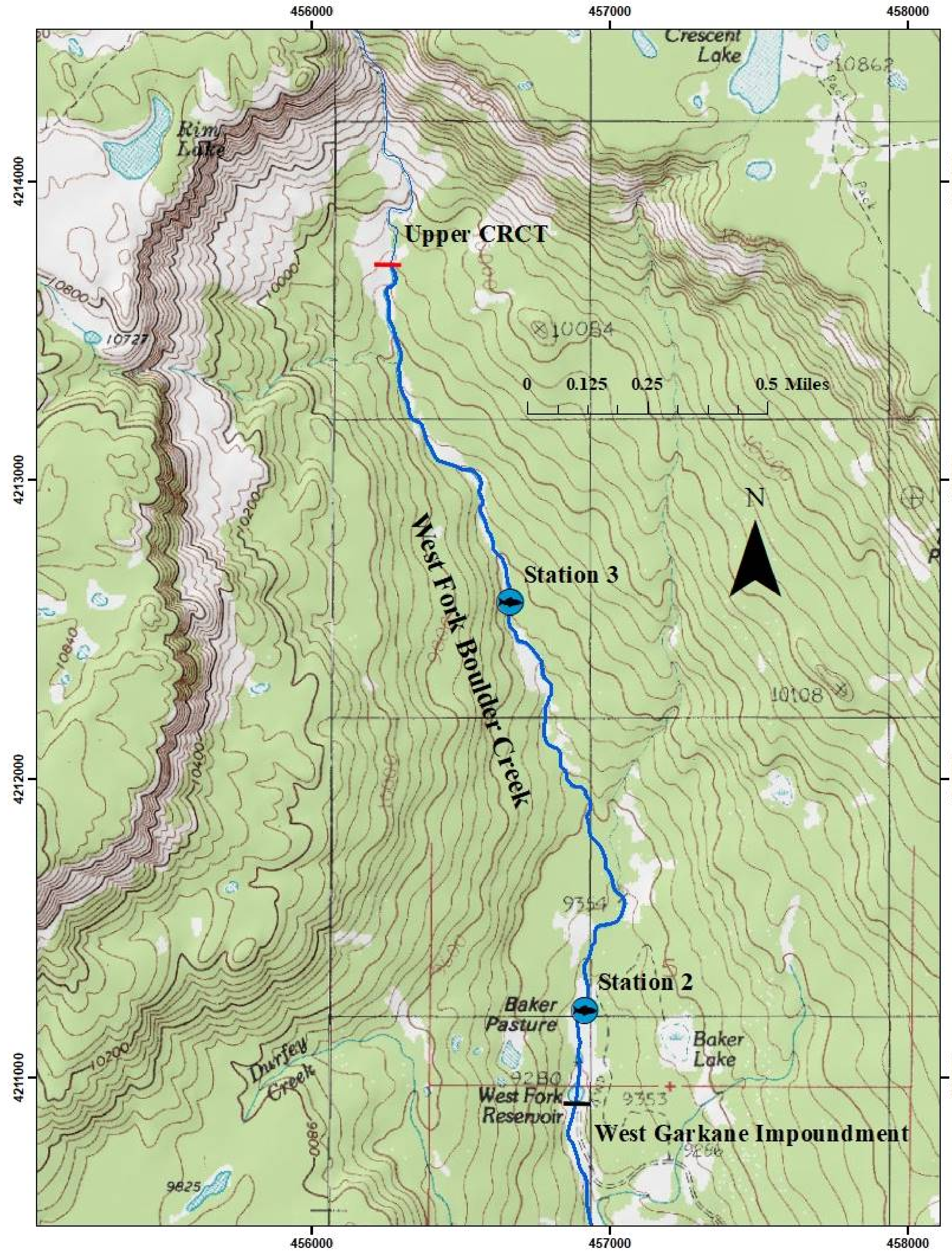

Figure A3. Locations of survey stations, barriers, and CRCT distribution in upper West Fork Boulder Creek.

Hall Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Sep 3, 2020** Biologist: **M. Golden**
2. Stream Information—
   Name, catalog #, section, county: **Hall Creek, I AJ 170C, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Waterfall below confluence of primary forks—120425233E 4188841N**
   Downstream range of native trout (general description and GPS): **Birch Creek confluence**
   Location (GPS) and description of barriers[1]: **Waterfall below confluence of primary forks; waterfall in Birch Creek (just upstream of North Creek confluence)—120439760E 4179942N; 15 km of desert wash habitat in Birch Creek**
   Stream Length—Occupied habitat: **3.9 km (2.4 mi)** Available habitat: **3.9 km (2.4 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **0.2 km upstream of admin road crossing—120427329E 4183944N**

Parameter	**Station 1**
Station length (m)	105 m
Mean stream width (m) (n)	1.38 m (10)
Station area (hectares)	0.0145 ha
CRCT	
Removal Pattern	42 6
Population estimate (95 % CI)	48 (±2)
Capture probability	0.889
Mean length (mm) (n)	124 (48)
Mean weight (g) (n)	24 (48)
Mean KTL (n)	0.91 (48)
Number fish per km (95 % CI)	457 (±19)
Number fish per ha (95 % CI)	3,313 (±138)
Biomass (kg per ha) (95 % CI)	79 (±4)

4. Comments: Young of the year abundant.

[1] – Admin road culvert (previous barrier) was replaced in 2019 with a timber crib bridge.

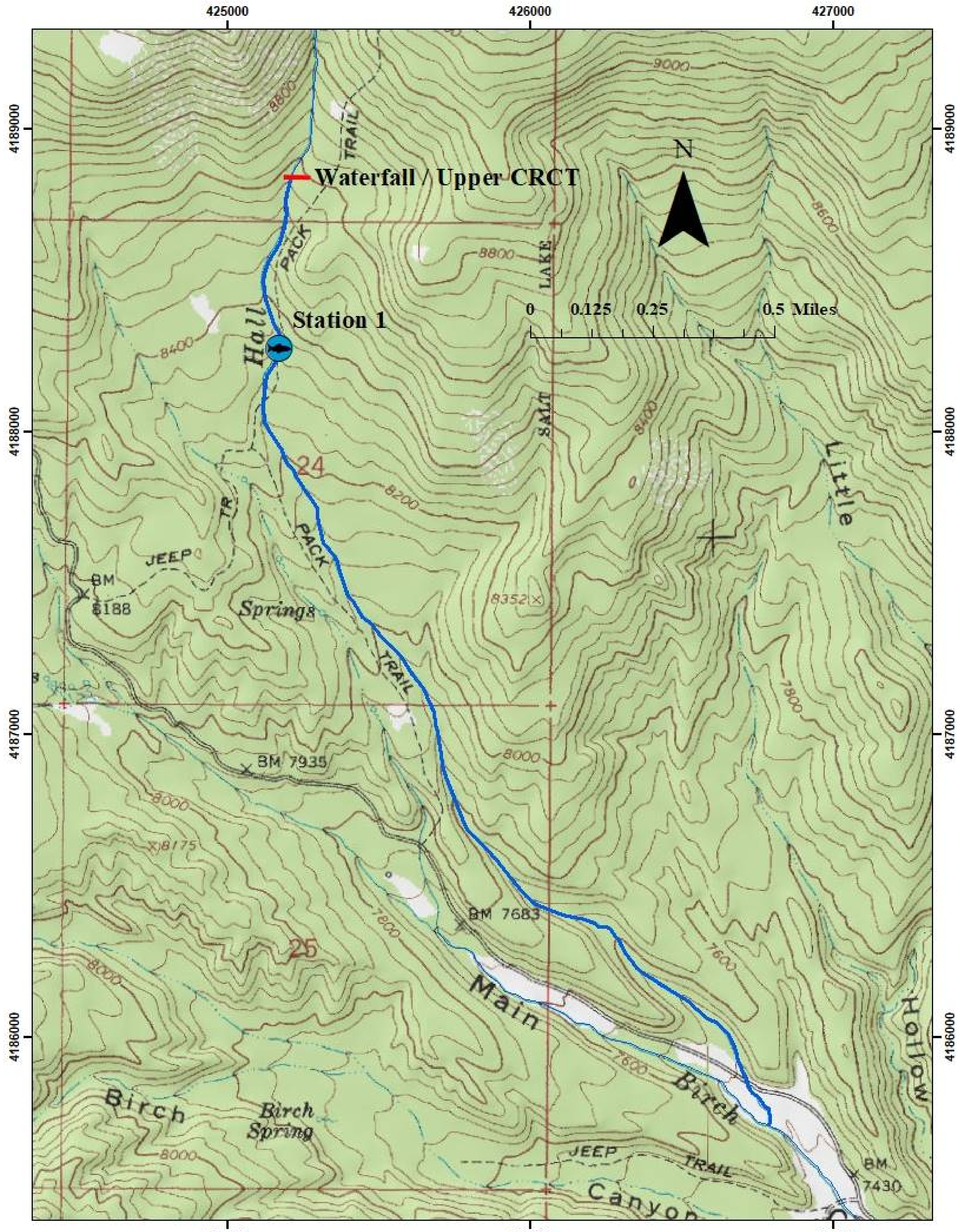

Figure A4. Locations of survey station and CRCT distribution in Hall Creek.

North Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Sep 9, 2020** Biologist: **M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **North Creek, I AJ 160, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Cascade upstream of Station 1—120428393E 4198292N**
   Downstream range of native trout (general description and GPS): **Cascades 0.6 km upstream of Barkers/Joe Lay outflow confluence—120428788E 4197745N**
   Location (GPS) and description of barriers: **Waterfall upstream of Station 1—120428387E 4198344N; Waterfalls downstream of Station 1—120428581E 4198104N to 120429203E 4197623N**
   Stream Length—Occupied habitat: **0.8 km (0.5 mi)** Available habitat: **13.4 km[1] (8.3 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **1.2 km upstream of Barkers/Joe Lay outflow confluence —120428460E 4198198N**

Parameter	**Station 1**
Station length (m)	100 m
Mean stream width (m) (n)	3.60 m (10)
Station area (hectares)	0.0360 ha
CRCT	
Removal Pattern	20 6
Population estimate (95 % CI)	27 (±4)
Capture probability	0.765
Mean length (mm) (n)	127 (26)
Mean weight (g) (n)	36 (26)
Mean KTL (n)	1.12 (26)
Number fish per km (95 % CI)	270 (±40)
Number fish per ha (95 % CI)	749 (±111)
Biomass (kg per ha) (95 % CI)	27 (±4)

4. Comments:
[1] – Includes 1.0 km upstream of current distribution to the Gap and 11.7 km downstream to North Creek Reservoir.

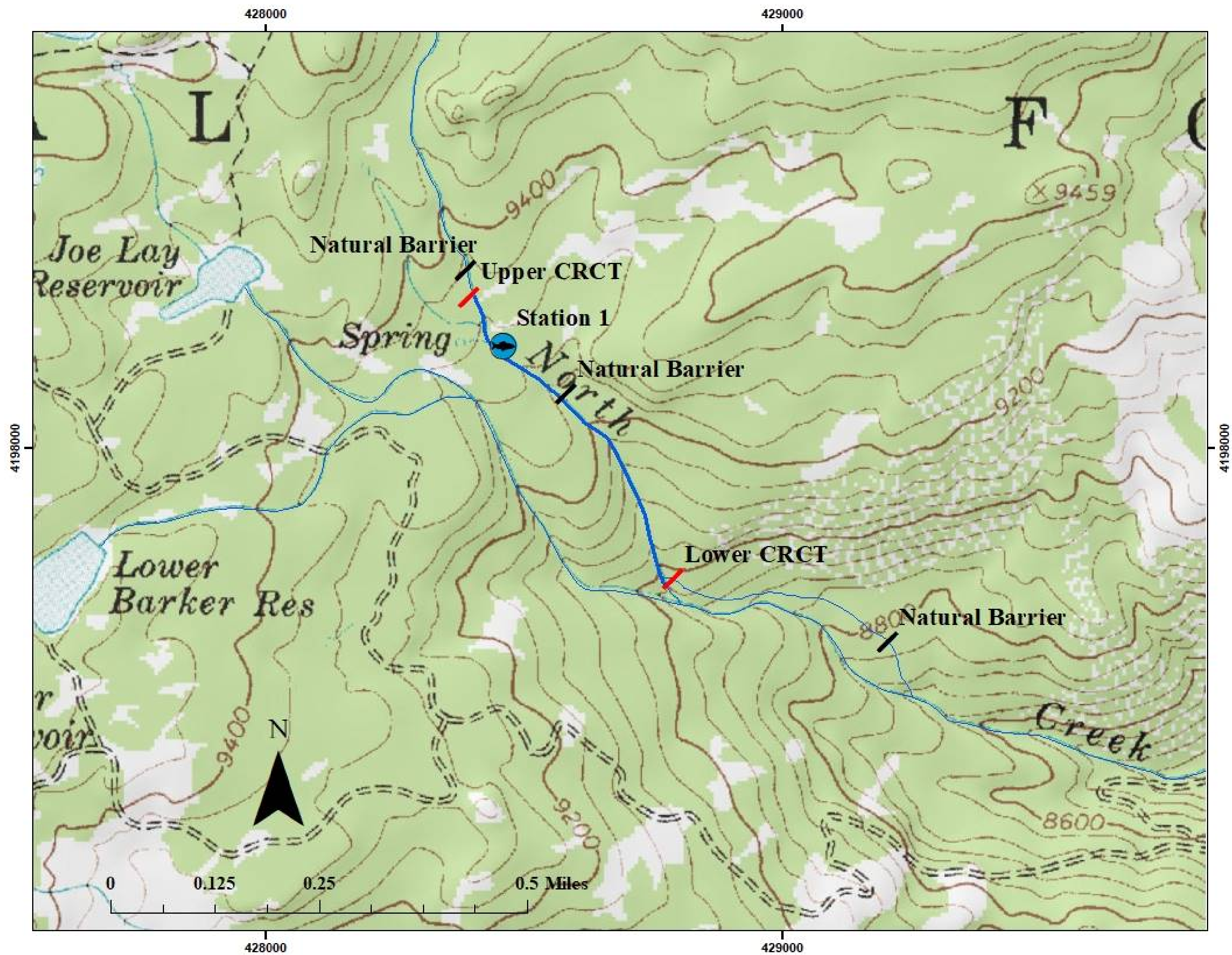

Figure A5. Locations of survey stations, barriers, and CRCT distribution in North Creek.

Twitchell Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 20, 2020** Biologist: **M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **Twitchell Creek, I AJ 160F, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Round Willow Bottom Reservoir dam—120425977E 4195752N**
   Downstream range of native trout (general description and GPS): **North Creek confluence**
   Location (GPS) and description of barriers: **Constructed barrier—120430257E 4195911N; waterfall—120428545E 4196627N**
   Stream Length—Occupied habitat: **5.4 km (3.4 mi)** Available habitat: **5.4 km (3.4 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **260 m upstream of construted barrier—120430020E 4195979N**
   Station 2: **130 m downstream of forks in Holby's Bottom—120427230E 4196427N**

Parameter	**Station 1**	**Station 2**
Station length (m)	100 m	100 m
Mean stream width (m) (n)	2.05 m (10)	2.19 m (10)
Station area (hectares)	0.0205 ha	0.0219 ha
CRCT		
Removal Pattern	24 5	63 11
Population estimate (95 % CI)	29 (±2)	75 (±4)
Capture probability	0.853	0.851
Mean length (mm) (n)	121 (29)	146 (43)
Mean weight (g) (n)	27 (29)	34 (43)
Mean KTL (n)	1.01 (29)	0.95 (43)
Number fish per km (95 % CI)	290 (±20)	750 (±40)
Number fish per ha (95 % CI)	1,418 (±97)	3,431 (±183)
Biomass (kg per ha) (95 % CI)	38 (±3)	110 (±6)

4. Comments: Young of the year observed.

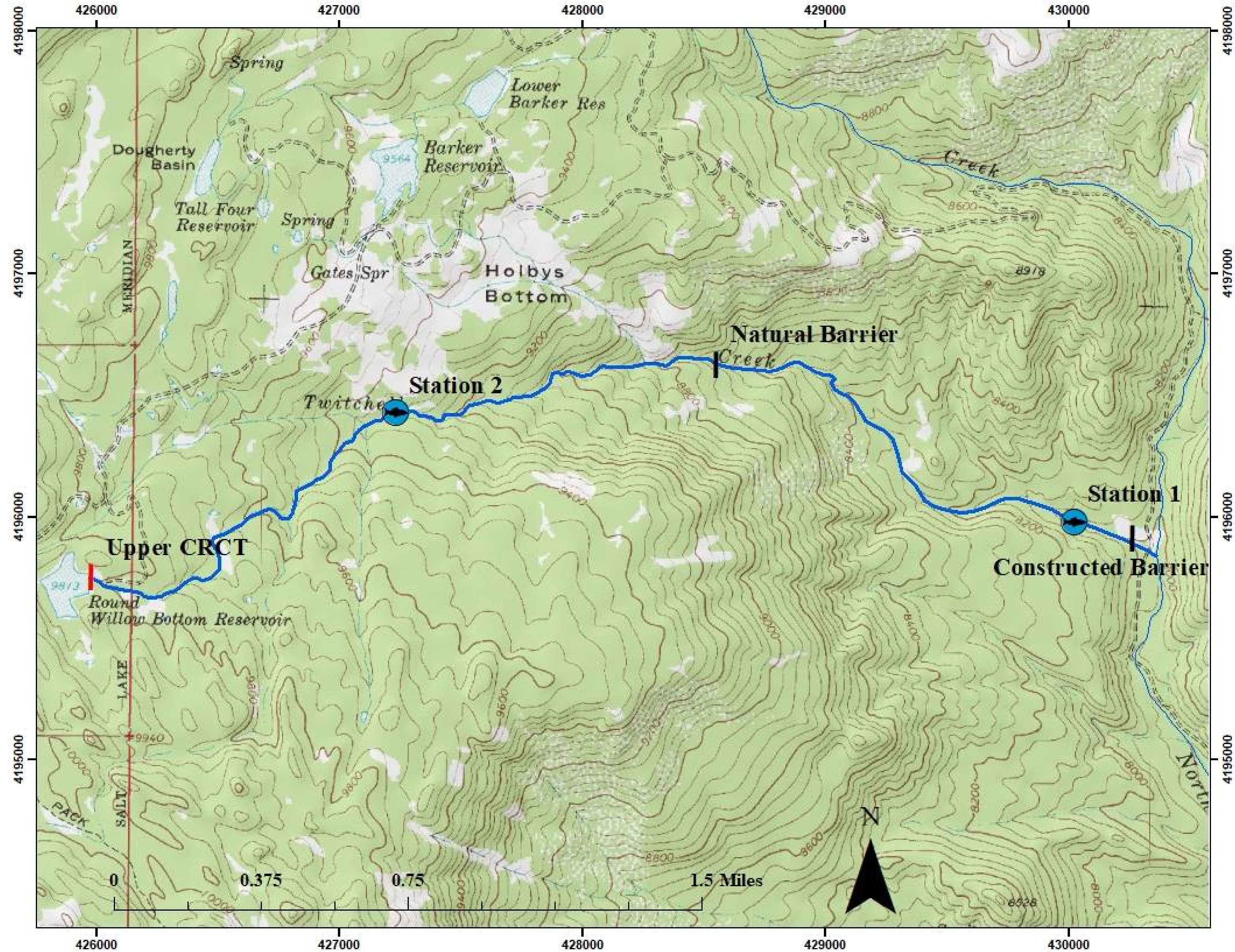

Figure A6. Locations of survey stations, barriers, and CRCT distribution in Twitchell Creek.

White Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 19, 2020** Biologist: **M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **White Creek, I AJ 160E, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Right Fork—120429120E 4194219N; Left Fork (road crossing)—120429009E 4193961N**
   Downstream range of native trout (general description and GPS): **North Creek confluence**
   Location (GPS) and description of barriers: **Lower constructed barrier—120431035E 4193612N; upper constructed barrier—120430955E 4193560N; waterfall—120430582E 4193672N**
   Stream Length—Occupied habitat: **3.0 km (1.9 mi)** Available habitat: **3.0 km (1.9 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **140 m upstream of upper barrier—120430891E 4193443N**
   Station 2: **100 m downstream of forks —120429864E 4194003N**

Parameter	**Station 1**	**Station 2**
Station length (m)	100 m	100 m
Mean stream width (m) (n)	2.12 m (10)	1.65 m (10)
Station area (hectares)	0.0212 ha	0.0165 ha
CRCT		
Removal Pattern	65 8	38 5
Population estimate (95 % CI)	73 (±2)	43 (±2)
Capture probability	0.901	0.896
Mean length (mm) (n)	140 (73)	146 (43)
Mean weight (g) (n)	30 (73)	34 (43)
Mean KTL (n)	0.93 (73)	0.95 (43)
Number fish per km (95 % CI)	730 (±20)	430 (±20)
Number fish per ha (95 % CI)	3,445 (±95)	2,602 (±121)
Biomass (kg per ha) (95 % CI)	102 (±3)	89 (±4)

4. Comments: Young of the year observed.

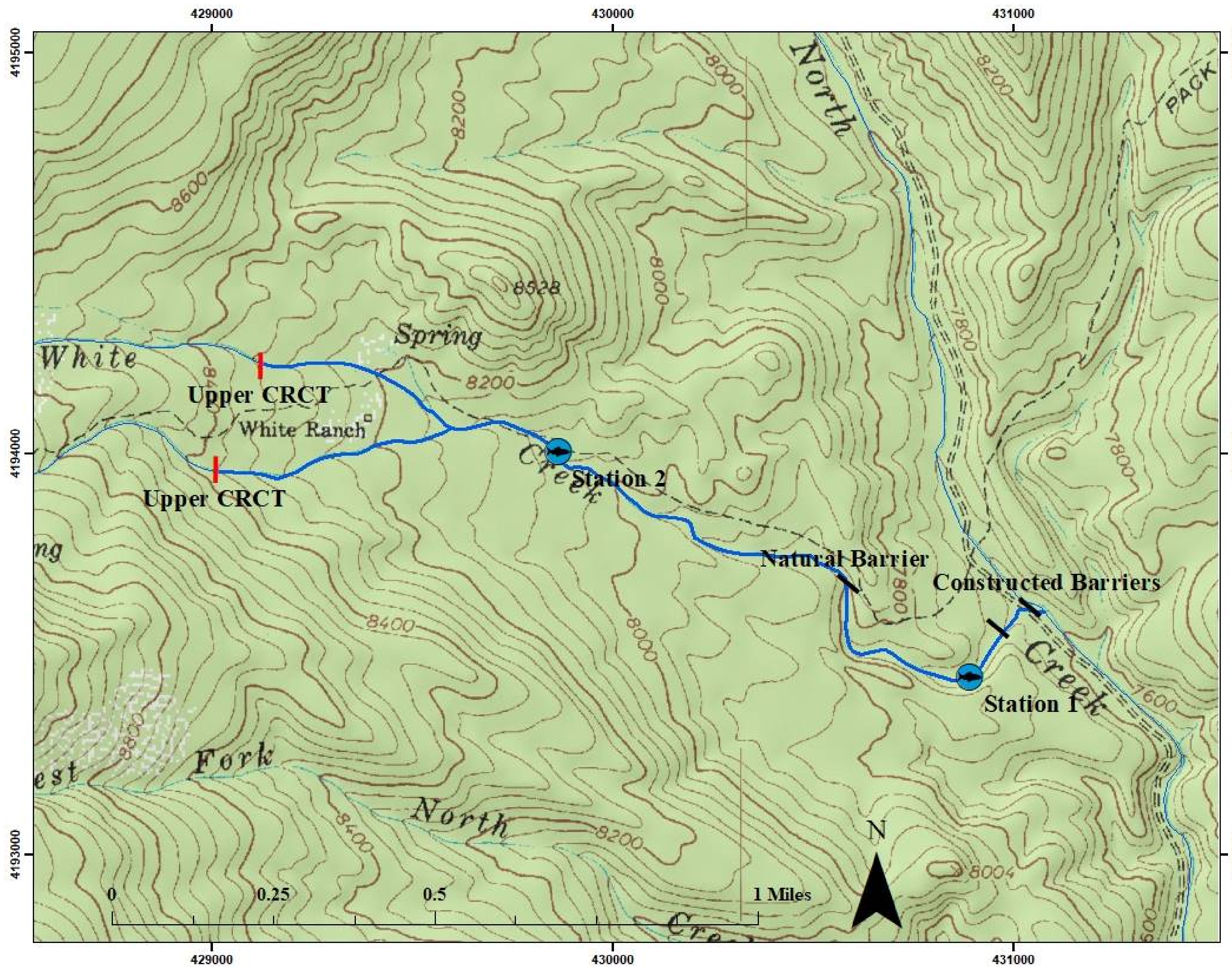

Figure A7. Locations of survey stations, barriers, and CRCT distribution in White Creek.

Pine Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 24-Sep 1, 2020** Biologist: **M. Hadley, M. Golden**
2. Stream Information—
   Name, catalog #, section, county: **Pine Creek, I AJ 150, 02, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Base of Griffin Top rim—120444342E 4208714N; headwater spring of north tributary—120443767E 4209406**
   Downstream range of native trout (general description and GPS): **Lower constructed barrier**
   Location (GPS) and description of barriers: **Natural waterfall—120442456E 4207689N; upper constructed barrier—120442716 4202668N; lower constructed barrier—120442605E 4202032N**
   Stream Length—Occupied habitat: **9.6 km (6.0 mi)** Available habitat: **30.3 km[1] (18.8 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **Cowpuncher Guard Station—120442424E 4203731N**
   Station 2: **1.0 km upstream of West Branch confluence—120442270E 4205498N**
   Station 3: **Jubliee Trail crossing (200 m downstream of forks confluence)—120443354E 42008848N**

Parameter	**Station 1**	**Station 2**	**Station 3**
Station length (m)	100 m	100 m	100 m
Mean stream width (m) (n)	2.51 m (10)	2.38 m (10)	1.97 m (10)
Station area (hectares)	0.0251 ha	0.0238 ha	0.0197 ha
CRCT			
Removal Pattern	101 15	53 12	62 3
Population estimate (95 % CI)	118 (±4)	67 (±5)	65 (±1)
Capture probability	0.859	0.802	0.956
Mean length (mm) (n)	142 (116)	140 (65)	140 (65)
Mean weight (g) (n)	36 (116)	40 (65)	40 (65)
Mean KTL (n)	0.92 (116)	0.99 (65)	0.99 (65)
Number fish per km (95 % CI)	1,180 (±40)	670 (±50)	650 (±10)
Number fish per ha (95 % CI)	4,709 (±159)	2,814 (±210)	3,305 (±51)
Biomass (kg per ha) (95 % CI)	171 (±5)	114 (±8)	68 (±1)

4. Comments: Young of the year observed.

[1] – Includes 20 km downstream of current distribution.

West Branch Pine Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Aug 31, 2020** Biologist: **M. Hadley, M. Golden**
2. Stream Information—
   Name, catalog #, section, county: **West Branch Pine Creek, I AJ 150C, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Confluence of intermittent forks—120439465E 4206234N**
   Downstream range of native trout (general description and GPS): **Pine Creek confluence**
   Location (GPS) and description of barriers: **None**
   Stream Length—Occupied habitat: **3.7 km (2.3 mi)** Available habitat: **3.7 km (2.3 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **1.0 km upstream of Pine Creek confluence (just above road crossing)—120441386E 4204868N**

Parameter	**Station 1**
Station length (m)	100 m
Mean stream width (m) (n)	3.01 m (10)
Station area (hectares)	0.0301 ha
CRCT	
Removal Pattern	101 17
Population estimate (95 % CI)	120 (±4)
Capture probability	0.849
Mean length (mm) (n)	124 (118)
Mean weight (g) (n)	24 (118)
Mean KTL (n)	0.93 (118)
Number fish per km (95 % CI)	1,200 (±40)
Number fish per ha (95 % CI)	3,988 (±133)
Biomass (kg per ha) (95 % CI)	94 (±3)

4. Comments: Young of the year abundant.

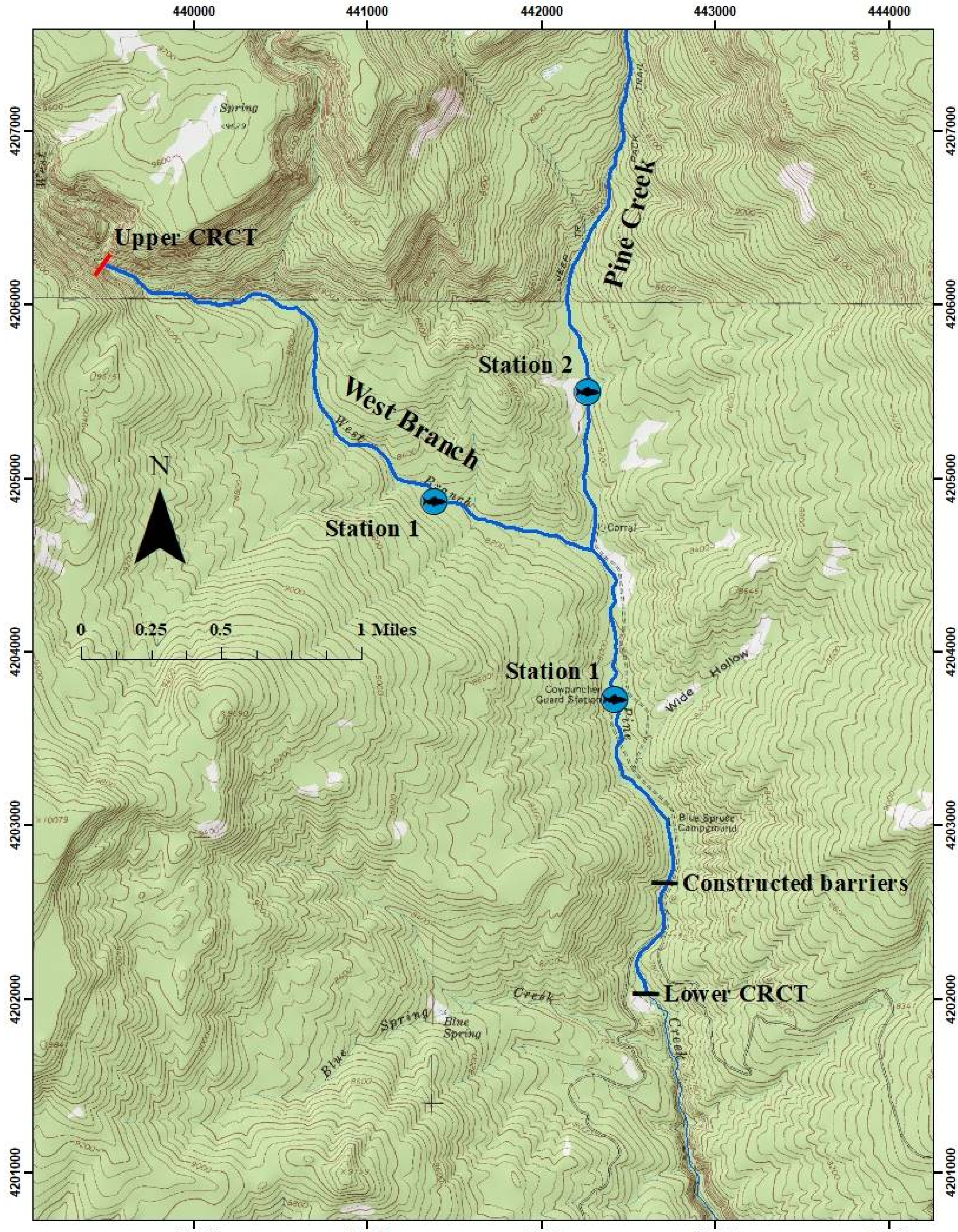

Figure A8. Locations of survey stations, barriers, and CRCT distribution in lower Pine Creek and West Branch Pine Creek.

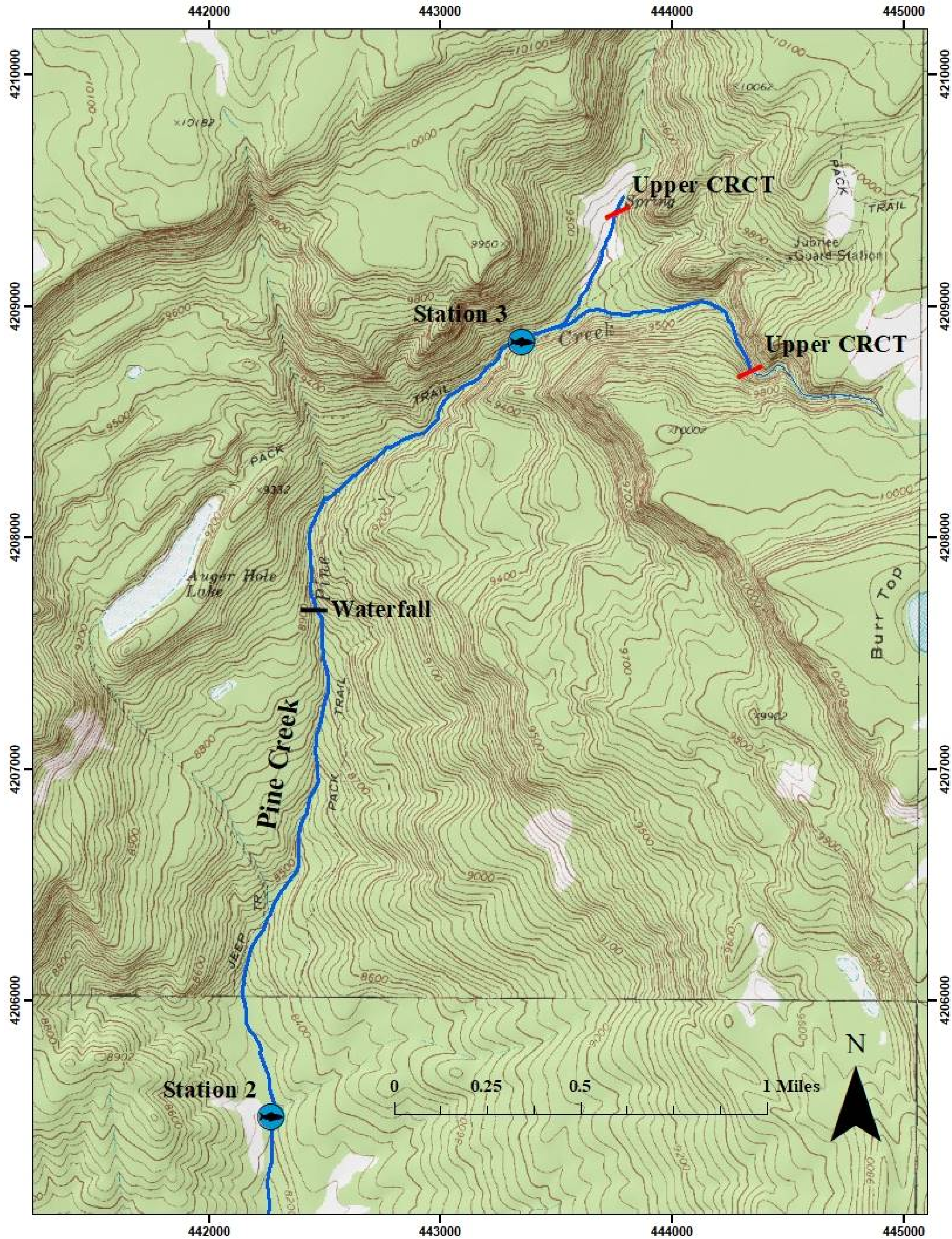

Figure A9. Locations of survey stations, barriers, and CRCT distribution in upper Pine Creek.

Water Canyon—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Sep 24 & 29, 2020** Biologist: **M. Hadley, M. Golden**
2. Stream Information—
   Name, catalog #, section, county: **Water Canyon, I AJ 170B, 01, Garfield**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Confluence with intermittent south tributary—120424359E 4183421N**
   Downstream range of native trout (general description and GPS): **Birch Creek confluence**
   Location (GPS) and description of barriers: **Waterfall in Birch Creek (just upstream of North Creek confluence)—120439760E 4179942N; 15 km of desert wash habitat in Birch Creek**
   Stream Length—Occupied habitat: **4.5 km (2.8 mi)** Available habitat: **4.5 km (2.8 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **100 m downstream of Cherry Hollow—120427329E 4183944N**
   Station 2: **0.5 km upstream of Cherry Hollow—120426751E 4183886N**

Parameter	**Station 1**	**Station 2**
Station length (m)	100 m	91 m
Mean stream width (m) (n)	1.16 m (10)	1.21 m (10)
Station area (hectares)	0.0116 ha	0.0110 ha
CRCT		
Removal Pattern	13 0	46 3
Population estimate (95 % CI)	13 (NA)	49 (±1)
Capture probability	1.000	0.942
Mean length (mm) (n)	152 (13)	117 (49)
Mean weight (g) (n)	42 (13)	20 (49)
Mean KTL (n)	1.03 (13)	0.92 (49)
Number fish per km (95 % CI)	130 (NA)	538 (±11)
Number fish per ha (95 % CI)	1,125 (NA)	4,449 (±91)
Biomass (kg per ha) (95 % CI)	48 (NA)	90 (±2)

4. Comments: Young of the year observed.
Lower reach affected by flood-prone north drainage just downstream (east) of Station 2.

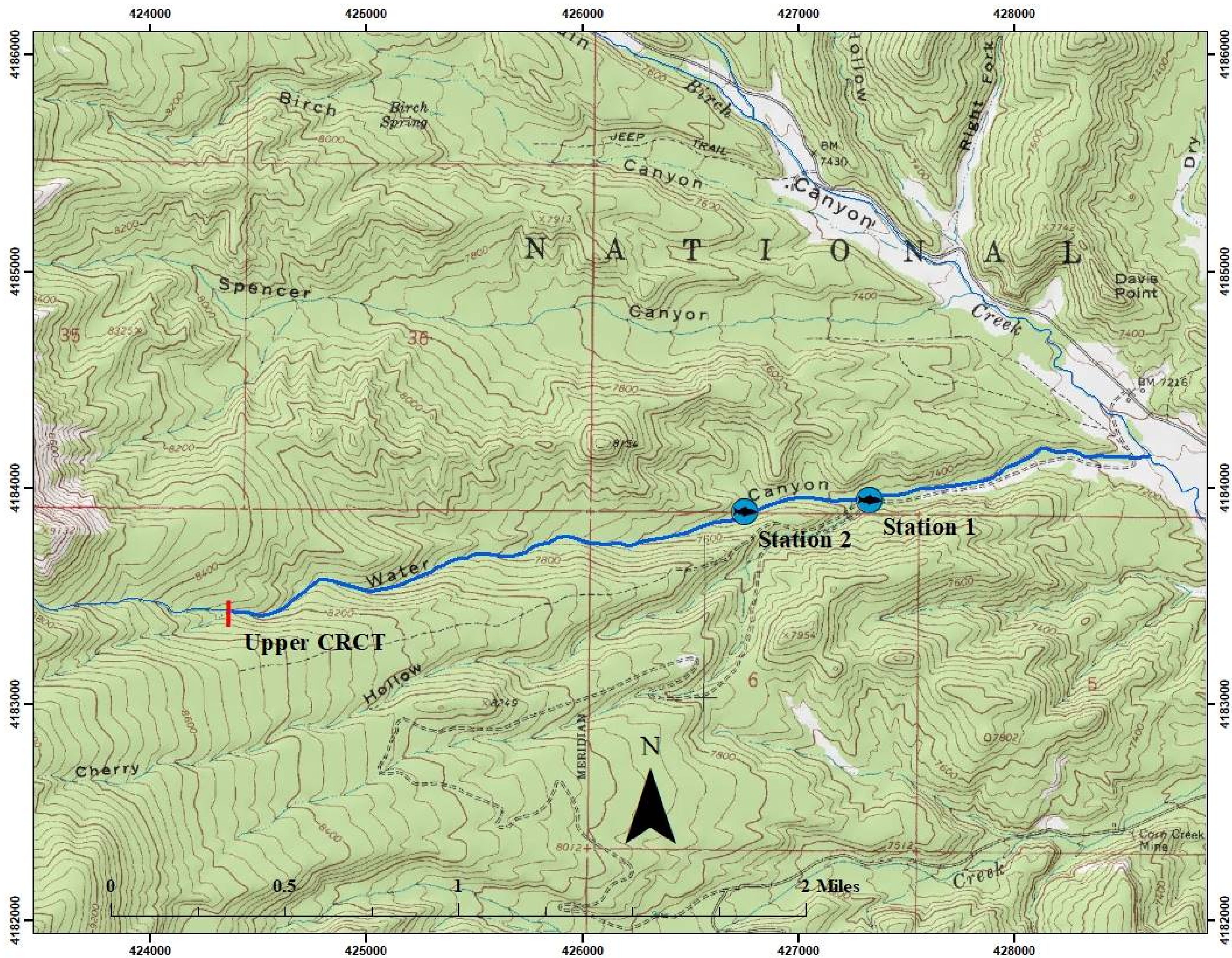

Figure A10. Locations of survey stations and CRCT distribution in Water Canyon.

Pine Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **July 23, Aug 6, Oct 5, 2020**
   Biologist: **J. Swensen, J. Whelan, M. Golden, M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **Pine Creek, I AZ 130U, 03, Wayne**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Base of hill in Pine Creek Cove—120451573E 4228669N**
   Downstream range of native trout (general description and GPS): **King Ranch pond—120449659E 4236384N**
   Location (GPS) and description of barriers: **Two constructed barriers just below Wildcat Hollow—120448713E 4235669N; cascade at Pine Creek Reservoir inlet—120450339E 4228198N**
   Stream Length—Occupied habitat: **15.3 km (9.5 mi)** Available habitat: **15.3 km (9.5 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **200 m upstream of constructed barriers—120448544E 4235456N**
   Station 2: **Livestock exclosure below Dark Valley Draw—120448434E 4231219N**
   Station 3: **0.5 km downstream of FR 571 crossing—120449824E 4229610N**
   Station 4: **0.8 km upstream of Pine Creek Reservoir—120451033E 4228010N**

Parameter	**Station 1**	**Station 2**	**Station 3**	**Station 4**
Station length (m)	100 m	100 m	100 m	100 m
Mean stream width (m) (n)	2.36 m (10)	1.67 m (10)	2.08 m (10)	3.32 m (10)
Station area (hectares)	0.0236 ha	0.0167 ha	0.0208 ha	0.0332 ha
CRCT				
Removal Pattern	47 3	83 6	75 17	38 6
Population estimate (95 % CI)	50 (±1)	89 (±1)	96 (±7)	44 (±2)
Capture probability	0.943	0.937	0.786	0.880
Mean length (mm) (n)	149 (50)	144 (89)	147 (92)	137 (44)
Mean weight (g) (n)	40 (50)	39 (89)	39 (92)	26 (44)
Mean KTL (n)	0.92 (50)	0.96 (50)	0.99 (92)	0.92 (44)
Number fish per km (95 % CI)	500 (±10)	890 (±10)	960 (±70)	440 (±20)
Number fish per ha (95 % CI)	2,119 (±42)	5,329 (±60)	4,627 (±337)	1,325 (±60)
Biomass (kg per ha) (95 % CI)	85 (±2)	210 (±2)	181 (±13)	35 (±2)

4. Comments: Young of the year observed at most stations.
No other species observed, however, brook trout are known to occur in a pond upstream of Station 3 and a limited number of tiger trout have been stocked in Pine Creek Reservoir.

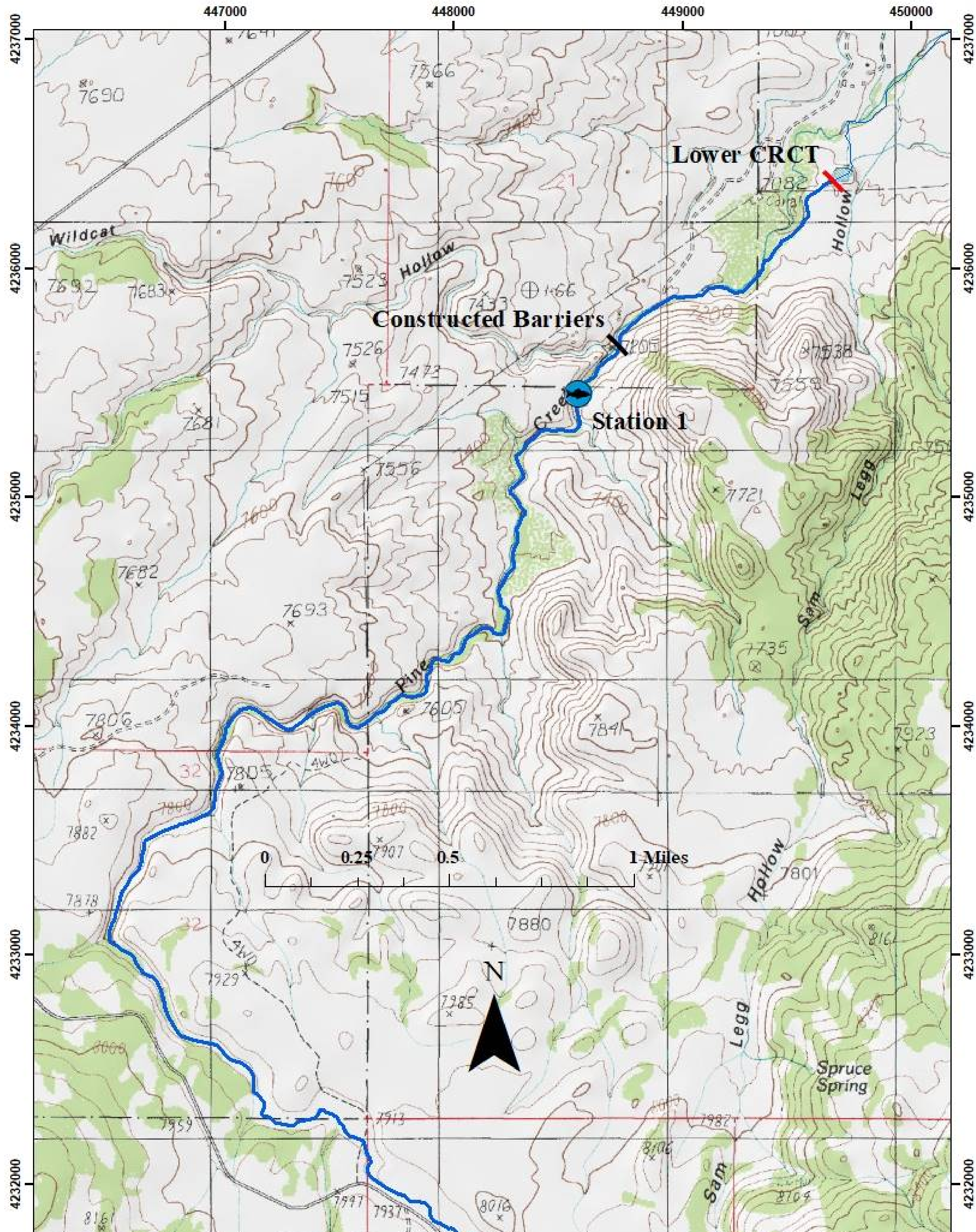

Figure A11. Locations of survey stations, barriers, and CRCT distribution in lower Pine Creek.

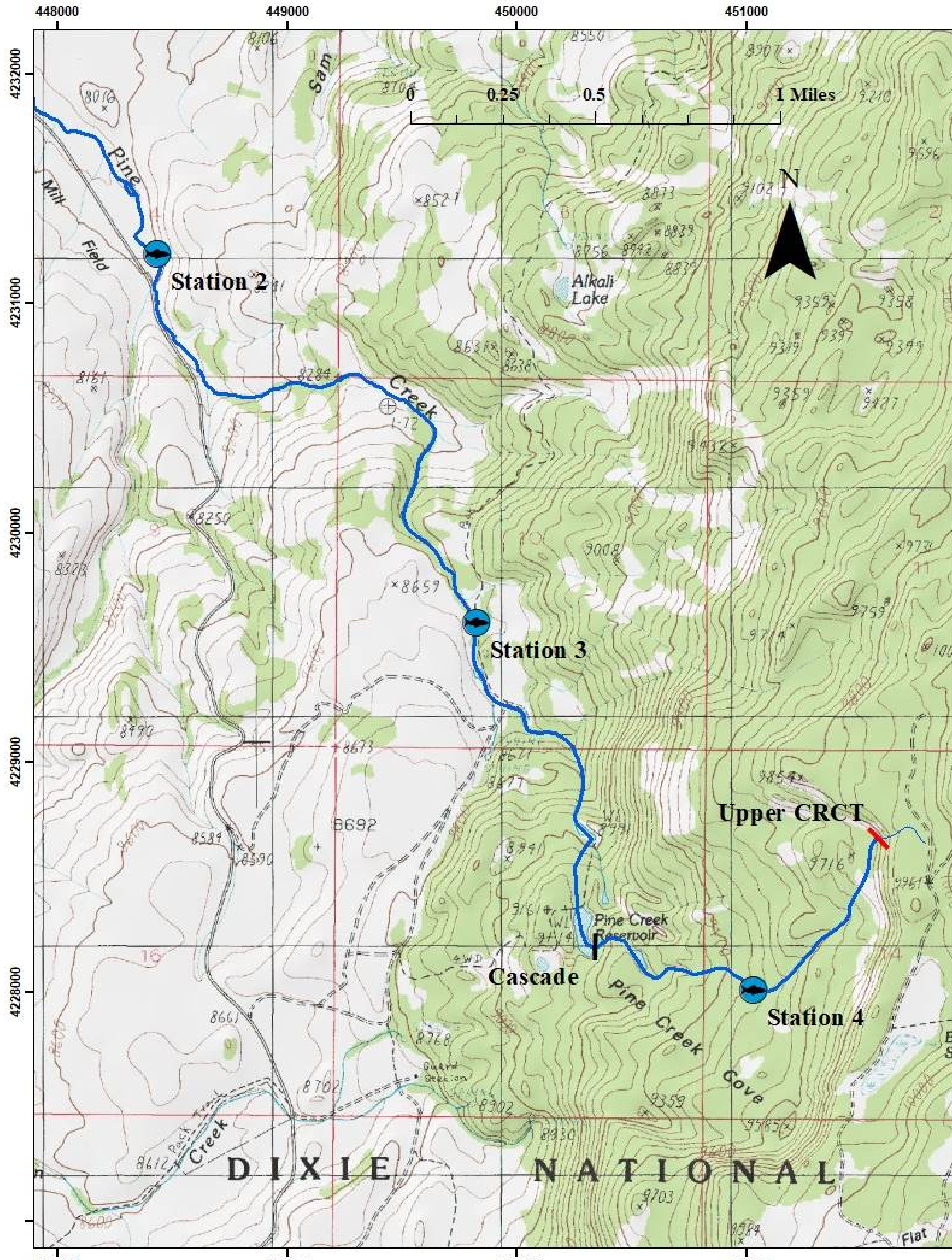

Figure A12. Locations of survey stations, barriers, and CRCT distribution in upper Pine Creek.

Sand Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **Oct 6, 2020** Biologist: **M. Hadley, J. Swensen**
2. Stream Information—
   Name, catalog #, section, county: **Sand Creek, I AZ 130M 01, 02, Wayne**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Steep gradient upstream of upper meadow—120459260E 4247835N**
   Downstream range of native trout (general description and GPS): **Insufficient habitat downstream of Hells Hole confluence—120459172E 4245721N**
   Location (GPS) and description of barriers: **Natural barrier at Hells Hole confluence — 120459172E 4245721N; Numerous waterfalls in middle reach—120459449E 4247241N**
   Stream Length—Occupied habitat: **2.6 km (1.6 mi)** Available habitat: **2.6 km (1.6 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **Meadow in upper reach—120459206E 4247514N**

Parameter	**Station 1**
Station length (m)	91 m
Mean stream width (m) (n)	0.97 m (10)
Station area (hectares)	0.0088 ha
CRCT	
Removal Pattern	13 1
Population estimate (95 % CI)	14 (±1)
Capture probability	0.933
Mean length (mm) (n)	156 (14)
Mean weight (g) (n)	45 (14)
Mean KTL (n)	1.00 (14)
Number fish per km (95 % CI)	154 (±11)
Number fish per ha (95 % CI)	1,592 (±114)
Biomass (kg per ha) (95 % CI)	71 (±5)

4. Comments: Young of the year abundant.

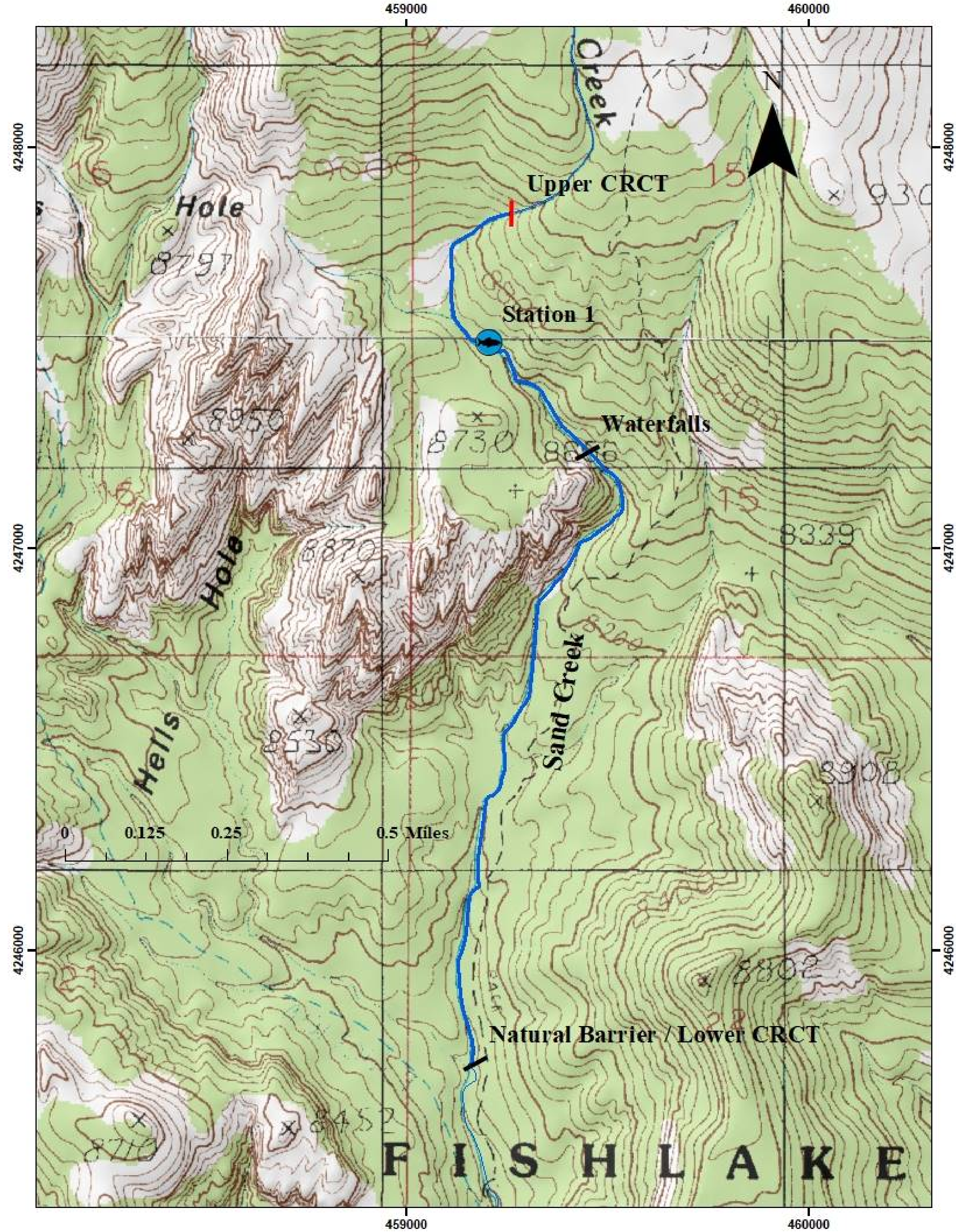

Figure A13. Locations of survey station, barriers, and CRCT distribution in Sand Creek.

UM Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **July 21, Aug 17-18, 2020**
   Biologist: **J. Swensen, J. Whelan, M. Hadley**
2. Stream Information—
   Name, catalog #, section, county: **UM Creek, I AZ 130Z, 02, Sevier**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Confluence of Right and Left Forks**
   Downstream range of native trout (general description and GPS): **Forsyth Reservoir**
   Location (GPS) and description of barriers: **Constructed barrier 1.6 km upstream of Forsyth Reservoir—120452185E 4266260N**
   Stream Length—Occupied habitat: **23.6 km (14.7 mi)** Available habitat: **23.6 km (14.7 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **2.4 km upstream of Forsyth Reservoir—120451633E 4266916N**
   Station 2: **Lower end of Danish Meadow—120449708E 4271699N**
   Station 3: **Just downstream of Water Flat bridge—120447957E 4276910N**

Parameter	**Station 1**	**Station 2**	**Station 3**
Station length (m)	143 m	152 m	100 m
Mean stream width (m) (n)	4.80 m (10)	4.13 m (10)	3.91 m (10)
Station area (hectares)	0.0687 ha	0.0628 ha	0.0391 ha
CRCT			
Removal Pattern	5 0	13 4	5 1
Population estimate (95 % CI)	5 (NA)	17 (±2)	6 (±1)
Capture probability	1.000	0.810	0.857
Mean length (mm) (n)	247 (5)	259 (17)	228 (50)
Mean weight (g) (n)	239 (5)	270 (17)	166 (50)
Mean KTL (n)	1.15 (5)	1.09 (17)	1.20 (50)
Number fish per km (95 % CI)	35 (NA)	112 (±13)	60 (±10)
Number fish per ha (95 % CI)	73 (NA)	271 (±32)	153 (±26)
Biomass (kg per ha) (95 % CI)	17 (NA)	73 (±9)	16 (±3)

4. Comments:

Additional Species Observed

	Tiger Trout			**Splake**
Station(s)	1	2	3	1
Fish per km	119	7	40	7
Fish per ha	248	16	102	15
Biomass (kg per ha)	73	9	49	4.5

Mottled sculpin abundant at all stations.

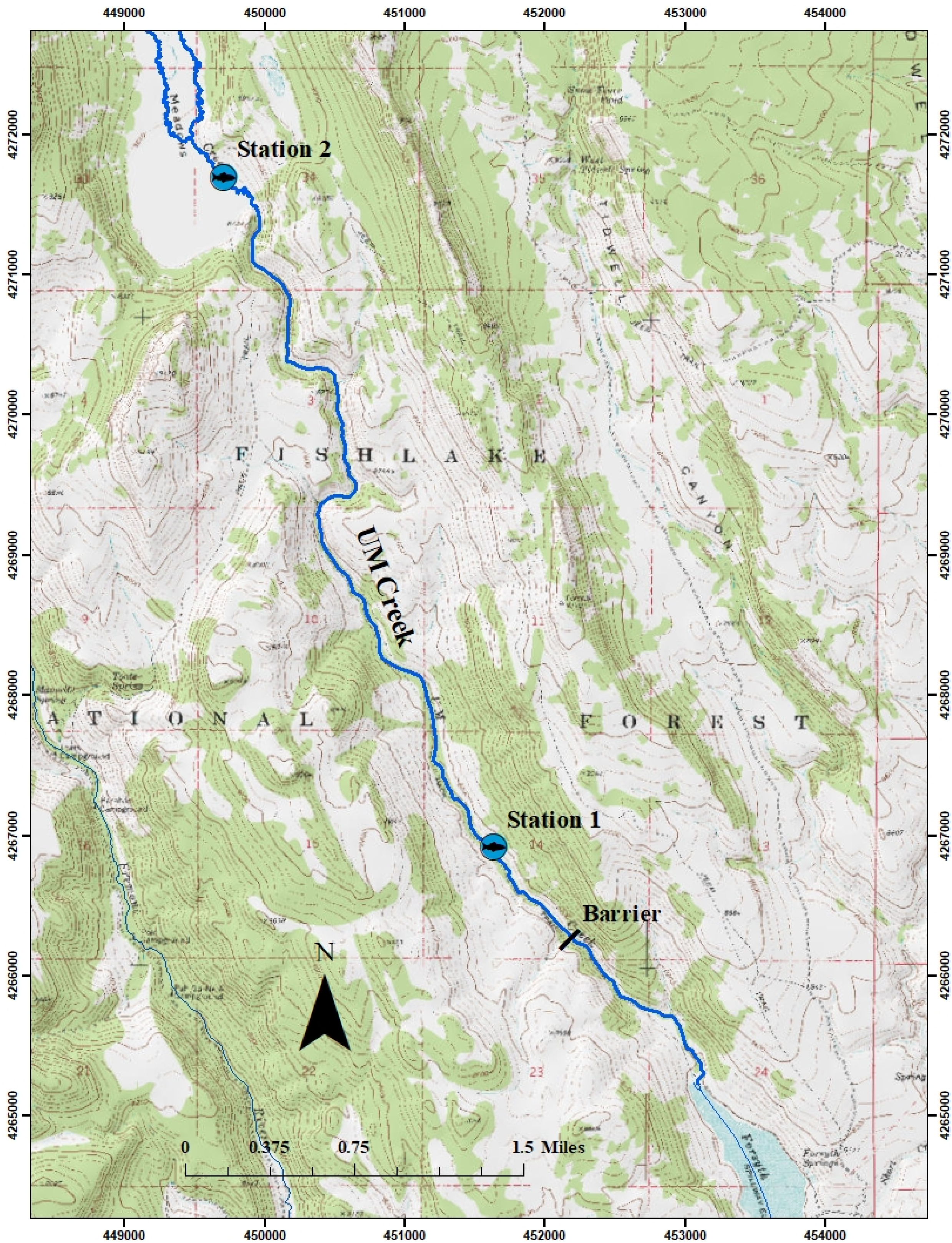

Figure A14. Locations of survey stations, barriers, and CRCT distribution in lower UM Creek.

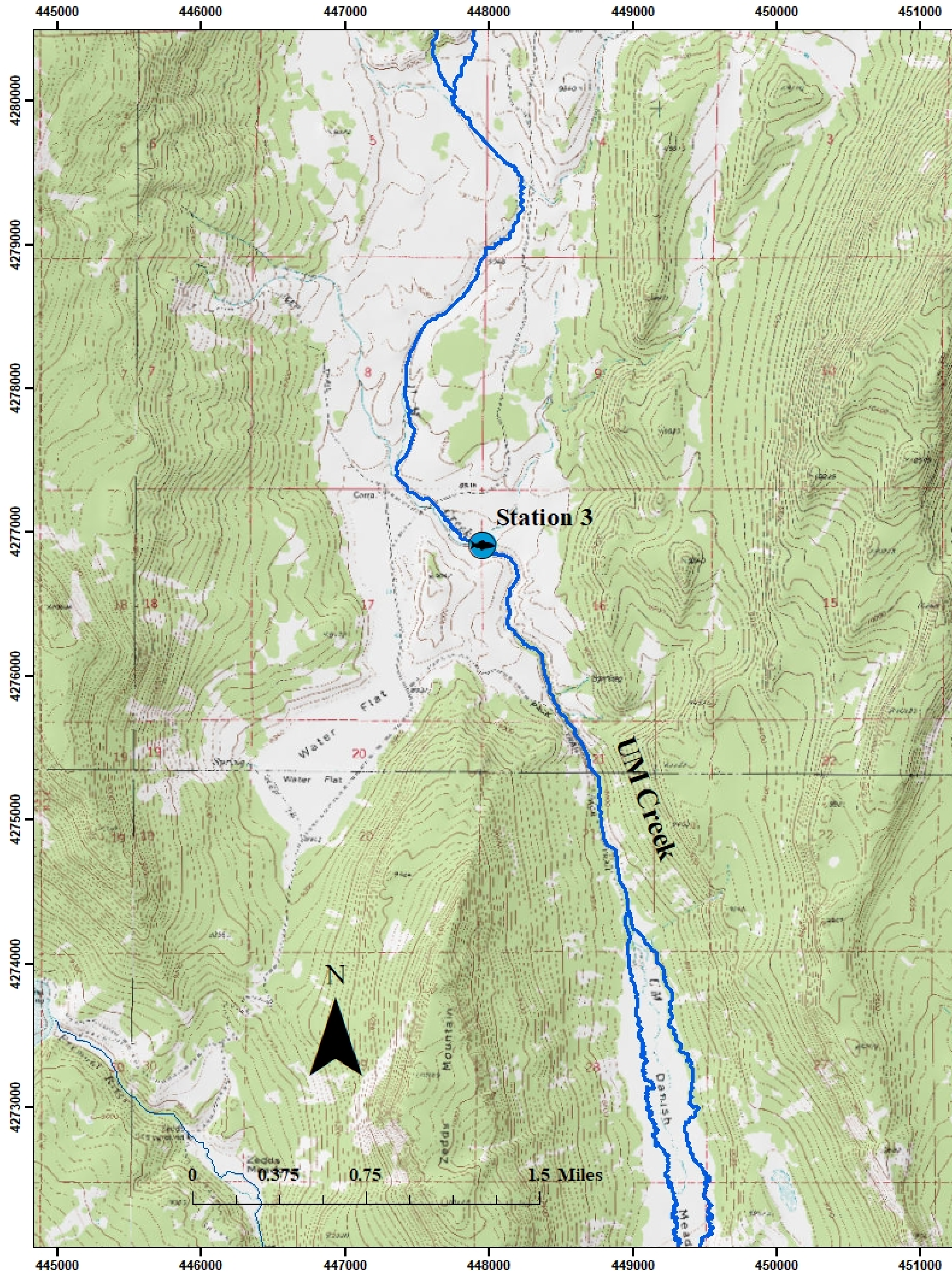

Figure A15. Locations of survey station and CRCT distribution in upper UM Creek.

Left Fork UM Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **July 22, 2020** Biologist: **J. Whelan**
2. Stream Information—
   Name, catalog #, section, county: **Left Fork UM Creek, I AZ 130Z 02, 01, Sevier**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Just downstream of upper ATV trail crossing—120445046E 4282886N**
   Downstream range of native trout (general description and GPS): **Right Fork confluence**
   Location (GPS) and description of barriers: **None**
   Stream Length—Occupied habitat: **5.1 km (3.2 mi)** Available habitat: **5.1 km (3.2 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **Just downstream of lower ATV trail crossing —12047559E 4280969N**

Parameter	**Station 1**
Station length (m)	100 m
Mean stream width (m) (n)	1.44 m (9)
Station area (hectares)	0.0144 ha
CRCT	
Removal Pattern	15 1
Population estimate (95 % CI)	16 (±1)
Capture probability	1.000
Mean length (mm) (n)	205 (16)
Mean weight (g) (n)	110 (16)
Mean KTL (n)	1.02 (16)
Number fish per km (95 % CI)	160 (±10)
Number fish per ha (95 % CI)	1,108 (±69)
Biomass (kg per ha) (95 % CI)	122 (±8)

4. Comments:
One tiger trout collected in station (10 fish/km, 69 fish/ha, 21 kg/ha).

Right Fork UM Creek—NATIVE TROUT POPULATION SURVEY

1. General Information— Date: **July 20-21, 2020** Biologist: **J. Swensen, J. Whelan**
2. Stream Information—
   Name, catalog #, section, county: **Right Fork UM Creek, I AZ 130Z 03, 01, Sevier**
3. Survey Site Information (see attached map)—
   Upstream range of native trout (general description and GPS): **Headwater spring—120446141E 4285729N**
   Downstream range of native trout (general description and GPS): **Left Fork confluence**
   Location (GPS) and description of barriers: **None**[1]
   Stream Length—Occupied habitat: **7.1 km (4.4 mi)** Available habitat: **7.1 km (4.4 mi)**
   Survey method & equipment: **backpack battery electrofisher; multiple-pass depletion**
   Survey sites (general description and UTM)—
   Station 1: **1.0 km upstream of Black Flat—120447926E 4282091N**
   Station 2: **Livestock exclosure 4.0 km upstream of Black Flat—120447082E 4284222N**

Parameter	**Station 1**	**Station 2**
Station length (m)	100 m	100 m
Mean stream width (m) (n)	3.40 m (10)	1.55 m (10)
Station area (hectares)	0.0340 ha	0.0155 ha
CRCT		
Removal Pattern	1 0	14 0
Population estimate (95 % CI)	1 (NA)	14 (NA)
Capture probability	1.000	1.000
Mean length (mm) (n)	163 (1)	204 (14)
Mean weight (g) (n)	44 (1)	111 (14)
Mean KTL (n)	1.02 (1)	1.09 (14)
Number fish per km (95 % CI)	10 (NA)	140 (NA)
Number fish per ha (95 % CI)	29 (NA)	903 (NA)
Biomass (kg per ha) (95 % CI)	1.3 (NA)	111 (NA)

4. Comments:

[1] – Previous constructed barrier removed in 2019.

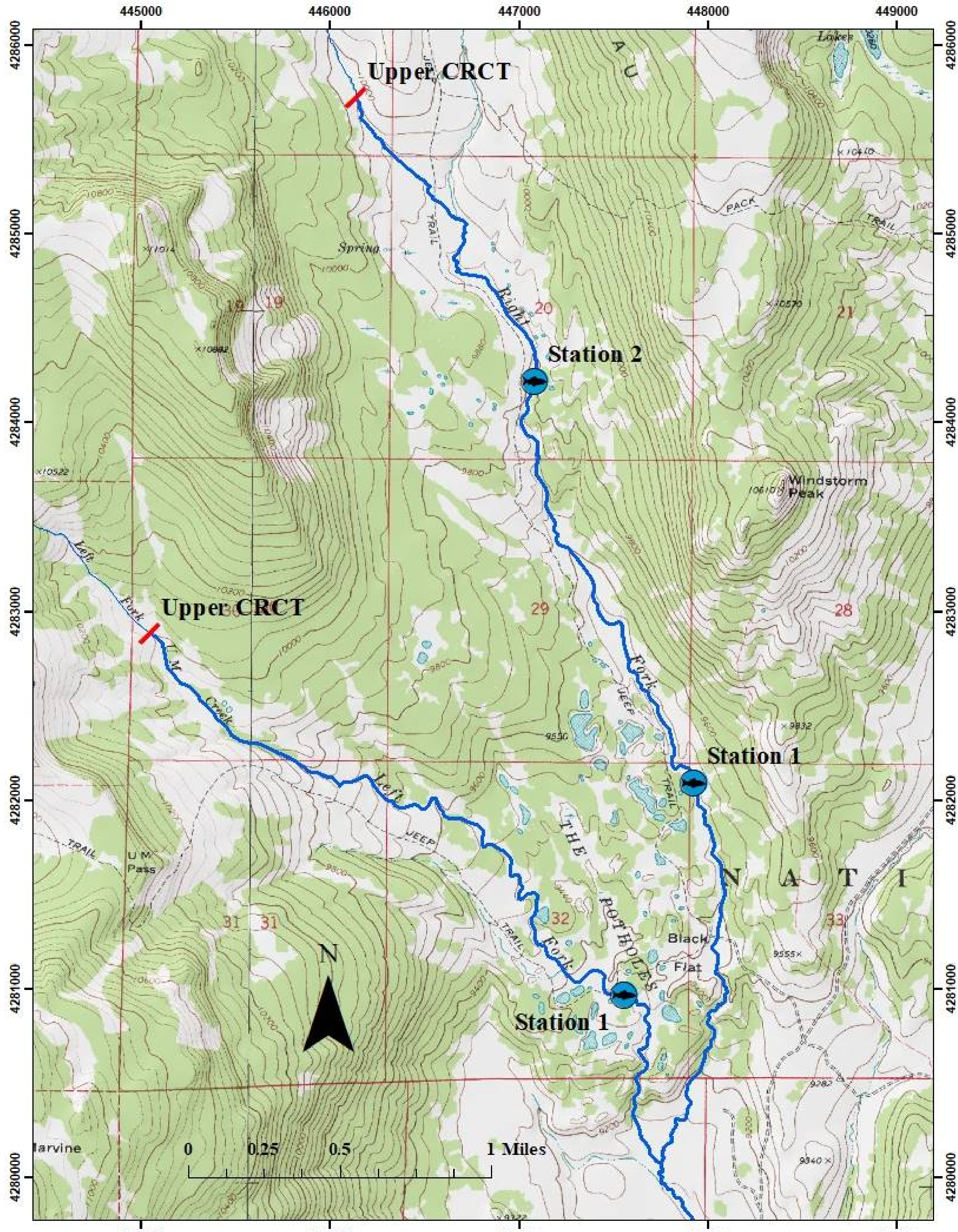

Figure A16. Locations of survey stations and CRCT distribution in the left and right forks of UM Creek.