SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM

WATERSHED PROJECT FINAL REPORT

Lower North Empire Creek Restoration Project

by

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Clear Creek Watershed Foundation

(November 2019)

This project was conducted in cooperation with the State of Colorado and the United States Environmental Protection Agency, Region 8.

CDPHE NPS Contract # CT FAAA 201800001720

1 EXECUTIVE SUMMARY

PROJECT TITLE Lower North Empire Creek Restoration Project

PROJECT START DATE 9-13-17 **PROJECT COMPLETION DATE** 10-31-19

FUNDING: TOTAL BUDGET $447,460

TOTAL EPA GRANT $255,583

TOTAL SECTION 319 MATCH ACCRUED $191,865

BUDGET REVISIONS Internal budget reallocation of $9,335, approved on 1-24-19.

TOTAL EXPENDITURES $447,448

SUMMARY ACCOMPLISHMENTS

The major focus for the Lower North Empire Creek Project was controlling runoff from severely impacted, virtually un-reclaimable, upland mined lands to the west of the creek. Two armored sediment containment structures were created in the vicinity of the Benton Mine Dump, Union Pit and Sprankle Mine area to aid in minimizing erosion and sediment. Additional BMPs included placement of energy dissipaters, boulder rundown structures and erosion control blankets to reduce the ongoing sedimentation. These actions set the preconditions for sediment removal from the stream and associated riparian stream restoration. An onsite mine waste repository was constructed to contain mine waste removed from the natural drainage channel. It is expected that, given its steep gradient, the channel will be self-cleaning with the degree of hill slope erosion being reduced and embankments becoming stable following revegetation.

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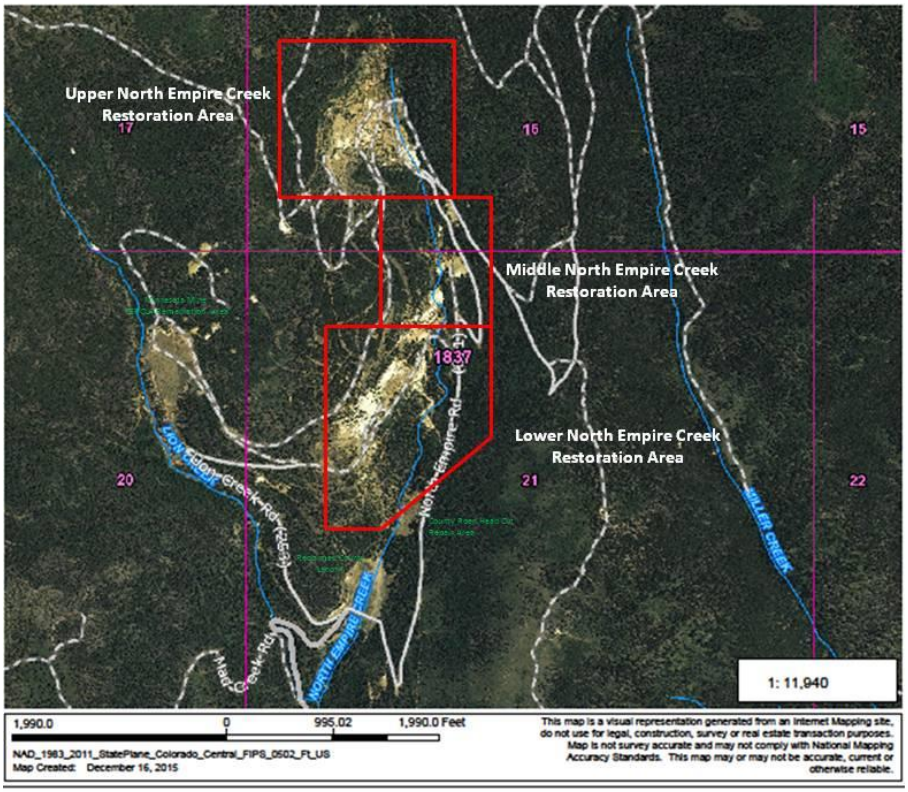
3 INTRODUCTION

The North Empire Mining District has been severely impacted by past mining activities. In general, North Empire Creek is a high-gradient drainage system with very steep side slopes, acid mine drainage and significant contamination from heavy metals. Past mining activities have included surface mining, hydraulic placer mining and lode mining. Most of the area disturbed by mining is on the slopes to the west of the Creek. Surface mined areas have also been developed along with shafts and adits mostly extending in a north-westerly direction into hardrock workings.

The placer mining removed not only the topsoil, but even much of the subsoil from many of the west side slopes of the north-to-south flowing drainage. These placer-mined hill slopes would be almost impossible to restore and revegetate using any practical and affordable approaches for reclamation. Therefore, the focus of this lower North Empire Creek project was controlling runoff from severely impacted, virtually un-reclaimable, upland mined lands to the west of the creek and containment of mine waste removed from the natural drainage channel, all in order to achieve water quality improvements.

North Empire Creek is a small watershed of approximately 1 mi^2, ranging in elevation from 11,522 ft at the headwaters, to 9,100 ft MSL where it discharges into Lion Creek. Flows in North Empire Creek range from approximately 20 gpm to 1,148 gpm (2.5 cfs). Below the confluence with North Empire Creek, Lion Creek drains southward into the West Fork of Clear Creek within the Town limits of Empire, located approximately 40 miles west of Denver, Colorado. The West Fork of Clear Creek joins the main stem of Clear Creek about one mile east of Empire. Clear Creek is a major tributary of the South Platte River, with its confluence located just north of Denver's city limits.

Figure 1 - Aerial View of North Empire Creek Restoration Areas



For purposes of stream restoration and mining reclamation, North Empire Creek has been divided into an upper, middle and lower reach, mainly defined by access considerations and historic mining

district boundaries. This project addressed mining related impacts in the lower reach of the creek. Please see Figure 1.

CCWF restored the *upper* reach in the fall of 2014 through a $400,000 Supplemental Environmental Project fund administered by CDPHE's Office of Sustainability, along with $30,000 in project funding provided by the Colorado Division of Reclamation, Mining and Safety (DRMS). The upper project resulted in the complete removal of the 18,250 CY Conqueror Mine tailings pile from the stream channel and its disposal in the Upper North Empire Creek mine waste repository. This repository was sited about ¼ mile west and 300 vertical feet above North Empire Creek.

North Empire Creek has pristine water quality above the Conqueror Mining district in the *upper* reach and now has good water quality through that area. There are several reaches of North Empire Creek that are reasonably intact with good riparian conditions. These have served as reference reaches for the restoration of impacted reaches.

The *middle* reach of North Empire Creek encompasses about ¼ of the entire drainage system. This area was heavily impacted by contaminated runoff and in-stream mine waste. The focus of the *middle* reach project was removal of mine waste from the stream channel and riparian zone and disposal of the mine waste in an approved onsite repository. The volume of mine waste removed from the *middle* reach was approximately 13,000 CY. This project was completed in December of 2016. The total expenditures for the Middle North Empire Creek Project was $368,154.

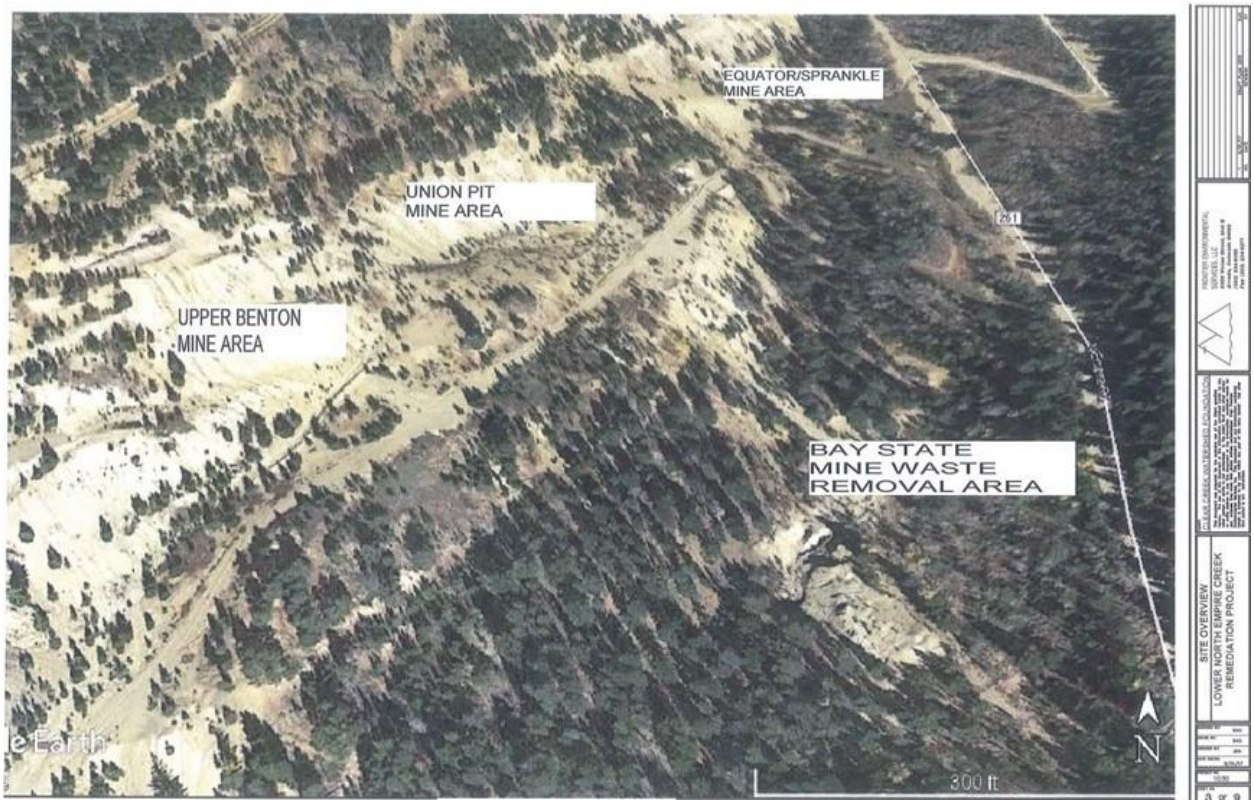
The following mining features were addressed as part of the Lower North Empire Creek Restoration Project (Figure 3).

Figure 2 - Interceptor Channel from Benson Mine Cribbing

1. Two constructed diversion channels and interceptor channel from the Benson Mine cribbing (Figure 2).
2. Two constructed sediment storage embankments along mining Road 253 in the upland drainage area of North Empire Creek.
3. A turning berm to divert mining impacted drainage flows to the north and to the south within runoff control interceptors following the roadway.
    a. The channel redistributes flows to the stream, utilizing Road 253 crossing locations near the Lower Placer Pit on the southern slope of the road, and near an abandoned pump house on the northern slope of the road. These road crossings transport the runoff water into loose boulder rundown structures toward North Empire Creek.
4. Removal and placement into approved repository of mine waste and contaminated sediment in streambed at the Bay State Mine location.

5. Restored natural bedrock channel and established healthy riparian buffer area.

Figure 3 - Lower North Empire Creek Site Overview



4 PROJECT GOALS, OBJECTIVES, AND ACTIVITIES

The overall goal of watershed scale restoration activities in North Empire Creek and Lion Creek is recovery of the macro invertebrate community, which has been destroyed by past mining activities. It should be noted that without significant habitat improvements (e.g., creation of winter water holding structures) in addition to water quality improvements, this steep drainage would not support reproducing fish populations.

North Empire Creek is a tributary of Lion Creek, which is severely impaired, but not *303(d)-listed*, because of its limited use classifications and applicable standards as shown in (Table 1). Lion Creek discharges into the West Fork of Clear Creek, which flows into segment 2b of Clear Creek, a §303(d) listed segment, and then into segment 2c of Clear Creek, also listed under §303(d) of the federal Clean Water Act.

From the headwaters of North Empire Creek downstream, approximately 1.2 miles, to the crossing of County Road 251 there are three distinct stream reaches (upper, middle and lower) identified primarily by access points and historic mining district boundaries, where mine waste piles directly intersect the Creek. There are literally hundreds of mining properties in this sub-watershed. The *upper* reach was restored through a Supplemental Environmental Project administered by CDPHE's Office of Sustainability. The *middle* reach was restored primarily with Section 319 Nonpoint Source Program

funding in 2016. Given the importance of Clear Creek as a water supply and recreational resource, these projects are considered beneficial to public health and source water protection.

The primary goal of this *lower* reach Nonpoint Source Project was to remove mine waste from the natural stream channel and its flood plain in order to establish a healthy riparian buffer area and a stable drainage channel with improved water quality. In order to achieve success, best management practices were employed for controlling runoff from mining impacted areas and providing an optimal storage repository for mine waste derived sediment.

The *lower* reach restoration project goals included:

1. Achieving significant reductions in toxic metal concentrations, including Aluminum, Cadmium, Copper, Iron, Manganese and Zinc.
2. Reducing acidity with a corresponding increase in pH.
3. Controlling runoff from the remaining exposed previously mined areas that were not reclaimed as part of this project.
4. Removal of mine waste from the natural stream channel and its flood plain in order to establish a healthy riparian buffer area and a stable bedrock drainage channel with improved water quality.
    a. There are several small sections of reaches of North Empire Creek that are reasonably intact with good riparian conditions. These functioned as reference sub-reaches for the restoration of impacted reaches.
5. Prevent contact between the stream and mine waste to significantly reduce pollution.
6. Managing the removed mine waste and contaminated sediment in an onsite repository, where exposure of the mine waste to surface and groundwater is minimized to the maximum practicable degree.

North Empire Creek was listed recently, in 2016. Lion Creek, of which North Empire Creek is a tributary, is severely impaired, but not listed because of its limited use classifications and minimal applicable standards as shown below in Table 1. Lion Creek discharges into the West Fork of Clear Creek, which flows into segment 2b of Clear Creek- a §303(d) listed segment and then into segment 2c of Clear Creek, also listed under §303(d).

Table 1 - Stream use classifications and applicable standards Lion Creek, West Clear Creek, Clear Creek, Mill Creek, Argo Tunnel

WBID	Segment Description	Portion	Colorado's M&E Parameter(s)	CWA 303(d) Impairment	303(d) Priority
COSPCL06	All tributaries to West Clear Creek from the source to the confluence with Clear Creek	North Empire Creek	SO4, Cd, Fe(Dis), Fe(Trec), Zn	Cu	H
COSPCL08	Mainstem of Lion Creek from the source to the confluence with West Clear Creek.	All	Note: This stream is classified for Aq Life Cold 2 and Recreation E. The only standards are: T=TVS (CS-I)ºC D.O. = 6.0 mg/l D.O. (sp)=7.0mg/l pH = 3.0-9.0 E. Coli=126/100ml	No. But, TVS are exceeded for pH, Al, Cd, Cu, Fe, Mn, Ni, Pb, Zn	N/A
COSPCL05	Mainstem of West Clear Creek			Not listed	N/A
COSPCL02b	Mainstem of Clear Creek from West Fork Clear to Mill Creek.	All		Cd, Zn	H
COSPCL02c	Mainstem of Clear Creek from Mill Creek to Argo Tunnel.	All		Cd	H

4.1 PLANNED AND ACTUAL MILESTONES, PRODUCTS AND COMPLETION DATES

This project was designed to result in significant reductions in toxic metal concentrations within North Empire Creek, including aluminum, cadmium, copper and zinc as well as a reduction of acidity, with a corresponding increase in pH. The ultimate goal of this project and the others constructed in North Empire Creek was to reduce the degree of impairment in the main stem of Clear Creek, which is a significant environmental and recreational resource and a major water supply serving mountain communities and major cities along the Front Range.

On October 7, 2017 Frontier Environmental Services, Inc. (FESI) mobilized and began construction of upland controls for impacted areas along mining Road 253. Rock was hauled to build a lower check dam and excavation began to construct a pioneer road to the lower North Empire Creek Bay State Mine area. A rip-rap check dam was constructed below the entire project area.

During the first month of construction rock was hauled to a staging area by the closed Town of Empire landfill and a low flow crossing was completed at the north end of the Road 253 cross point (Figure 4).

Construction began on a berm and spillway at the Union Pit mining area (Figure 5) and the Benton Mine cribbing interceptor channel. A laser level was used to evaluate the slope of Road 253.

The gradient evaluation of Road 253 showed the high point in the road at its highest elevation at a 2' gradient difference between the lowest points north and south of the Benson Mine cribbing location. To address this challenge the run-off ditch was widened where feasible to reduce the depth of the ditch to meet grade. A berm was placed along this portion of the run-off ditch to prevent vehicle traffic from driving into the ditch.

Figure 4 - North Road 253 Crossing Point Low Flow Crossing and Gradient Evaluation

Also, based on this gradient difference, changes were made to the work plan to construct a run-off ditch of approximately 40' on the southern portion of Road 253 starting at the high point of the road located directly below the Benson Mine cribbing. An intercept channel was shaped on the south side of the Benson Mine area to connect with a southern Road 253 run-off ditch, and a low flow crossing was added at the lowest point of southern Road 253.

An additional 40+ cubic yards of rock for the Road 253 run-off ditch was needed due to the work plan change. Soil was spread to prepare the area for revegetation. By the second week in November the berm on Road 253 was complete. While the Benson Mine main intercept channel was being completed, straw waddles were placed at the Bay State area and Sprankle Pit mining area (Figure 6) to prepare build out of the sediment detention basins.

Figure 5 - Union Mine Area Sedimentation Detention Basin Engineering Features

Figure 6 -Sprankle Mine Area Sedimentation Detention Basin Engineering Features

The crew then mobilized to the Bay State Mine area to begin grubbing the repository. The grubbed trees were stockpiled for reuse as site revegetation contour. A temporary stream bypass interceptor was placed, and repository excavation began. Crews started moving the west creek side mine waste piles into the repository. A discovery was made that the western most waste pile had a depth greater then estimated (Figures 7 and 8).

Figure 8 - West Mine Waste Pile Before

Figure 7 - West Mine Waste Pile Removal Activity

It was an unusually warm winter and the crews were able to work through December. During December they continued to move east and west mine waste piles into the repository. The higher volume of waste discovered required expansion of the repository. It was taken to greater depth and widened further west to meet with the east creek side waste pile. A dozer was added to the equipment onsite to expedite movement of waste. It was also determined that a higher volume of cap soil would be necessary to cover the expanded repository.

FESI evaluated the channel grade at Bay State to determine depth to positive flow. Test holes were dug to determine the depth of the fluvial fan (Figure 9). The loader sunk into the fan, got stuck and had to be towed out. At the center of the fluvial fan it was determined that the maximum depth to bedrock was over 16'. The stream gradient and slope reevaluation identified the need for additional repository adjustment due to increased quantities of waste discovered in fan.

The waste in the channel fan area far exceeded the estimate of 1000 CY. The actual depth of the fan waste was between 16' – 20' feet and expanded into the creek bank along both sides (Figure 10). Removal of this waste would create steep slopes that had to be addressed. Also, an underground seep was discovered along the west bank of the creek channel in the fluvial fan area.

Figure 9 - Bay State Mine Area Fluvial Debris Fan

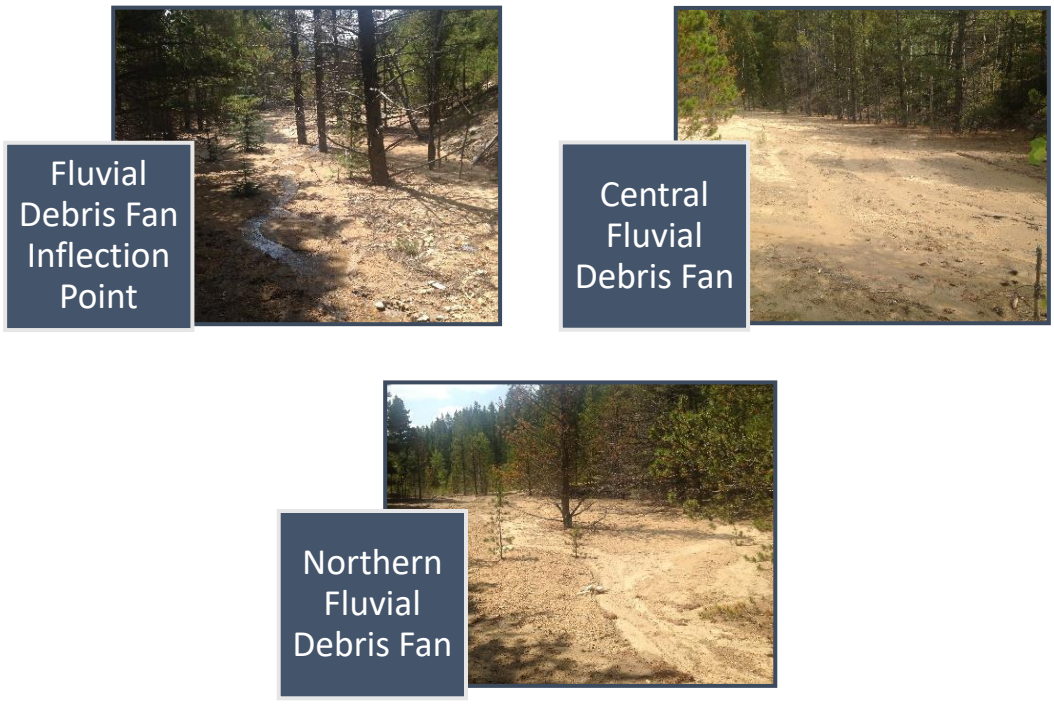


Figure 10 - Fluvial Debris Fan Depth

In January 2018, FESI began removal of waste in the creek channel. The waste along the creek side was removed by undercutting the stream bank followed by dropping the clean soil down from above the undercut to serve as cap, thereby reducing the slope gradient of the hillside above the stream bank (Figure 11). Large rock was keyed into the hillside and extensive grub was used as cover to perform as a mulch in the steep slope sections, which are at the same grade as the natural slopes (Figure 12).

A rock lined rundown channel was created with velocity check points at approximately 10’ intervals on the lower east hillside of Road 251 where runoff flows into the creek. Stream channel improvements consisted of re-establishing the natural pattern of step pools, cascades and boulder-reinforced meanders that are necessary to dissipate the energy of North Empire Creek flows and to minimize channel erosion along its steep gradient. All the

Figure 11 - Dropping Clean Soil Down to Reduce Hillside Gradient

radically disturbed areas that were affected by restoration activities were reclaimed using rigorous grading, topsoiling / soil amendment and revegetation protocols.

Figure 12 - Large Rock and Grub Placed on Hillsides

By the first week of February the repository was completed and holds approximately 18,000 cubic yards of waste, versus the estimated 8,000 cubic yards determined during presurvey efforts. The soil cap and compost cover were placed on the repository and preliminary seeding was put down.

A spring evaluation showed that the preliminary seed did not take. A soil scientist was engaged to collect and analyze representative soil samples from reclaimed areas at the site to develop a more robust protocol for a remedial revegetation effort. Recommendations for soil amendments were received along with a revised seed list.

Figure 13 - May 2018 Hydromulch of Repository

In the Spring of 2018, a revegetation took place (Figure 13). Gypsum, Lot 125 and Eco-Flex, seed, fertilizer, hydromulch and water were applied.

In June of 2019, a second season of revegetation efforts was advised. Late fall / early winter 2018 site reviews revealed poor results for revegetation in the project area. This was likely due to the warm weather and very low precipitation in 2018. FESI was contacted and developed a plan to plant shrubs and forbs at the site and incorporate a watering plan for spring / summer 2019.

On June 5, 2019 spring revegetation took place. A manifold system with four 500-gallon tanks was constructed on site and filled with water. Drip tubing was strung to 300 planted plugs that include Aspen, Pine, Mountain Mahogany and Dogwood. A 2,000-gallon water truck topped off the tanks for a total of 40 watering events through the summer (Figure 14). The tank system was checked on a weekly basis.

Figure 14 - Manifold System with Four 500-gallon Tanks

By mid-August, site visits revealed a high percentage of weed growth associated with the compost from the cap, but there is also a well-established mix of reclamation grasses. The Bristlecone is experiencing particularly good success and the Dogwood near the creek are taking hold.

Figure 15 - Mix of Reclamation Grasses on Repository

Table 2 - NPS Summary of Completed Construction Activities Lower North Empire Creek Restoration Project

	Activity	Description	Date Completed
NPS Summary of Completed Construction Activities Lower North Empire Creek			
	Rights of Access; Design and Construction Documents; Project Permitting	Negotiation with landowners, site surveying, drawings, permitting with County, State Stormwater, local BMP and Excavation permits	28-Jul-17
	EPA comfort letter	Submit planning/design + PIP to EPA Project Officer. EPA Comfort Letter under CERCLA issued to CCWA	6-Jul-17
	NPS Contract Approval	CDPHE NPS Contract # CT FAAA201700001997 final state execution	13-Sep-17
	Project Mobilization	Project equipment and staging area	2-Oct-17
	North Low Flow Crossing Road 253	Complete low flow crossing at Road 253 north cross point	14-Oct-17
	Benton Mine Area Main Intercept Channel	Upland controls, berm build up intercept from Benson mine waste cribbing area	28-Oct-17
	Union Pit Sediment Basin	Sediment storage embankment capturing run-off from Benson Mine north	28-Oct-17
	Sprankle Pit Sediment Basin	Sediment storage embankment capturing Sprankle Mine run-off	28-Oct-17
	Southern Low Flow Crossing Road 253	Complete low flow crossing at Road 253 south cross point and	11-Nov-17
	Grade Contours Road 253	Complete widening and gradient adjustments to Road 253 run-off ditch and berm on Road 253 run-off ditch	18-Nov-17
	Western Mine Waste Piles Removal	Remove mine waste adjacent to creek on west side at Bay State Mine site	13-Jan-18
	Rock Lined Rundown Channel	Place rock lined rundown channel with velocity check points on lower east hillside of Road 251	20-Jan-18
	East Mine Waste Piles Removal	Remove mine waste adjacent to creek on East side at Bay State Mine site	27-Jan-18
	Remove Sediment Creek Channel	Remove contaminated sediment in 16'+ fluvial fan in creek channel	27-Jan-18
	Restore Bedrock Channel	Restore channel grade at Bay State to depth to positive flow and place rock	27-Jan-18
	Final Repository	Store approximately 16,660 cubic yards of contaminated sediment and mine waste in on-site repository	27-Jan-18
	Place Soil Cap, Compost and Seed	Complete soil cap and compost cover on repository, preliminary seeding	3-Feb-18
	Establish Riparian Area	Mountain species seed and plugs planted, tanks and system placed to water	16-Jun-19

4.2 EVALUATION OF GOAL ACHIEVEMENT AND RELATIONSHIP TO THE STATE NPS MANAGEMENT PLAN

Colorado's approach to nonpoint source control for inactive mine sites is addressed in Chapter 5 of the state's Nonpoint Source Management Program. This project was fully consistent with that approach, insofar as it identified *reclamation and hydrologic controls for implementation, wherever feasible*. The fact that segments 2b and 2c of Clear Creek are listed as impaired because of past mining activities, raised the priority of this proposed project, because it directly addressed these causes of impairment. This project prevented any direct contact of North Empire Creek with highly mineralized mining waste in the *lower* reach of North Empire Creek. This contact between the drainage and its associated mine waste had been shown by USGS, USFS, CCWF and CSM to be a significant source of acidity, cadmium, copper and zinc. Both cadmium and Zinc are listed causes of impairment in the main stem of Clear Creek.

Post project monitoring commenced during the Summer of 2018, including multiple visual assessments; water quality sampling events for laboratory analysis; and, analysis for field parameters and dissolved metals. This monitoring was in accordance with the provisions of the approved SAP for North Empire Creek. All sample results obtained by CCWF have been entered in the Colorado Data Sharing Network.

Project inspection and maintenance consisted of comprehensive assessments in the field during and following the spring runoff each year from 2017-2019, to determine any required maintenance requirements. A second season of revegetation efforts was advised for 2019 due to site reviews revealing poor results in the project area. This was likely due to the warm weather and very low precipitation in 2018.

With the budget having been expended, maintenance responsibilities now have fallen back to the landowners (i.e., County and private parties) as discussed in the original Project Implementation Plan

5 BEST MANAGEMENT PRACTICES DEVELOPED AND/OR REVISED

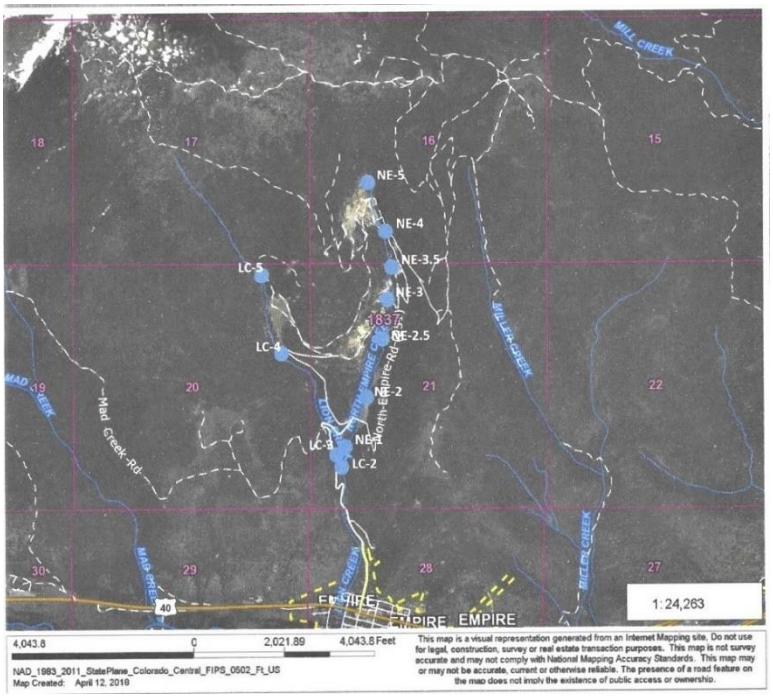
All the BMP's proposed and implemented during the course of the Lower North Empire Creek Restoration Project, were *tried-and- true* methods, which have been employed in prior projects.

6 MONITORING RESULTS

A Sampling and Analysis Plan (SAP) already had been developed in support of the overall Quality Assurance Project Plan (QAPP) for the restoration of the Lion Creek Watershed. This SAP was updated and revised for the purposes of the North Empire Creek projects and was provided as a separate deliverable. The SAP served as the primary field guidance for all the water-quality and mine-waste sampling work conducted for this effort. In addition to data from CCWF-conducted field surveys, data from other sources (e.g., Colorado School of Mines' and Clear Creek Consultants) were evaluated. The SAP is included as Appendix A of this Final Report.

This project included mine waste and water quality sampling & laboratory analysis, toxicity investigations and contemporaneous flow measurements. This includes complete chemical analysis (i.e., 13 metals and hardness) for 6 sampling events at five stations (NE-1, 2, 3, 4 and 5) as represented in Figure 16. NPS Pollution Source categories addressed are habitat modification (drainage/filling wetlands, stream bank destabilization) and mining. NPS Pollutants addressed are metals and pH.

Figure 16 - Water Quality Monitoring Locations in Lion Creek watershed (incl. North Empire Ck.)



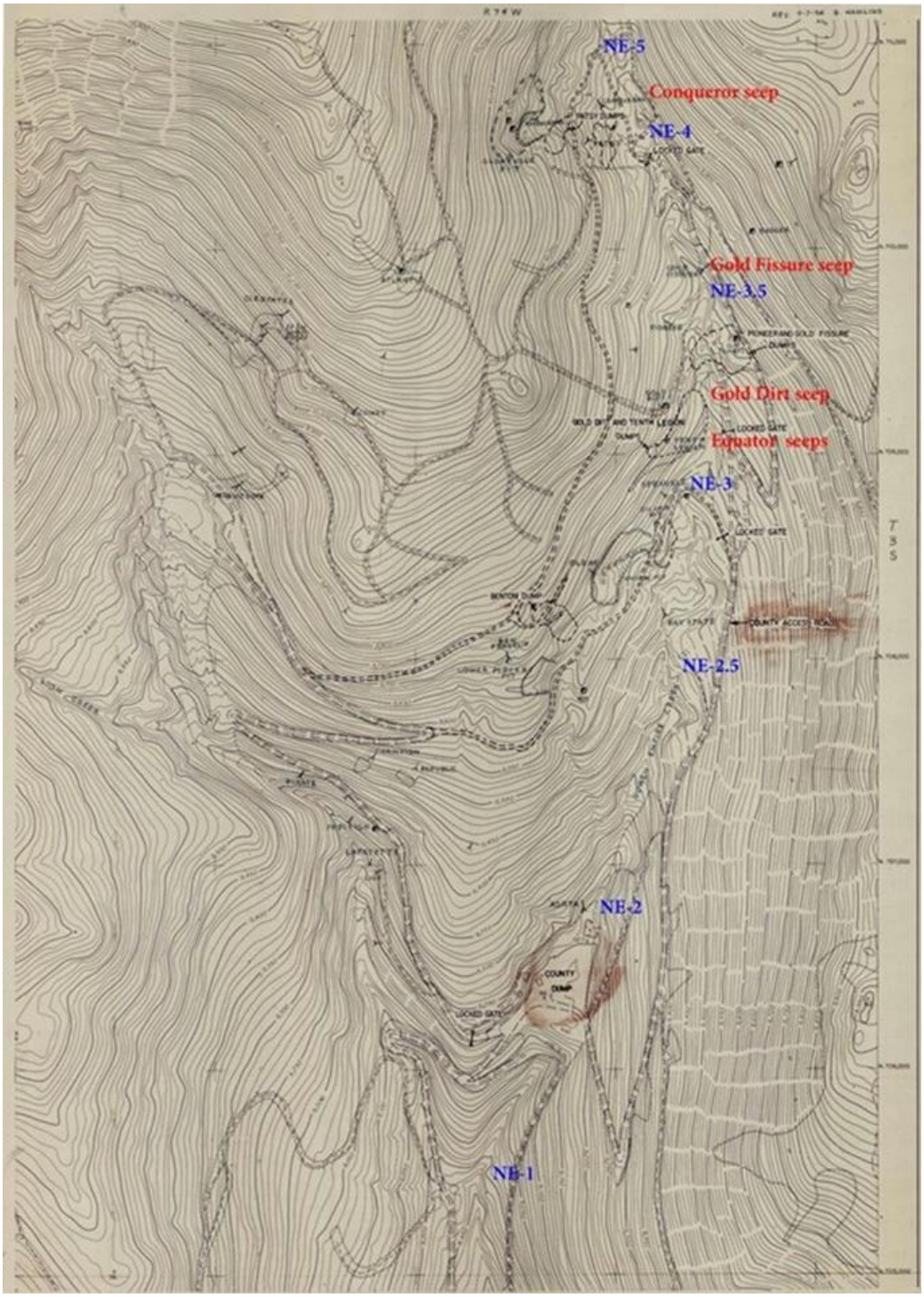
This project is expected to result in significant reductions in toxic metal concentrations loading over the long term, including aluminum, cadmium, copper, manganese and zinc as well as a reduction of acidity with a corresponding increase in pH. Given the importance of Clear Creek as a water supply and recreational resource, these are considered public health and source water protection benefits.

Water quality data collected as part of this project was uploaded on to the Colorado Data Sharing Network, as has been done for previous projects.

6.1 BMP EFFECTIVENESS EVALUATIONS

The water-quality assessment begins with a focus on water quality at monitoring sites located immediately upstream and downstream of the project area. For example, monitoring site NE-3 is located below the entire *middle* project area. Sampling site NE-2 is located just below the project-restoration improvements from the Lower North Empire Creek Project. A complete assessment of the downstream water quality improvement associated with all three projects in North Empire Creek was provided in Appendix B.

Figure 17 - North Empire Creek mining features, monitoring sites, and recently discovered mineralized seeps



Normally, BMPs such as those that were implemented by CCWF during the *lower* reach project, would not be expected to result in 100% metal loading reduction, because there are other diffuse sources of loading from natural mineralization and groundwater inflow and from uncontrolled upstream sources. Also, mine waste removal efforts are *never* 100% effective in capturing any given source. Nonetheless, the water quality improvements achieved by the *lower* North Empire Creek Restoration Project are very good because, there is no longer any increase in concentration, or loading, as the creek moves through the lower project area, from which **more than 18,000 Cubic yards of mine waste was removed**.

A brief summary of the water quality results obtained from the upper North Empire Creek projects is provided below in Table 3 for additional context. The instream copper concentration dropped by 99%, Aluminum dropped by 96%, Zinc levels fell by 80%, Manganese levels fell by 77% and Nickel dropped by 40%. The water quality at NE-4 now looks like the relatively pristine water quality at NE-5, which is upstream of most mining impacts. Load reductions are proportional to concentration reductions for any given flow regime. For an example of load reductions following implementation of both projects for the upper and middle reaches of North Empire Creek please see Table 4, below. All values represent conditions on May 18, 2018. Note the impact measured at NE3 that is attributed to the newly discovered mine seeps near the Equator Mine, which are discussed further below.

Table 3 - Pre and post project average metal concentrations (ug/L) - upper North Empire Creek Restoration Project

Site ID	Date	Al	Cu	Mn	Ni	Zn
NE-4	pre project	623.0	286.0	201.0	3.0	82.0
NE-4	post project	23.6	3.8	47.4	1.2	17.0
NE-5	All Data	56.3	4.0	41.5	0.57	32.0

Table 4 - Post restoration project-loading profile on 5-18-2018

Site ID	Total load (mg/s)	Total Load(lb/yr)	Q (L/s)	Site description	Flow direction
NE-5	1.40	97.13	78.70	Pristine headwaters of N. E. Ck.	
NE-4	1.50	104.07	64.00	Post Upper N.E. Ck. project	
NE-3.5	0.60	41.63	52.40	Post Middle N.E. Ck. Project (above seepage)	
NE-3	44.10	3059.62	48.00	Continuing impact from mine seepage	

6.2 SURFACE WATER IMPROVEMENTS

6.2.1 CHEMICAL

The *lower* reach of North Empire Creek begins just below the CR 252 road culvert at site NE-3 and ends at the confluence of North Empire Creek with Lion Creek, approximately ¾ mile downstream. The Lower North Empire Creek Restoration Project area is bracketed by sites NE-3 and NE 2.5 (the latter which was not monitored prior to 2018).

Table 5 indicates the water-quality conditions reported at site NE-2.5 during spring-runoff periods, after all project work was completed, in comparison to what had been reported in 2014 (pre-project). We do not have results for this site during low-flow periods, because it was added after our SAP was approved and funds were authorized for analysis based on the approved SAP and designated sites.

Table 5 - North Empire Creek downstream of the Lower Restoration Project area

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-2.5	5/20/14	0.9	3500	693	540	11	182	3.5
NE-2.5	5/18/18	1.9	1757	304	410	7.7	35.9	3.3
NE-2.5	5/14/19	0.6	5413	1438	1673	45.7	197.2	3.3

The high-flow results for site NE-2.5 (Table 5) have a similar pattern to those observed at site NE-3 (as given previously in Table 4). In 2018, there were lower concentrations of trace metals at site NE-2.5 than in 2014, before restoration work had commenced in the Bay State Mine area. But in 2019, all indicator TMs had higher concentrations than in 2014. No flowing mineralized seeps have been observed between sites NE-3 and NE-2.5. The flow measurement at NE-2.5 was lower in 2019 than in either 2018 or 2014.

NE-3 is the water quality monitoring station immediately downstream of the Middle North Empire Creek Restoration Project area. The *middle* reach is bracketed by monitoring sites NE-3.5 and NE-3 -- encompassing about ¼ mile of stream length. It also contains four mineralized seeps, which emerged only after the removal of about 16,000 CY of mine-waste materials in and alongside the stream-channel bottom. The Gold Dirt and Tenth Legion Mine adits and shafts are shown above on Figure 17. These are located on the west side of North Empire Creek. These shafts, adits, and subsurface mine workings are suspected sources of mine waste seepage that enters North Empire Creek at the toe of the Gold Dirt and Tenth Legion mine dumps.

Metal concentrations at NE 3 were still quite elevated after the *middle* reach project was completed. However, several seeps and springs have appeared in the vicinity of the Equator Mine waste removal area, alongside North Empire Creek. These seeps were not visible prior to the commencement of the *middle* reach project, because they were buried by about 20' of mine waste. They are in the area where the toe of the Equator Mine waste pile encroached upon North Empire Creek, before it was removed. In addition, these discharges have a different chemical composition than North Empire Creek.

Table 6 shows the change in water quality from sampling station NE-3.5, which is above the newly discovered seeps, to below the seeps, at monitoring station NE-3. These seeps may, in fact, be surface expressions of an underground mine pool associated with the shaft mine located just above the top of the Equator Mine waste pile. This shaft was partially filled and closed by DRMS in 2014. More investigation into the likely source of these seeps is needed.

Table 6 - Mine drainage impact discovery in middle North Empire Creek

May 18, 2018 High Flow Sampling Event							
Site ID	Date	Al	Cu	Mn	Ni	Zn	pH
NE-3.5	5/18/18	584	16	50	BDL*	BDL*	6.1
NE-3	5/18/18	608	137	148	2.6	23.5	4.7
*BDL- Below Detection Limit							

Clearly, the mine seepage is having a major impact on the stream below the former location of the Equator Mine waste pile and if it were not a factor, the reclamation work done during the *middle* reach project would be deemed quite successful.

Figure 18 below indicates a post-restoration profile of the total-metals load in North Empire Creek after all reclamation work had been completed upstream of monitoring site NE-3. The TMs load profile is a "snapshot", or instantaneous (time-of-sampling) reflection of the cumulative mass loading from all trace metals (TMs) for which there are laboratory results for that one sampling event and time.

Figure 18 - Total-metals load profile, May 18, 2018, versus May 14, 2019

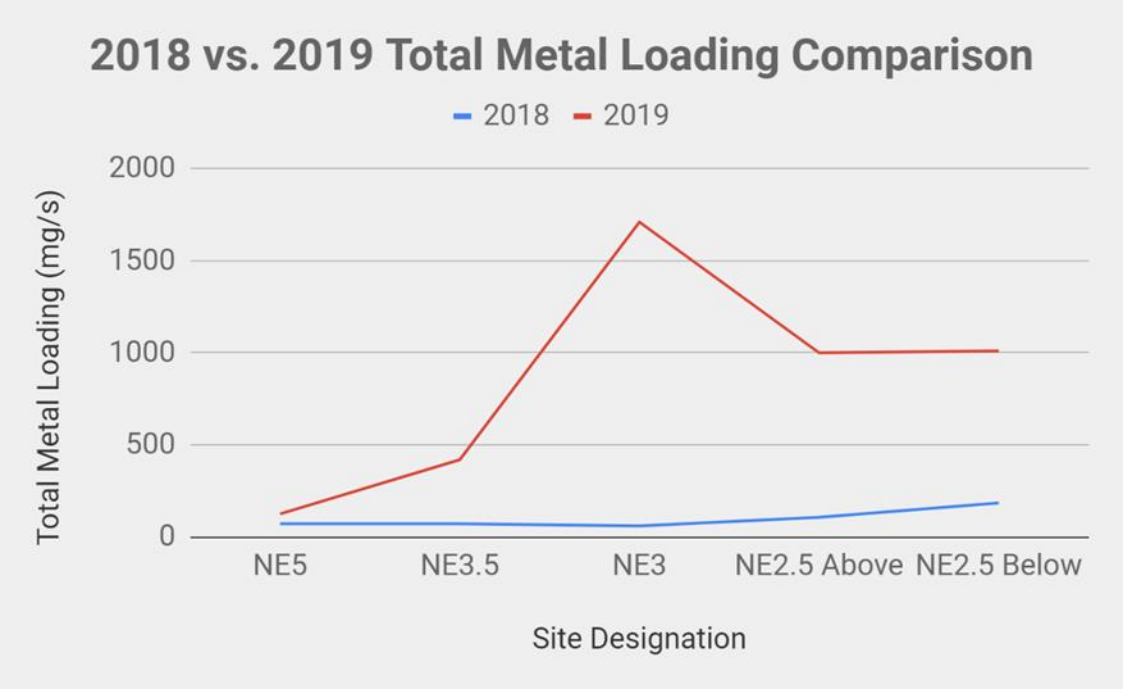


Table 7 - Total dissolved trace-metals loads during relative high flow

Site Designation	Loading 2018 (mg/s)	Loading 2019 (mg/s)
NE5	5.54	125
Conqueror Seep	0.487	11.4
NE4	0	506
Gold Fissure Seep	0.369	0
NE3.5	8.01	419
Gold Dirt Seep	6.25	43.1
Equator Upper Seep	30.4	-
Equator Lower Seep	16.7	265
NE3	0	1710
NE2.5 (Above Project)	106	1000
NE2.5 (Below Project)	184	1010

In the area addressed by the Lower North Empire Creek Restoration area, it is apparent that the stream already is carrying most of its maximum load of trace metals and acidity. The most interesting observation about the beneficial impact of the lower project is that there is presently only a tiny increase in metal loading through that project area. This is best represented by the total metal loading observed at NE-2.5 above and below the project area, as shown in Table 7. There is a total increase of only 10 ug/L for all 9 metals that were analyzed through the lower project area. This was a highly contaminated area from which 16,660 CY of mine waste and contaminated sediment were removed from the stream-channel bottom and emplaced in a repository.

Located further downstream from the Lower Empire Creek Restoration Project area is monitoring site NE-2, which is near the Aorta Mine. At this point, North Empire Creek is diverted and flows into an 880 LF culvert (which bypasses the streamflow around the closed Empire Landfill. At the lowest point in the North Empire Creek sub-watershed, preliminary findings show an overall reduction in metal concentrations except for manganese as shown on Table 8. Aluminum, copper, and zinc concentrations have decreased to levels better (lower) than those observed at site NE-2 in 2014. The manganese concentration in 2019 increased to unprecedented levels, exceeding that observed at site NE-2 in 2014. Nickel concentrations increased (e.g., above the detection level) at site NE-3 and remain as dissolved form in the water column down to the confluence with Lion Creek, at times reaching, or exceeding the CDPHE-WQCD's chronic aquatic-life toxicity level of ~52 ug/L.

Table 8 - Water quality in Lower North Empire Creek near the Aorta Mine, upstream of the landfill

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-2	5/20/14	0.537	3300	671	780	N/A	288	3.7
NE-2	7/27/17		2100	380	3350	30.1	210	3.8
NE-2	9/19/17		3160	226	10,000	66.4	338	
NE-2	5/18/18	0.613	692	261	353	8.25	81.4	4.7
NE-2	8/1/18		1600	348	677	12.3	91.6	3.4
NE-2	10/18/18		3370	99.2	15,600	102	1100	3.2
NE-2	5/14/19	0.148	2773	606	3486	44	230	3.8

Finally, at site NE-1 just above the confluence with Lion Creek, the pH values have increased indicating relatively less unbuffered acidity in the system at this point. Relatively high manganese concentrations occur in all sample results at this site, as well.

Table 9 - Water quality in Lower North Empire Creek near the confluence with Lion Creek

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-1	5/20/14	0.86	2467	576	8190	72	352	5.9
NE-1	7/27/17	0.078	123	97.5	6620	38.2	145	5.7
NE-1	9/19/17	0.056	28.8	7.9	10500	51.9	137	
NE-1	5/18/18	1.34	658	225	1060	12.1	112	
NE-1	8/1/18	0.078	50	6.6	10100	42.3	133	5.9
NE-1	10/18/18		50	2.9	27850	50.7	103	5.7
NE-1	5/14/19	0.347	1042	214	4995	37.7	167.5	5.5
*Below Detection Limit; **This site was not sampled until 2018, after project completion								

6.2.1.1 Project-related Metal Load Reductions

There are strong indications shown in Tables 8 and 9 that metal concentrations are lower in 2018 and 2019, than in 2014, which is the baseline year for comparison. But comparisons in actual metal loads are necessary to understand whether the situation has really improved. Indeed, Tables 10 and 11 below, show that metal load reductions downstream of the Project Improvements are noteworthy at monitoring sites NE1 and NE2.

Metal Loading is simply the multiplicative product of the metal concentration and the stream flow (with appropriate unit conversions). Mass loading is often expressed in units of mg/s, or lb/day, when small datasets are available over short time frames, as in the present case. When there is adequate representative data to characterize water quality seasonally, with accompanying flow measurements over one or more years, chemical loading may be expressed more accurately (and usefully) in units of lb/month, or lb/year. Tables 10 and 11 present metal loads in the familiar unit of measurement- lb/day. Fortunately, the actual loads calculated in this way are of magnitudes that are convenient for comparison.

Example Calculation of Copper load at NE-1 on 5/20/14, as shown in Table 11
(Note: concentration and flow values were obtained from Table 9)
[Cu Concentration] *(streamflow) * [unit conversion constant]

[Cu] * $Q_{NE\ Ck}$ *[unit conversions] = Copper load

(576 ug/L)* 0.86 ft^3/s)*[(3.8L/gal)*(7.5gal/ft^3)*(g/10^6 ug)*(lb/455 g)(86,400 s/day] = 2.68 lb/day

Typically, metal loading in North Empire Ck. is highest during annual high flow events. May is generally the month when the highest flows occur. Accordingly, the project-related load reductions shown in Table 10 below, are presented for sampling events conducted in May of 2014, before any of the project improvements were accomplished and in May of 2018 and 2019 after all project work was completed in the Upper, Middle and Lower reaches of North Empire Ck. The construction work for the Lower North

Empire Creek project was completed in early February 2018. (Please note that some additional seeding work was done in June of 2018 with no appreciable effect on water quality.) Sampling Site NE-2 is located just upstream of the County Landfill and adjacent to the Aorta Mine. This is the closest monitoring site to the downstream limit of the Lower North Empire Creek project area. Meanwhile, sampling Site NE-1 is located immediately upstream of the confluence of North Empire Creek and Lion Creek, approximately 1/3 mile below site NE-2.

Load reductions are calculated by comparing the baseline load measured in 2014 at monitoring sites NE-1 and NE-2 to the loads measured in 2018 and 2019 after project completion.

Example calculation of % Copper load reduction at NE-2 measured on 5/18/18

Baseline Cu load 1.95lb/day
5/18/18 Cu load -0.87lb/day
Actual load reduction 1.08 lb/day

$$\% \text{ load reduction} = \frac{1.08}{1.95} \times 100 = 55\%$$

Table 10 - Metal Load Reductions observed at NE-2 in 2018 and 2019

Sampling Site	Date	Cu Load (lb/day)	Mn Load (lb/day)	Ni Load (lb/day)	Zn Load (lb/day)
NE-2 (Baseline)	5/20/14	1.95	2.27	N/A	0.84
NE-2	5/18/18	0.87	1.17	0.03	0.27
Actual Load reduction		1.08	1.10	N/A	0.57
% Load reduction		55%	49%	N/A	68%
NE-2	5/14/19	0.49	2.79	0.04	0.18
Actual Load reduction		1.46	-0.52	N/A	0.66
% Load reduction		75%	22%	N/A	79%

The load reductions observed at monitoring site NE-2 in 2018 range from 49% to 68% for the suite of metals that were evaluated. In 2019 the load reductions were 75% for Copper and 79% for Zinc. There was not a baseline result for Ni in 2014, so load reductions for Ni could not be calculated at monitoring station NE-2, either in 2018, or 2019. Inexplicably, there was a 49% reduction in the manganese load in 2018, but, (as highlighted in Table 10 with a red font) in 2019, there was a 22% *increase* in load over the baseline value.

Table 11 - Metal Load Reductions observed at NE-1 in 2018 and 2019

Sampling Site	Date	Cu Load (lb/day)	Mn Load (lb/day)	Ni Load (lb/day)	Zn Load (lb/day)
NE-1 (Baseline)	5/20/14	2.68	38.1	0.34	1.63
NE-1	5/18/18	1.63	7.68	0.09	0.81
Actual Load reduction		1.05	30.4	0.25	0.82
% Load reduction		39.2%	80%	74%	50%
NE-1	5/14/19	0.40	9.3	0.07	0.32
Actual Load reduction		2.28	28.8	0.27	1.31
% Load reduction		85.1%	76%	79%	80%

Table 11 shows that load reductions at monitoring Site NE-1 in 2018, ranged from 39% to 80% for metals evaluated. In 2019, the load reductions ranged from 76% to 85%, which was quite impressive after such major construction activities in the stream channel. Copper and Zinc had the greatest load reductions at both sites and in both years. The overall water quality results were good and met expectations given the type of reclamation work that was undertaken, which mainly consisted of removing mine waste from the stream channel. This work was very thorough, and it would be difficult and costly to improve upon. The fact that this work uncovered several previously unknown mineralized groundwater seeps, which may be connected to underground mine workings, means that mine drainage rather than mine waste may have to be targeted and addressed to obtain further water quality improvements.

6.2.2 BIOLOGICAL

West Denver Chapter of Trout Unlimited and Colorado School of Mines (CSM) conducted bioassessment reconnaissance surveys in 2014 and 2015. Sampling and identification of macro-invertebrate populations was not possible because they were simply not present within North Empire Creek, at that time. But on October 18, 2018, a single stonefly nymph was observed at sampling site NE-4 during the Clear Creek Watershed Foundation's (CCWF's) water-quality sampling survey. This was a positive indication of the success of the reclamation work completed as part of the Upper North Empire Creek Restoration project.

Outside of the stream location where newly discovered mine drainage is impacting water quality in the *middle* reach, it is likely that macro-invertebrates will begin to repopulate the stream now that so much restoration work has been done upstream of site NE-2. We recommend that quantitative biological monitoring be done for this drainage going forward.

6.2.3 PHYSICAL/HABITAT

Physical habitat assessment protocols were not performed in the North Empire Creek watershed. This stream is not a likely candidate for reintroduction of fish or other organisms of a higher order than macroinvertebrates. There are obvious physical habitat problems that limit the aquatic life use of the stream. During hot summer periods and wintertime, flow in the creek is discontinuous, disappearing into the bottom substrate and reappearing well downstream at points where bedrock outcrops in the channel. The overall gradient of North Empire averages about 20% and there are many sections with falls and cascades, which would also be barriers to normal fish migration. Moreover, there are no pools with holding water where fish could survive, especially during the winter months. Construction of such pools is not feasible given the continuously steep gradient.

North Empire Creek has been impacted by extreme sedimentation associated with past hydraulic mining activities. From the headwaters to water quality monitoring station NE-2, near the Aorta Mine, Sediment deposits 20-35 feet deep have been discovered during CCWF's reclamation activities. This sediment is highly porous and very mineralized in certain locations. Much of this contaminated sediment, but not all, has been removed during our project work. As noted above, surface water drains into this artificially created alluvial formation and disappears, leaving interspersed sections of dry stream channel.

6.3 GROUND WATER IMPROVEMENTS

Groundwater is associated with the sandy alluvial sediment deposits, which largely resulted from hydraulic placer mining in the late 1880s. This groundwater is under bedrock control, which results in significant mixing of surface and groundwater, everywhere bedrock-outcrops occur in the channel. Therefore, all improvements in surface water quality will accrue to groundwater quality, as well.

6.3.1 NUTRIENTS

The North Empire Creek Watershed has no significant non-mining related impacts. There is only one home in the entire watershed, and it is well removed from the stream channel. Nitrogen and phosphorous levels are quite low and representative of other pristine mountain water bodies, or at least, the reference conditions that have been established for such water bodies. None of the BMPs that were implemented in this watershed were aimed at nutrient reduction.

6.4 QUALITY ASSURANCE REPORTING

Detailed weekly field reports were compiled and submitted to CDPHE, DRMS and EPA during and immediately following construction. The contractor provided invoices from vendors, trip reports, mine waste haulage records, back-up information for labor, equipment and mobilization/demobilization costs. CCWF maintained a strong presence at the site during construction and kept close tabs on day-to-day activities.

6.5 RESULTS OF BMP OPERATION AND MAINTENANCE REVIEWS

CCWF conducted a field site review of BMP Operation and Maintenance needs with the project contractor in October of 2018. A budget reallocation was submitted by CCWF and approved by CDPHE on January 24, 2019 to cover the cost of additional revegetation site activities. The following revegetation tasks and activities were identified by the contractor.

1. A manifold system with four 500-gallon tanks constructed on site and filled with water. Drip tubing strung to 300 planted plugs:
   Limber Pine - 60
   Bristlecone Pine - 30
   Lodgepole Pine - 30
   Englemann Spruce - 60
   Aspen - 30
   Dogwood - 30
   Mountain Mahogany - 60

2. A 2,000-gallon water truck to top off the tanks approximately 10 times (40 watering events) through the summer. Tank system checked on a weekly basis. Each plant will be receiving approximately 1.6 gallons per watering.

6.6 COORDINATION EFFORTS

CCWF coordinated closely with the USFS Arapaho-Roosevelt National Forest and the USFS Abandoned Mine Program in Boulder, CO. CCWF obtained most current surveying information from USFS, which

provided precise boundaries of mining claims and Forestlands in the project area. No USFS lands were affected by this project.

6.7 COORDINATION FROM OTHER STATE AGENCIES

DRMS was a major donor to the *upper* reach project providing $30,000 in support of that effort. DRMS also provided helpful technical guidance for revegetation efforts and runoff control. DRMS provided $39,000, as Cash Match funding for the *middle* reach project. DRMS provided generously $50,000, as Cash Match funding for the *lower* reach project. DRMS was treated as a project sponsor (as was CDPHE and EPA) throughout the period of performance for our state contact.

6.8 OTHER STATE ENVIRONMENTAL PROGRAM COORDINATION

A Grading and Excavation permit and a BMP permit were issued by Clear Creek County for the lower reach project. A new state stormwater permit was required for new areas of proposed disturbance. All permitting was complete by July 28, 2017.

6.9 FEDERAL COORDINATION

Since this project is located within EPA's Clear Creek/Central City Superfund Study Area, it was closely coordinated with EPA' Superfund program, as well as the Region VIII Nonpoint Source Program. Our project was approved for utilization of EPA's ESAT Laboratory as part of the agency's basin-wide metals characterization effort. This contribution was acknowledged in the *middle* North Empire Project final report. In addition, a site-specific Good Samaritan Comfort Letter was obtained on July 6, 2017 from EPA regarding liability protection for CCWF under CERCLA.

6.10 OTHER SOURCES OF FUNDS

Cash Match from CDRMS	$50,000.00
Cash Match from UCCWA - Compost	$ 4,000.00
Special Road Maintenance by Clear Creek County	$ 8,242.30
Sign Design & Installation	$ 1,713.10
Rock Products Donation Frei Quarry	$17,455.55
Colorado School of Mines Environmental	
Intensive Synoptic Sampling & Laboratory Analysis	$87,780.00
WQ Analysis Consulting, TDS	$ 2,004.00
Pre-project Design Frontier Environmental Services	$ 6,000.00
CCWF Project Director and Project Manager	$18,387.60
TOTAL	$195,582.55

7 SUMMARY OF PUBLIC PARTICIPATION

Public involvement in the project was garnered through continuing media coverage, project signage, outreach meetings with UCCWA, Clear Creek County, the Town of Empire and an educational booth display during the annual Sustaining Colorado Watersheds Conference. We also made presentations to the Upper Clear Creek Watershed Association, Clear Creek County Commissioners, Empire SWAP

Planning Group and the 2017 Colorado School of Mines Mining Summit. In cooperation with Clear Creek County, we also have placed a large full color, fact-filled informational project sign at a highly visible location on County land, where all the project work for North Empire Creek has taken place (Figure 19).

Reclamation of the overall Lion Creek Watershed (including North Empire Creek) was heartily supported by the upper clear creek watershed community. The Town of Empire and the Clear Creek County Commissioners have expressed their support through official votes. The Upper Clear Creek Watershed Association has been very supportive of this effort. This project was incorporated into the adopted Upper Clear Creek Watershed Management Plan. The Freeport MacMoRan (FMI) Henderson Mine has been a technical partner providing reclamation consultation and funding for CSM 's involvement in senior design projects and the environmental field sessions.

MolsonCoors has provided major financial support (i.e., non-federal cash match) to CCWF for project management and program administration. The Frei Walstrum quarry donated rock materials for this project, also in the form of Non-federal In-Kind Match. Clear Creek County agreed to perform much-needed road maintenance on County Road 251, in order to facilitate the project which was another source of In-Kind Match for this project. This project received positive news media coverage in the Clear Creek Courant, the Firestarter and through an extended on-air interview with CCWF on KGYT radio in Idaho Springs. A Trout Unlimited Good Samaritan Site Tour took place on August 6, 2018 that included U.S. Senator Cory Garner.

Over the past 10 years, CCWF has enjoyed a longstanding partnership with the Colorado School of Mines. We have worked together on nearly a dozen projects of mutual interest through EPICs courses, Senior Design Projects and Summer Environmental Field Sessions. CSM has helped enormously in the characterization of the environmental issues in the overall Lion Creek Watershed and in the development of site-specific reclamation plans. We had two senior design projects related to the *middle* reach project and environmental field sessions from 2013-2019 and devoted to the North Empire Creek and Lion Creek problem areas.

8 ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

8.1 REVEGETATION EFFORTS

Follow-up maintenance and revegetation was necessary at the project site. Based on late fall / early winter site reviews, the site had poor results for revegetation. This was due partly to unusually warm winter weather and very low precipitation. We also contracted with a soil scientist who collected and analyzed representative soil samples from reclaimed areas in the project area to develop a more robust protocol for a remedial revegetation effort. The sampling revealed a high salinity content likely due to soil transported from

Figure 19 - Informational Project Sign at Highly Visible Location on County Land

eastern plains dairy farms. We received recommendations for soil amendments and more appropriate seeding.

9 FUTURE ACTIVITY RECOMMENDATIONS

Removal of mine waste in the *middle* reach project area near the toe of the Equator pile revealed two intermittently flowing seeps or springs and one seep below the Gold Dirt waste pile. The water emanating from these seeps was sampled and analyzed for its quality. It was significantly contaminated. Follow-up investigations are needed to determine the source of these seeps, as their water quality differs from that observed in North Empire Creek at this location.

10 LIST OF APPENDICES

10.1 Appendix A - Revised SAP for Lion Creek and North Empire Creek

10.2 Appendix B - Assessment of WQ Improvements from NEC Restoration Projects Final Report