Coalition for the Upper South Platte (CUSP)

Mine Assessment Project:

Report on Surface and Mine Water Sampling and Monitoring in the Upper South Platte Watershed, Park County, Colorado

2010

By

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1.0 Executive Summary

This report summarizes the 2010 Mine Assessment Project (MAP) conducted by the Coalition for the Upper South Platte (CUSP). CUSP is a nonprofit watershed group focused on the protection of water quality and ecological health of the Upper South Platte Watershed through cooperative efforts of watershed stakeholders, with an emphasis placed on community values and economic sustainability. Through financial support by the Colorado Water Conservation Board and the Healthy Rivers Fund, CUSP was able to identify the water-quality impacts of historical mining throughout the watershed.

Although inventories of abandoned mines had been conducted within the watershed by the U.S. Forest Service, the Bureau of Land Management, the Colorado Geologic Survey, and the Colorado Division of Reclamation and Mine Safety, these studies were performed in the early 1980s and 1990s. Since that time there has been a drastic increase in population and in demand for water resources from the watershed. Additionally, there have been tremendous advances in testing and mapping technologies over the last quarter-century. The primary objectives of the 2010 MAP were to: (1) develop partnerships and an advisory committee that included appropriate agencies, local citizens, property owners, and other interested groups; (2) collect all relevant background reports and literature associated with mining and water quality within the watershed; (3) carry out site visits and inventories of abandoned mines and prominent tributaries that had experienced historical mining within the watershed; (4) collect water-quality field parameters, samples for laboratory analysis, and GPS coordinates of mine features; (5) determe property ownership and mine site boundaries; (6) prioritize mine sites and develop a monitoring strategy to further characterize problem sites, to facilitate management and remedial decisions; (7) compile a comprehensive document of the abandoned mine lands within the watershed including relevant historical information, past abandoned mine inventories, and recent inventory data collected during the 2010 field season.

In summary, all of these objectives were completed. Approximately 50 mine sites were visited; 50 water-quality samples were sent to Denver Water Laboratories for in-kind analysis; 73 sites were tested for field parameters throughout 8 prominent tributaries; basic property ownership and boundaries were determined for the 50 sites; and mine sites and tributaries were prioritized for continued monitoring. Most importantly, partnerships with local, state, and federal agencies and groups were developed and positive connections were made with mine owners.

The 2010 MAP confirmed three sources of natural water-quality degradation associated with hydrothermally altered geologic terrain. Handcart Gulch and Geneva Creek tributaries to the North Fork of the Upper South Platte and drainage from the Red Amphitheater in Buckskin Gulch, a tributary to the Middle Fork of the Upper South Platte, represent sources of metal loading to the watershed. Water chemistry throughout the watershed is dominantly controlled by the surrounding geology. This was demonstrated by the neutral to basic pH readings in the Middle Fork and South Fork drainages. These are associated with surface and groundwater interaction with the carbonate sedimentary formations that also hosted the ore deposits exploited by the miners of gold, silver, lead, zinc, and copper. The data collected in the 2010 season confirmed that not all mines discharge acid mine drainage, and that neutral to basic mine drainage dominated the Upper South Platte inventory. Although the majority of mine drainage was neutral, heavy metals were detected that exceeded state aquatic life standards and in some cases surpassed drinking water standards.

Mines and drainages that need further monitoring and characterization consist of: (1) the Buckskin Creek drainage, including the Kentucky Bell Mine, the Sweet Home Mine, the Mineral Park Mill ponds, and the Buckskin Joe Mine; (2) both the north and south forks of Mosquito Creek, including the American Mill site and the Orphan Boy Mine; (3) the North Fork of the Upper South Platte, including the Missouri and Whale Mine complex; and (4) the Fourmile Creek drainage.

2.0 Introduction

The Upper South Platte Watershed encompasses almost 2,600 square miles and represents approximately 26% of the entire South Platte Watershed within Colorado. The watershed is situated southwest of the Denver metro area (Figure 1). About 75% of Colorado's residents count wholly or in part on water that comes from the watershed (either native or transmountain diversion waters) for drinking, industrial, and agricultural use (CUSP, 2001). Mining, traditionally an important economic engine within the Upper South Platte Watershed, has left its mark: runoff from waste rock, tailings, and discharging adits may result in environmental degradation and water contamination. Mine issues were ranked as an "issue of high priority" in the Coalition for the Upper South Platte's (CUSP's) overall strategic plan (originally completed in 2000 and updated in 2006). As a result, an assessment of abandoned and inactive mines was conducted to assess the potential impacts and to prioritize sites for future monitoring and reclamation.

2.1 Hydrologic and Climate Setting

The Upper South Platte Watershed begins along the Continental Divide in the Mosquito Range and ends at Strontia Springs Reservoir (Figure 2). It varies in elevation from about 6,000 feet to over 14,000 feet above mean sea level (amsl). The Upper South Platte Watershed includes Park County and parts of Douglas, Teller, Jefferson, and Clear Creek counties. The watershed above Strontia Springs Reservoir can be defined by six main subwatersheds: main stem of the Upper South Platte River (upstream of the Strontia Springs to the confluence of the South and Middle Forks), North Fork, South

Fork, Middle Fork, Horse Creek, and Tarryall Creek. There are five major municipal reservoirs within the watershed and several smaller reservoirs (CUSP, 2001).

Climate within the watershed is highly dependent on elevation and location. The semi-arid Front Range climate transitions to an alpine climate at the headwaters of the watershed. The eastern portion of the watershed is characterized by warm, dry summers and mild winters, with monthly temperatures ranging from 20°F to 80°F. In contrast, the western region and South Park experience mild summers and cold winters, with average temperatures ranging from below 0°F to 70°F. Average annual precipitation ranges from about 10 to 40 inches and varies with altitude (Miller and Ortiz, 2007). The lowest annual precipitation amounts occur in the vicinity of Hartsel, and the highest amounts occur along the Continental Divide in the western part of the watershed. Much of the precipitation at the higher altitudes is in the form of snow, which can accumulate to more than 300 inches per year in the mountains (Miller and Ortiz, 2007).

2.2 Mine Assessment Project

To evaluate water-quality impacts from historical mining, the Coalition for the Upper South Platte (CUSP) began an inventory of abandoned mines within the watershed in 2010. This inventory was made possible with financial aid from the Healthy Rivers Fund, administered by the Colorado Water Conservation Board (CWCB), and partnerships with Denver Water, the U.S. Forest Service (USFS), Region 8 of the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the Colorado Division of Reclamation and Mine Safety (DRMS), and other local nonprofits, interested citizens, and small government bodies.

The Mine Assessment Project (MAP) began with the compilation of existing mine inventories and previous studies for the area of interest. This compilation focused on collecting background reports and data from various advisory group members and included such information as: hydrogeological characterizations, information on historical uses, contaminant loading data, and USFS mine inventories. An inventory of known abandoned mine lands (AMLs) on National Forest land was conducted by the Colorado Geological Survey in the mid-1990s. Data collected at these mines included:

mapping of the features at the sites, environmental information at the AML, environmental and safety ratings, and water and waste samples from select sites. DRMS conducted an inventory of AML throughout Park County in the 1980s. That inventory focused heavily on the north and west portions of the county, with smaller amounts of information gathered in other parts of Park County.

The initial literature and data compilation for the MAP focused on the mine sites that were identified in either the USFS or DRMS inventories as having potential or confirmed environmental degradation. Approximately 45 mines or general areas of concern were identified within the watershed for further investigation. The majority of mining occurred in the northwest portion of the watershed, in the Colorado Mineral Belt (Figure 3), and the tributaries in these areas were targeted during the 2010 field season. This report summarizes the 2010 findings.

3.0 Methodology

The primary objective of the 2010 field season was to visit the mines identified in the background research, as well as all the subdrainages within the watershed that experienced widespread historical mining. Many of the sites identified during the background research are located on private property and required special attention to property boundaries when the researchers performed field investigations. Owners of identified mines were sent a notification letter regarding the project and the researchers' desire to obtain access to the mine sites. In the process of determining the owners of each mine to contact, it became apparent that obtaining permission to access each mine site would require a long-term effort in building positive relationships with and identifying the numerous owners. Many mines are owned by more than one party; in contrast, a large number of mines are owned by one party solely. A major challenge, but also strength, of this project was its intention to inventory both public and private properties. Because of this challenge, many of the private mine sites were not sampled during the 2010 field season. However, the building blocks of positive relationships with the private owners have been laid and future sampling and site visits to their mines looks promising for the 2011 field season.

Although the private mine sites were not directly accessed, field investigations were performed around the sites and as close to the property lines as possible. Full site inventories were conducted at mines located on public lands. Field investigations included: collection of GPS locations of significant mine features, such as extent and placement of tailings piles, draining adits, mine structures, etc.; collection of water-quality data, such as pH, water temperature, dissolved oxygen, and electrical conductivity; and collection of detailed field notes describing the sites. If appropriate, the USFS Abandoned Mine Land Inventory (AMLI) data form (Appendix 1) was filled out. The USFS–AMLI field guide was generally followed during each visit to ensure complete site descriptions. Water samples were collected at 50 locations throughout the watershed and were sent to Denver Water Laboratories for analysis. Occasionally, the dissolved split had a higher concentration than the total split. In general, this discrepancy is within the accuracy of the instrumentation and may have resulted from induced error associated with the automated dilution process taken by the instrumentation. Additional water samples were analyzed for total alkalinity, Cd, Cu, Mn, sulfate, and Zn with a Hach DR2800 spectrophotometer. Details of sampling procedures are described in the Sampling and Analysis Plan (SAP) and the Quality Assurance Project Plan (QAPP), both found in Appendix 1. Table Value Standards (TVS) were calculated from average hardness values for each water-quality sample using the Year 2000 formulas of the Water Quality Control Division of the Colorado Department of Public Health and Environment. Dissolved metals concentrations were compared to the Acute and Chronic TVS for an evaluation of whether or not water quality exceeded recommended standards. Calculated TVS for each sample are provided in Table A and the TVS equations from the CDPHE are provided in Table B, both tables are provided in Appendix 1.

4.0 Geologic Setting and Drainage Hydrogeochemistry

4.1 Carbonate Geology of the Middle and South Fork Subdrainages and Its Influence on Buffering Capacity and Water Chemistry

The geology of the Middle and South Forks of the Upper South Platte is dominated by highly faulted Proterozoic schist and gneiss, as well as Paleozoic marine carbonate, shale, and siltstone that were later intruded by Tertiary-age sills and dikes. Extensive Pleistocene glaciation is evident in the broad U-shaped valleys and small glacial tarn lakes situated at the bases of mountain cirques and arêtes. The valley bottoms are filled with both glacial debris and periglacial Quaternary gravels. These deposits host the gold placers exploited by early miners. The carbonate-rich geology of the western part of the watershed may be responsible for the neutral to basic pH values found during the 2010 field season. The following geologic summary of pertinent mines and tributaries further describes the relationship between mine workings and carbonate host rocks.

The headwalls of upper Buckskin Gulch, just south of Montgomery Gulch, are comprised of Archean schists and gneisses and intrusive igneous rocks with Cambrian quartzite capping the tops of the peaks skylining the Buckskin amphitheater. Mines in this district exploited the silver-lead mantos and veins in carbonate host rocks, specifically the dolomite of the upper Mississippian Leadville Limestone. Other mines in the Buckskin subdistrict exploited polymetallic metal sulfide veins, hosted in both the Proterozoic igneous and metamorphic rocks and the Cambrian Sawatch Quartzite (Scarbrough, 2001). The Sawatch Quartzite is comprised of quartzite beds overlain by the Peerless Shale Member that includes layers of white and purple quartzites, limestone intervals, and grayish-green shale (McGookey, 2002).

The Orphan Boy Mine, in the Mosquito Drainage, is the southernmost vein and manto deposit of the Phillips Mine Group in the Buckskin drainage. The deposit is typical of the Sawatch Quartzite manto and vein deposit, in which the ore is confined to poorly developed quartzite-hosted mantos composed of massive pyrite containing variable amounts of galena, sphalerite, and chalcopyrite. Locally theses sulfides constitute up to 30% of the vein along with calcite gangue (Patton et al., 1912). The Mosquito Gulch drainage is comprised of the same general geology as the Buckskin and Montgomery drainages. The London Group, the largest mine complex in the subdrainage, exploited a series of thick quartz monzonites and rhyolite sills (the London ore porphyry zone), hosted in a 175–575-foot-thick shattered zone near the base of the Pennsylvanian Weber Formation, comprised of siltstone, sandstone, and shale beds (Scarbrough, 2001). The London Group also exploited sills in the dolomitic portions of the Mississippian Leadville Limestone and Devonian-Mississippian Dyer Dolomite, the typical Mosquito Range host rock (Singewald and Butler, 1941). Mines located in the South Fork drainage also exploited similar deposits hosted in the typical Mosquito Range carbonate formations.

Approximately three-quarters of the way up Buckskin Gulch from the town of Alma there is a semicircular break in the wall of the Ordovician sedimentary rocks, a thousand feet or more above the valley bottom along the southwest side of Mount Bross (Photograph 23). Named the Red Amphitheater, the scree and talus slopes are various shades of red and yellow iron oxides. The Red Amphitheater represents a zone of pyritic hydrothermal alteration associated with the intrusion of the Buckskin stock into the Precambrian metamorphic rocks (McGookey, 2002). A small tributary drains the amphitheater and crosses CR 8 just above its confluence with Buckskin Creek. This tributary is often cloudy with suspended and dissolved sediment and metals and represents a source of metal loading to Buckskin Creek that is considered natural rock drainage rather than mining-impacted.

Water-quality sampling within the Middle and South Fork tributaries, including the Montgomery, Buckskin, Mosquito drainages, and even the Fourmile drainage, revealed generally neutral to slightly basic pH values and relatively high hardness contents. Water hardness in these drainages is directly related to interactions with the extensive carbonate bedrock in the western part of the watershed. As described above, mines in these drainages exploited porphyry deposits hosted in the carbonate sedimentary rocks or in quartzite formations surrounded by carbonate-rich country rock. Therefore, groundwater flowing through the underground mine workings and surface waters flowing through the waste rock piles are interacting with these same sedimentary formations. Any acid generation resulting from water interaction with sulfides present in the mineralized zone of the ore deposit is minimized by the presence of carbonate host or country rock.

4.2 Hydrothermally Altered Terrain and Natural Acid Rock Drainage

The geology in the area where headwaters of the North Fork of the Upper South Platte, Handcart Gulch, and Geneva Creek originate consists of Precambrian schist and gneiss that have been pyritically altered by hydrothermal fluids (Streufert, 1993b). This alteration is related to the emplacement and cooling of the Montezuma stock (Neuerberg and Botinelly, 1972). Groundwater and surface water interaction with this altered bedrock has resulted in naturally occurring water-quality degradation and acid rock drainage (ARD). Specifically, acid metal seeps originate as groundwater in pyritically altered quartz monzonites of the Oligocene-age Montezuma stock intrusives reach the surface.

Hall Valley is primarily underlain by Precambrian-age Swandyke hornblende gneiss that was later intruded by Tertiary-age quartz monzonites of the Montezuma stock. These mineralized Tertiary-age intrusions were the primary exploration targets for prospectors (Neubert and Wood, 2004). Both placer gold and vein-type base- and precious-metal load deposits are found in Hall Valley, including metallic minerals such as silver, gold, galena, sphalerite, tetrahedrite, various bismuth minerals, pyrite, and chalcopyrite. Gauge minerals are mainly quartz, barite, impure dolomite, and various impure micas (Lovering, 1935). The metamorphic country rock that hosts the mineralized zones has significantly lower quantities of carbonate minerals, compared to the sedimentary geology in the Mosquito Range, and therefore has less neutralizing capability, resulting in low pH values and acidic conditions.

5.0 Results and Discussion

5.1 North Fork of the Upper South Platte

5.1.1 Hall Valley

Site Setting

Hall Valley is in northwest Park County just north of Kenosha Pass and west of Grant, Colorado (Figure 2). The headwaters of the North Fork of the Upper South Platte River begin in Hall Valley, located at the base of Teller Mountain to the north, Handcart Peak to the east-northeast, and Bullion Mountain to the south. The entire North Fork sub-basin drains an area of 476 square miles, comprising 18.3 % of the Upper South Platte watershed. The Hall Valley subdrainage covers approximately 11.2 square miles and is bounded by the Continental Divide on the north and west, the Jefferson Creek subdrainage to the south, and the Handcart Gulch drainage to the north and east. Elevations range from 9,800 feet amsl at the confluence of Hall Valley and Handcart Gulch to approximately 12,600 feet amsl along the Continental Divide at the headwaters of the North Fork of the Upper South Platte. Lovering's (1935) investigation of the Montezuma quadrangle provides the most thorough geological study done in Hall Valley.

Other previous investigations of interest to this project include the CDPHE Analytical Results Report for the Hall Valley Watershed (Mackey, 2001) and the preliminary assessment/site investigation (PA/SI) by J. Neubert of the USFS and R. Wood of the Colorado Geological Survey (CGS) (2004). In 2008, a Total Maximum Daily Load (TMDL) assessment was conducted for the Upper South Platte River Segment 4, Hall Valley/Handcart Gulch. This portion of the main stem of the North Fork of the Upper South Platte River and tributaries from the Hall Valley area to the confluence with Geneva Creek near Grant has been identified as impaired on all of the 303(d) lists since the first list was prepared in 1992. The 1998 303(d) list identified Al, Cd, Cu, Fe, and Pb as causing the water-quality impairment of the waterbody based on 1991 sampling. The 2002 303(d) list delisted the segment for Cd, Fe, and Pb, since it was meeting those standards, and removed the Al listing because there was no assigned Al standard for the segment. The 2004 and 2006 303(d) lists identified segment 4 as impaired or in non-attainment of the aquatic life baseline because of copper concentrations in excess of the assigned standards (CWQCC, 2008). Acid rock drainage (ARD) in Handcart Gulch has resulted in natural degradation and therefore Handcart Gulch was given a Load Allocation (LA) in the 2008 TMDL rather than a Waste Load Allocation (WLA), which was given to the Missouri Mine, considered an unpermitted point source for Cu loading. The TMDL for this segment of the North Fork is split 80% LA and 20% WLA (CWQCC, 2008).

Missouri and Whale Mines

History and Ownership

The Missouri and Whale mines are the most significant mine workings in Hall Valley and are situated at the headwaters of the North Fork of the Upper South Platte. The Whale Mine is located above the Missouri and is opened by seven adits ranging from 12,100 to 12,530 feet amsl (Photograph 1).

The Whale Mine area includes a variety of patented private claim holdings as well as National Forest Service (NFS) lands. The Whale lode was located in 1867, making it one of the earliest lode mines in Colorado. The mine was the chief producer for the Hall Valley Silver-Lead Mining and Smelting Co., Ltd., and was worked into the late 1920s (Mackey, 2001). The Whale vein mainly produced silver, but smaller quantities of lead and copper were also recovered. Between 1877 and 1930, about 836 tons of ore were shipped from the Whale Mine, yielding 939 oz. gold, 44,108 oz. silver, 265,404 lbs. lead, and 10,790 lbs. copper (Lovering and Goddard, 1950). The mine was briefly worked in the 1960s and 1970s.

Photograph 1: The Upper Hall Valley, showing the Whale Mine dump in the upper right corner.

The Missouri Mine is located approximately one-half mile south of the Whale Mine on the south side of the headwall of Hall Valley, adjacent to the North Fork of the Upper South Platte River (Photograph 2). The Missouri Mine is comprised of three patented claims, the Leftwick, the Laclede, and the Missouri which overlap in the vicinity of the two lower adits (levels No. 4 and 5) of the Missouri Mine. The unpatented Silver Queen lode overlapped the Missouri lode in the vicinity of the mine. The Missouri Mine is almost entirely privately owned, except for small portions of the mine dumps which are on USFS lands. The Leftwick lode was discovered in 1866 but wasn't officially located until 1872 (Neubert and Wood, 2004). The Missouri lode was located in 1880. The Missouri and related claims were worked until the early 1940s, with a final shipment of 27 tons of gold-silver-copper-lead ore in 1941 to the Ruth Mill in Idaho Springs (Henderson and Martin, 1943, in Neubert and Wood, 2004).

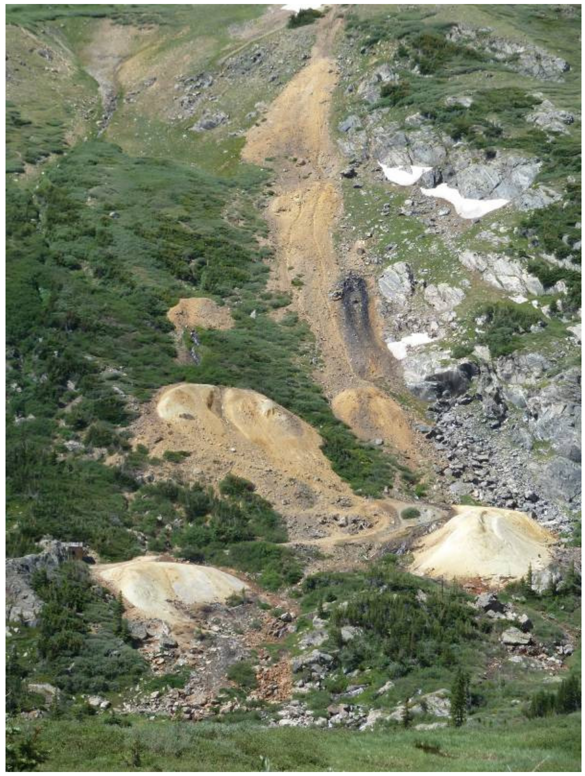
Photograph 2: The Upper Hall Valley, with the Missouri Mine in the foreground.

Field Data

Site visits were conducted August 5 and 6, 2010, with representatives from CUSP, the North Fork Foundation, the EPA, and the U.S. Forest Service. Flow measurements taken by the EPA. Hall Valley is accessed by CR 60 and the upper mine sites are accessed by FS 120. Weather conditions were mild, with afternoon thunderstorms that did not produce significant precipitation. Sampling locations are shown on Figure 4. Sampling was conducted at 18 locations over the two days. These 18 locations correspond to samples #025 through #041. After further GIS analysis, it was found that sample #035 was taken on private land and therefore was thrown out, because access to the private property has not yet been granted. FS 120 forks in the upper reaches of the valley. The north (right) fork leads to the Whale Mine, which was not visited because of private-property access issues. The south (left) fork leads to the Missouri Mine area. From the fork in the road, the Whale, Missouri, and other miscellaneous mine sites are easy to see because of the associated oxidized waste-rock piles across the upper North Fork basin (Photographs 1 through 6).

Field water-quality data for the Hall Valley is shown in Table 1. Sample #038 was collected upstream of the Missouri Mine, from drainage originating in a upper tarn lake. It is assumed that this sample represents background water chemistry, as there was no significant mining in the upper cirque above the Missouri and Whale mine complexes. Sample #038 had a neutral pH of 7.49 and moderately low adjusted conductivity of 79.7 µS. The USFS–ALMI field guide indicates that natural waters from alpine basins generally have conductivities of less than 100 µS. The background conditions at this site are below this general limit. Mine effluent pH and conductivity should be compared to the background values when assessing the environmental degradation of a site.

Adjusted conductivities for the remainder of the upper Hall Valley samples range from 78.5 µS (Sample #029, Missouri Mine adit drainage) to 258.9 µS (Sample #036, Great Eastern adit drainage). The sample pH values range from 3.47 (Sample #027) to 7.71 (North Fork of the Upper South Platte (NFSP) upstream of Handcart Gulch confluence). Sample #027 was taken from a seep or spring, flowing <1 gpm, below the waste-rock pile associated with the Rosalie claim. Figure 4 shows the sample locations color-coded by pH value. Four samples were taken lower in the drainage at the confluence of the North Fork of the Upper South Platte and Handcart Gulch (Figure 5). The adjusted conductivity of Handcart Gulch was 566 µS with a pH of 2.89. The conductivity value of Handcart Gulch is significantly higher than that of any other sample taken in this drainage. The low pH of Handcart Gulch reduces the pH of the North Fork below their confluence from 7.71 to 4.09.



Photograph 3: The Missouri Mine.

Analytical Results

Laboratory analysis results for the samples collected in Hall Valley are shown in Table 2. The background water-quality sample (Sample #038) did not exceed the acute or chronic TVS. The primary metals exceeding state standards were Al, Cd, Cu, Mn, Pb, and Zn. Sample #037, collected near #038 upstream of the Missouri Mine, had excess quantities of Cu and Pb, at 2.3X and 3.5X (respectively) above the chronic aquatic-life standards. Sample #037 was collected in a very braided riparian area where there is flow contribution from non-mining impacted tributaries (Sample #038) and drainage from the Ypsilanti and Great Eastern claims (Sample #036). Sample #036 contained Al at 2.5X the acute TVS and almost 22X the chronic TVS; its Pb content was almost 3X the chronic TVS; Mn exceeded the MCL of 50 µg/L; and the total recoverable Sb concentration (5.9µg/L) is very close to the drinking-water supply TVS of 6 µg/L. The Al and Pb detected in Sample #037 may be coming from the Great Eastern draining adit, although the drainage was minor <1gpm. Copper concentrations were low for the Great Eastern sample; therefore, there must be another source contributing to the high Cu concentration in Sample #037, potentially drainage from the Ypsilanti or the Whale Mine complex.

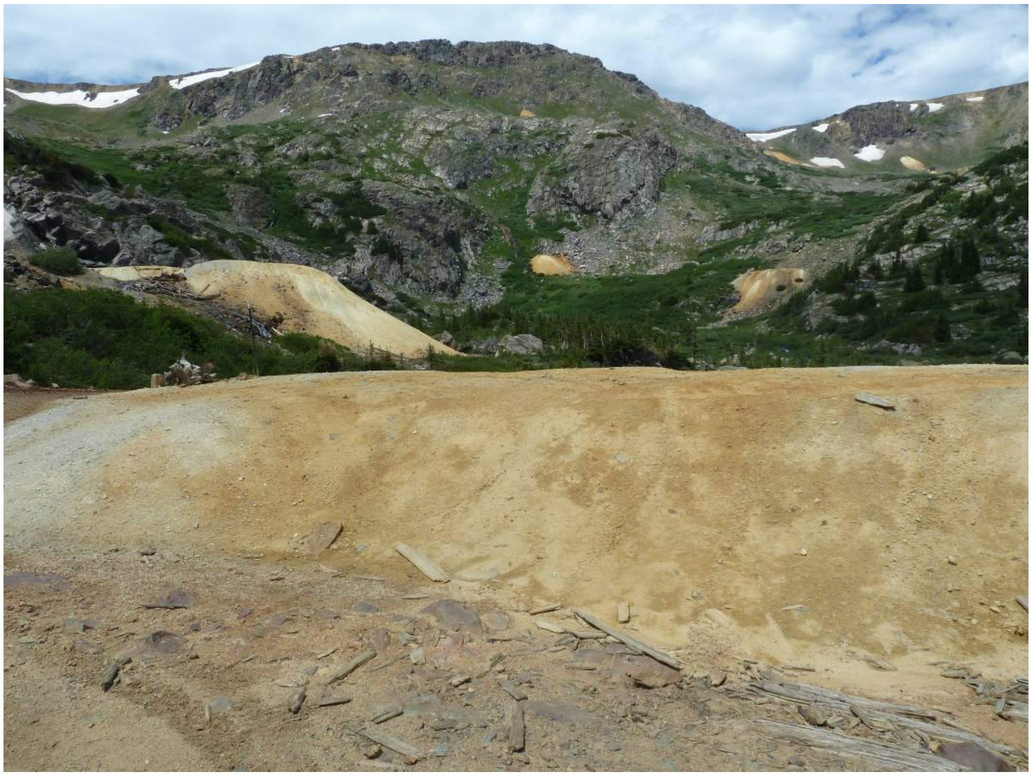
Photograph 4: One of the braided headwater tributaries to the North Fork above the Missouri Mine, looking at the Great Eastern Mine.

Just below sample location #037 is the first in a series of beaver ponds. Sample #030 was taken below this beaver pond. It includes some drainage from the lower western portal of the Missouri Mine but is above input from the eastern portal of the Missouri Mine. This sample comes from the same approximate location as sample MH-01-24 taken by Neubert in 2001 as part of the PA/SI conducted in Hall Valley (Neubert and Wood, 2004). Sample #030 did not exceed any of the state TVS, indicating that the Al, Cu, and Pb that exceeded state standards upstream had been somewhat attenuated, possibly by the presence of the beaver pond, dilution, and healthy riparian vegetation.

Sample #029 was taken just above where the drainage from the eastern Missouri Mine portal flows down and through the waste-rock pile into the second large beaver pond. This is the same approximate location as samples MH-01-22 and MH-01-23 taken by Neubert in 2001 (Neubert and Wood, 2004).

Photograph 5: Sample #029 location, below the Missouri Mine where drainage flows into a beaver pond.

This sample exceeded state TVS for acute and chronic Cu concentrations by 11.8X and 16.3X respectively. Sample #029 also exceeded state standards for Mn, Pb, and Zn. There were no detections of Cd above the detection limit for this sample, in contrast to 2001 sample MH-01-22, which had a Cd concentration of 0.9 µg/L, 1.4X the state standard. Although Sample #029 represents the majority of the flow from the Missouri Mine, it is unknown how much water seeps into the waste-rock pile and is not captured in this sample. Water interaction with the waste-rock pile above this sampling location may result in mineral dissolution or precipitation; therefore, it is important that a sample be collected at the mouth of the portal (before the water interacts significantly with the waste-rock pile) to determine what is actually going on at this location.



Photograph 6: The waste-rock piles for the Missouri Mine and for the Ypsilanti Mine (center top).

Sample #039, corresponding to sample MH-01-20 taken by Neubert in 2001 (Neubert and Wood, 2004), was taken on a small tributary that comes from the Whale Mine complex and the Swordfish Mill site before it flows into the large beaver pond. This sample exceeded the state TVS for Al above the chronic aquatic life standard by 5X. In addition, this sample had Ba concentrations >850 µg/L, which is above the detection limits and may be very close to the state drinking-water supply standards. Sample #031 was taken downstream from the large beaver pond, below all contributions from the Missouri and Whale mines but above contributions from two small tributaries flowing from the east. This sample contained Cu at 6.4X and 7.8X the acute and chronic TVS, exceeded the state MCL for Mn with concentrations greater than 50 µg/L, and tested for Pb just above the chronic TVS. Approximately a quarter-mile downstream (Sample #025), the Cu concentrations decreased, probably because of dilution from non-impacted tributaries and natural attenuation within the wetland beaver pond corridor. Sample #025 exceeded the state acute and chronic Cu aquatic life standards by 3.7X and

5.2X, respectively. Sample #026, collected just upstream of #025, exceeded the Cu acute and chronic aquatic life standards by 4.5X and 6.2X, respectively, and the state Mn MCL by 1.9x. A small, non-mining– impacted, tributary joins the North Fork just below Sample #026 and above #025. Dilution associated with this tributary (Sample #028) results in a reduction of the copper concentration and in the degree to which standards are exceeded. Although this non-mining–impacted tributary did not exceed the state TVS for Cu, its did exceed the TVS for Al, almost 5X the chronic aquatic-life standard, indicating that there is a natural source of Al influencing the water quality of the North Fork.

Additional samples collected in the upper reaches of the North Fork drainage include: the North Fork upstream and downstream of the confluence with Handcart Gulch; Handcart Gulch; and the hand water pump in the Hall Valley campground. Upstream of Handcart Gulch (Sample #040), copper exceeded the chronic aquatic-life standard by 1.3X; no other constituents exceeded the state standards. At Handcart Gulch (Sample #034) Al, Cd, Cu, Mn, and Zn exceeded the state TVS. The total recovered Al (19,000 µg/L) exceeded the acute aquatic-life standard by 25X and the chronic standard by 218X. Copper (200 µg/L) concentrations were greater than 30X the acute aquatic-life standard and almost 44X the chronic standard. Manganese concentrations (300 µg/L) exceeded the state MCL of 50 µg/L by 6X and zinc (130 µg/L) was present at levels almost 2X the acute and chronic standards. Cadmium exceeded the chronic standard by 3.3X. Downstream of Handcart Gulch (Sample #041), Al concentrations exceeded the state acute and chronic aquatic-life standards by 6.8X and 58X, Cu exceeded those standards by 9.8X and 13.6X, Mn exceeded the MCL by 1.8x, and the Pb concentration was just above the chronic aquatic-life standard. Copper loading upstream of Handcart Gulch was 110.8 kg/day. Downstream of Handcart Gulch, copper loading was 1,545.7 kg/day.

5.1.2 Geneva Creek

Site Setting

The upper Geneva Creek Basin is located on the eastern slope of the Continental Divide in Clear Creek County. The headwaters of Geneva Creek are approximately 13 miles northwest of Grant, Colorado, in the Pike National Forest. Geneva Creek is a primary tributary to the North Fork of the Upper South Platte River and is accessed by FS 119, off of the Guanella Pass Road. The prominent mine sites in this subdrainage are located on the flanks of Santa Fe Peak. Elevations range from 10,000 feet amsl to 12,889 feet amsl on Revenue Mountain. The Geneva Creek drainage is a characteristic glaciated valley, with steep walls and a typical flat U-shaped bottom. Geneva Creek is a steep mountain stream that runs southeast from its headwaters, which are comprised of runoff from the southern slope of Revenue Mountain and the eastern slope of the Continental Divide.

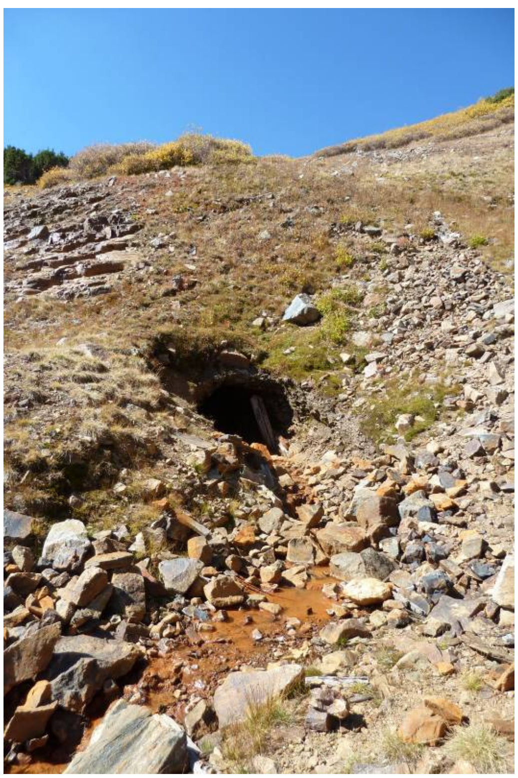
The lower section of Geneva Creek, from Scott Gomer Creek to the confluence with the North Fork of the Upper South Platte River, was listed in the 2008 303(d) list for impaired waters. The original 1998 303(d) evaluation listed this segment for non-attainment of Cu and Zn. A decade later, the 2008 list removed Cu but retained Zn as a contaminant for this section (CWQCC, 2008, Geneva Creek TMDL, 2008). The majority of the Geneva Creek Basin is owned by the U.S. Forest Service as part of the Pike National Forest. Geneva Creek is classified for Aquatic Life Use (Cold 1), Water Supply Use, Agriculture Use, and Recreation Use (1a), and is currently in non-attainment of the aquatic-life use based zinc standards. There are no permitted point source discharges in the Geneva Creek Basin and according to the 2008 TMDL the minimal legacy mining features in upper Geneva Creek are not affecting surface drainages.

<u>Sill Mine and Mary Ann Mine</u>

History and Ownership

The greatest activity in the Geneva Creek Mining District occurred between 1881 and 1888, when the major producing areas, including Revenue Mountain and Santa Fe Mountain, were being actively explored (Lovering and Goddard, 1950). The baritic lead-silver ores of Geneva Gulch were discovered about 1871. The Sill and Mary Ann mines are located in such close proximity that it is unclear which adits and waste- rock piles belong to one or the other (Photographs 7 through 16b).

Photograph 7: Looking west toward the Sill Mine and Mary Ann Mine complex, in the upper Geneva Creek Basin.



Photographs 8a and 8b: Lower Mary Ann Mine open adit.

Field Data

The Geneva Creek drainage was sampled on September 21, 2010, in conjunction with representatives from the CDPHE as part of their Geneva Creek Watershed Area

Site Investigation. No samples were collected by CUSP representatives for laboratory analysis, but both water and sediment samples were collected for laboratory analysis by CDPHE as part of their site investigation. As soon as these results are available they will be added to this report as an addendum. A total of 12 locations were tested for pH, conductivity, DO, and temperature. In addition, 8 of the 12 samples were analyzed for alkalinity, sulfate, Cd, Cu, Mn, and Zn, using a DR2800 Hach Spectrophotometer. Figures 6 and 7, from the CDPHE SAP, show the sampling locations. The field data collected during this visit is provided in Table 3. Spectrophotometer results are provided in Table 4. At the time of the site visit, the collapsed adit associated with the Sill Mine did not show any sign of discharge or drainage. The two lower Mary Ann Mine open adits were draining, as was the upper collapsed Mary Ann Mine adit, draining from a small (2-inch diameter) metal pipe (Photographs 12a and 12b). Tailings associated with the Sill Mine mill are laden with significant amounts of copper salts and oxides, apparent by their blue-green color (Photographs 14 to 16b). These tailings appear to be eroding off the mill foundation down toward the wetland area associated with the braided headwaters of Geneva Creek.

Photograph 9: Concentrated pyrite on top of the Sill Mine waste-rock pile.

Photograph 10: On top of the Sill Mine waste-rock pile, looking northeast down at historical mine building, with the lower Mary Ann Mine open adit waste-rock pile at left center.

Photograph 11: The Mary Ann Mine upper open adit.

Photograph 12a: Representatives from CDPHE taking water samples from the pipe draining the Mary Ann Mine upper collapsed adit.

Photograph 12b: Pipe draining the upper Mary Ann Mine collapsed adit.

Photograph 13: Headwaters of Geneva Creek above the Sill Mine and Mary Ann Mine complex, at the background sample location.

Photograph 14: Remains of the Sill Mine Mill.

Photograph 15: Tailings from the Sill Mine Mill; note the blue-green color associated with copper salt precipitates and oxides.

Photograph 16: Close-up of copper-rich tailings.


Photographs 16a and 16b: Drainage gulley below the Sill Mine complex where tailings have eroded (16b). The pictures were taken in the gulley approximately 250 feet below the mill area.

Samples #065 and #066 represent the background water quality in upper Geneva Creek, although the 1992 AMLI conducted by Colorado Geological Survey personnel (Streufert, 1993a) indicates that "the surface flow of Upper Geneva Creek is somewhat degraded as it enters the Sill Mine site…the degradation is undoubtedly caused by sulfide mineralization in contact with groundwater in the upper mine workings of the Silver Wave mine on Santa Fe Peak." Personal communication with Neubert (2010) indicated that the Silver Wave Mine is not a significant source of degradation and water samples taken at locations #065 and #066 do represent generalized background conditions. Both samples had relatively low pH values of 4.5 and 4.45, respectively. Adjusted conductivity values for these background samples were 257 µS and 200 µS, respectively. Although these pH values are low and the conductivity values are somewhat high, these values can be attributed to surface and groundwater interaction with the hydrothermally altered geologic terrain associated with the Montezuma stock. Adjusted conductivities for the remainder of upper Geneva Creek range from 111 µS (Jackwhacker Gulch) to 375 µS (Geneva Creek below iron fens). The pH values range from 3.21 (Geneva Creek below iron fens) to 7.11 (Mary Ann Mine upper open adit). It appears that the natural degradation in Geneva Creek associated with the iron fens and natural ARD is more impacting than the Sill or Mary Ann mines.

5.2 Middle Fork of the Upper South Platte

The Middle Fork of the Upper South Platte originates in the snow-fed tarns of the upper Platte and Wheeler drainages. Mount Democrat (14,148 ft. amsl), Traver Peak (13,852 ft. amsl), Clinton Peak (13,857 ft. amsl), Wheeler Mountain (13,690 ft. amsl), and North Star Mountain (13,614 ft. amsl) (from south to north) surround the headwaters of the Middle Fork. Montgomery Reservoir is located approximately 2.5 miles from the confluence of Platte and Wheeler gulch, the start of the main stem of the Middle Fork. The headwaters are accessed from CR 4 to FS 408 which is an advanced 4x4 recreational road. The majority of mines near the headwaters are located high on the north slopes of Mount Lincoln (14,286 ft. amsl) or high on the south slopes of North Star Mountain. Land ownership is a mix of USFS and private mining claims. Prominent tributaries in the upper Middle Fork drainage include Quartzville Creek, Dolly Varden Creek, Buckskin Creek, Mosquito Creek, and Sacramento Creek. The Middle Fork drains an area of 250 square miles comprising 9.6% of the Upper South Platte watershed.

5.2.1 Montgomery Gulch

Site Setting

As described above, the headwaters of the Middle Fork of the Upper South Platte originate high in Montgomery Gulch. Glacial geomorphology is dominant in this part of the watershed, including hanging valleys, broad U-shaped valleys, steep valley walls, glacial tarns (Upper and Lower Wheeler lakes), and prominent glacier cirques and arêtes. Outcrops of banded gneiss in Montgomery Gulch have deep grooves or glacial striations. The majority of the placer deposits in the Alma District originated from Montgomery Gulch. Montgomery was the first established mining camp in the Greater Alma Mining District in about 1861, the present location of Montgomery Reservoir. Early prospectors washed the glacial gravels for gold. Later, lode deposits of gold and silver were exploited by mines such as the Present Help, Orion, Kansas, Sovereign, Magnolia, and Tippecanoe. Some of these mines were located in the sedimentary formations of upper Mount Lincoln, while others were located along the gold-bearing fissure-type deposits in the schists on both sides of the Middle Fork of the Upper Platte River above Montgomery (Patton et al., 1912). The geology of Montgomery Gulch is typical of the Mosquito Range and consists of east-dipping Paleozoic sediments cut by east-dipping high-angle reverse faults and intruded by several sills and stocks.

Magnolia Mine and Mill

History and Ownership

The Magnolia Mine is located on the south-facing slopes of North Star Mountain, among several other notable claims such as the Ling Mine and the Sovereign Mine. The Magnolia claim is located on both private and USFS lands. The area is accessed by FR 188 and FR 189 near 11,900 ft. amsl. The Magnolia Mine is currently owned by Earth Energy Resources, LLC, which also owns the Missouri Mine, the Russia Mine, much of the Moose Mine, and almost the entire top of Mount Lincoln. An aerial tramway connected the Magnolia Mine to the Magnolia Mill. The cable and towers are still present today (Photograph 17). The Magnolia Mill is a massive structure at the inlet of Montgomery Reservoir (Photograph 18). By 1862 as many as 1,000 people lived at the Montgomery town site. Six gold mills, including the Magnolia, processed ore from the area's many mines.

Photograph 17: Cable tower from the Magnolia Mine to the Magnolia Mill, looking west toward the headwaters of the Middle Fork of the Upper South Platte.

Photograph 18: Magnolia Mill, with Montgomery Reservoir in the background.

Field Data

The numerous mine sites located on the south slope of North Star Mountain were visited on July 30, 2010. A significant rain event occurred on July 29, which may have contributed to higher conductivities and more turbid water. The Magnolia Mine itself was not visited during this site visit, due to the private property, but it was observed from below. At the time of the site visit, no drainage was observed from the Magnolia Mine site. Many of the other unnamed prospects and mines in the area have been closed by DRMS. A total of 4 water samples, shown in Table 5, were taken during this visit, primarily from a mine site to the east of the Magnolia Mine. Sample locations are shown in Figure 8. In general, the mine sites in this area are “high and dry” and have minimal seasonal drainage. The adjusted conductivities range from 102.9 (Sample #023) µS to 233.9 µS (Sample #022). These samples are from two tributaries that cross FS 188 and may be impacted by many different mine sites. The pH values are nearly neutral to slightly basic and range from 7.22 to 8.35.

Analytical Data

Although Al levels were elevated in the samples taken near the Magnolia Mine area, none of the results exceeded the state standards. The water-quality results for the Middle Fork of the Upper South Platte are shown in Table 6.

5.2.2 Placer Valley and Alma State Wildlife Area

Site Setting

Placer Valley begins at the base of Hoosier Pass and is defined by the flanks of Mount Lincoln and Mount Bross to the west and Mount Silverheels to the east. The valley itself is deeply covered with glacial drift and alluvial wash. Highway 9 travels up the east side of the valley and provides a great vantage point from which to observe the valley and mountains above. The Middle Fork of the Upper South Platte meanders through the valley and is characterized by numerous beaver ponds and wetland features. This section of the Middle Fork runs through the Alma State Wildlife Area (ASWA). The ASWA is a wonderful wetland ecosystem that has been preserved through the generous donation of a conservation easement on the entire corridor. The Colorado Division of Wildlife (DOW) manages the ASWA and has made improvements to provide fishing access along the corridor. The ASWA ends at the outlet of the Columbia Reservoir, which is a small fishing pond of approximately 5.2 acres.

Field Data

Sampling within the upper Middle Fork drainage occurred on three separate dates. On July 19, 2010, the historic Quartzville area was investigated and one sample was collected from a shallow prospect adit that had standing water approximately 1 foot deep. An additional 6 samples were collected along the Middle Fork occurred on August 17, 2010. These samples were taken within the ASWA from the Montgomery Reservoir outlet to the Columbia Reservoir outlet. On August 23, 2010, 2 samples were collected upstream of Montgomery Reservoir, one above the Magnolia Mill and one below the mill. The conductivities of these two samples are identical, making their results questionable. The pH upstream of the mill was 8.55, which is relatively high for this area, and below the mill the pH was 7.73. In addition to being downstream of the mill, the lower sample was taken at the base of Magnolia Falls, a short section of steep waterfalls that once powered the mill. Figure 9 shows the sampling locations for the 9 samples taken in the Middle Fork drainage, some of which were taken on small tributaries near their confluence with the Middle Fork. Table 5 summarizes the field data collected along the Middle Fork.

Analytical Data

The water-quality results for the Middle Fork of the Upper South Platte, including the Quartzville sample location, are shown in Table 6. Sample #019, collected from the shallow Quartzville adit, exceeded the acute and chronic Cu TVS by 1.8X and 2.5X, respectively. This sample also exceeded the acute and chronic Zn TVS by 1.8X and 2.0X, respectively. Although the standing water within the adit contains concentrations of Cu and Zn that could adversely affect aquatic life, this adit is located approximately a quarter-mile away from Quartzville Creek and any seasonal drainage from the adit would not make it to the creek; therefore this adit does not represent a loading source to Quartzville Creek.

5.2.3 Buckskin Gulch

Site Setting

Buckskin Gulch is the first major tributary to the Middle Fork just south of Placer Valley (Photograph 19). The Buckskin subdistrict within the Greater Alma Mining District was settled and prospected in 1859 and derives its name from buckskin-clad prospector Joseph Higgenbottom. The booming camp of Buckskin Joe boasted many saloons, gambling halls, stores, offices, mills, and hotels, including the Tabor general store. The headwaters of Buckskin Creek originate from Kite Lake and Lake Emma. These two small glacial cirque lakes are located at the bases of Mount Democrat and Mount Bross (Photograph 20). Buckskin Gulch was heavily mined and prospected until the last operating mine, the Sweet Home rhodochrosite mine, closed in 2004. Today there are a few small-scale active claims that are prospected seasonally.

Photograph 19: Buckskin Gulch, looking toward Mount Democrat.

<u>Lake Emma, Kite Lake, and the Kentucky Bell Mine</u>

History and Ownership

Lake Emma is located above Kite Lake to the west, at an elevation of approximately 12,600 ft. amsl. Emma Lake is a typical glacial tarn that feeds the headwaters of the west fork of Buckskin Creek. The Buckskin Amphitheater is a very popular recreational area with a heavily used trailhead leading to the summits of the surrounding 14,000-ft. peaks, including Mounts Bross, Lincoln, Democrat, and Cameron. Prominent claims on the eastern slope of the ridge connecting Buckskin Mountain and Mount Democrat include the Black Barnet MS #3745, Queen of the Lakes MS #2162, and Little Mary MS #2161, all owned by the Chiwawa Mining Co., and the Ora King MS 3073, owned by the Climax Molybdenum Co. (Photograph 21). Directly behind Kite Lake to the north, on the slopes of Mount Democrat, prominent claims include the Humbolt MS #3044, owned by the Ducommun Business Trust, the Quail MS #3508 (just to the north of the Humbolt), owned by the Chiwawa Mining Co., and the Kentucky Bell group, owned by Earth Energy Resources.

Photograph 20: Lake Emma, Buckskin Gulch.

The most popular and productive mine site in the upper Buckskin drainage is the Kentucky Bell Mine. Buildings associated with the Kentucky Bell are located on the upslope of a ridge connecting Mount Democrat and Mount Cameron. The Kentucky Bell Mine exploited pyrite-associated gold veins, hosted in a northwest-striking porphyry dike intruding the granite country rock (Patton et al., 1912). The soft nature of the porphyry made stopping treacherous, requiring significant amounts of lumber supports. Almost all of the work done at the Kentucky Bell was done by hand. In the summer of 1910, the mine was leased and bonded by the Colorado Gold Mining and Smelting Co. to provide ore to its smelter located in Alma (Patton et al., 1912). The production at this mine was limited by the high haulage costs from the high-elevation mine via wagons down to Alma. In 1910, the haulage capacity was one trip per day transporting about twenty tons of ore (Patton et al., 1912).

Photograph 21: Prospects above Lake Emma.

The Kentucky Bell group was inventoried by CGS personnel in the 1994 USFS–AMLI and given an Environmental Degradation Rating of 1 (extreme) because the test results exceeded state standards for aquatic life (chronic) in Al, Cd, Cu, Pb, and Zn and secondary drinking water standards for Mn (Neubert, 2006). In 1998, the U.S. Bureau of Reclamation (BOR) did a preliminary assessment of the mine and, based on visual observations, field testing, and the water samples collected in 1994, concluded that the mine effluent from the crosscut adit of the Kentucky Bell MS #19928 could be negatively impacting aquatic life as well as the Town of Alma's water supply (located approximately 4 miles downstream). The crosscut portal was closed by the DRMS in 2001 (Neubert, 2006). The site was inventoried again in 2006 as part of a Land Transaction Screening Process instigated by a possible donation of the land to the USFS. This study concluded that although the mine effluent is degraded with respect to several trace metals, especially copper and to a lesser extent zinc, the effluent is naturally attenuated and meets all water-quality standards before it reaches Kite Lake, approximately 1,000 feet downstream from the mine (Neubert, 2006). Due to the proximity of the site to a popular access route to the Fourteeners (mountains higher than 14,000 feet) above, this site is highly visible and accessed by the public.

Photograph 22: Hanging Valley above Kite Lake, looking at Mount Bross.

Field Data

The upper Buckskin Amphitheater near Lake Emma was visited on July 14, 2010. During this site visit, field data was collected at 7 sample locations and 5 samples were collected for laboratory analysis (Figure 10 and Table 7). Sample #001 was collected near the top of the trail leading from Kite Lake to Lake Emma (Photograph 22b). This sample was collected from a black plastic pipe that was discharging water from a cement closed adit corresponding to the Black Barnet claim. Sample #002 was taken from the Lake Emma outlet and represents the background conditions for the headwaters of Buckskin Creek. Although there are some small prospects on the northeast side of the lake corresponding to the Ora King claim, they do not drain any water and have very small wasterock piles and therefore do not represent a contamination source that would impact the background quality of sample #002. Adjusted conductivity values ranged from 20.9 µS at the Lake Emma outlet to 103.2 µS at the Black Barnet draining adit.

Values of pH ranged between 5.99, at a natural spring in the hanging valley above Kite Lake, to 6.63, at a small prospect to the southwest of Lake Emma.

Photographs 22a and 22b: Sampling Locations in upper Buckskin Gulch.

Synoptic sampling in the upper Buckskin drainage occurred on July 15, 2010. A total of 6 samples were taken, from the outlet of Kite Lake (the east fork of the Buckskin Creek headwaters) to below the Buckskin Joe Mine, approximately 3.5 miles downstream (Figures 10 through 13). Samples were collected from the following locations: a draining adit near the west fork of Buckskin Creek on USFS land above the confluence of the east and west forks of upper Buckskin Creek; below the confluence (represents conditions above the Sweet Home Mine); at the Red Amphitheater tributary; Buckskin Creek below and above the Sweet Home Mine on USFS land; and upstream of the Buckskin Joe Mine and downstream of the mine where the river flows under FS 192. Adjusted conductivities ranged between 47.4 µS, at the small discharging prospect above the confluence of the east and west forks of Buckskin Creek, to 297.3 µS, at the Red Amphitheater tributary. Values of pH ranged from 5.57, at the prospect upstream of the confluence, to 7.73, at the Red Amphitheater tributary.

Analytical Data

The waterquality results for the Buckskin drainage are shown in Table 8. Sample #002, considered the background sample, did not exceed any of the state TVS. Sample #003 was taken from a small spring located above Kite Lake in the hanging valley below Lake Emma. This sample is not mining-impacted and exceeded the acute and chronic Ag TVS by 26X and 160X, respectively, and the acute and chronic Cu TVS by 7X and 9X, respectively. Sample #004 was taken just below the spring on the west fork of Buckskin Creek. At this location, Ag concentrations increased and exceeded the acute and chronic TVS by 27X and 160X, respectively; there was no detection of Cu above the detection limits for this sample. Sample #006 was taken just below Kite Lake above the confluence of the tributary draining the western slope of Mount Bross and above the confluence with the west fork of Buckskin Creek. This sample exceeded the acute and chronic TVS for both Ag and Cu by 4X and 20X, and by 2X and 3X respectively. The 2006 Neubert report indicated that Cu from the Kentucky Bell #4 claim was attenuated prior to flowing into Kite Lake. The Cu concentration in 2006 just upstream of Kite Lake was 4.3 μg/L; the Cu concentration just below Kite Lake in 2010 was 8 μg/L. This indicates that there may be another source of Cu in the upper reaches of Kite Lake or that the Cu from Kentucky Bell #4 is not being attenuated to the degree observed in 2006. Sampling occurred about one month earlier in 2010 than in 2006, therefore there may be more discharge from the Kentucky Bell #4 and consequently more Cu loading. Future sampling in the same locations as were used for the USFS 2006 investigation and at the Kentucky Bell closed adit will help determine if mine discharge is responsible for the Cu concentrations in Kite Lake and the east fork of Buckskin Creek or if there is another unidentified source in the vicinity, such as the small waste-rock pile just to the east of the sample location.

Sweet Home Mine

History and Ownership

The Sweet Home Mine is located at the base of the Red Amphitheater, approximately 1.3 miles downstream from the Kite Lake parking area. The Sweet Home Mine was originally located as a silver mine in 1873 and in its first 20 years of operation this mine shipped approximately $185,000 in ore (Voynick, 1998, in Misantoni et al., 2006). The mine was dormant until the late 1910s, when it was reactivated through the 1920s, producing over $30,000 in silver prices of the time. Silver exploration was renewed in the 1960s through the 1980s without significant production (Voynick, 1998, in Misantoni et al., 2006). Although rhodochrosite was found early in the mine's history, it wasn't until the 1960s when it became valuable enough to mine as a byproduct. The Collector's Edge Minerals Company mined rhodochrosite from the early 1990s until 2004. Specimens from the Sweet Home Mine have been sold for over $1 million and the total gross production value of rhodochrosite specimens is estimate to be on the order of $15 million (Misantoni et al., 2006). In 2004, the Sweet Home Mine closed, the workings were plugged, the mine entrance adit collapsed, and the hillside was completely regraded and reclaimed. At the time of this inventory, there was a small amount of water draining in the vicinity of the reclaimed adit at <1 gpm.

Field Data

Sampling in the vicinity of the Sweet Home Mine was concurrent with the July 15, 2010, sampling event. Sample #008 is the closest upstream sample above the Sweet Home Mine. Sample #009 was taken from the tributary draining the Red Amphitheater (Photograph 23), directly adjacent to the Sweet Home Mine building (Figure 11).

Photograph 23: Mount Bross and the Red Amphitheater.

Due to private property limitations, no sample was taken below the confluence of the tributary and Buckskin Creek above the Sweet Home Mine. Sample #010 is the closest sample downstream of the Sweet Home Mine, taken on USFS property. From sample #008 to #010, the pH changes from 6.65 to 6.31 even with the input of the tributary, with a pH of 7.33 (Sample #009). Conductivity values change from 132 µS above to 131.7 µS below the Sweet Home Mine. It is interesting that there is a slight reduction in conductivity values, even with the input of the tributary that had a conductivity of 297.3 µS. From CR 8 near the Sweet Home Mine, a small waste-rock pile was observed on the west side of the road with its toe directly next to Buckskin Creek. The waste-rock pile is approximately 60 x 60 ft. and is yellow-colored. No significant investigation occurred on the site due to private property.

Analytical Data

The water-quality results for the Buckskin drainage, including samples taken near the Sweet Home Mine, are shown in Table 8. Sample #008 was taken near the confluence of the east and west forks of Buckskin Creek; in the field, Sample #008 was thought to have been collected below the confluence, but after reviewing the aerial photograph it now looks like this sample was collected just above the confluence on the east fork from Kite Lake. This sample just exceeded the chronic Cu standard; no other metals exceeded the state standards. The dissolved Cu concentration for Sample #008 is greater than the total recoverable concentration, which resulted in a non-detect, therefore the comparison to the chronic Cu standard may not be applicable. Between Samples #008 and #010, it appears that there could be surface water contributions from the Red Amphitheater tributary draining the western slope of Mount Bross and from two potentially mining-impacted tributaries draining the eastern slope of Loveland Mountain; in addition there are a number of mining claims and prospect pits, including the Sweet Home Mine, between these two sample locations. Discharge increases between sample locations #008 and #010, from 6.6 cfs upstream to 22.3 cfs downstream. This significant increase may be attributed to the tributaries described above and to baseflow contribution from groundwater.

Sample #010 exceeded the acute and chronic Ag TVS by 2X and 13X, respectively; this sample also exceeded the chronic total recoverable Al standard by 1.6X, the chronic Cd standard by almost 3X, and the acute and chronic Zn standards by 3X and 3.5X, respectively. Similar to sample #008, there was no detection of Ag above the detection limits for the total recoverable split, whereas the dissolved split reflected Ag presence above the TVS, therefore this determination of excess may not be valid. The Zn loading at Sample #008 was 306 kg/day where as the Zn loading at Sample #010 was 12,574 kg/day, an increase in loading may be attributed to contributions from the Red Amphitheater, the two tributaries from Loveland Mountain, drainage from the Sweet Home Mine, or associated waste-rock piles and other miscellaneous mines located between these two sample locations. The mixture of private and public lands prevented discrete sampling between these two locations, but future sampling and monitoring in this drainage should focus on better characterizing each tributary and mine prospect.

<u>Buckskin Joe Mine</u>

History and Ownership

The Buckskin Joe Mine site was originally located as the Phillips lode, and was one of the earliest lode claims in the Alma Mining District circa 1859. "The rapid success of this mine was such, it has been reliably reported, that about $300,000 was recovered from it within the first two years of its discovery" (Patton et al., 1912). The ore from the Phillips was originally crushed using one of the 7 arastras in Buckskin Creek. Shortly thereafter, stamp mills could be heard echoing through Buckskin Gulch. The first stamp mill was erected in 1860 by Charles M. Farrend to crush ore from the Phillips (Fossett, 1878). By April 1862, there were 9 stamp mills in operation in Buckskin Gulch, totaling 78 stamps. In 1878, only 20 residents lived in Buckskin Joe and the Phillips lode was owned by J. Q. Hart (Fossett, 1878). The Buckskin Joe Mine (listed as the Phillips in the Park County assessor database) is predominantly on private lands and therefore was not thoroughly investigated. The Buckskin Joe Mine consists of upper and lower sections, the upper being more extensive with a large waste-rock pile and several buildings still standing. It is believed that there are over 5 miles of underground workings between the upper and lower portions of the Buckskin Joe Mine (personal communication with Maury Reiber). The Phillips MS #234 and MS #2259A is owned by Tobias Munk of Germany; these claims cover the upper and part of the lower Buckskin Joe Mine. The remainder of the lower mine, Phillips MS #143, is owned by the Peggi Tabor 1989 Trust.

Field Data

Upstream and downstream samples were taken on July 15, 2010 (Figure 12 and Table 7). During a subsequent field visit, it was observed that an adit between the upper and lower sections of the Buckskin Joe Mine discharges deep red water at approximately 5 gpm. The water flows into a pipe that runs under the mining road and surfaces approximately 100 feet from Buckskin Creek. Sample #011 was taken upstream of the mine area and had an adjusted conductivity value of 118.4 µS, with a pH of 6.31, and a flow of 23 cfs. Downstream of the mine site the adjusted conductivity was 124.3 µS, the pH was 7.34, and the flow was 25 cfs. The rise in conductivities indicates that the Buckskin Joe Mine site may be contributing solute loading to Buckskin Creek. Just upstream of the historical mine site is a newer mill site (circa 1930s–1940s) on the Gold Bug Mill claim owned by Tobias Munk. The mill is in good condition and has corrugated metal siding. Adjacent to the mill site are two dry tailings ponds.

Analytical Data

Sample #011 was taken upstream of the Buckskin Joe Mine site on Buckskin Creek. This sample exceeded the acute and chronic Zn TVS by 1.6X and 1.8X, respectively, with a concentration of 140 µg/L and a flow measurement of 23.4 cfs, resulting in a loading of 8,015 kg/day. Downstream of the Buckskin Joe Mine site, Sample #012 exceeded the chronic Cd TVS by 2X and the acute and chronic Zn TVS by 2X. The flow measurement at this sample location was 25.1 cfs; therefore, there was an increase in flow of 1.7 cfs over the quarter mile between sampling locations that can be attributed to discharge from the Buckskin Joe Mine and baseflow contributions. There was no detection of Cd above the detection limits above the mine, while below the mine Cd exceeded the chronic aquatic-life standard. The Zn loading increased from 8,015 kg/day above the mine to 11,055 kg/day below the mine. From these samples, it appears that runoff or discharge from the Buckskin Joe Mine is negatively impacting the water quality of Buckskin Creek, since there are no other significant mines or tributaries between the sample locations.

<u>Mineral Park Mill Ponds</u>

History and Ownership

The Mineral Park area is located near timberline on Mount Bross, overlooking Alma and the greater South Park area. It is accessed off of CR 8 (Buckskin Gulch) via CR 787 (the Windy Ridge Road). The Mineral Park mine and mill are more closely related to the high-elevation workings on the east side of Mount Bross, such as the Moose and Dolly Varden mines, than to those on the southwest side of Mount Bross, bounding the Buckskin drainage. The Mineral Park Mine itself is located on private land but is a popular parking area for access to the Bristlecone Pine Scenic Area. There are three mining buildings still standing at the mine site and a culvert with grate closing has been installed over a historical shaft. The mill actually lies upslope from the mine site at an elevation of approximately 11,600 ft. amsl (Figure 13). All that remains of the mill site is a concrete foundation (Photograph 24). Just to the east of the mill foundation are five tailings ponds of variable sizes. At the time of the site visit, only one of the ponds still contained standing water (Photograph 25). There are a significant amount of tailings fines in each bermed pond. The Mineral Park Mine site is owned by a number of individuals, but the mill lies within the boundaries of the Bristlecone Pine Scenic Area and is therefore on USFS property.

Photograph 24: Mineral Park Mill, looking at the east side of Mount Bross.

Photograph 25: Mineral Park Mill pond.

Field Data

A site visit to the Mineral Park Mill ponds was concurrent with the July 15, 2010, sampling event. Only one of the five ponds had standing water, which had an adjusted conductivity of 139.1 µS and a pH of 7.38. These are surprisingly high pH and low conductivity results, considering that the water was interacting with over 6 inches of mill tailings. No samples were taken near the Mineral Park Mine site due to private property, but it appears that there is no significant environmental degradation occurring at that site as indicated by healthy, diverse vegetation and no apparent precipitates or oxidized sediment in the vicinity of Dolly Varden Creek.

Analytical Data

Sample #005 was taken from one of the Mineral Park Mill ponds and sent to Denver Water for analysis (Table 8). This sample exceeded the acute and chronic Ag TVS by 3.2X and 21X, respectively; the chronic Al TVS by 2.5X; the acute and chronic Cu TVS by 2.9X and 4.2X, respectively; and just exceeded the acute Pb TVS while it exceeded the chronic Pb TVS by almost 26X. The closest surface-water feature to the ponds is Dolly Varden Creek, approximately 600 feet downhill from the ponds. It appears that the ponds occasionally overflow and drain toward the gulch, as is evident from tailings distribution, but it does not appear that any flow ever reaches the gulch. Although the standing water in the ponds exceeds some state standards, the ponds do not directly impact the nearby surface water. Nonetheless, they may represent a hazard to wildlife or visitors to the Bristlecone Pine Scenic Area.

5.2.4 Mosquito Gulch

Site Setting

Mosquito Gulch is the next drainage to the south from the Buckskin drainage and can be accessed by CR 12 approximately one mile from the town of Alma. The headwaters of Mosquito Creek begin as north and south forks in the high elevations of the Mosquito Range and extend approximately 3.6 and 3 miles, respectively, from the confluence to their sources. A series of cirque lakes, including Cooney Lake at the base of Treasure Vault Mountain (13,701 ft. amsl) and Oliver Twist Lake at the base of Mosquito Peak (13,781 ft. amsl), feed the headwaters of North Mosquito Creek. North Mosquito Creek is bound to the north by Loveland Mountain (13,361 ft. amsl) and separated from South Mosquito Creek by London Mountain (13,194 ft. amsl). Some of the largest nuggets found in Colorado are from London Mountain.

South Mosquito Creek originates just to the south of the Mosquito Pass summit (13,186 ft. amsl). The South Mosquito drainage (approximately 4.4 square miles) is bounded by London Mountain to the north and Pennsylvania Mountain (13,006 ft. amsl) to the south. Both drainages experienced intense mining activity from the 1860s until the South London Mine closed in 1989. Property ownership is dominated by private mining claims, primarily owned by the Write Trust. The remainder of the public lands are owned by the State of Colorado, the Bureau of Land Management (BLM), and the USFS. At the time of this investigation the Write Trust was not interested in cooperating with site investigations and sampling. Therefore sample collection was limited to public lands or to where stream segments crossed county or USFS roads.

Both the north and south forks of Mosquito Creek were listed on the 1998 303(d) list and targeted for TMDL assignment by the CWQCC. South Mosquito Creek below the

London Mine is designated as an Aquatic Life Use (Cold 1) stream that was not supporting its designated use due to high levels of Cd, Fe, Zn, and Mn. The main stem of Mosquito Creek below its confluence with the South Mosquito to the confluence with the Middle Fork of the Upper South Platte is also designated as an Aquatic Life Use (Cold 1) stream that was only partially supporting its designated use due to high levels of Zn, Cd, and Pb. The 2002 303(d) listings and TMDL assignments for both segments could not be recovered at the time of this report.

Studies done by NUS Corporation and CDPHE indicated that aquatic life in South Mosquito Creek is essentially nonexistent and that aquatic life in Mosquito Creek below the confluence of the north and south forks is severely depleted. The CDPHE identified five sources of contamination in the South Mosquito and Mosquito Creek drainage basins during a study in August 1988, including the Montgomery (Alma-Betts) Mill tailings, the historical London Mine tailings, the Butte tailings, the North London Mill tailings, and the drainage from the London Extension Tunnel, this last identified as the largest single source of metal contamination to the Mosquito Creek watershed (Herron, 2004).

In 1997, as part of a 319 Nonpoint Source Pollution Control Program, a water treatment project was implemented to treat the mine drainage emerging from the London Extension Tunnel. Completed in 1998 and modified in 2002, the treatment system removes over 99.8% of the heavy metals with the effluent maintained at a pH between 9.5 and 10.0. The zinc removal averages approximately 20 pounds per day. The system consists of a collection system inside the mine, followed by the cement kiln dust (CKD) addition equipment and settling pond. The collected water is mixed with a measured amount of CKD, which acts as a neutralizing agent thereby precipitating the heavy metals. Total construction cost for the treatment system was approximately $150,000 and annual operation costs are expected to be at least $10,000 (Herron, 2004).

London Mine Complex

History and Ownership

The London gold vein was discovered in 1873 on the basis of mineralized float and sporadic outcrops. In 1875, the North London Mine was developed into a lode gold mine exploiting the London Fault ore body and specifically the contact zones between Tertiary intrusives and the Pennsylvanian-age Weber Formation and the Mississippian-age Leadville Limestone. The London vein is a structurally controlled polymetallic quartz vein that averages 1:1 gold to silver. The London Group of Mines is extensive, spanning both sides of London Mountain including the London, North London, South London, London Extension, and Butte mines. Production was continuous until at least 1942, with production totals of 263,273 oz. gold, 237,178 oz. silver, 5,897,725 lbs. lead, and 165,520 lbs. of copper. From the 1970s through the early 1990s, sporadic mining occurred in the lowest tunnel of the complex, associated with the South London and the London Extension tunnel (Herron, 2004). The American Mine shaft is located about one-quarter mile north of the London Extension tunnel at an elevation of 12,200 feet and provides natural ventilation to all the workings of the London Extension and water tunnel levels. The American Mine shaft was also used to transport ore between the workings of the London mine complex and to the valley bottom. The history and legacy of this mine require an additional venue for their story, which can not be accommodated in this investigation.

Field Data

As previously stated, the London Mine group is almost entirely privately owned and access to each mine site has not been granted for this analysis. Therefore water samples were taken in closest available proximity to the mine site while respecting private property. Site visits to Mosquito Gulch in the vicinity of the London mines were conducted on August 17 and 18, 2010, during which a total of 7 sample locations were visited. In the days preceding the sampling event, the drainage experienced heavy rains resulting in noticeably higher than usual turbidity and suspended sediment.

Upstream and downstream samples taken near the North London Mill site on the 17th had adjusted conductivities of 50 µS and 86 µS and pH values of 6.9 and 6.86, respectively. During subsequent sampling events, samples were collected on South Mosquito Creek below the South London Mine complex, downstream of the confluence of the north and south forks, and downstream of Park City (Table 9 and Figure 14). Conductivity values were highest below the South London Mine near the settling ponds associated with the London Extension treatment system, and field notes indicate significant amounts of fine sediment in the river at this location as well as distressed vegetation. Downstream of the confluence, the conductivities drop by almost 200 µS, and field observations indicate healthy vegetation and numerous beaver ponds, but rocks showed signs of iron oxide precipitation. Below Park City, field observations include fish sightings and minimal iron precipitate.

Analytical Data

The water-quality results for the Mosquito drainage, including the London Mine area, are shown in Table 10. Sample #053, taken on the South Fork of Mosquito Creek below the South London and London Extension complex, had elevated levels of Al, but because of the high pH and hardness concentrations it did not exceed any state aquatic-life standards. Although the North London Mill area is extensive and has the potential for water-quality degradation associated with mill tailings, there were no instances where results exceeded the state TVS up- or downstream of the mill area. The American Mill area, investigated in 2004 by John Neubert, may represent a source of degradation to the North Fork of Mosquito Creek. This site was reclaimed as part of a voluntary cleanup action some time in the 1990s. During the 2004 investigation, Neubert indicated that tailings were exposed where the remedial clay cap was deteriorated. Water samples taken as part of this investigation indicated that "the Alma American Mill site contributes measurable quantities of metals into this part of Mosquito Creek," even though there were no instances of metals exceeding standards in the sample taken below the mill site (MC-04-03) Sample #052 was taken on the North Fork of Mosquito Creek below the American Mill site and did not exceed any of the state standards, although Al levels were elevated. Although the South Fork of Mosquito Creek and Mosquito Creek below the confluence of the north and south forks are on the 303(d) list, the samples collected on the North Fork, South Fork, and main stem of Mosquito Creek did not show significant over-standard quantities of Cd, Mn, Pb, and Zn. Specifically, Sample #054, collected from a small spring located below the confluence of the north and south forks, had Mn in excess of the MCL and Samples #052 and #053 had high levels of Al that were nonetheless below the state standards.

Orphan Boy Mine

History and Ownership

One of the original mines in the Leadville land district with an initial survey number of 37, the Orphan Boy gold mine is another substantial mine in the Mosquito drainage, downstream of the London Complex. The mine is located near Park City, once a stage stop on the route to Leadville over Mosquito Pass (McGookey, 2002). The Orphan Boy group is made up of 23 patented claims that cover approximately 133 acres on the eastern slope of Loveland Mountain. The gold ore of the Orphan Boy is closely associated with pyrite and chalcopyrite. At one point, the Orphan Boy workings included the tunnel house or shop; an ore house with bins of 75 tons capacity; a power house containing two boilers, a 6-drill Rand Imperial compressor, a 3-drill Norwalk compressor, a large air receiver, and feed-water heaters; a boarding house; and an assay office.

The adits in the Orphan Boy are generally driven in the northwest direction until contact with the ore-bearing horizon, where the main bore was diverted to the northeast to follow the strike of the beds. The principal production of the mine has been from the workings below the Honeycomb chute. In 1912, James Moynahan of Alma (a future Colorado state senator) was president of the Kennebec Mining Company and had plans of resuming operations at the dormant mine (Patton et al., 1912). By 1912, over 11,000 tons of ore had been recovered from the Orphan Boy Mine, generally averaging 0.25–0.5 opt gold, 10–25 opt silver, 3–4% copper, and 20% zinc (Patton et al., 1912).

Field Data

The Orphan Boy Mine is almost entirely privately owned. Therefore, a full site investigation was not conducted during the August 23, 2010, site visit. Effluent from the Orphan Boy Mine flows through a series of mine-drainage–created wetlands and crosses FS 449. Sample #057 was collected at this road crossing (Photographs 26 and 27). Adjusted conductivity and pH values were 485 µS and 8.7, respectively (Figure 14 and

Table 7). From previous unrelated site visits, it is known that the water exits the Orphan Boy portal and flow approximately 20 feet before infiltrating the large waste-rock pile, it emerges at the base of the pile, and flows through a series of wetlands above and below FS 499. The high pH may be attributed to interaction with the calcite gangue associated with waste rock from the ore zone. In addition to very red iron precipitates on the rocks at the sampling location, the standing water had suspended chelated iron mats probably associated with the organic acids and bacteria in the wetlands. Sample #058 was taken at a culvert where the drainage from the wetlands flows under CR 12. It is not precisely known what inputs may occur from FS 499 to CR 12, but it can be assumed that the flow at this sample location is impacted by the mine drainage. This may also be the Copper Creek drainage. Adjusted conductivity and pH values for this sample were 499 µS and 7.93, respectively. There was no significant iron precipitate on the rocks or culvert at this sample location and the water was clear.

Photograph 26: Orphan Boy Mine waste-rock piles.

Photograph 27: Orphan Boy Mine drainage below FS 499.

Analytical Data

The water-quality results for the Mosquito drainage, including drainage from the Orphan Boy Mine, are shown in Table 10. Sample #057 exceeded the acute and chronic aquatic-life standards for Cd by 1.3X and 9X, respectively, and the MCL by 5X. This sample also exceeded the state MCL for Mn by 2.6X and the acute and chronic aquatic-life standards for Zn by 4.8X and 5.6X, respectively. Sample #056 was taken on the main stem of Mosquito Creek downstream of the Orphan Boy Mine and Park City. This sample did not exceed state standards, indicating that metals from the Orphan Boy Mine are attenuated or diluted. Sample #058 needed to be re-analyzed by Denver Water laboratories and was not available at the time of this report. From the sampling of the Mosquito drainage, it appears that the primary mine of concern for water degradation is the Orphan Boy Mine, although there still may be metal contributions from the London Mine complex and the American Mill site. It will be important to continue monitoring both the north and south forks and the main stem of Mosquito Creek during the spring runoff and again in the fall of 2011 to better determine the impacts from each mine site or to rule out sites that are not contributing to water degradation.

5.3 South Fork of the Upper South Platte

Site Setting

The South Fork of the Upper South Platte originates near the summit of Weston Pass (11,921 ft. amsl). The drainage is accessed via CR 22 approximately 9 miles south of Fairplay. The South Fork drains an area of 402 square miles comprising 15.5% of the Upper South Platte watershed. A number of smaller tributaries feed the headwaters of the South Fork, including: Rich Creek, Rough and Tumbling Creek, Twelvemile Creek, Cave Creek, and Sheep Creek. The South Fork flows through 63 Ranch State Wildlife Area at the edge of the South Park basin and the rise of the Mosquito Range, after which it flows into Antero Reservoir. Fourmile Creek, another significant drainage in the southern extent of the Mosquito Range, flows into the South Fork after its outlet from Antero Reservoir near the junction of Highways 9 and 24.

The Weston Pass Mining District was discovered in the early 1890s and was most active for about five years during the turn of the century and from 1912–1916. During World War I, about 800 tons of oxidized zinc ore were shipped from the Ruby Mine, as well as lesser subordinate amounts from the Cincinnati and Colin Campbell mines. Grades ranged from 22% to 40% zinc, 5% to 18% lead, and 0.3 opt silver (Scarbrough, 2001).

<u>Ruby Mine</u>

History and Ownership

The Ruby Mine (Photographs 28 and 29) was the most prominent mine in the Weston Pass district, but little else is known about the mine. Although the majority of the mine complex is located on private land, it is frequented by visitors traveling over Weston Pass.

Photograph 28: Partially collapsed adit of the Ruby Mine, Weston Pass, South Fork of the Upper South Platte.

Photograph 29: Ruby Mine historic building, with Ruby Lake located just above the road in the background.

Field Data

The South Fork drainage was minimally sampled on July 23, 2010. There was significantly less mining in the South Fork drainage when compared to the northern part of the watershed. Therefore, only three samples were collected (two for laboratory analysis) to address the potential impact to water quality. Samples were collected at Ruby Lake near Weston Pass summit and on the South Fork just below the Ruby Mine (Figure 15). The adjusted conductivity and pH of the Ruby Lake sample were 107.2 µS and 8.73, respectively, and the corresponding measurements downstream of the Ruby Mine were 198.7 µS and 7.7 (Table 11). Although heavy iron precipitate was observed in the stream substrate, there were a significant amount of insects and no signs of vegetative distress. A large shaft (10 x 12 ft.) was discovered on the west side of the creek approximately 500 feet upslope. There was standing water approximately 12 feet from the top of the shaft, with floating, deteriorated wood supports. Although there was a warning deterrent sign, this shaft poses a significant risk to the general public due to its proximity to the highly traveled recreational road.

Analytical Data

The water-quality results for Samples #017 and #018 are shown in Table 12. Neither sample exceeded any of the state aquatic-life standards or drinking-water MCLs.

5.3.1 Fourmile Creek

Site Setting

Fourmile Creek is located one drainage to the north of the headwaters of the South Fork of the Upper South Platte drainage. The headwaters of Fourmile Creek begin as outflow from the Leavick Tarn, a small glacial lake located at the base of Horseshoe Mountain (13,898 ft. amsl). The Horseshoe cirque is a prime example of glacial action and has magnificent exposures of Lower Paleozoic sedimentary outcrops intruded by Late-Cretaceous Early Tertiary sills (Photograph 30).

Photograph 30: Horseshoe Tarn and Horseshoe cirque.

Prominent mines of the Horseshoe subdistrict of the Greater Alma Mining District include the Hilltop–Last Chance Mine, the Dauntless Mine, the Peerless Mine, and the Leavick site (Photographs 31 through 33).

Photograph 31: Dauntless Mine complex.

The Hilltop Mine is frequented by climbers on their trek to the summits of Mount Sheridan (13,748 ft. amsl) and Mount Sherman (14,007 ft. amsl). The Hilltop–Last Chance silver-lead deposit was discovered in the mid-1870s and was in production until 1923. The mine consists of two shafts and extensive underground workings. The grade of ore prior to 1901 averaged about 25 opt silver and 20% lead (Scarbrough, 2001). The Dauntless Mine is located just below the Hilltop Mine and is an extensive complex, with a blocked portal just off the popular hiking-access road and numerous historical features, such as track, buildings, engines, and boilers. The Peerless Mine is located high on the slopes of the south fork of Fourmile Creek.

Photograph 32: Hilltop Mine.

Photograph 33: Hilltop Mine.

Field Data

The Fourmile Creek drainage was sampled July 16, 2010. During this sampling event, a total of 4 samples were collected: 2 below the Dauntless Mine, 1 from the Horseshoe Tarn, and 1 from the main stem of Fourmile Creek (Figure 16). There was no apparent drainage from the Hilltop or Peerless mines. The Dauntless Mine was draining approximately 30 gpm. A sample of this effluent was taken where it comes closest to CR 18. This is also near the approximate location of the headwaters of the north fork of Fourmile Creek. The adjusted conductivity and pH values for this drainage ranged between 201.9 μS (the farthest downstream sample on Fourmile Creek) to 132 μS (drainage from Dauntless Mine), and from 8.82 (Horseshoe Tarn) to 7.3 (Dauntless Mine) (Table 13).

Analytical Data

The water-quality results for samples #013 to #016 are shown in Table 14. Sample #016 exceeded the chronic aquatic-life standard for Pb by 2X. In the Fourmile Creek drainage, there were no other measurements exceeding the standards. There were elevated levels of Ba and Zn, but not near the state standards. Sample #016 is the farthest downstream sample in the drainage. No samples were taken between the confluence of the north and south forks of Fourmile Creek and the Sample #016 location due to private property, therefore the source of the Pb is unknown, but it is assumed to be downstream of the confluence.

6.0 Conclusions and Recommendations

The Upper South Platte watershed has many drainages that experienced intense historic mining activity. The 2010 field season accomplished many of the goals and objectives of the Mine Assessment Project, including: collection and review of background reports; site visits to each drainage and to mines located on public lands; partial establishment and mapping of ownership at prominent mine sites; making positive connections with mine owners with future hopes of collaboration and more in-depth visits to private mine sites; and identification of mines to be placed on a more intensive monitoring plan to fully characterize their sites for potential remediation alternatives. In addition to these basic objectives, the 2010 field season achieved additional progress. It permitted the researchers to establish the sampling protocol to be used for future field seasons; to identify the necessary field equipment and, when possible, to purchase that equipment, which will also be used for following field seasons; and to inventory an extensive amount of the watershed, at least on the reconnaissance level, which will permit future visits to focus on the most prominent mine sites.

The majority of the mine sites had minimal mine drainage. Effluent that was tested often had neutral pH values and conductivity values typical of high alpine streams. The neutral pH values at most mine sites and drainage sample locations may be attributed to the carbonate sedimentary geology of the western part of the watershed; in general, mines within the Upper South Platte watershed have neutral mine drainage, in contrast to the typical assumption that mine drainage is generally acidic. Two areas in the watershed were identified in previous reports and confirmed in this investigation to be areas of naturally occurring acid-rock drainage (ARD) and natural water-quality degradation. Handcart Gulch and Geneva Creek, in the North Fork drainage, have natural ARD associated with groundwater interaction with the hydrothermally altered

Montezuma stock. The Red Amphitheater, in the Buckskin Creek drainage, also has natural degradation associated with the altered country rock correlated to intrusion of the Buckskin stock.

6.1 Mine Priority and Future Monitoring

Within each subdrainage there are mines that will require additional monitoring, due to indications of potential environmental and water-quality degradation. In addition, the reconnaissance-level investigation conducted in 2010 only shows a snapshot of the water quality of each drainage. To fully characterize the water quality of the watershed, it will be necessary to establish annual and seasonal trends. This investigation will also be required if any reclamation work is to be conducted within the watershed. An optimal monitoring scheme to fully characterize the hydrology and water quality of each drainage and mine site would involve monthly sampling, as permitted by site access and seasonal drainage conditions.

At this point, locations of particular interest for more detailed study include:

- The Upper Hall Valley, including the Missouri, Rosalie, and Whale mine complex.
- The Kentucky Bell #4, to determine whether the Cu detected at the outlet of Kite Lake is from the mine or some other unidentified source.
- The Sweet Home Mine area in the Buckskin Creek drainage, with better delineation of the metal loading of each tributary, including the Red Amphitheater tributary and waste-rock piles associated with the Sweet Home and other mine prospects in the vicinity.
- The Buckskin Joe (Phillips) Mine in the Buckskin Creek drainage.
- The London Mine Group, with continued monitoring that specifically includes impacts from the American Mill area.
- The Orphan Boy Mine in the Mosquito Creek drainage.
- Fourmile Creek, including the Dauntless and Peerless mines and downstream delineation of the Pb loading source.

6.2 Future Research and Goals

One of the dominant conclusions from the 2010 season is the need for additional sampling, specifically on private land. Therefore, one of the primary goals for the future of the MAP is to establish cooperative relationships with the mine owners and to obtain permission to fully inventory each mine site of interest. Detailed historical research into each mine will help develop a better understanding of the groundwater–surface water connections resulting from interactions in underground workings. Although an attempt was made to get discharge measurements at each sample location during the 2010 field season, seasonal discharge measurements and storm-event sampling will provide necessary hydrologic information to determine the loading of each contamination source (mine drainage or erosion of waste-rock piles). No sediment or waste rock samples were collected during the 2010 season. Therefore, this represents a significant goal for the 2011 season, again to better characterize each site and its potential environmental degradation as well as the optimal remediation alternatives.

Acknowledgements

Special thanks to John Neubert of the USFS for all the background reports and site visit company, Lauren Barrows OSM intern that was my companion for the 2010 field season and obtained needed field equipment in a pinch, and Linda Ferguson Rosales of Denver Water for sample analysis.

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Table 1
Hall Valley Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C	Flow (cfs)
Hall Valley NFSP main stem of river below Missouri Mine	025	8/5/2010, 11:00 AM	426976	4374400	7.05	61.9	88.7	9.5	3.7
Oxbow downstream of Missouri, Whale, and Rosalie mines	026	8/5/2010, 11:45 AM	426903	4374457	6.91	62.6	87.7	10.1	3.7
Drainage/spring below Rosalie waste rock pile	027	8/5/2010, 12:00 PM	426899	4374507	3.47	169	252.8	8	< 1 gpm
Not mining impacted tributary above sample 25 location	028	8/5/2010, 12:30 PM	426948	4374387	6.86	70.1	96.4	10.7	
Missouri Mine drainage	029	8/5/2010, 12:45 PM	426427	4374723	6.6	57.7	78.5	11.3	30 gpm
Upstream of Missouri Mine	030	8/5/2010, 1:00 PM	426336	4374808	7.02	64.2	91.7	9.3	1.18
Downstream of Missouri Mine beaver pond NFSP	031	8/5/2010, 2:00 PM	426537	4374687	6.99	62.7	86.7	10.6	2.57
North tributary flowing on road to Missouri Mine	032	8/5/2010, 2:30 PM	426615	4374494	7.59	69.6	113.9	4.6	
South tributary flowing on road to Missouri Mine	033	8/5/2010, 2:45 PM	426645	4374484	6.62	61.8	94.4	6.9	
Handcart Gulch	034	8/5/2010, 3:45 PM	430498	4370864	2.89	403	566	9.9	2.98
Great Eastern	036	8/6/2010, 11:00 AM	426239	4374965	7.14	157.6	258.9	4.7	
Above Missouri Mine	037	8/6/2010,11:40 AM	426211	4374857	7.44	91.3	128.7	9.8	0.24
Upper Hall Valley Tarn	038	8/6/2010, 12:00 PM	426178	4374847	7.49	51.9	79.7	6.8	0.749
East tributary Upper Hall Valley	039	8/6/2010, 12:45 PM	426477	4374797	7.33	58.8	79.9	11.3	0.541
NFSP upstream of Handcart Gulch confluence	040	8/6/2010, 3:10 PM	430480	4370712	7.71	59.7	79	12.2	9.06
NFSP downstream of Handcart Gulch confluence	041	8/6/2010, 3:40 PM	430670	4370613	4.09	125.5	166.1	12.2	11.7
Hall Valley Campground water pump	042	8/6/2010, 4:10 PM	430670	4370614					

note: NFSP reefers to the main stem of the North Fork of the Upper South Platte

Table 2
Hall Valley Analytical Results

Sample #	Units	025	026	027	028	029	030	031	034	034 dup	036	037	038	039	040	041	042
Ag-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.4	<0.5	<0.5	0.7	<0.5	<0.5	<0.5
Al-D	µg/L	41	52	928	<20	53	<20	57	18000	18000	79	61	22	47	33	4600	48
Al-T	µg/L	**106**	**301**	**1000**	**429**	**117**	23	**101**	**19000**	**19000**	**1900**	523	39	**443**	54	**5100**	<20
As-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
As-T	µg/L	<1	1	<1	<1	2	<1	<1	<1	<1	6	<1	<1	<1	<1	<1	<1
Ba-D	µg/L	26	33	16	28	18	18	21	21	21	23	26	15	24	24	24	43
Ba-T	µg/L	29	98	20	33	17	19	22	22	23	73	43	15	**>850**	26	24	42
B-D	µg/L	<2	<2	3	<2	<2	<2	<2	3	3	2	<2	<2	<2	2	3	5
Be-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
B-T	µg/L	<2	<2	2	<2	<2	<2	<2	3	3	<2	<2	<2	<2	2	2	3
Ca-D	mg/L	13	12	22	14	12	13	12	8	8	41	19	11	11	11	10	8
Ca-T	mg/L	13	12	22	14	12	14	12	8	8	42	20	11	12	11	10	8
Cd-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**0.8**	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cd-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co-D	µg/L	<1	<1	4	<1	<1	<1	<1	30	30	<1	<1	<1	<1	<1	8	<1
Co-T	µg/L	<1	<1	4	<1	<1	<1	<1	30	31	3	<1	<1	<1	<1	8	<1
Cr-D	µg/L	<1	<1	<1	<1	<1	<1	<1	3	3	<1	<1	<1	<1	<1	<1	<1
Cr-T	µg/L	<1	<1	1	<1	<1	<1	<1	3	4	4	2	<1	<1	<1	<1	<1
Cu-D	µg/L	**22**	**25**	**11**	<5	**67**	<5	**35**	**200**	200	8	**13**	<5	<5	**5**	**54**	**13**
Cu-T	µg/L	31	59	14	<5	110	<5	56	200	200	41	8	<5	5	7	55	10
Fe-D	mg/L	0.06	0.09	0.25	<0.05	0.06	<0.05	0.06	18	19	0.17	0.2	<0.05	0.13	<0.05	<0.05	0.06
Fe-T	mg/L	0.2	0.53	0.87	0.67	0.23	<0.05	0.17	18	20	4.26	0.68	0.06	1.21	0.09	2.98	0.08
Hg-D	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
K-D	mg/L	0.6	0.6	1	0.8	0.6	0.7	0.6	1.6	1.6	0.9	0.9	0.8	0.4	0.7	1	0.8
K-T	mg/L	0.6	0.6	1.1	0.9	0.7	0.8	0.6	1.6	1.7	1.1	1	0.8	0.5	0.7	1	0.8

Table 2
Hall Valley Analytical Results

Sample #	Units	025	026	027	028	029	030	031	034	034 dup	036	037	038	039	040	041	042
Mg-D	mg/L	2.3	2.3	7.2	2.9	2.5	2.3	2.2	6.3	6.5	6	2.8	2.1	1.7	2.2	3.3	3.6
Mg-T	mg/L	2.4	2.4	7.2	3.3	2.6	2.5	2.4	6.5	6.6	6.9	3.1	2.2	1.9	2.4	3.5	3.8
Mn-D	µg/L	**98**	**140**	**770**	<2	**150**	26	**160**	**300**	**310**	**54**	<2	19	6	4	**89**	7
Mn-T	µg/L	110	180	790	23	160	29	160	310	320	510	40	21	660	17	93	8
Mo-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mo-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Na-D	mg/L	<1	<1	4	<1	<1	<1	<1	3	3	1	<1	<1	1	1	2	3
Na-T	mg/L	1	1	4	<1	<1	<1	<1	4	4	2	<1	1	1	1	2	3
Ni-D	µg/L	1	1	10	<1	3	<1	1	62	63	1	<1	<1	<1	<1	16	1
Ni-T	µg/L	1	2	10	1	3	<1	1	62	64	4	1	<1	2	<1	17	1
Pb-D	µg/L	<1	**2**	1	<1	**3**	<1	**1**	<1	<1	**9**	**5**	<1	<1	<1	**1**	<1
Pb-T	µg/L	3	13	2	14	10	<1	4	<1	<1	130	6	1	**45**	1	2	1
Sb-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5
Sb-T	µg/L	<0.5	0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	**5.9**	<0.5	<0.5	1.4	<0.5	<0.5	<0.5
Se-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Se-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Si-D	mg/L	2.6	2.6	9.8	2	3.1	2	2.3	19	19	3.4	2.1	2.1	3	3.1	7.1	6
Si-T	mg/L	2.7	3	9.7	2.9	3.2	2.1	2.5	21	21	6.3	3.1	2.2	3.6	3.2	7.4	6.2
Tl-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.5	3.6	2.6	<0.5	<0.5	<0.5	<0.5	1.1	<0.5
U-T	µg/L	<0.5	0.9	0.6	0.5	0.7	<0.5	0.6	3.6	3.7	4.9	1.5	<0.5	<0.5	<0.5	1.2	<0.5
V-D	µg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
V-T	µg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	5	<2	<2	<2	<2	<2	<2
Zn-D	µg/L	18	19	82	<5	**68**	5	31	**130**	**130**	43	6	7	9	7	42	**260**
Zn-T	µg/L	24	33	83	12	76	8	37	130	140	89	23	8	75	11	45	230

Note: Numbers in bold indicate results that exceed state Table Value Standards (TVS).

Table 3
Geneva Creek Field Data

Site Name	Sample #	Date & Time	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C	TDS (ppm)	DO (ppm)	Flow (cfs)
Lower Mary Ann adit	062	9/21/2010, 11:00 AM	5.97	232	139	3.76	116	1.16	1 gpm
Upper Mary Ann open adit	063	9/21/2010, 11:30 AM	7.11	229	140	4.14	115	1.47	<1 gpm
Mary Ann collapsed adit	064	9/21/2010, 11:45 AM	4.73	236	173	10.67	118	1.36	0.12 gpm
Above Sill Mine background southeast fork	065	9/21/10, 1:10 PM	4.5	426	257	4.07	213	2.6	4 gpm
Above Sill Mine background southwest fork	066	9/21/10, 1:30 PM	4.45	287	200	8.99	144	2.56	
Spring/seep, below Sill Mine	067	9/21/10, 1:50 PM	3.7	369	214	2.82	184	2.32	45 gpm
Stream at road crossing, headwater section of Geneva Creek	069	9/21/10, 2:40 PM	3.94	417	324	13.27	209	2.21	
Stream below road crossing	070	9/21/10, 3:10 PM	3.45	416	328	13.86	208	2.25	
Tributary below Sill Mine draining from the north	071	9/21/10, 3:40 PM	3.93	351	249	9.72	176	2.51	35 gpm
Tributary crossing FS119 below iron fens	072	9/21/10, 4:10 PM	6.38	158	111	9.41	79	201	90 gpm
Geneve Creek above Smelter Gulch	073	9/21/10, 4:40 PM	3.21	553	375	8.08	277	2.85	

Table 4
Spectrophotometer Data

Sample #	Alkalinity (mg/L)	Cd (mg/L)	Zn (mg/L)	SO4 (mg/L)	Mn (mg/L)	Cu (mg/L)
032	273.00	0.170	0.120	12.00	0.00	0.01
033	129.00	-0.089	0.030	7.00	0.20	0.03
037	124.00	-0.061	0.030	29.00	0.20	-0.02
042	166.00	-0.208	-0.070	7.00	0.80	0.17
043	209.00	-0.025	0.040	5.00	0.10	0.02
044	185.00	-0.041	0.030	5.00	0.10	0.09
045	320.00	-0.076	0.040	29.00	0.00	0.04
046	243.00	-0.043	0.020	21.00	0.20	0.05
047	235.00	-0.094	0.010	8.00	0.10	0.06
048	108.00	-0.034	0.240	26.00	0.00	0.01
049	499 (++)	-0.017	0.010	20.00	0.30	0.04
059	7.02 (U)	-0.077	0.100			0.04
060	22.2 (U)	-0.127	0.100			0.04
061	18.7 (U)	-0.125	0.100			0.03
062	26.80	-0.014	0.430	>81	4.70	0.31
063		-0.065	0.010			0.24
066	32.90	0.093	-0.120	118.00	15.70	0.26
067	0.95	-0.028	-0.050	113.00	10.10	0.39
068	-12.70	-0.014	0.050	122.00	0.80	0.75
069	-4.02	0.235	0.170	104.00	6.60	0.21
070	63.20	0.01 U	0.040	>106	6.00	0.20
073	-6.54	-0.048	0.100	122.00	2.40	0.54

Table 5
Middle Fork of the South Platte Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C
Quartzville mine (unnamed)	019	7/29/2010, 3:30 PM	406555	4354738	6.2	65.4	104	5.5
Shaft in east Magnolia Mine site	020	7/30/2010, 10:50 AM	406964	4357873	7.22	132.3	188.8	9.2
Pond below shaft in east Magnolia Mine site	021	7/30/2010, 11:05 AM	406964	4357873	7.29	137.4	183.6	11.2
Above Montgomery Reservoir, east of Magnolia Mine	022	7/30/2010, 12:45 PM	407270	4357691	8.35	198	233.9	17
Drainage east of Magnolia Mine	023	7/30/2010, 1:00 PM	407589	4357504	7.23	79.2	102.9	12.9
Downstream of Montgomery Reservoir in Wildlife Area	042b	8/17/2010, 10:05 AM	408168	4356075	6.8	90	126	9.84
At Wildlife area sign in Alma Wildlife area	043	8/17/2010, 10:20 AM	408234	4356000	6.89	61	83	11.19
At Beresford Crossing	044	8/17/2010, 10:35 AM	408613	4354715	6.78	80	108	11.44
North tributary at Last Chance Ranch	045	8/17/2010, 10:55 AM	408962	4353988	7.01	211	273	13.01
West braid at Last Chance Ranch	046	8/17/2010, 11:20 AM	408791	4353854	6.97	133	208	5.97
At Columbia Reservoir outlet	047	8/17/2010, 11:30 AM	408430	4352187	6.9	106	148	9.98
Above magnolia mill	060	8/23/2010, 2:30 PM	406525	4357022	8.55	60	76	14.26
Below magnolia mill	061	8/23/2010, 3:00 PM	406656	4356984	7.73	60	76	14.05

Table 6
Middle Fork of the South Platte Analytical Results

Sample #	Units	019	020	021	022	023
Ag-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Al-D	µg/L	<20	44	<20	<20	31
Al-T	µg/L	55	234	<20	86	359
As-D	µg/L	<1	<1	<1	<1	<1
As-T	µg/L	<1	<1	<1	<1	<1
Ba-D	µg/L	9	8	7	31	23
Ba-T	µg/L	9	12	8	31	29
B-D	µg/L	4	<2	2	3	3
Be-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
B-T	µg/L	3	3	<2	3	3
Ca-D	mg/L	11	22	22	29	13
Ca-T	mg/L	11	23	23	29	12
Cd-D	µg/L	0.5	<0.5	<0.5	<0.5	<0.5
Cd-T	µg/L	0.5	<0.5	<0.5	<0.5	<0.5
Co-D	µg/L	<1	<1	<1	<1	<1
Co-T	µg/L	<1	<1	<1	<1	<1
Cr-D	µg/L	<1	<1	<1	<1	<1
Cr-T	µg/L	<1	<1	<1	<1	<1
Cu-D	µg/L	**11**	<5	<5	<5	<5
Cu-T	µg/L	13	<5	<5	<5	<5
Fe-D	mg/L	<0.05	0.21	<0.05	<0.05	0.08
Fe-T	mg/L	0.1	1.38	<0.05	0.12	0.76
Hg-D	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1
K-D	mg/L	3.3	0.4	0.5	0.5	0.4
K-T	mg/L	0.8	0.6	0.5	0.7	0.5

Table 6
Middle Fork of the South Platte Analytical Results

Sample #	Units	019	020	021	022	023
Mg-D	mg/L	4.1	12.4	11.6	17.7	5.8
Mg-T	mg/L	4.2	13.4	12.7	17.6	6
Mn-D	µg/L	<2	23	<2	<2	13
Mn-T	µg/L	14	90	5	7	59
Mo-D	µg/L	<1	<1	<1	<1	<1
Mo-T	µg/L	<1	1	<1	<1	<1
Na-D	mg/L	<1	<1	<1	<1	<1
Na-T	mg/L	<1	<1	<1	<1	<1
Ni-D	µg/L	<1	<1	<1	<1	<1
Ni-T	µg/L	<1	1	<1	2	1
Pb-D	µg/L	<1	1	<1	<1	<1
Pb-T	µg/L	3	5	<1	<1	<1
Sb-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Sb-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Se-D	µg/L	<1	<1	<1	<1	<1
Se-T	µg/L	<1	<1	<1	<1	<1
Si-D	mg/L	2	1.9	1.8	1.7	2.2
Si-T	mg/L	2	2.2	1.9	1.7	2.7
Tl-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
U-D	µg/L	<0.5	<0.5	<0.5	0.7	<0.5
U-T	µg/L	<0.5	<0.5	<0.5	0.7	<0.5
V-D	µg/L	<2	<2	<2	<2	<2
V-T	µg/L	<2	<2	<2	<2	<2
Zn-D	µg/L	**130**	7	7	<5	<5
Zn-T	µg/L	110	30	10	9	5

Note: Numbers in bold indicate results that exceed state Table Value Standards (TVS).

Table 7
Buckskin Creek Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C
Lake Emma Mine	001	7/14/2010, 10:45 AM	401592	4353858	6.34	67.3	103.2	6.9
Lake Emma Outlet	002	7/14/2010, 11:25 AM	401783	4353980	6.24	12.6	20.9	4.4
West of Lake Emma	002b	7/14/2010, 11:45 AM	401735	4353628	6.33	38.9	56.8	8.4
West of Lake Emma	002c	7/14/2010, 11:45 AM	401735	4353628	6.63	44	68.2	6.8
Natural Spring	003	7/14/2010, 12:30 PM	401981	4353617	5.99	44.5	63.7	9.5
Downstream of confluence	004	7/14/2010, 1:30 PM	402041	4353622	6.36	17.8	25.6	9.1
Mineral Park Ponds	005	7/14/2010, 2:11 PM	406766	4352652	7.38	135.5	139.1	25.9
East Buckskin Creek	006	7/15/2010, 11:00 AM	402775	4353730	6.16	60.5	76.1	14.2
Prospect below Lake Emma	007	7/15/2010, 11:50 AM	402362	4353504	5.57	31.3	47.4	7.2
Buckskin Creek above Sweet Home Mine	008	7/15/2010, 12:30 PM	402837	4353051	6.65	106.1	132	14.6
Road and spring Crossing	009	7/15/2010, 1:30 PM	403361	4352241	7.33	246.9	297.3	16.3
Downstream of Sweet Home Mine	010	7/15/2010, 1:45 PM	403733	4351240	6.31	102.6	131.7	13.5
Upstream of lower Buckskin Joe Mine	011	7/15/2010, 3:30 PM	405452	4349711	6.31	89.9	118.4	12.5
Downstream of Buckskin Joe Mine	012	7/15/2010, 4:30 PM	405874	4349649	7.34	93	124.3	12.2
Buckskin Creek below CR 10 pond	048	8/17/2010, 1:20 PM	407528	4348839	6.88	136	185	11.21
Pond at CR 10	049	8/17/2010,1:35 PM	407508	4348775	6.91	350	428	15.37

Table 8
Buckskin Creek Analytical Results

Sample #	Units	001	002	003	004	005	006	007	008	009	010	011	012
Ag-D	µg/L	**1**	<0.5	**1.6**	**2.3**	**2.1**	**0.6**	<0.5	<0.5	**0.6**	**1.2**	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5	2.3	3.3	5.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Al-D	µg/L	<20	<20	<20	<20	25	26	<20	<20	38	118	49	47
Al-T	µg/L	<20	56	<20	28	223	37	55	23	179	**140**	61	70
As-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
As-T	µg/L	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Ba-D	µg/L	<5	7	8	6	160	10	9	23	25	18	20	20
Ba-T	µg/L	<5	8	8	8	180	10	9	23	26	18	20	21
B-D	µg/L	2	<2	<2	<2	3	2	<2	3	3	<2	<2	<2
Be-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	0.9	<0.5	<0.5
B-T	µg/L	<2	<2	2	<2	3	<2	<2	<2	<2	<2	<2	<2
Ca-D	mg/L	12	3	4	4	14	7	5	16	34	13	15	15
Ca-T	mg/L	12	3	4	4	15	7	5	16	35	13	15	16
Cd-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	**0.7**	<0.5	0.6
Cd-T	µg/L	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	0.8	0.7	<0.5	0.7
Co-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Co-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr-D	µg/L	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cu-D	µg/L	<5	<5	**14**	<5	**21**	**8**	<5	**6**	<5	<5	<5	<5
Cu-T	µg/L	<5	<5	16	<5	27	**7**	<5	<5	<5	<5	<5	<5
Fe-D	mg/L	<0.05	<0.05	4.25	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe-T	mg/L	<0.05	0.11	0.05	<0.05	0.75	0.06	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg-D	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
K-D	mg/L	5.9	0.2	11	15	12	6.6	5	4.1	6.5	8.8	0.6	0.6
K-T	mg/L	0.5	0.2	10	15	1.2	0.3	0.3	0.5	1.2	0.5	0.6	0.5
Mg-D	mg/L	2.2	<0.5	0.6	0.7	3.9	1.6	1.1	3.9	13.2	3.4	4.8	5
Mg-T	mg/L	2.3	<0.5	0.6	0.7	4.1	1.6	1.1	3.9	13.7	3.4	4.8	5.1

Table 8
Buckskin Creek Analytical Results

Sample #	Units	001	002	003	004	005	006	007	008	009	010	011	012
Mn-D	µg/L	<2	18	25	<2	16	6	<2	<2	<2	12	3	15
Mn-T	µg/L	8	28	7	<2	18	10	5	3	73	13	4	17
Mo-D	µg/L	1	1	<1	1	13	3	<1	4	3	2	2	2
Mo-T	µg/L	1	1	<1	1	14	3	<1	3	2	2	2	2
Na-D	mg/L	1	<1	<1	<1	1	<1	1	1	1	<1	<1	<1
Na-T	mg/L	1	<1	<1	<1	1	<1	<1	<1	1	<1	<1	<1
Ni-D	µg/L	<1	<1	<1	<1	1	<1	<1	<1	1	<1	<1	<1
Ni-T	µg/L	<1	<1	<1	<1	1	<1	<1	<1	1	1	<1	<1
Pb-D	µg/L	<1	<1	<1	<1	**31**	<1	**4**	<1	<1	<1	<1	<1
Pb-T	µg/L	<1	<1	<1	<1	320	<1	1	<1	<1	<1	<1	<1
Sb-D	µg/L	<0.5	<0.5	<0.5	<0.5	2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sb-T	µg/L	<0.5	<0.5	<0.5	<0.5	5.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Se-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Se-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Si-D	mg/L	2.7	0.8	1	0.8	3.6	1.3	1.9	1.7	2.3	1.6	1.8	1.9
Si-T	mg/L	2.7	0.9	0.9	0.7	4.1	1.2	2	1.7	2.5	1.7	1.8	1.9
Tl-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-D	µg/L	6.2	<0.5	0.8	0.5	<0.5	<0.5	0.8	1.1	1.7	0.8	0.8	0.7
U-T	µg/L	6.4	<0.5	0.9	1	<0.5	0.6	1.3	1	1.6	0.6	0.7	0.7
V-D	µg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
V-T	µg/L	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Zn-D	µg/L	37	<5	17	12	22	26	**38**	19	91	**230**	**140**	**180**
Zn-T	µg/L	38	<5	19	16	160	17	33	14	170	230	140	190

Note: Numbers in bold indicate results that exceed state Table Value Standards (TVS).

Table 9
Mosquito Creek Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C	TDS (ppm)	DO (ppm)
Upstream of London Mill	050	8/17/2010, 2:05 PM	400502	4350668	6.9	37	50	11.62		
Downstream of London Mill	051	8/17/2010, 3:05 PM	401052	4349555	6.86	63	86	11.02		
Below American Flats	052	8/20/2010, 11:10 AM	401901	4348663	8.19	71	101	9.2		10.58
Below London Mine (South Mosquito fork)	053	8/20/2010, 11:40 AM	401521	4347854	8	217	307	9.54	157	8.04
Natural Spring after South Mosquito / North Mosquito Confluence	054	8/20/2010, 1:30 PM	402916	4348304	7.95	135	200	7.83		5.46
Below North Mosquito / South Mosquito confluence	055	8/20/2010, 1:40 PM	403021	4348269	7.86	82	108	12.3		8.47
Mosquito Creek downstream of Park City	056	8/20/2010, 2:15 PM	406755	4347727	7.92			12.84		9.65
Orphan Boy Mine drainage	057	8/23/2010, 10:00 AM	405064	4348193	8.7	325	485	7.6	164	9.68
Orphan Boy Mine drainage near CR 12	058	8/23/2010, 10:40 AM	405414	4347954	7.93	371	499	11.46	250	7.18
Downstream of Highland Princess Lode	059	8/23/2010, 1:30 PM	403698	4357720	7.84	44	59	11.08	30	9.45

Table 10
Mosquito Creek Analytical Results

Sample #	Units	050	051	052	053	054	055	056	057
Ag-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Al-D	µg/L	<20	<20	<20	<20	<20	<20	<20	52
Al-T	µg/L	35	40	108	136	39	33	30	109
As-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
As-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Ba-D	µg/L	17	30	32	47	40	34	45	23
Ba-T	µg/L	18	32	36	49	53	36	47	24
B-D	µg/L	<2	<2	<2	3	3	<2	2	2
Be-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
B-T	µg/L	<2	<2	3	4	3	2	2	3
Ca-D	mg/L	7	10	11	37	25	12	24	61
Ca-T	mg/L	7	10	12	38	25	13	25	62
Cd-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**8**
Cd-T	µg/L	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	8.7
Co-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Co-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cr-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cr-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Cu-D	µg/L	<5	<5	<5	<5	<5	<5	<5	<5
Cu-T	µg/L	<5	<5	<5	<5	<5	<5	<5	7
Fe-D	mg/L	0.08	0.08	0.09	<0.05	0.11	0.12	0.08	<0.05
Fe-T	mg/L	0.12	0.14	1.54	0.14	2.11	0.2	0.18	0.37
Hg-D	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
K-D	mg/L	0.2	0.3	0.4	0.6	0.7	0.4	0.5	0.4

Table 10
Mosquito Creek Analytical Results

Sample #	Units	050	051	052	053	054	055	056	057
K-T	mg/L	0.2	0.4	0.5	0.7	0.6	0.4	0.5	0.4
Mg-D	mg/L	1.9	4.8	5.5	16.2	11.6	6	11.3	27.1
Mg-T	mg/L	2.1	5.3	6.1	17.1	12	6.4	12	29.1
Mn-D	µg/L	19	11	14	15	**93**	24	25	**130**
Mn-T	µg/L	22	14	44	17	600	29	29	130
Mo-D	µg/L	<1	<1	<1	1	<1	<1	<1	<1
Mo-T	µg/L	<1	<1	<1	1	<1	<1	<1	<1
Na-D	mg/L	<1	<1	<1	<1	<1	<1	<1	<1
Na-T	mg/L	<1	<1	1	<1	<1	<1	<1	<1
Ni-D	µg/L	<1	<1	<1	2	<1	<1	<1	2
Ni-T	µg/L	<1	<1	<1	2	<1	<1	<1	2
Pb-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Pb-T	µg/L	<1	2	7	3	4	2	2	3
Sb-D	µg/L	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5
Sb-T	µg/L	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5
Se-D	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Se-T	µg/L	<1	<1	<1	<1	<1	<1	<1	<1
Si-D	mg/L	1.6	1.6	1.7	1.9	2.2	1.7	1.8	2.1
Si-T	mg/L	1.7	1.8	2	2.1	2.3	1.8	1.9	2.3
Tl-D	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U-D	µg/L	3.3	3.2	3.4	6.1	8.4	3.6	3.8	<0.5
U-T	µg/L	3.9	3.5	4.1	6.3	8.7	3.8	3.8	<0.5
V-D	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
V-T	µg/L	<2	<2	<2	<2	<2	<2	<2	<2
Zn-D	µg/L	<5	9	26	180	14	27	65	**1600**
Zn-T	µg/L	5	16	56	190	82	33	82	1700

Note: Numbers in bold indicate results that exceed state Table Value Standards (TVS).

Table 11
South Fork of the South Platte Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C
Weston Pass	017	7/23/2010, 2:05 PM	398243	4331876	8.73	88.1	107.2	15.7
Inlet stream	017b	7/23/2010, 2:15 PM	398243	4331876	6.89	73.6	104.2	9.5
Downstream of Ruby Mine	018	7/23/2010, 3:00 PM	398230	4331593	7.7	131.8	198.7	7.6

Table 12
South Fork of the South Platte Analytical Results

Sample #	Units	017	018
Ag-D	µg/L	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5
Al-D	µg/L	<20	<20
Al-T	µg/L	29	<20
As-D	µg/L	2	<1
As-T	µg/L	2	<1
Ba-D	µg/L	52	60
Ba-T	µg/L	53	58
B-D	µg/L	2	3
Be-D	µg/L	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5
B-T	µg/L	2	3
Ca-D	mg/L	13	28
Ca-T	mg/L	13	27
Cd-D	µg/L	<0.5	<0.5
Cd-T	µg/L	<0.5	<0.5
Co-D	µg/L	<1	<1
Co-T	µg/L	<1	<1
Cr-D	µg/L	<1	<1
Cr-T	µg/L	<1	<1
Cu-D	µg/L	<5	<5
Cu-T	µg/L	<5	<5
Fe-D	mg/L	<0.05	<0.05
Fe-T	mg/L	0.08	<0.05
Hg-D	µg/L	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1
K-D	mg/L	0.6	0.3
K-T	mg/L	0.6	0.3
Mg-D	mg/L	6.1	11.1
Mg-T	mg/L	6.1	10.8
Mn-D	µg/L	<2	5
Mn-T	µg/L	5	4
Mo-D	µg/L	<1	<1
Mo-T	µg/L	<1	<1
Na-D	mg/L	<1	<1
Na-T	mg/L	<1	<1
Ni-D	µg/L	<1	1
Ni-T	µg/L	<1	1
Pb-D	µg/L	<1	<1
Pb-T	µg/L	<1	2
Sb-D	µg/L	<0.5	<0.5
Sb-T	µg/L	<0.5	<0.5
Se-D	µg/L	<1	<1
Se-T	µg/L	<1	<1
Si-D	mg/L	1.9	2.1
Si-T	mg/L	2	2
Tl-D	µg/L	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5
U-D	µg/L	1.5	1.1
U-T	µg/L	1.5	1.1
V-D	µg/L	<2	<2
V-T	µg/L	<2	<2
Zn-D	µg/L	<5	61
Zn-T	µg/L	8	60

Table 13
Fourmile Creek Field Data

Site Name	Sample #	Date & Time	xUTM	yUTM	pH	Conductivity (µs)	Adjusted Conductivity 25°C (µs)	Temp °C
Dauntless Mine	013	7/16/2010, 9:45 AM	398932	4340534	7.3	74.5	132	1.7
Downstream of confluences below Dauntless Mine	014	7/16/2010, 11:20 AM	399876	4339972	8.29	94.1	133	7.1
Upper Horseshoe Tarn	015	7/16/2010, 12:15 PM	398987	4338752	8.82	113.7	143.7	14.1
Fourmile Creek	016	7/16/2010, 1:10 PM	404280	4340173	8.16	147.6	201.9	10.9

Table 14
Fourmile Creek Analytical Results

Sample #	Units	013	014	015	016
Ag-D	µg/L	<0.5	<0.5	<0.5	<0.5
Ag-T	µg/L	<0.5	<0.5	<0.5	<0.5
Al-D	µg/L	<20	<20	<20	<20
Al-T	µg/L	32	23	40	23
As-D	µg/L	<1	<1	1	<1
As-T	µg/L	1	<1	2	<1
Ba-D	µg/L	86	150	61	90
Ba-T	µg/L	93	150	64	91
B-D	µg/L	<2	<2	2	4
Be-D	µg/L	<0.5	<0.5	<0.5	<0.5
Be-T	µg/L	<0.5	<0.5	<0.5	<0.5
B-T	µg/L	<2	<2	<2	4
Ca-D	mg/L	17	18	17	25
Ca-T	mg/L	18	19	18	25
Cd-D	µg/L	<0.5	<0.5	<0.5	<0.5
Cd-T	µg/L	<0.5	<0.5	<0.5	<0.5
Co-D	µg/L	<1	<1	<1	<1
Co-T	µg/L	<1	<1	<1	<1
Cr-D	µg/L	<1	<1	<1	<1
Cr-T	µg/L	<1	<1	<1	<1
Cu-D	µg/L	<5	<5	<5	<5
Cu-T	µg/L	9	<5	<5	<5
Fe-D	mg/L	<0.05	<0.05	0.06	<0.05
Fe-T	mg/L	0.45	0.05	0.15	<0.05
Hg-D	µg/L	<0.1	<0.1	<0.1	<0.1
Hg-T	µg/L	<0.1	<0.1	<0.1	<0.1

Table 14
Fourmile Creek Analytical Results

Sample #	Units	013	014	015	016
K-D	mg/L	0.3	0.4	0.3	0.5
K-T	mg/L	0.3	0.4	0.3	0.5
Mg-D	mg/L	6.3	6.9	8.9	11.7
Mg-T	mg/L	7.2	7.3	10	12.2
Mn-D	µg/L	<2	<2	13	5
Mn-T	µg/L	11	<2	32	6
Mo-D	µg/L	<1	<1	<1	<1
Mo-T	µg/L	<1	<1	<1	<1
Na-D	mg/L	<1	<1	<1	<1
Na-T	mg/L	<1	<1	<1	<1
Ni-D	µg/L	<1	<1	<1	<1
Ni-T	µg/L	1	<1	<1	1
Pb-D	µg/L	<1	<1	<1	**6**
Pb-T	µg/L	14	3	2	9
Sb-D	µg/L	<0.5	<0.5	<0.5	<0.5
Sb-T	µg/L	<0.5	<0.5	<0.5	<0.5
Se-D	µg/L	<1	<1	<1	<1
Se-T	µg/L	<1	<1	<1	<1
Si-D	mg/L	1.4	1.6	0.8	1.7
Si-T	mg/L	1.4	1.6	0.8	1.7
Tl-D	µg/L	<0.5	<0.5	<0.5	<0.5
Tl-T	µg/L	<0.5	<0.5	<0.5	<0.5
U-D	µg/L	0.7	1.2	1.6	1.5
U-T	µg/L	0.7	1.1	1.7	1.4
V-D	µg/L	<2	<2	<2	<2
V-T	µg/L	<2	<2	<2	<2
Zn-D	µg/L	37	15	<5	60
Zn-T	µg/L	53	19	5	62

Note: Numbers in bold indicate results that exceed state Table Value Standards (TVS).

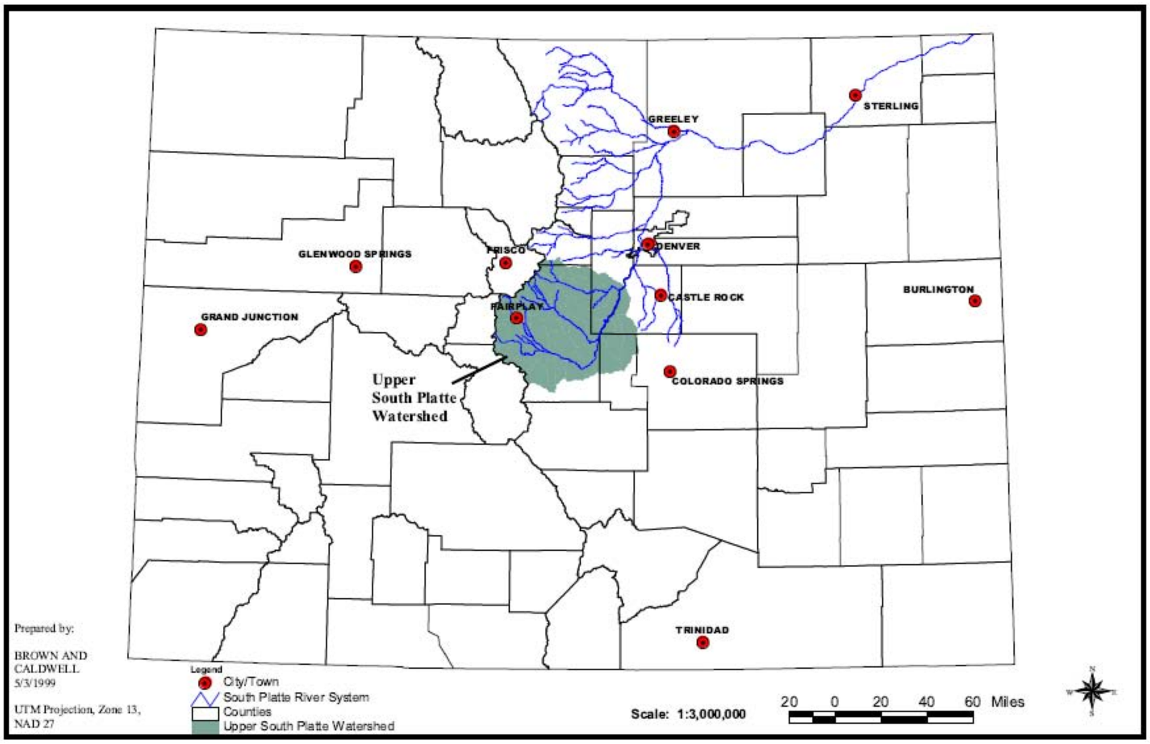


Figure 1 Upper South Platte Watershed Location

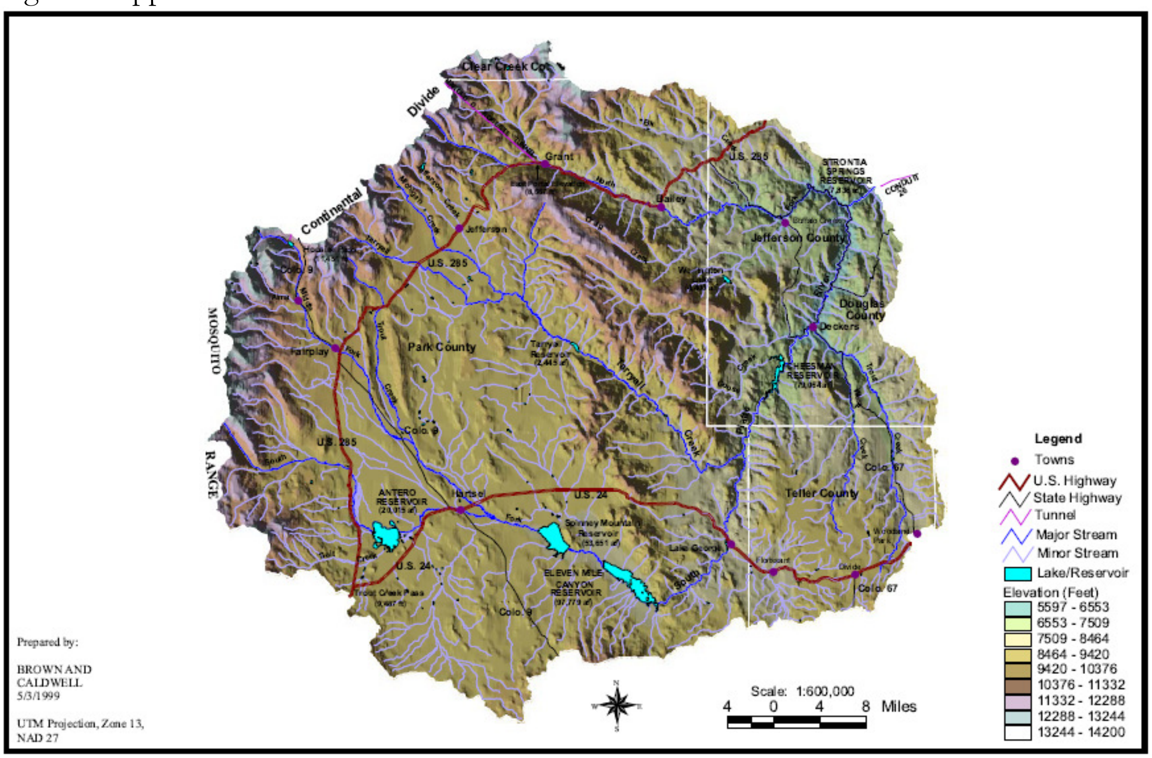


Figure 2 Major Tributaries in the Upper South Platte Watershed

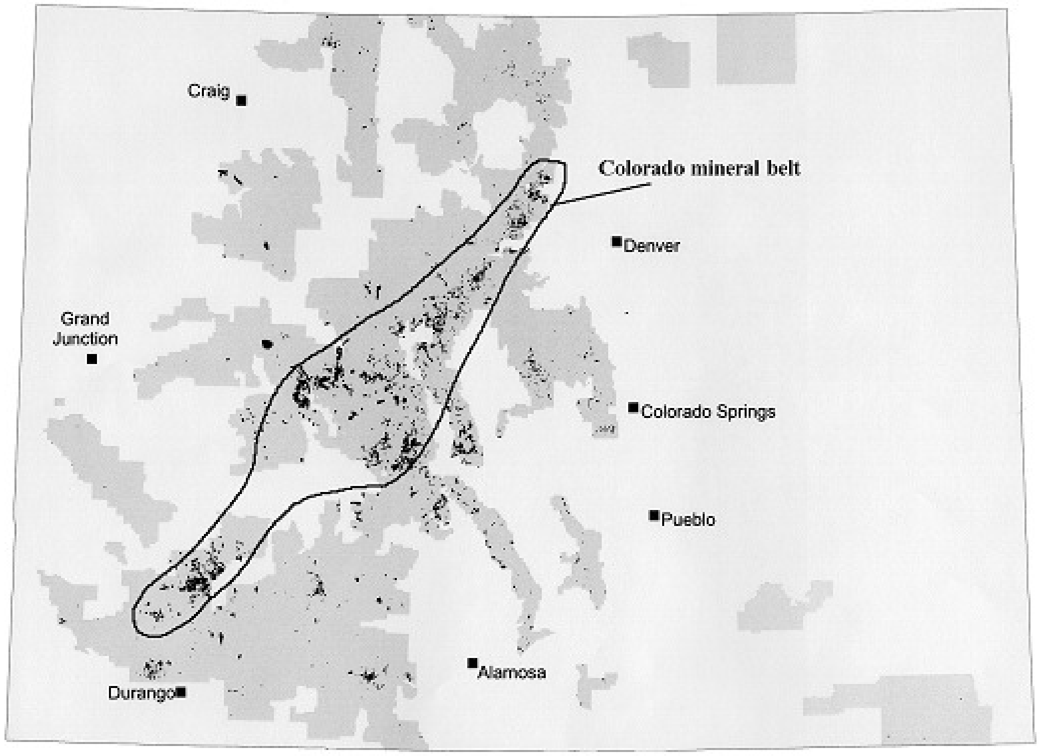


Figure 3 Distribution of the Colorado Mineral Belt

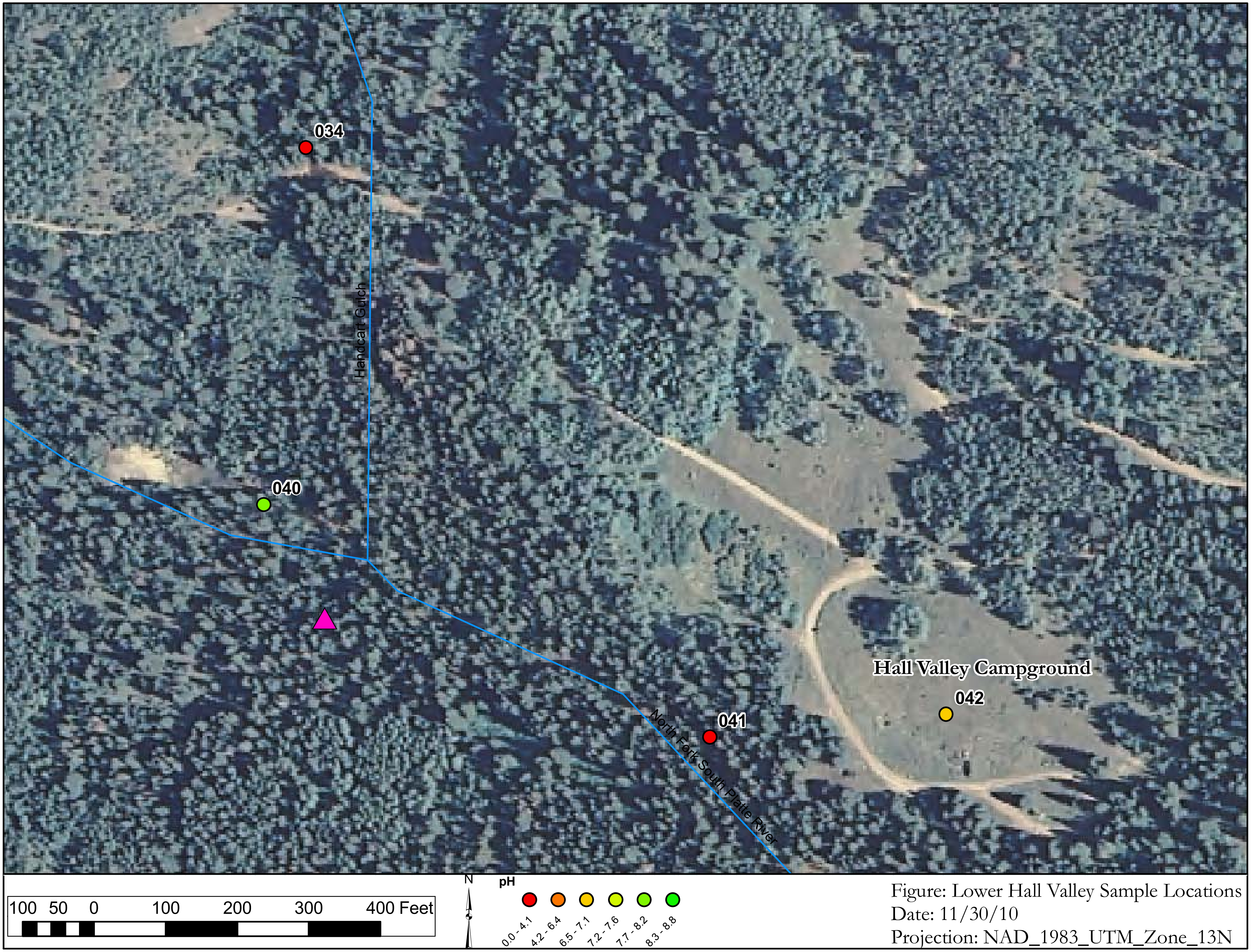


Figure: Lower Hall Valley Sample Locations
Date: 11/30/10
Projection: NAD_1983_UTM_Zone_13N

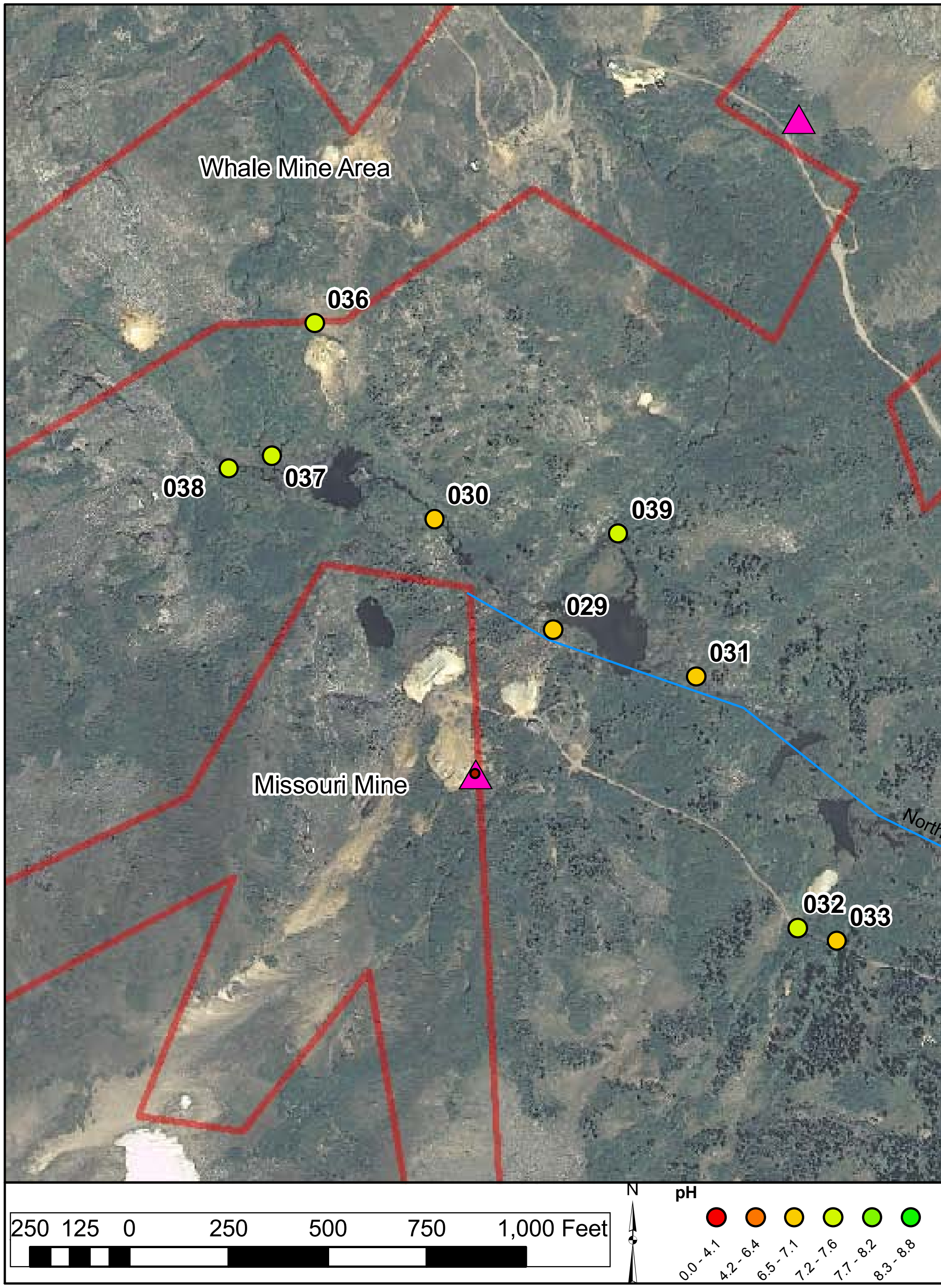
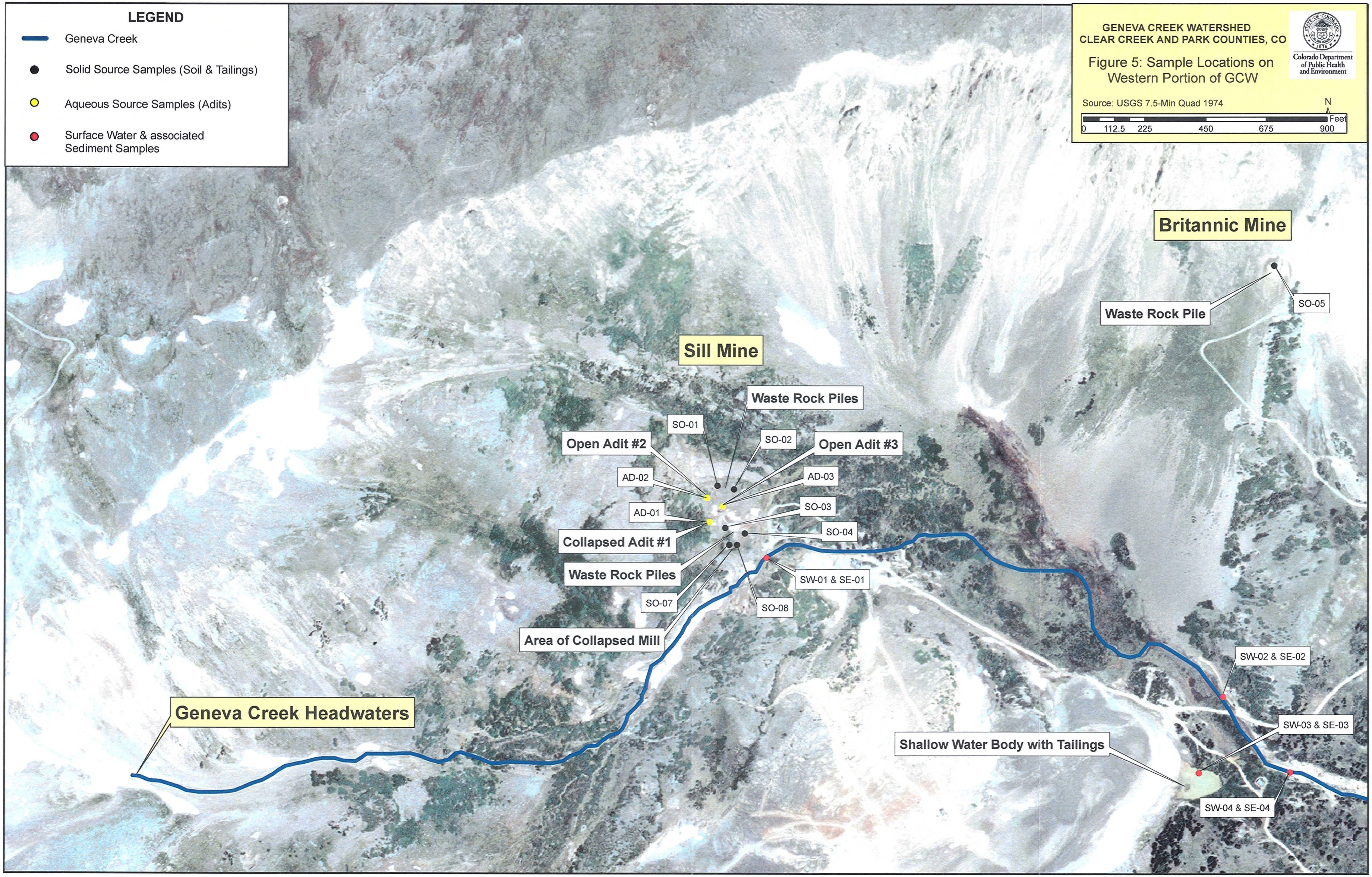
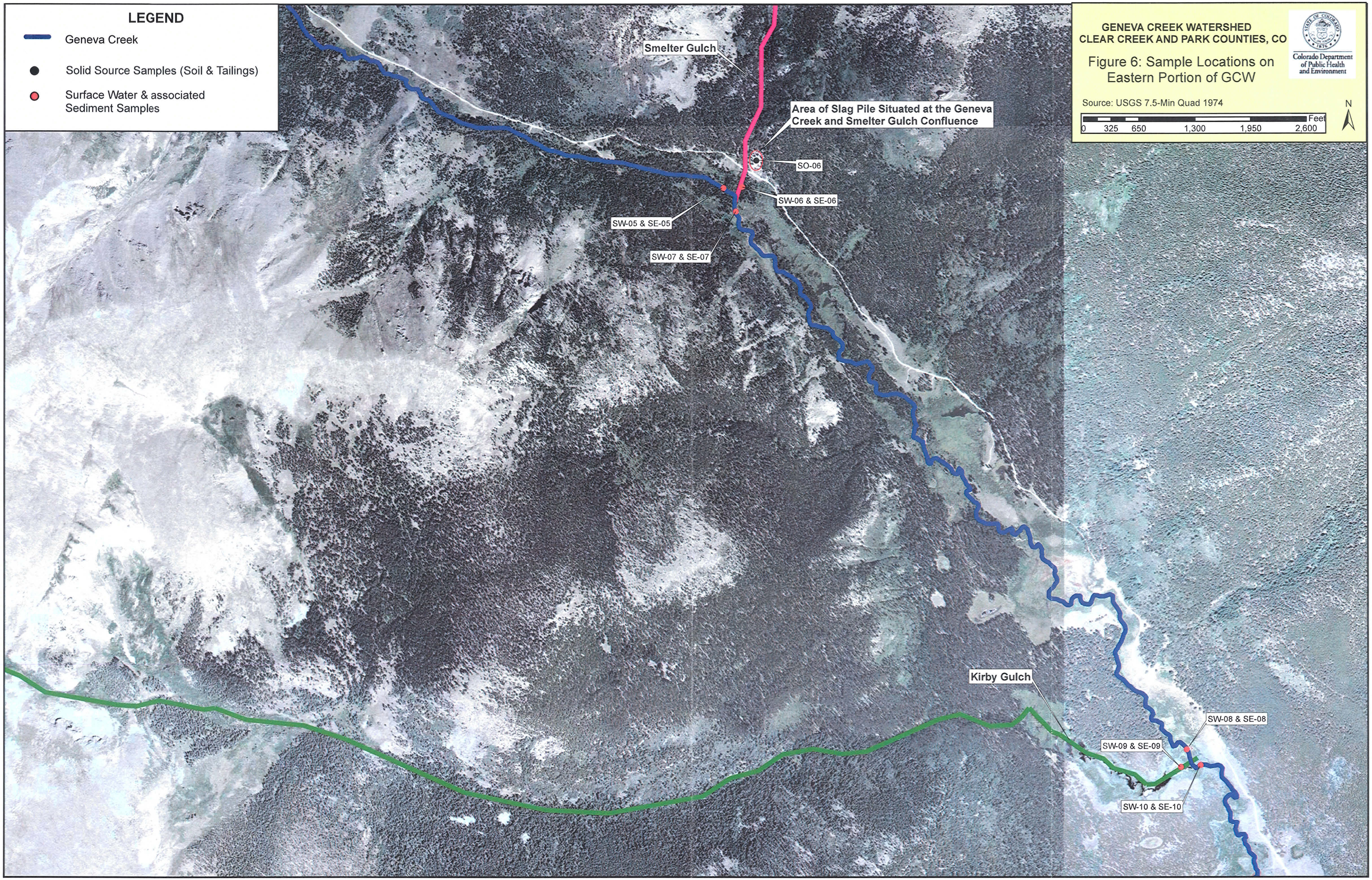


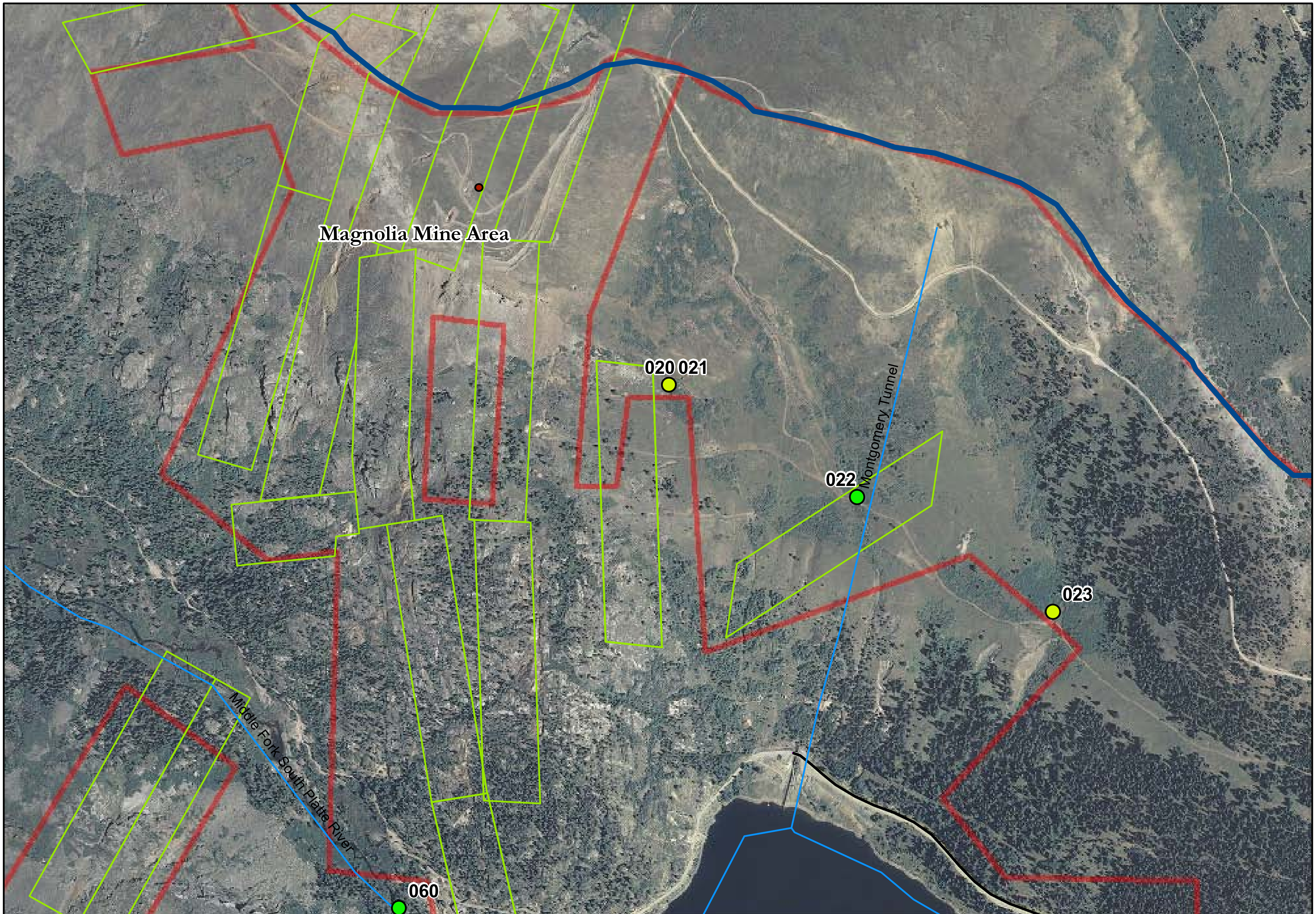
Figure: Upper Hall Valley Sample Locations
Date: 11/30/10
Projection: NAD_1983_UTM_Zone_13N



LEGEND
Geneva Creek
Solid Source Samples (Soil & Tailings)
Aqueous Source Samples (Adits)
Surface Water & associated Sediment Samples
GENEVA CREEK WATERSHED
CLEAR CREEK AND PARK COUNTIES, CO
Figure 5: Sample Locations on Western Portion of GCW
Colorado Department of Public Health and Environment
Source: USGS 7.5-Min Quad 1974
N
Feet
0 112.5 225 450 675 900
Britannic Mine
Waste Rock Pile
SO-05
Sill Mine
Waste Rock Piles
SO-01
SO-02
Open Adit #2
Open Adit #3
AD-02
AD-03
AD-01
SO-03
Collapsed Adit #1
SO-04
Waste Rock Piles
SW-01 & SE-01
SO-07
SO-08
Area of Collapsed Mill
SW-02 & SE-02
SW-03 & SE-03
Geneva Creek Headwaters
Shallow Water Body with Tailings
SW-04 & SE-04



LEGEND
Geneva Creek
Solid Source Samples (Soil & Tailings)
Surface Water & associated Sediment Samples
GENEVA CREEK WATERSHED
CLEAR CREEK AND PARK COUNTIES, CO
Figure 6: Sample Locations on Eastern Portion of GCW
Colorado Department of Public Health and Environment
Source: USGS 7.5-Min Quad 1974
Feet
0 325 650 1,300 1,950 2,600
N
Smelter Gulch
Area of Slag Pile Situated at the Geneva Creek and Smelter Gulch Confluence
SO-06
SW-06 & SE-06
SW-05 & SE-05
SW-07 & SE-07
Kirby Gulch
SW-08 & SE-08
SW-09 & SE-09
SW-10 & SE-10



400 200 0 400 800 1,200 1,600 Feet

N

pH

0.0 - 4.1
4.2 - 6.4
6.5 - 7.1
7.2 - 7.6
7.7 - 8.2
8.3 - 8.8

TaxParcel

Figure: Montgomery Gulch Sample Locations
Date: 11/30/10
Projection: NAD_1983_UTM_Zone_13N

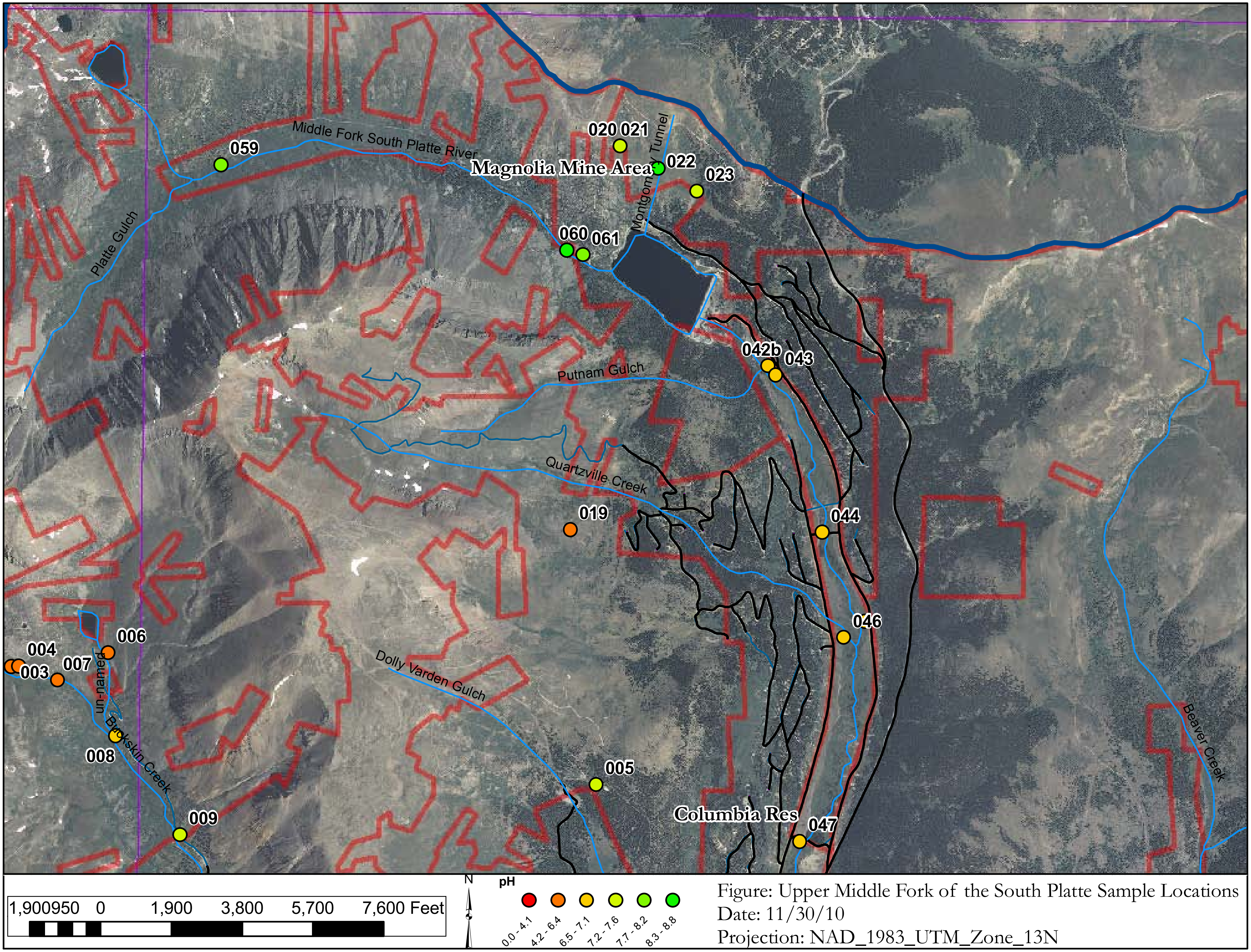


Figure: Upper Middle Fork of the South Platte Sample Locations
Date: 11/30/10
Projection: NAD_1983_UTM_Zone_13N

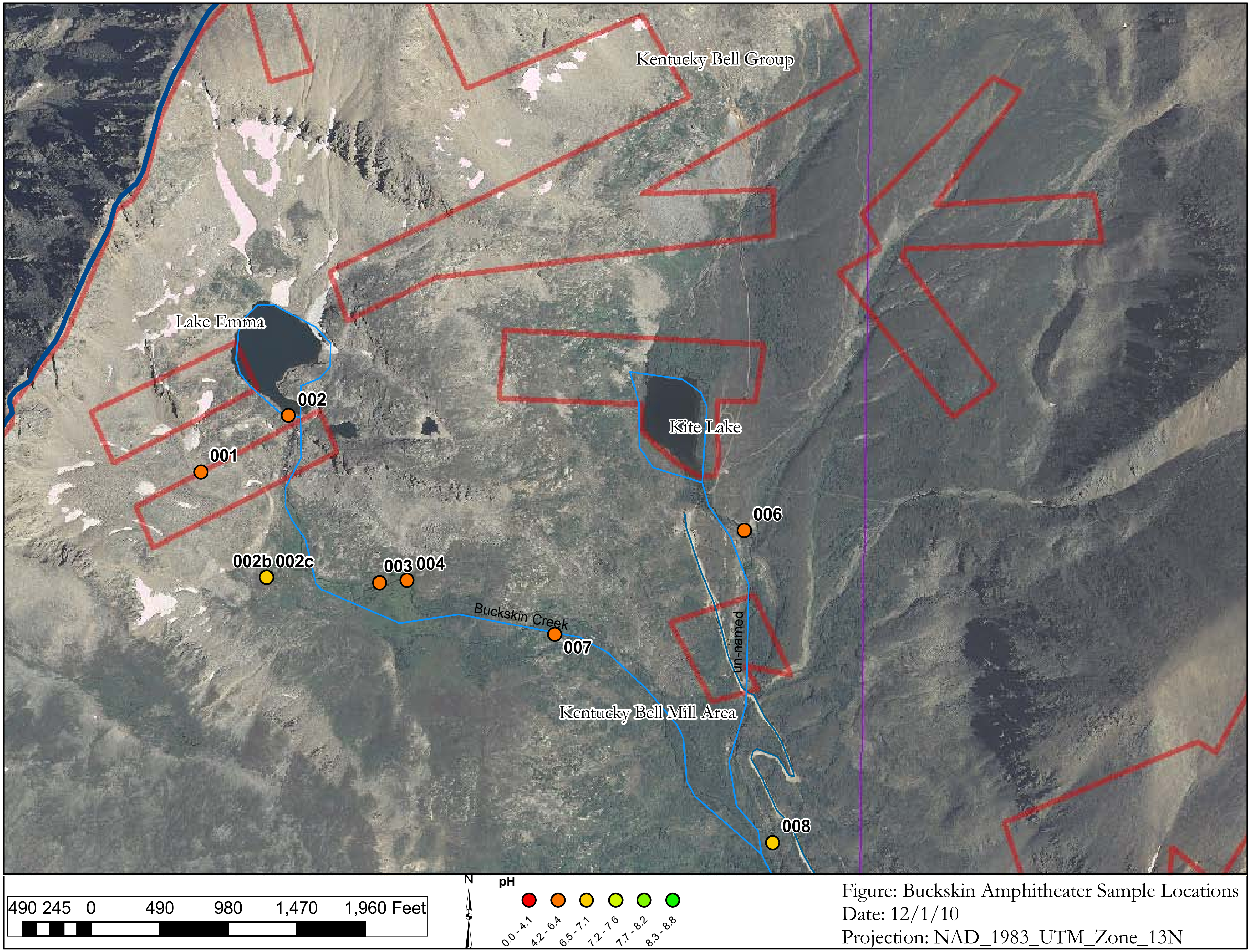


Figure: Buckskin Amphitheater Sample Locations
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N

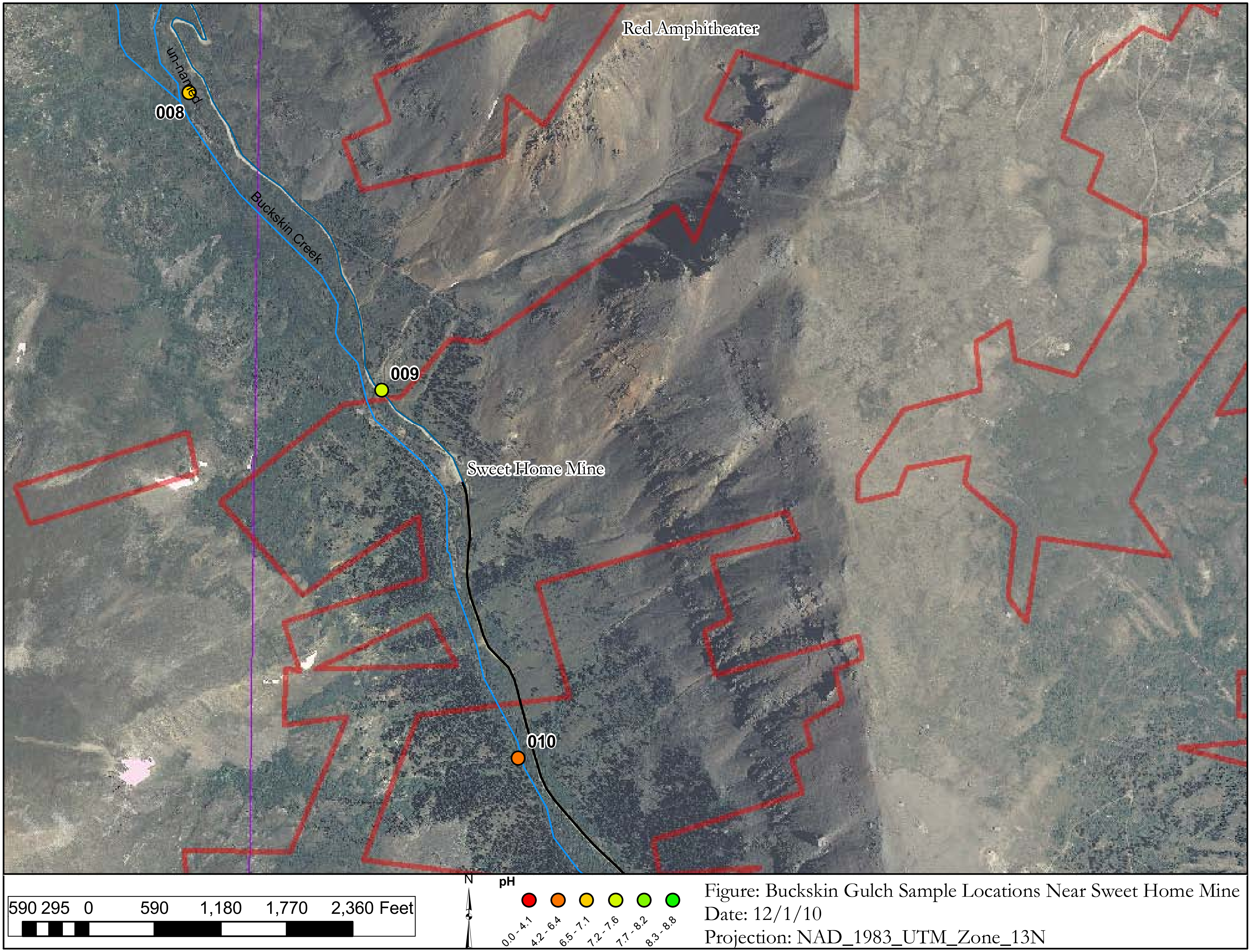


Figure: Buckskin Gulch Sample Locations Near Sweet Home Mine
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N

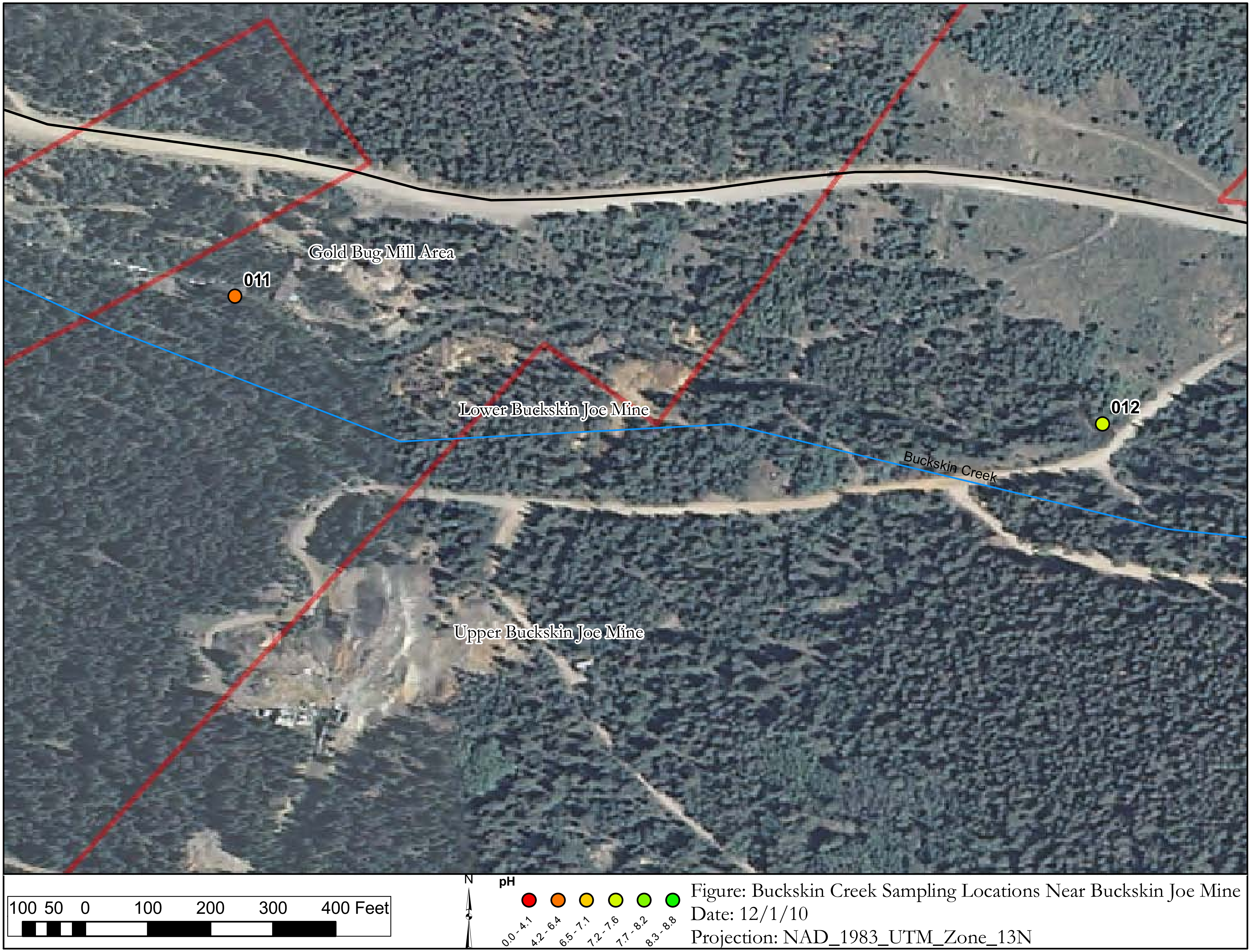
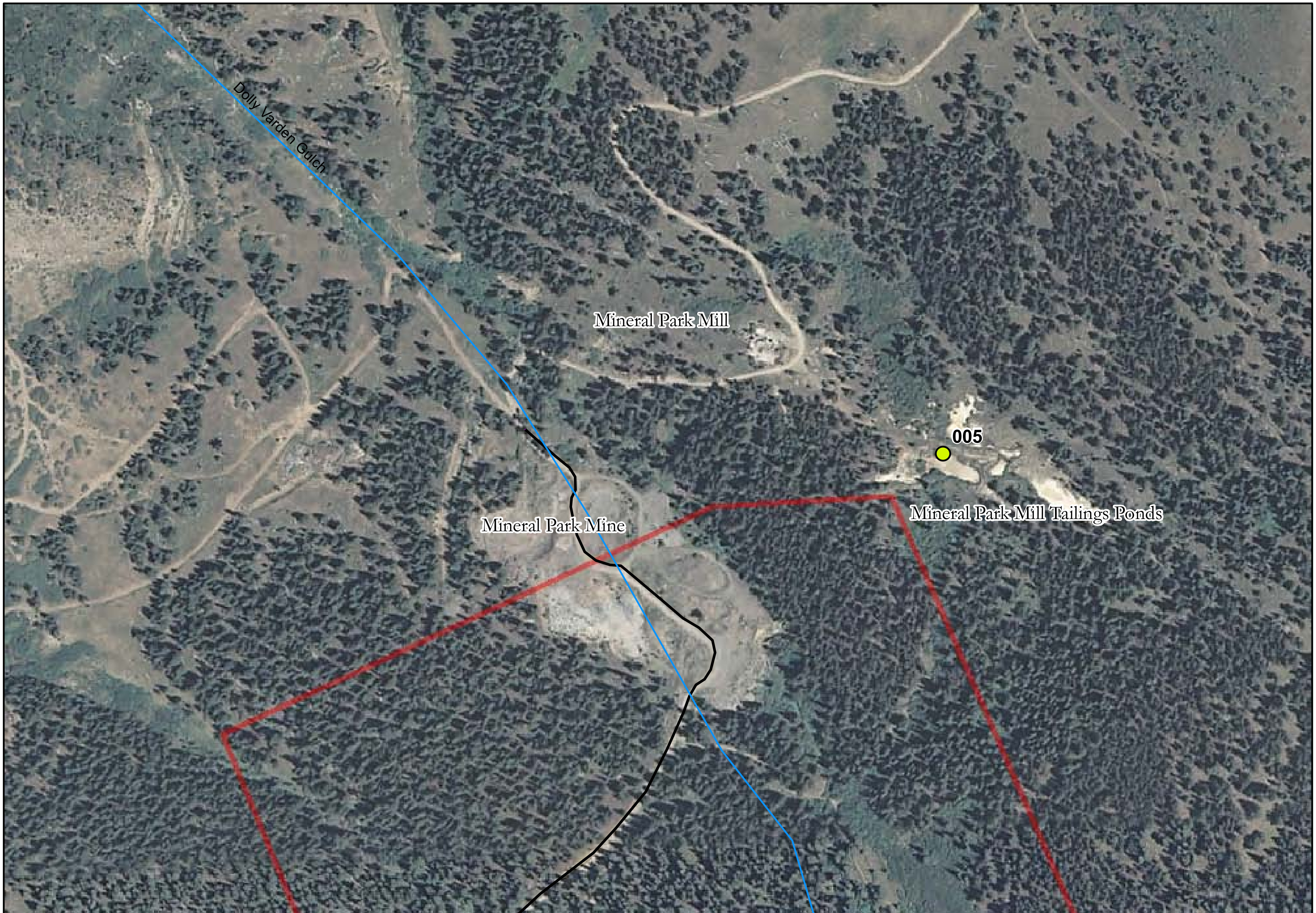


Figure: Buckskin Creek Sampling Locations Near Buckskin Joe Mine
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N



160 80 0 160 320 480 640 Feet

N

pH

0.0 - 4.1
4.2 - 6.4
6.5 - 7.1
7.2 - 7.6
7.7 - 8.2
8.3 - 8.8

Figure: Mineral Park Mine and Mill Sampling Locations
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N

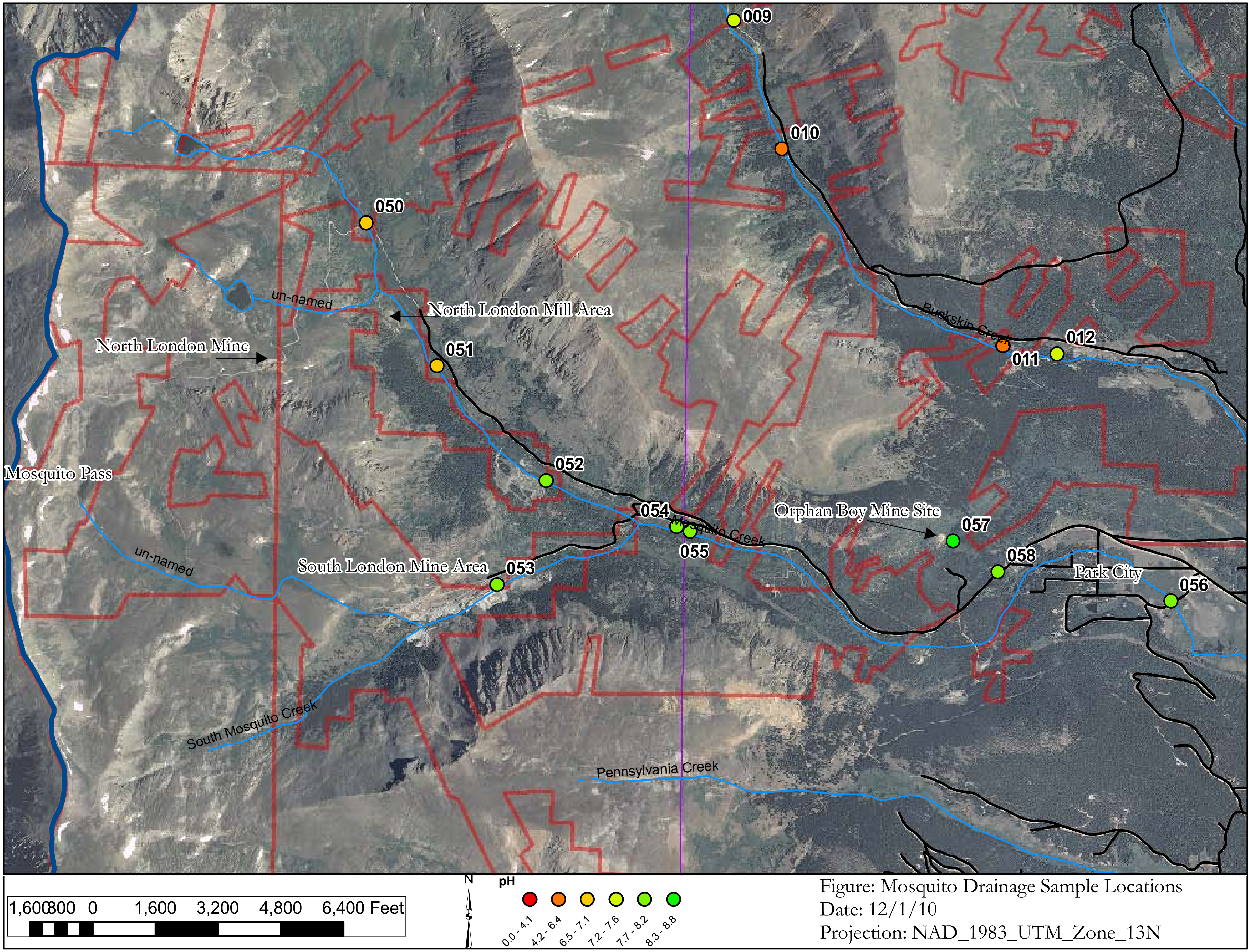


Figure: Mosquito Drainage Sample Locations
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N

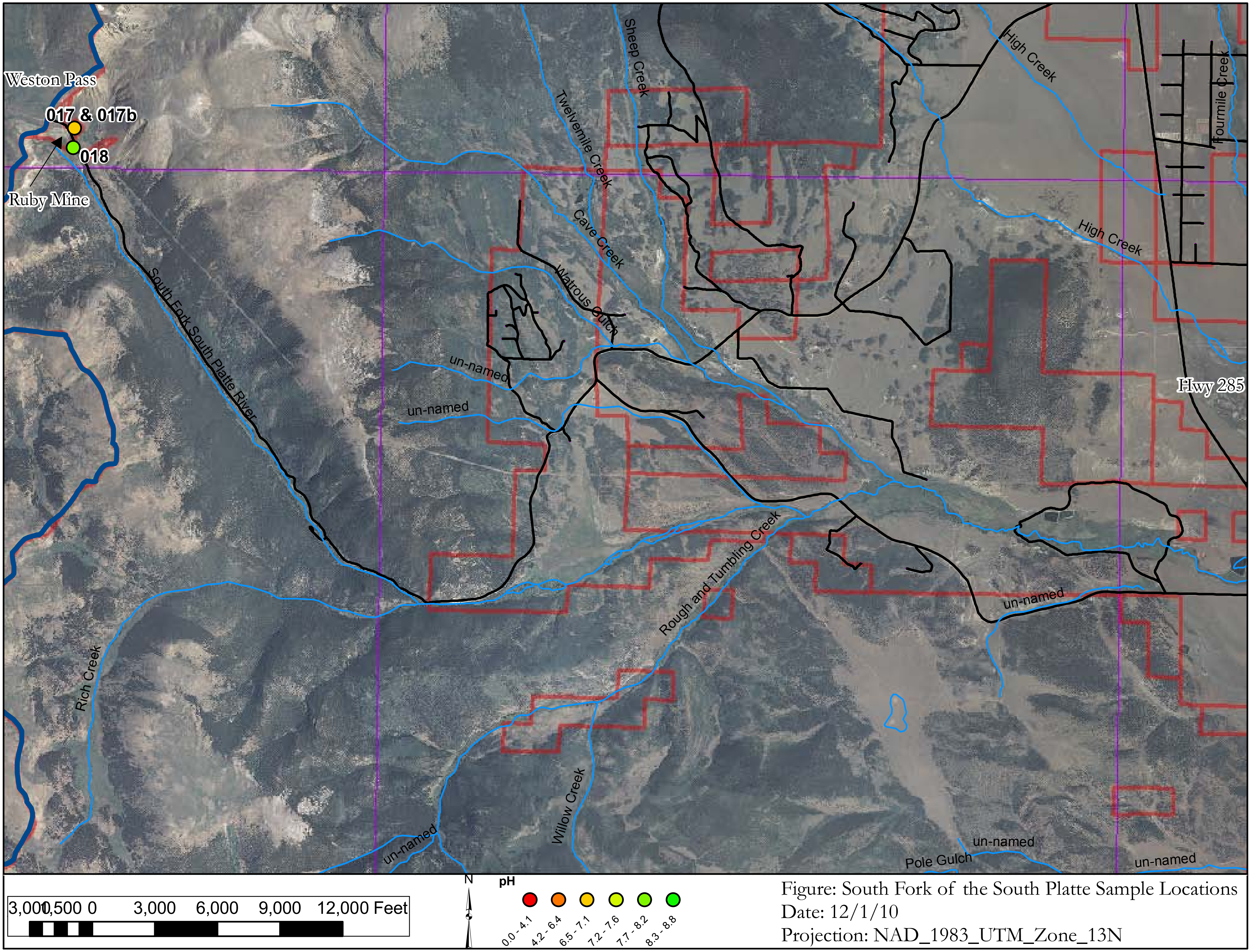


Figure: South Fork of the South Platte Sample Locations

Date: 12/1/10

Projection: NAD_1983_UTM_Zone_13N

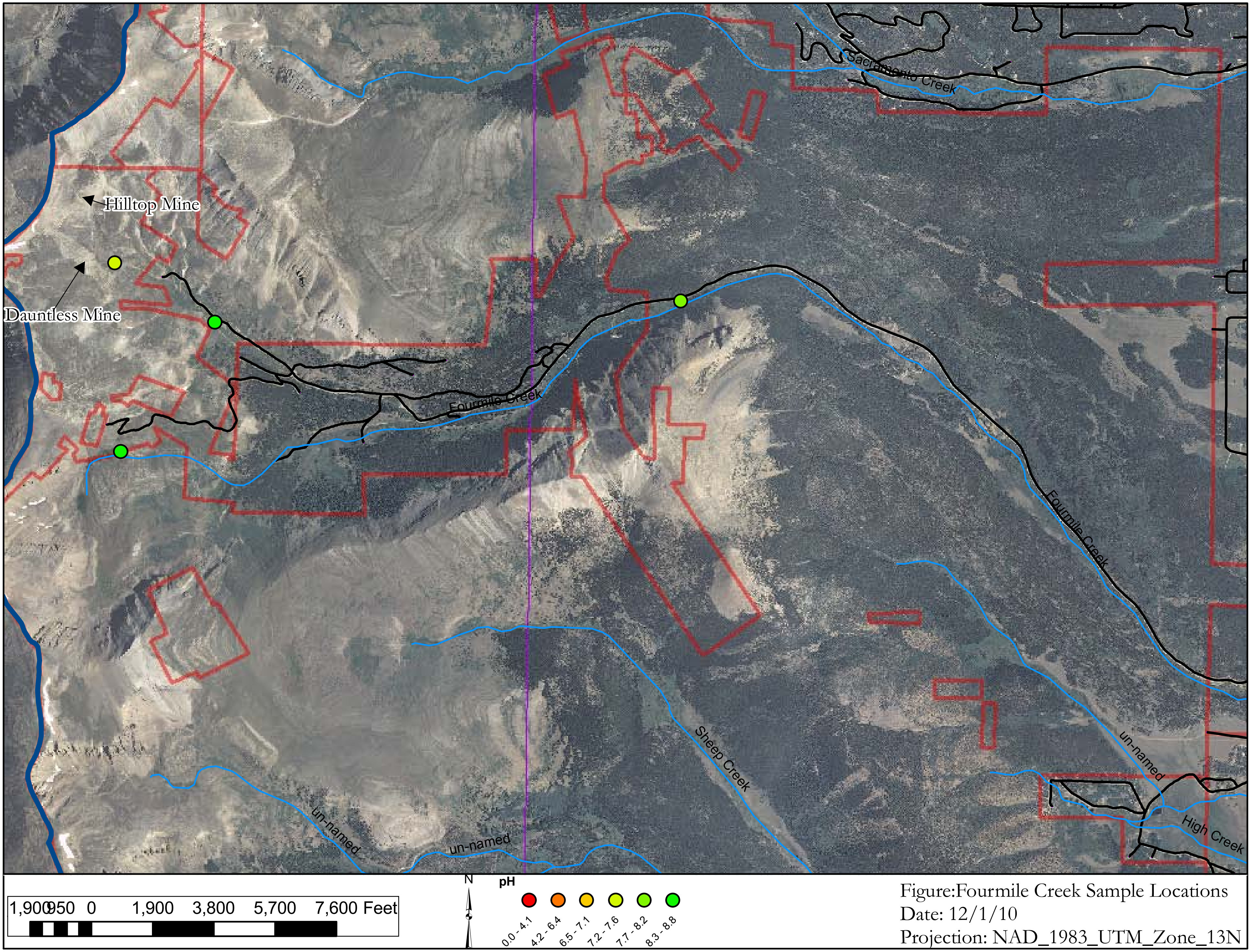


Figure:Fourmile Creek Sample Locations
Date: 12/1/10
Projection: NAD_1983_UTM_Zone_13N