COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

Colorado Department of Natural Resources
Division of Mining Reclamation and Safety
1313 Sherman Street, Room 215
Denver, Colorado 80203

Colorado Underground Coal Mine Fires
2018 Inventory Report

TETRA TECH

August 2019

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1313 Sherman Street, Room 215
Denver, Colorado 80203

PRESENTED BY

Tetra Tech
350 Indiana Street, #500
Golden, Colorado 80401

P +1-303-217-5700
F +1-303-447-1836
www.tetratech.com

EXECUTIVE SUMMARY

There are approximately 1,736 known abandoned coal mines in the State of Colorado. In 2017 and 2018, on behalf of the State of Colorado Department of Natural Resources Division of Mining Reclamation Safety (DRMS), Tetra Tech, Inc. inspected 38 coal mine fire sites across Colorado. Site conditions included highly active fires, low activity and dormant fires and sites that were previously reclaimed and confirmed as dormant/extinguished. Several coal waste piles were included in the inventory site visits. Several sites exhibit high-intensity indicators of coal combustion including ash, venting, and extremely hot temperatures at the surface. In some instances, the sites were visited on more than one occasion to collect additional data and identify trends in the state of the fires. In addition to coal mine fires, outcrop or paleo fires exist across the state.

As stated by Rushworth and others in the 1989 *Reconnaissance Study of Coal Fires in Inactive Colorado Coal Mines*, "Mine and coal crop fires and coal waste fires can all present a serious safety hazards to the public. Coal fires are dangerous due to instability of the ground surface and the possibility of toxic exhaust gases being trapped in hollows under certain atmospheric conditions." Time is also a critical factor in coal mine fires. Comparison of site conditions over the past three decades has shown that fires evolve and are subject to change at any time. Sites that appear dormant can become active again due to subsidence or other factors. The susceptibility of coal mine fires to change necessitates diligent monitoring and engineered safeguards to protect human health and the environment.

This report presents a summary of the findings for each of the coal mine fire sites visited during the 2017-2018 inventory. Data collected at each site includes aerial photography, thermal imagery, elevation data, emissions data, surface temperatures, and intake mapping where appropriate. Unmanned aerial systems (UAS) were used extensively to safely gather data in areas with substantial risk of exposure to toxic gases and unstable ground conditions.

The data presented in this report represents conditions at each of the coal mine fire sites at a specific moment in time and should serve as the basis for future comparisons to evaluate the overall changes in sites conditions at coal mine fire sites in Colorado. Routine monitoring of coal mine fire sites aids in the prioritization to best focus available funding to the sites with the highest risk factors.

Tetra Tech developed a multi-criterion decision analysis tool to aid in the prioritization of fire site reclamation efforts. Each site is scored subjectively for risk in the following areas: distance from populated areas, public accessibility and likelihood of trespassing, objective dangers at the site, risk of wildfire, emissions, public concern and visibility, and overall activity of the fire. After completing all the site visits, these values were assigned and a semi-quantitative ranking of the relative priority of the sites was determined (**Table ES-1**).

This report was authorized and funded by the Colorado Department of Natural Resources Division of Mining Reclamation and Safety under Contract CT-PKAA-1000-2018*1873 dated August 31, 2017.

Table ES-1 – Colorado Mine Fire Priority List

Rank	Fire	Score	Overall Risk	Comments
1	South Canyon West	8.3	High	Highly active. Vents up to 500°F. New vents forming. Near trail system.
2	South Canyon East	8.1	High	Highly active. Vents up to 678°F. CO emissions. Near trail system.
3	Sunshine	7.0	High	Vegetation near 300°F vent. Wildfire risk. Unstable ground. CO emissions.
4	Vulcan	6.8	High	Low activity but recent/ongoing subsidence. Near condominiums.
5	Axial	6.8	High	Temperatures as high as 860°F. Near highway. Developing fractures.
6	Haas /IHI No. 3	6.6	High	Vents up to 600°F. Near recreation area. Difficult firefighting access.
7	New Castle 3	6.4	Medium	Moderate activity. Publicly visible. Fractures and steep terrain.
8	Kaspar	5.4	Medium	Vents up to 300°F. Fire migrating. Some vegetation nearby.
9	Bear	5.3	Medium	Low-temperature vents. Steep, unstable slopes. Near town of Somerset.
10	Harvey Gap	5.0	Medium	Vents up to 310°F. Little vegetation. Not readily accessed by public.
11	Elk Creek	4.9	Medium	Vents up to 230°F. Little vegetation. Not readily accessed by public.
12	Black Diamond	4.7	Medium	Vents up to 237°F. Some high-CO vents. Near trail system.
13	New Castle 1	4.6	Low	Low temperatures. Private property. Steep terrain.
14	Morgan	4.5	Low	Moderately active. Not easily accessed by public. Little vegetation.
15	Coryell	4.5	Low	Low activity. No dangerous surface features. Near town of New Castle.
16	Gem	4.1	Low	Confined fire area but vegetation nearby. Moderately active.
17	IHI No. 2	3.8	Low	Low activity. Remote. Some subsidence.
18	North Coal	3.7	Low	Highly active but confined. Noxious emissions. Remote. Locked gate.
19	Marshall 1 and 2	3.6	Low	Low activity. In Open Space but off-trail.
20	McElmo	3.6	Low	Very low activity but high risk of trespassing.
21	Oliver	3.6	Low	Low activity but visible from highway. Methane exhaust.
22	Garfield	3.4	Very Low	Very low activity. Some unstable ground and risk of trespassing.
23	Lewis 1 and 2	3.1	Very Low	Low activity. Open Space property but no trail network.
24	Go Boy	3.0	Very Low	Low activity. Private property.
25	West Sopris	2.9	Very Low	Remediation planned or in progress.
26	Double Dick	2.9	Very Low	Low activity. Private property.
27	Davis	2.7	Very Low	No active vents. Private property.
28	States	2.7	Very Low	No active vents. Private property.
29	Minnesota Creek	2.7	Very Low	Low activity. Remote.
30	Wise Hill 3	2.7	Very Low	Abatement in progress. Revisit after abatement completed.
31	Slagle/Bright Diamond	2.5	Very Low	Remote. Only 1 low-temperature vent.
32	Riach	2.4	Very Low	Low activity. Remote. Partially remediated.
33	Farmers Mutual	2.4	Very Low	May be dormant.
34	Soda Springs	2.1	Very Low	Temperatures as high as 109°F. Locked gate. Remote. Little vegetation.
35	Pocahontas	2.1	Very Low	May be dormant.
36	Skull Creek	2.0	Very Low	May be extinguished.
37	Morley Waste Dump	2.0	Very Low	Abated and controlled.
38	Rienau Number 2	NA	NA	No landowner permission to access.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
BGS	Below Ground Surface
BLM	Bureau of Land Management
BMP	Best Management Practice
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DRMS	Division of Mine Safety and Reclamation
°F	Fahrenheit
ft	Foot/Feet
H_2S	Hydrogen Sulfide
I-25	Interstate 25
I-70	Interstate 70
mya	Million Years Ago
O_2	Oxygen
UAS	Unmanned Aerial System

1. INTRODUCTION

Colorado's mineral resources played an important role in the development of the State. Coal mining started with the arrival of the first settlers and prospectors to Colorado's Front Range. At one point there were over 100 producing coal mines in Boulder and Weld Counties alone. As the population of Colorado grew and moved westward, the mining followed, with coal mining occurring in all of Colorado's coal fields at one point or another during the state's growth and development. As a result of the dependence on coal and availability around the state, there are approximately 1,736 known abandoned coal mines.

This report summarizes site conditions at the 38 known underground coal mine fires located in coal fields across the State of Colorado. An inventory of coal mine fires in the State of Colorado is completed every five years by the *Colorado Department of Natural Resources – Division of Reclamation Mining and Safety (DRMS)* to evaluate the mine fire activity, potential resource loss, and threat to public safety. Building upon the previous statewide inventory reports from 1989, 2005 and 2013, Tetra Tech visited each of the mine fire sites to gather current site condition data by using new tools and approaches, including: drone-based aerial photogrammetry and thermal imagery, emissions monitoring, remote seismological sensing, active seismic surveys, integrated 3D modeling, and deployment of remote monitoring stations.

Tetra Tech compared data collected in 2018 to observations reported in the 1989, 2005 and 2013 Coal Mine Fire Inventory reports, as well as other sources, to attempt to quantify the nature and extent of changes at each of the mine fire sites. Such changes range from subsidence, fracturing, and additional venting to the complete abatement of the fire.

In this report, the general geologic setting and characteristics of the eight Colorado coal region and numerous subfields therein are discussed in Section 2.0. Although the varying geologic settings across the state present individual challenges, there are overarching lessons to be learned and applied. The mine fire sites often share common features and characteristics despite the differences in geographical location and setting. Additionally, varying levels of background information were identified for each site. In some instances, there was a detailed mine map available as well as a knowledgeable landowner with direct experience with the mining operation on their property. In other cases, data available for a site was limited to what was visible at the surface, including: fractures vents, stressed vegetation, thermally altered rocks, gas contents, surface temperatures, or subsidence features that we could measure.

In Section 3.0, the tools and methods used to complete the mine fire inventory are described. The role and limitations of each dataset in the overall site characterization model are discussed. Safety was the number one priority during the site visits, and some of the key components of the safety program implemented for this project include gas monitoring and remote sensing of hazardous areas with unmanned aerial systems (UAS) or drones. The aircraft were modified to collect thermal data in addition to the data provided by the standard camera.

In Section 4.0, a summary of conditions observed at each site during the mine fire inventory inspections is presented. This section includes a brief history of the mine and fire when available, mine information, description of fire observations and data collected during the site visits, and directions to each site.

Section 5.0 summarizes the current priority ranking of all the mine fire sites across the state. A multi-criteria decision analysis (MCDA) tool was used to objectively determine which sites present the highest risk and help the State of Colorado prioritize funding.

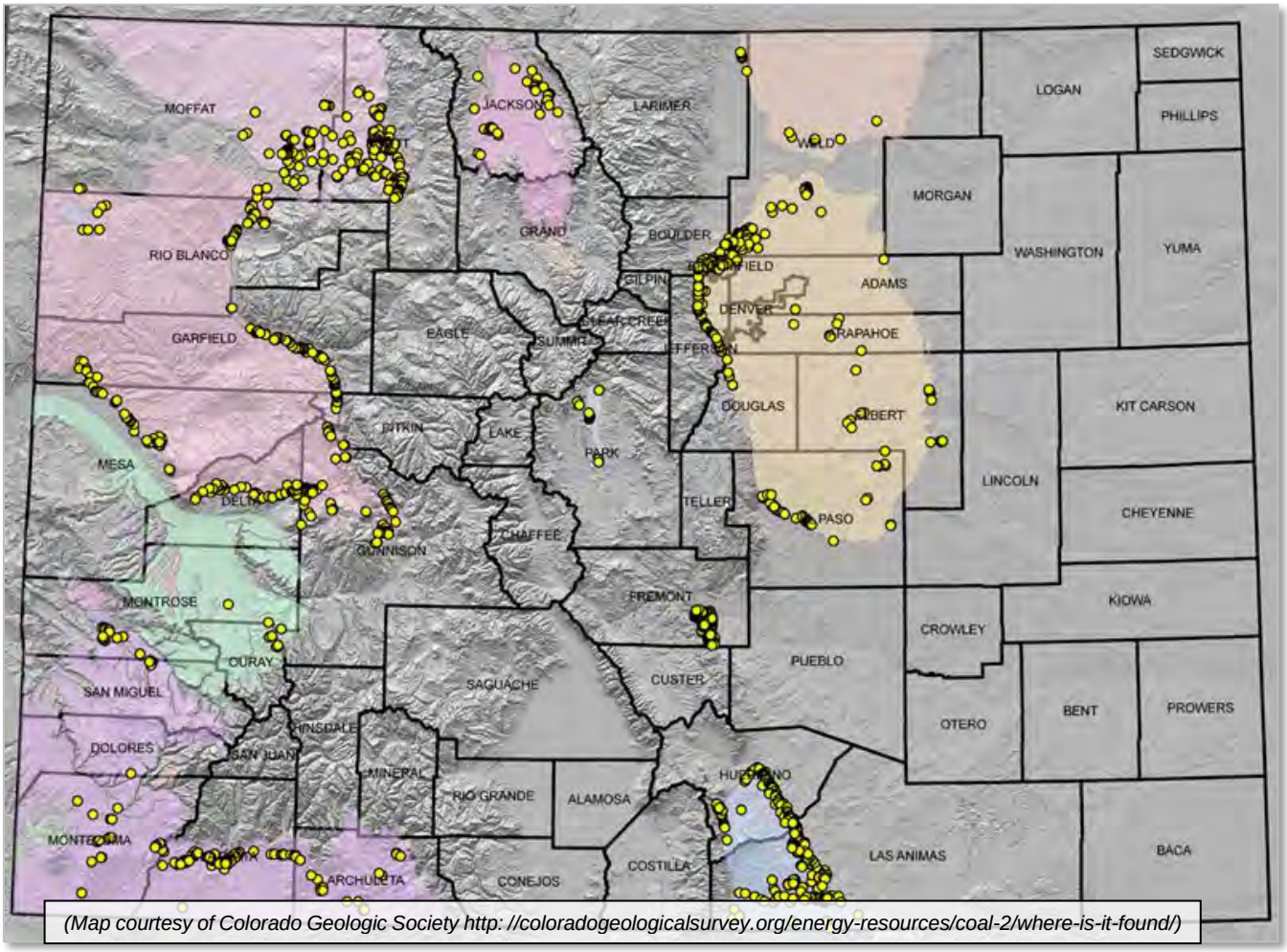
References used during the research and writing of this report are listed in Section 6.0.

The 2018 Colorado Underground Coal Mine Fire Inventory was completed for the Colorado Department of Natural Resources – Division of Reclamation Mining and Safety (DRMS) under contract CT-PKAA-1000-2018*1873 dated August 31, 2017.

2. COLORADO COAL FIELDS

2.1 Locations

There are eight distinct coal mining regions in Colorado identified and discussed in this report. Figure 2-1 shows the locations of these coal fields and areas within them, known to be undermined. The Green River Coal Region, Uinta Coal Region, and San Juan River Coal Region, all found on the Western Slope, account for most of the coal mining activity in Colorado. Smaller basins containing coal in the central part of the state include the North and South Park Coal Regions and the Cañon City Coal Region. Finally, the Denver Coal Region and Raton Mesa Coal Region lie along the I-25 Front Range corridor.



(Map courtesy of Colorado Geologic Society http: //coloradogeologicalsurvey.org/energy-resources/coal-2/where-is-it-found/)

Figure 2-1 – Colorado Coal Regions and Abandoned Mines

The Colorado Historical Society (Fell and Twitty, 2006) documents the history of mining in Colorado, including that of coal industries. The following is a summary thereof.

The Front Range hosted the first coal mines in Colorado. Riding the coattails of the Pike's Peak gold rush in 1859, coal mining began in Boulder County. The generally low-quality lignite was insufficient for smelting or steam production, however, and although the towns of Marshall, Erie, and Louisville were by far the most important in the

state, production was seasonal because the coal was used almost exclusively for home heating. Higher-quality bituminous coal discovered near Cañon City fueled—both literally and figuratively—substantial expansion of railroads beginning in the 1870s, and coal production expanded to the Raton Mesa Region. Within a decade, metal mining was booming (most notably the silver-lead mines in Leadville), railroads were expanding, and demand for coal both to produce steam and to process ore soared. Towns from Trinidad to Walsenburg to Pueblo grew to fuel smelters and produce steel. Coal mining picked up in the greater Roaring Fork Valley near Crested Butte and Glenwood Springs, allowing ore from, for example, silver mines near Aspen to be processed more locally. For 30 years or so, coal production clipped along riding the waves of the metal, mineral, and overall national economy until the 1900s when the first heavy-gauge rail line overtopped the Continental Divide in central Colorado. The Denver Northern and Pacific left the capital (largely following the modern path of the Union Pacific), passing the coal mines at Leyden to South Boulder Creek and up to Rollinsville before a monumental crossing of the Divide into Middle Park near modern Winter Park. Now in the relatively benign Colorado River drainage, the railway could access the reserves of North Park and then the Green River and northern Uinta areas. As a result, production in the Green River Region especially skyrocketed.

A protracted decline in Colorado coal production began following World War I. Trains switched to petroleum, and houses to natural gas. Coal was primarily used for smelting, so mines producing coking-quality coal fared well through WWII, but the Denver Basin and Cañon City were especially hard-hit. The expansion of coal-fired power plants in the post-war years gave a boost to some parts of Colorado. In particular, several surface strip mining operations in the San Juan Uinta and Green River Regions served as on-site supply for power plants, with coal mined directly onto conveyors bound for the incinerator. At others, conveyors dumped coal directly into waiting trains that had only one cargo and only one destination: the power plant. Furthermore, the comparatively low sulfur content of Colorado coal made it increasingly attractive as environmental regulations were tightened to keep pace with development. These same regulations and the environmental movement in general may have been impediments to strip mines, but—coupled with improvements in mining equipment—spurred interest in underground, and especially longwall, mines in Colorado into the 1990s. Declining natural gas prices have put a squeeze on coal-fired plants in the past 10 years, and coal mining has steadily declined nationwide.

Integrated from 1864 to present, coal production is roughly evenly split between the Front Range (Denver and Raton Mesa) and the Western Slope (Uinta and Green River), with each contributing more than 350 million tons and each accounting for more than 45% of total statewide production. Cañon City has provided another 5%, and the remainder is split among the San Juan River basin and North and South Park.

Over the last decades, however, production has been dominated by the Western Slope. The Green River and Uinta Regions contributed 89% of all Colorado coal from 15 active mines (out of 21) in 1990. Four additional mines split between Raton and Cañon City provided another 10%. The San Juan River basin and North Park each hosted one operating mine, but no coal mines were active in Denver or South Park.

Following national trends, Colorado coal mines have become less active over the past several years, producing 1/3 of the coal produced as recently as 2007. Nevertheless, Colorado is the 11th leading coal producer in the United States (2.1% of national total). The most recent Colorado Geological Survey report (O'Keefe and Berry, 2016) describes eight active mines that account for 1,086 direct jobs and $500 million in product. Four are spread across the Uinta Region and account for 60% of statewide production. Two in the Green River Region contribute an additional 34%, and the final two in the San Juan Region provide the final 6%. No mines are active in Denver, Cañon City, Raton, or North or South Park.

2.2 Geology

Colorado coal was formed during the late Cretaceous and Paleocene Periods—approximately 55-100mya—in fresh-water swampy peat mires along coastal plains bordering the Western Interior Seaway. The process of burial by sediments, heat, and time transform peat into varying types of carbon-rich deposits such as lignite, bituminous coal, and anthracite.

Despite their common origin, modern coalbeds in Colorado comprise widely varying grades of coal, lie at varying depths beneath the surface, and have varying dips. As a result, mining methods vary between surface and underground mining. Over 90 percent of the coal mining in Colorado is underground, with some of the shallow mines in Moffat County being operated as open pit mines. The geology of each of Colorado's eight distinct coal regions are generally described below. Colorado Geological Survey Special Publication 36 (*1990 Summary of Coal Resources in Colorado*) provides extensive information on production, coal quality, and geology (Tremain et al., 1990). Much of our summary is drawn from this resource, but we have expanded focus on areas with mine fire sites. The locations of the regions described below are shown on Figure 2-1.

2.2.1 Green River Coal Region

Located in northwestern Colorado and southwestern Wyoming, the Green River Coal Region is bounded by the Park Range on the east, on the south by the White River Uplift, on the west by Uinta Uplift, and to the north by Sand Wash Basin and flank of the Axial Basin Anticline. The region is complicated structurally by folding, faulting, and late-Tertiary igneous intrusives in the southwest part of Sand Wash Basin and by the deformation of the Axial Basin Anticline (Collins, 1977).

The primary coal-bearing unit in the area is the Upper Cretaceous Mesaverde Group, which was deposited in a southwest-trending delta-plain/delta progression that extends across most of western Colorado. Both the Iles and Williams Fork Formations within the Mesaverde Group contain numerous thin coal seams. The Mesaverde Group consists of massive ledge-making sandstones, together with thinner-bedded sandstones, sandy shales, and coal beds. This group typically forms ridges because the sandstone members offer greater resistance to erosion than either the overlying or underlying shale units. Additional, but less substantial, coal seams also occur in the overlying (Cretaceous to Paleocene) Lance, Fort Union, and Wasatch Formations.

The two mine fires in this region are in the Yampa Coal Field in the coal beds of the middle group of the Williams Fork Formation (Rushworth, 1989). Yampa is the only named coal field in the region.

2.2.2 Uinta Coal Region

At present, the Uinta Coal Region is the most active in Colorado, and it also has the most mine fire sites. The coals of the Uinta Coal Region are also found in the Upper Cretaceous Mesa Verde Formation and were deposited in a deltaic sequence that progressed southeastward across western Colorado. This sequence is the same as discussed in the Green River Coal Region. The Axial Basin Uplift on the north side of the Uinta Coal Region separates it from the Green River Region.

The eastern boundary of the Uinta Coal Region is the Grand Hogback, a prominent monoclinal ridge extending south-southeast for about 125 miles from Rangely to Redstone. The Hogback hosts a high concentration of coal mines because it avails the opportunity for stope mining, which uses the near-vertical orientation of the coalbeds to an advantage for the mineral extraction. The monoclinal structure creates asymmetric basins, including the Piceance Basin, with more steeply dipping strata on the east side than the west, and north-northeast-trending axes. The Piceance Basin lies in the northern part of the Uinta Region and is one of the deepest basins in the state. The southern portion of the basin has been intruded by the West Elk and Elk Mountain igneous suites, baking and locally

coking coal. At least eight coal fields have been described with the Uinta Region, and six of these have mine fire sites; these six fields are detailed below.

2.2.2.1 Book Cliffs Coal Field

The Books Cliffs Coal Field structure has relatively flat-lying rocks, dipping a few degrees to the northeast. It is located in the Piceance Basin, adjacent to the Uncompahgre Uplift. The Upper Cretaceous Mesa Verde Group are the home of the coal bearing sequences in the field, deposited by coastal on-lap/off-lap sequence. Coal in the Mt. Garfield Formation (roughly equivalent to the Lower Williams Fork Formation) is typically found in lagoonal deposits behind offshore sandstones (Young, 1955). Correlation of the coal bearing zones in the Book Cliffs Coal Field is complicated by the discontinuous nature of lagoonal depositional environments.

The Go Boy Mine was completed in the four- to six-foot Cameo bed in the Cameo Member of the Mt. Garfield Formation.

2.2.2.2 Grand Hogback Field

The Laramide Grand Hogback Monocline marks the eastern physiographic edge of the Colorado Plateau. The steeply dipping limb of the monocline contains the coal-bearing Mesaverde Group. The near-vertical seams are advantageous for stope mining. As a result, the Grand Hogback Field both is one of the most productive in the Uinta Region and hosts the most coal mine fire sites of any field.

Numerous seams are mined in the Grand Hogback Field. The most productive have been the Fairfield and South Cañon members of the lower Williams Fork Formation. Both the underlying upper Iles Formation (Black Diamond member) and overlying upper Williams Fork (Keystone member) are also mined.

2.2.2.3 Grand Mesa Field

The Grand Mesa Field lies on the southern edge of 10,000-foot Grand Mesa, a plateau capped by mostly mafic Tertiary-age volcanic flows. The coals in this field are found in the Mt. Garfield Formation of the Mesaverde Group. Numerous coal seams are known within the formation and the Cameo seam hosts several of the mines discussed in this report.

2.2.2.4 Somerset Field

The Somerset Field lies in the Gunnison River drainage, and mines generally target the Bowie and Paonia members of the Williams Fork Formation, part of the Mesaverde Group. Seams can reach thicknesses of 25-30 feet.

2.2.2.5 Danforth Hills Field

The Danforth Hills Field occupies the northeastern corner of the Uinta Region, situated against the Axial Uplift, which counterintuitively is a topographic low where the coal-bearing Mesaverde Group has been eroded away.

Both the Williams Fork and Iles Formations are present, availing numerous seams up to 20 feet thick. Strata are primarily flat-lying to gently dipping, so—unlike most of the Grand Hogback Field—surface mines are common. Several such mines have multiple benches to access multiple seams.

2.2.2.6 Lower White River Field

The final Field in the Uinta Region that contains mine fire sites is the Lower White River. This extensive region occupies the northwestern portion of the Uinta Region, including most of the western Piceance Basin and the Douglas Creek Arch and extending well into Utah. As with its eastern neighbor, Danforth Hills, both the Williams Fork and Iles Formations are present.

There is moderate structural complexity in the Lower White River. The most prolific portion of the region is where the Rangely Anticline is breached, and the resistant Mesa Verde sandstone beds acts as rimrock, exposing numerous seams beneath. (This same area and overall structure hosts the Rangely Oilfield, perhaps the largest in the state.)

2.2.3 San Juan River Coal Region

The San Juan River Coal Region extends over a broad swath of southwestern Colorado and contains numerous individual coal fields, generally sub-basins that are cut by the Uncompahgre and Gunnison Uplifts. Coal occurs in multiple Upper Cretaceous units: as many as four thin beds (a few feet thick) in the Dakota Sandstone, nine thin beds in the Menefee Formation (the local name for the middle member of the Mesaverde Group), and three more substantial beds in the Fruitland Formation.

2.2.3.1 Durango Field (and Pagosa Springs Field)

The Durango Field primarily lies in the San Juan Basin but also extends into the Red Mesa and Mesa Verde areas. The San Juan Basin is an asymmetrical syncline (thickening toward the northeast, generally) with a multi-phase structural history. The Paleozoic Ancestral Rockies orogeny formed the Uncompahgre Uplift to the northeast of the basin, specifically the Archuleta Anticlinorium. Roughly 200 million years later, the Hogback Monocline (which is distinct from the Grand Hogback farther north) grew early in the Laramide orogeny, creating the southwestern boundary of the basin. Subsequent growth of the Nacimiento and Zuni Uplifts to the east and south, respectively, tilted the basin down to the northwest.

Near the city of Durango, on the northern edge of the San Juan Basin, there is moderate structural complexity in the Upper Cretaceous units that is associated with the northeastern continuation of the Hogback Monocline. Thermal alteration in this area has locally upgraded coal seams to coking quality.

The Durango and Pagosa Springs Fields have been separated in some previous reports, but the difference is inconsequential in the context of this report.

2.2.3.2 Tongue Mesa Field

The Tongue Mesa Field occupies the northeastern corner of the San Juan River Region. Here, late Cretaceous and Tertiary volcanic rocks cap underlying coal-bearing Cretaceous units. Erosion has stripped away surrounding rocks, leaving the remnant high topography of Cimarron Ridge.

The coals in the Tongue Mesa Field are found on Cimarron Ridge in a 900-foot thick sequence correlative with the Kirtland/Fruitland/Pictured Cliffs Formations in the San Juan Basin to the south. Four coal seams are present. The largest—the Cimarron/Lou Creek—is 40 feet thick, in the lower Fruitland Formation.

2.2.3.3 Nucla-Naturita Field

The surficial geology of the western part of the San Juan River Region is dominated by modestly deformed Cretaceous sediments that have been extensively eroded and dissected along combinations of joints, salt dome collapse features, and Laramide faults. As a result, the landscape comprises complex topography of steep-sided mesas and narrow valleys, and coal-bearing units are absent in most places. Nevertheless, three seams in the Dakota Sandstone are locally persistent. Though thin (3-5 feet), these seams have been widely mined.

2.2.4 North Park Coal Field

The North Park Coal Field is situated in a high, intermontane basin in a Laramide syncline bounded by the Medicine Bow/Front Range Uplift to the east, the Rabbit Ears Volcanic Field on the south and southwest and the Park Range Uplift on the west. The coal beds in the North Park Coal Field occur in the late Paleocene to early Eocene age Coalmont Formation. The formation consists of terrigenous clastics, carbonaceous shales, and coals. The Coalmont Formation strikes west of north and dips 10 to 25 degrees to the northwest. Most of the productive seams, however, are found in local areas of structural complexity: dips often exceed 45 degrees, seams are often faulted and lenticular, and the coal is often upgraded by this tectonothermal history. Structurally, the area is dominated by a series of northwest trending normal faults associated with the downward warping of the basin (Rushworth, 1989), though secondary anticlinal structures are also present. In particular, the prominent Marr strip mine is located on the eastern flank of the McCallum Anticline.

2.2.5 South Park Coal Field

The South Park Coal Field is also located in an intermontane valley. The topographic valley reflects a large-scale synclinal structure bounded by the Mosquito Range to the west and the Front/Rampart Range to the east. The primary coal-bearing unit is the Upper Cretaceous Laramie Formation, which consists primarily of fine- to medium-grained sandstones and silty clays. The coal beds were deposited in a delta plain in swampy environment and are thickest in the lower portion of the unit, though thinner beds are found in the middle and upper portions as well.

The Laramie and other Paleozoic and Mesozoic units are exposed by myriad west-vergent, east-dipping thrust slices along the western half of the basin of Laramide age (Sterne, 2006). Coal seams outcrop in the northern portion of South Park around the flanks of the Michigan Syncline. In the northwestern part of the topographic and structural basin, the Laramie Formation dips steeply eastward, as much as 45 degrees, and was mined extensively in the latter third of the 19th century. No mines are currently active, however.

2.2.6 Raton Mesa Coal Region

The asymmetrical Raton structural basin is home to the Raton Mesa Coal Region. The axis of the basin is located near its western edge, close to the Sangre de Cristo and Culebra ranges, and plunges southward. Attendant to this structure, formations dip gently westward on the eastern edge of the basin—near I-25—and steeply eastward or are locally overturned near the mountain front. The basin formed as a result of Laramide thrust faulting of the Sangres and Culebras, but was subsequently intruded by the mid-Tertiary Spanish Peaks. Mainly radial dikes associated with these intrusions, as well as cogenetic high heat flow, have baked and in some places coked coal in the central portion of the Raton Basin. Coal appears in the Upper Cretaceous Vermejo shale and sandstone and the middle and upper members of the Paleocene/Cretaceous Raton Formation. The Raton Formation comprises a basal sandstone/conglomerate that unconformably overlies the Vermejo, a middle coal-bearing sandstone/shale/mudstone, and a sedimentologically similar upper coal-bearing member.

Raton Mesa has produced the most coal of any region in Colorado, approximately 31% of the statewide total. The majority of this coal has been mined on the east side of the basin from the lower portion of the Vermejo Formation (Tremain et al., 1990).

2.2.7 Cañon City Coal Field

The Laramide Cañon City structural basin is home to the Cañon City Coal Field, located in the southwest portion of the Denver Basin. The field itself is in a structural embayment bounded on the north by the Front Range Uplift, on the west and southwest by the Wet Mountains Uplift, and on the south by Apishapa Uplift. The Apishapa Uplift caused the removal of the coal-bearing sequences that were once continuous between Cañon City and Raton Basins (Murray, 1982).

Stratigraphically, the Cañon City Region is more similar to the Raton Basin than the Denver Basin. Late Cretaceous-age Vermejo Formation is the only coal-bearing sequence in the Cañon City Coal Field. The sequence is comprised of coals, claystones, siltstones, and sandstones deposited in delta plain settings. The coal beds formed parallel to major fluvial channels, with intermittent splays (Billingsley, 1978).

2.2.8 Denver Coal Region

The Denver Coal Region lies within the Denver structural basin, which was formed during the Laramide Orogeny. The basin is bounded on the south by Apishapa Uplift, the north by Wyoming, on the east by the Las Animas Arch, and on the west by the Front Range/Rampart Range Uplift. The synclinal axis is near the west edge of the basin (Rushworth et al., 1989). The Denver Basin is structurally complex. Two main sub-basins, Denver in the south and Cheyenne in the north, are separated by the Greeley Arch. These basins are further complicated by mainly northeast-trending grabens and half-grabens. Mining has occurred largely in graben areas where coal is thicker, generally five to ten feet and locally up to twenty feet (Weimer, 1977).

The important coal-bearing interval of the Denver Region is the Upper Cretaceous Laramie Formation, which consists primarily of fine- to medium-grained sandstones and silty clays. The Laramie Formation is nearly vertical near the western part of the region, but the dip decreases rapidly to the east. The coal beds were deposited in a delta plain in swampy environment and are found in the lower portion of the formation in a zone 50 to 275 feet thick. Individual seams are typically lenticular and are more abundant in the Denver than Cheyenne sub-basin (5-10 and up to 20 feet thick versus 3-7 feet).

In the Denver sub-basin only, the Laramie is overlain by the Denver Formation, an arkosic sandstone derived from the rising Rocky Mountains. Multiple local beds of coal occur in the central portion of the basin in the Denver Formation, likely reflecting two episodic Paleocene swamps (north and south) amid the alluvial plain draining the growing mountains to the west. The northern deposits are more abundant than the southern (10-30 and up to 50 feet thick versus 5-10 and up to 30 feet).

The earliest developed, the Denver Region was dominated by shaft rather than stope or drift mining. Shafts are or were typically 250-500 feet deep. Additionally, approximately the eastern half of the Laramie coals and almost all of the Denver Formation seams are within 200 feet of the surface, making them potential targets for surface mining.

2.3 Fires

The details of this report describe the current conditions of both active and dormant fires at abandoned coal mines in Colorado. In 2018, 38 active or dormant coal mine fires were documented in the state inventory. Additional, unknown, coal mine fires and outcrop fires are likely to exist.

Fires in this report are classified into one or more of four categories defined by Renner (2005): active fire, dormant fire, refuse pile fire and, outcrop fire, as described below:

1) **Active fire** describes a site at which the combustion of coal is causing measurable heating of the ground surface above ambient ground temperatures. Active fire sites also typically have vents on the ground surface producing exhaust.

2) **Dormant fire** sites are described as sites that were noted as active in previous reports, but at the time of the 2017-2018 site visits conducted by Tetra Tech and DRMS, no significant anomalies were measured at the surface or in previously installed borehole thermocouples. Underground coal combustion may still be present at these sites, but at the time of the inventory no data confirm the fire is active.

3) **Refuse pile fires** are related to the stockpiling and storage of coal refuse or coal waste material. Typically, these sites burn through oxidation, which occurs if introduction of oxygen to crushed coal causes heating, sometimes to the point of combustion.

4) **Outcrop fire** refers to the burning of unmined in-situ coal by means of oxidation or natural ignition (lightning strike, wildfire, etc.).

Coal mine fires described in this report are organized by county, and the fire locations across the state are summarized on Table 2-1 and shown on Figure 2-2.

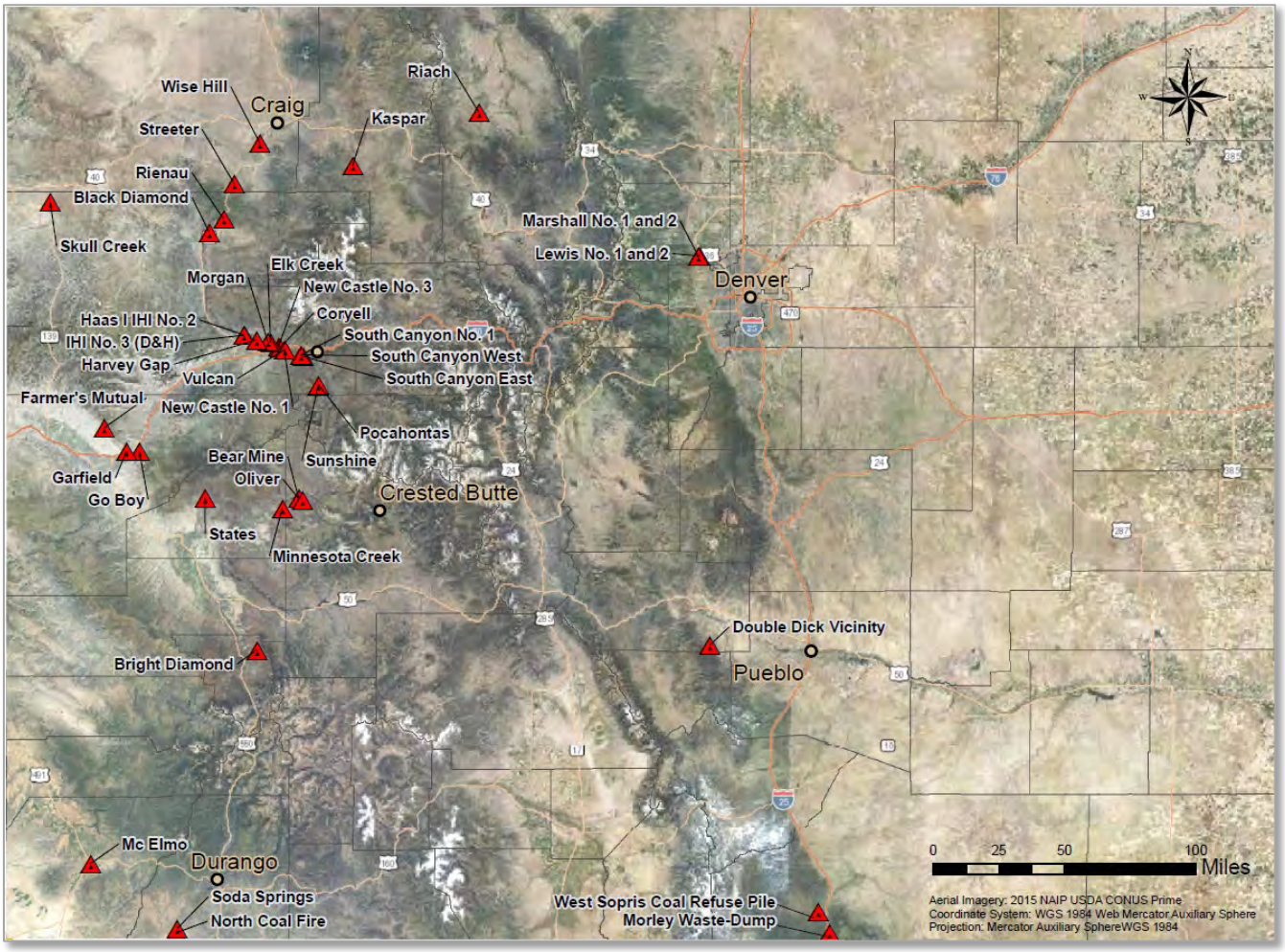


Figure 2-2 – Colorado Coal Mine Fire Locations

Table 2-1 – Mine Fire Information

County	Fire Name	Latitude (N)	Longitude (W)	Coal Field	Activity
Boulder	Lewis No. 1 and 2	39°57'23.04"	105°13'20.28"	Boulder-Weld	Very Low
	Marshall No. 1 and 2	39°57'16.92"	105°13'45.84"	Boulder-Weld	Very Low
Delta	Davis	38°55'49.41"	107°58'21.45"	Grand Mesa	Very Low
	Minnesota Creek	38°52'54.12"	107°31'23.88"	Somerset	Low
	States	38°55'33.96"	107°56'57.12"	Grand Mesa	Low
Fremont	Double Dick (vicinity)	38°17'26.88"	105°10'0.84"	Cañon City	Low
Garfield	Coryell	39°34'3.41"	107°31'58.47"	Grand Hogback	Low
	Elk Creek	39°35'22.11"	107°35'22.30"	Grand Hogback	High
	Gem	39°32'31.32"	107°26'2.04"	Grand Hogback	Moderate
	Haas / IHI No. 2	39°37'10.20"	107°43'54.48"	Grand Hogback	Low
	Harvey Gap	39°36'3.96"	107°39'54.36"	Grand Hogback	Moderate
	IHI No. 3 (D&H)	39°37'14.16"	107°44'6.00"	Grand Hogback	High
	Morgan	39°35'38.40"	107°36'12.24"	Grand Hogback	Moderate
	New Castle Number 1	39°33'39.60"	107°30'44.28"	Grand Hogback	Low
	New Castle Number 3	39°34'23.52"	107°32'37.68"	Grand Hogback	Moderate
	Pocahontas	39°24'41.60"	107°19'23.17"	Grand Hogback	Very Low
	South Canyon East	39°31'55.58"	107°24'49.02"	Grand Hogback	Very High
	South Canyon West	39°32'12.78"	107°25'20.84"	Grand Hogback	Very High
	Sunshine	39°24'6.02"	107°19'33.65"	Grand Hogback	High
	Vulcan	39°33'31.48"	107°29'59.85"	Grand Hogback	Moderate
Gunnison	Bear	40°25'44.31"	107°38'47.69"	Somerset	Low
	Oliver	38°55'28.40"	107°25'54.20"	Somerset	Low
Jackson	Riach	40°33'37.44"	106°26'22.56"	Coalmont	Low
Las Animas	Morley Refuse Pile	37°2'3.84"	104°30'27.00"	Trinidad	Very Low
	West Sopris Refuse Pile	37°7'45.66"	104°34'6.87"	Trinidad	Low
La Plata	North Coal Fire	37°2'8.88"	108°6'27.72"	Durango	Moderate
	Soda Springs	37°3'17.95"	108°5'44.83"	Durango	Low
Mesa	Farmer's Mutual	39°13'26.48"	108°30'18.70"	Book Cliffs	Very Low
	Garfield	39° 7'37.92"	108°22'52.68"	Book Cliffs	Very Low
	Go Boy	39° 7'33.24"	108°18'39.60"	Book Cliffs	Very Low
Moffat	Axial	40°15'45.00"	107°47'25.08"	Danforth	High
	Wise Hill Number 3	40°25'44.31"	107°38'47.69"	Yampa	Low
Montezuma	McElmo	37°20'18.96"	108°34'49.08"	Nucla-Naturita	Very Low
Ouray	Slagle / Bright Diamond	38°16'14.16"	107°39'43.92"	Tongue Mesa	Low
Rio Blanco	Black Diamond	40°3'26.43"	107°55'33.98"	Danforth	Moderate
	Rienau Number 2	40°6'43.21"	107°50'47.24"	Danforth	Moderate
	Skull Creek	40°11'4.92"	108°48'10.08"	Lower White River	Very Low
Routt	Kaspar	40°20'16.83"	107° 8'5.91"	Yampa	High

3. INVENTORY METHODS

3.1 Site Visits

Tetra Tech began the statewide Mine Fire Inventory project in October 2017 and completed visits to 38 coal fire sites by November 2018. Data collected during the site visits included: thermal imagery; spot temperature readings; exhaust gas composition readings; ground-based photography (when possible, site visits were coordinated to take advantage of snowfall and cold temperatures for thermal imaging and snowmelt photographs); and UAS imagery including aerial photos, thermal, and elevation data. This new data was integrated with existing site information to rank and prioritize coal mine fire sites across Colorado.

3.2 Safety

Because of remote and rugged terrain and often hazardous site features, the "buddy system," or minimum two-person team, was employed during site inspection activities. Each member wore standard field protective gear (hiking or steel-toed boots, high-visibility vests, hard hat when appropriate, and sun protection).

UAS drone flights were used to inspect hazardous site features while the team remained in a safe area. Known vents were approached from the upwind side. Ground temperatures around vents were checked using a laser infrared thermometer or FLIR thermal camera to insure a safe working area.

Inspection teams carried personal four-gas meters to monitor for concentrations of oxygen (O_2), methane (CH_4), hydrogen sulfide (H_2S), and carbon monoxide (CO). The personal four-gas air monitor is worn at or above chest level while working at the fire site. If the monitor's alarm sounds, the area is evacuated in the upwind direction until safe atmosphere is reached and the alarm turns off. Table 3-1 provides the alarm levels of the personal four-gas monitoring.

Table 3-1 – BW Honeywell GasAlert XL Factory Alarm Settings

	FACTORY ALARM SETTINGS			
	O_2	LEL	H_2S	CO
Alarm	% Vol	% LEL	PPM	PPM
Low	19.50	10.00	10	35
High	23.50	20.00	15	200
TWA	NA	NA	10	35
STEL	NA	NA	15	50

3.3 Mine Fire Emissions Monitoring

Tetra Tech quantified mine fire emissions by measuring gas concentrations at and calculating the flowrates of vents. The equipment used to measure the gas concentrations were the Landtec GEM 5000 landfill gas monitor and the Testo 350 combustion gas monitor. Table 3-2 presents the analysis capabilities of this equipment. Flowrates from the vents were determined by measuring the air speed using a Kestrel 1000 flowmeter and multiplying this speed by the cross-sectional area of the vent. The concentration data and flowrates were used to calculate annual emission rates in tons/year.

Table 3-2 – Emissions Analysis Equipment

Equipment	Measurement Parameter								
	CH_4	CO	CO_2	O_2	H_2S	SO_2	NO	NO_2	Gas Temperature
Landtec GEM 5000	X	X	X	X	X				
TESTO 350 XL		X	X	X		X	X	X	X

Vent cross-sectional area and velocity can be difficult to determine because of high gas temperatures and diffuse, complex fracture venting. In some cases, vents were inaccessible for monitoring because of unsafe ground conditions and toxic atmospheres. Because of these limitations, emissions from these areas of the mine fire are estimated in the field by analyzing gas concentrations of vents in the area to use as representative vent emissions and estimating the total cross-sectional area and average velocity of vents in the region. Although imperfect, this approach allows for the estimation of emissions for regions of the mine fire that otherwise could not be measured safely.

3.4 Infrared Temperature Monitoring & Thermal Imaging

Surface temperature measurements and mapping are key components of coal mine fire site inventories. Tetra Tech utilized a variety of handheld infrared thermometers and thermal imaging cameras to accurately characterize exhaust vent temperatures and the overall extents of heat at the surface. These instruments are also key components of the health and safety program, allowing field technicians the ability to identify and monitor hotspots near working areas.

3.5 Aerial Imaging

UAS drone data were a key element of the coal mine fire inventory project and provide a cost-effective and repeatable method for rapid evaluation of coal mine fire sites. Mission planning and management were essential components of the data acquisition at the various coal mine fire sites. UAS use dramatically reduced the time spent collecting ground survey data for large or hazardous areas, and the survey team was able to gather key data from safe locations.

3.5.1 Photogrammetry

In support of the inventory effort, Tetra Tech developed a drone program to add value to the types of data acquired for an inventory report. Photogrammetry provides survey-level measurements from a collection of georeferenced airborne photographs. The use of drone-based photogrammetry allows for near real-time assessment of a site and requires a low level of pre-survey work, making it an excellent tool for these remote sites. By establishing a baseline dataset for each site with aerial-based photogrammetry, Tetra Tech has provided the State with the ability to measure changes over time. The detailed maps generated by photogrammetry provide a metric for long-term monitoring of vegetation, erosion, deformation or subsidence, and risk management or encroachment. Tetra Tech suggests the following uses of this baseline drone data:

- Monitoring subsidence features over time
- Hi-resolution drone mapping and comparative analysis
- Surface feature mapping and measurements

Repeating site visits over time and repeating such analysis would provide a quantitative measure of fire progression and impact.

3.5.2 Aerial Thermal Photography

Thermal photography provides valuable insight into the measurable level of heat at the surface of a given site. By implementing this technology into the UAS program, Tetra Tech acquired more complete imagery than ground-based thermal surveys and provided more repeatable information at each mine fire site. Tetra Tech deployed the FLIR® DUO R thermal camera on the drone-based platform to coincide with the gimbal-regulated aerial photography. The dual-sensor FLIR® camera collects both thermal and visible light simultaneously, allowing for accurate positioning of the thermal data over a map of the site. Aerial temperature measurements can then be confirmed on the ground with IR thermometers. During the entire inventory project, Tetra Tech observed strong correlation between temperature data gathered with the drone and ground observations, validating the use of drone-based thermal photography for rapid assessment of large or hazardous areas.

3.5.3 Geomorphic Analysis

Tetra Tech uses photogrammetry and LiDAR based UAS systems to develop 3D models and contours of Abandoned Mine Lands sites. These 3D models allow engineers and scientists to evaluate the site for erosion and subsidence features and estimate quantities required for repair and maintenance. Collecting thermal imagery allows Tetra Tech to find vents and warm ground associated with underground coal mine fires far more efficiently and accurately than a typical site inspection alone. This survey then directs a targeted site inspection and helps delineate the fire expression area. High-resolution aerial imagery provides a point-in-time reference to allow for the tracking of reclamation performance.

4. 2018 COLORADO COAL MINE FIRE INVENTORY SITE SUMMARIES

During the 2017-2018 Inventory field investigations 38 coal mine fire sites were visited to document current site conditions. The mine fire sites and their location information are summarized on Table 2-1 and shown on Figure 2-2.

4.1 Boulder County

There are two known coal mine fires in Boulder County, Colorado. The Marshall and Lewis fires are in the southwestern part of Boulder County in an area with numerous abandoned underground coal mines in coal seams of the Upper Cretaceous Laramie Formation. The fire intensity at both locations has been observed to fluctuate over time as the fires burn, subsurface conditions change, and subsidence occurs. In 2018, the fires had very low activity and posed minimal risk.

4.1.1 Lewis Mine

Figure 4-1 – Lewis Mine Fire Looking North

FIRE ACTIVITY

Very Low

FIRE HAZARD RANKING

23 of 38

LOCATION

Latitude: 39°57'23.04"

Longitude: 105°13'20.28"

Nearest Town: Boulder, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Boulder-Weld

Seam: Unnamed

Strike and Dip: N45E & 4°

Mining Method: Drift

Years of Operation: 1914-1946

Production: 164,064 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Fissure mapping
- Snowmelt mapping
- Coal outcrop mapping
- Mine maps

2018 – Inventory
- Snowmelt Pictures
- 3D surface mapping
- Orthophotography
- Aerial thermal mapping

FIRE DESCRIPTION

The Lewis mine fire site is located approximately 1 mile south of Boulder, CO on the northeast corner of the intersection of Marshall Road and Cherryvale Road. The mine fire is located on private and public property and accessed with permission of the landowner. The Lewis mine was a small production mine operating from 1914 to 1946. Evidence of the mine is apparent at the surface, with numerous north-south orientated subsidence features up to six feet deep. The subsidence features are related to the initial mining of a shallow coal seam, the small overburden thickness, and fractured nature of the roof material of the mine.

In October 2003, it was reported that the fire showed very little activity; there was only one active vent, which had air temperatures 30 degrees above normal ground temperatures (Renner, 2005). By 2013, no vents were observed and only a small, 5ft x 10ft, patch of bare ground near the coal seam outcrop did not hold snow after a storm. During the 2013 inventory the fire was observed to be in a dormant state (Koveva Ltd, 2013).

FIRE OBSERVATIONS

The fire was visited on February 8, 2018 to collect aerial orthophotography and thermal images, 3D surface mapping, and analyze potential fire risks. No venting or elevated surface temperatures were observed at this time. Aerial thermal images showed substantial subsidence has occurred around and under a concrete aqueduct. A cavity approximately 3ft tall, 10ft wide, and 30ft long has developed underneath the concrete aqueduct (Figure 4-1). This is not believed to be related to the fire.

On February 12, 2018, the site was revisited to collect snowmelt pictures. One vent (Figure 4-2) was found at 39° 57' 31.93", 105° 13' 10.49". The gas temperature was slightly above ambient. The landowner mentioned that he has observed steam and snowmelt in the winter time in an area south of the lined irrigation ditch, but that area was not active at the time of this inventory.

Figure 4-2 – Lewis Mine Fire Vent

FIRE RISK AND RECOMMENDATIONS

The fire's activity is very low and thus presents little public safety risk or potential to start a surface fire. While part of the fire is on City of Boulder Open Space, the parcel sees limited activity in the vicinity of the fire. No fire abatement work is recommended for the Lewis fire because of this low potential risk.

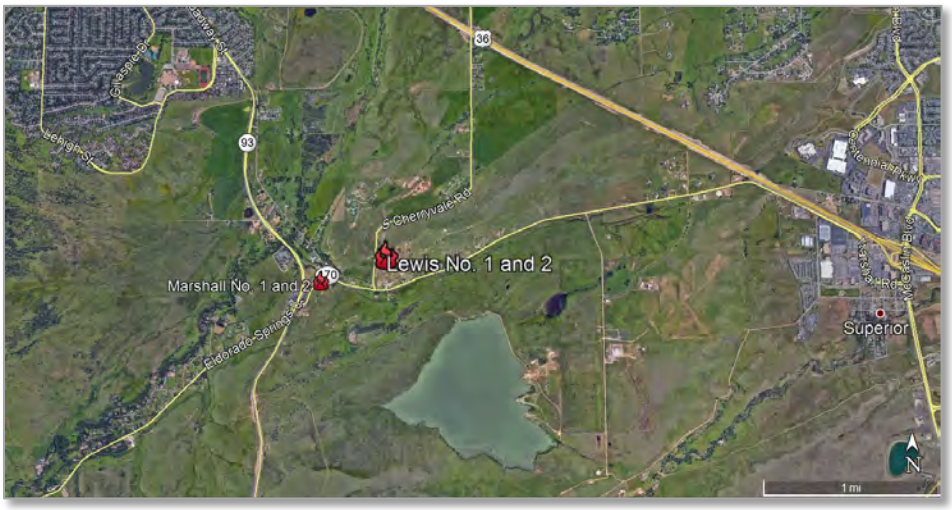


Figure 4-3 – Lewis Mine Fire Location Map

DIRECTIONS TO FIRE

From Boulder, CO, take Hwy 93 south to Marshall Rd and turn left (east). Stay on Marshall Rd for 0.5 miles, then turn left (north) onto Cherryvale. Fire is on the right (east) side of the road.

4.1.2 Marshall Mine

Figure 4-4 – Marshall Mine Fire Looking South

FIRE ACTIVITY

Very Low

FIRE HAZARD RANKING

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LOCATION

Latitude: 39°57'16.92"

Longitude: 105°13'45.84"

Nearest Town: Boulder, Colorado.

Landowner: Public

MINE INFORMATION

Coal Field: Boulder-Weld

Seam: Unnamed

Strike and Dip: N45E & 4°

Mining Method: Drift

Years of Operation: 1863-1939

Production: Unknown

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Fissure mapping
- Snowmelt mapping
- Coal outcrop mapping
- Mine maps

2018 – Inventory
- Snowmelt Pictures
- Surface Feature Mapping

FIRE DESCRIPTION

The Marshall mine fire site is located approximately 1 mile south of Boulder, CO on the southeast corner of the intersection of Hwy 93 and Marshall Road. The mine fire is located on City of Boulder Open Space.

In October 2003, it was reported that the fire was moderately active with ground temperatures ranging from 118°F to 130°F. The smell of coal combustion was noted near the venting fractures (Renner, 2005).

In February 2005, a recently constructed building was inspected for damage caused by subsidence believed to be related to the Marshall Coal Mine. Vents and subsidence features were identified under and around the building (Amundson, 2005).

On December 20, 2005, a brush fire was started by a hot vent from the Marshall Coal Mine Fire. The fire was quickly contained and extinguished. The origin of the fire was traced back to a 373°F vent. In January 2006, fire abatement was undertaken by the Office of Surface Mining to fill in vents with small rock material to reduce the potential of starting another surface fire. 275 tons of unwashed aggregate was placed over the vent area to a total depth of 18 inches (Blackburn, 2006).

In 2016, two areas of trough subsidence were excavated, compacted, and backfilled to natural grade. Both areas, shown on Figure 4-4, were in areas where surface expression of the mine fire had been observed. During the subsidence mitigation work, a few small vents were uncovered in both locations. In all cases, the exhaust was warm, moist air with temperature less than 90°F. No new evidence of subsidence or other indicators of the coal mine fire were observed during the completion of the remedial activities. Gas monitoring during construction did not detect gases associated with coal combustion over the background levels.

FIRE OBSERVATIONS

The fire was visited October 2018 after one inch of snow fell the previous night. The fire area was inspected, and no signs of fire features or snowmelt were observed. Additionally, no coal combustion odors were noted during the site visit. The area was not imaged with a UAS due to City of Boulder Open Space restrictions. Drone perspective photographs were collected from outside the property boundary.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is very low and thus presents little potential to start a surface fire. Although the fire is on City of Boulder Open Space and near the Marshall Mesa parking lot, the off-trail fire area sees little foot traffic, and there are no dangerous surface features. The fire poses limited risk to public safety.

No abatement is recommended. This fire has behaved erratically in the past, so it is recommended that it be monitored annually to check for increases in fire activity.

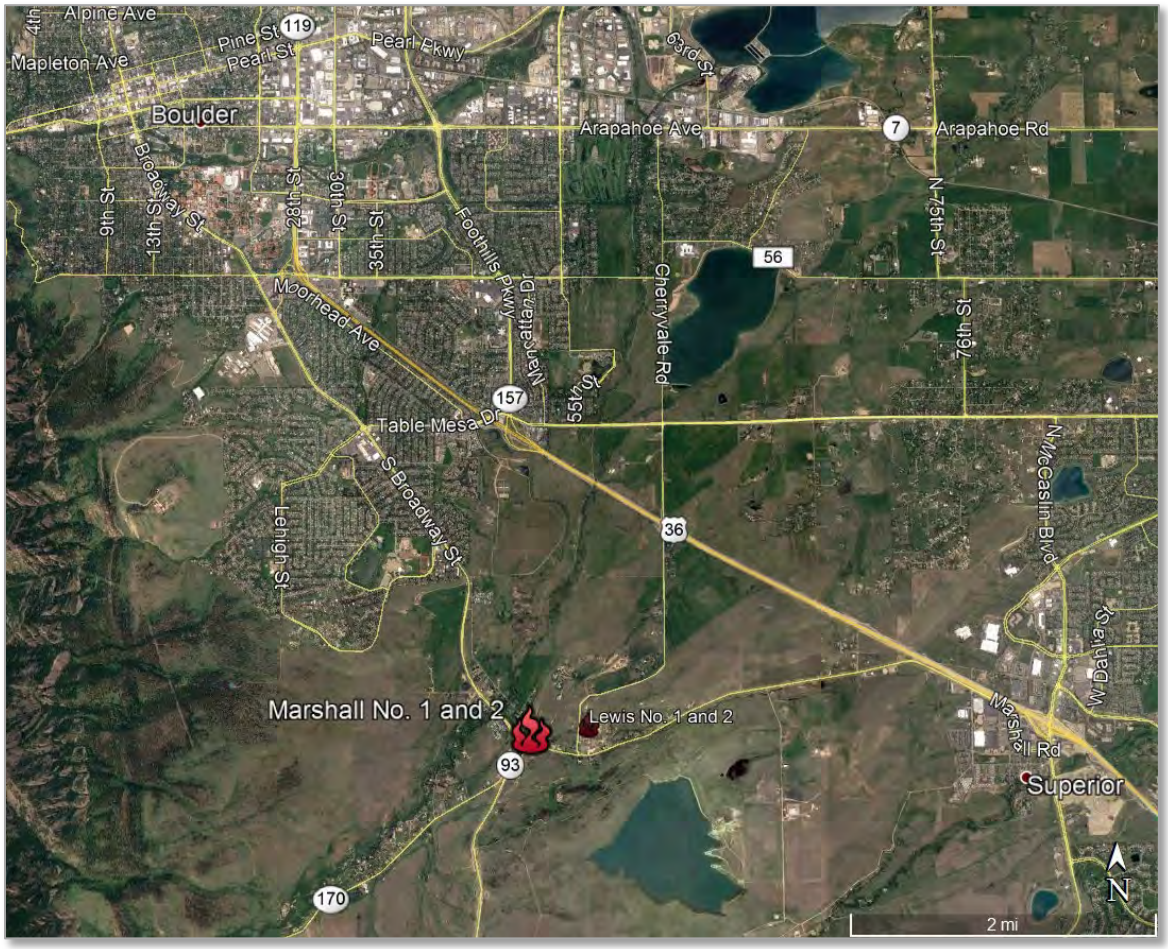

Figure 4-5 – Marshall Mine Fire Location Map

DIRECTIONS TO FIRE

From Boulder, CO, take Hwy 93 south to Marshall Rd and turn left (east). Take the immediate right (south) into the Marshall Mesa Open Space parking lot. The fire is to the northeast of the main parking lot.

4.2 Delta County

Delta County, Colorado is home to three known coal mine fire sites: the Davis, Minnesota Creek, and States coal mine fires. All three fires had very low or no observed fire activity during the 2018 Coal Mine Fire Inventory site visits. The risk presented by these fires is rated as low, although periodic monitoring is warranted.

Figure 4-6 – Delta County Coal Mine Fire Location Map

4.2.1 Davis Mine

Figure 4-7 – Davis Mine Fire Looking Northwest

FIRE ACTIVITY

Very Low

FIRE HAZARD RANKING

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LOCATION

Latitude: 38°55' 49.41"

Longitude: 107°58' 21.45"

Nearest Town: Cedaredge, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Mesa

Formation/Seam: MesaVerde/ NA.

Strike and Dip: NA

Mining Method: Drift

Years of Operation: NA

Production: NA

DATA COLLECTION

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Aerial Imagery

FIRE DESCRIPTION

Figure 4-8 – Vent Pipe

The Davis Mine fire site is located 3.2 miles northwest of Cedaredge, CO and lies in the Grand Mesa coal field. It is a new fire to the inventory and is an unusual fire in that it is beneath a house, built directly above the mine entrance. The original owner of the house had planned to heat the house with a coal-fired boiler—which was inside the mine workings—with coal from the mine. A one-foot diameter vent pipe from the boiler system installed in the mine workings is set alongside the house (Figure 4-8). The inside of the mine can be seen through a hole immediately adjacent to the vent pipe. The fire was believed to be limited to an area at the entrance to the mine workings. Recently, DRMS backfilled the two mine entrances to reduce air flow to the fire and to allow water to build up inside the mine and quench the fire (Tafi, 2018).

The history of the Davis Mine is unknown. Anecdotal information from the current landowner places the operation around the 1900s and 1910s. Two drifts extend in along the seam. There was one shaft approximately 600 ft from the mine entrance that accessed a second, overlying seam.

FIRE OBSERVATIONS

The Davis Mine Fire was visited on November 19, 2018 to inspect the site for fire activity and collect aerial imagery. During the site inspection no fire activity or coal combustion gases were observed. A temperature

reading taken through the vent pipe hole of the mine workings was 56°F. No air movement could be detected in or out of the vent pipe hole. Water was present outside of the backfilled mine entries but was not flowing.

On November 20, 2018 the site was flown to collect thermal imagery. Ambient temperature was 21°F. There were three areas of elevated temperature: one was the vent pipe hole and the other two were the outcrop directly above the mine entries. The vent pipe hole was at 54°F and the outcrops were 45°F. These temperatures are typical for underground coal mine workings.

FIRE RISK AND RECOMMENDATIONS

The Davis Mine Fire activity is very low, and no substantially elevated temperatures or combustion gases were observed. The risk of wildfire is low because of the lack of active vents. The risk to the public is low because the fire is located on private property and no active fire expressions were found.

It is recommended that the fire be investigated further to determine if it is extinguished. It is recommended that more permanent closures of the mine entries be constructed.

Figure 4-9 – Davis Mine Fire Location Map

DIRECTIONS TO FIRE

The States Mine Fire is located northwest of Cedaredge, CO at the intersection of Ward Creek Rd and 2085 Ln. Take Main St west out of Cedaredge. At 1.9 miles, take the sharp right to stay on R Rd. At 2.9 miles, R Rd becomes Ward Creek Rd. At 4.5 miles, turn right (east) onto 2085 lane and fire will be on the left (north).

4.2.2 Minnesota Creek Mine

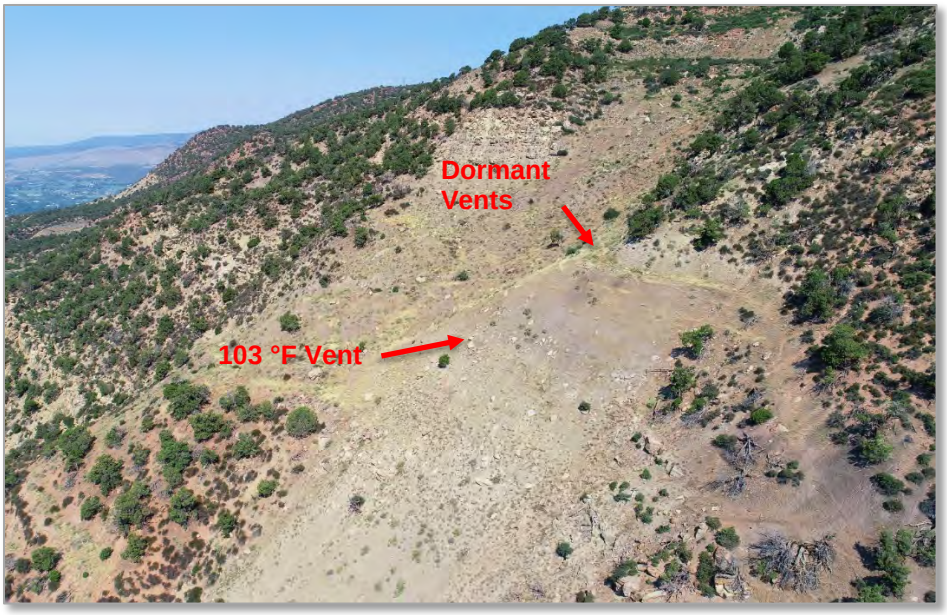

Figure 4-10 – Minnesota Creek Fire Looking West

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

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LOCATION

Latitude: 38°52' 54.12"

Longitude: 107°31' 23.88"

Nearest Town: Paonia, Colorado.

Landowner: Public, BLM

MINE INFORMATION

Coal Field: Somerset

Formation/Seam: Mesa Verde/ NA.

Strike and Dip: NA

Mining Method: Drift

Years of Operation: 1934-1936

Production: NA

DATA COLLECTION

2005 – Inventory

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Site inspection.

FIRE DESCRIPTION

The Minnesota Creek Fire is located 4 miles east of Paonia, CO on the south side of Jumbo Mountain. The site is accessed from Minnesota Creek Road through private property, with permission of the landowner, along the original mine road. The mine was operated for a brief period from 1934 to 1936. One entry was driven 120 ft along the coal bed from the outcrop. Coal was reported by the operator as 41 inches thick. The fire was first reported in 1937 by a landowner on Minnesota Creek. He stated that he initially thought mine workings had caught fire, but that he found the fire to be in an outcrop higher up the hillside and farther to the west of the mine. The fire was found to be 200 feet stratigraphically above the mine workings. The coal fire encompassed an area of 300 feet in diameter and was burning in two seams both approximately 5 ft thick. In 1961, a surface sealing operation was undertaken to smother the fire. Trees within 50 feet of the edge of the fire were removed, the outcrop was excavated, and an earthen cover was constructed over the fire to reduce airflow (Jolley, 1961).

FIRE OBSERVATIONS

The Minnesota Creek Fire was visited by Tetra Tech on July 31, 2018 to inspect the site for fire activity and collect aerial and thermal imagery. Two drone surveys were flown from a clearing below the fire to generate a 3D surface and thermal imagery for the site. The ground surface at Minnesota Creek site had an average ambient temperature of approximately 80°F during the site visit. The earthen cover area was thoroughly inspected for intakes, exhaust vents, and any other failures or deformation. Gas from the combustion of coal was detected near a small vent on the

Figure 4-11 – Small Vent

south side of the cover area (Figure 4-11). The vent measured four inches by six inches and had a temperature of 103°F. Gas readings from the vent showed elevated levels of CO, low H_2S, low oxygen, and no methane. A dormant vent with no elevated temperature or gas readings was found on the upper bench on the north end of surface seal. The vent locations are shown in Figure 4-10.

Revegetation of the surface seal at the Minnesota Creek site has progressed slowly. The surface seal area has a cover of sparse weeds and annual grasses. The center of the cover area near where the coal seam outcrops has notably less vegetation. This could reflect poor soil, the southwesterly aspect, or elevated ground temperature due to fire. High ambient air and ground surface temperatures during the site visit prevented the thermal aerial photography from capturing any elevated temperatures over the site including over the vent.

FIRE RISK AND RECOMMENDATIONS

The Minnesota Creek Fire activity is low relative to other Colorado sites, with only one low-temperature vent located on site. This vent is not located near considerable vegetation and the exhaust temperatures are low; consequently, there is not a significant risk of wildfire. The risk to the public is low because of the remote location of the coal fire and the lack of hazardous fire features.

Snowmelt imagery could help with mapping the extents of the fire activity on site and Tetra Tech recommends that aerial thermal imagery be collected in the winter months. No other mitigation action is recommended at this time.

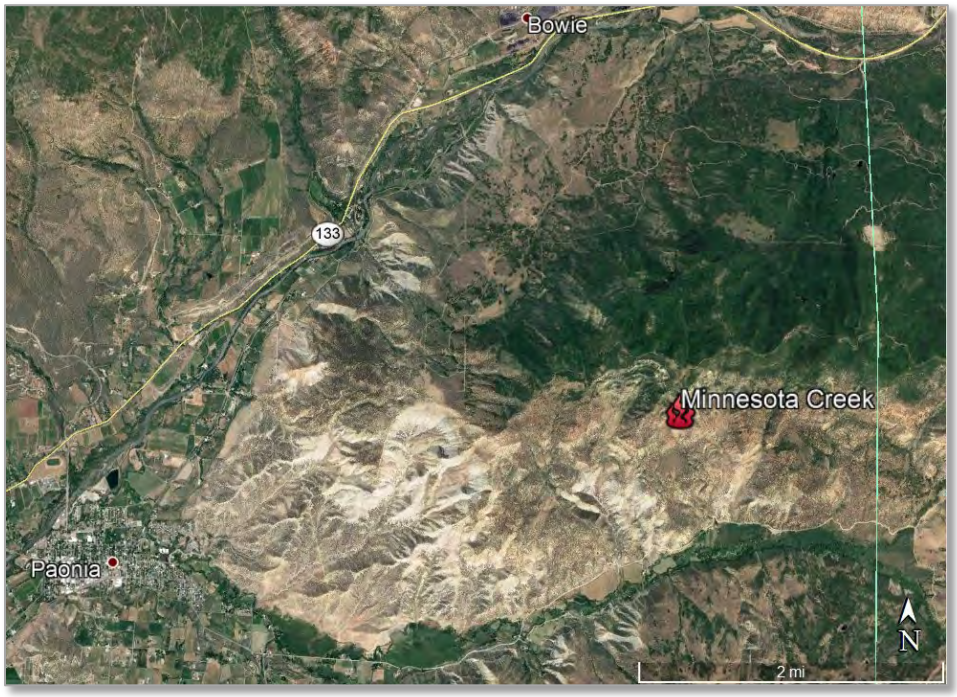

Figure 4-12 – Minnesota Creek Fire Location Map

DIRECTIONS TO FIRE

The Minnesota Creek Fire is located east of Paonia, CO north of 44888 Minnesota Creek Rd, Paonia, CO 81428. From Paonia, CO, take 3rd Street West to Colorado Ave and turn south (right). Colorado Ave turns into Minnesota Creek Road after 0.5 miles. Continue Minnesota Creek Road for 4.2 miles and park on the north (left) side of the road near the trailer home. Landowner's house is on south side of road and fire is 0.75 miles north on mountainside. Road to fire site starts behind the trailer home.

4.2.3 States Mine

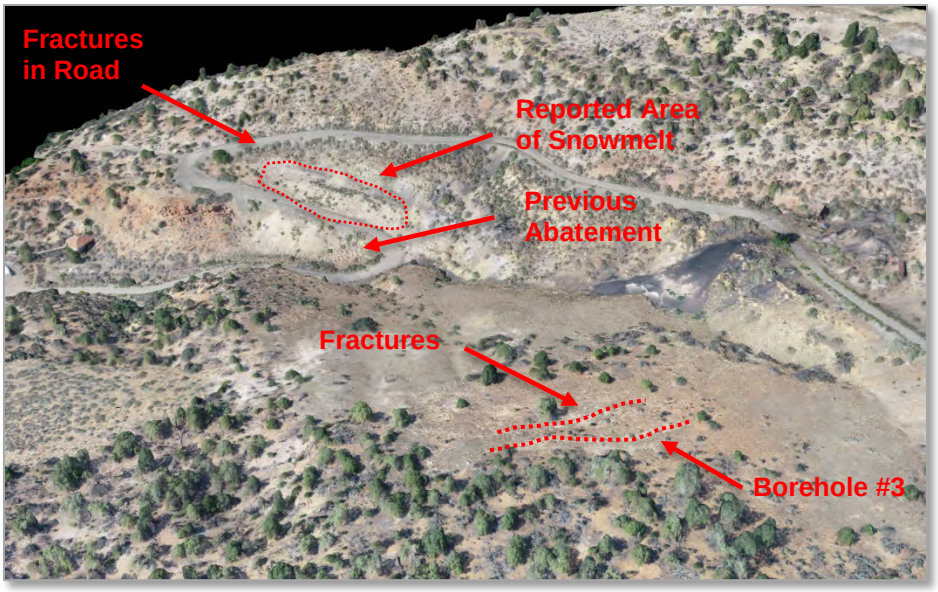

Figure 4-13 – 3D Model of States Mine Looking North

FIRE DESCRIPTION

The States Mine fire site is located 2.3 miles northwest of Cedaredge, CO and lies on the southern edge of Grand Mesa in the Uinta Coal Region. The current landowner is the grandson of the original homesteader and mine owner. The landowner said the mine was operated until December of 1952 by a contract operator. Loose coal was being stockpiled underground inside the mine workings and spontaneously combusted, igniting the fire and ultimately forcing the closure of the mine.

An effort to control the fire was undertaken in 1988 by placing material on vents emitting noxious odors that were bothering the landowners (Rushworth, 1989). In 1997, the Division of Minerals and Geology drilled seven boreholes and installed thermocouples to monitor coal fire activity at the site (Renner, 2005).

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

28 of 38

LOCATION

Latitude: 38°55' 49.41"

Longitude: 107°58' 21.45"

Nearest Town: Cedaredge, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Mesa

Formation/Seam: Mesa Verde/ NA.

Strike and Dip: N 36W & 6

Mining Method: Drift

Years of Operation: 1914-1951

Production: 101,660 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Snowmelt mapping

2018 – Inventory
- Thermal mapping
- 3D mapping
- Aerial imagery

Figure 4-14 – Dormant Fractures

FIRE OBSERVATIONS

The States Mine Fire was visited by Tetra Tech on July 30, 2018 to inspect the site for fire activity and collect aerial and thermal imagery. Thermal imagery was not collected during this site visit because the day was sunny and hot, and ambient ground surface temperatures were greater than 90°F. A manual inspection of the entire site was completed, and no obvious fire activity was observed. Fractures on the south end of the fire were found to be at ambient temperatures and had no evidence of active venting (Figure 4-14). The landowner mentioned that an area between the road switchbacks typically does not hold snow after a snowstorm and that steam can be seen rising from this area following precipitation at the site. This area was inspected, and no vents or fractures were found. Fractures were found in the road immediately to the northwest of this area. No venting was observed.

Borehole #3 was the only borehole available to measure with the thermocouple. The other holes either could not be located or were locked. The previous inventory report states that Borehole #3 had a sensor temperature measurement of 125°F in 2005. The temperature observed at Borehole #3 during this site visit measured 136°F.

FIRE RISK AND RECOMMENDATIONS

The States Mine Fire activity was observed as very low with no active fire expressions located. The risk of wildfire at the site is low because of the lack of active vents. The risk to population is also low because the fire is located on private property and no active fire expressions were found.

Snowmelt and wintertime thermal imagery could help map hotspots on site and delineate the extent of any present fire activity. It is recommended that snowmelt and thermal imagery be collected for inclusion with the next mine fire inventory report.

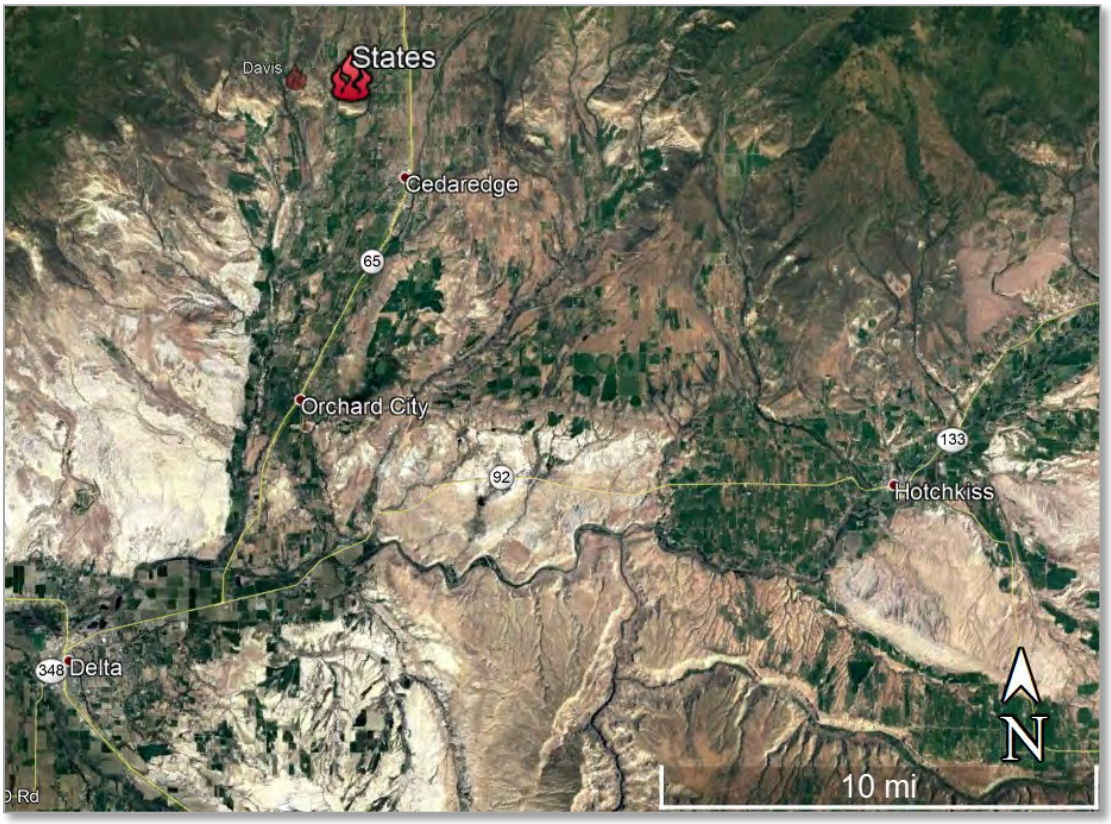

Figure 4-15 – States Mine Fire Location Map

DIRECTIONS TO FIRE

The States Mine Fire is located northwest of Cedaredge, CO at address 21903 T Road. Take Main St west out of Cedaredge. At 1.1 miles, Turn right (north) onto Happy Hollow Road. At 1.9 miles, turn left (west) onto Green Valley Road. Main Street becomes R Road. At 1.9 miles, take a right turn to stay on R Road. At 3.5 miles, turn right (east) onto T Road. at 3.7 miles, landowner's house is on left side of road and mine fire is 0.2 miles further east on T Road. T Road is closed on east side of property.

4.3 Fremont County

Fremont County is home to one coal mine fire, the Double Dick Vicinity Mine Fire. This fire is located south of the town of Florence in the Cañon City coal field.

4.3.1 Double Dick Vicinity Mine

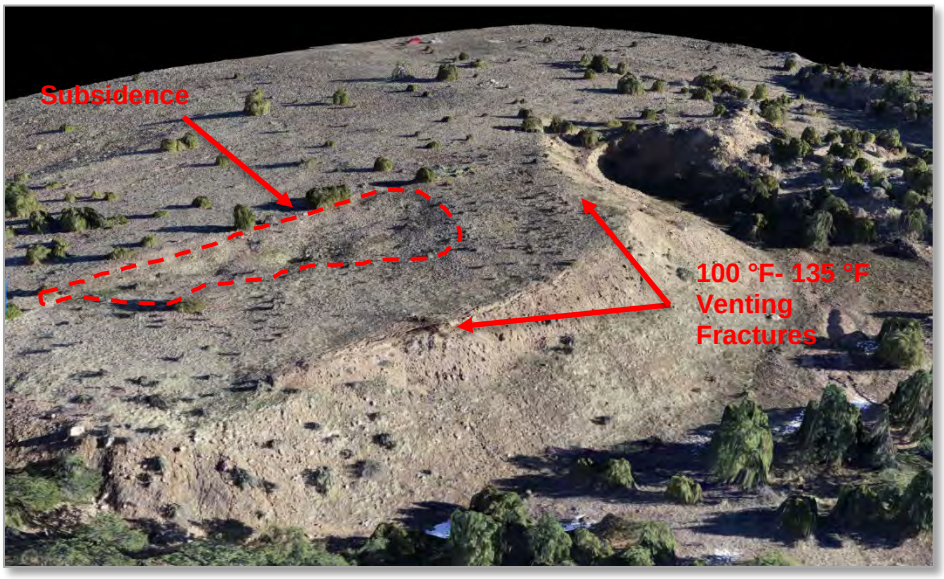

Figure 4-16 – 3D Model of Double Dick Vicinity Mine Fire Looking Northeast

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

26 of 38

LOCATION

Latitude: 38°17'42.88"

Longitude: 105°9'58.83"

Nearest Town: Florence, Colorado.

Landowner: Corley Ranch (Private)

MINE INFORMATION

Coal Field: Cañon City

Formation/Seam: Vermijo/Brookside

Strike and Dip: N5E & 6

Mining Method: Drift

Years of Operation: 1929-1968

Production: 540,686 tons

DATA COLLECTION

2005 – Inventory

2018 – Inventory
- Thermal mapping
- 3D mapping
- Aerial imagery
- Surface Features Map

FIRE DESCRIPTION

The Double Dick Vicinity Mine fire site is located 7 miles south-southwest of Florence, CO and lies in the Cañon City coal field. The site was visited in November of 2018 to complete an aerial thermal survey along with ground inspections of known and any new features at the site. The landowner was onsite during the survey and provided additional information about the site, including that the mine was operated until the 1970s, with the first mine fire starting in 1982.

Figure 4-17 – Venting Fractures

There are two unrelated fire features at the site: one is a trench originally used to cut off the burning coal seam; the other is a coal waste pile that has been is some form of combustion since the 1980s as well.

FIRE OBSERVATIONS

The Double Dick Mine Fire was visited on November 27, 2018. Ambient air and ground temperatures in the early morning were low enough (50-60°F) to fly an aerial thermal survey to map the locations of any active vents in the area. Inspection of the coal refuse pile (also referred to as the Mesa

Side in the 2005 Inventory Report) revealed numerous small cracks along the southern edge of the pile. These cracks were stained dark black and were emitting steam and some H_2S at low levels. The temperatures recorded in approximately 15-20 individual cracks ranged from 100-135°F. Additionally, vegetation within the immediate proximity to the vents was absent (Figure 4-17).

South of the waste pile, along the tree line, approximately 15 large subsidence features were noted. These subsidence features ranged in diameter from 15-30 feet and were as deep as 12-15 feet. Most of the subsidence features were discrete circular features; however, several long trough subsidence features were also noted. Lack of vegetation noted inside the depressions could be the result of recent subsidence and/or lack of moisture due to draining through the fractured ground into the mine below.

Inspection of the trench area at the Double Dick site revealed numerous linear erosion pathways that seem to be focused directly over the alignment of the trench. These features are likely being caused by settlement of material over the backfilled trench.

The landowner noted that the adjacent Black Diamond mine is likely connected to the Double Dick, and an underground fire could have spread between the two mines. Nevertheless, there was no evidence observed during the 2018 site inspection to confirm this claim.

FIRE RISK AND RECOMMENDATIONS

The Double Dick Vicinity Mine Fire activity is relatively low, but heating and venting during oxidation of the coal waste pile is present. The risk of wildfire is relatively low because of the lack of vegetation surrounding the oxidation areas. The risk to population is low because the fire is located on private property and is emitting only a small amount of gases far from any occupied structures.

Snowmelt imagery was not able to be collected during this site visit. Snowmelt imagery could help with mapping the extents of the fire activity should it exist elsewhere on site. It is recommended that snowmelt imagery be collected for inclusion with the next mine fire inventory report.

Mitigation of the waste pile would be recommended should the elevated temperatures persist through additional monitoring.

DIRECTIONS TO MINE

The Double Dick Mine Fire is located south-southwest of Florence, CO at 38°17'42.88"N, 105°9'58.83"W west of county road 15. Take highway 67 south from the town of Florence for 4.3 miles. Turn right onto County Rd. 15 continue for 2.7 miles. Turn right onto County Rd. 94 (also County Rd. 15) and continue for an additional mile before reaching a sign for Corley Ranch; this is the private property boundary and access through the locked gate is granted from the property owner.

Figure 4-18 – Double Dick Mine Fire Location Map

4.4 Garfield County

There are 13 underground coal mine fires and two paleo fires currently known in Garfield County. Their locations are shown on Figure 4-19 and Figure 4-20. The complex geology, mining methods, and highly combustible nature of the coal in the Grand Hogback Coal Field create ideal fire conditions resulting in a series of intense fires down the Grand Hogback, with seven ranked in the top ten of the priority list. The Garfield County fires are characterized by fires burning in stopes mined above entryways. Intake features like old adits and subsidence fractures feed oxygen to the base fires and vents form above the burn zone in old workings or air shafts or through fractures in the ground and the resulting chimney effect amplifies the intensity of the fires.

Figure 4-19 – Eastern Garfield County Mine Fire Locations

Figure 4-20 – Western Garfield County Mine Fire Locations

4.4.1 Coryell Mine

Figure 4-21 – Coryell Mine Fire Looking West

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

15 of 38

LOCATION

Latitude: 39°34' 3.24"

Longitude: 107°31' 58.38"

Nearest Town: New Castle, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Allen and Wheeler

Strike and Dip: N 65W & 44 SW

Mining Method: Drift

Years of Operation: 1898-1909

Production: 484,511 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer survey
- Gas Composition/isotope
- Fissure mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The Coryell Mine fire site is located ¼ mile south of New Castle, CO on the north side of the Grand Hogback. The Coryell Mine was active from 1898 to 1909, producing 484,511 tons of coal from the Allen and Wheeler seams. The fire is most noticeable while driving on I-70 after snowfall because the fire expression areas do not hold snow.

FIRE OBSERVATIONS

On February 21, 2018, the fire site was flown using a drone to collect snowmelt images after one inch of snowfall overnight. Data from this flight was used to delineate the active fire area. The site was not inspected on foot because of the steep terrain and icy conditions. The site was flown again on August 27, 2018 to update aerial imagery and site elevation data.

The snowmelt imagery delineated a primary fire expression covering approximately ½ acre (Figure 4-22). Ground temperatures in this expression area were 20°F to 30°F above ambient ground temperature.

FIRE RISK AND RECOMMENDATIONS

The Coryell Mine Fire is a low-activity fire and has few fire features of concern. No large or high-temperature vents could be located. There is moderate hazard of wildfire due to the fire's moderate activity. Nevertheless, the potential consequences of a wildfire are high because of the proximity to the town of New Castle, CO. As a result, the risks posed by wildfire are moderate to high. The steep terrain around this fire and lack of dangerous surface features means it presents a limited risk to trespassers.

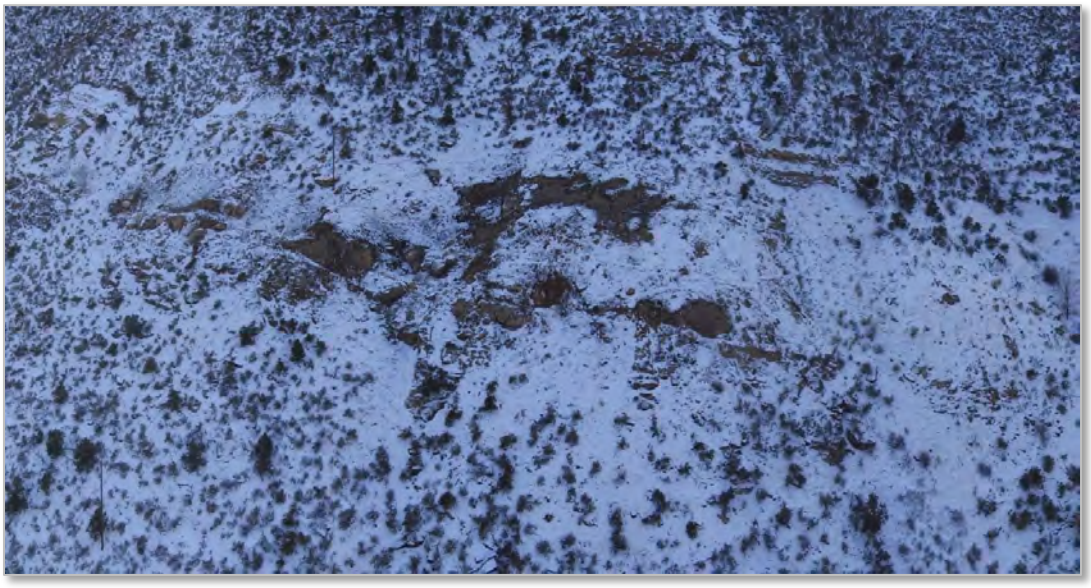

Figure 4-22 – Coryell Mine Fire Snowmelt

Figure 4-23 – Coryell Mine Fire Location Map

DIRECTIONS TO FIRE

The Coryell Fire is Located ¼ mile south of New Castle, CO on the south side of the Colorado River. To access the site, take I-70 to Exit 105. Turn left (south) across the Colorado River and then turn right (west) on County Rd. 335. In 0.75 miles, park and hike up the Grand Hogback to the south.

4.4.2 Elk Creek Mine

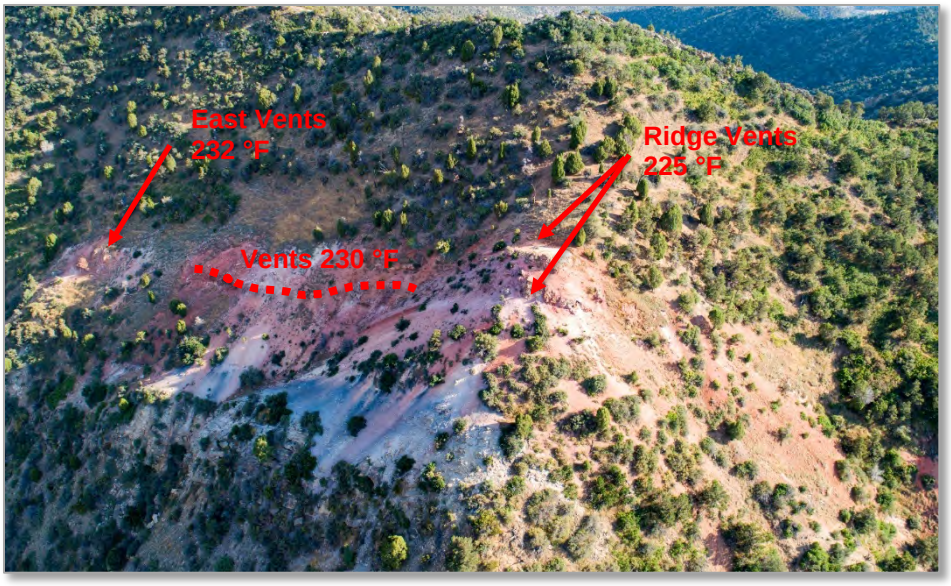

Figure 4-24 – Elk Creek Mine Fire Looking Southeast

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

11 of 38

LOCATION

Latitude: 39°35' 21.11"

Longitude: 107°35' 22.30"

Nearest Town: New Castle, Colorado.

Landowner: Public - BLM

MINE INFORMATION

Coal Field: Grand Hogback

Seam: NA

Strike and Dip: N 73W & 55 SW

Mining Method: Drift

Years of Operation: 1896-1936

Production: 3,171 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The Elk Creek Mine fire is located 3 miles west-northwest of the town of New Castle, CO. The site is situated near the top of the Grand Hogback at an elevation of approximately 7340 ft AMSL. The fire can be viewed from Buford Rd and vent steam can regularly be seen on humid, cool days. The site lies on BLM land, but is accessed from private property on Buford Rd with the permission of the landowner. The Elk Creek Mine was active from 1986 to 1936 and produced 3,171 tons of coal.

Figure 4-25 – 225 °F Vents

FIRE OBSERVATIONS

The Elk Creek Mine fire site was visited on July 19, 2018. Permission to access the mine fire was obtained from the landowner of a private residence on the north slope of the Grand Hogback directly below the fire. Several vents were discovered near the outcropping ridge near the highest surface elevation of the mine fire site. The temperatures at these vents were measured around 225°F (Figure 4-25). Exhaust flow was detected but flow rates were low to moderate, and no vegetation or other combustibles were nearby. Therefore, wildfire risk is limited. Additional vents were discovered within the sandstone cap overlying the steeply dipping coal seam. Numerous old vents are evident from staining of the rock, but no elevated temperatures or gases were being emitted from these vents. Gas at the active vents had slightly elevated levels of H_2S and CO as detected on the 4-gas meter. On the eastern side of the site, vents in the fractured sandstone showed moderately elevated temperatures and were emitting exhaust at a low to moderate rate.

The highest surface temperatures measured between 190°F and 230°F. The vents on the east side pose limited risk for wildfire because there is little vegetation nearby.

After completion of the on-ground inspection, two drone flights were performed to collect thermal imagery, aerial imagery, and elevation data.

FIRE RISK AND RECOMMENDATIONS

The fire is moderately active, with vent temperatures around 230°F. Elevated ground temperature has kept most vegetation from growing near the vents, reducing the potential for wildfire. The fire expressions are well defined and free of major vegetation. There is moderate risk of wildfire because of the fire's moderate activity. While the fire is on public land, there is no easy access to the site, meaning the potential for trespassing is low.

Currently, no abatement actions are recommended at the site. It is recommended that a snowmelt drone flight be performed to delineate the fire expression area.

Figure 4-26 – Elk Creek Mine Fire Location Map

DIRECTIONS TO FIRE

The Elk Creek Mine fire is accessed from a private residence on Buford Rd. From Interstate 70, take Exit 105, turn right (north) and proceed onto Castle Valley Blvd (Buford Rd.) for 5.4 miles. Access the fire through private property on the south side of road. Fire is a 1-mile hike to the south.

4.4.3 Gem Mine

Figure 4-27 – Gem Mine Fire Looking Southeast

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

16 of 38

LOCATION

Latitude: 39°32' 31.32"

Longitude: 107°26' 2.04"

Nearest Town: Glenwood Springs, Colorado.

Landowner: Public, City

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler, D, E, & U

Strike and Dip: N 53W & 57 SW

Mining Method: Stope

Years of Operation: 1938-1968

Production: 61,306 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The Gem Mine fire site is located approximately 6 miles west of Glenwood Springs, CO and ½ mile south of the Glenwood Springs landfill. The site lies on land owned by City of Glenwood Springs. The Gem Mine was active from 1938 to 1968 and produced 61,306 tons of coal. The fire has two main expression areas on the north aspect of the Grand Hogback.

FIRE OBSERVATIONS

On January 25, 2018, the fire site was flown using a drone to collect snowmelt after 4 inches of overnight snowfall. Data from this flight allowed for the delineation of the two active fire expressions totaling ½ acre, where ground temperatures were 50°F and vent temperatures ranged from 130°F to 185°F (Figure 4-28). Moss covers most of the expression area, with some bare ground where temperatures are too high to support vegetation growth.

FIRE RISK AND RECOMMENDATIONS

The fire is moderately active but has few concerning fire features. The fire expressions are well defined and free of major vegetation. The main concern with this fire would be a new vent opening in the heavy vegetation that surrounds the fire expressions. There is moderate risk of wildfire because of the fire's moderate activity. The steep terrain around this fire, the controlled access to the landfill, and secluded location means it presents a limited risk to trespassers.

Regular vegetation and subsidence monitoring are recommended.

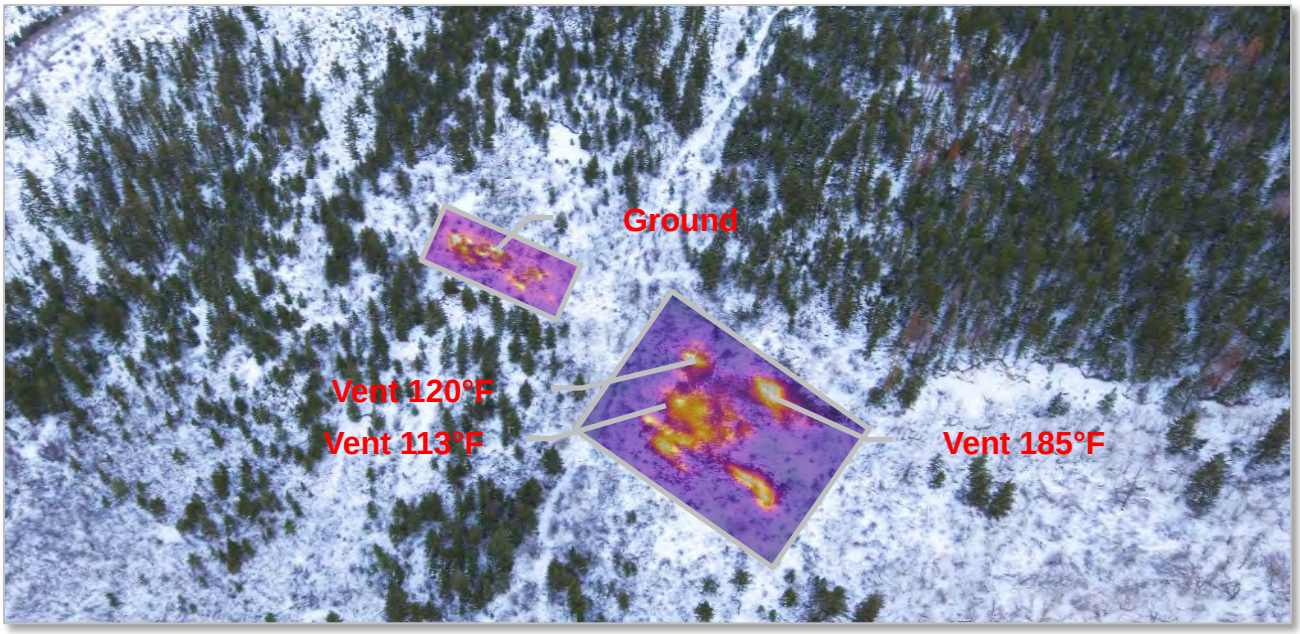

Figure 4-28 – Gem Mine Fire Thermal Overlay

Figure 4-29 – Gem Mine Fire Location Map

DIRECTIONS TO MINE

The Gem Mine fire is accessed from the City of Glenwood Springs landfill. To get to the landfill, take Interstate 70 west from Glenwood Springs to Exit 111. Take County Rd. 134 south for approximately 1.5 miles and turn right (west) into the landfill. After checking in at the landfill office, continue west and park near the slash pile. Fire is a 0.75 hike to the south.

4.4.4 Harvey Gap Mine

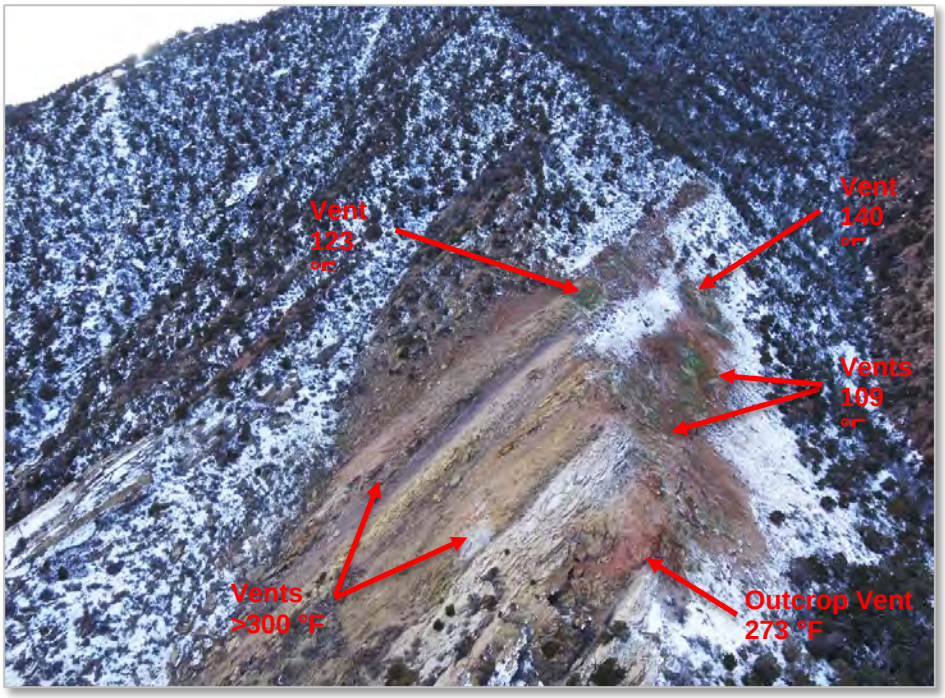

Figure 4-30 – Harvey Gap Fire Looking Southwest

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

10 of 38

LOCATION

Latitude: 39°36' 8.87"

Longitude: 107°39' 56.09"

Nearest Town: Silt, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Multiple

Strike and Dip: N 74W & 50 SW

Mining Method: stope

Years of Operation: 1913-1968

Production: 84,109 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer survey
- Gas Composition/isotope
- Fissure mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

Harvey Gap Numbers 1, 2, and 3 were worked from 1913 to 1968 and produced a combined total of 84,109 tons of coal. Multiple coal seams in the fire area were mined using multiple entrances near the valley floor. Two mined coal seams are on fire along with a smaller, intermediate rider seam.

A fire abatement project was undertaken in 2003 in which 450 cubic yards of cement/fly ash grout was injected into the workings of two seams and into a large vent that presented a public safety risk. The project slightly reduced vent temperatures and decreased the public safety risk (Renner, 2005).

FIRE OBSERVATIONS

Figure 4-31 – West Most 140°F Vent

The site was visited twice by Tetra Tech in 2018: once on January 27 to collect snowmelt photos and aerial imagery, and again on September 12th to inspect the site for fire activity.

The fire features discussed by Renner in the 2005 Inventory report were all visited, and several new vents were located during the September site visit, including one on the south-facing slope with exhaust temperatures around 310°F. This vent was producing little carbon monoxide but no other detectable gases at the surface. Within the same coal seam, several other vents were producing steam but no other gases of concern. Another south-facing vent area was found in an outcrop approximately 140 feet south in an overlying seam. This

area had previously been sealed with grout but was very active, venting gases at well over 300°F. The combustion gases were hot and dry with no creosote, indicating an efficient fire in that area. Vent temperatures on the north aspect of the fire area ranged from 109°F to 140°F and were smaller and more dispersed than those on the south aspect of the fire (Figure 4-31). Snowmelt imagery and the lack of vegetation indicate the fire is moving in a northwestern direction along the two mined coal seams.

FIRE RISK AND RECOMMENDATIONS

The fire is moderately active with vent temperatures range from 109°F to 310°F. Ground heat has kept most vegetation from growing near the vents, reducing the potential for wildfire. The fire expressions are well defined and free of major vegetation. There is moderate risk of wildfire due to the fire's moderate activity. While the fire is on public land, there is no easy access to the site, meaning the potential for trespassing is low.

Currently, no abatement actions are recommended at the site.

Figure 4-32 – Harvey Gap Site Location

DIRECTIONS TO FIRE

The Harvey Gap mine fire site is located approximately 4 miles north of Silt, CO on the west side of the Canyon, south of Grass Valley Reservoir. The Harvey Gap Mine Fire can be accessed from Silt, CO. From Main St in Silt, drive west then turn right (north) onto N 1st St. In 1.2 miles, turn left (west) onto Silt Mesa Rd. After 0.7 miles, turn right (north) onto Harvey Gap Rd. In 1.5 miles, Fire will be on left (west) side of the road.

4.4.5 IHI No.2 Mine

Figure 4-33 – IHI No. 2 Mine Fire Looking East

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

17 of 38

LOCATION

Latitude: 39°37' 10.20"

Longitude: 107°43' 54.48"

Nearest Town: Rifle, Colorado.

Landowner: BLM

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Allen

Strike and Dip: N 75W & 57 SW

Mining Method: stope

Years of Operation: 1946-1957, Black Raven 1959-1963

Production: 65,587 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Fissure mapping
- Coal outcrop mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The IHI No. 2 mine fire is located 6 miles north northeast of Rifle, CO in a valley on the south aspect of the Grand Hogback 1.5 miles east of Rifle Gap. The fire lies on the opposite side of the valley from IHI No. 3. The IHI No. 2 mine was operated from 1946 to 1957 and produced a total of 65,587 tons of coal. Operation restarted around 1959 as the Black Raven Mine. In 1963, a fire was reported to have started in the Black Raven Mine from spontaneous combustion in underground stockpiled coal. By 1972, the fire had propagated along the outcrop of the 10 ft thick Allen seam. In September and October of 1972, the Bureau of Mines constructed a surface seal with the intent to extinguish the fire by smothering it (Shellenberger, 1973). Maintenance continued throughout the 1970s as portions of the fire would flare up and the surface seal would require repairs. The 2005 inventory report describes subsidence features and vents with temperatures ranging from 80°F to 400°F.

FIRE OBSERVATIONS

The site was visited on July 18, 2018 to inspect the fire area and look for evidence of fire activity. The site was also flown with a drone to collect thermal imagery and data to develop a 3D model of the site.

A 6-foot by 5-foot by 1-foot deep subsidence feature was discovered near the western (lower) end of the surface seal (Figure 4-34). Combustion gases were observed near the feature, but temperatures were not elevated. Besides the subsidence feature, no other combustion gases or newly stressed vegetation were observed around the site.

Figure 4-34 – Subsidence Feature

FIRE RISK AND RECOMMENDATIONS

The fire's current activity is low and presents little risk of starting a wildfire. The remote location of the mine fire and the lack of dangerous surface features means this fire poses little public safety risk.

Currently, no abatement actions are recommended at the site. Drone snowmelt imagery was not taken of the site but could help identify area of potential fire activity.

Figure 4-35 – IHI No. 2 Mine Fire Location Map

DIRECTIONS TO FIRE

From Rifle, CO, take Hwy 13 north and turn right (east) onto Hwy 325 N. In 1.5mi, turn right onto County Rd. 251. Drive for 3.5 miles and fire is on right (east) side of road.

4.4.6 IHI No. 3 Mine

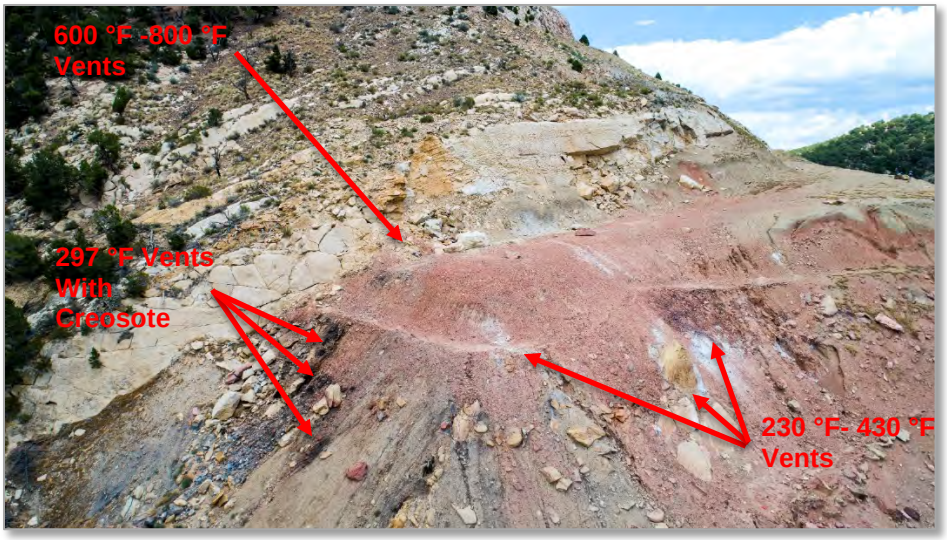

Figure 4-36 – IHI No. 3 Mine Fire Looking North

FIRE ACTIVITY

High

FIRE HAZARD RANKING

6 of 38

LOCATION

Latitude: 39°37' 14.16"

Longitude: 107°44' 6.00"

Nearest Town: Rifle, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler, D

Strike and Dip: N 75W & 57 SW

Mining Method: stope

Years of Operation: 1898-1916

Production: 51,804 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Fissure mapping
- Coal outcrop mapping
- Snowmelt mapping
- Magnetometer

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The IHI No. 3 Mine fire—also known as the D&H Mine fire—is located 6 miles north-northeast of Rifle, CO in a valley on the south aspect of the Grand Hogback, 1.5 miles east of Rifle Gap. The fire lies on the opposite (west) side of the valley from IHI No. 2. The IHI No. 3 mine was operated from 1898 to 1916, producing 51,804 tons of coal from the Wheeler and D seams until a fire was reported in the underground workings. It is believed the fire started from spontaneous combustion of stockpiled loose coal (Russell, 1976). From 1973 to 1975, a large-scale fire control project was undertaken by the Bureau of Mines, which included drilling, blasting, and dozing of rock fragments and a surface seal (Shellenberger, 1975).

Subsequent activities at the site have include drilling investigations, thermocouple installation, temperature monitoring, intake mapping, magnetometer surveys, thermal imaging, and 3D site modeling.

Figure 4-37 – >600 °F Vent

FIRE OBSERVATIONS

The site was visited on April 12, 2018 to evaluate surface seal performance after heavy rains in 2017. The site was accessed using the BLM road in the valley bottom. This road was heavily damaged during these rains and subsequent debris flows and is inaccessible by standard 4x4 vehicles. No substantial damage to the surface seal was found during the inspection.

The site was visited again on July 18, 2018 to inventory fire activity and to collect thermal imagery and data to be used to develop a 3D surface model. The south side of the surface seal, on the hillside above the lower road, hosted numerous vents. Vent temperatures ranged from 230°F to

430°F. Combustion emissions from these vents were primarily CO_2, with no CO or H_2S detected. The openings were surrounded by white precipitant. Along the lower, southern portion of the surface seal, the smell of sulfur was apparent, and vents had buildups of sulfur crystals at their openings. Elevated levels of CO and H_2S were encountered, and the team had to leave the immediate area. This area was circumvented, and the northwest corner of the surface seal was then evaluated. A one-foot diameter vent was found against the large sandstone outcrop bounding the northern edge of the primary fire area. This glowing orange vent had a high flow rate and temperature in excess of 600°F (Figure 4-37). The vent could not be approached due to elevated CO levels and intense heat. The nearest vegetation was approximately 30 feet up the slope about the vent. The western vents were 297°F with substantial amounts of creosote around their openings, indicating that the fire has moved into unburnt coal in this area. These vents were 20 feet away from vegetation.

Approximately 400 feet northwest from the main fire area, along the fire access road, three small, high water-vapor content vents measuring 250°F were found in a fractured sandstone outcrop. No vegetation was present near these vents.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is high and presents a substantial risk of starting a surface fire. If a fire were to start, access would be difficult because of the washed-out road. The toxic gases and extremely hot vent and ground temperatures also present a substantial risk to public safety. The fire has a relatively high potential for trespassing, as it is on BLM land in an area popular for 4-wheeling and other motorsports, and there is no signage or fencing to keep the public away from the fire.

It is recommended that the access road be repaired to allow for emergency response in case of a wildfire. It is also recommended that fencing and signage be installed around the main fire area to deter trespassing.

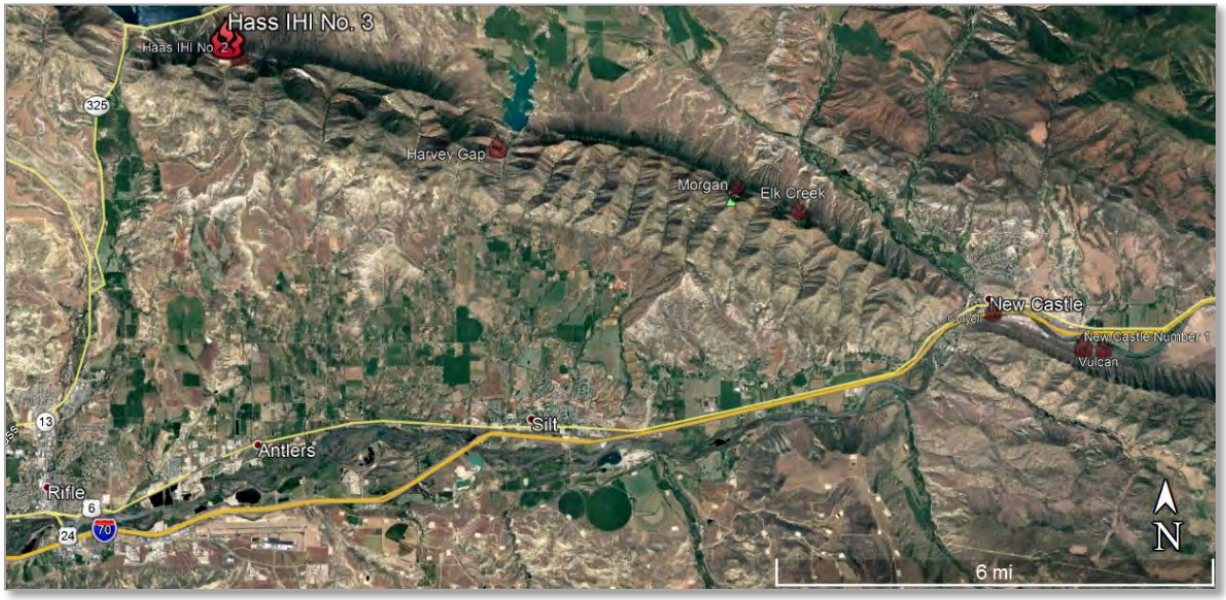

Figure 4-38 – IHI No. 3 Mine Fire Location Map

DIRECTIONS TO MINE

From Rifle, CO, take Hwy 13 north and turn right (east) onto Hwy 325 N. In 1.5mi, turn right onto County Rd. 251. Drive for 3.5 miles and fire is on left (west) side of road.

4.4.7 Morgan Mine

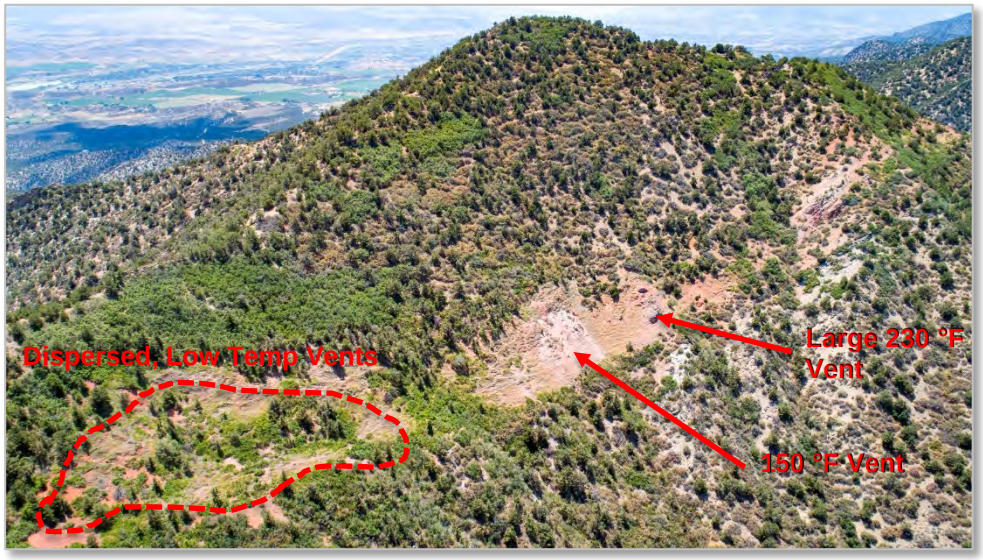

Figure 4-39 – Morgan Mine Fire Looking Southwest

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

14 of 38

LOCATION

Latitude: 39°35' 38.40"

Longitude: 107°36' 12.24"

Nearest Town: New Castle, Colorado.

Landowner: Public - BLM

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler

Strike and Dip: N 70W & 53 SW

Mining Method: stope

Years of Operation: 1929-1941

Production: 11,640 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The Morgan Mine fire is another site along the north-facing slope of the Grand Hogback, west-northwest of New Castle, CO. The Morgan fire is located approximately 0.75 miles north west of the Elk Creek Mine fire and is situated in the same geological unit as the Elk Creek site. The fire area is at approximately 7300 ft elevation and was accessed from the Elk Creek Mine site by traversing the hogback to the northwest.

FIRE OBSERVATIONS

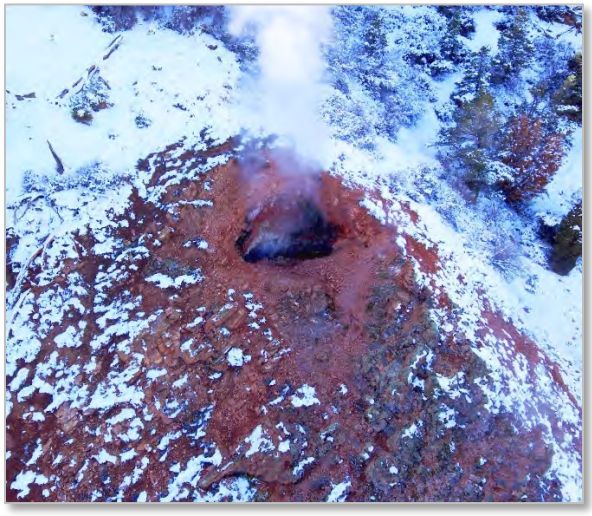

Figure 4-40 – Large 230 °F Vent

The Morgan site was visited twice in 2018. The first visit was performed on January 24, 2018 by Tetra Tech and a BLM representative. Recent snowfall allowed for the collection of snowmelt pictures but prevented close-up inspection of the fire area.

The second visit was performed on July 19, 2018 and accessed from the Elk Creek mine fire. The primary vents observed on site were focused around a large opening in the sandstone cap measuring 8 ft by 4 ft. Heat shimmer was observed in the exhaust from the vent, and measured temperatures exceeded 230°F. Several other vents were discovered nearby, with measured temperatures around 130-150°F. The emissions of these vents had no detectable odor and were cool enough to allow wasps to fly in and out of the vents. Heavy staining on rock throughout the site provided evidence of additional dormant vents, although these dormant

vents were not actively emitting any heat or detectable gasses. The site is moderately vegetated, with grasses covering most of the ground and forest surrounding the greater Morgan site. Dispersed high water-vapor content, low-temperature vents were found on the eastern end of the site. These vents are near vegetation, but there is no evidence of excessive heat harming vegetation.

Figure 4-41 – Large 230 °F Vent Looking Southeast

FIRE RISK AND RECOMMENDATIONS

The fire is moderately active, with vent temperatures around 230°F. Ground heat has kept most vegetation from growing near the vents, reducing the potential for wildfire. The fire expressions are well defined and free of major vegetation. There is moderate risk of wildfire because of the fire's moderate activity. Although the fire is on public land, there is no easy access to the site, so the risk to public safety is low.

Currently, no abatement actions are recommended at the site.

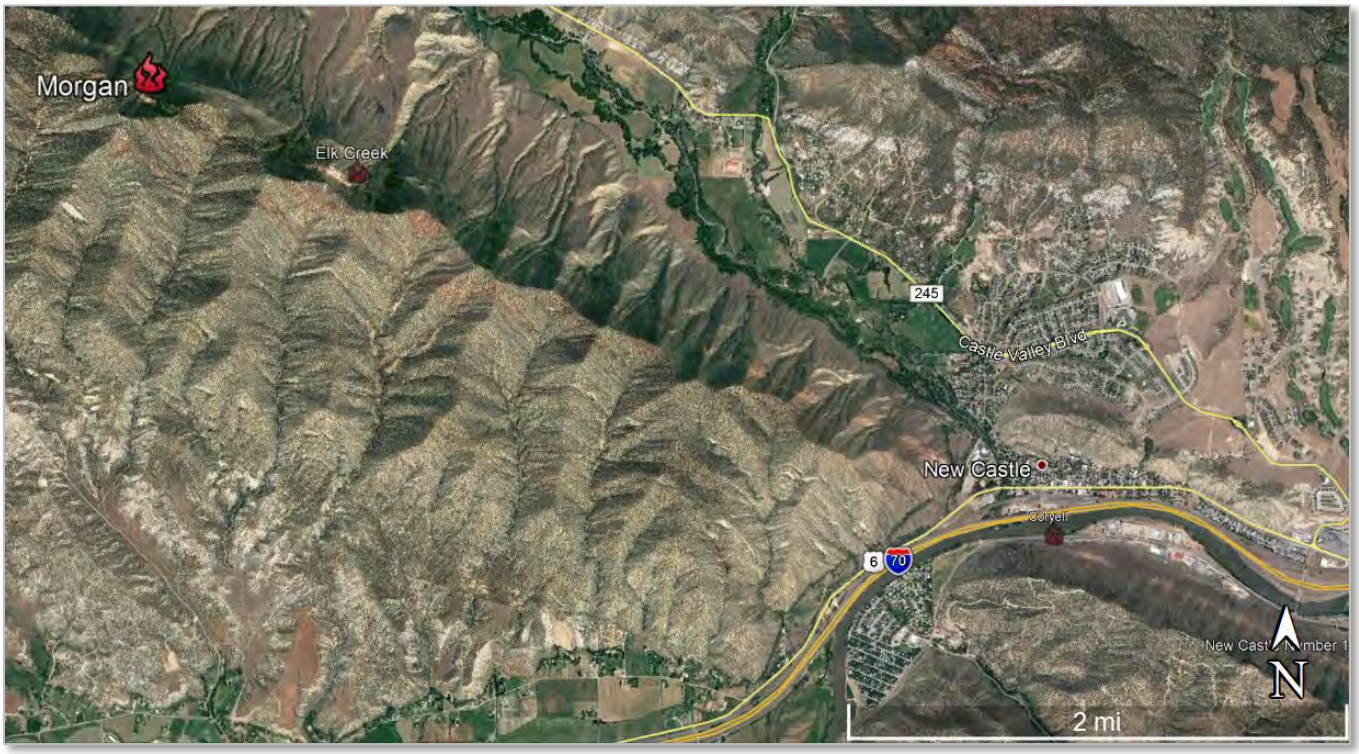

Figure 4-42 – Morgan Mine Fire Location Map

SITE DIRECTIONS

The Morgan Mine Fire is best accessed from the southwest side of the Grand Hogback. From Silt, CO, Take HWY 6 east 1.5 miles and turn left (north) on Davis Point Rd. In 0.7 miles, turn left (west) on Peach Valley Rd. In 0.8 miles, turn right (north) onto unnamed dirt road. At 1.6 miles, park and hike 1 mile up the road the until it ends. Morgan Mine Fire is over the ridge directly to the east.

4.4.8 New Castle No. 1 Mine

Figure 4-43 – New Castle No. 1 Mine Fire Looking Southeast

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

13 of 38

LOCATION

Latitude: 39° 33'39.60"N

Longitude: 107°30'44.28"W

Nearest Town: New Castle, Co.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Allen

Strike and Dip: N67W & 50°

Mining Method: Drift

Years of Operation: 1888-1954

Production: 1,345,461 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer
- Gas composition
- Surface feature mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The New Castle No. 1 Fire is located 1.5 miles southeast of New Castle, CO on the Grand Hogback, south of the Colorado River. The fire is just west of the Vulcan fire but lies approximately 600 feet higher stratigraphically in the Allen seam. The fire is located on private property and accessed with permission of the landowner. The New Castle Number 1 mine produced approximately 1,345,500 tons of coal from 1888-1954. The fire expression typically does not hold snow during the winter months.

Figure 4-44 – Fire Expression

FIRE OBSERVATIONS

The fire was visited in February 21, 2018 to gather surface temperatures, vent temperatures, analyze potential fire risks, and collect drone thermal and mapping images. The fire was not accessed on foot because of the steep terrain and snow. A drone with thermal camera was used to take temperature measurements of the fire expression areas. The air temperature was 25°F and ground temperature was 37°F. No surface heating from the sun had occurred.

Two main fire expressions were present during the site visit, with ground temperatures approximately 61°F across the fire

expressions and a maximum temperature of 80°F. Areas of snowmelt appear in areas of thin vegetation including small grass and moss, suggesting that the fire is relatively stable (Figure 4-44).

FIRE RECOMMENDATIONS

The New Castle No. 1 Mine fire does not present a substantial risk to public health or potential to start a wildfire because it lacks high-temperature surface expressions, subsidence features, noxious gases, and is on private property and in steep terrain.

No work is recommended on the New Castle No. 1 Mine Fire at this time.

Figure 4-45 – New Castle No. 1 Fire Location Map.

DIRECTIONS TO MINE

To access the site, take I-70 to Exit 105. Turn left (south) across the Colorado River and then turn left (east) on County Rd. 335. In 0.3 miles, turn right (south) onto private road. Park and hike up the Grand Hogback to the south.

4.4.9 New Castle No. 3 Mine

Figure 4-46 – New Castle No. 3 Mine Fire Looking West

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

7 of 38

LOCATION

Latitude: 39°34' 23.52"

Longitude: 107°32' 37.68"

Nearest Town: New Castle, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: NA

Strike and Dip: N 65W & 56 SW

Mining Method: NA

Years of Operation: NA

Production: NA

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer survey
- Gas Composition/isotope
- Fissure mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The New Castle No. 3 Mine fire is located immediately west of downtown New Castle, on the Grand Hogback, above the elementary school. The coal mine fire is on private property and accessed with the permission of the landowner. The fire is one of the most publicly prominent in the state, given its location and easy visibility from I-70 and the town of New Castle. The fire is characterized by areas of bare soil, rock and ash and a large subsidence feature. During the winter, the main eastern aspect of the fire does not hold snow.

Figure 4-47 – Small Vent

FIRE OBSERVATIONS

On February 21, 2018, the fire site was flown using a drone to collect snowmelt pictures and thermal data after one inch of new snow from the previous night. Most of the east aspect slope was bare of snow. Periodic snowmelt was observed for approximately 700 ft west of the main fire area. These areas of snowmelt occur at the two coal outcrops on the slope. Data from this flight allowed for the delineation of the active fire area. The site was not accessed on foot because of the steep terrain and snow.

The site was visited again on November 19, 2018 to perform an on-ground inventory of the fire. The main feature of this

fire is a 75 ft by 200 ft subsidence feature that has warm ground and dispersed 170°F hotspots. Two fractures, spaced 20 feet apart, run perpendicular to the stratigraphy north from the subsidence feature. The lower fracture was not actively venting and had filled in with loose material (Figure 4-48), and the upper fracture had multiple vents along it measured at 270°F. Exhaust in this area of the fire was hot and dry and had very low amounts of CO and sulfur, indicating a very efficient combustion. The higher areas of the fire are on a north aspect slope. Two 137°F vents were found along the lower seam. The westmost vents of the fire were found along the upper seam and measured 130°F (Figure 4-47). Many small, dispersed vents were found on the north aspect slope between the two coal seams. The vent exhaust in this area was very low in CO and sulfur and had higher water content than exhaust of the lower area vents. The vents and much of the ground on the north aspect slope had thick moss and grass growth because of the warmth and elevated water-vapor content of the fire exhaust.

Figure 4-48 – Lower Fracture

FIRE RISK AND RECOMMENDATIONS

The New Castle No. 3 Mine fire is moderately active but appears to have an established fire area. Areas where the fire is most active are denuded of vegetation, giving this fire a limited risk of starting a surface fire. The large fractures, steep terrain, and subsidence features mean this fire poses a moderate public safety risk. The fire's visibility and ease of access means the risk of trespassing is moderate.

Currently, no abatement actions are recommended at the site. However, it is suggested that signs and a fence be installed to deter potential trespassing.

Figure 4-49 – New Castle No. 3 Mine Fire Location Map

DIRECTIONS TO MINE

The New Castle No. 3 Mine Fire is located 500 ft west of Elk Creek Elementary School in New Castle, CO. To access the site, take main street west out of downtown New Castle. In 0.2 miles, turn right (north) into the Elk Creek Elementary School parking lot and fire is on left (west) side of lot.

4.4.10 Pocahontas No. 1 and 2 Mine

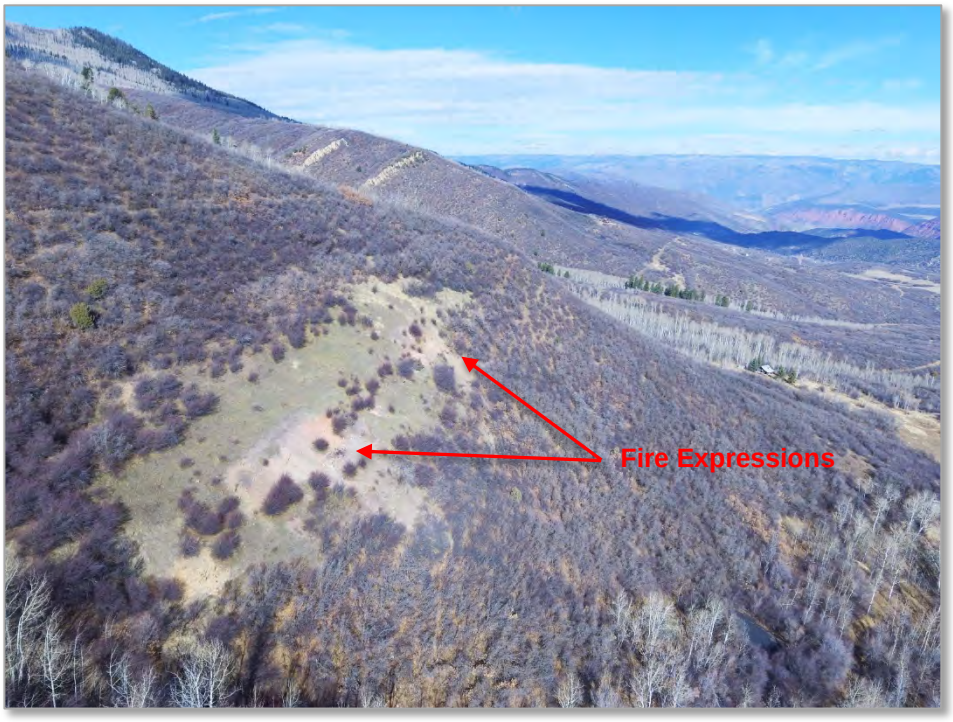

Figure 4-50 – Pocahontas Mine Fire Looking North

FIRE ACTIVITY

Low/Dormant

FIRE HAZARD RANKING

35 of 38

LOCATION

Latitude: 39.4113

Longitude: -107.3253

Nearest Town: Glenwood Springs, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: A, C, and D

Strike and Dip: N17W & 42°

Mining Method: Drift

Years of Operation: 1899-1951

Production: 176,222 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer survey
- Fissure mapping
- Snowmelt Mapping

2018 – Inventory
- 3D Surface mapping
- Snowmelt mapping
- Thermal mapping
- Orthophotography

FIRE DESCRIPTION

The Pocahontas mine fire site is located approximately 9.5 miles south of Glenwood Springs, CO and 1/2 mile north of the Sunshine mine fire. The mine fire is located on private property and accessed with permission of the landowner. The mine was operated from 1899 to 1951 and produced 176,222 tons of coal. The surface features associated with this mine fire include red, thermally altered rock at the fire expression and subsidence features caused by previous fire activity.

In 2005, Steve Renner reported that the fire was active, with ground temperatures 15°F to 40°F above normal ground temperatures. By 2011, Koveva Ltd. observed that the fire had become dormant and the area showed no snowmelt a week after snowfall.

FIRE OBSERVATIONS

The fire was visited in May and November 2017 to gather surface data and analyze potential fire risks. No venting or elevated surface temperatures were observed. There were no signs of newly stressed vegetation, but bare spots were still present at previous fire expressions (Figure 4-50). No odor or recent subsidence was observed during these site visits.

The site was revisited in February 2018 to gather ground temperatures and snowmelt pictures. No indications of an active fire were observed at the surface. Ground temperatures were uniform, and no snowmelt was observed the morning after a four-inch snowstorm (Figure 4-51).

Figure 4-51 – Pocahontas Mine Fire Dry vs. Snow Looking West

FIRE RECOMMENDATIONS

The fire poses limited risk to the public and of starting a wildfire because it is located deep in wooded, rugged terrain, on private property and because the fire is dormant.

No work is recommended on this fire at this time.

DIRECTIONS TO FIRE

The Pocahontas mine is located approximately 9.5 miles south of Glenwood Springs, CO near Sunlight Ski Area. Access to the fire must be coordinated with the landowner. From Grand Ave in Glenwood Springs, CO, take 27th St west and at the roundabout head south on Midway Ave. After 1.3 miles, take the slight right onto 4 Mile Road. In 6.9 miles, the landowner's house is on right (west) side of the road.

Figure 4-52 – Pocahontas Mine Fire Location Map

4.4.11 South Canyon East Mine

Figure 4-53 – South Canyon East Mine Fire Looking Northeast

FIRE ACTIVITY

High

FIRE HAZARD RANKING

2 of 38

LOCATION

Latitude: 39°31' 55.58"

Longitude: 107°24' 49.02"

Nearest Town: Glenwood Springs, Colorado.

Landowner: Public, City of Glenwood Springs

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler, D, U, E

Strike and Dip: N 60W & 53 SW

Mining Method: Stope

Years of Operation: 1887-1951

Production: 924,974 tons East and West

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer
- Gas Composition
- Snowmelt Mapping
- Methane Seep Mapping

2017 – Emissions Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Aerial Imagery
- Seismic Data

FIRE DESCRIPTION

The South Canyon East Mine fire is located approximately 5 miles west of Glenwood Springs, CO and 1 mile south of the Glenwood Springs landfill. The site lies on land owned by City of Glenwood Springs. The South Canyon Mine, which is associated with both the South Canyon East and South Canyon West Fires, was active from 1887 to 1951 and produced 924,974 tons of coal.

South Canyon East can be separated into the upper and lower areas. The lower area is characterized by subsidence features up to 80 ft in diameter and 20 ft deep. No elevated ground temperatures or exhaust vents are found in this area. Intake holes are can be found in and around the subsidence features. The upper area is characterized by 1 acre of very active surface venting. Lower vents in this area are hot and dry with little water vapor or sulfur. The upper vents include more visible smoke, water vapor, sulfur, and creosote.

Mitigation and investigation at the South Canyon East fire have been ongoing since the late 1990s. Remedial activities have included abatement of burning coal waste piles, closure of adits, reclamation and sealing of subsidence features, and installation of thermocouples as part of geotechnical drilling investigations. Monitoring, investigation, and abatement activities are ongoing at the site.

FIRE OBSERVATIONS

The site was visited many times during the mine fire inventory because of concerning drought conditions. The final inventory visit was performed on November 19, 2018. The lower area was inspected and no elevated ground temperatures were found. One 4 ft diameter subsidence feature was found inside a larger, 80 ft diameter subsidence feature. At the bottom of the feature was a 1 ft wide, 5 in tall intake hole. Additionally, 4 intakes ranging in diameter from 4 to 8 inches were found in a line on the northern end of a large subsidence feature (Figure 4-54). In the upper area, vent temperatures ranged from 551°F to over 678°F. Areas of sulfur crystals and creosote were found at the top of the upper area burn zone (Figure 4-55). The vents along the road cut above the main fire area were 172°F, heavily stained with creosote, and releasing high concentrations of carbon monoxide, indicating that it is the youngest area of the fire.

Figure 4-54 – Intake Hole

Figure 4-55 – Creosote and Sulfur Build-up at Upper Vents

FIRE RISK AND RECOMMENDATIONS

The South Canyon East Fire is highly active. The main fire expression has very high ground and vent temperatures. The fire does not seem to be moving from its current location and most vegetation is at least 30 ft from high-temperature vents. The main concern with this fire would be the opening of new vent in the heavy vegetation that surrounds the fire expressions. There is moderate risk of wildfire because of the fire's activity. The fire access road and visibility from the road give it a moderate risk to trespassing. This risk will only increase as the City of Glenwood Springs develops trail systems in the South Canyon Area. The risk to potential trespassers is high because of the high temperature and toxic gases emitting from the vents.

Fire abatement is planned for 2019.

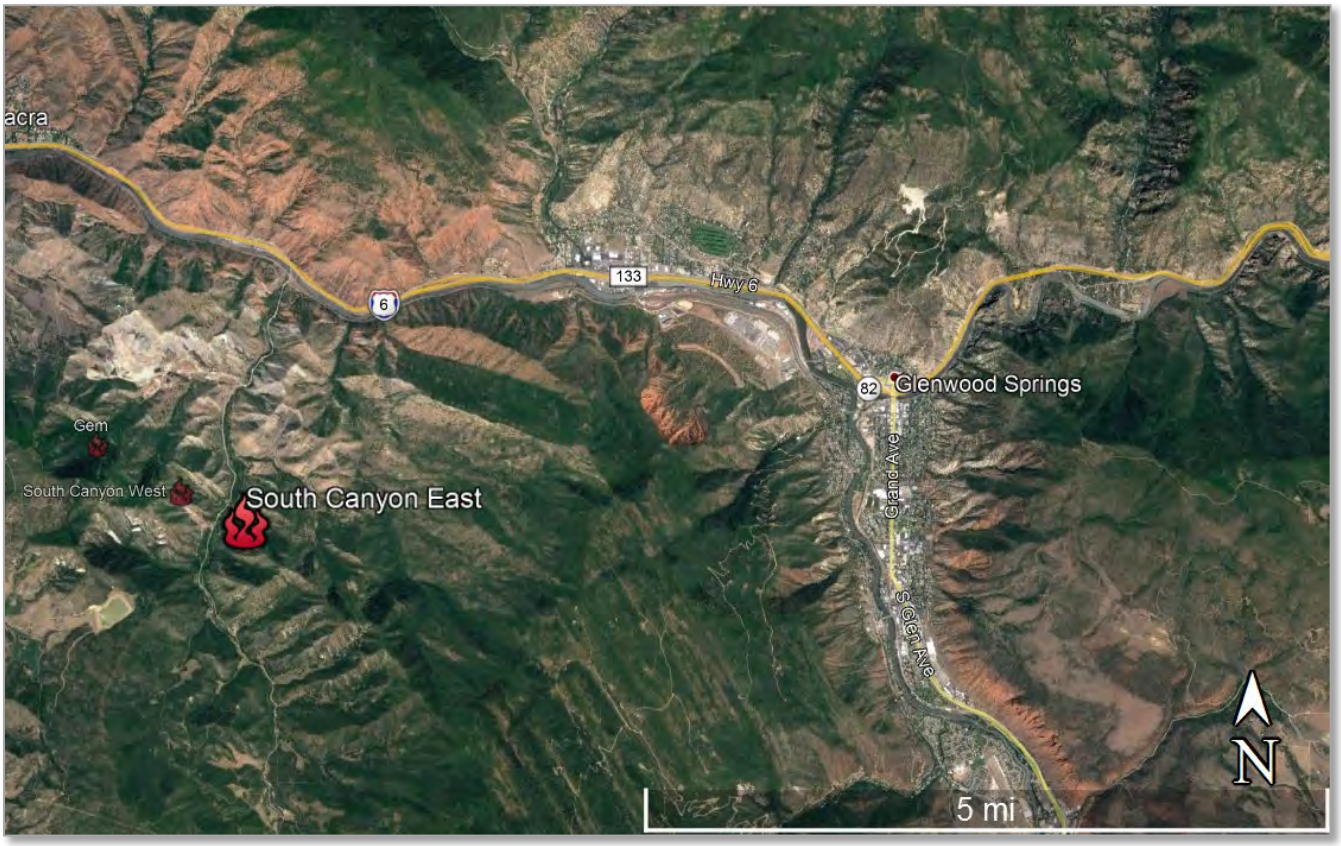

Figure 4-56 – South Canyon East Mine Fire Location Map

DIRECTIONS TO MINE

Take Interstate 70 west from Glenwood Springs to Exit 111. Take County Rd. 134 south for approximately 2.5 miles and fire will be on the left (East) side of the canyon.

4.4.12 South Canyon West Mine

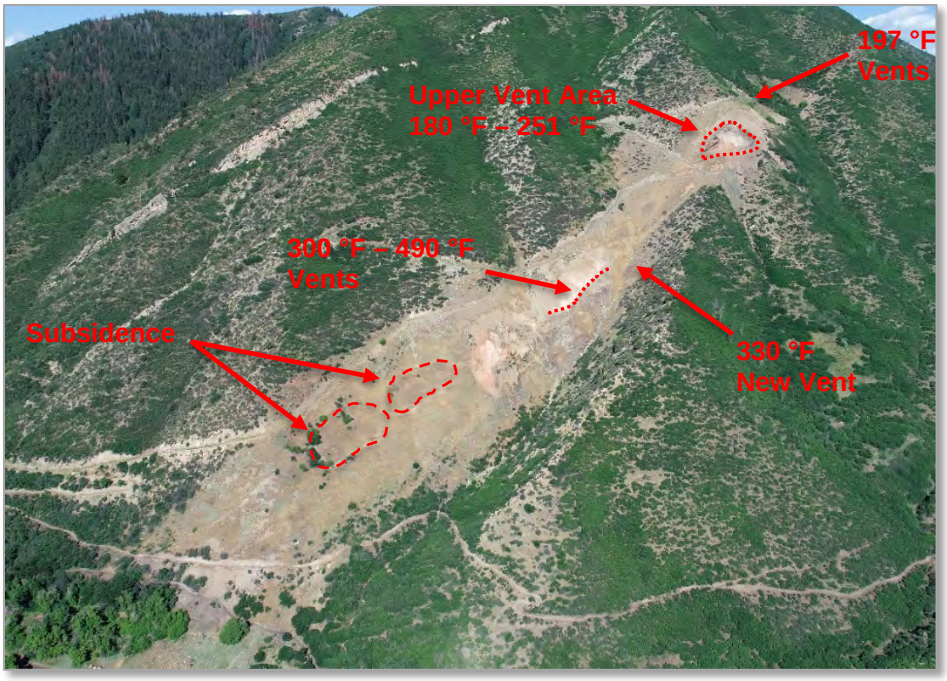

Figure 4-57 – South Canyon West Mine Fire Looking Southwest

FIRE ACTIVITY

High

FIRE HAZARD RANKING

1 of 38

LOCATION

Latitude: 39°32' 12.78"

Longitude: 107°25' 20.84"

Nearest Town: Glenwood Springs, Colorado.

Landowner: Public, City of Glenwood Springs

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler, D, U, E

Strike and Dip: N 60W & 53 SW

Mining Method: Stope

Years of Operation: 1887-1951

Production: 924,974 tons East and West

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer
- Gas Composition
- Snowmelt Mapping
- Methane Seep Mapping

2017 – Emissions Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Aerial Imagery

FIRE DESCRIPTION

The South Canyon West fire is located approximately 5 miles west of Glenwood Springs, CO and 1 mile south of the Glenwood Springs landfill. The site lies on land owned by City of Glenwood Springs. The South Canyon Mine, which is associated with both the South Canyon East and South Canyon West Fires, was active from 1887 to 1951 and produced 924,974 tons of coal.

South Canyon West fire covers 4 acres and extends for 1,200 ft along the two coal seam outcrops. This fire is believed to be the origin of the 2002 Coal Seam Wildfire, which burned 12,000 acres and destroyed 29 homes (McGregor, 2012).

Mitigation and investigation at the South Canyon west fire have been ongoing since the late 1990s. Remedial activities have included abatement of burning coal waste piles, closure of adits, reclamation and sealing of subsidence features, and installation of thermocouples as part of geotechnical drilling investigations. Monitoring, investigation, and abatement activities are ongoing at the site.

FIRE OBSERVATIONS

The site was visited many times in 2017 and 2018 during the mine fire inventory because of concerning drought conditions. This fire can be separated into a lower and upper area. The lower area is characterized by two large subsidence features each measuring approximately 170 ft by 70 ft. No elevated ground temperatures could be found within these features. 150 ft west of these features is a large fire expression with many hot and dry vents ranging in temperature between 300°F and 490°F. The ground around these vents is covered in white ammonium sulfate precipitate and high concentrations of CO.

The upper area consists of a ¼ acre fire expression area characterized by many dispersed vents with creosote and yellow sulfur crystal buildup. Vent temperatures in this area range from 180°F to 251°F. Vents in this area had concentrations of CO in excess of 1100 ppm. From this fire expression, an area of snowmelt 170 ft long and 10 ft wide extends along the coal seam to the west and terminates at a group of vents measuring 197°F (Figure 4-58). These vents appear to be well established and not moving into new areas of vegetation.

In February 2017, a new vent was found in the lower, Wheeler seam. This 330°F vent developed in an area with little vegetation in the bottom of the gully below the upper fire expression. When revisited on January 25, 2018 the new vent was inactive, though creosote staining could still be seen on the surface. On August 16, 2018 the vent was inactive but ground temperatures in the area were 212°F, 110°F above ambient.

Figure 4-58 – Snowmelt with Westernmost Vent

Figure 4-59 – New Vent, February 21, 2017

FIRE RISK AND RECOMMENDATIONS

The South Canyon West Fire is highly active. The lower fire expression vent temperatures approach 500°F. Most of the fire is well established, with vegetation a safe distance from the main vent areas. The new vent developing near the base of the gully is an exception. There is moderate risk of wildfire because of the fire's activity and development of the new vent area. The fire access road, new trail system, and visibility from the road give it a moderate risk to trespassing. This risk will only increase as the City of Glenwood Springs develops trail systems in the South Canyon Area. The risk to potential trespassers is high because of the elevated temperatures and toxic gases emitting from the vents.

It is recommended that vegetation be cleared from around the new vent area and that this area be monitored closely for changes in activity.

Figure 4-60 – South Canyon West Mine Fire Location Map

DIRECTIONS TO MINE

Take Interstate 70 west from Glenwood Springs to Exit 111. Take County Rd. 134 south for approximately 2.5 miles and fire will be on the left (East) side of the canyon.

4.4.13 Sunshine Mine

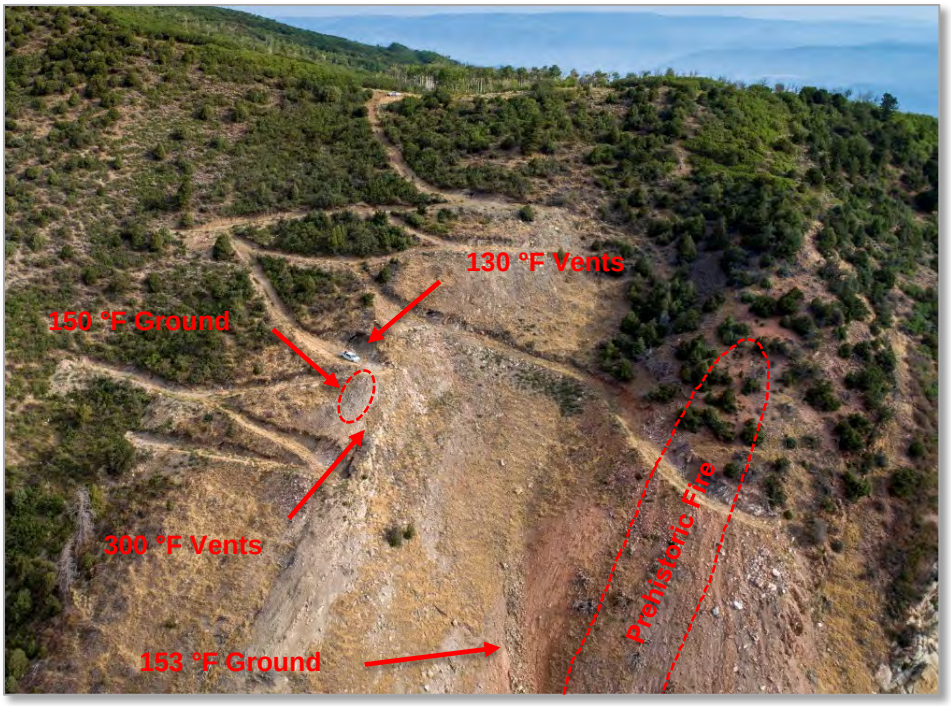

Figure 4-61 – Sunshine Mine Fire Looking North

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

3 of 38

LOCATION

Latitude: 39°24'6.02"

Longitude: 107°19'33.65"

Nearest Town: Glenwood Springs, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Sunshine

Strike and Dip: N18W & 40 SW°

Mining Method: Stope

Years of Operation: 1987-1903

Production: 434,911 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer survey
- Fissure mapping
- Snowmelt Mapping

2018 – Inventory
- 3D Photo mapping
- Snowmelt mapping
- Thermal mapping
- Orthophotography

FIRE DESCRIPTION

The Sunshine mine fire site is located approximately 10 miles south of Glenwood Springs, CO and 1/2 mile east of the Sunlight ski area. The mine fire is located on private property and accessed with permission of the landowner. The Sunshine Mine was operated from 1887 to 1903 and produced approximately 435,000 tons of coal from the 9 ft thick Sunshine Seam. This mine fire is a relatively new fire first reported in 2003. It is believed that a prehistoric outcrop fire 250 ft to the east ignited the Sunshine mine workings. The fire expression area covers approximately ¼ acre along the ridgeline formed by sandstone overlying the Sunshine coal seam.

In 2015 and 2016, two phases of drilling occurred totaling 15 boreholes. Conditions encountered included a variable assemblage of intact coal, shale and sandstone overburden, fractured ground, ash, rubble, and open mine voids. While drilling, the borings commonly exhausted heat and combustion gases, sometimes at high velocity, depending on the location with respect to the burning front. No boreholes drew in air, but venting was observed at 12 of 15 boreholes. Additionally, the drilling rods occasionally got stuck in caving boreholes. During this drilling, 9 thermocouples were installed to monitor underground fire temperatures. Between 2015 and 2018, temperatures in the boreholes showed limited fluctuation to indicate change in underground fire activity.

FIRE OBSERVATIONS

The fire was visited August 16, 2018 to gather surface data, analyze potential fire risks, and perform a visual and thermal drone flight. The thermal data was collected first to allow for a targeted surface inspection. The majority of the fire expression is isolated to the ridgeline formed by the sandstone that overlies the Sunshine coal seam. The

Sandstone outcrop above Pad 1 has many small, low flowrate vents. The exhaust from these vents is 130°F and has a high water-vapor content evidenced by moss growth around the vent openings. The main area of the fire expression occurs 30 ft south of Pad 1 and is a 30 ft by 20 ft area of hot ground measuring 150°F (Figure 4-62). The area is completely bare of vegetation. Another 30 ft south of the large feature is a low-flowrate vent with an exhaust temperature of 300°F. Vegetation was within 2 ft of this vent. The exhaust was hot and dry, indicating an older region of the fire. Another hotspot was inspected that was located at the bottom of a gully 170 ft east of the main fire expression. This hotspot was 153°F and located in an area of no vegetation. This hotspot is believed to be associated with the prehistoric outcrop fire.

Figure 4-62 – Main Fire Expression

FIRE RECOMMENDATIONS

The Sunshine Mine fire is moderately active. The fire poses a high risk of surface fire because of vegetation near the 300°F vent. The fire poses a moderate public safety risk because of unstable ground conditions and some areas with high concentrations of CO. The risk to trespassing is limited because of the very steep terrain between the fire and 4 Mile Rd.

It is recommended that vegetation be removed around and upslope of the 300°F vent to reduce the risk of fire.

DIRECTIONS TO MINE

The Sunshine mine is located approximately 10 miles south of Glenwood Springs, CO near Sunlight Ski Area. Access to the fire must be coordinated with the landowner. From Grand Ave in Glenwood Springs, CO, take 27th St west and at the roundabout head south on Midway Ave. After 1.3 miles, take the slight right onto 4 Mile Road. In 6.9 miles, the landowner's house is on right (west) side of the road.

Figure 4-63 – Sunshine Mine Fire Location Map

4.4.14 Vulcan Mine

Figure 4-64 – Vulcan Fire Looking Southeast

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

4 of 38

LOCATION

Latitude: 39° 33'31.73"

Longitude: 107° 29'59.85"

Nearest Town: New Castle, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Grand Hogback

Seam: Wheeler

Strike and Dip: N 63W & 47

Mining Method: Stope

Years of Operation: 1892-1918, 1956-1962

Production: ~500,000 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Gas Composition
- Snowmelt Mapping
- Methane Seep Mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Aerial Imagery
- Snowmelt mapping

FIRE DESCRIPTION

The Vulcan Mine Fire is located 2 miles southeast of New Castle, CO on the Grand Hogback, south of the Colorado River. The fire is located on private property and accessed with permission of the landowner. The Vulcan Mine was operated from 1892 to 1918 and closed after multiple explosions. The mine was reopened in 1956 and then closed in 1962 by fire. The fire area spans approximately 400 yards along the seam and is 10 yards wide in which the 7 distinct fire expressions are present and occur on north-south ridges.

FIRE OBSERVATIONS

The fire was visited in February 21, 2018 to gather surface temperatures, vent temperatures, gas compositions, analyze potential fire risks, and collect drone thermal and mapping images. This site visit was performed after 2 inches of overnight snowfall that allowed for precise mapping of the fire extent by delineating the snowmelt boundaries. The air temperature was 18°F and ground temperature was 12°F. No surface heating from the sun had occurred. The fire expression temperatures ranged from 28°F to 46°F. Small, low-flowrate vents were observed at the fire expressions. The venting air temperatures ranged from 52°F to 81°F. The venting gas did not contain elevated CO or H_2S but had lower levels of oxygen than ambient air. Very little odor was noticed at the fire expressions.

In July of 2017, a wildfire started near County Rd. 335 and burned through the Vulcan Mine fire area. This has resulted in increased erosion on the steep slopes and debris flows in the gullies. Increased erosion is expected until ground cover has reestablished itself.

Figure 4-65 – Large Subsidence Feature

The Vulcan Mine fire was revisited on August 27, 2018 after a 45 ft diameter subsidence feature appeared and had been steaming after a rainstorm (Figure 4-65). A drone flight was performed to create a 3D model of the new feature, look for other potential subsidence features, and collect thermal data of the site. No elevated ground temperatures were found near the new subsidence feature. Two other subsidence features were mapped and reported to DRMS. A four foot diameter subsidence feature was located 180 ft northwest of the new feature. Fractures have recently developed around an existing subsidence feature located 900 ft east of the new feature.

FIRE RECOMMENDATIONS

The Vulcan Mine fire's activity is low to moderate. The fire presents a limited risk of starting a surface fire, but the recent increased subsidence activity presents a significant risk to public safety. The fire is on private property, but nearby condominiums increase the likelihood of public trespassing onto the site.

It is recommended that access to the area near the 4 ft sinkhole be restricted or the sinkhole mitigated. Subsurface investigations could identify high-risk subsidence zones.

Figure 4-66 – Vulcan Fire Location Map

DIRECTIONS TO MINE

To access the site, take I-70 to Exit 105. Turn left (south) across the Colorado River and then turn left (east) on County Rd. 335. In 0.3 miles, turn right (south) onto private road. Park and hike up the Grand Hogback to the south.

4.5 Gunnison County

4.5.1 Bear Mine

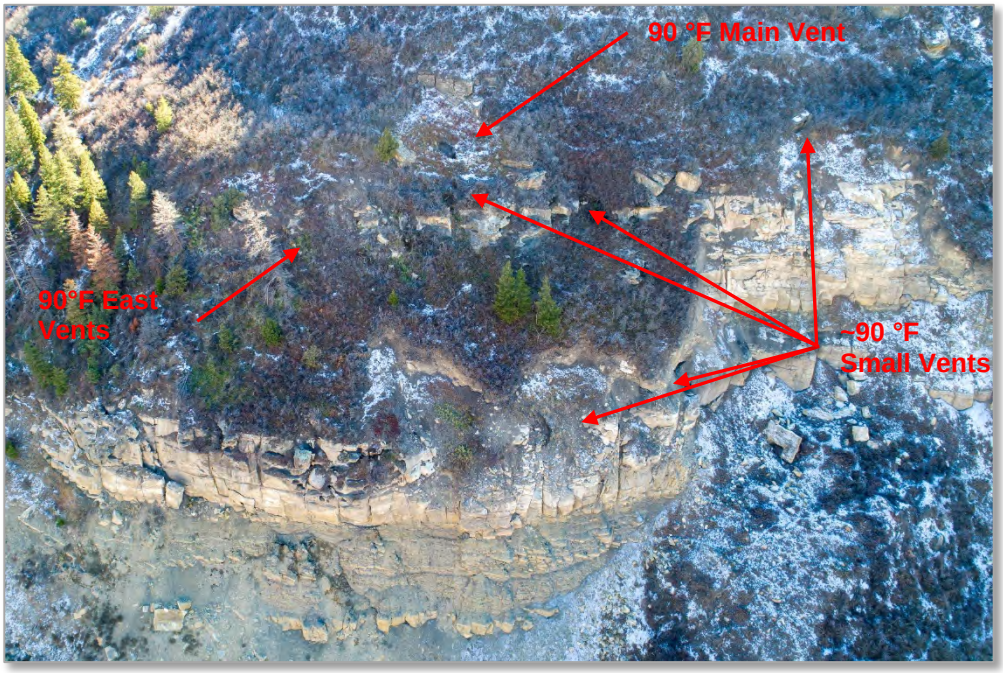

Figure 4-67 – Bear Mine Fire Looking South

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

9 of 38

LOCATION

Latitude: 38°55'33.38"

Longitude: 107°27'48.36"

Nearest Town: Somerset, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Somerset

Seam: C (Bear)

Strike and Dip: NA

Mining Method: NA

Years of Operation: NA

Production: NA

DATA COLLECTION

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Aerial thermal mapping.

FIRE DESCRIPTION

The Bear mine fire site is located approximately ¼ miles east of Somerset, CO atop an outcrop on the south side of the North Fork of the Gunnison River. A closed road bridge is used to access the property. The mine fire is located on private property and accessed with permission of the landowner. Little evidence of the mine exists at the surface, and it may have been buried by landslides.

Figure 4-68 – Main Vent

FIRE OBSERVATIONS

The fire was first visited on October 18, 2017 to inventory the fire activity and collect aerial imagery and data to develop a 3D model of the site. The fire expression is located on top of a cliff 400 ft above the valley floor. The fire is accessed by hiking up a draw to the east side of the fire and traversing west to the expression area. The main fire expression is a subsidence feature approximately 5 ft x 10 ft x 20 ft deep with two small openings at the bottom (Figure 4-68). This feature was venting high water-vapor content, 90°F mine fire exhaust. Northwest of the main vent is a line of smaller vents along the top of the ridge. These vents were also around 90°F.

The fire was inspected again on July 31, 2018 using a drone to collect thermal and orthophotography. Ambient temperature was 85°F, and the main venting subsidence feature was cooler than ambient. No other vents were found.

The fire was inspected for a third time the morning of November 24, 2018 using a drone with thermal camera. Immediately upon visual inspection it was apparent that more vents were active to the west of the large venting subsidence feature than during previous inspections. Thermal imagery revealed at least 19 vents dispersed across the fire area ranging from 60°F to 110°F. All of the vents appeared to have high water-vapor content evidenced by high amounts of steam and condensation around the vents. Most of these vents are on or above the cliff face in thick vegetation and would be very difficult to inspect safely on foot.

FIRE RISK AND RECOMMENDATIONS

The fire's activity and vent temperature are both low, but the steep terrain and unstable landforms add a level of unpredictability to the fire. The consequences of a wildfire are high due to the proximity to the town of Somerset. The steep terrain limits access to the fire, but the main vent presents a significant fall risk to trespassers. Signage and fencing were not in place as of October 2017, and it is recommended that they be installed around the subsidence and vent features. No fire abatement work is recommended for the Bear Fire because of it low vent temperatures.

Regular monitoring of the Bear Mine fire is recommended.

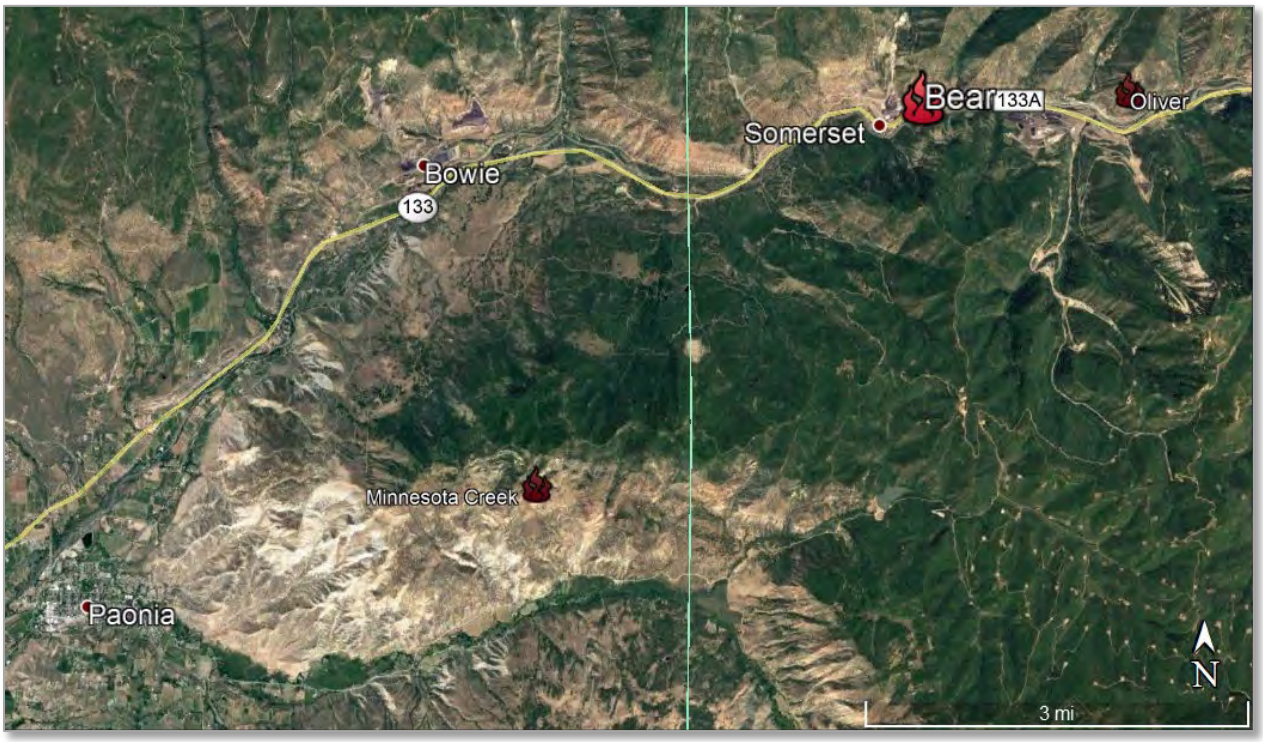

Figure 4-69 – Bear Mine Fire Location Map

DIRECTIONS TO FIRE

The Bear Mine Fire is located near Somerset, CO in Gunnison County. To reach this fire from Somerset, travel east from the post office to the unnamed street between 8th and 9th streets. Take unnamed road east down to the river and park at the bridge. Proceed on foot across the bridge. Fire is on cliff to the south.

4.5.2 Oliver Mine

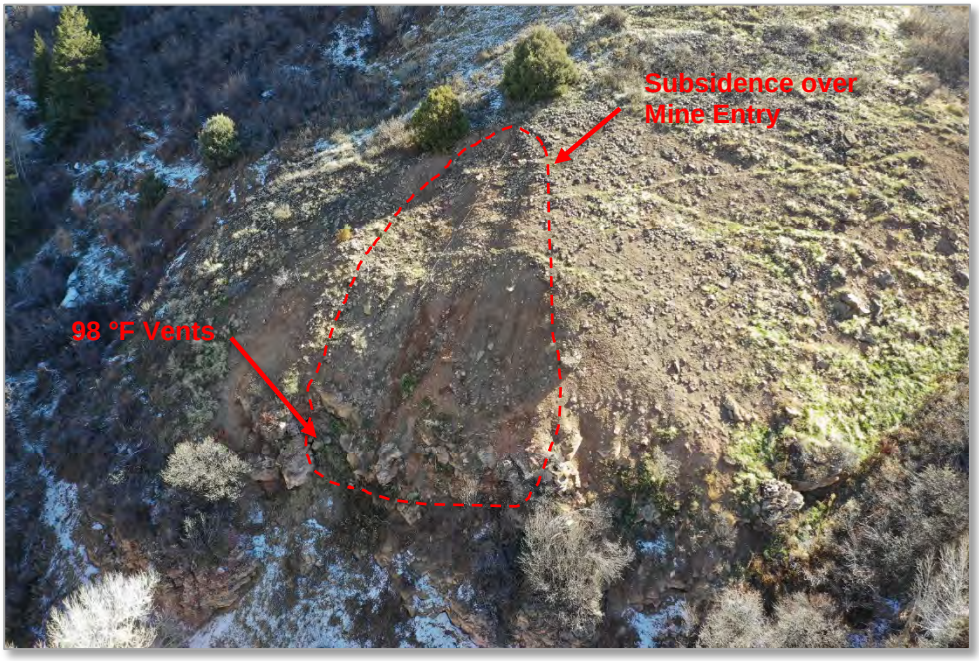

Figure 4-70 – Oliver Mine Fire Looking Southeast

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

21 of 38

LOCATION

Latitude: 38°55' 29.2"

Longitude: 107°25' 54.1"

Nearest Town: Somerset, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Somerset

Formation/Seam: Mesaverde/ NA.

Strike and Dip: N 90W and 3N

Mining Method: room and pillar

Years of Operation: 1923-1944

Production: ~1,200,000 tons

DATA COLLECTION

2005 - Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The Oliver Mine Fire is located 2 miles east of Somerset, CO on a hillside south of Hwy 133. The site is located on West Elk Mine property and accessed with permission of the mining company.

Figure 4-71 – 98°F Vent

FIRE OBSERVATIONS

The Oliver Mine Fire was visited on July 31, 2018 to inspect the site for fire activity and collect aerial imagery and thermal imagery. Ambient temperature was around 90°F. A cluster of three vents was found near what is believed to be the original mine entrance (Figure 4-71). These vents were 98°F, low in oxygen, low in H_2S, no CO, and 2% methane. The vents were 6 inches in diameter but opened into a larger void space below the surface. A large subsidence feature was noted running south-southeast from the vents and possible entrance.

The top of the fire area had little vegetation and consisted mostly of bare soil and cobbles. Ground movement monuments with survey reflectors were found installed across the fire area.

FIRE RISK AND RECOMMENDATIONS

The Oliver Mine Fire presents a minimal risk of starting a surface fire because of its low fire activity and low vent temperatures. The risk to the public is moderate because of its proximity to and visibility from Hwy 133, steep slopes around the base of the site, and the high percentage of methane in the fire exhaust.

Snowmelt imagery was not collected with this inventory. Snowmelt imagery could help with mapping the extents of the fire activity. It is recommended that snowmelt imagery be collected for inclusion with the next mine fire inventory report.

No abatement action is recommended at this time.

Figure 4-72 – Oliver Mine Fire Location Map

DIRECTIONS TO FIRE

The Oliver Mine Fire is located east of Somerset, CO on Hwy 133. The address is approximately 6005 Hwy 133. From Somerset, CO, take Hwy 133 east for 2.2 miles. Fire will be on south (right) side of the highway. Park on the road north of the highway.

4.6 Jackson County

4.6.1 Riach Mine

Figure 4-73 – Riach Mine Fire Looking South

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

32 of 38

LOCATION

Latitude: 40°33' 37.44"

Longitude: 106°26’ 22.56"

Nearest Town: Walden, Colorado.

Landowner: private

MINE INFORMATION

Coal Field: Coalmont

Seam: Riach

Strike and Dip: N 30E & 15

Mining Method: Drift

Years of Operation: 1890-1916

Production: 357,500 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography

FIRE DESCRIPTION

The Riach Mine Fire is located approximately 14 miles southwest of Walden, CO. The mine has been referred to by many names, including Bimey, North Park No. 1 and Coalmont No. 1 (Rushworth, 1989). The mine produced 357,500 tons of coal from the 45 ft thick Riach seam from 1890 to 1919. An underground coffee-warming fire is believed to have started the mine fire in the winter of 1915-1916. The fire slowly burned throughout the mine workings, eventually forcing the closure of the mine in 1919 (Shellenberger, 1974). Over the next 50 years, the fire consumed the mine, collapsing the roof and creating a 12.5-acre pit. A surface sealing operation was undertaken in 1974, placing a 3- to 8-foot-thick cover over the active fire area along perimeter of the pit (Figure 4-74). An inspection in the late 1970s determined the fire was still active. In 2002, the fire was reported to have low activity on the east side of the fire, with vent temperatures 55°F-110°F (Renner, 2005).

Figure 4-74 – 1974 surface seal

FIRE OBSERVATIONS

Figure 4-75 – Venting Fracture w/ Moss

The fire was visited on July 2, 2018. The pit was thoroughly inspected for evidence of fire activity. Substantial amounts of clinker that litter the site demonstrate the scale of this once highly active coal fire. The features mentioned in previous inventory reports were found on the eastern edge of the pit. The eastern rim of the pit is characterized by terraces created during the 1974 surface seal with intermixed large subsidence features and fractures. The previously active northernmost vents in this area were found to be dormant and infilled with loose material. Ground temperatures around the vents were not elevated, and vegetation was noticeably denser than in pictures from the 2005 inventory report. A series of moss-lined vents along a fracture 100 ft south of the dormant vents were venting at 58°F, 12°F over ambient ground temperatures (Figure 4-75). No sulfurous odor was observed emitting from these vents.

While inspecting the southwest rim of the pit, periodic smells of coal combustion odors were noticed. It was traced back to coal refuse pile near the entrance road to the site located at 40°33'38.85" N, 106°26'32.59" W. This pile was emitting some CO and had areas of tar-like material and ammonium chloride buildup.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is low, with few low-temperature vents along one fracture. The potential risk of this fire starting a surface fire is low because of this low activity. The public safety risk to trespassers is low because of the remote location of the site, lack of major surface features and low vent temperatures.

No abatement activities are recommended for this site. A snowmelt or thermal drone flight would help determine the extent of the fire and is recommended for the next inventory.

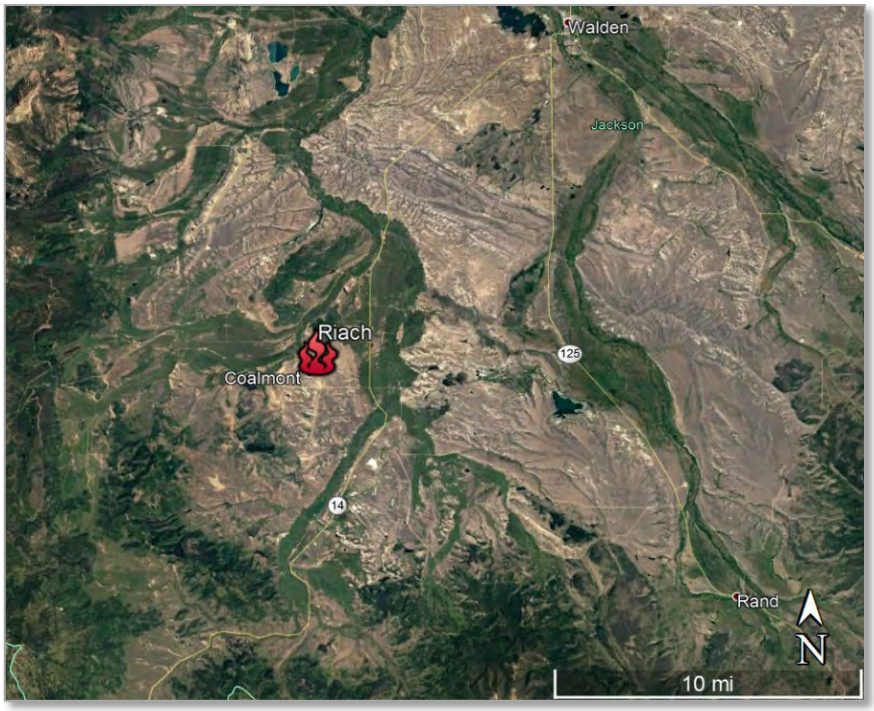

Figure 4-76 – Riach Mine Fire Location Map

DIRECTIONS TO FIRE

To get to the Riach Mine Fire from Walden, CO, take CO-125 South for 1.1 miles and turn right (west) onto CO-14 W. Stay on CO-14 W for 11.4 miles then turn right (west) onto County Rd. 24. Continue down County Rd. 24 for 3.7 miles. Fire is on the left (east).

4.7 Las Animas County

During the 2018 Coal Mine Fire Inventory two coal waste pile sites were visited in Las Animas County: the Morley Coal Waste Pile and the West Sopris Waste Pile.

4.7.1 Morley Coal Refuse Pile

Figure 4-77 – Morley Coal Refuse Pile Looking West

FIRE ACTIVITY

Very Low/Dormant

FIRE HAZARD RANKING

37 of 38

LOCATION

Latitude:
37° 2' 3.84" N

Longitude:
104°30' 27.00" W

Nearest Town: Trinidad, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Trinidad

Seam: NA, Pile

Strike and Dip: NA

Mining Method: NA

Years of Operation: 1906-1956

Production: 11,000,000 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The Morley coal refuse pile fire is located approximately 10 miles south of Trinidad, CO on the west side of I-25. The mine fire is located on private property and accessed with permission of the landowner. The pile is composed of reject coal and rock from the Morley Mine, which operated from 1906 to 1956 and produced over 11 million tons of coal.

In November 2010, Colorado DRMS contracted Shannon and Wilson, Inc. to observe and monitor fire abatement on the Morley waste dump. Over the next five months, the fire was extinguished by excavating, quenching the fire with water and firefighting foam, and backfilling. Approximately 60,000 cubic yards of burning coal refuse was quenched requiring 1.5 million gallons of water and 4,600 gallons of foam concentrate (Sorenson, 2011).

FIRE OBSERVATIONS

The fire was visited in January 2018 to determine the fire's activity and analyze potential fire risks. The site was visited over two days before and after an overnight snowfall of 2 inches, allowing for the collection of snowmelt pictures. No venting, elevated surface temperatures, or odor was observed at the site. Snowmelt pictures, as seen in Appendix A, show no indication of fire activity.

FIRE RISK AND RECOMMENDATIONS

This fire presents a very low risk of wildfire and a low risk to the pubic despite the relative ease of access onto the refuse pile. This is because of the lack of surface fire expression and the absence of subsidence.

No work is needed to reduce the risk associated with the fire. Revegetation performed during the abatement has established well. Areas of the refuse pile that were not excavated or reclaimed—primarily the northeast slope of the pile—show signs of erosion due to the 1.4:1 slope and little vegetation. It is recommended that the erosion control BMPs be implemented on the northeast slope to lessen the water-quality impacts associated with the refuse pile on Raton Creek (Figure 4-77).

Figure 4-78 – Morley Coal Refuse Pile Location

DIRECTIONS TO FIRE

From Trinidad, CO take Interstate 25 south for 7.3 miles to exit 6. Take the bridge across Raton Creek and turn left (south) on Fisher Peak Pkwy. In 2.6 miles, the fire will be on the left (northwest) side of the road.

4.7.2 West Sopris Coal Refuse Pile

Figure 4-79 – West Sopris Coal Refuse Pile Looking Southeast

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

25 of 38

LOCATION

Latitude:
37° 7' 45.66" N

Longitude:
104°34' 6.87" W

Nearest Town: Trinidad, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Trinidad

Seam: NA, Pile

Strike and Dip: NA

Mining Method: NA

Years of Operation: 1887-1928

Production: 8,921,000 tons

DATA COLLECTION

2017 – DRMS Pictures

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

2018 – Test Pit Investigation
- Test Pit Data
- Thermal Imagery

FIRE DESCRIPTION

The West Sopris coal refuse pile fire is located approximately 4 miles southwest of Trinidad, CO on the south side of Trinidad Lake. The mine fire is located across 2 private property parcels and accessed with permission of the landowners. The pile is composed of reject coal and rock from the Sopris No. 1 and 2 mines, which operated from 1887 to 1928 and produced approximately 9 million tons of coal.

DRMS has contracted Shannon and Wilson, Inc. to reshape and reclaim the West Sopris coal refuse pile, and work is anticipated to start in 2019.

Figure 4-80 – Snowmelt

FIRE OBSERVATIONS

In December 2017, Colorado DRMS contracted Tetra Tech to investigate potential fire activity within the refuse pile. On January 10, 2018 Tetra Tech met with DRMS and a contractor to observe the fire and develop a plan for the fire investigation. Coal combustion could be smelled on the pile, and white and yellow sulfur precipitate was observed. Shovel excavations near the precipitate exposed elevated temperature approximately 30°F above surface temperature. On January 11, 2018, an overnight 2-inch snowstorm allowed for the collection of snowmelt pictures to help delineate the potential fire areas for further investigation (Figure 4-80).

On March 13, 2018 Tetra Tech performed a test pit investigation to determine the extent and intensity of the fire (Figure 4-81). Four test pits were excavated: 3 inside the suspected active fire areas and 1 outside to be used as a control. An excavator was used to dig the test pits to an average depth of 20 ft. The maximum temperature recorded was 127°F, and heat was uniform across the pile. Fire was not intercepted in any of the test pits and conditions were representative of coal oxidation. It is believed that infiltration of water into the pile erodes fines from the coal waste pile matrix, allowing airflow and starting the oxidation process and heating of the area.

Figure 4-81 – Test Pits

FIRE RECOMMENDATIONS

Because of the lack of fire activity and the planned reclamation, no work is recommended for the West Sopris coal refuse pile at this time. It is recommended that efforts be taken during reclamation to reduce the pile's potential to oxide and/or catch fire. This could involve mixing the refuse with more inert material, effectively reducing the coal concentration of the pile and/or using a low infiltration/oxygen cover to reduce the potential for oxidation.

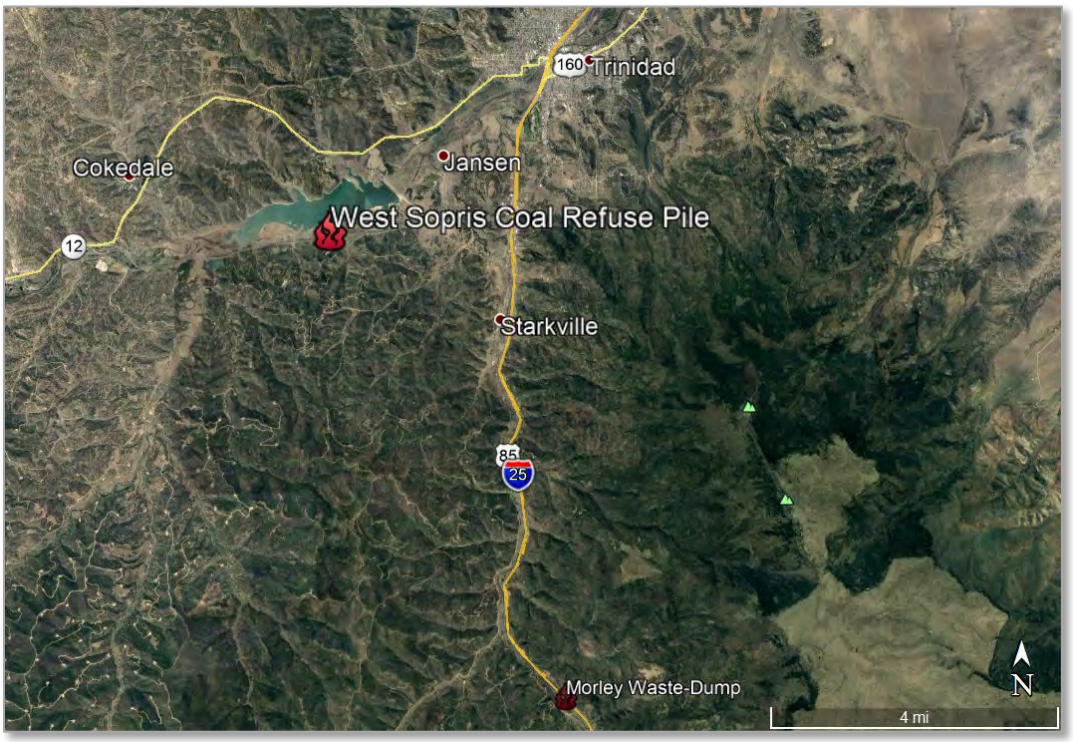

Figure 4-82 – West Sopris Coal Refuse Pile Location

DIRECTIONS TO FIRE

From Trinidad, CO take Interstate 25 south 1.7 miles to exit 11. Turn right (west) and then left (south) onto County Rd. 69.1. Take County Rd. 69.1 for 0.6 miles then turn right (northwest) onto County Rd. 18.3. In 0.6 miles, take the slight left (west) onto Old Sopris Rd. Stay on Old Sopris Rd for 2.5 miles then turn right (north) onto Sopris Mine Trail. Continue 1.3 miles, and the refuse pile will be in the valley to the northwest.

4.8 La Plata County

There are two known underground coal mine fires in La Plata County: the North Coal Mine Fire and the Soda Springs Coal Mine Fire. Both sites were visited in 2018. Observations from the site visits are summarized below.

4.8.1 North Coal Mine

Figure 4-83 – North Coal Mine Fire Looking South

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

18 of 38

LOCATION

Latitude: 37°2' 8.88"

Longitude: 108°6' 27.72"

Nearest Town: Durango, Colorado.

Landowner: Public -Tribal

MINE INFORMATION

Coal Field: San Juan

Seam: Unknown Seam, Fruitland Formation

Strike and Dip: NA

Mining Method: NA

Years of Operation: NA

Production: NA

DATA COLLECTION

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Thermocouple Temps

FIRE DESCRIPTION

The North Coal Mine fire site is located approximately 20 miles southwest of Durango, CO in the Southern Ute Reservation at approximately 6,300 ft elevation. The site is a previously reclaimed fire area accessed from dirt roads that support oil and gas operations in the area. Vehicle access to the site was prevented by a combo-locked gate marked with signage explaining elevated levels of H_2S gas.

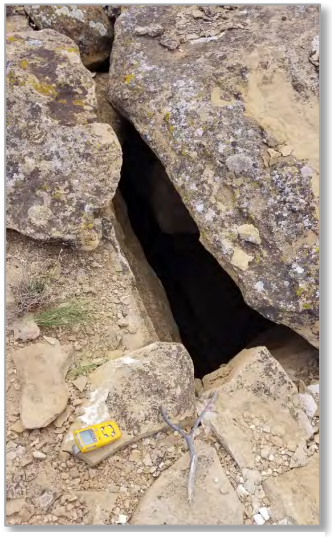

Figure 4-84 – Fracture

A feasibility test of power generation from underground coal fires was performed at the North Coal fire. The system appears to have been abandoned for some time.

FIRE OBSERVATIONS

Tetra Tech visited the North Coal Mine fire site on September 10, 2018 to acquire drone-based aerial photogrammetry along with a ground-based assessment of the site. The drone flights took off from a clearing near the southern edge of the reclaimed area and flew north-south transects over the North Coal site. Multiple ground fissures and fractures were discovered during the site walk, including some that appeared to have been filled or plugged with cement or another grouting material. A 1 ft wide, 20 ft deep northeast-southwest trending fracture was found

near the center of the clearing (Figure 4-84). This fracture was cool and not venting. Additionally, multiple thermocouples were observed and measured during the site evaluation. Temperatures ranged from 54°F to 267°F and generally increased towards the north end of the site. Wellheads with values were distributed across the north half of the clearing.

Figure 4-85 – Vent Around Vertical Pipes

An abandoned water tank and injection system at the north end of the site showed visible signs of exhausting heat, along with the odor of hydrocarbon combustion. The heat and exhaust were focused around a vertical vent at the center of the tank system and had 2 borehole pipes oriented vertically, sticking out of the vent (Figure 4-85). Thermocouples were found inside surface pipes and numerous small-diameter boreholes near the actively exhausting vent. Temperature in these thermocouples exceeded 660°F and IR temperature reading at the surface of the vent registered over 300°F. Further assessment of the site showed evidence of more than 50 permanently installed thermocouples. While inspecting the eastern portion of the clearing a sulfurous odor was noticed. It was traced back to wellheads just outside the clearing. The well was not approached because of H_2S concerns, but black corrosion (iron sulfide) could be seen in the valve opening, indicating high levels of the gas.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is high but appears to be well confined, reducing its risk of starting a surface fire. There is a considerable public safety risk associated with the fire, but the potential for trespassers is low because of the remote location, locked gate, and many poisonous gas warning signs. It is recommended that this site be evaluated in winter months for both snowmelt and thermal photography.

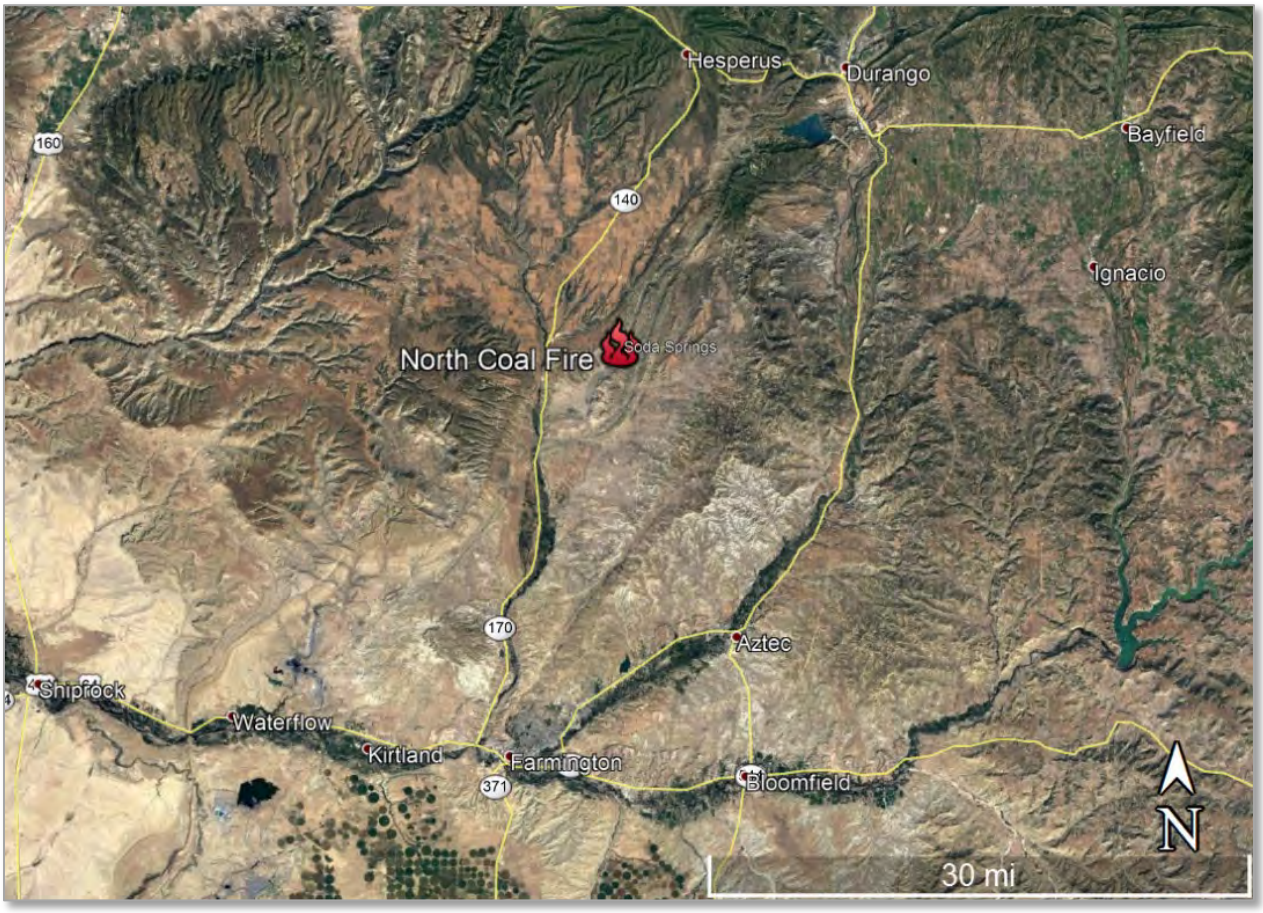

Figure 4-86 – North Coal Mine Fire Location Map

DIRECTIONS TO FIRE

To get to the North Coal Fire from Durango, Co, take US-160 west 2.8 miles to County Road 141 and turn left (southwest). Stay on County Rd. 141 for 11.4 miles and then turn left (southwest) onto CO-140 south. In 5.1 miles, turn left (south) onto County Rd. 134. Stay on County Rd. 134 (turns into Indian Rte 111) for 10.0 miles. Take the road to the right (southwest) for 0.25 miles, then turn right (northwest) again. Road ends in 0.5 miles at gate.

4.8.2 Soda Springs Mine

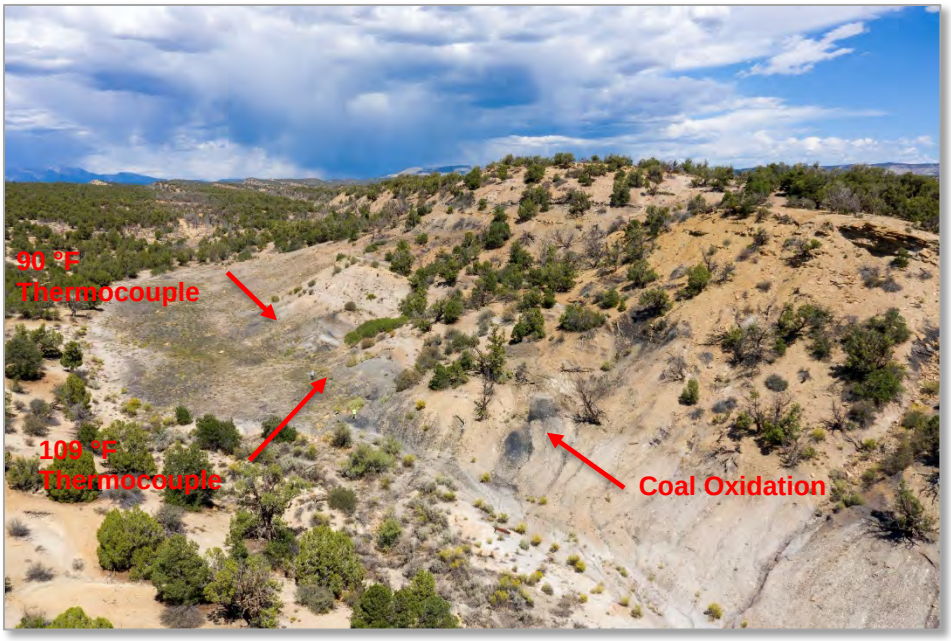

Figure 4-87 – Soda Springs Fire Looking North

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

34 of 38

LOCATION

Latitude: 37°3' 17.95"

Longitude: 108°5' 44.83"

Nearest Town: Durango, Colorado.

Landowner: Public -Tribal

MINE INFORMATION

Coal Field: San Juan

Seam: Unknown Seam, Fruitland Formation

Strike and Dip: NA

Mining Method: NA

Years of Operation: 1888-

Production: NA

DATA COLLECTION

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Thermocouple Temps

FIRE DESCRIPTION

The Soda Springs Fire is located approximately 19 miles southwest of Durango along the Fruitland Formation outcrop on Southern Ute land and one mile northeast of the North Coal Mine Fire. The fire is associated with the Fort Lewis Mine, which was operated from 1888 to 1941 and then reclaimed in 1986. The fire is located within a 3-acre clearing created during the reclamation of the site (Rodebaugh, 2011). The site is accessed by a network of dirt roads that support the oil and gas operations in the area.

FIRE OBSERVATIONS

On September 10, 2018 Tetra Tech conducted the inventory site visit and collected drone-based images of the fire area. Drone data were acquired over the reclaimed area, with additional ground and air-based perspective photos also collected. The odor of sulfur was noticeable on the southern edge of the site, though this may have been caused by the outcropping bedrock that contains sulfur. No hotspots were recognized in the vicinity of the sulfur odor. Two thermocouples on the southeastern edge of the reclaimed surface measured 90°F and 109°F. No active venting was found onsite, but a hotspot was discovered south of the reclaimed area in a weathered coal outcrop. Surface temperature at this hotspot was

Figure 4-88 – Vent Around Vertical Pipes

105°F over an area approximately 20 ft by 20 ft. It is likely that this hotspot is related to oxidation of coal near the surface. Revegetation efforts at the site appeared to be successful, based on the drone photography and ground-based inspection.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is low and poses negligible risk to of starting a surface fire. There is little public safety risk associated with the fire because of the lack of dangerous surface features, and the potential for trespassing is low because of the remote location and locked gate.

No abatement is recommended at this time. It is recommended that a snowmelt survey be conducted with the next inventory report.

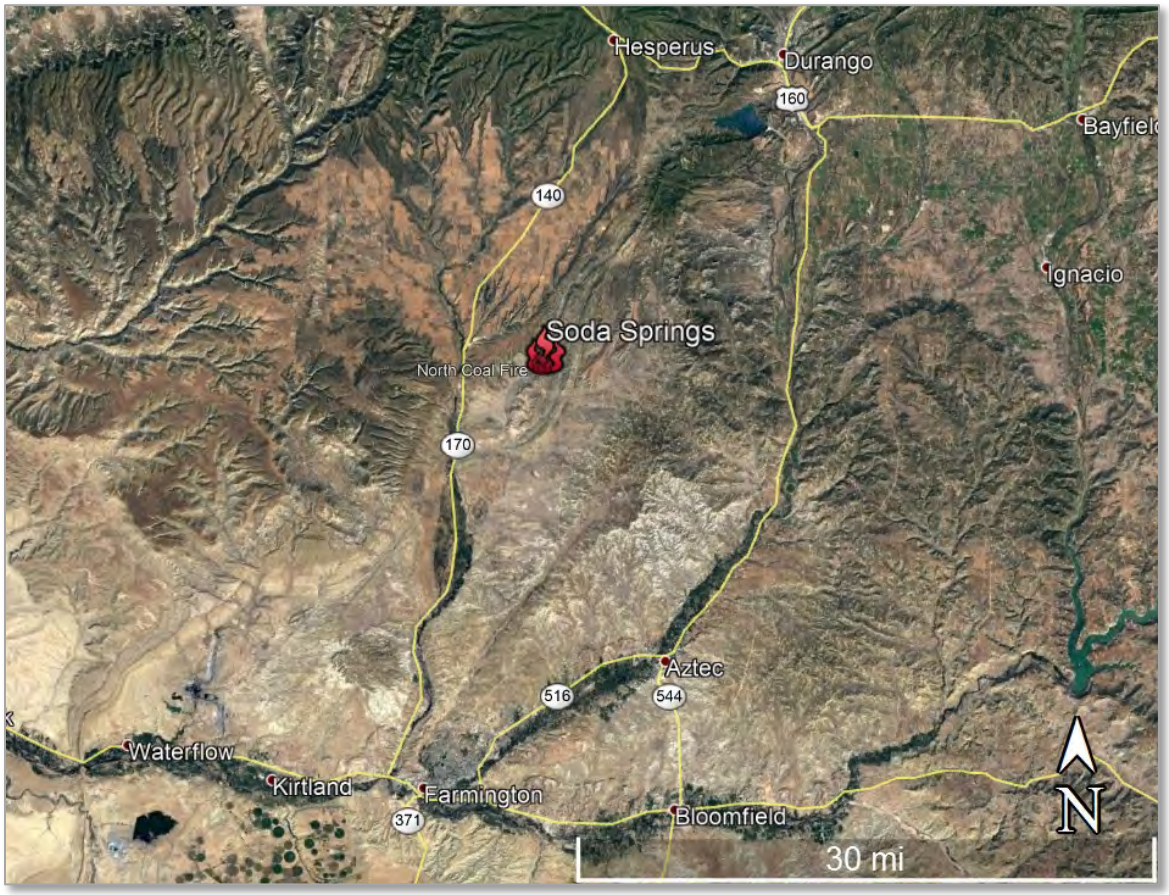

Figure 4-89 – Soda Springs Fire Location Map

DIRECTIONS TO FIRE

To get to the North Coal Fire from Durango, Co, take US-160 west 2.8 miles to County Road 141 and turn left (southwest). Stay on County Rd. 141 for 11.4 miles and then turn left (southwest) onto CO-140 south. In 5.1 miles, turn left (south) onto County Rd. 134. Stay on County Rd. 134 (turns into Indian Rte 111) for 8 miles then turn left (north) on to an unnamed road up Soda Springs Canyon. Drive for 0.25 miles and park on left at gate. The site is 0.5 miles north past the gate along the road.

4.9 Mesa County

Three underground mine fire sites were visited in Mesa County as part of the 2018 Mine Fire Inventory. No surface expressions of fires were observed at any of the sites during the 2018 site visits. Site conditions at each of the sites are described in the sections below and imagery for the sites is shown on Figure 4-90 through Figure 4-96.

4.9.1 Farmers Mutual Mine

Figure 4-90 – Farmers Mutual Mine Fire Looking Southeast

FIRE ACTIVITY

Very Low

FIRE HAZARD RANKING

33 of 38

LOCATION

Latitude: 39°13'26.48"

Longitude: 108°30'18.70"

Nearest Town: Grand Junction, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Book Cliffs

Seam: Cameo

Strike and Dip: N20W & 3°

Mining Method: Slope

Years of Operation: 1908-1951

Production: 46,782 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Fissure mapping
- Snowmelt mapping
- Coal outcrop mapping
- Mine maps

2018 – Inventory
- Snowmelt Pictures
- 3D surface mapping
- Orthophotography
- Aerial thermal mapping.

FIRE DESCRIPTION

The Farmer's Mutual Coal Mine fire site was inspected on April 11, 2018. The site is located approximately 12 miles north of Grand Junction, CO at the terminus of County Road 27 at the base of the Book Cliffs. The former mine is located in a box canyon that was home to several other coal mines, leaving numerous coal waste piles, timbers, and assorted mining waste scattered throughout the canyon. Site inspection activities included traversing the site to collect temperature data, condition observations, photographs, and aerial mapping.

Multiple visits were made to the site during 2001, 2002, and 2003 by Steve Renner. During the initial visit, he observed odors associated with coal combustion but did not find active surface expressions of the fire. During follow-up visits, no odors or visible evidence of the fire were observed. The site was visited again in 2012 and 2013 by Koveva. No evidence of a fire was observed during either visit, including no snowmelt during a snowstorm. The fire was considered dormant.

FIRE OBSERVATIONS

In 2018 multiple traverses were made at the site, across the outcrops at the base of the sandstone cliffs and along the top of the cliffs looking for signs of heat and/or venting. No odors, elevated temperatures, visible emissions, fractures, or mineral deposition/alteration were observed during the site visits. Some vegetation in the vicinity of the fire appears stressed, but it is unclear if the source of the stress is underlying heat associated with the mine fire, poor soils, drought, or any combination of factors.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is very low or dormant, and no indications of a mine fire were observed at the Farmer's Mutual site during the April 2018 site visit. The current risk to public safety is low because of the absence of heat or emissions at the surface.

Figure 4-91 – Farmer's Mutual Mine Fire Location Map

DIRECTIONS TO FIRE

The Farmer's Mutual Mine fire is located near Grand Junction, CO. To reach this fire from Grand Junction, travel north on N. 12th St. towards Grand Junction Regional Airport. Take a left on G Rd, then a right on 27 Rd. After approximately 3 miles, take a right onto the dirt road to stay on 27 Rd. Drive over a small water canal, and follow the dirt road for approximately 6.5 miles where the road becomes inaccessible to cars. Park. Follow the dirt path for about ¼ mile. The Farmer's Mutual fire is on the right.

4.9.2 Garfield Mine

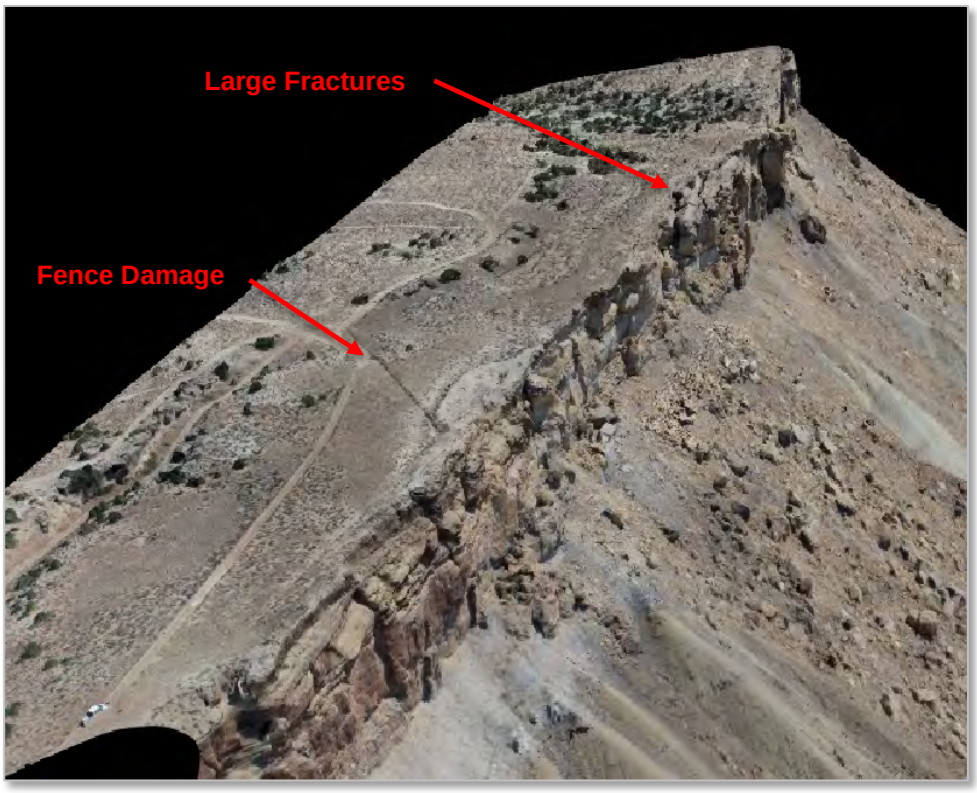

Figure 4-92 – 3D Model of Garfield Mine Fire Looking East

FIRE ACTIVITY

Very Low

FIRE HAZARD RANKING

22 of 38

LOCATION

Latitude: 37°7' 37.92"

Longitude: 108°22' 52.68"

Nearest Town: Palisade, Colorado.

Landowner: Public

MINE INFORMATION

Coal Field: Book Cliffs

Seam: Palisade Coalbed

Strike and Dip: N7W & 11N°

Mining Method: Drift

Years of Operation: 1897-1948

Production: 288,097 tons

DATA COLLECTION

2002 – Inventory

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Aerial thermal mapping.

FIRE DESCRIPTION

The Garfield Mine fire site is located approximately 2 miles northwest of Palisade, CO on the rim of the Book Cliffs. The site is accessed from I-70 using the Cameo exit and following BLM roads to the west and south. The mine fire is located on publicly accessible BLM land. *Note: A seasonal wildlife closure between December 1 and May 1 of each year prevents access to the site*. The mine has four openings (one main entry, three air courses) that are in the coal outcrop below the 150 ft cliff of the Rollins sandstone formation. The Garfield mine was operated from 1897 to 1948, producing approximately 288,000 tons.

The mine fire was first reported in July of 1966 by the operator at the adjacent Gearhart Mine. Four site investigations were performed from 1966 to 1968 to determine the appropriate control methods for the fire. In 1969 a fire control project was undertaken with plans to drill in from the top of the Rollins sandstone and collapse the overlying sandstone into the fire with explosives. The natural fractures of the sandstone and the newly formed fractures from the blasting program made this project unsuccessful in mitigating the fire. During site visits over the next 6 years, increasing amounts of slumping, heat, and venting in fault-sink areas were reported. In 1975, surface cover sealing was undertaken using a bulldozer to push

Figure 4-93 – Fence Damage and Subsidence

material into the fault-sink areas and reduce the air intake of the fire. Inspections in 1976 reported little or no heat near the mine entries or on top of the Rollins sandstone.

FIRE OBSERVATIONS

The fire was visited by Tetra Tech on July 30, 2018 to collect aerial photogrammetry and thermal imagery, 3D surface mapping, and analyze potential fire risks on site. No venting or elevated surface temperatures were observed at the time of the site visit. Aerial thermal images showed no elevated temperatures, and the shaded fracture zones were cooler than ambient surface temperatures (Figure 4-94). There was no evidence of the recent fire activity, and all subsidence features appeared to be the results of the earlier fire. Several subsidence features were noted onsite, aligning parallel to the main surface fractures near the south rim of the cliff. A small section of fence has some damage or is starting to deteriorate due to age (Figure 4-93).

Figure 4-94 – Large Fractures at Cliff Edge

FIRE RISK AND RECOMMENDATIONS

The fire activity at the Garfield Mine Fire site is very low and poses limited risk of wildfire. The subsidence and unstable ground combined with the proximity to the cliff face present the greatest risk to the public. It is recommended that the fence on top of the mesa be fixed and maintained to limit access and signage be placed to inform potential trespassers of the dangers.

Figure 4-95 – Garfield Mine Fire Location Map

DIRECTIONS TO FIRE

The Garfield Mine Fire is located on the book cliffs northwest of Palisade, CO in Mesa County. To reach the fire from Interstate 70, take the Cameo exit, #46. Cross under the Interstate and take the frontage road north for 0.35 miles. Take the first left across the river and stay on the main road for ½ mile and turn right. Take road staying near the creek bed for 5 to 5.20 miles and turn left on road uphill to the south. The site is ½ mile up the road on the left.

4.9.3 Go Boy Mine

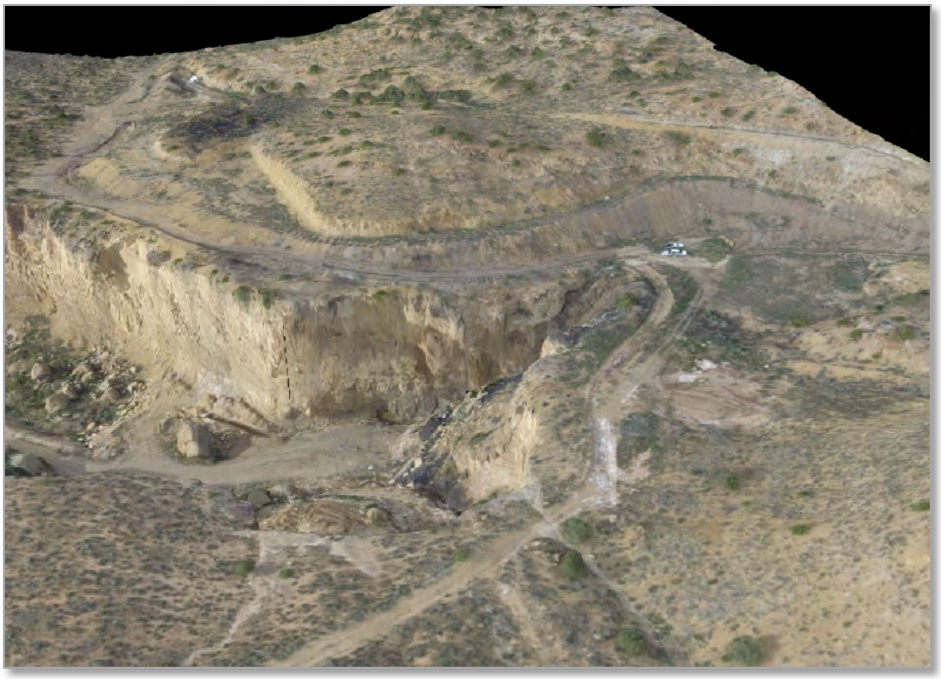

Figure 4-96 – 3D Model of Go Boy Mine Fire Looking Northeast

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

24 of 38

LOCATION

Latitude: 39° 7'33.24"N

Longitude: 108°18'39.60"

Nearest Town: Palisade, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Book Cliffs

Seam: Cameo

Strike and Dip: N25W & 2°

Mining Method: Slope

Years of Operation: 1911-1968

Production: 22,765 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Fissure mapping
- Snowmelt mapping
- Coal outcrop mapping
- Mine maps

2018 – Inventory
- Surface Feature Mapping
- 3D surface mapping
- Aerial imagery

FIRE DESCRIPTION

The Go Boy Mine fire site is located approximately 2.5 miles northeast of Palisade, CO. The mine fire is located on private property and accessed with permission of the landowner. The Go Boy Mine was a small production mine operating from 1911 through 1968.

In June 2002 it was reported that the fire showed no signs of activity. No subsidence features or vents were observed and there was no smell of coal combustion detected. It was determined that the fire had very low activity or was dormant (Renner, 2005).

In 2013, Koveva Ltd. observed very slight activity near the coal seam outcrop but noted that it did not melt snow on a heavy snow day. They listed the fire as dormant.

A representative of the landowner was present during the site visit and commented that he had not seen any indications of a fire since remediation was completed in 1985.

FIRE OBSERVATIONS

The site was visited April 12, 2018 to look for surface indications of the underground coal mine fire. The site was walked and flown with a drone to collect aerial imagery and elevation data. There were no signs fire at the surface and no odors were detected.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is very low and almost dormant, and thus presents very little risk to the public and of starting a surface fire. No dangerous surface features are present at the site, so the fire poses little public safety risk. The site is located on private property behind a locked gate, so the risk of trespassing is low.

No fire abatement is recommended for the Go Boy Mine. It is recommended that snowmelt and thermal imagery be collected for the next inventory to check for elevated ground temperature.

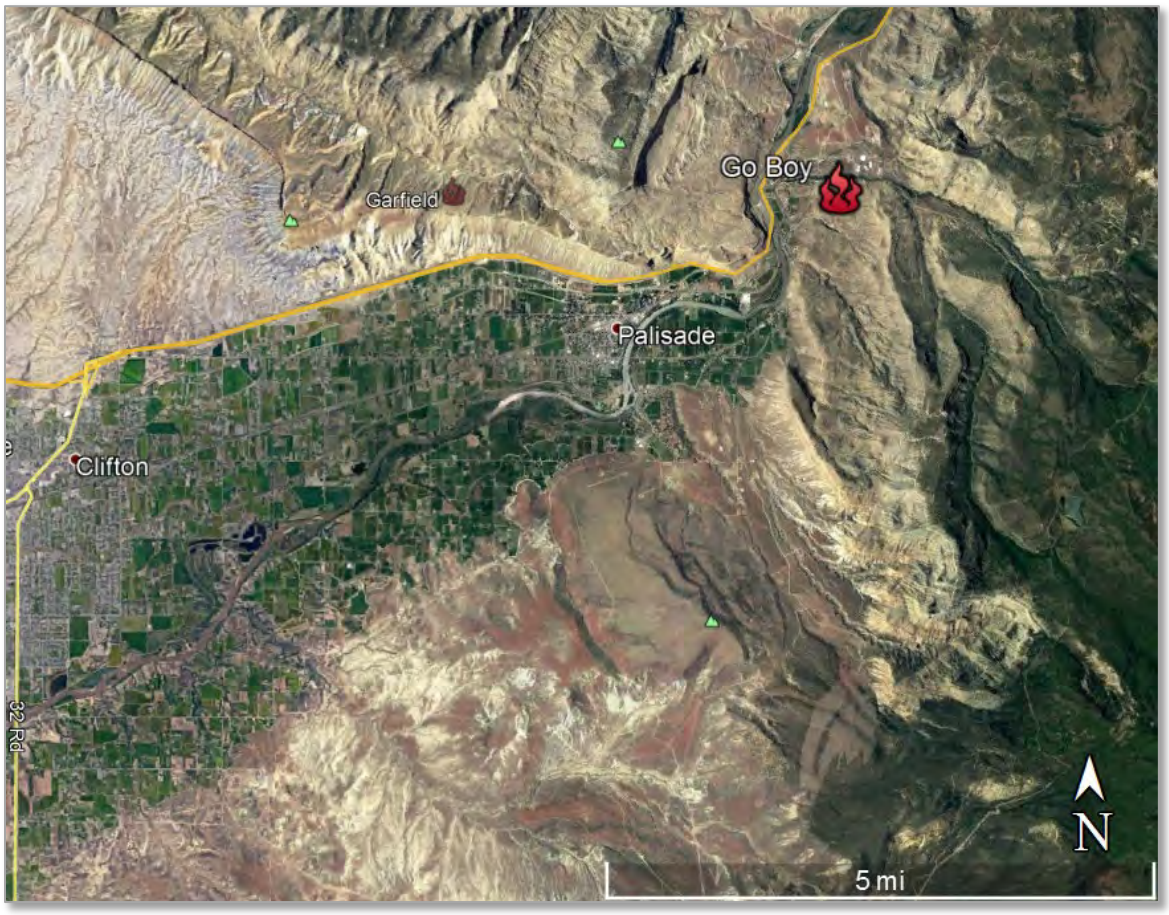

Figure 4-97 – Go Boy Mine Fire Location Map

DIRECTIONS TO FIRE

The Go Boy Mine is approximately 2.5 miles northeast of Palisade, CO. To reach this fire from Palisade, take G Rd./U.S. Hwy. 6E east. Take a slight right onto Rapid Creek Rd., which is the last possible right before merging onto I-70E. Travel approximately 0.6 miles on Rapid Creek Rd. and take a right onto an unnamed gravel road. Proceed for another ½ mile to reach the turnoff for the mine with a powered black gate that will have to be opened by the property owner. The Go Boy Mine is 0.4 miles on this road.

4.10 Moffat County

There are two known underground coal mine fires in Moffat County.

4.10.1 Axial Mine

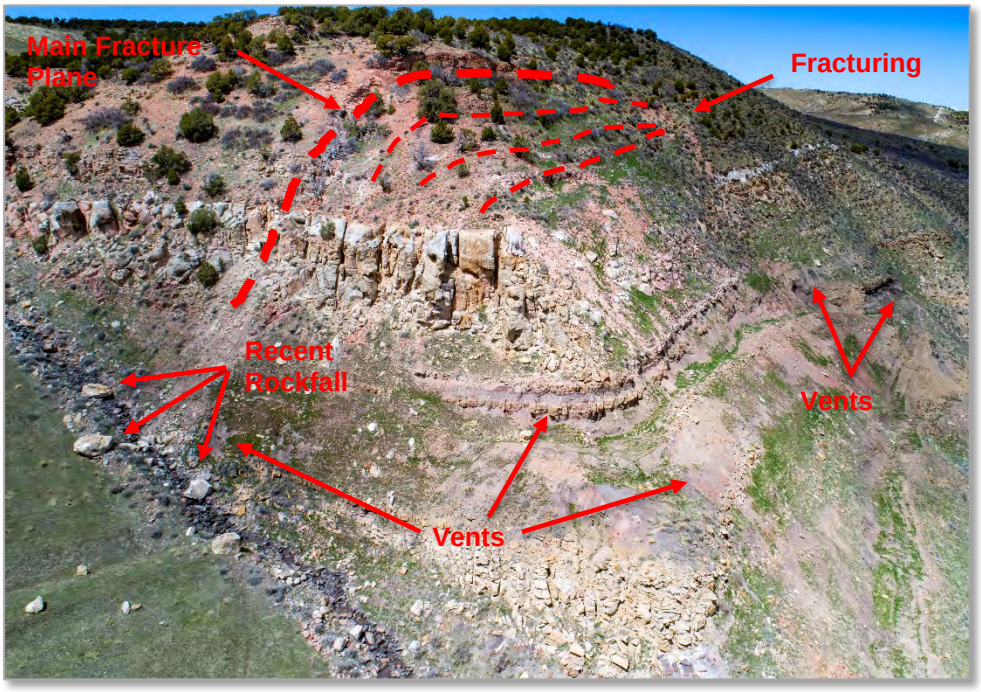

Figure 4-98 – Axial Mine Fire Looking Northwest

FIRE ACTIVITY

High

FIRE HAZARD RANKING

5 of 38

LOCATION

Latitude: 40° 15' 45.09"

Longitude: 107°47' 27.06"

Nearest Town: Meeker, Colorado.

Landowner: Private and Public

MINE INFORMATION

Coal Field: Danforth Hills

Seam: Collom, A

Strike and Dip: NA and 2°

Mining Method: NA

Years of Operation: 1914-1952

Production: 640,000 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Snowmelt mapping
- Surface feature mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs
- Thermocouple Temps

FIRE DESCRIPTION

The Axial Coal Mine Fire—also known as the Streeter/Collom—is located 18 miles north of Meeker, CO on the west side of Highway 13. The fire is located within the Colowyo Mines permit boundary and is located 2 miles north of the open pit of that mine. The Collom and then Streeter mines operated from 1914 to 1951, producing approximately 640,000 tons of coal.

In 1953, a mine fire in the Streeter mine workings was reported to the State Coal Mine Inspection Division, but it is believed the fire may have started in 1951 as the result of a cave-in in the Streeter workings. A surface seal project was undertaken in 1962 to reduce airflow to the fire. In 1971 the fire had expanded into a portal intersection with the then-active Red Wing Mine. The Axial Phase II project was performed in late 1972, involving construction of a surface seal and fire barrier in the underground workings. (Shellenberger, 1972). The fire cooled for 2 years but inspections in the mid-1970s indicated that new vents were forming, and the fire's activity was increasing (Rushworth, 1989). The fire's activity has been reported as high in inventories ever since.

FIRE OBSERVATIONS

The Axial Mine Fire was visited on February 13, 2018 to inventory surface features and assess fire risks. The fire area was inspected and thermocouple temperatures were recorded. The fire is characterized by venting along the

mid-slope line on both the south and east hillsides. More venting occurs on the top of the east hillside. Temperatures from thermocouples that were installed during a 2001 drilling project were recorded. In general, the thermocouples along the lower section of road range from 160°F to 410°F. A thermocouple on the southwest corner of the hillside recorded the highest fire temperature of 860°F. A large fracture that trends north-south was inspected. The rock in the main fracture subsidence area is thermally altered sandstone (Figure 4-99), although no elevated temperatures could be found. Movement in the fracture zone caused by fire activity could be causing rockfall on the southern end of the hillside. Three large boulders measuring approximately 20 ft in diameter have calved from the cliff face in recent years.

Figure 4-99 – Fracture Face and Subsidence Area

FIRE RECOMMENDATIONS

The Axial Mine Fire is highly active, with many complex surface features. It poses substantial risk of starting a surface fire. The fire area contains many vents and has the potential to subside along the developing fractures, which presents a sigificant risk to public safety. The risk of tresspasing is moderate because of the fire's proximity to HWY 13.

It is recommended that survey monuments be installed on the top of the hillside east of the main fracture to measure future movement of this hillside.

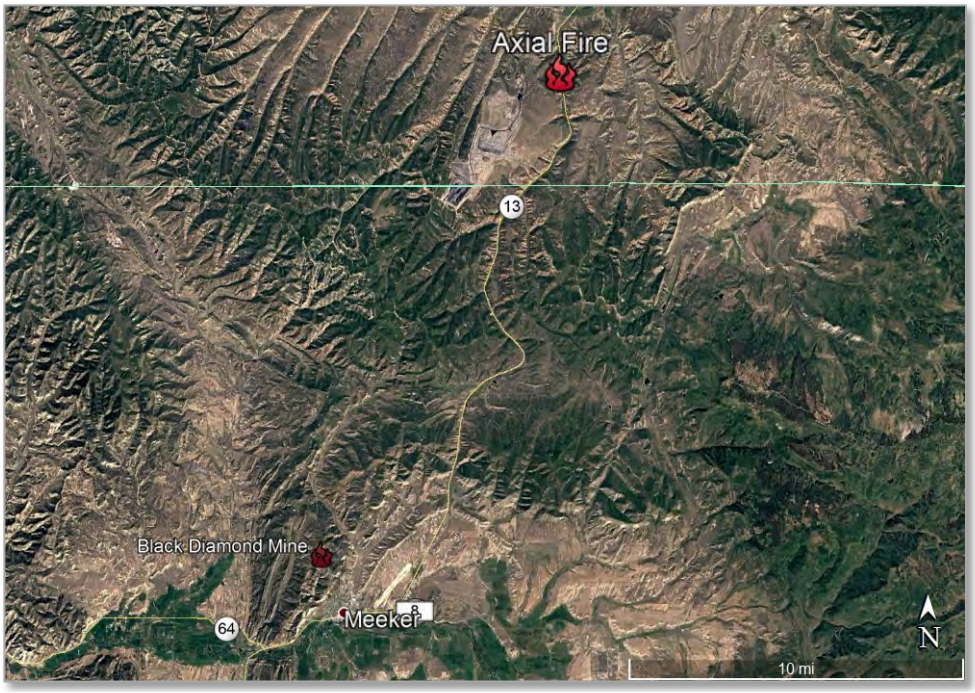

Figure 4-100 – Axial Mine Fire Location Map

DIRECTIONS TO FIRE

From Meeker, CO, take HWY 13 north for 19.8 miles and fire is on left (west) side of the road. Permission must be received from Colowyo Mine to enter their property.

4.10.2 Wise Hill Mine

Figure 4-101 – Wise Hill Fire Abatement Looking Southeast

FIRE ACTIVITY

High

FIRE HAZARD RANKING

30 of 38

LOCATION

Latitude: 40°25'44.31"

Longitude: 107°38'47.69""

Nearest Town: Craig, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Yampa

Seam: Hart, 2 rider seams

Strike and Dip: N30E and 8°

Mining Method: Drift

Years of Operation: 1940-1970

Production: 1,232,699 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer
- Methane Analysis

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The Wise Hill Mine Fire is located 5 miles south of Craig, CO on the east side of Hwy 13. The fire is located across private property and land leased by Peabody Energy from the State of Colorado. The Wise Hill Mine was operated from 1940 to 1970, producing over 1.2 million tons of coal.

The mine caught fire soon after it closed. Many attempts were made to extinguish the fire including two surface seals (1976, 1987), drilling and grouting (1995), and an attempt to flood the fire (2004), but the fire remained active. A large vent opening (3.5 ft by 2.5 ft) at the southern end of the site was backfilled in June of 2002 (Renner, 2005).

Mine fire management and investigation activities included vegetation clearing in 2009 and 2010 and exploratory drilling in 2012 and 2013.

In 2014, the State of Colorado contracted Tetra Tech to oversee drilling to determine the area and depth of excavation required to suppress the fire near the outcrop and reduce the oxygen supply to the fire deeper the in the mine workings. In 2015, fire abatement activities began with drilling, grouting and foam injections. In 2016 the excavation of portions of the mine fire started with the stockpile of topsoil and subsequent trench excavations. When warm overburden, ash, or coal was intercepted, the hot material would be blended with inert material and allowed to cool. Once the lowest seam was intercepted, the trench was backfilled,

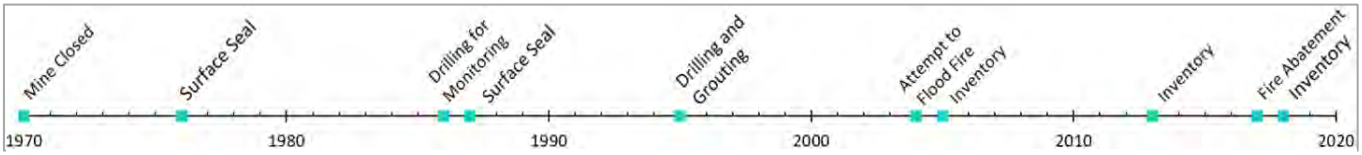

Figure 4-102 – Wise Hill Timeline of Events

and the process would start again in a new area. Over 345,000 cubic yards of material was excavated and backfilled over nine acres during this abatement.

FIRE OBSERVATIONS

The fire was visited throughout 2017 and 2018 to perform construction oversight of the fire abatement and monitor underground fire activity. Excavation activities were completed in late 2018 and the site was recontoured to match the existing landscape. Revegetation activities are scheduled for the spring of 2019 and the site will be monitored regularly.

FIRE RECOMMENDATIONS

Since intensive fire abatement was performed from 2015 to 2018, the Wise Hill Mine fire does not present a significant risk to public health or potential to start a wildfire. However, it is recommended that 6 months after completion of fire abatement reclamation activities the site be assessed to establish a baseline for post-abatement fire activity. This should include reporting of any remaining vents, drone thermal imagery, and borehole temperatures.

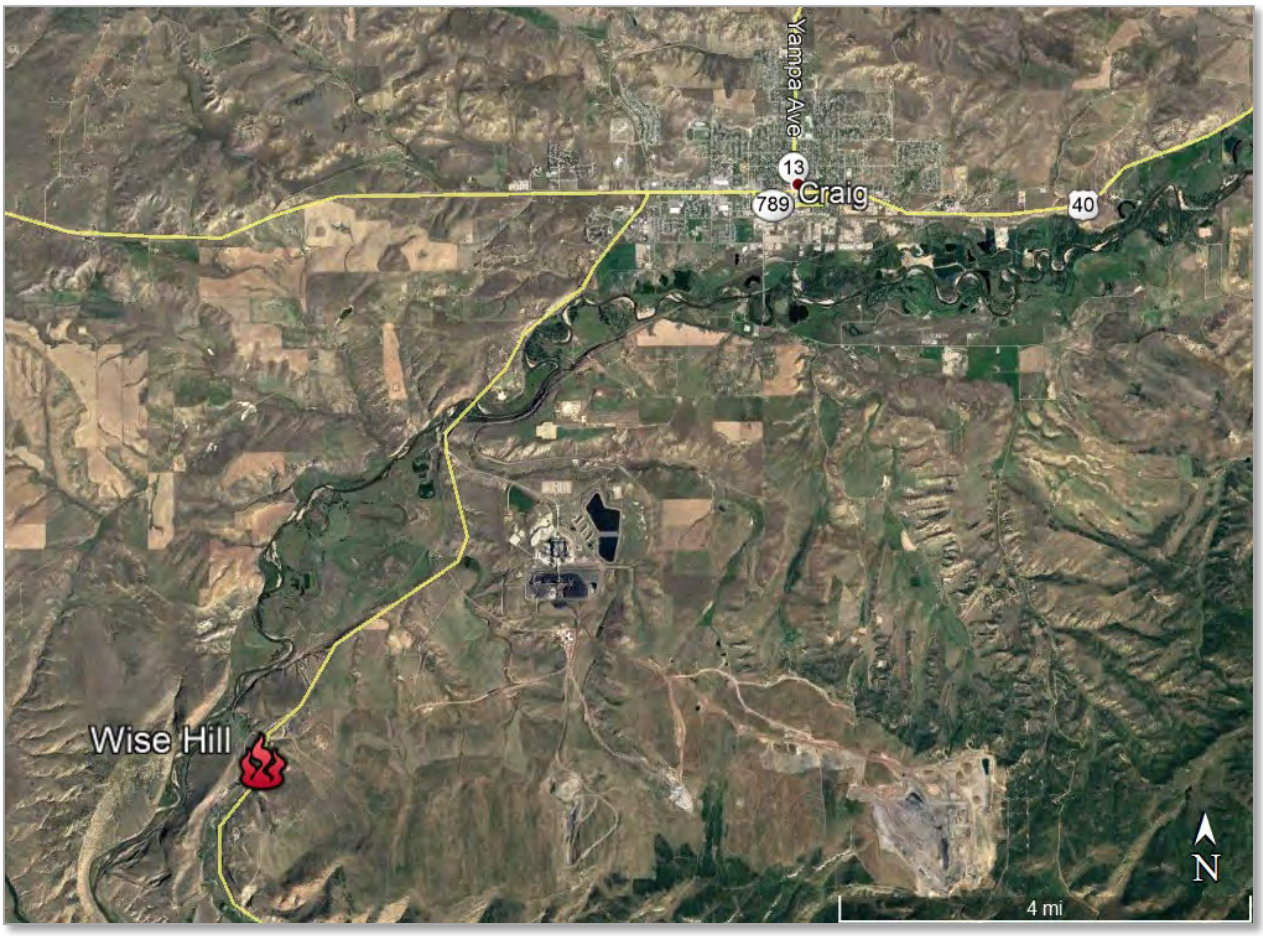

Figure 4-103 – Wise Hill Fire Location Map

DIRECTIONS TO FIRE

From Craig, CO, take Hwy 13 south of 7.6 miles. Fire is on left (east) side of road.

4.11 Montezuma County

Montezuma County currently has one coal mine fire, the McElmo Fire. This fire is located just outside the town of Cortez in the San Juan Coal Field.

4.11.1 McElmo Mine

Figure 4-104 – McElmo Mine Fire Looking North

FIRE ACTIVITY

Low/Dormant

FIRE HAZARD RANKING

20 of 38

LOCATION

Latitude: 37°20' 18.96"

Longitude: 108°34' 49.08"

Nearest Town: Cortez, Colorado.

Landowner: Public

MINE INFORMATION

Coal Field: San Juan

Seam: Unnamed, Below Dakota Formation

Strike and Dip: NA & 4°

Mining Method: Drift

Years of Operation: 1914-1924

Production: 7,124 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Not Inventoried

2018 – Inventory
- 3D surface mapping
- Orthophotography

FIRE DESCRIPTION

The McElmo Mine fire site is located 300 yards south of the intersection of 7th St. and S. Madison St. in Cortez, CO and is on City of Cortez-owned land. The McElmo Mine was operated from 1914 to 1924, producing approximately 7,100 tons of coal. The fire was accessed from the top of the bluff east of the fire, which is currently subdivided into lots for single-family housing.

Figure 4-105 – Former McElmo Entry

FIRE OBSERVATIONS

The fire was visited by Tetra Tech on September 11, 2018 to collect aerial imagery and photogrammetry, conduct 3D surface mapping, and inspect the site for signs of fire activity. The west and south sides of the outcrop were thoroughly inspected, and no evidence of active fire was encountered. Remnants of a mine entry were found and appear to have recently been used as transient shelter (Figure 4-105). No active or dormant vents were discovered, and no coal combustion or oxidation odors were noticed. Minimal deformation related to fire activity was discovered during the site visit.

An area resident who frequently walks near the site mentioned that after rainstorms large enough to produce runoff alongside the road to the water treatment plant, steam can be seen coming from an area approximately 60 yards south of the gate. The roadside channel in that area has been grouted along with a small sandstone ledge to the east (Figure 4-106). It is believed this work was completed to reduce infiltration and consequent oxidation of underlying coal. No elevated ground temperatures or exhaust vents were found in the area.

Figure 4-106 – Grout Seal in Sandstone Outcrop

FIRE RISK AND RECOMMENDATIONS

The fire's activity is very low and could be considered dormant if confirmed by a drilling investigation and a winter thermal drone flight. If indeed dormant, this fire does not present risk of wildfire. There is, however, considerable risk to trespassers because of the opening into the coal seam. People entering the confined space—possibly into old workings—could face hazardous mine atmosphere conditions and rock fall. There is also the potential of people unintentionally starting or reigniting a coal fire with a camp fire, since the opening shows signs of repeated overnight use. It is recommended that the mine entry be sealed off.

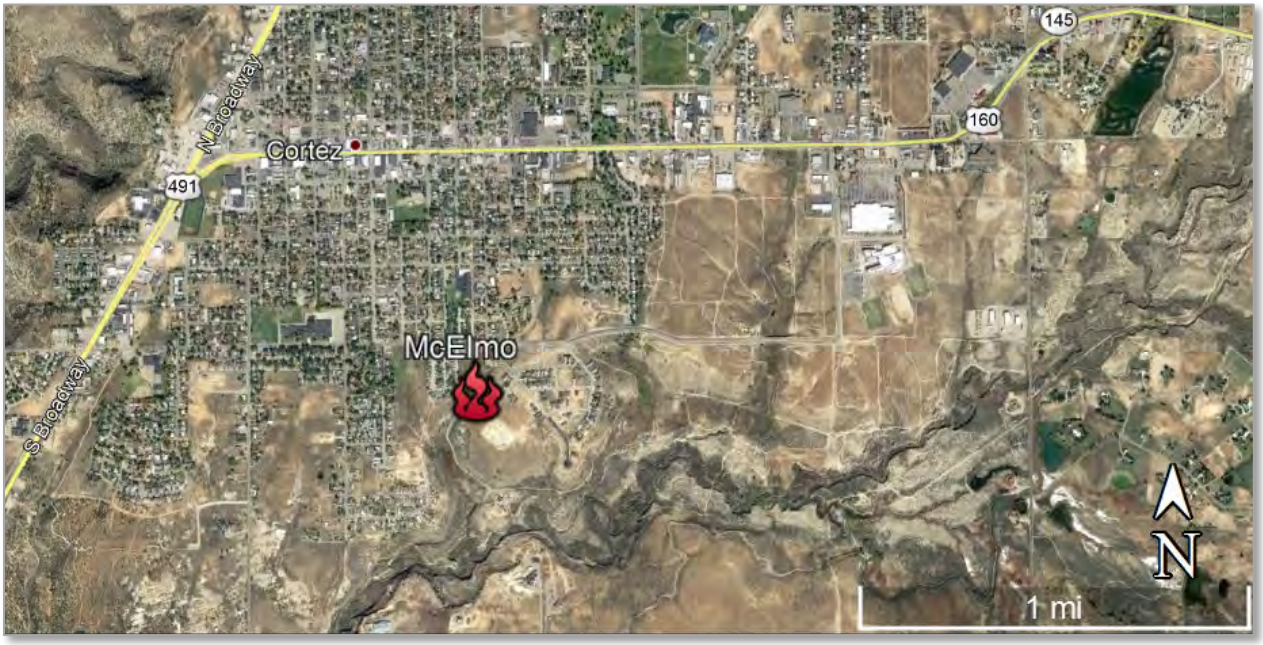

Figure 4-107 – McElmo Coal Mine Fire Location Map

DIRECTIONS TO FIRE

The McElmo Mine Fire is located on the south side of the town of Cortez along the access road to the city's north waste water treatment plant. This road is gated but the site can be easily accessed from the Southern Bluffs Subdivision. From the intersection of E 7th St and Bluffs Blvd, take Bluffs Blvd south to Jenning Dr. Jenning Dr. ends, but a dirt road continues out into an open dirt area. Park and walk west-northwest to the fire.

4.12 Ouray County

Ouray County is home to one coal mine fire, which is associated with the Slagle, or Bright Diamond, Mine. This fire is located in the Tongue Mesa Coal Field at an elevation of 9,000 ft, making it the highest mine fire in the state.

4.12.1 Slagle/Bright Diamond Mine

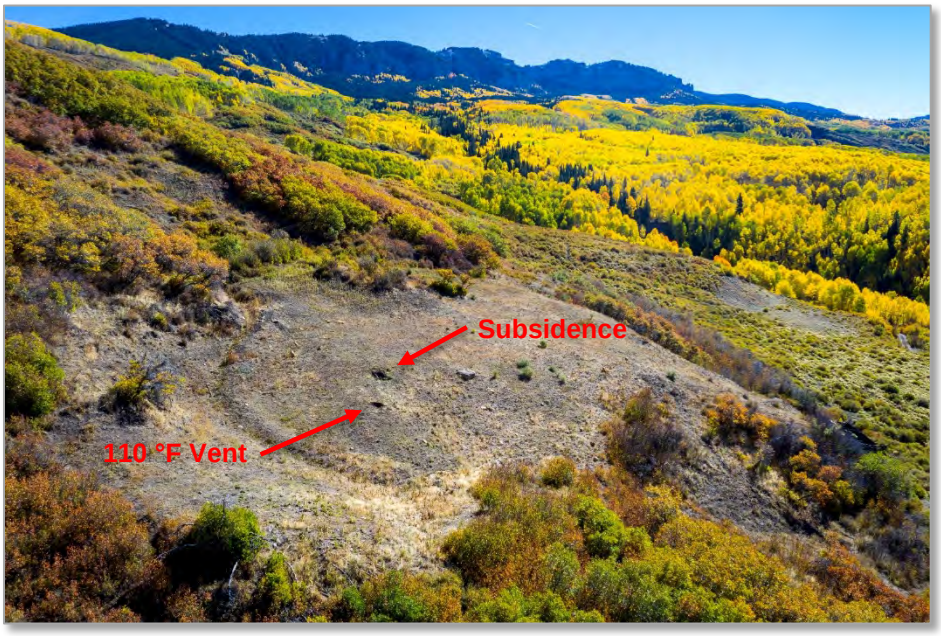

Figure 4-108 – Slagle Mine Fire Looking East

FIRE ACTIVITY

Low

FIRE HAZARD RANKING

31 of 38

LOCATION

Latitude: 38°16' 14.16"

Longitude: 107°39' 43.92"

Nearest Town: Ridgway, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Tongue Mesa

Seam: NA

Strike and Dip: NA

Mining Method: NA

Years of Operation: NA

Production: NA

DATA COLLECTION

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Vent temperature
- Surface feature mapping

FIRE DESCRIPTION

The Slagle Mine—also known as the Bright Diamond Mine—is located approximately 10 miles northeast of Ridgway, CO at an elevation of 9,100 ft. The fire is on private land accessed with the permission of the landowner. The landowner indicated that the fire steams after precipitation or in cold weather.

Figure 4-109 – Vent

The fire reportedly started in 1939. A surface seal was performed by the Bureau of Mines in 1951 to suffocate the fire (Shellenberger, 1954). In 2011, a 1-acre area of surface seal maintenance work was performed.

FIRE OBSERVATIONS

The fire was visited on September 28, 2018 to collect aerial imagery, thermal imagery, 3D surface mapping, and inspect the site for signs of fire activity. The site was accessed from County Rd. 4 through the Billy Creek state wildlife area. The site was flown before sunrise to accurately inspect the site with the thermal camera before the ground received any sun. The only surface temperature anomalies found with the thermal camera were in the

area of the surface seal maintenance performed in 2011. The area was thoroughly inspected for evidence of fire activity. A 5 ft diameter, 2 ft deep subsidence feature was found. The ground temperature in this feature was elevated 8°F above ambient ground temperature. Fifteen feet west of this feature is another subsidence feature measuring 4 ft in diameter and 1 ft deep. Within this feature is a 5 inch by 2 inch vent with a temperature of 110°F, which seems to originate from the direction of the east subsidence feature (Figure 4-109). The revegetation across the surface seal maintenance area appears to be uniform, indicating that ground temperature is not high enough to affect vegetation growth.

The area outlined in the 2005 inventory report as the presumed surface expression was inspected and no elevated ground temperatures or evidence of fire could be found. This area is not believed to be part of the active mine fire area.

FIRE RISK AND RECOMMENDATIONS

The fire's activity is low, with only 1 active low-temperature vent. The fire poses a limited risk of starting a surface fire. The fire poses very little risk to public safety given its remote location, 3 miles by road from the nearest public land. No abatement is recommended for the site. It is recommended that the fire be visited every 2 years to monitor the progression of the subsidence features.

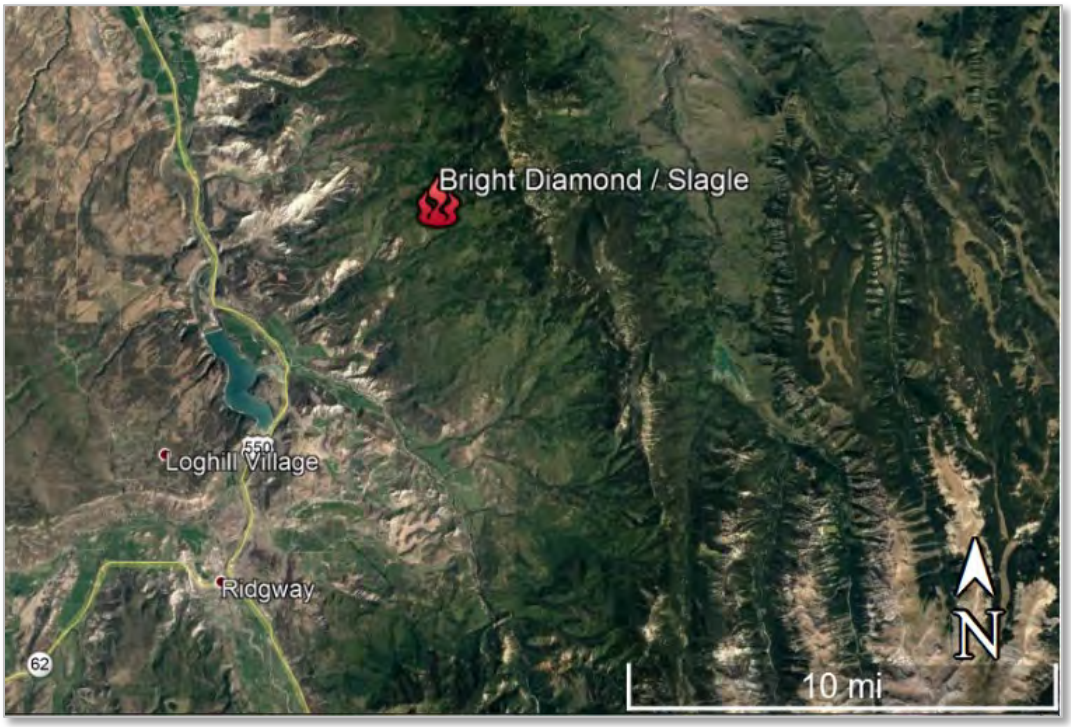

Figure 4-110 – Slagle Mine Fire Location Map

DIRECTIONS TO FIRE

To get the Slagle Mine fire from Ridgway, head north on highway 550 for 8.8 miles and turn right (east) onto County Rd. 4. Stay on County Rd. 4 for 4.7 miles until gate. Enter gate with permission of the landowner and walk for 2.9 miles. Fire will be on left (north) side of road above cabin.

4.13 Rio Blanco County

Rio Blanco County holds three of the state's 38 coal mine fires: The Skull Creek Fire near Rangely, CO, and the Black Diamond Mine and Rienau Number 2 fires outside of Meeker, CO. The Skull Creek Fire lies in the Lower White River coal field and the Black Diamond and Rienau Number 2 mines are part of the Danforth Hills coal field.

4.13.1 Rienau Number 2 Mine Fire

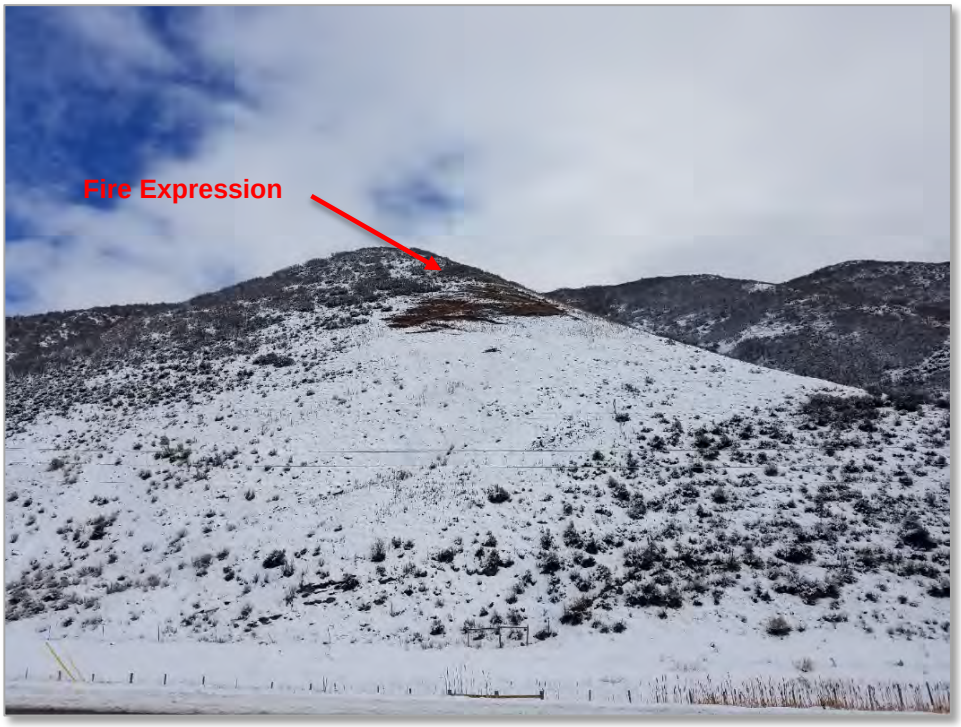

Figure 4-111 – Rienau Number 2 Mine Fire Looking East

FIRE ACTIVITY

Moderate (Estimated)

FIRE HAZARD RANKING

NA of 38

LOCATION

Latitude: 40°6'43.21"

Longitude: 107°50'47.24"

Nearest Town: Meeker, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Danforth Hills

Formation/Seam: NA

Strike and Dip: N 30 W & 18 N

Mining Method: Drift

Years of Operation: 1928-1965

Production: 476,976 tons

DATA COLLECTION

2005 - Inventory

2018 – Inventory
- Snowmelt pictures

FIRE DESCRIPTION

The Rienau Number 2 Mine Fire site is located 6.5 miles north of Meeker, CO immediately east of Hwy 13. The Rienau Number 2 Coal mine operated from 1928 to 1965 and produced approximately 480,000 tons of coal. In the spring on 2003, the Meeker Fire Department contained and extinguished a small brush fire that started at the base of the hill near the backfilled mine entry. This area was cool in 2002, but at the time of the fire was venting at temperatures of 300-450°F. Within two months of the fire, the vents had cooled to 150-200°F, demonstrating the sporadic natural of underground coal fires (Renner, 2005).

FIRE OBSERVATIONS

The Rienau Number 2 Mine Fire was not visited for this inventory at the request of the landowner. However, on February 13, 2018 snowmelt photos were collected from Hwy 13. These photos indicate that most of the activity is located on the top of the hillside. Comparing these snowmelt pictures to those in the 2005 Inventory report indicates that fire activity near the base of the hill may have decreased.

FIRE RISK AND RECOMMENDATIONS

Fire risks could not be determined for the Rienau Number 2 Mine Fire. It is recommended that an on-ground inspection be performed pending landowner approval.

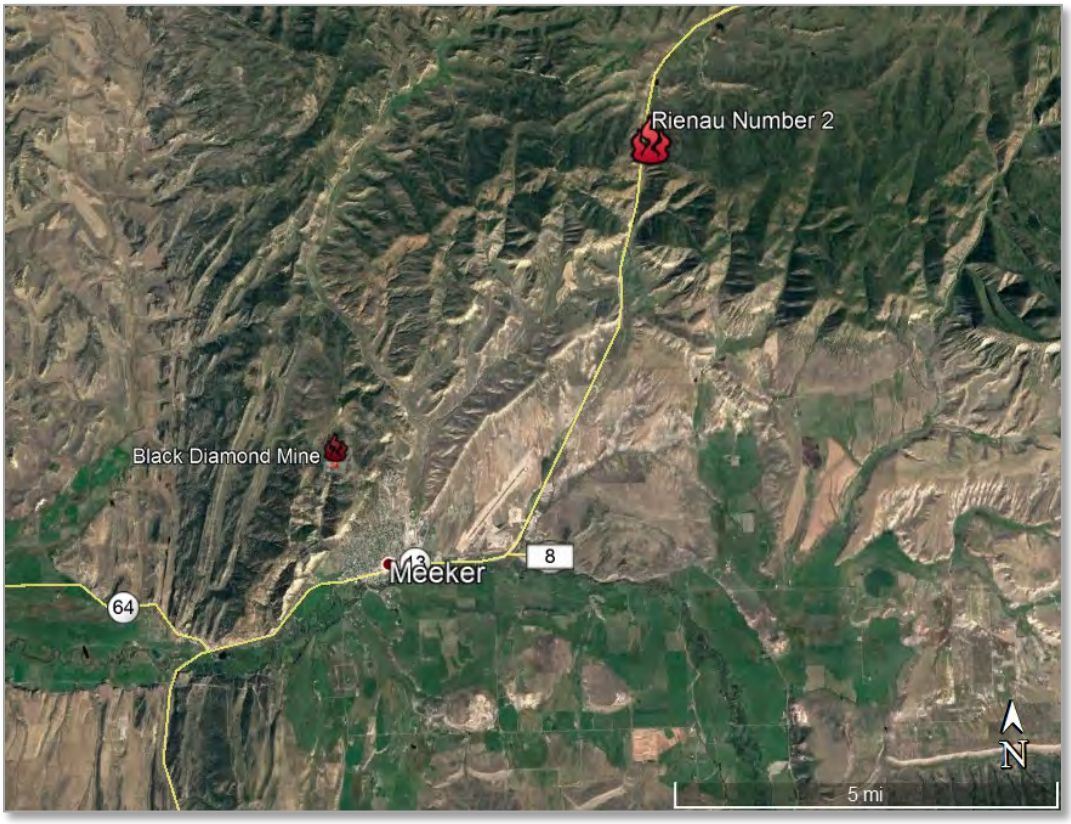

Figure 4-112 – Rienau Number 2 Mine Fire Location Map

DIRECTIONS TO FIRE

From Meeker, CO, take HWY 13 north for 6.5 miles and fire is on right (east) side of the road.

4.13.2 Black Diamond Mine

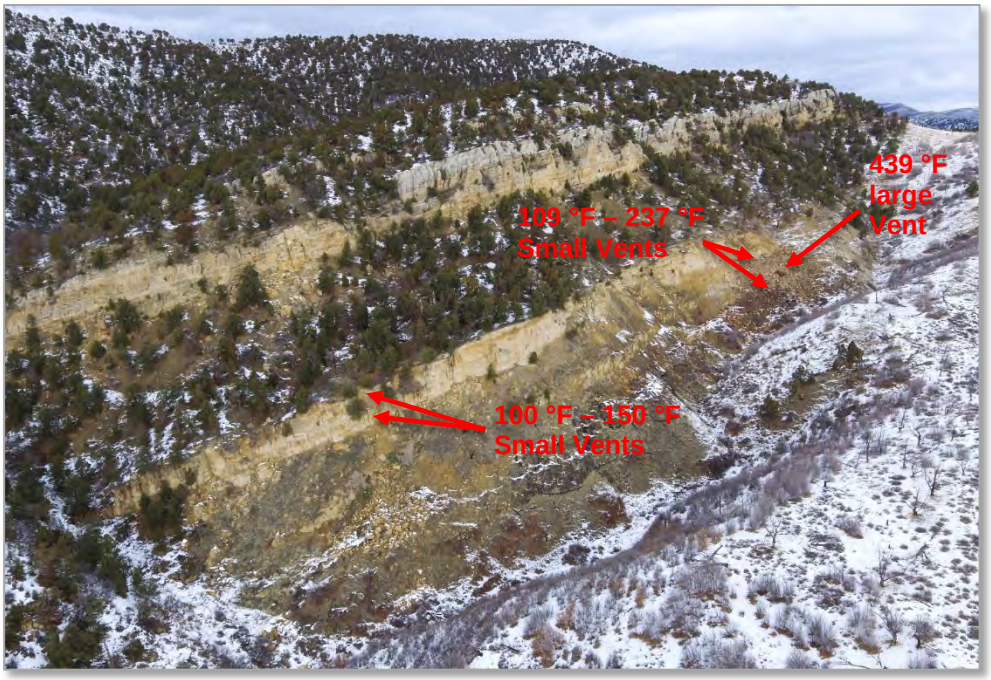

Figure 4-113 – Black Diamond Mine Fire Looking Northeast

FIRE ACTIVITY

Moderate

FIRE HAZARD RANKING

12 of 38

LOCATION

Latitude: 40°3' 26.43"

Longitude: 107°55' 33.98"

Nearest Town: Meeker, Colorado.

Landowner: Private

MINE INFORMATION

Coal Field: Danforth Hills

Seam: Black Diamond group, Pollard Bed

Strike and Dip: N 30W & 18 N

Mining Method: Slope

Years of Operation: 1906-1930

Production: 30,818 tons

DATA COLLECTION

2005 – Inventory

2013 – Inventory
- Magnetometer

2018 – Inventory
- 3D surface mapping
- Orthophotography
- Thermal Imagery

FIRE DESCRIPTION

The Black Diamond Mine fire site is located on a tributary of Anderson Gulch approximately one mile northwest of Meeker, CO. The fire is on a private inholding surrounded by BLM land accessed with the permission of the landowner. The mine is known to have been worked by George M. Lord prior to 1906 (Gale, 1906) and then by the Electric Coal Company from 1916 to 1930. Production during the Electric Coal Company's operation of the mine was 30,818 tons, with a depletion of 61,636 tons.

In 2015 and 2016, a mine fire abatement project was completed at the Black Diamond site. The remediation entailed excavation of the burning outcrop, regrading the slope, and covering the area with a layer of locally sourced riprap. Access for the abatement activities was granted through a partnership with BLM, and the access roads were reclaimed as new multi-use single-track trails connected to the trail system in Meeker, CO. Based on high-resolution 3D modeling and observations during the excavation, it seems likely that the outcrop fire was started after the fire in the mine progressed out the air shaft, and the air shaft continues to vent through the soil of the regraded slope and riprap armor layer. The vent location is easily identifiable by heavy creosote staining.

FIRE OBSERVATIONS

The fire was visited on February 14, 2018 to perform an inventory of surface features and collect aerial and thermal imagery. The main fire expression is in the vicinity of the mine's airshaft. This expression has many dispersed vents surrounding a large vent (Figure 4-114). The dispersed vents had high concentrations of CO and temperatures ranging from 110°F to 237°F. No vegetation was near these vent openings. The large vent was 439°F and had deposited creosote over an area of 100 ft^2. The vent is located in an area of riprap and is 70 ft away from the nearest

Figure 4-114 – Large vent

vegetation. Another area of activity was found near the southern entrance to the mine and is characterized by multiple vents with temperatures ranging from 100°F to 150°F. These vents are located along the bottom and the top of the sandstone cliff face. The vents on the top of the cliff were within a few feet of pinon trees.

FIRE RISK AND RECOMMENDATIONS

The Black Diamond Mine fire is moderately active, with multiple low temperature vents and one high-temperature vent. The high-temperature vent is isolated from vegetation, reducing the risk of it starting a surface fire. Overall, it is believed this fire poses moderate risk of wildfire. The presence of elevated vent temperatures and high concentrations of CO present a moderate risk to public safety. The site is relatively close to the town of Meeker, CO and a new trail system has been constructed to within ¼ mile of the fire. No fences and only one sign are installed to deter trespassers. Consequently, the site has a moderate risk of trespassing.

No abatement is recommended at the site. It is recommended that fencing and signs be installed at the north and south ends of the fire site. It is also recommended that the vents at the southern end of the site be further investigated to determine the level of risk they present to starting a surface fire.

DIRECTIONS TO FIRE

The fire is accessed from the parking lot at the westmost end of Hill St. in Meeker, CO. Walk the China Wall Trail north from the parking lot for 0.5 mile and then follow the bottom of Anderson Gulch north for 1 mile. Fire will be on Northwest side of the gully.

Figure 4-115 – Black Diamond Mine Fire Location Map

4.13.3 Skull Creek Mine

Figure 4-116 – Skull Creek Mine Fire Looking North

FIRE ACTIVITY

Extinguished

FIRE HAZARD RANKING

36 of 38

LOCATION

Latitude: 40°11' 4.92"

Longitude: 108°48' 10.08"

Nearest Town: Rangely, Colorado.

Landowner: public - BLM

MINE INFORMATION

Coal Field: Lower White River

Seam: Williams Fork Coal bed

Strike and Dip: Strike NA, Dip 5 NE.

Mining Method: NA

Years of Operation: NA

Production: NA

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer survey
- Gas Composition
- Fissure mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Orthophotography

FIRE DESCRIPTION

The Skull Creek Mine Fire site is located approximately 7 miles north/northeast of Rangely, CO on BLM land. It is unclear whether this fire was associated with a mine or if it started as an outcrop fire. An initial abatement project was performed in 1951. The project involved excavating a 600 ft long, 60 ft deep cutoff trench to isolate the fire from the rest of the coal in the mesa. Approximately 9,000 yd^3 of coal excavated during this abatement project was left in two piles on either side of the trench (Russell, 1951). In 2015 and 2016, abatement of the mine fire was completed. The fire was abated through mass excavation, then mixing and cooling of hot materials. The site was regraded to the original contours, had the surface roughed to 18-inch swales, and seeded with a native seed mixture.

FIRE OBSERVATIONS

The fire site was visited on February 14, 2018 to collect aerial and thermal imagery, develop a 3D surface model, and inspect the site for signs of fire activity. The fire was accessed from the west side of the site. No elevated ground temperatures were observed in the thermal imagery. The excavation area was inspected, and no active or dormant vents were discovered, and no coal combustion or oxidation odors were noticed.

FIRE RISK AND RECOMMENDATIONS

The fire is believed to be extinguished. Because of this, the fire does not present a risk of starting a surface fire. Since being reclaimed, the fire site does not have any features that pose a public safety risk. No additional abatement work is recommended for the site. Annual monitoring is recommended to ensure that the fire has been completely extinguished.

Figure 4-117 – Skull Creek Mine Fire Location Map

DIRECTIONS TO FIRE

To access the Skull Creek Mine Fire from Rangely, CO take HWY 64 east 9.0 miles to County Road 65 and turn left (north). Take County Road 65 for 5.3 miles and turn left (west) onto County Road 96. Stay on County Road 96 for 3.0 miles and fire will be on straight ahead at intersection.

4.14 Routt County

Although Routt County has seen extensive coal mining, it currently has just one active coal mine fire associated with the Kaspar Mine. Three previous mine fires were listed as dormant in the 2005 inventory report. The Yampa Coal Field, which extends over three counties, is the primary coal field in Routt County.

4.14.1 Kaspar Mine

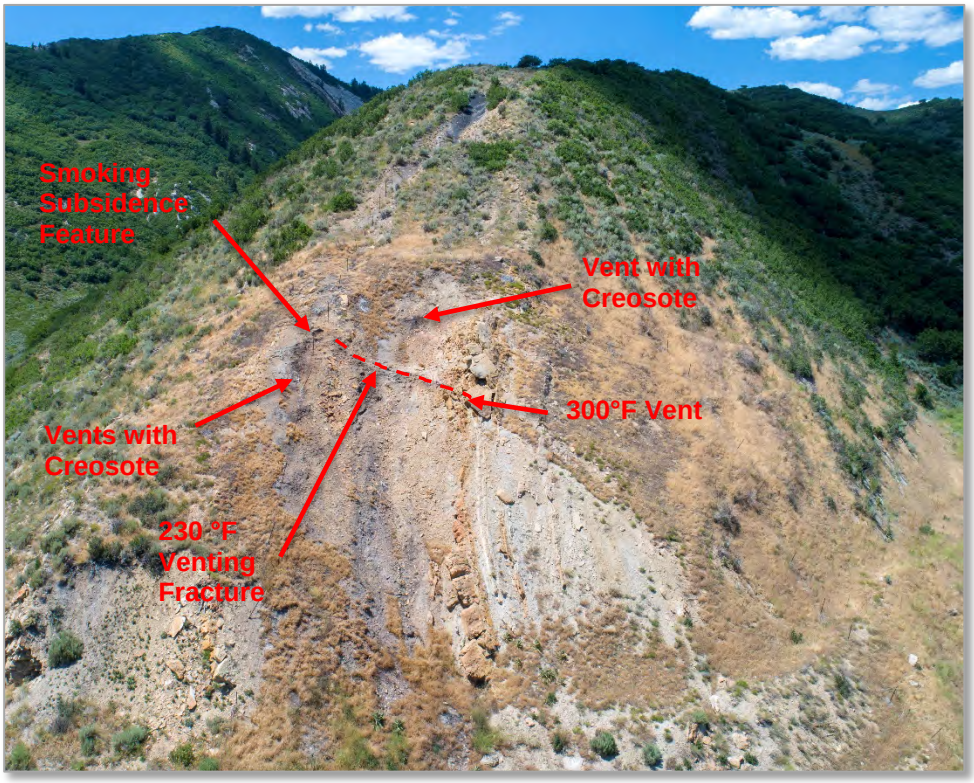

Figure 4-118 – Kaspar Mine Fire Looking North

FIRE ACTIVITY

High

FIRE HAZARD RANKING

8 of 38

LOCATION

Latitude: 40°20' 16.83"

Longitude: 107°8' 5.91"

Nearest Town: Hayden, Colorado.

Landowner: private

MINE INFORMATION

Coal Field: Yampa

Seam: Wadge

Strike and Dip: N 40W & 28

Mining Method: Slope

Years of Operation: 1930s -1940s-

Production: 215,000 tons

DATA COLLECTION

2002 – Inventory

2013 – Inventory
- Magnetometer survey
- Gas Composition/isotope
- Fissure mapping
- Snowmelt mapping

2018 – Inventory
- 3D surface mapping
- Thermal Imagery
- Orthophotography
- Snowmelt photographs

FIRE DESCRIPTION

The Kaspar Mine Fire is located approximately 12 miles southeast of Hayden, CO. The mine has been referred to by many names including Weber, Weber Wagon, Webers-kirch, and Fish Canyon (Rushworth, 1989). The mine is comprised of a portal driven along strike 500-700 ft to the northwest. A vent airshaft was driven up the coal seam to the outcrop 650 ft along the slope above the portal. It is believed the fire started when the mine tipple was destroyed by fire in 1970. The fire was first discovered after it started a 30-acre wildfire in July of 1972. The fire burned throughout the lower workings and to within 150 ft of the airshaft opening (Donner, 1973).

In August 1972, a surface seal operation was undertaken by the Bureau of Mines to smother the fire. The vent airshaft and lower portal were backfilled with fine sediment, and borrow material was placed in the area between these features that was demonstrating fire activity.

In 1989, Rushworth reported that fire activity was observed in the vicinity of the 1972 surface seal. In 2005, Renner reported a bowl-shaped subsidence feature area uphill of the surface seal. Two cool vents with creosote buildup were found to the northwest of the subsidence feature.

FIRE OBSERVATIONS

Figure 4-119 – Smoking Subsidence Feature

The fire was visited on July 2, 2018. The mine fire has 2 active fire expression areas that both corelate with the subsidence "Feature 2", discussed by Renner in the 2005 report. "Feature 1" from the 2005 report is currently not active. At the upper fire expression, hot and dry mine fire emissions are venting at multiple locations along the upper coal seam. Similar emissions are found on the east side of a 25 ft long, 3-inch-wide fracture running perpendicular to the stratigraphy. Vents along the west side of this fracture have more creosote buildup around them, indicating the fire in this area is in an earlier stage of its combustion cycle. This fracture extends west towards what appears to be a new area of fire in an underlying coal seam outside of the current fire perimeter fence. The surface of this new fire area is defined by a few dry and dead bush trunks, creosote staining in the soil, and a 3 ft by 5 ft by 0.5 ft deep subsidence feature that was actively smoking during the site visit (Figure 4-119). Ground temperatures in this area are 180°F. Vegetation is about 6 ft from the subsidence feature. Grasses are within 2 ft of vents in some areas, and 2 vents have developed at the base of bushes. One of these vents was 230°F and had charred some of the bush's branches. This bush was removed to alleviate immediate safety concerns while Tetra Tech was onsite.

The lower fire expression appears be an older area of the fire. The vents in this area show no evidence of creosote and the emissions are hot and dry. The lower expression does not seem to be propagating in any direction and vegetation is at a safe distance away.

FIRE RISK AND RECOMMENDATIONS

The fire is moderately active, with ground temperatures of 180°F and vent temperatures between 180°F and 300°F. (Figure 4-120). Although ground heat has kept most vegetation from growing near the vents in the existing fire expression, the fire appears to be moving into an area of vegetation. Consequently, the fire has a high potential of starting a surface fire. The fire is located on steep terrain, on private land, so the potential for trespassing is low.

Figure 4-120 – Creosote Stained Soil

It is recommended that vegetation be removed from around the new fire expression area. It is also recommended that the fire perimeter fence be moved to include the new fire expression area. A snowmelt or thermal drone flight would help determine

the extents of the surface expression of the fire. Since this fire seems to be progressing rapidly, drone snowmelt or thermal imagery would assist with tracking the fire's movement over time.

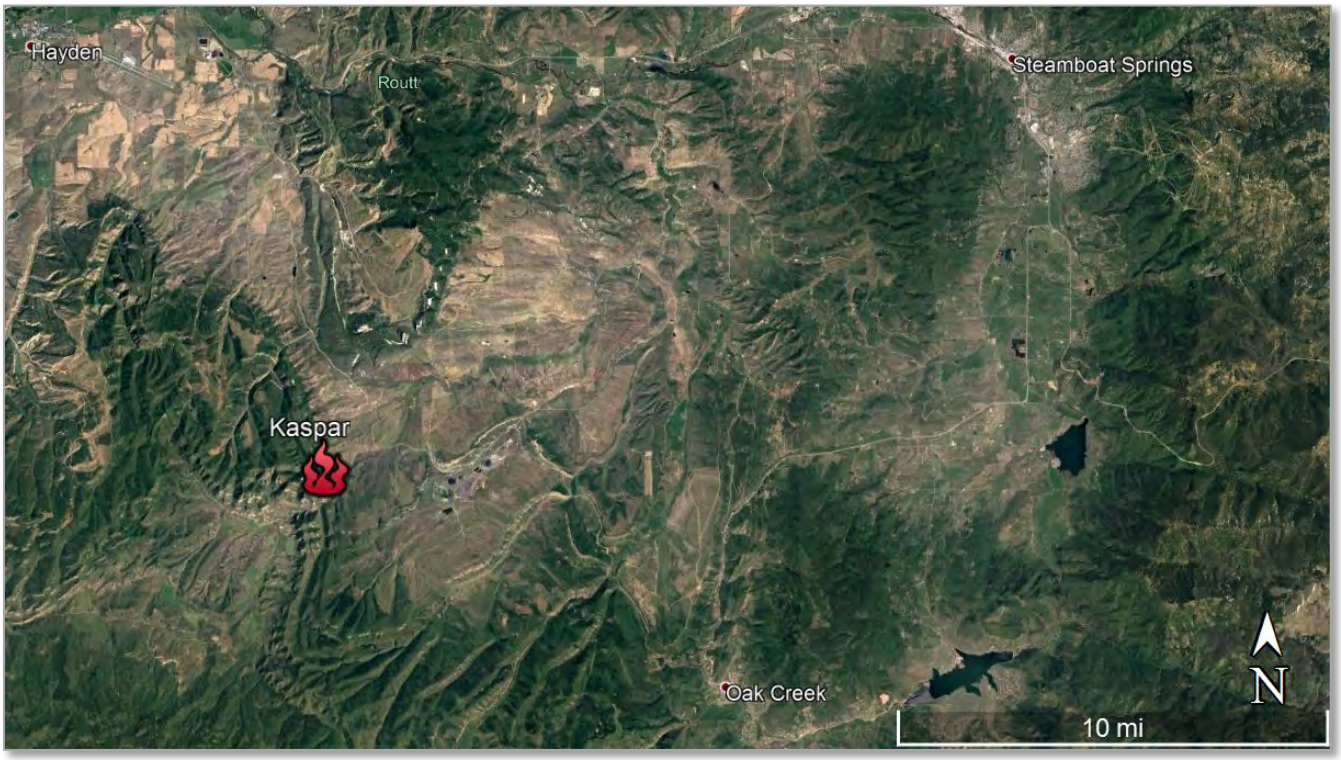

Figure 4-121 – Kaspar Mine Fire Location Map

DIRECTIONS TO FIRE

To get to the Kaspar Mine Fire from Hayden, CO, take US 40 east and turn right (south) onto County Rd. 27. Continue on County Road 27 for 10.4 miles and turn right (west) onto County Rd. 37. Follow County Road Rd 37 for 2.5 miles and fire is located on the right (north) side of the road.

5. SITE PRIORITIZATION

Following completion of the inventory evaluations and review of all of the data for each of the sites, a prioritization process was developed to rank the mine fire sites and identify the sites that pose the highest risk to human health, the environment, and infrastructure.

Tetra Tech developed a Multi-Criteria Decision Analysis (MCDA) tool to assist in the prioritization of mine fire reclamation efforts. The MCDA tool allows the user to establish relative importance factors, a number from 1 to 10, for each of the risk criteria listed in Table 5-1. The mine fires are then scored by the user on their potential risk for each of these criteria. The MCDA tool uses this information to output a ranked list of the mine fire sites based on the amount of risk posed to the general public. Incorporating MCDA tools into decision making has allowed for the quantification of subjective observations and the efficient use of project funding. Table 5-2 presents the mine fire priority list developed from the MCDA tool.

Table 5-1 – MCDA Tool Criteria Descriptions

Criteria	Description
Risk to Population	Distance from populated areas.
Risk to Trespassing	Public accessibility to the mine fire area.
Site Danger	Risk of injury on-site.
Risk of Wildfire	Risk of the mine fire starting a wildfire.
Emissions	Quantity of emissions
Public Concern / View	Public concern for and the visibility of the mine fire
Fire Activity	General activity of the fire. This increases the potential for the fire to move to a new area or for unexpected events to occur.

The MCDA tool does not consider feasibility or cost of abatement for these fires. The cost of abatement will vary widely between fires due to the type of abatement required, differences in site accessibility, extents of the fires, dip of coal seam(s), and the number of seams on fire.

Table 5-2 – Colorado Mine Fire Priority List

Rank	Fire	Score	Overall Risk
1	South Canyon West	8.3	High
2	South Canyon East	8.1	High
3	Sunshine	7.0	High
4	Vulcan	6.8	High
5	Axial	6.8	High
6	Haas /IHI No. 3	6.6	High
7	New Castle 3	6.4	Medium
8	Kaspar	5.4	Medium
9	Bear	5.3	Medium
10	Harvey Gap	5.0	Medium
11	Elk Creek	4.9	Medium
12	Black Diamond	4.7	Medium
13	New Castle 1	4.6	Low
14	Morgan	4.5	Low
15	Coryell	4.5	Low
16	Gem	4.1	Low
17	IHI No. 2	3.8	Low
18	North Coal	3.7	Low
19	Marshall 1 and 2	3.6	Low
20	McElmo	3.6	Low
21	Oliver	3.6	Low
22	Garfield	3.4	Very Low
23	Lewis 1 and 2	3.1	Very Low
24	Go Boy	3.0	Very Low
25	West Sopris	2.9	Very Low
26	Double Dick	2.9	Very Low
27	Davis	2.7	Very Low
28	States	2.7	Very Low
29	Minnesota Creek	2.7	Very Low
30	Wise Hill 3	2.7	Very Low
31	Slagle/Bright Diamond	2.5	Very Low
32	Riach	2.4	Very Low
33	Farmers	2.4	Very Low
34	Soda Springs	2.1	Very Low
35	Pocahontas	2.1	Very Low
36	Skull Creek	2.0	Very Low
37	Morley Waste Dump	2.0	Very Low
38	Rienau Number 2	NA	NA

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APPENDIX A: Photo Log

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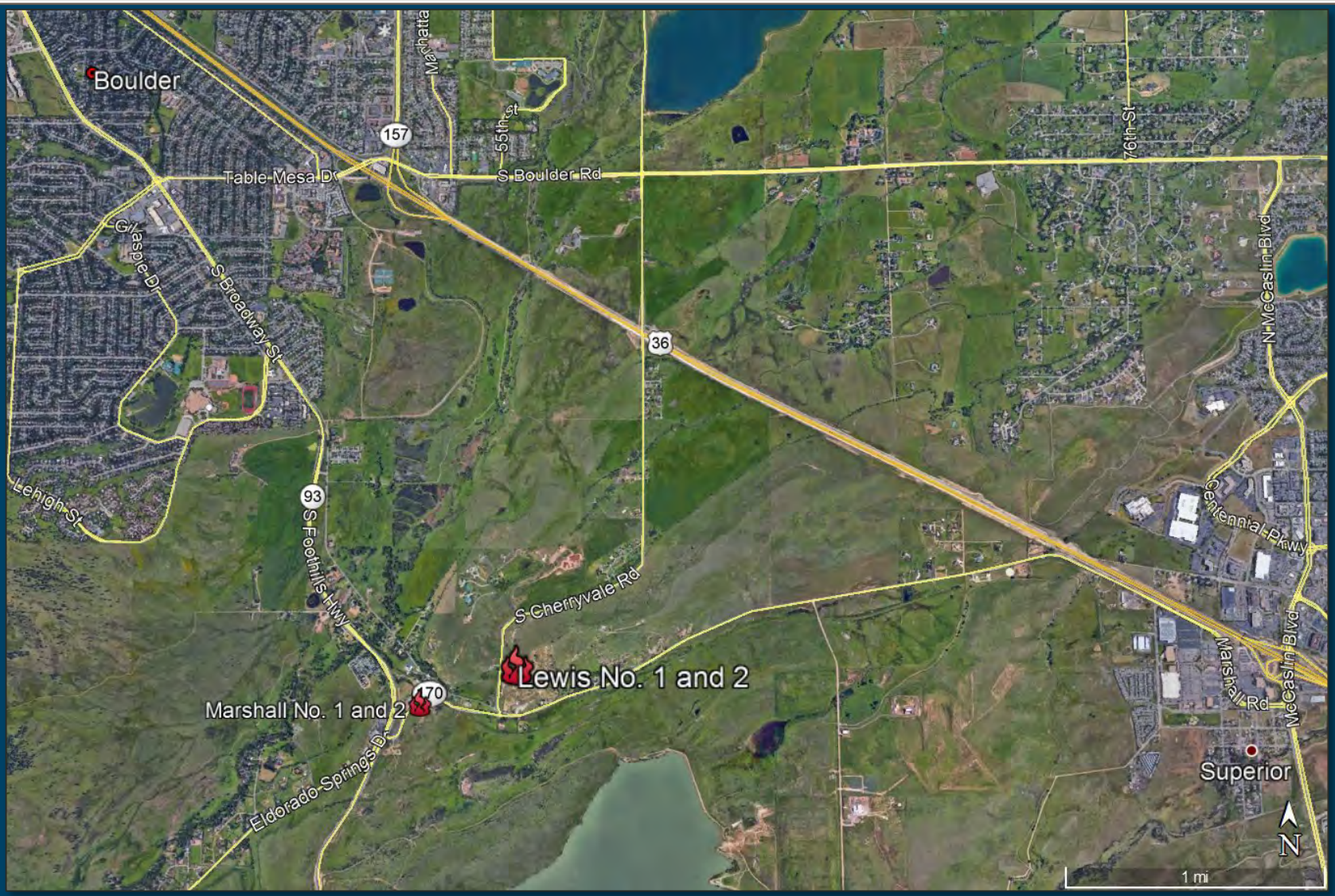
Boulder County



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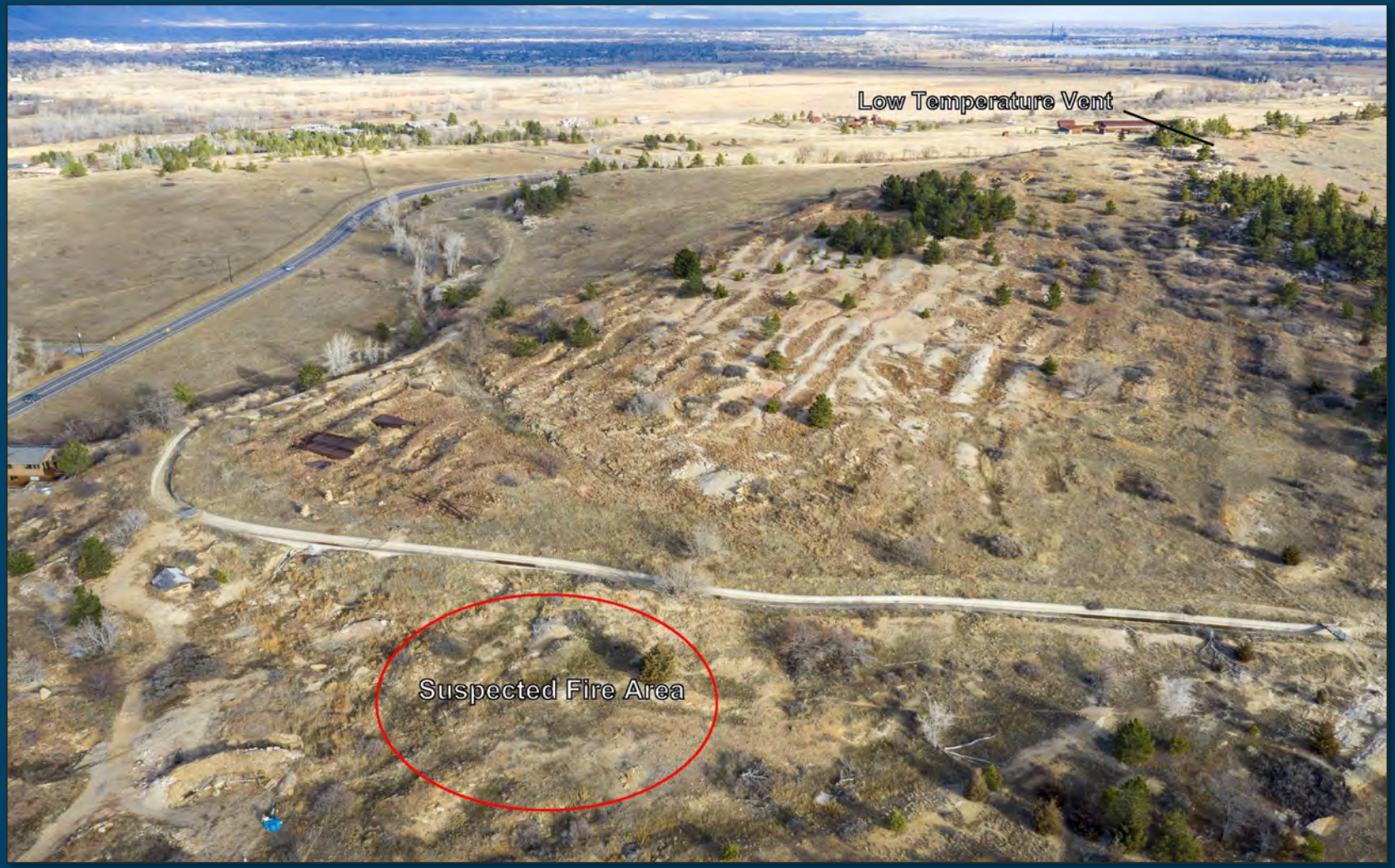
Lewis Mine



Lewis Mine fire looking North

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Lewis Mine

Subsidence under aqueduct

Subsidence under aqueduct

Lewis Mine

Flow fill of two voids under aqueduct May 7, 2018

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Marshall Mine

Marshall Mine fire looking South

Marshall Mine

Fire area looking Southwest

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Marshall Mine

Northern 2016 abatement area looking Southwest

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Marshall Mine

Southern 2016 abatement area looking Southwest

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Delta County

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Davis Mine

Davis Mine fire looking North

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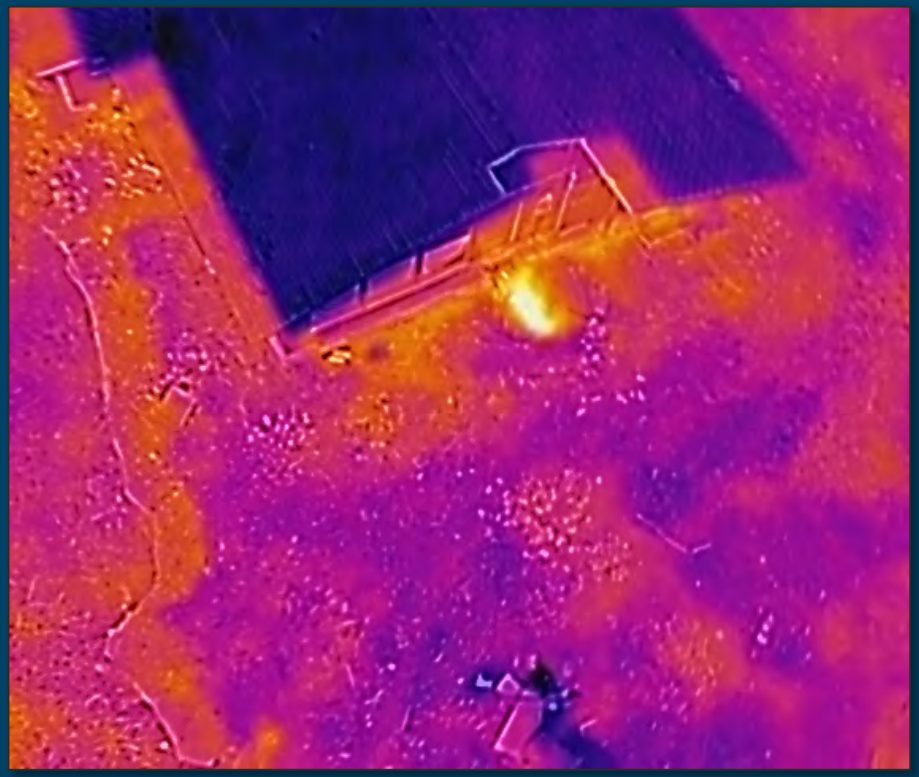
Davis Mine

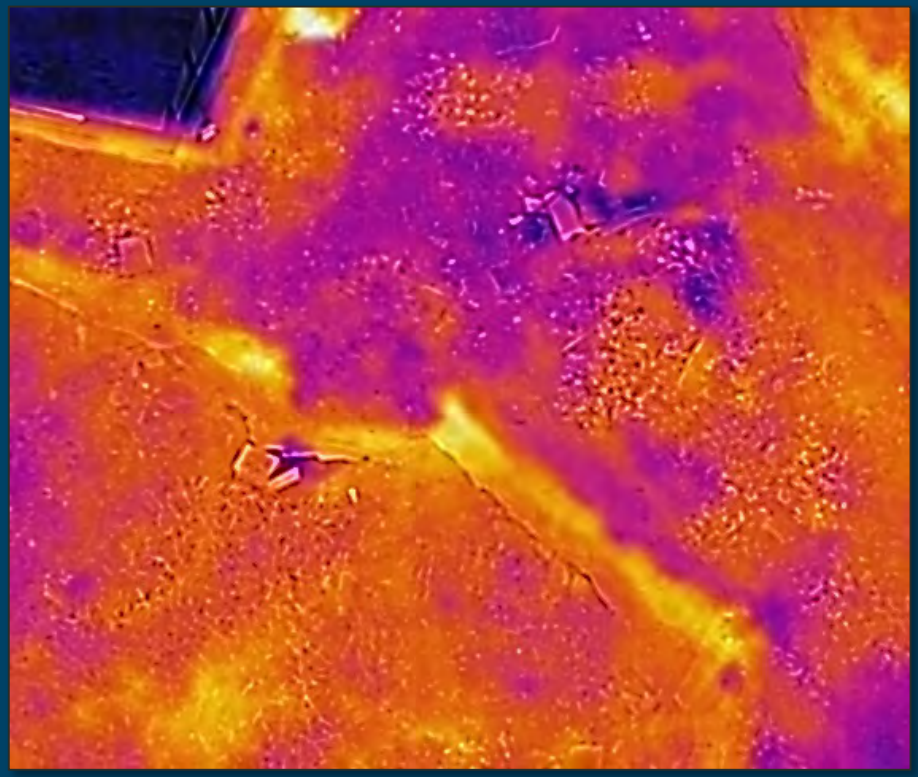
Vent pipe with opening into mine workings

Looking down on mine entrances

Davis Mine



Vent Pipe area at 55 °F
(underground temperature)



Mine entrances at ambient temperature

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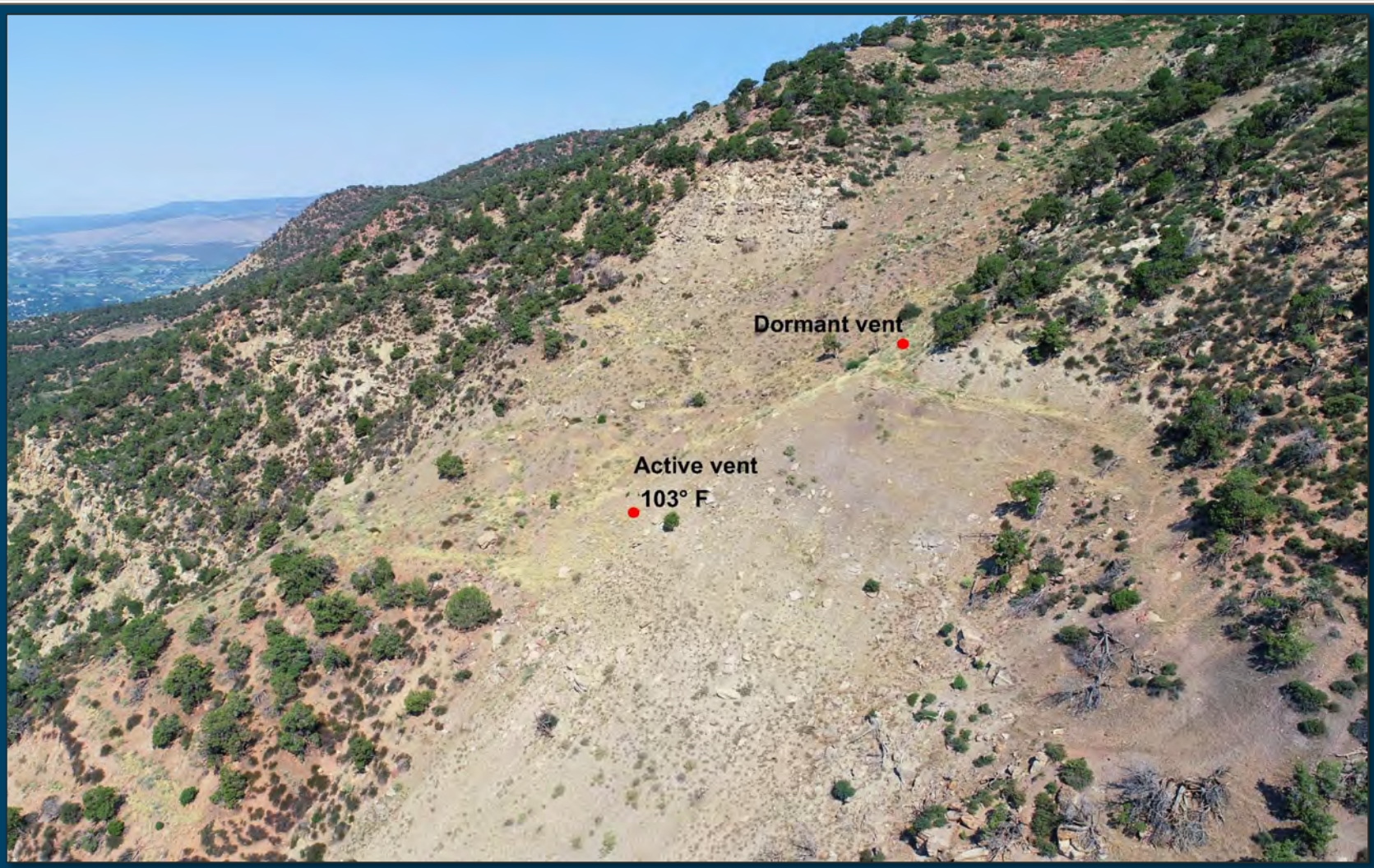
Minnesota Creek



Minnesota Creek Mine fire looking West

Minnesota Creek

Active vent 103 °F

Dormant vent area

Minnesota Creek

Surface seal cover looking Southeast

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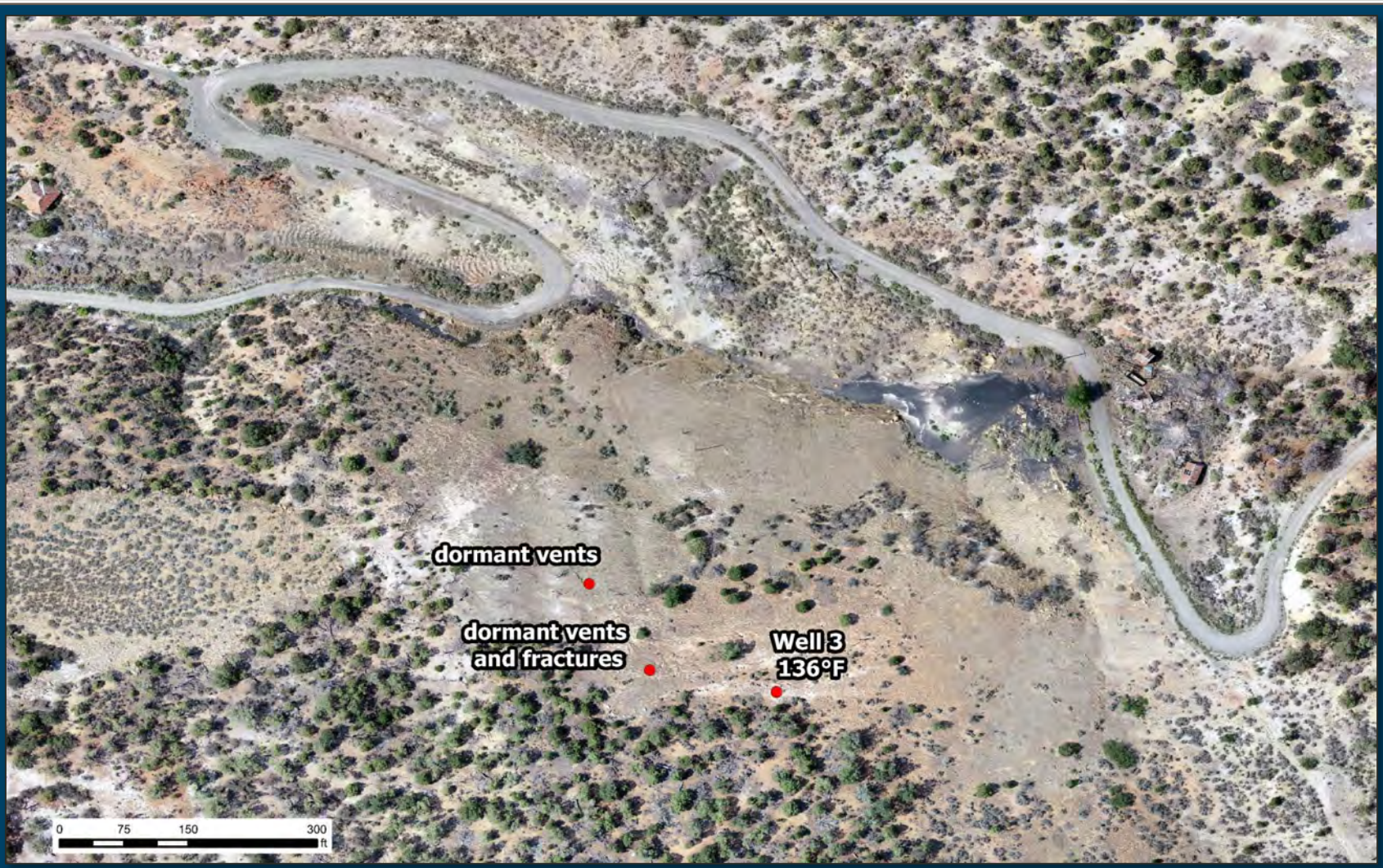
States Mine



States Mine fire feature map

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States Mine

Large fracture, no venting

Dormant vent

States Mine

Ash in Coal Refuse Pile - No Active Fire

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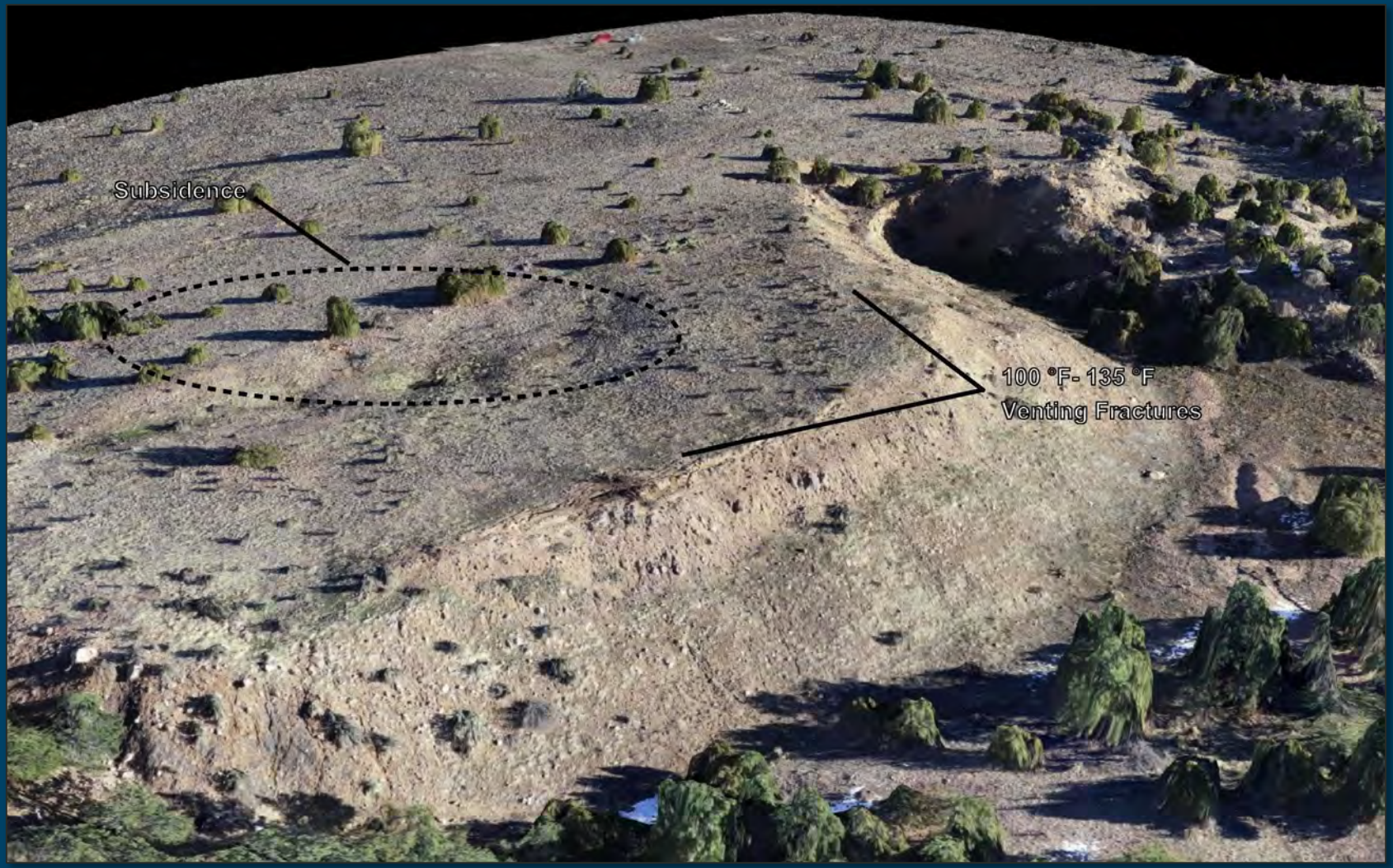
Fremont County

Double Dick Vicinity



Double Dick Vicinity Mine fire looking Northeast

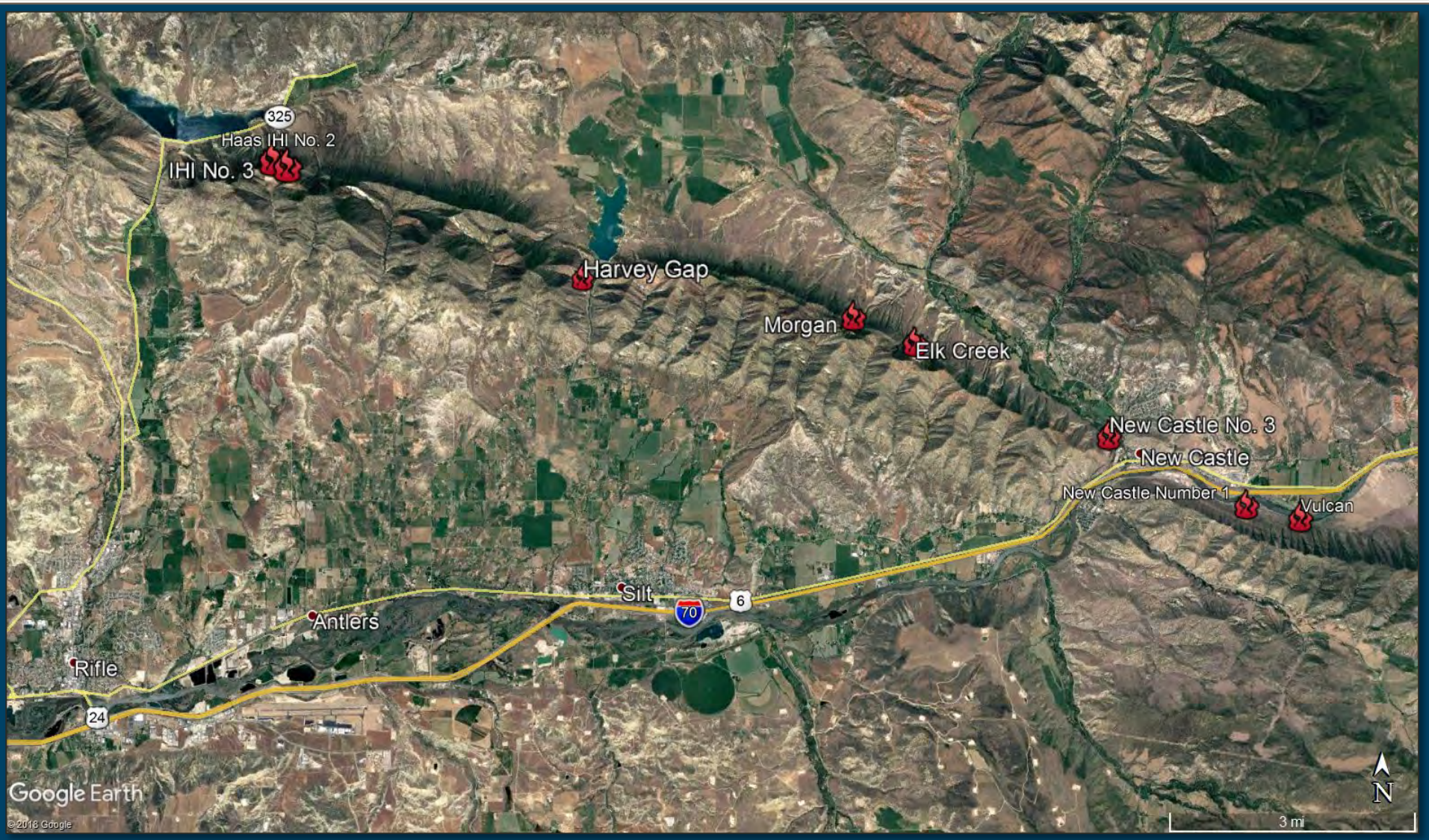
Double Dick Vicinity

Vents with creosote

Slumping near vents

Garfield County - East

Garfield County - West

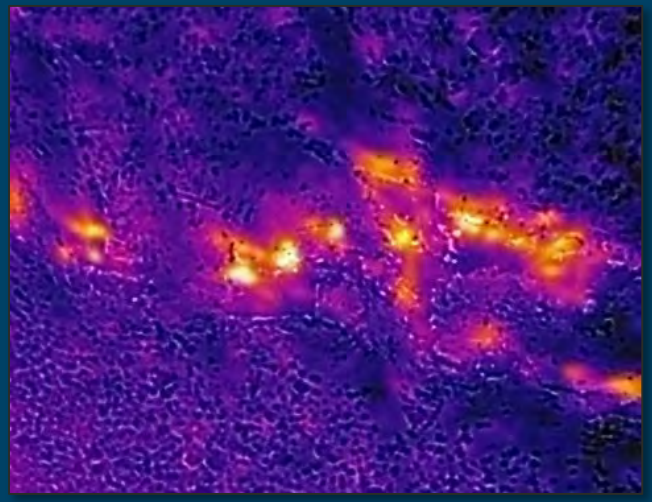


Coryell Mine

Coryell Mine fire looking West

Coryell

Snowmelt looking South



Thermal image of fire expression

Snowmelt looking East

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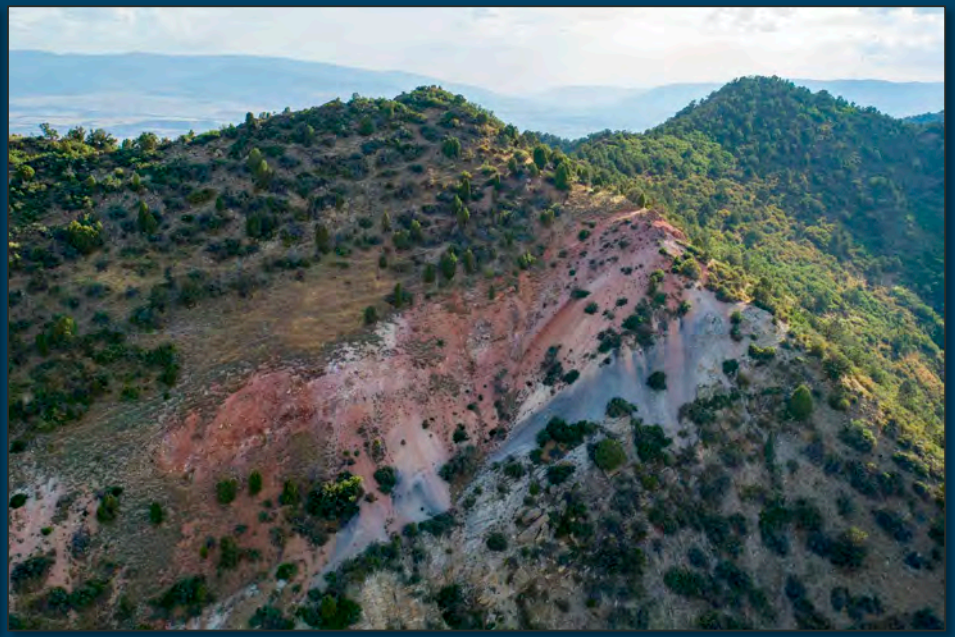
Elk Creek

Elk Creek Mine fire looking South

Elk Creek

Snowmelt and steam viewed from Buford Rd.



Fire area looking Southwest

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Elk Creek

225 °F vents near ridge

232 °F vents at outcrop

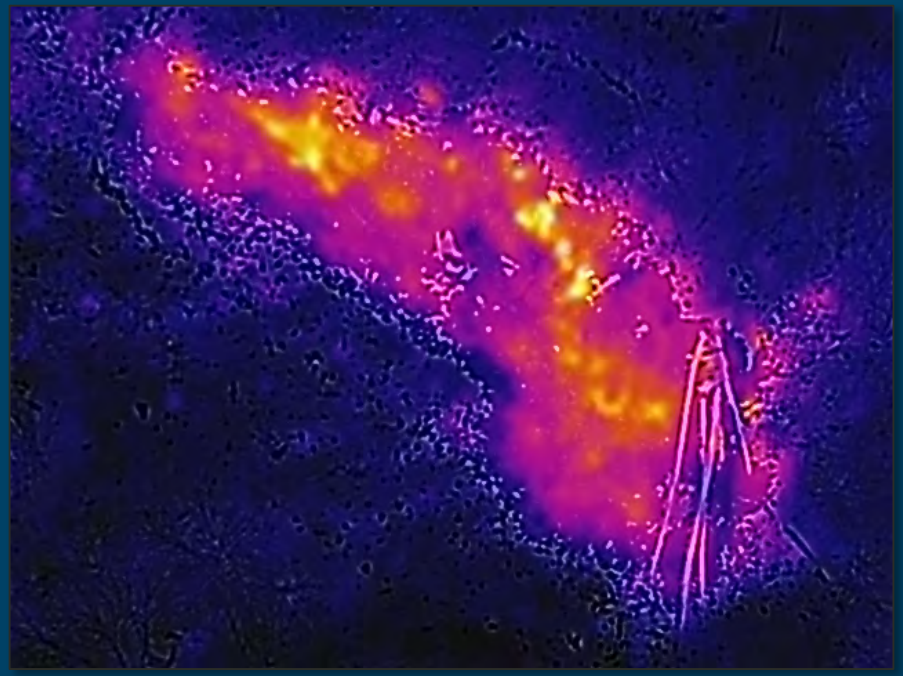
Gem Mine

Gem Mine fire looking Southeast

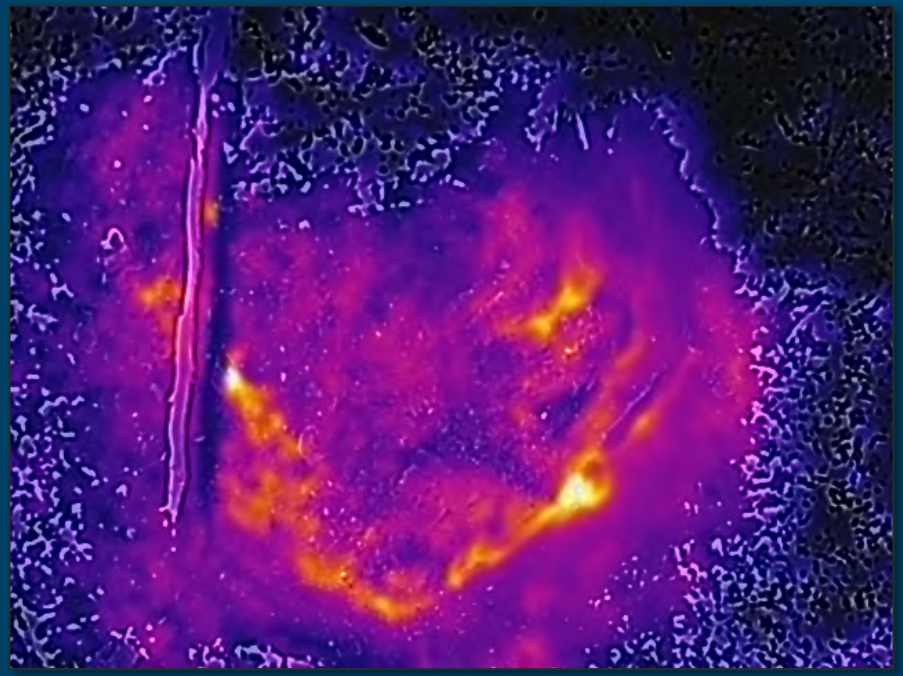
Gem Mine

West fire expression

Gem Mine



Thermal image of fire expression



Thermal image of fire expression

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Harvey Gap Mine

Harvey Gap Mine fire looking Southwest

Harvey Gap Mine

273 °F outcrop vents

310 °F vents

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Harvey Gap Mine

300 °F vents with grout looking West

300 °F vents with grout looking South

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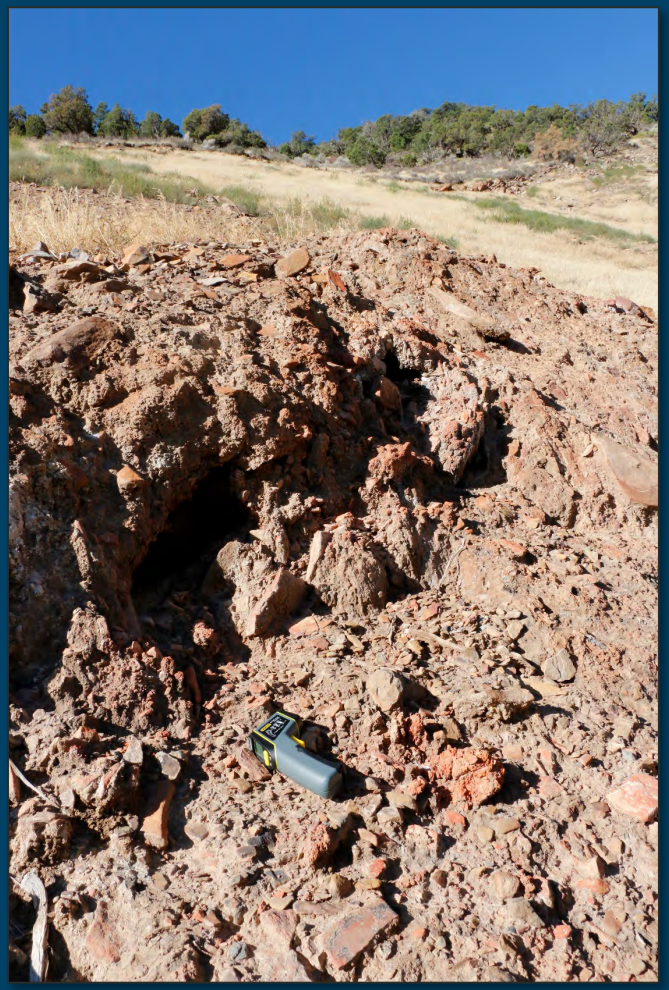
Harvey Gap Mine

123 °F vents



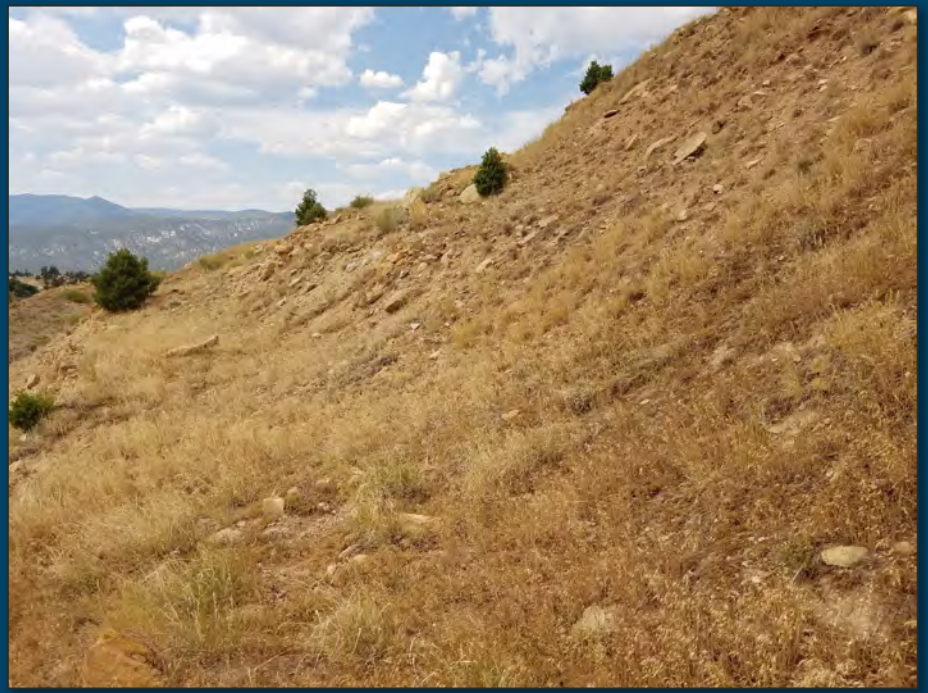
120 °F vents

Haas IHI No. 2 Mine

Haas IHI No. 2 Mine fire looking East

IHI No. 2 Mine

6 ft by 5 ft subsidence feature



Surface seal vegetation

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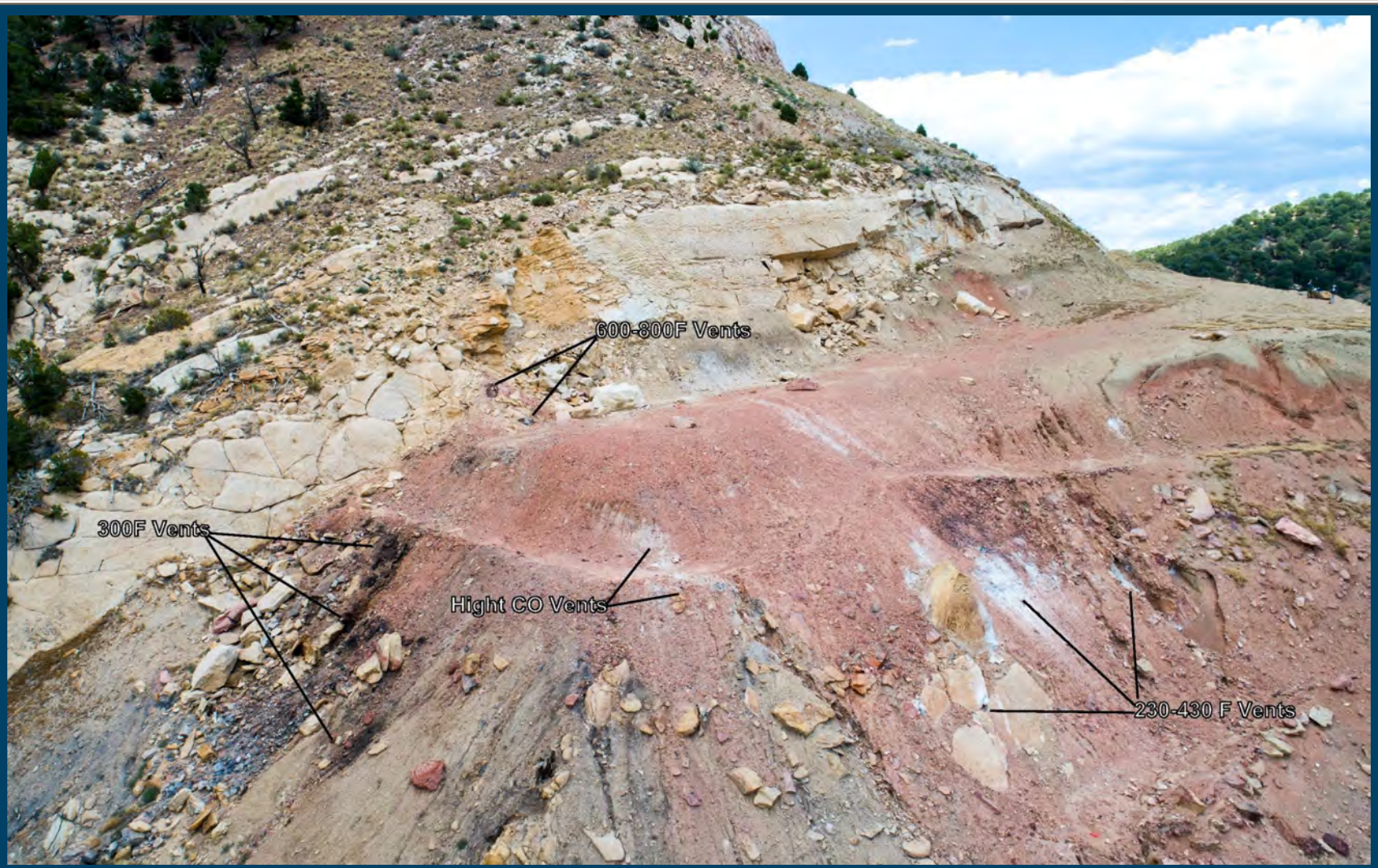
IHI No. 3 Mine



IHI No. 3 Mine fire looking North

IHI No. 3 Mine

Vent with white precipitate

Vent with sulfur precipitate

IHI No. 3 Mine

Western vents with creosote staining

>600 °F vents

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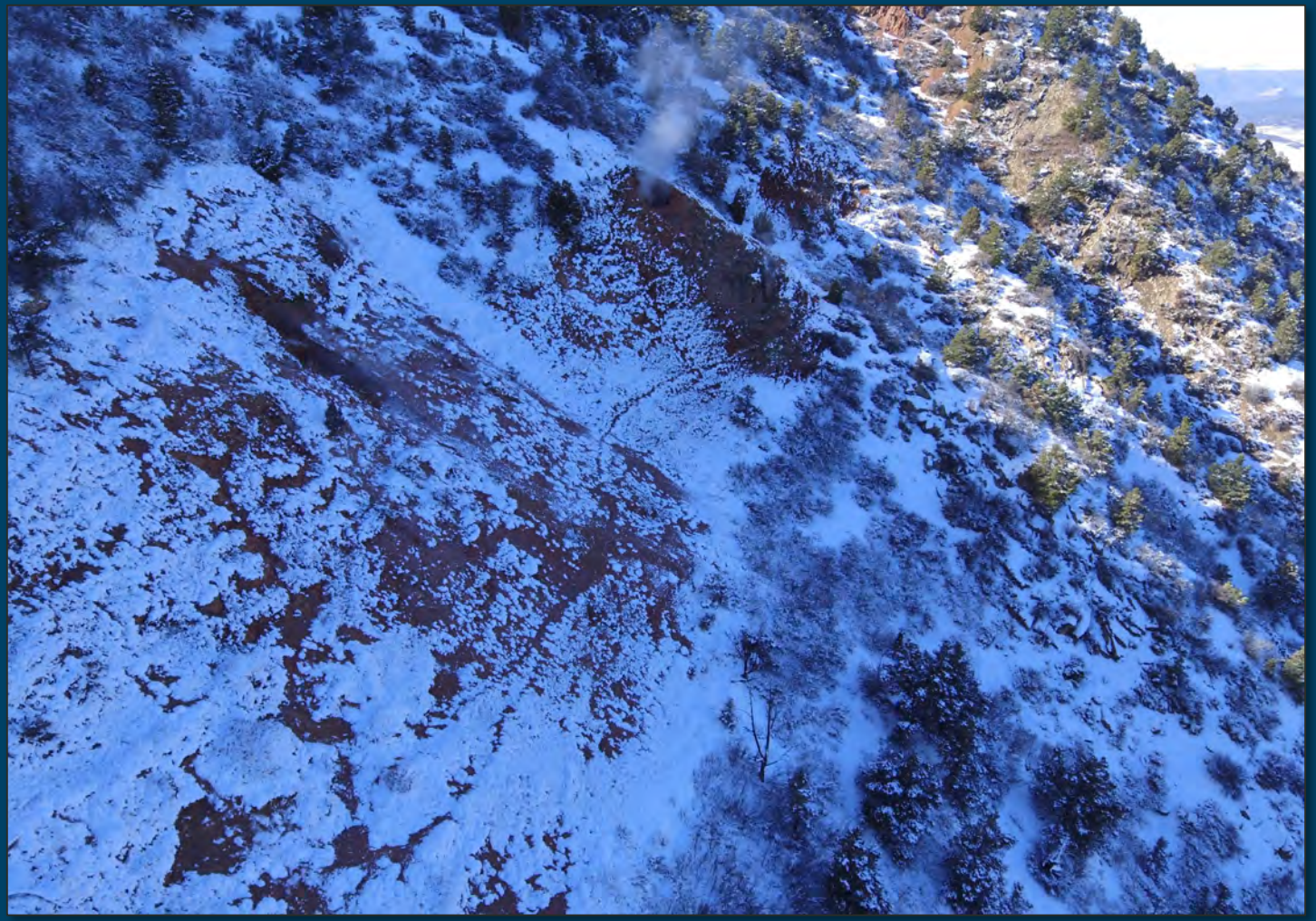
Morgan Mine

Morgan Mine fire looking South

Morgan Mine



Snowmelt looking Southwest

Morgan Mine

230 °F large vent looking South

New Castle No. 1

New Castle No. 1 Mine fire looking Southeast

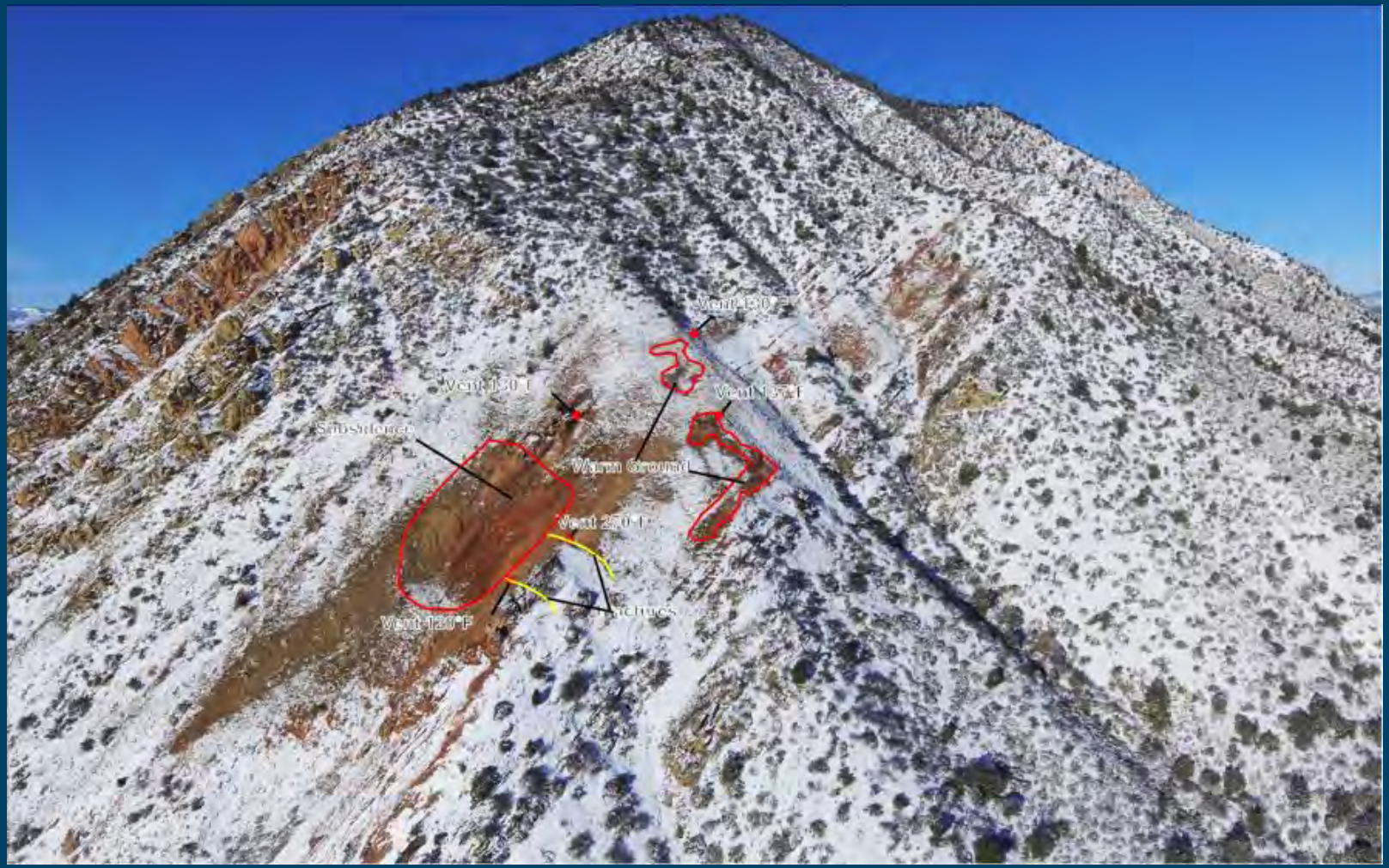
New Castle No. 1

Fire area looking Southwest

New Castle No. 1

Fire expression looking West

New Castle No. 3



New Castle No. 3 aerial image looking West

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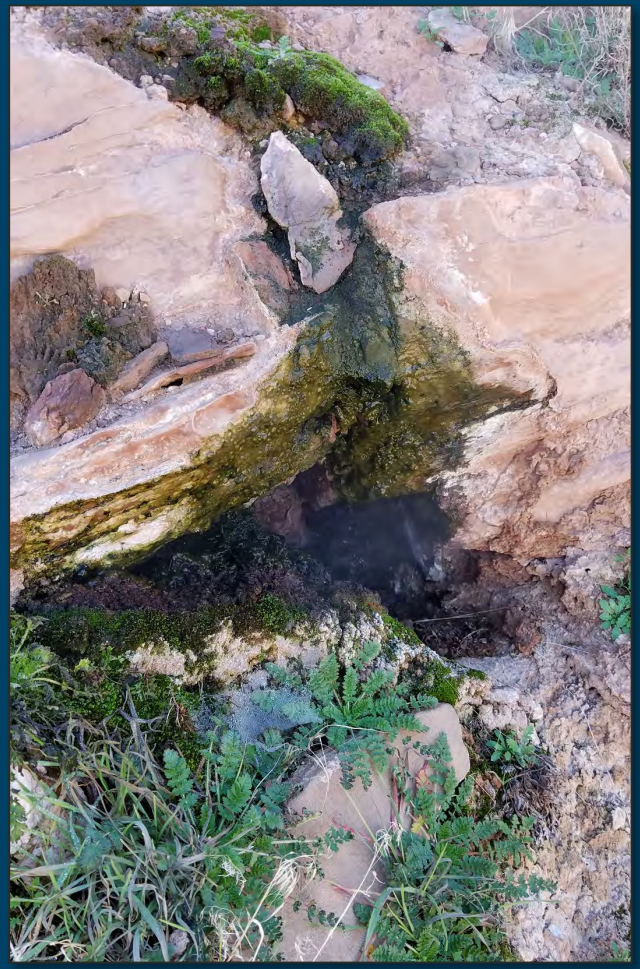
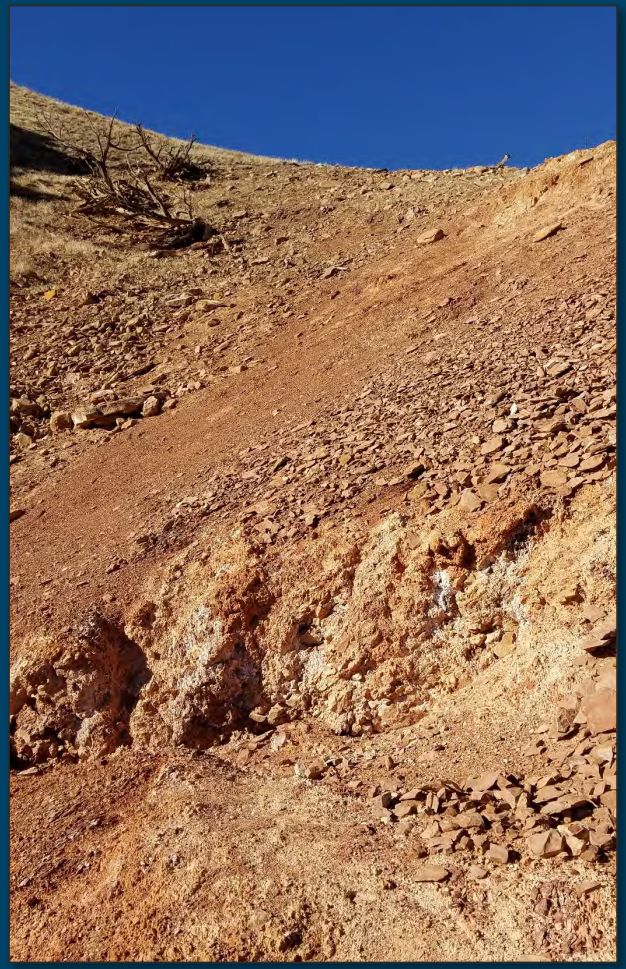
New Castle No. 3



130 °F vent



Large subsidence feature

New Castle No. 3

270 °F vent

Small subsidence on upper fracture

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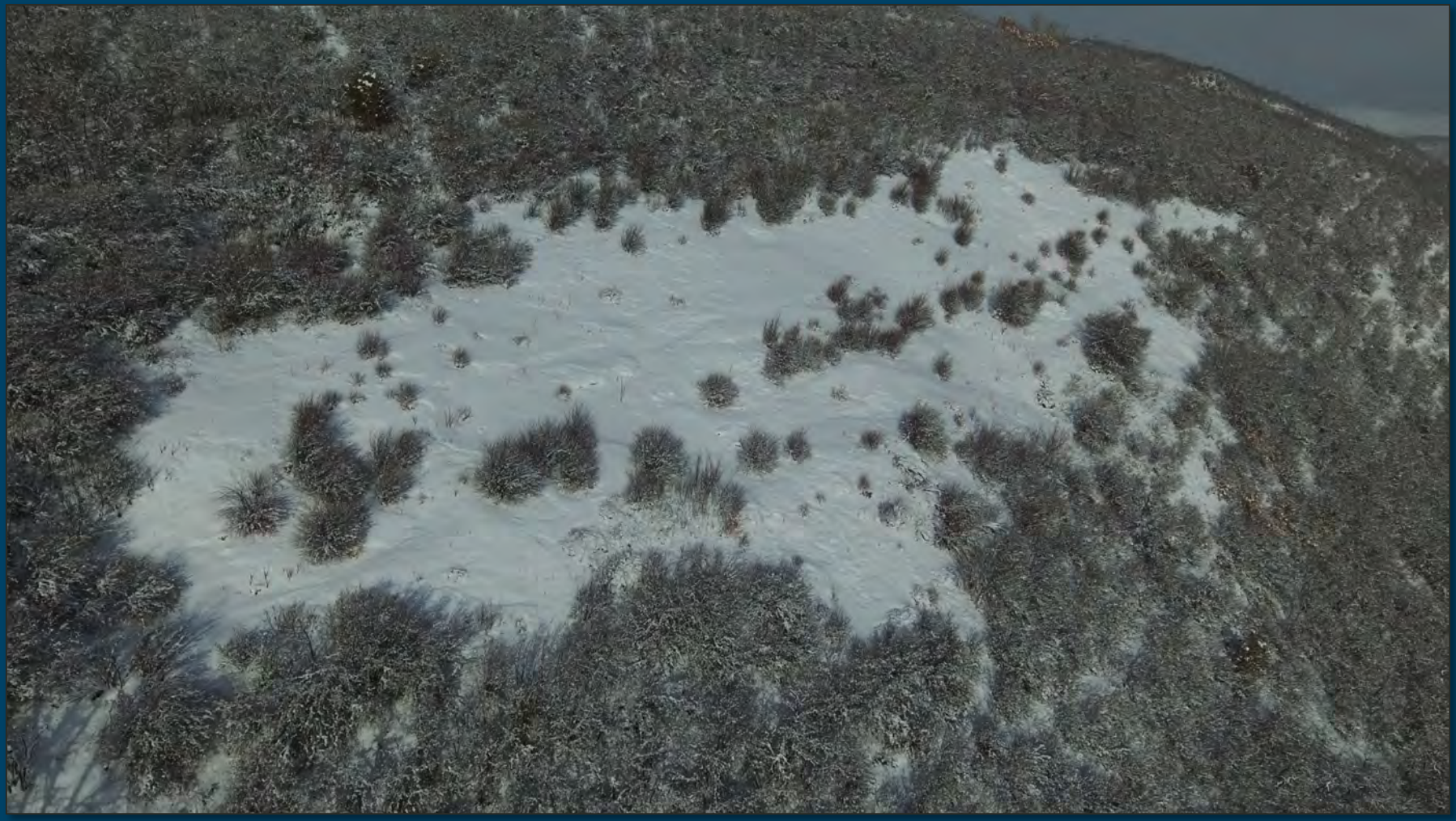
Pocahontas

Pocahontas Mine fire looking North

Pocahontas



Fire area with snow cover looking Northwest

Pocahontas

Outcrop looking North

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South Canyon East

South Canyon East Mine fire looking Northeast

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South Canyon East

Fire area looking East

South Canyon East

Intake hole

Upper road cut vents with creosote

South Canyon East

Main fire expression looking Northeast

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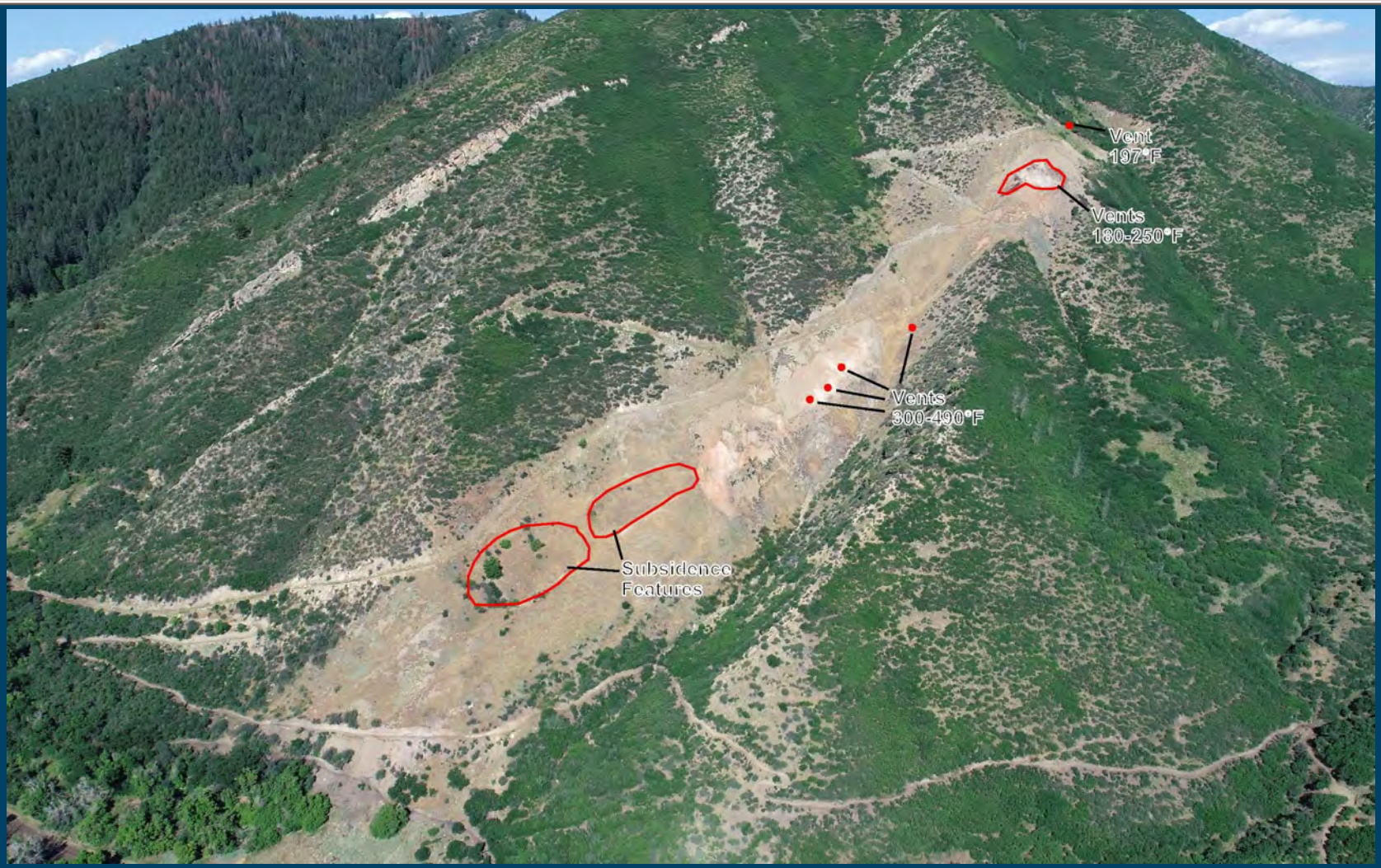
South Canyon West



South Canyon West Mine fire looking Southeast

South Canyon West

Emissions inventory equipment

197 °F westernmost vents

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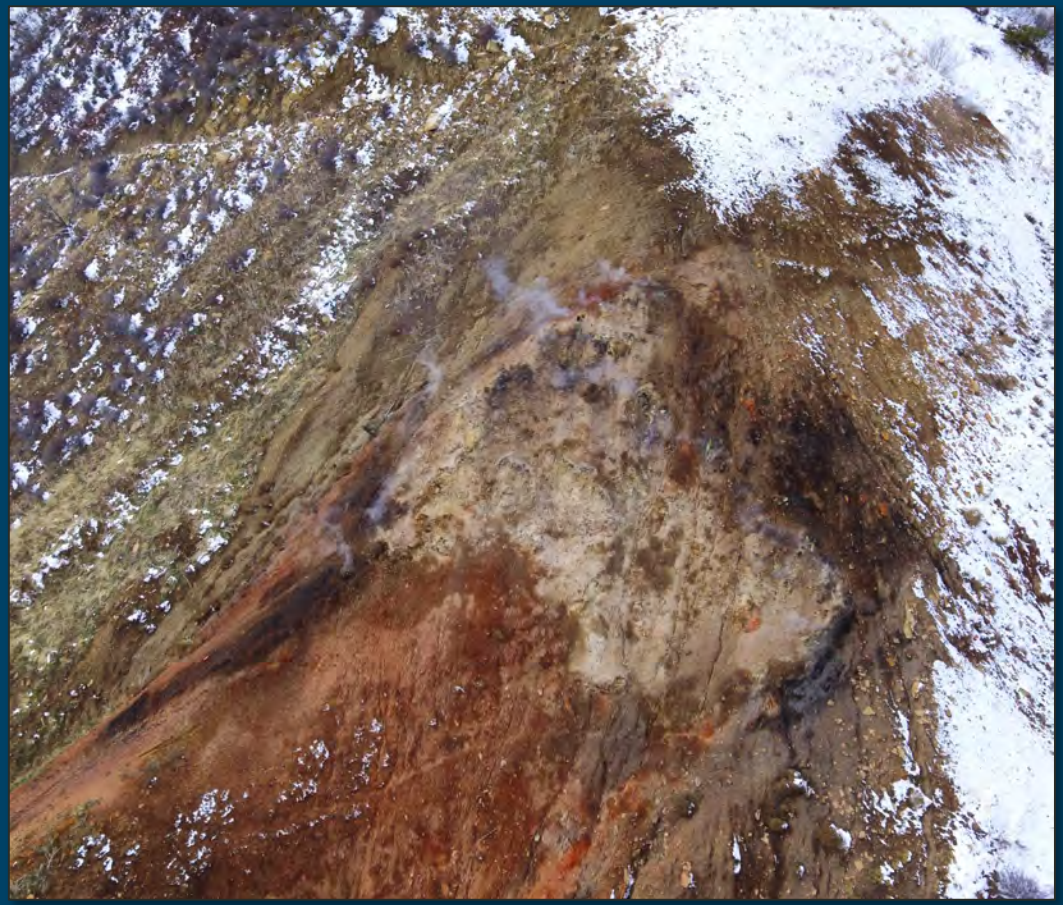
South Canyon West

Lower area vents



Main upper vent area

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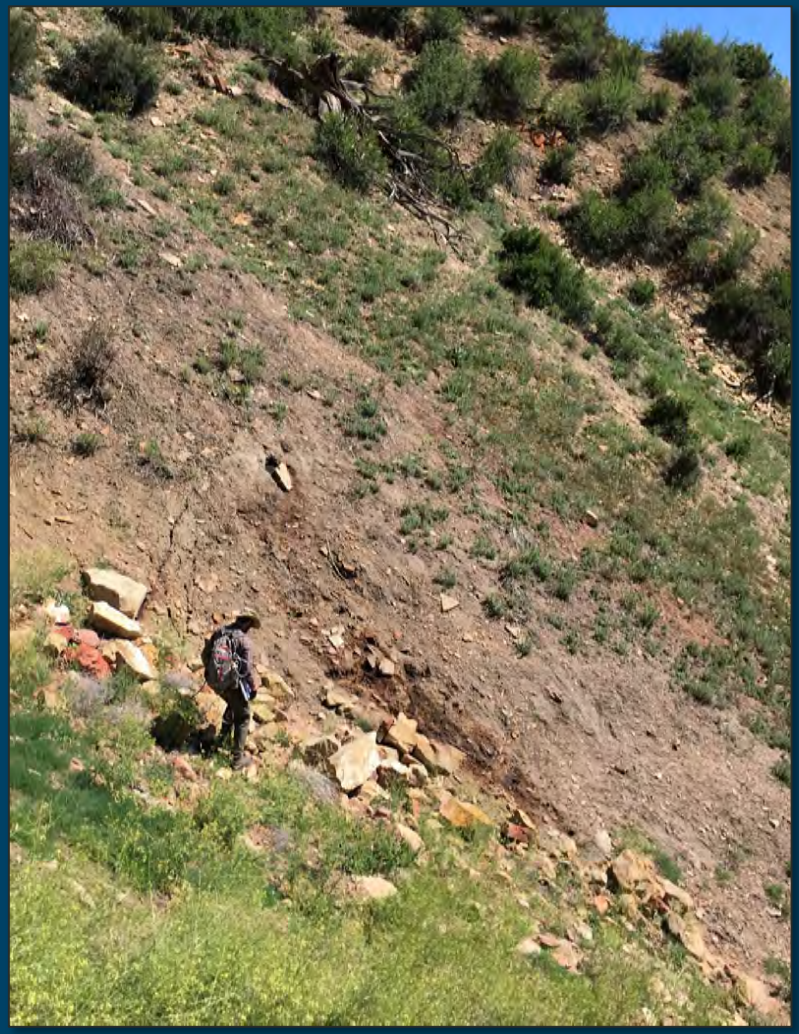
South Canyon West



New vent May 24, 2017

New vent January 25, 2018

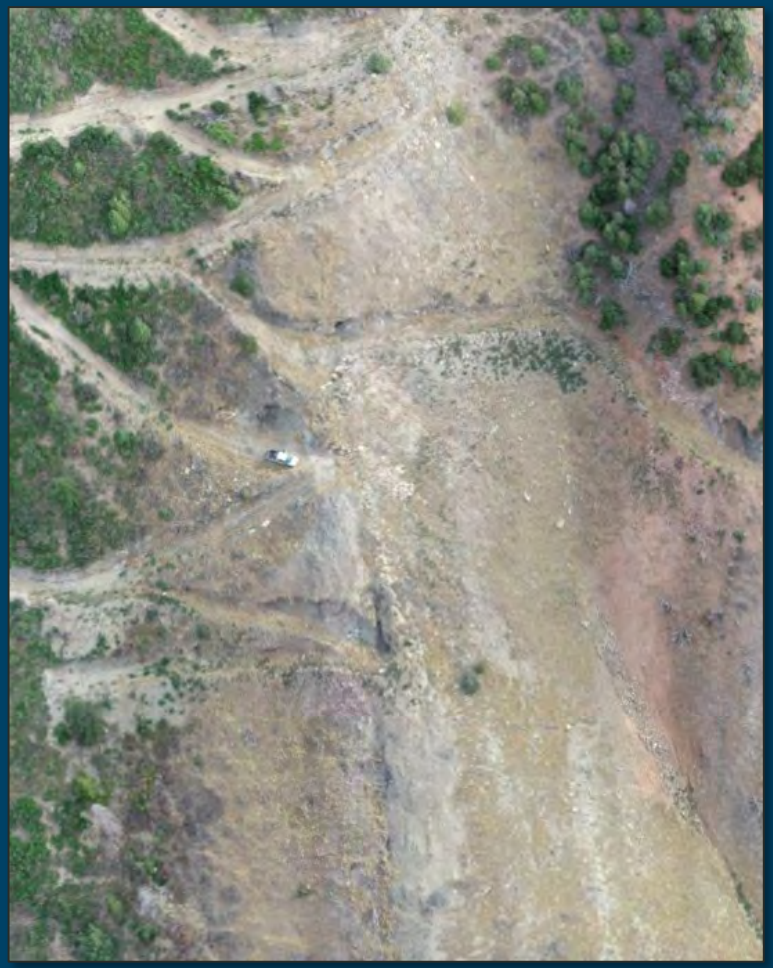
South Canyon West

Snowmelt looking Southwest January 25, 2018

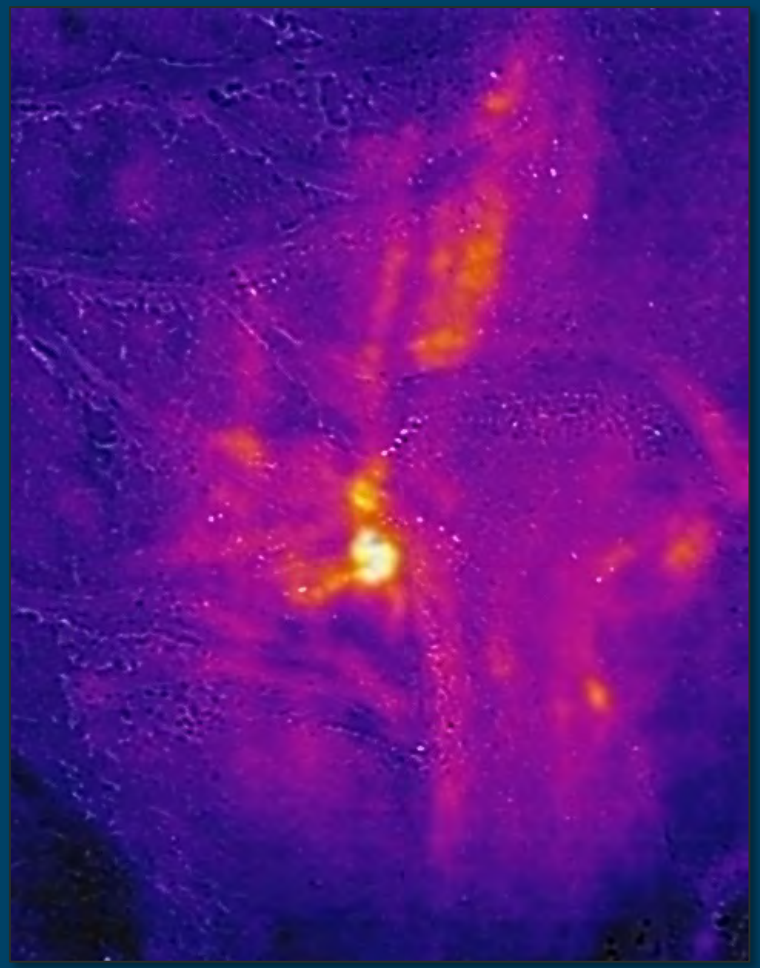
Sunshine Mine

Sunshine Mine fire looking North

Sunshine Mine



Visual imagery



Thermal imagery

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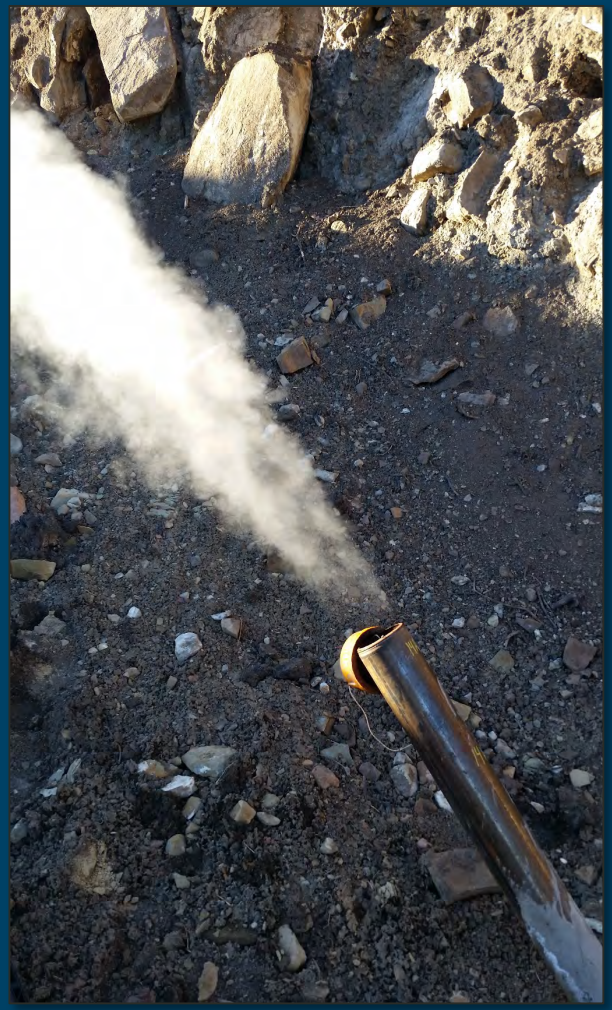
Sunshine Mine

Vent Southeast of main expression



BH-14 exhaust

Emissions inventory

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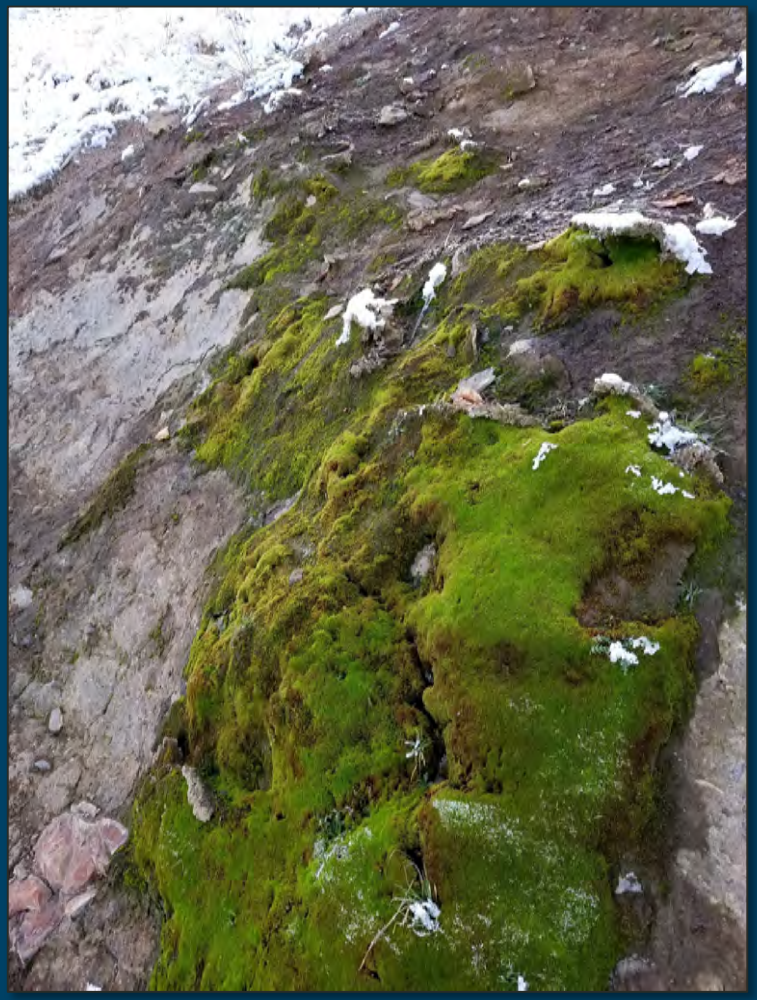
Vulcan Mine

Vulcan Mine fire looking South

Vulcan Mine

Small vent



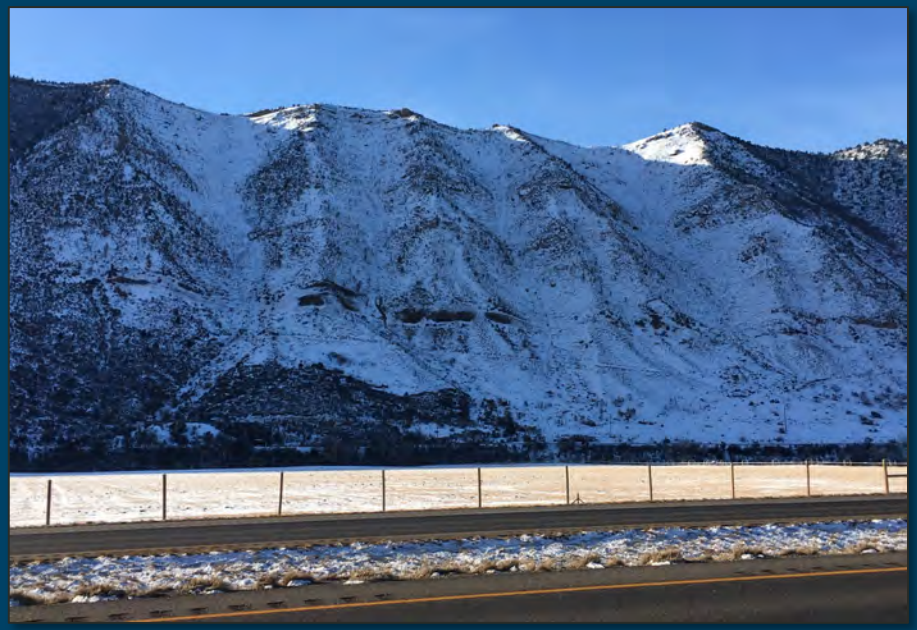
Small vents with moss growth

Vulcan Mine

Vents in outcrop

Vulcan Mine

Snowmelt drone imagery February 21, 2018



Snowmelt from Interstate 70 January, 24, 2018

Easternmost snowmelt February 21, 2018

Vulcan Mine

45 ft diameter subsidence feature looking West

Vulcan Mine

45ft diameter subsidence feature looking down

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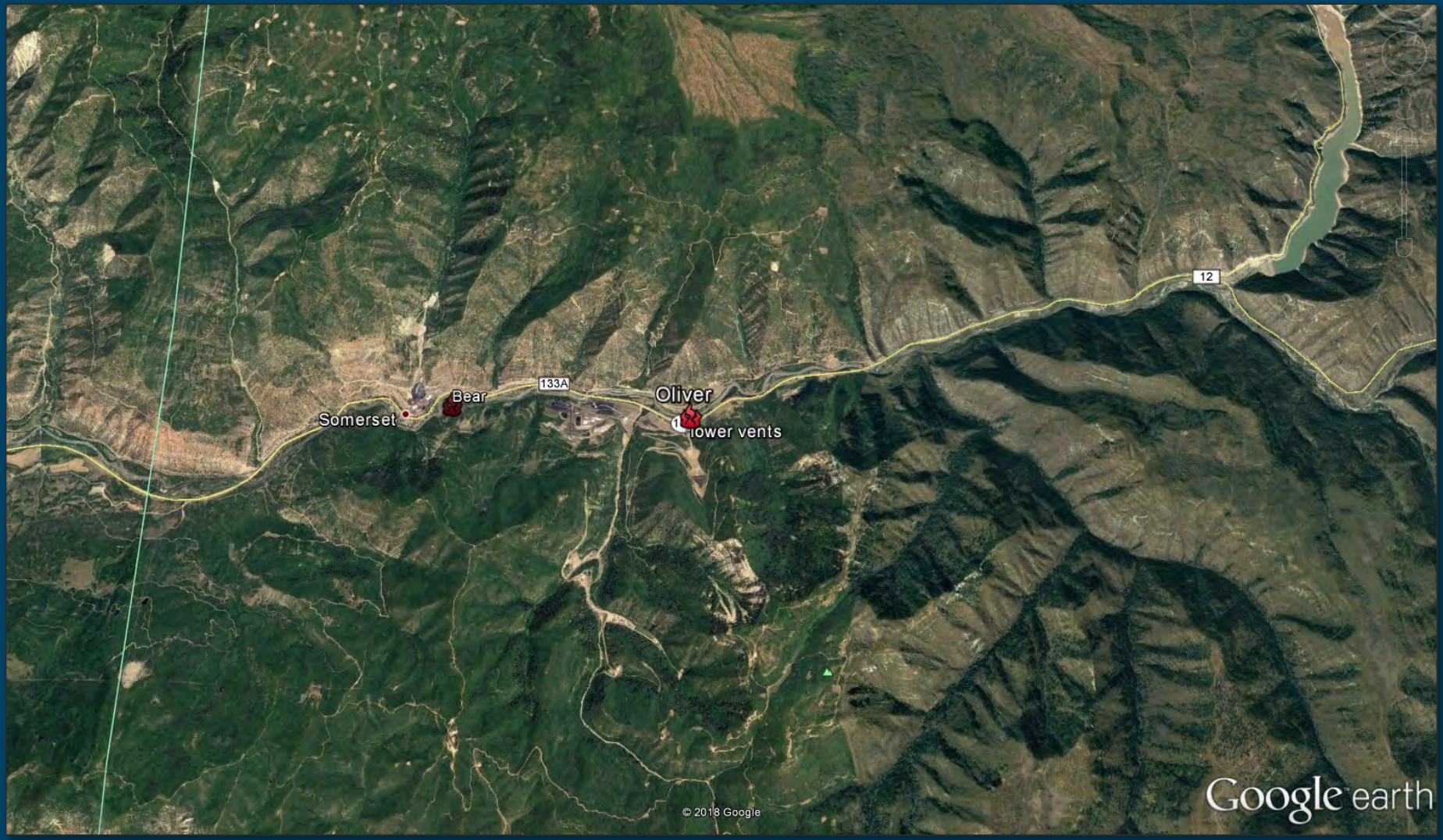
Gunnison County



Bear Mine Fire

Bear Mine fire looking South

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Department of Natural Resources

Bear Mine

90 °F main vent

Main vent looking West

Bear Mine

East vents

Bear Mine

90 °F West vent

90 °F West vent

Bear Mine

90 °F lower vent

Oliver Mine

Oliver Mine fire looking Southeast

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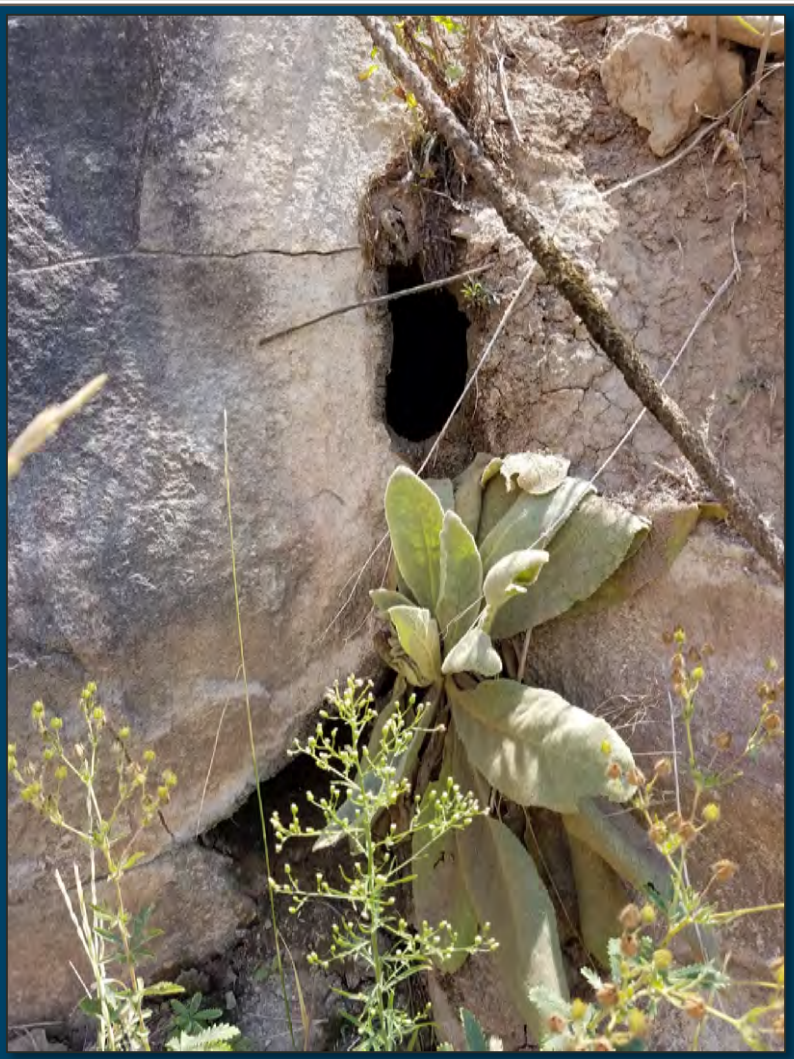
Oliver Mine



93 °F vents with elevated methane

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Oliver Mine

Subsidence area over adit with monitoring monuments

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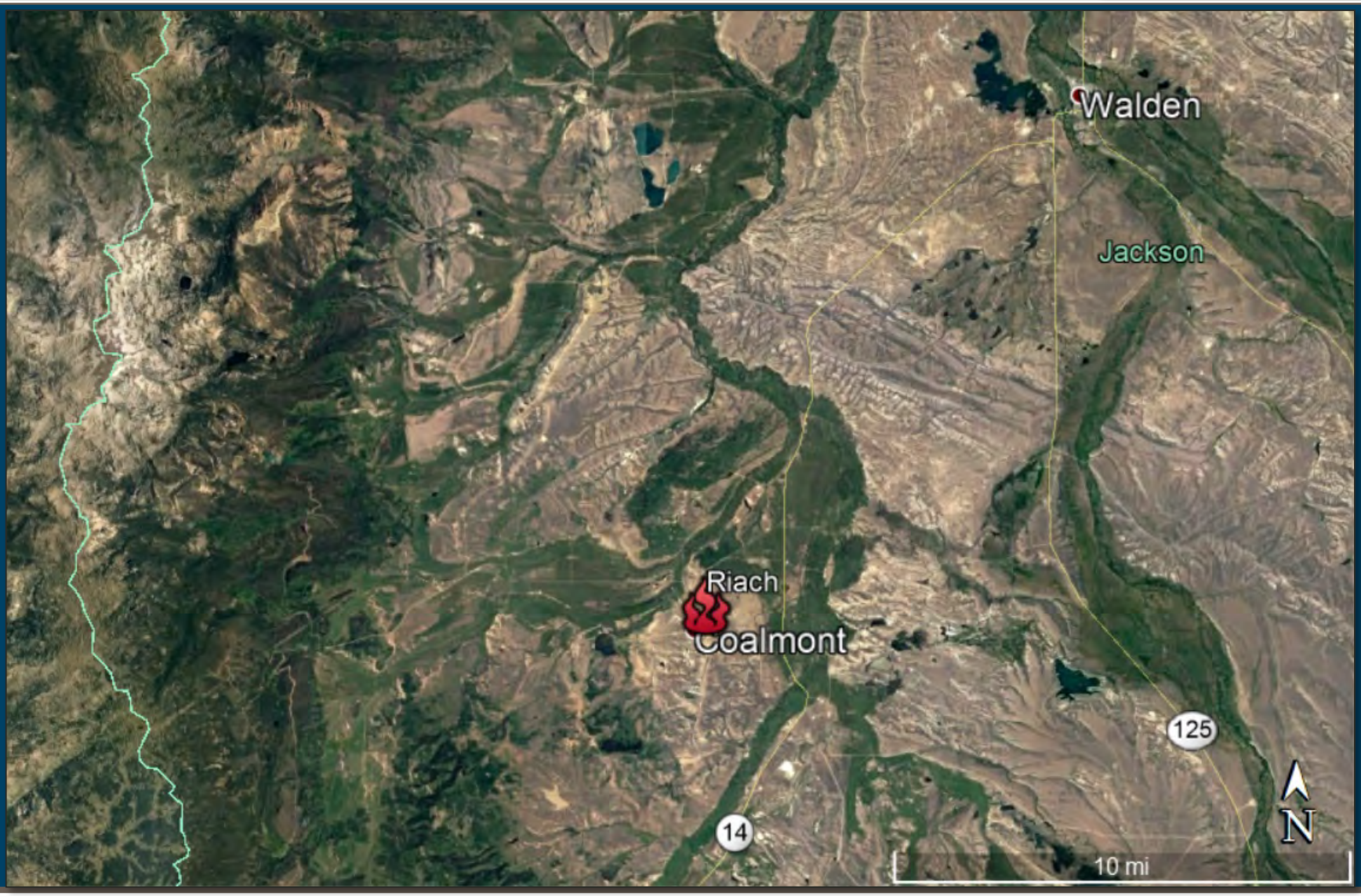
Jackson County



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Riach Mine

Riach Mine fire looking South

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Riach Mine

Fire area looking West

Riach Mine

58 °F vents along fracture

Small moss lined vents

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Riach Mine

Coal refuse pile

Coal oxidation in refuse pile

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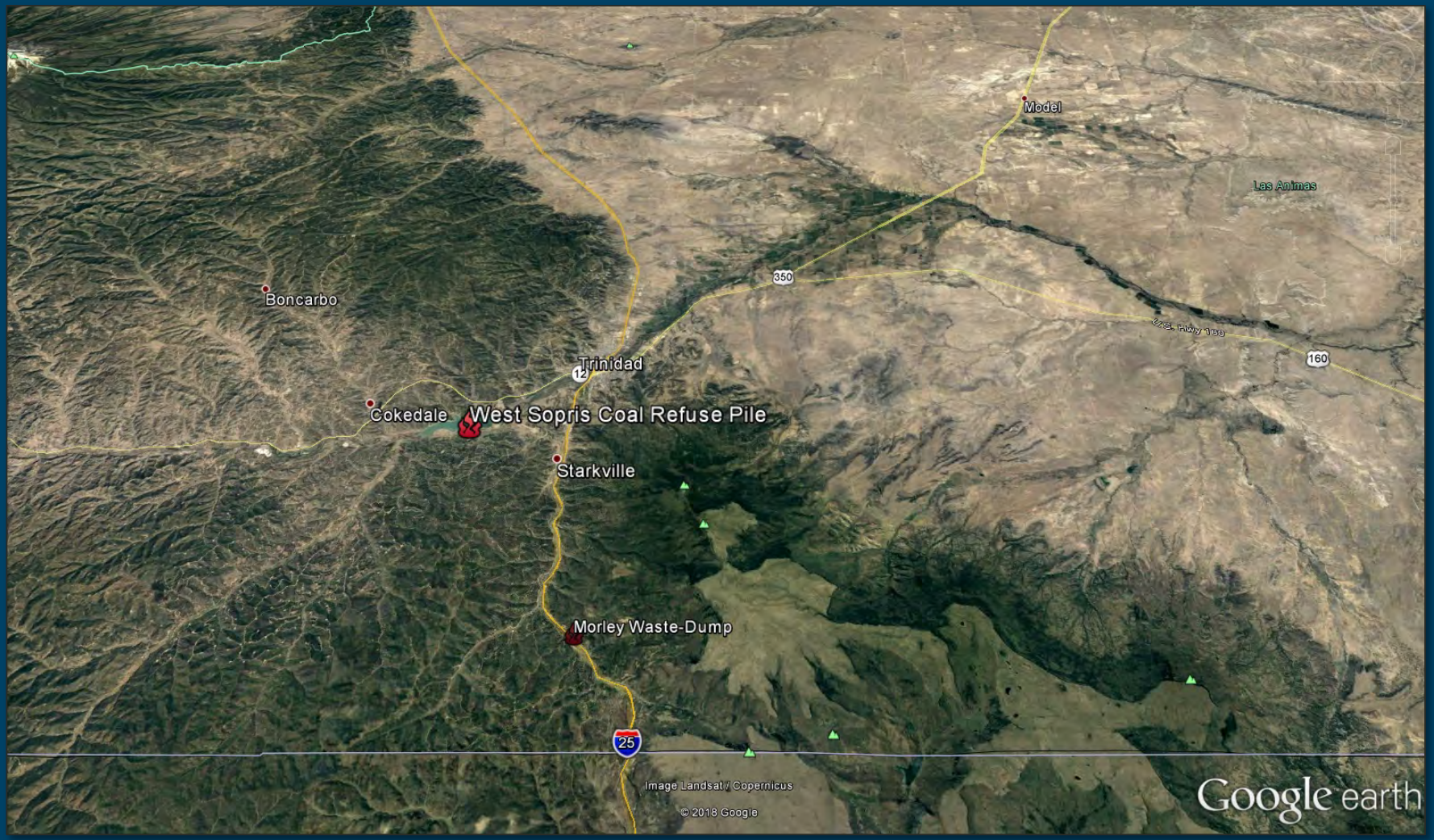
Las Animas County



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Morley Coal Refuse Pile

Morley Coal refuse pile fire looking West

Morley Coal Refuse Pile

Dry refuse pile looking West

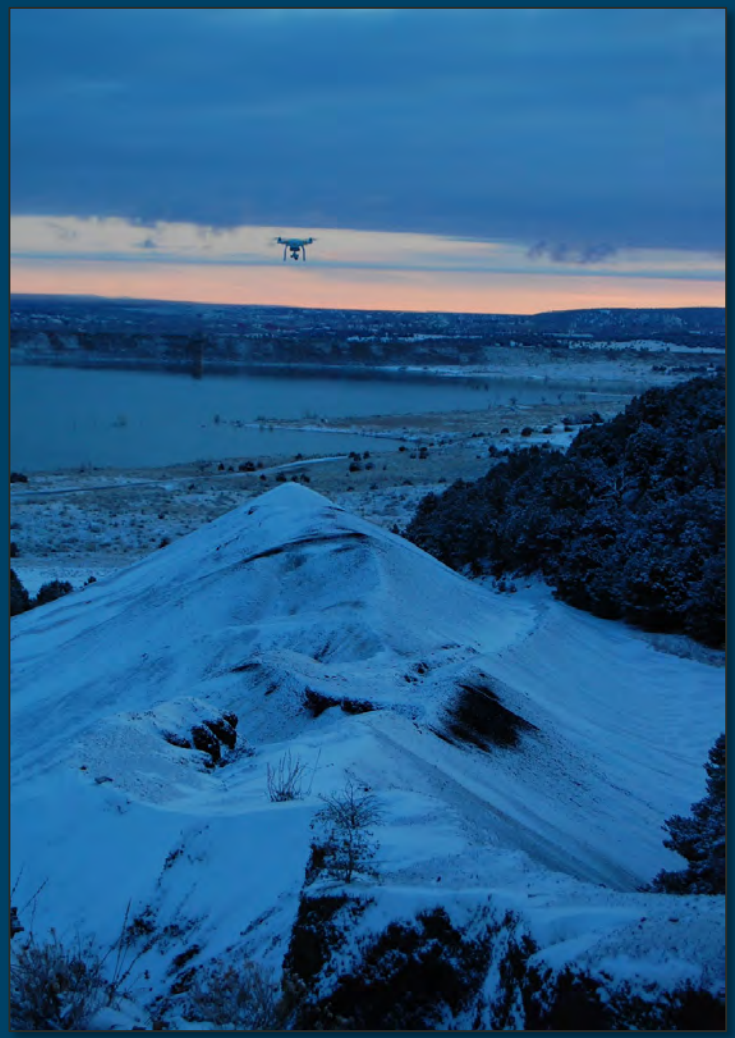
West Sopris Coal Refuse Pile

West Sopris coal refuse pile fire looking Southeast

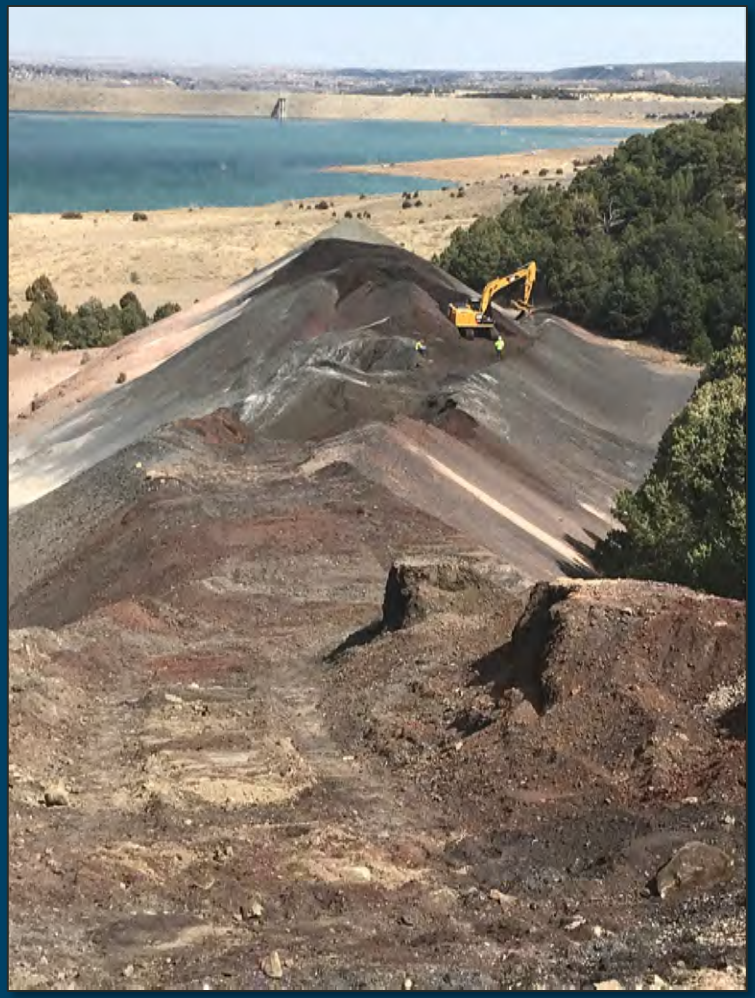
West Sopris Coal Refuse Pile

Refuse pile aerial images comparing the dry (January 10, 2018) to snow cover(January 11, 2018)

West Sopris Coal Refuse Pile



Drone capturing snowmelt imagery

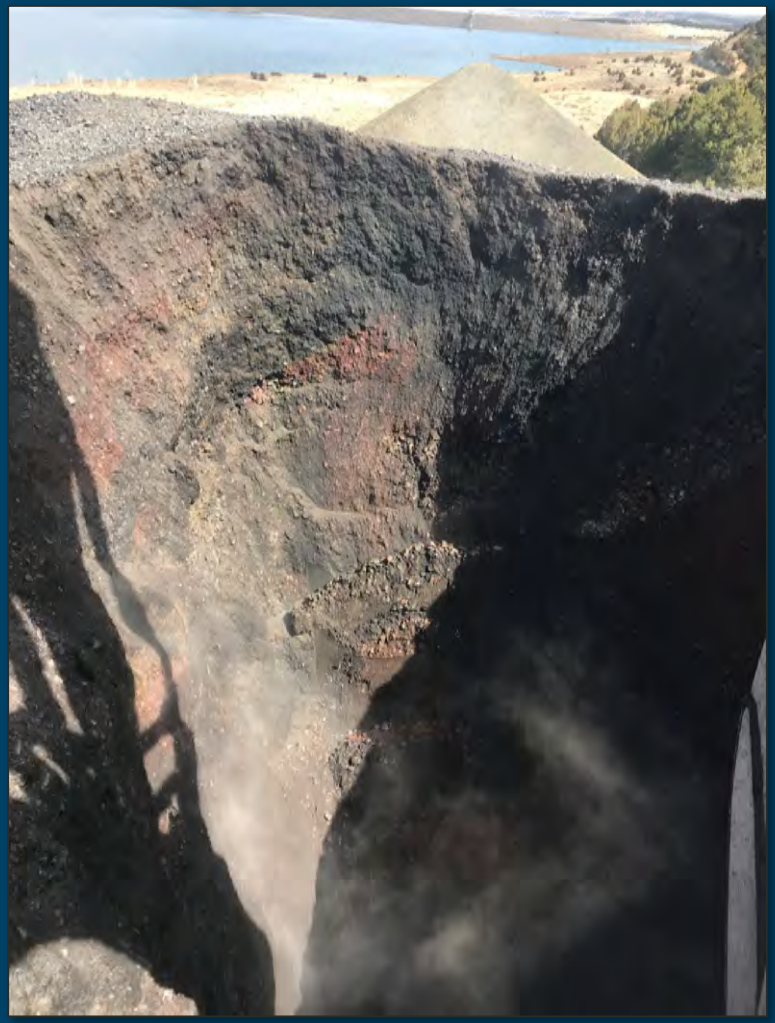


Test pit investigation

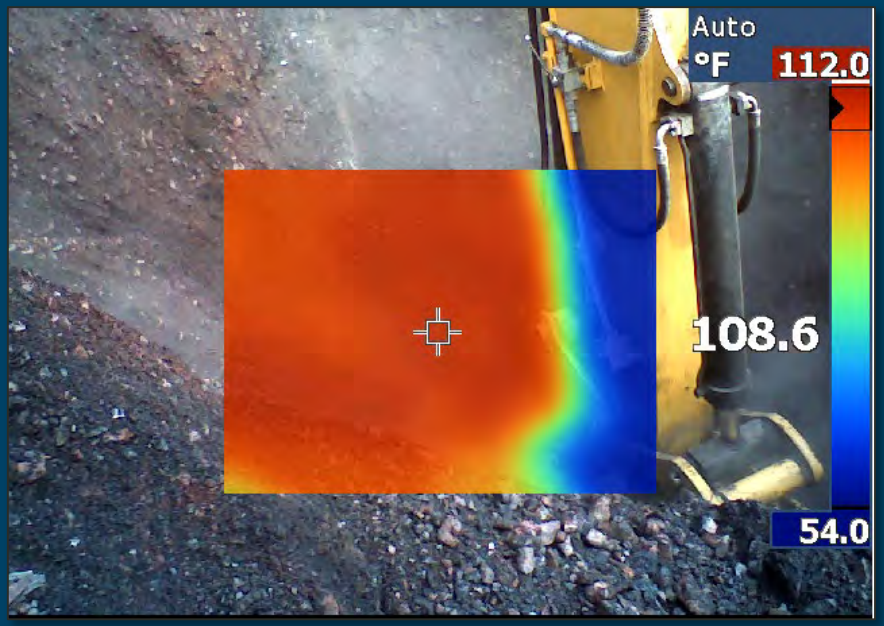
West Sopris Coal Refuse Pile

Excavating test pit

West Sopris Coal Refuse Pile

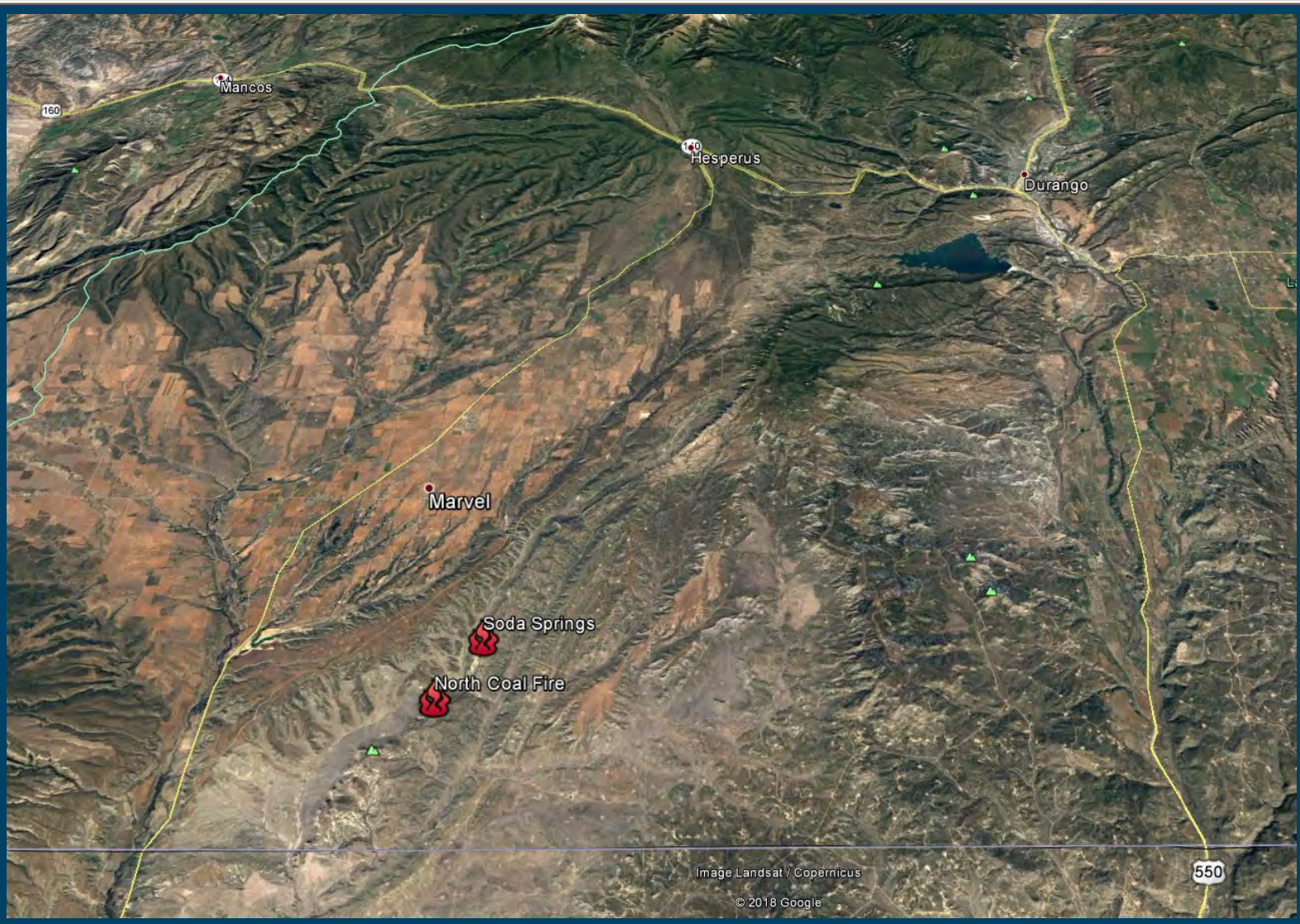


Test pit



Thermal image of test pit

La Plata County



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North Coal Mine

North Coal Mine fire looking South

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North Coal Mine

Clearing looking North

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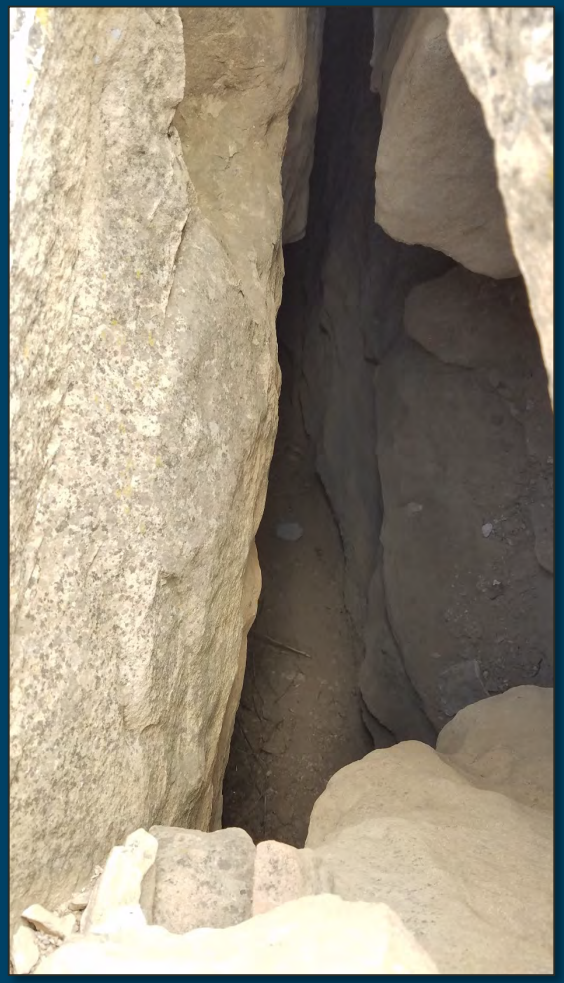
North Coal Mine

Coal fire power test system

North Coal Mine



Large fracture

Open wellhead venting H_2S gas

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Soda Springs

Soda Springs Mine fire looking East

Soda Springs

Fire area looking North

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Soda Springs

Area of low heat/oxidation looking North

Small vents

Area of low heat/oxidation looking East

Small vents

Mesa County


Farmer's Mutual
Garfield
Go Boy
Palisade
Clifton
Grand Junction
Redlands
Fruita
Mesa
Molina
North Ave
Hwy 24
S 5th St
32 Rd
340
50
6
65
330
39
Image Landsat / Copernicus
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Google earth

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Farmer's Mutual Mine

Farmer's Mutual Mine fire looking East

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Farmer's Mutual Mine

Fire area looking North

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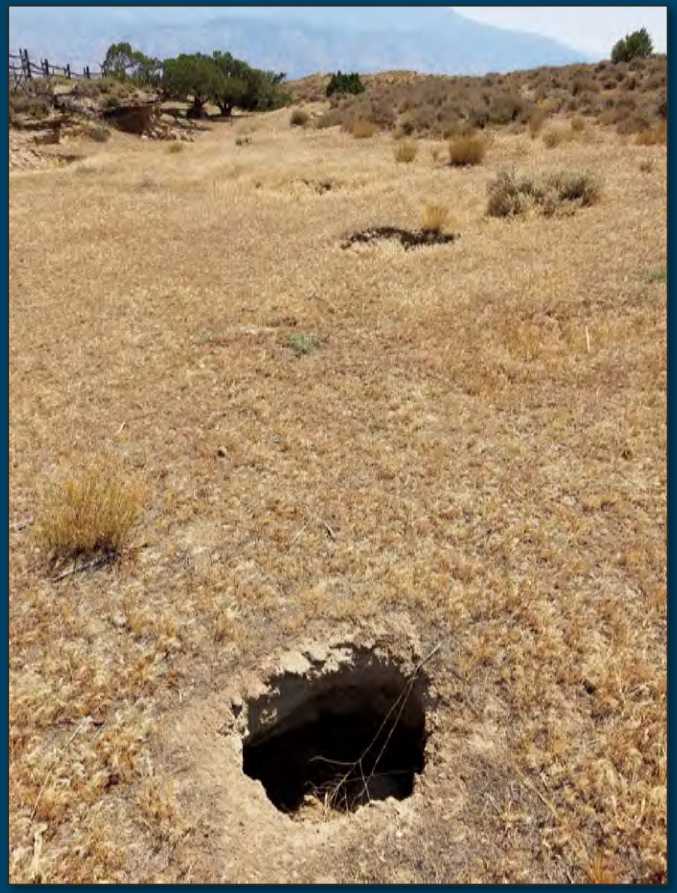
Garfield Mine

Garfield Mine fire looking West

Garfield Mine

Broken fence and subsidence feature



Subsidence within fenced area

Garfield Mine

Large fractures

Go Boy Mine

Go Boy Mine fire looking Northeast

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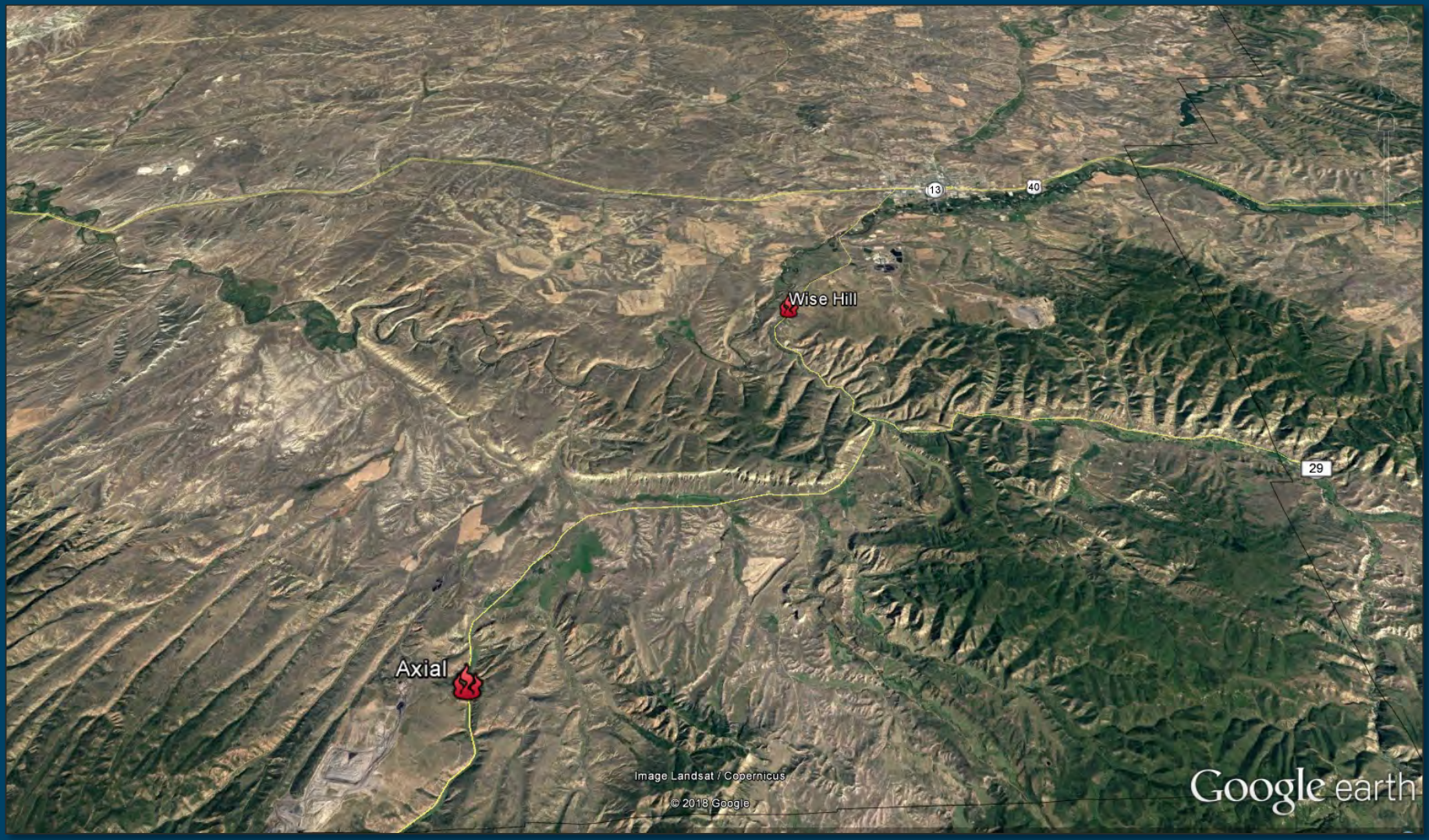
Moffat County

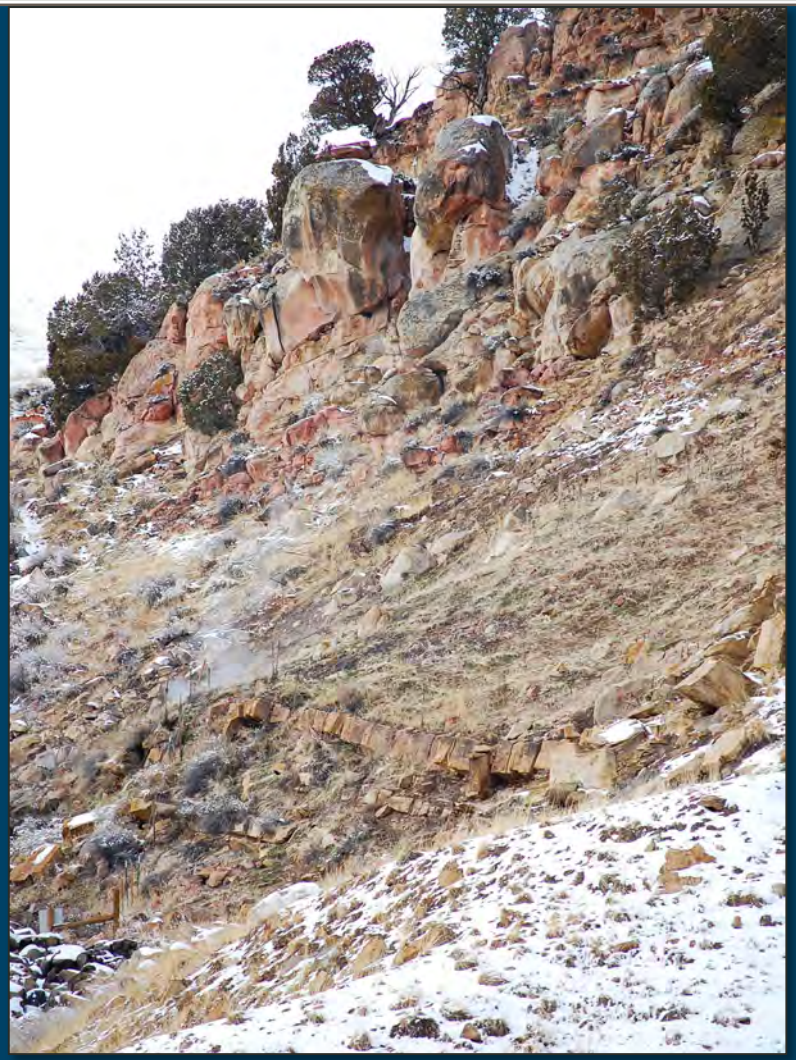


Axial Mine Fire

Axial Mine fire looking Northwest

Axial – South Side

South hillside looking Northeast



Vents on South hillside looking West

Axial – East Side

Vents in east-facing outcrop

Vents in outcrop

Looking North below vents

Looking East at Axial site

Axial - Fracture

Large fracture looking North

Wise Hill Mine

Aerial image looking South-southeast

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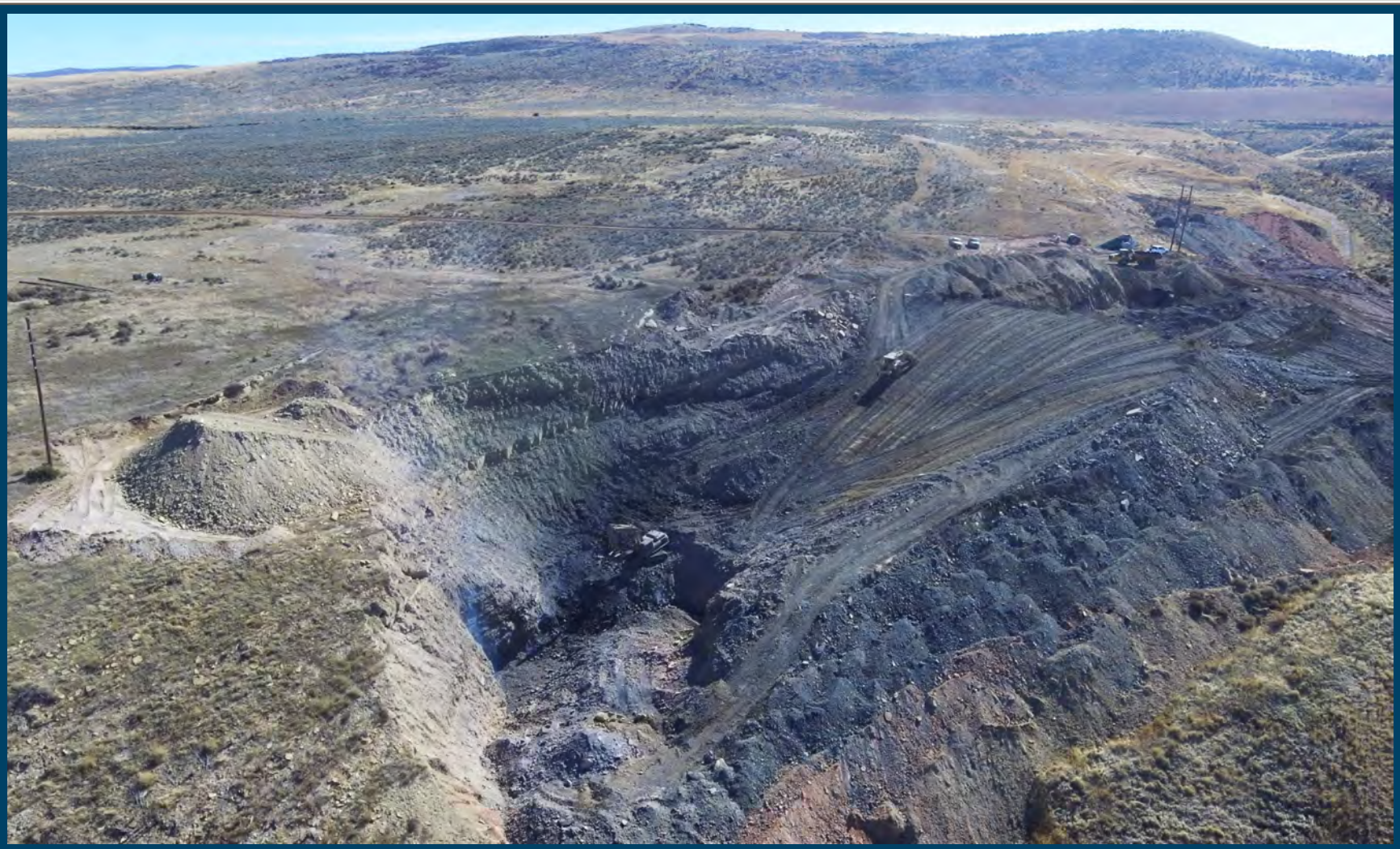
Wise Hill Mine



North abatement area with open seam looking Southeast (October 17, 2017)

Wise Hill Mine

North abatement area with open seam looking Southeast (November 2, 2017)

Wise Hill Mine

Abatement area looking East (February 13, 2018)

Wise Hill Mine

Southern abatement area looking North at excavated coal seam (May 8, 2018)

Wise Hill Mine

Abatement area looking East (February 13, 2018)

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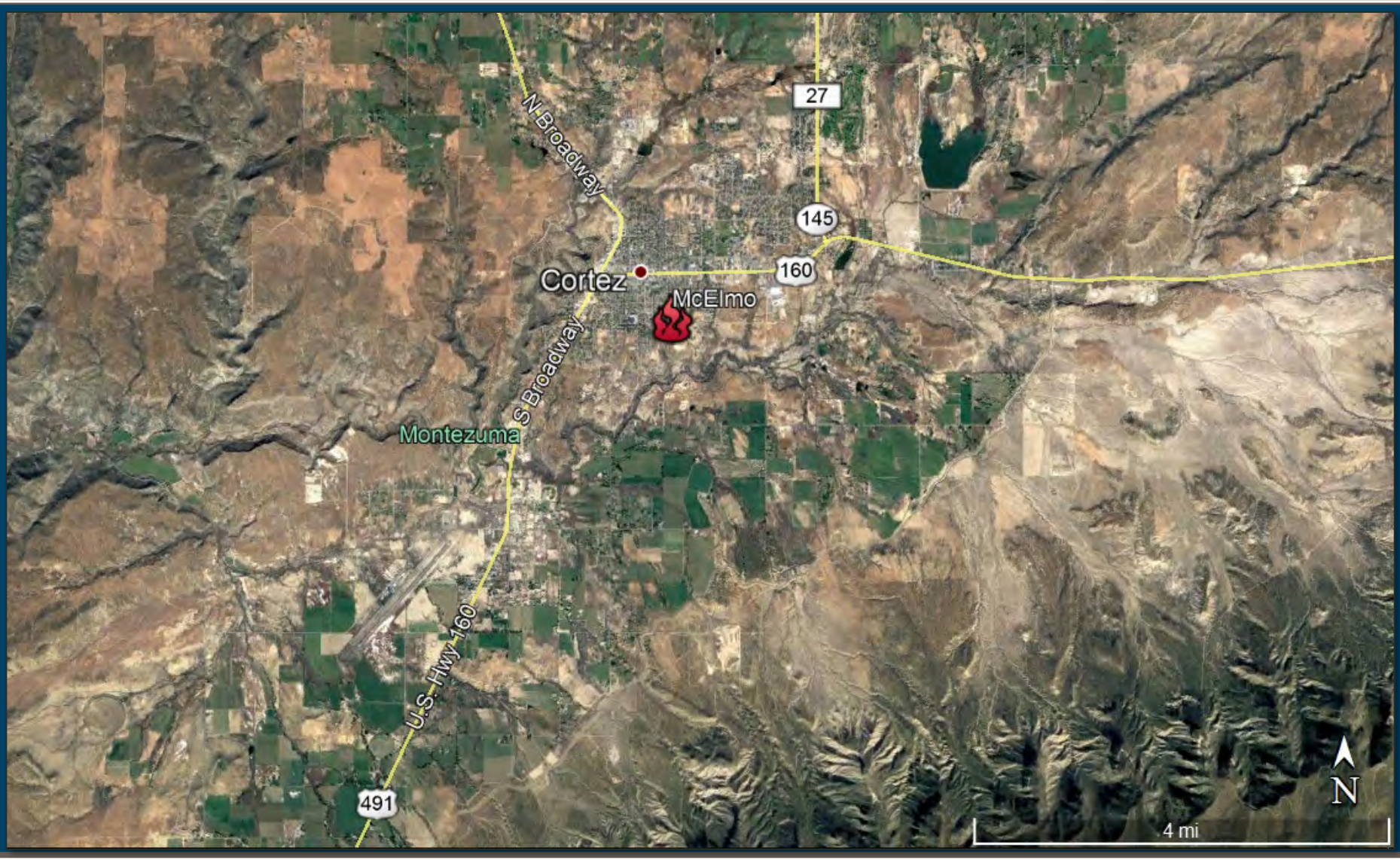
Montezuma County



McElmo Mine

McElmo fire area looking Northeast

McElmo Mine

Fire area looking East

McElmo Mine

Older grout at sandstone outcrop

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McElmo Mine

Open mine adit

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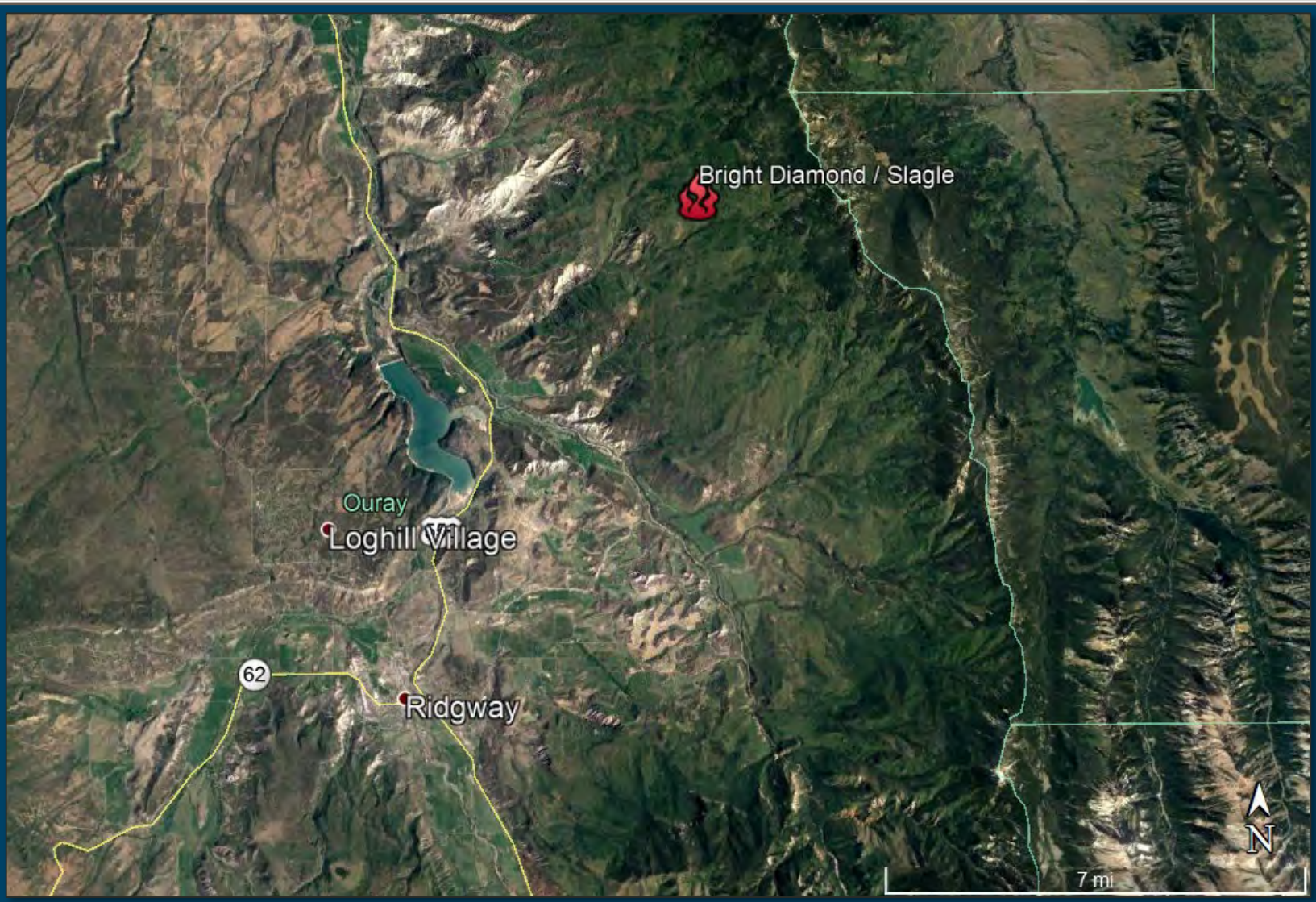
Department of Natural Resources

Ouray County



Slagle/Bright Diamond

Slagle/Bright Diamond Mine site looking East

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Slagle/Bright Diamond

Surface seal looking West

Slagle/Bright Diamond

110 °F vent

110 °F vent (foreground), subsidence (background)

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Rio Blanco County

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Department of Natural Resources

Black Diamond

Aerial image of main fire area

Black Diamond

North adit area

Black Diamond - North Adit Area – Large Vent

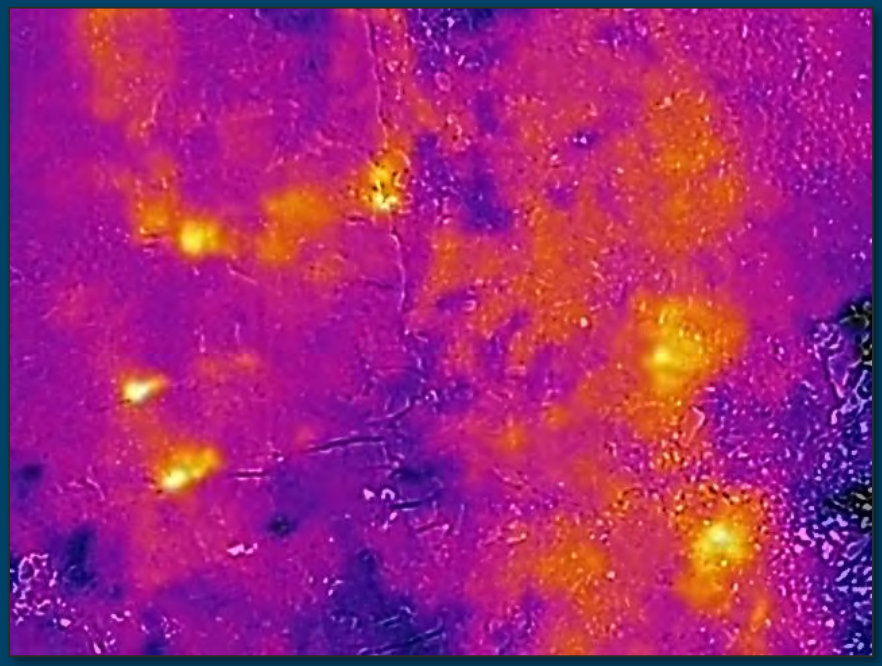
Large vent

Vents along cliff base

Black Diamond

South adit area

Black Diamond - South Adit



Thermal image

Visual image

Skull Creek

Skull Creek Mine site looking North

Skull Creek

Fire abatement looking West

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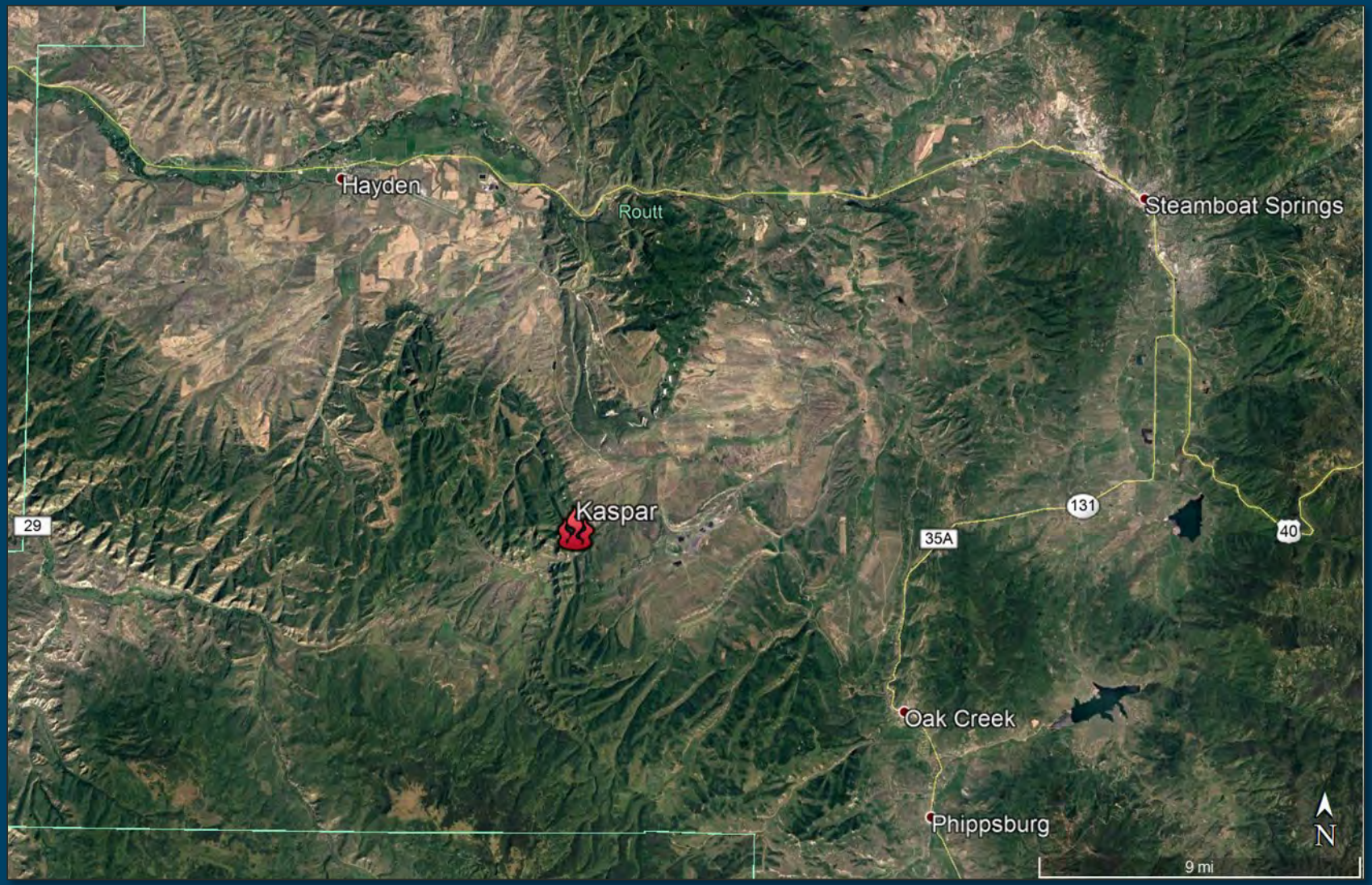
Department of Natural Resources

Skull Creek

Revegetation

Routt County



Kaspar

Kaspar Mine site looking North

Kaspar

Brush over venting fracture

Venting fracture

Kaspar

Venting South of smoking subsidence feature

Smoking subsidence feature

Kaspar

Dormant vent

Creosote staining on ground

Tetra Tech, Inc.
350 Indiana Street Golden, Colorado 80401n

tetratech.com