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

1313 Sherman Street, Room 215
Denver, CO 80203

DATE: August 19, 2014

BY: Allen Sorenson

RE: Preliminary Evaluation of Feasibility for Water Impounding Concrete Bulkheads, Red and Bonita Mine, San Juan County Colorado

Background

The Red and Bonita Mine adit is located ten miles north of the Town of Silverton on the east side of the valley of Cement Creek. The Red and Bonita adit drains the mine workings and surrounding rock with a discharge at the portal measured at 336 gallons per minute (gpm) in May 2009. Subsequent flow measurements from the adit are 180 gpm in April 2010, 314 gpm in May 2012, 202 gpm in October 2012, and 197 gpm in May 2013. The U.S. Environmental Protection Agency (EPA) and the Colorado Inactive Mine Reclamation Program (CIRMP) have undertaken a preliminary evaluation of feasibility to install water impounding concrete bulkheads in the Red and Bonita adit.

Water impounding concrete bulkheads installed at strategic locations in draining and discharging underground mine workings have the potential to flood the workings and create a mine pool that will eventually establish a ground water system with water table and flow paths similar to the pre-mining system. Saturation of sulfide minerals in the flooded workings and country rock will limit the generation of acid rock drainage (ARD) and bulkhead installation will minimize direct discharge of ARD from mine portals. The Red and Bonita discharge pH measured in 2009-2011 is slightly acidic and the dissolved metals carried by the discharge are derived by ARD mechanisms through the oxidation of sulfide minerals. After the collapsed portal was reopened by EPA in 2011, the pH of the adit discharge became more acidic, exhibiting a pH of between four and five standard units during the summer of 2012. It has also been observed that the pH of the adit discharge drops when metal oxy-hydroxide sediments and precipitates are stirred-up by activities within the mine. Otherwise, the pH of the mine water has ranged from a low of 5.31 to a high of 6.06 standard units over the course of nine sampling event from September of 2010 to May of 2013.

Multiple bulkheads have previously been installed in mine workings in the vicinity of the Red and Bonita. Notably, since bulkheads were installed in the American Tunnel in the 1990s, located approximately one-half mile south and 330 feet below the Red and Bonita workings, the flow at the

Red and Bonita portal has increased from a negligible discharge to the present levels in excess of 300 gallons per minute.

Bulkhead Design Considerations

Einarson and Abel (1990) present a step-by-step procedure for design of underground water impounding bulkheads. Conservatism in design of the bulkheads is necessary because of the safety and environmental implications of a bulkhead failure, the long life required for the bulkheads, and the ultimate inaccessibility of the bulkheads. The American Concrete Institute's "Building Code Requirements for Reinforced Concrete (ACI 318-89)" is used because the bulkheads are analogous to reinforced deep-beam concrete structures and because of the inherent conservatism of the code. The analysis presented in this memo generally follows the Einarson and Abel template.

The portal of the Red and Bonita adit is faced-up in ferricrete, and the adit is then driven through Burns Member rhyodacite of Silverton Volcanics Formation. The Burns Member was deposited adjacent to the San Juan and Uncompahgre calderas after their collapse, but before subsidence of the Silverton caldera. In order for bulkheads in the Red and Bonita adit to be effective, they must be installed in locations where water pressure behind the bulkhead will not hydrofrac (fracture) the surrounding rock. When the valve and monitoring tube on the main American tunnel bulkhead were grouted shut in May 2001, the mine pool elevation in the Sunnyside Mine workings had equilibrated at 11,661 feet. For the purpose of this feasibility evaluation, it is assumed that Sunnyside pool pressure will be exerted on any Red and Bonita bulkheads, which would be at an elevation of about 10, 973 feet. The maximum hydraulic head and pressure at a potential Red and Bonita bulkhead are calculated as follows:

$H = 11{,}661' - 10{,}973' = 688$ feet (10,973 feet is the elevation of the Red and Bonita portal)

$$\rho = \frac{H\gamma_w}{144 in^2 / ft^2} = \frac{688 \times 62.4}{144} = 298\, psi$$

where: H = hydrostatic head (feet)
γ_w = water density (62.4 pounds per square foot)
ρ = pressure head (psi)

The bulkhead must be constructed at a depth below ground surface that will provide sufficient overburden pressure to prevent hydrostatic pressure from the impounded water hydrofracing the rock surrounding the bulkhead. The hydrostatic pressure at which hydrofracing will occur is the formation breakdown pressure. Intentional hydrofracing of rock from within drill holes is frequently undertaken by the petroleum industry for the purpose of stimulating oil well production, and as a result has been intensively studied and is well understood. In oil field applications, formation breakdown pressure (B_p) is a function of (1) the tensile strength of the rock immediately adjacent to the drill hole, (2) the in situ stress field in the plane perpendicular to the drill hole, and (3) the pore pressure present in the formation. Bredehoeft, et al (1976) presented the following equation for breakdown pressure:

$$B_p = T_s + (3 \times S_{\min}) - S_{\max} - P_f$$

where: B_p = breakdown pressure
T_s = tensile strength
S_{min} = minimum stress normal to the drill hole
S_{max} = maximum stress normal to the drill hole
P_f = formation pore pressure
all terms in psi

The equation can be simplified for the case of hydraulic pressure behind a bulkhead in an adit. The tensile strength can be assumed to be zero because the adit wall rock is jointed and is fractured by blasting, and the pore pressure in and near adit wall rock must be low and can be assumed to be zero. A simple assumption is that hydrostatic stress conditions are equal to the overburden stress. This assumption is generally conservative since the overburden stress must be present and the more general stress state measured is for the horizontal stresses to equal or exceed the overburden stress. Normal formation breakdown pressures encountered in oil field work range from 1.4 to 2.8 times the overburden stress, indicating that the hydrostatic stress assumption where the breakdown pressure equals two times the overburden stress is not unreasonable. This analysis yields the following simplified breakdown equation:

$$S_{ob} = \frac{B_p}{2}$$

where: S_{ob} = overburden stress in psi

The overburden pressure is the product of the height and the density of the rock overlying the bulkhead. A density of 170 pounds per cubic foot is conservatively at the low end of expected density for the Burns member rhyodacite that the Red and Bonita adit penetrates. The minimum height of overburden cover for the bulkhead to prevent hydrofracing can be calculated as follows:

$$S_{ob} = \frac{\gamma \times H}{144 in^2 / ft^2} = \frac{B_p}{2}$$

where: γ = rock density in pounds per cubic foot
H = height of overburden in feet

Solving for H yields:

$$H = \frac{72 \times B_p}{\gamma}$$

For a bulkhead in the Red and Bonita adit, the required minimum overburden height to prevent hyrofracing is 126 feet for the 170 pcf overburden rock density and the 298 psi maximum hydraulic pressure, as follows:

$$H = \frac{72 \times 298}{170} = 126 \text{ feet}$$

At the the nearest to surface location identified during reconnaissance of the Red and Bonita as suitable for bulkhead installation, 265 feet inby the portal, there is approximately 215 feet of overburden. Therefore, hydrofracing around a bulkhead at that location, or at any locations inby where bulkheads could be installed, will not occur.

Bulkhead Length

<u>Design for Hydraulic Pressure Gradient</u>
The pressure gradient across a bulkhead is the hydraulic pressure divided by the length of the bulkhead. Garrett and Campbell-Pitt (1961) present a graph indicating and ungrouted plug will withstand a pressure gradient of 21 psi/ft at a safety factor of one. They recommend a minimum safety factor of four in good rock, yielding a recommended maximum pressure gradient of just over 5 psi/ft. They further indicated that low-pressure grouting of the bulkhead/rock contact would permit pressure gradients of 165 psi/ft without leakage. Applying a safety factor of four produces a design pressure gradient of 41 psi/ft. Using these criteria allows the following calculations of bulkhead length for the pressure gradient component of the design:

Ungrouted Bulkhead $$L = \frac{298\, psi}{5\, psi / ft} = 59.6\, feet$$

Low Pressure Grouted Bulkhead $L = \dfrac{298\,psi}{41\,psi\,/\,ft} = 7.3\,feet$

Clearly, with an almost eight fold decrease in required bulkhead length, low pressure grouting is a necessity for the proposed bulkhead.

Design for Concrete Shear on Red and Bonita Adit Perimeter

The length of the bulkhead must be sufficient to keep the shear stress developed in the bulkhead concrete below the ACI 318-89 limits. Shear strength of concrete is related to its compressive strength as follows:

$$f'_s = 2\sqrt{f'_c} = 2\sqrt{3000} = 110\,psi$$ (ACI 318-89, Section 11.3.1.1)

where: $f'_s =$ concrete shear strength (psi)

$f'_c =$ concrete compressive strength (psi)

It can be assumed that the adit wall rock at the bulkhead location has higher shear strength than the concrete, so concrete shear will control the design. The required bulkhead length for the concrete shear component of design, with minimum bulkhead concrete compressive strength specified at 3000 psi, is calculated as follows:

$$L = \frac{\rho \times h \times \ell}{2 \times (h + \ell) \times f'_s} = \frac{298 \times 8 \times 8}{2 \times (8 + 8) \times 110} = 5.4\,\text{feet}$$

where: L = bulkhead length (feet)

ρ = pressure head (psi)

h = adit height (feet)

ℓ = adit width (feet)

$f'_s =$ concrete shear strength (psi)

Therefore, the 7.3 foot minimum bulkhead length required for pressure gradient exceeds the bulkhead length required for concrete shear, and pressure gradient controls the design at this stage of the analysis. Note that the 8' x 8' adit dimensions input to the concrete shear equation are considered to be conservative based on observations and measurements made in the Red and Bonita adit. However, the maximum adit dimensions at the bulkhead location must be precisely measured and concrete shear analysis verified after the bulkhead location has been scaled and cleaned in preparation for bulkhead installation.

Design for Plain Concrete Deep Beam Bending Stress

American Concrete Institute codes can be used to determine the required length for a plain concrete bulkhead to resist deep-beam bending stress. For the analysis, the dead or fluid load acting on the bulkhead is multiplied by 1.4 (ACI 318-89, Section 9.2.1) and the plain concrete bending strength reduction factor of 0.65 is applied (ACI 318-77, Section 9.3.2). ACI directs that the design tensile bending strength be:

$$f_t = 5\sqrt{f'_c} \qquad \text{(ACI 318-77, Section 15.11.1)}$$

$$f_t = 5\sqrt{3000} = 273 \text{ psi, with minimum 3000 psi compressive strength specified}$$

$$\omega = 1.4 \times \rho \times 144 in^2 / ft^2 = 1.4 \times 298 \times 144 = 60077 \text{ pounds per foot}$$

$$M_u = \frac{\omega \times \ell^2}{8} = \frac{60077 \times 8^2}{8} = 480616 \text{ foot pounds}$$

$$M_n = \frac{M_u}{0.65} = \frac{480616}{0.65} = 739409 \text{ foot pounds}$$

$$S = \frac{I}{c} = \frac{bh^3/12}{h/2}$$

$$f_t = \frac{M_n}{S} = \frac{M_n}{(bh^3/12)/(h/2)} = \frac{6 \times M_n}{bh^2}$$

$$h^2 = \frac{6 \times M_n}{b \times f_t} = \frac{6 \times 739409}{1 \times 273 \times 144 in^2/ft^2} = 113 \text{ square feet}$$

$$h = 10.6 \text{ feet}$$

where: f_t = flexural stress (psi)

f'_c = concrete compressive strength (psi)

ω = pressure (dead) load (pounds per foot)

ρ = pressure head (psi)

M_u = maximum bending moment (foot pounds)

ℓ = adit width (feet)

M_n = design bending moment (foot pounds)

S = section modulus (cubic inches)

I = moment of inertia (inches^4)

c = centroidal distance (inches)

b = beam width (one inch)

h = bulkhead length (feet)

The forgoing analysis demonstrates that required minimum length for a plain concrete bulkhead is 10.6 feet, a significant increase over the bulkhead length of 7.3 feet required for the hydraulic pressure gradient aspect of the design. This increase in bulkhead length for plain concrete combined with the advisability of including reinforcing steel on the outby end of the bulkhead to control temperature and shrinkage induced stresses, leads to the conclusion that the bulkhead must be reinforced.

Design for Reinforced Concrete Deep Beam Bending Stress

The following design calculations follow ACI 318-89, section 9.3.2.3 and Wang and Salmon (1985).

$$C = \phi \times f'_c \times b_w \times a = 0.85 \times 3000 \times 12 \times a = 30600 \times a$$

$$T = A_s \times f_y = 60000 \times A_s$$

$$C = T$$

$$a = \frac{60000 \times A_s}{30600} = 1.961 \times A_s$$

$$M_u = \frac{\omega \times \ell^2}{8} = \frac{60077 \times 8^2}{8} = 480616 \text{ foot pounds}$$

$$M_n = \frac{M_u}{\phi} = \frac{480616}{0.9} = 534018 \text{ foot pounds = 6408216 inch pounds}$$

$$M_n = A_s \times f_y \left(d - \frac{a}{2} \right)$$

$$d = L - m_c = \left(7.3\,feet \times \frac{12 inches}{foot} \right) - 3.5 = 84.1\,\text{inches}$$

$$M_n = 60000 \times A_s \left(74.5 - \frac{1.961 \times A_s}{2} \right) = (5046000 \times A_s) - (58830 \times A_s^2)$$

$$\therefore 6408216 = (5046000 \times A_s) - (58830 \times A_s^2)$$

$$58830 A_s^2 - 5046000 A_s + 6408216 = 0$$

$$(A_s - 84.48)(58830 A_s - 75890.7) = 0$$

$A_s = \frac{75890.7}{58830} = 1.29$ square inches per foot of beam is the reinforcing steel area required

Standard #9 rebar has 1.00 square inch cross section, so installation of #9 bars on 9 inch centers, both ways, yields:

$A_s = \frac{1.0 sq.in.}{0.75\,ft.} = 1.33$ square inches per foot of beam reinforcing steel area where: C = compressive bending force (lb)

ϕ = ACI strength reduction factor; 0.85 shear concrete; 0.90 flexure rebar

f'_c = concrete compressive strength (psi)

b_w = beam web width = 12 inches

a = compression zone depth (inches)

T = tensile bending force (pounds)

A_s = area of rebar (square inches per foot)

f_y = rebar yield strength = 60,000 psi for standard bars

M_u = maximum bending moment (foot pounds)

ω = pressure (dead) load (pounds per foot)

ℓ = adit width (feet)

M_n = design bending moment (foot pounds)

d = distance, extreme compression fiber to rebar centroid (inches)

L = bulkhead length (feet)

m_c = minimum cover, form face to rebar surface = 3.5 inches

Preliminary Design Parameters for the Red and Bonita Bulkhead

- bulkhead dimensions are 8’ x 8’ x 7.3’ long
- bulkhead volume is 17.3 cubic yards
- low pressure grouting is necessary
- flexural reinforcing at the bulkhead outby end is #9 bars on 9 inch centers, both ways
- temperature shrinkage rebar at the bulkhead inby end is #6 bars on 12 inch centers, both ways
- stainless steel bypass and monitoring piping is necessary
- Concrete will use maximum ¾ inch aggregate, Type V cement, 16 percent fly ash, pozzolan, water/cement ratio of 0.45 by weight, and will be over sanded to enhance pumpability

Final design must be based on precise measurements of adit dimensions following scaling and cleaning at bulkhead location, and must consider bulkhead stability under seismic loading.

Underground Mine Workings

Prior to the commencement of EPA's investigations of the Red and Bonita in 2011, there was very little information available about the extent and configuration of the underground mine workings. Ransome (1901) states:

> The adit tunnel of (the Red and Bonita) mine runs in an easterly direction into Bonita Mountain, from a point about 100 feet above Cement Creek. About 3,000 feet of work has been done from this tunnel, but the ore could not be made to pay and the attempt was abandoned. The workings are no longer accessible and the lode was not seen. The Red and Bonita mill is equipped with Gates crusher, 2 sets of rolls, jigs, 10 stamps, and 4 Frue vanners.

A rudimentary layout of the Red and Bonita underground workings is depicted in an 1899 mineral survey of the adjacent American Eagle Mill site. This layout and its relationship to overlying mine claims is illustrated in the "Report of Structural Geologic Investigation, Red and Bonita Mine" DRMS, (2007), and is attached to this memorandum as Figure 1. DRMS (2007) includes a discussion of the volume of the Red and Bonita mine waste dump, and concludes that the extent of the underground workings must be much greater that depicted in the 1899 mineral survey map (3560 feet of 5ft. x 7ft. workings indicated by the mine dump versus 595 lineal feet of workings depicted on the 1899 map). As discussed below, underground entries in 2012 and 2013 verified the much greater extent of the mine.

In 2011, EPA and their contractors re-opened and stabilized the Red and Bonita adit portal, which had been collapsed for many decades (URS, 2012). In June of 2012, preparations were made for an entry into the mine to conduct reconnaissance and mapping, and to evaluate mine hydrology. It was known from the 2011 portal stabilization work that there were deposits of precipitates and sediments on the floor of the adit that would be released into the mine discharge and subsequently into Cement Creek by personnel entering the underground workings. Oxygen levels of less than 19.5 percent had been measured just inby the portal in 2011 and in 2012. Therefore, EPA and their contractors installed water treatment and filtration facilities and a ventilation fan in preparation for the underground entry. Typically, adits are driven at a slight upgrade of around one percent. Therefore, given the water line that developed when the adit was collapsed was about three feet above the mine floor at the portal, it had been hoped that the precipitates and sediments would taper and pinch out against the mine floor within approximately 300 feet of the portal.

On June 6, 2012, a three-person CIMRP team entered the mine. Oxygen levels remained safe throughout the period of underground reconnaissance, but the sediments on the floor of the adit did not pinch-out. Therefore, the team released volumes of sediment that consumed the filtration capacity of the treatment systems, and the mine entry had to be curtailed after proceeding to only about 680 feet from the portal along the main easterly heading of the mine. This easterly heading was observed to be the main route of water flow from the mine.

A sketch map of the underground workings observed during the June 2012 entry is included as Figure 2. Due to the time constraints discussed above, none of the southerly headings depicted on the sketch map were explored. Rather, the orientation of these headings were shot with a Brunton compass, and their length estimated by shining mine lamps into the headings. Since bedrock walls were observed at the distal end of each heading, these appeared to be dead ends. As will be described below, the second southerly side heading inby the portal is not a dead end, but takes an easterly turn that made it appear to end when shined with the mine lamps. These incomplete observations led to the incorrect conclusion that the 1899 map included as Figure 1 was not an accurate depiction of the underground workings.

In July and early August 2013, EPA and their contractors installed water treatment systems at the Red and Bonita with capacity to remove the large volume of sediments and precipitates from the mine discharge that would be released during thorough investigation and mapping of the mine. During this same period, EPA contractors entered the mine numerous times and to much greater depths than were possible during the 2012 reconnaissance effort. These preparations allowed a multidisciplinary team of EPA, CIMRP personnel, EPA contractors, and a local landowner to safely investigate and map the mine on August 13, 2013. The map produced by CIMRP as a result of the investigation is included as Figure 3.

Comparison of the maps in Figures 1 and 3 show that at the time of the 1899 mineral survey, the Red and Bonita workings consisted of the crosscut adit from the portal to station 2+75, the 275 drift, and the 640 drift. All of the other workings shown in Figure 3 must have been driven after the 1899 mineral survey. The extent of entry into the mine in August 2013 was terminated when flooded conditions were encountered at the eastern extend of the two main headings. Approximately 2,000 total lineal feet of workings were investigated. Given the discussion of the mine dump volume above, this means that as much as 1,560 linear feet of additional workings may extend to the east from the terminal locations of the August 2013 mine entry.

Relationship of Red and Bonita to other Mines in the Area

The two most significant and productive mines in the vicinity of the Red and Bonita are the Sunnyside Mine and the Gold King Mine. A plan map and vertical projections of the underground workings of these mines is included as Plate 8 in Burbank and Luedke (1969) and reproduced here as Figure 4. The relationship of these mines to the Red and Bonita workings is illustrated on Figure 5. Primary access to the Sunnyside Mine during its latter years of operation was via the American and Terry Tunnels. The Sunnyside Mine workings are interconnected with the Mogul Mine workings, but there is no mined connection between Sunnyside and the Gold King or the Red and Bonita. The approximate elevations of the portals to these mines are given in the following table.

Portal Name	**Elevation**
American Tunnel	10,617 feet
Red and Bonita	10,973 feet
Mogul	11,400 feet
Gold King 7-level	11,400 feet
Terry Tunnel	11,560 feet

At the time that the Sunnyside Mine ceased production in 1991, the American Tunnel discharged between 1600 and 1700 gallons per minute (gpm) and the Terry Tunnel discharged 10 gpm in the winter, and more than 1000 gpm during snowmelt. In the early to mid-1990s discharge from the Mogul Mine averaged around 10 gpm, from the Gold King 7-level around 5 gpm, and the Red and Bonita was essentially dry.

During the 1990s, water impounding concrete bulkheads were installed in the American and Terry Tunnels and on the B- and F-level connections between the Sunnyside and Mogul Mines. The bulkheads flooded the Sunnyside Mine workings to an elevation of 11,661 feet and elevated the local water table as fracture flow paths long drained by the American Tunnel were re-saturated. The following table lists mine discharge rates prior to and following bulkhead installation.

Mine Name	**Pre-Bulkhead Discharge**	**Current Discharge**
American Tunnel	1600 to 1700 gpm	80 to 140 gpm
Red and Bonita	Dry	220-340 gpm
Mogul Mine	10 gpm	50-150 gpm
Gold King 7-level	5 gpm	160-250 gpm

The CIMRP has created a three dimensional model of the mine workings and their relationship to surface topography. This model may be viewed at the following link, and a view from the model is included as Figure 6:

http://www.tips.osmre.gov/newsroom/success_stories/2012/2012jun-28.shtml

Bulkhead Locations

The ideal location for bulkhead installation in the Red and Bonita identified during the mine entries conducted in 2012 and 2013 is near Station 2+65 (Figure 3). A bulkhead at this location would impound essentially all of the flow from the mine. The rock at Station 2+65 is competent, but intensely jointed. However, the joints are very tight and thin. In order to further evaluate this potential bulkhead location, the rock quality and hydraulic conductivity should be measured by drilling and packer testing. Because of the confined 5'W x 7'H adit dimensions and because of the difficulty managing water and sediment during entries into the mine, jack leg drilling is recommended. Jack leg holes will not provide core for accurate Rock Quality Determination (RQD), but observation of drill action and insertion of a borehole camera following drilling to observe joints will be sufficient to evaluate RQD.

Three or four jack leg holes should be drilled into the rib and back of the adit near Station 2+65. The holes should be 10-12 feet long and two-inch in diameter to facilitate camera work and packer testing. The holes should be thoroughly jetted and washed following drilling. Packers should be installed near the collar of the holes, then pressure applied into the packed holes with water take over time recorded to calculate permeability indices. If the rock is conductive at Station 2+65, this would not necessarily rule out a bulkhead at this location, but formation grouting would be required, increasing the cost and difficulty of the project. Alternatively, a bulkhead could be installed at or around Station 4+00, identified as a suitable location during the 2013 mine entry, but a bulkhead at this location would not impound the 40-50 gpm flowing from the 275 drift. Another option would be installation of a bulkhead at Station 4+00 with a secondary bulkhead at Station 2+65. A disadvantage of this option is that several years of performance evaluation would be necessary between the installation of the first and second bulkheads.

Potential Impacts from Red and Bonita Bulkheading

Impoundment of flow from the Red and Bonita would result in an immediate and substantial reduction in metal loading to Cement Creek. The limited open mine workings behind the bulkhead would quickly fill with water, and the trough of depression in the ground water table created by the draining adit would begin to fill through the fracture flow system that controls regional ground water flow in the Upper Animas River Basin, including the Cement Creek Basin. This will eventually result in discharge of ground water and metal loading to surface streams that will reduce the initial benefit to water quality provided by bulkheading.

It can be anticipated that following bulkhead installation in the Red and Bonita, flows from the Mogul Mine and Gold King Level-7 will increase from present rates. It can further be anticipated that ground water seepage and spring flows may increase along the North Fork and on Cement Creek. As sulfate salts precipitated in unsaturated fracture systems are dissolved and flushed out to surface streams, there is the possibility of significant metal loading to the creeks, but this first-flush impact would be temporary. Bulkheading the Red and Bonita will eventually return ground water flow paths to an approximation of the configuration that existed prior to the mine workings creating a free-flowing ground water drainage pathway.

Mogul Mine Bulkhead

In 2003, a bulkhead was installed approximately 250 feet inby the portal of the No. 1 Tunnel of the Mogul Mine. The No. 1 Tunnel was drifted along a vein structure, and was less than ideal for bulkheading due to the potential for leakage along the vein. The continuing discharge observed at the Mogul Mine is a result of leakage around the bulkhead. An option under consideration for the Mogul Mine is investigating the potential to grout zones of leakage around the bulkhead. This action, in combination with bulkheading the Red and Bonita, has the potential for long term water quality improvement in Cement Creek and the Upper Animas River.

Contingency Plan

An important consideration of bulkhead projects, is that a by-pass pipe installed through the bulkhead serves as a contingent environmental protection measure. If, even after careful evaluation and planning, bulkheads that are installed do not improve hydrologic conditions, or are found to make conditions worse, the valve on the bypass pipe can be opened and the site returned to its previous condition. Alternatively, the bypass pipe and valve can be used to manage and control the mine pool elevation. If, after sufficient time to allow for equilibration of post-valve closure hydrologic conditions, bulkheading is demonstrated to be effective, the bypass pipe and valve are grouted solid as a final closure safeguard, eliminating the both the open penetration through the structural concrete and valve corrosion issues which can significantly compromise longterm safety of the bulkhead closure.

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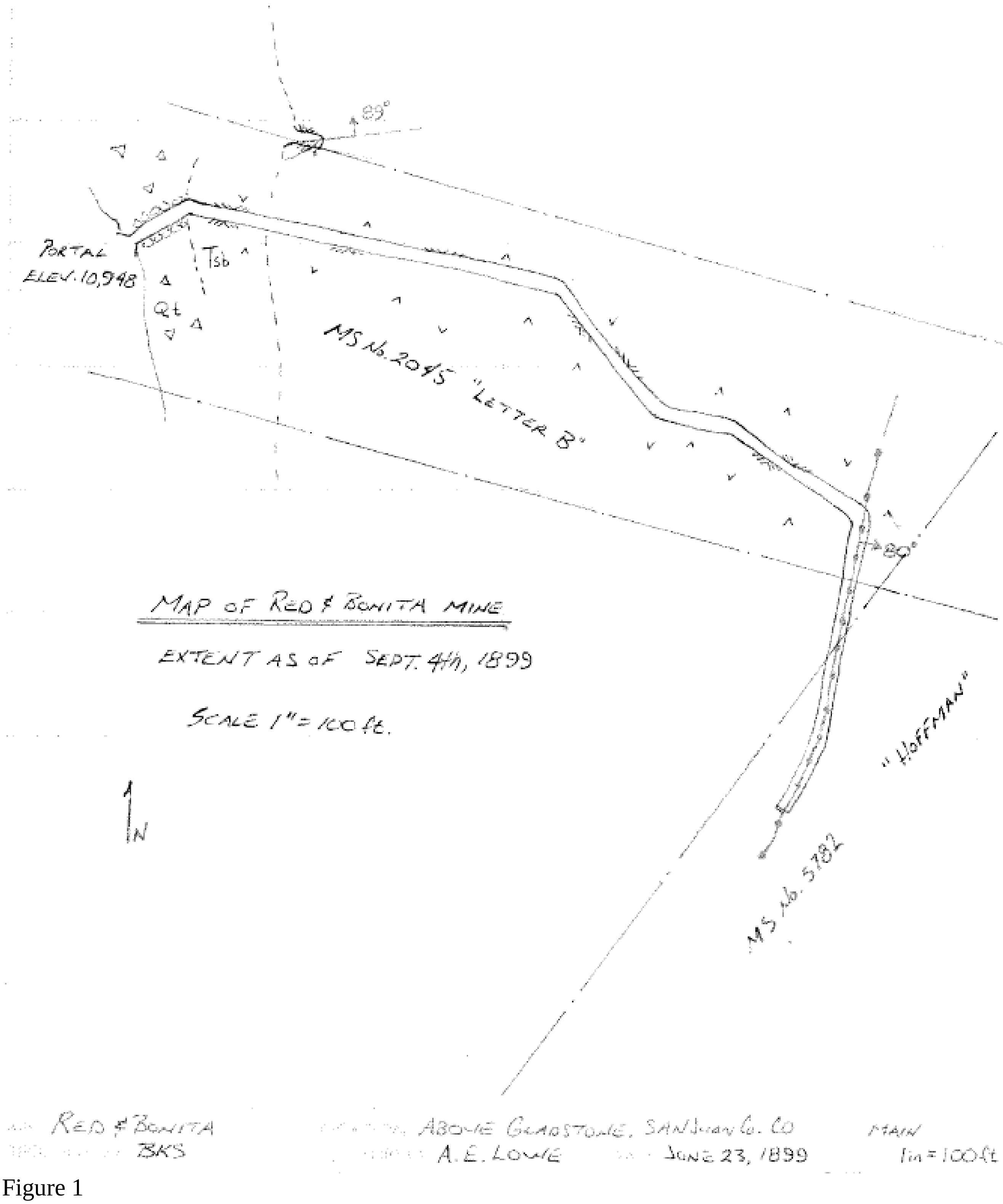

89°
PORTAL
ELEV. 10,948
Tsb
Qt
MS No. 2045 "LETTER B"
80°
MAP OF RED & BONITA MINE
EXTENT AS OF SEPT. 4th, 1899
SCALE 1" = 100 ft.
N
"HOFFMAN"
MS No. 5782
RED & BONITA
BKS
ABOVE GLADSTONE, SAN JUAN Co. CO
A. E. LOWE
JUNE 23, 1899
MAIN
1in = 100 ft

Figure 1

Red and Bonita Mine, Sketch Map of June 2012 Reconnaissance of Adit

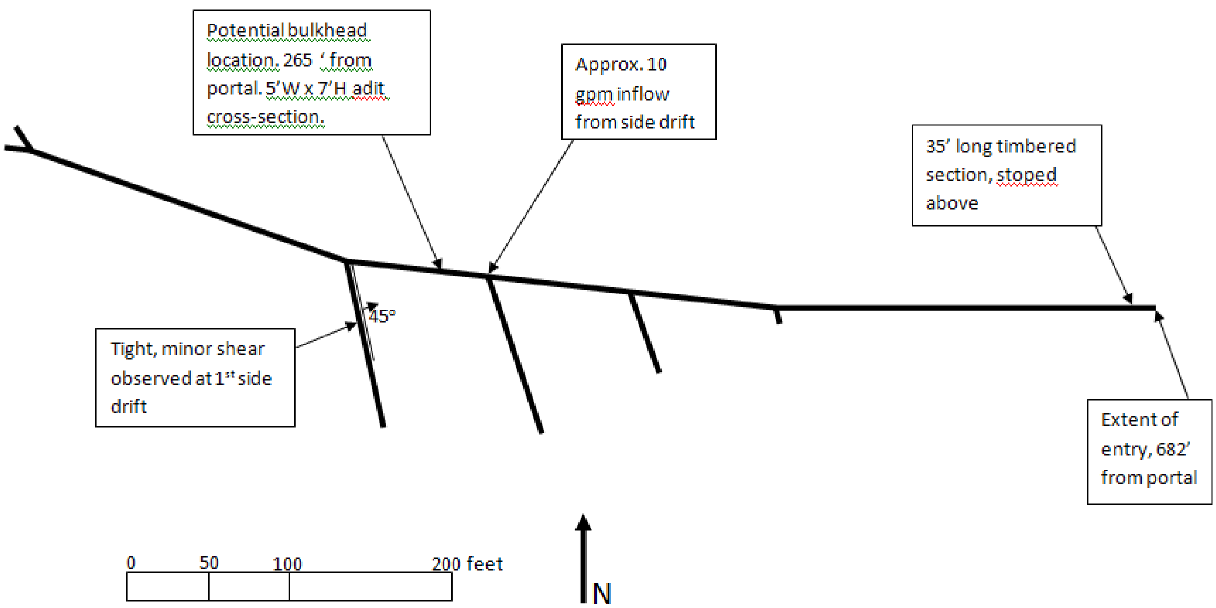


Figure 2

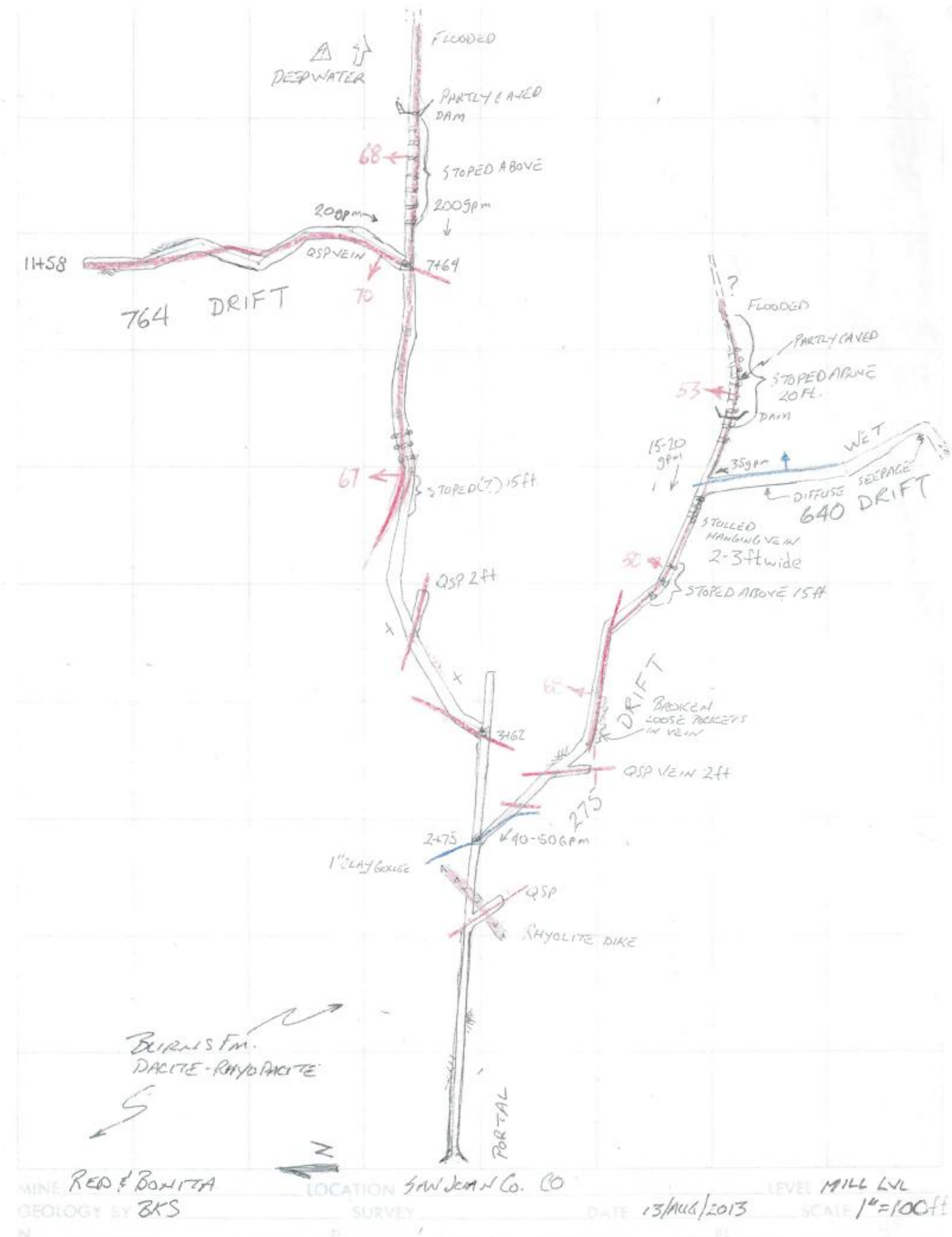
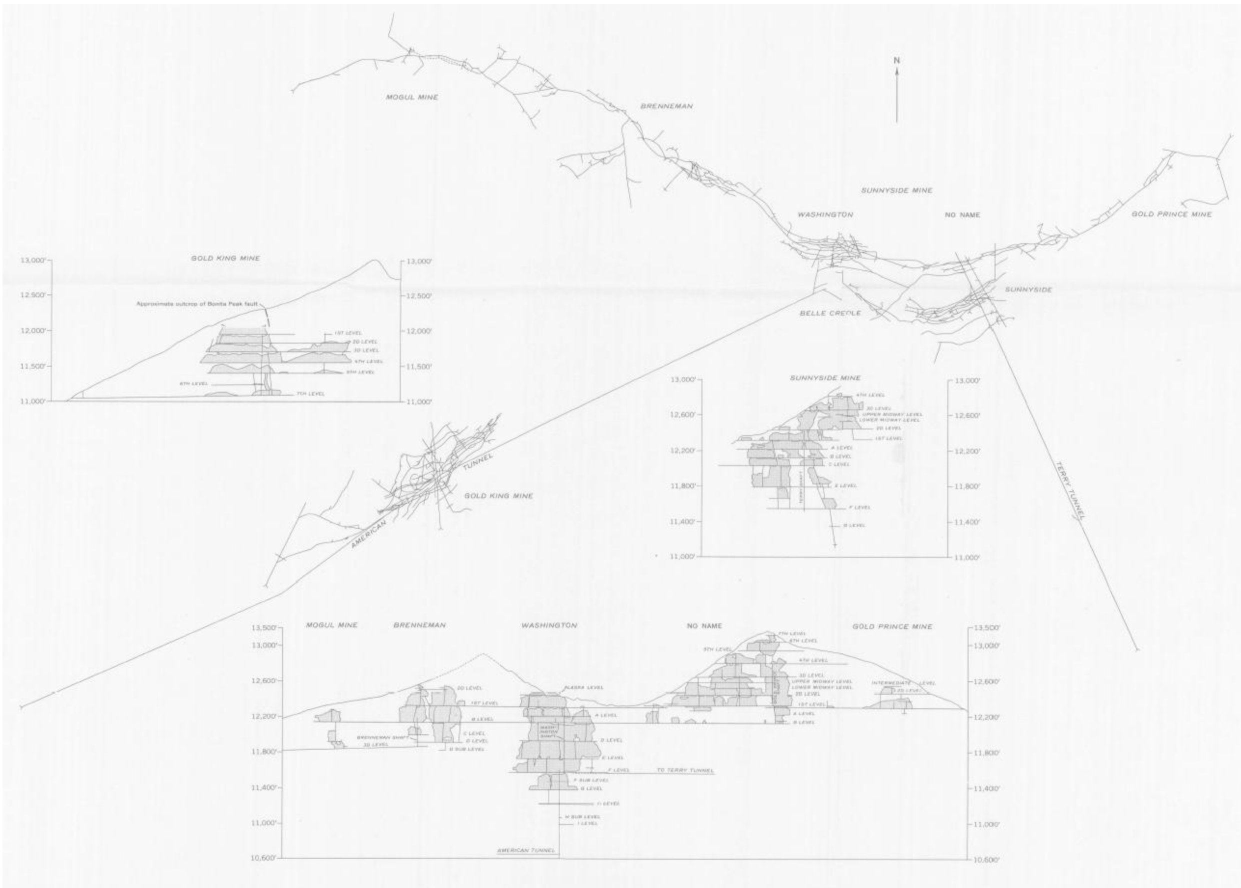

FLOODED
DEEP WATER
PARTLY CAVED
DAM
68
STOPED ABOVE
200gpm
20gpm
QSP VEIN
7+64
11+58
764 DRIFT
70
FLOODED
PARTLY CAVED
STOPED ABOVE 20 ft.
53
DAM
15-20 gpm
35gpm
WET
SEEPAGE
DIFFUSE
640 DRIFT
67
STOPED(?) 15ft.
STULLED HANGING VEIN
2-3ftwide
STOPED ABOVE 15ft
QSP 2ft
BROKEN LOOSE POCKETS IN VEIN
DRIFT
3+62
QSP VEIN 2ft
275
2+75
40-50GPM
1" CLAY GOUGE
QSP
RHYOLITE DIKE
BURNS FM.
DACITE - RHYODACITE
N
PORTAL
MINE RED & BONITA
LOCATION SAN JUAN Co. CO
LEVEL MILL LVL
GEOLOGY BY BKS
SURVEY
DATE 13/AUG/2013
SCALE 1"=100ft
N
E
EL

Figure 3



PLAN MAP AND VERTICAL PROJECTIONS OF MINE WORKINGS AND STOPES IN THE SUNNYSIDE AND GOLD KING MINES, EUREKA MINING DISTRICT, SAN JUAN MOUNTAINS, COLORADO

0 800 1600 2400 3200 FEET

350-451 O - 70 (IN POCKET)

Figure 4

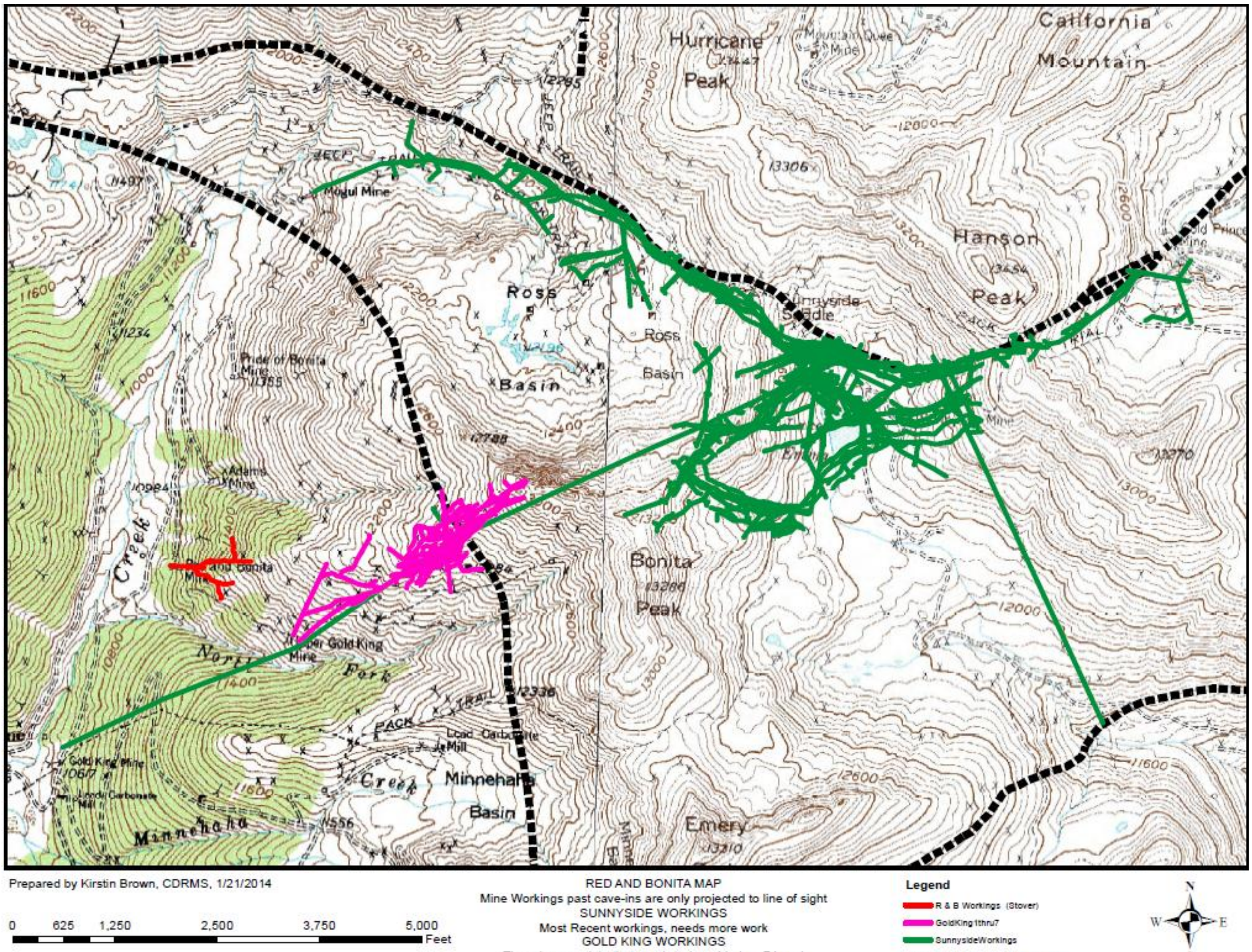

California Mountain
Hurricane Peak
Hanson Peak
Ross Basin
Sunnyside Saddle
Bonita Peak
Emery
Minnehaha Basin
Modul Mine
Pride of Bonita Mine
Adams Mine
Red and Bonita
Upper Gold King Mine
Gold King Mine
North Fork
Creek
Lead Carbonate Mill
Prepared by Kirstin Brown, CDRMS, 1/21/2014
0 625 1,250 2,500 3,750 5,000 Feet
RED AND BONITA MAP
Mine Workings past cave-ins are only projected to line of sight
SUNNYSIDE WORKINGS
Most Recent workings, needs more work
GOLD KING WORKINGS
There is more data that needs to be added on 7 Level
Legend
R & B Workings (Stover)
GoldKing1thru7
SunnysideWorkings
USGS Mapped Faults PP 1651
N
W
E
S

Figure 5

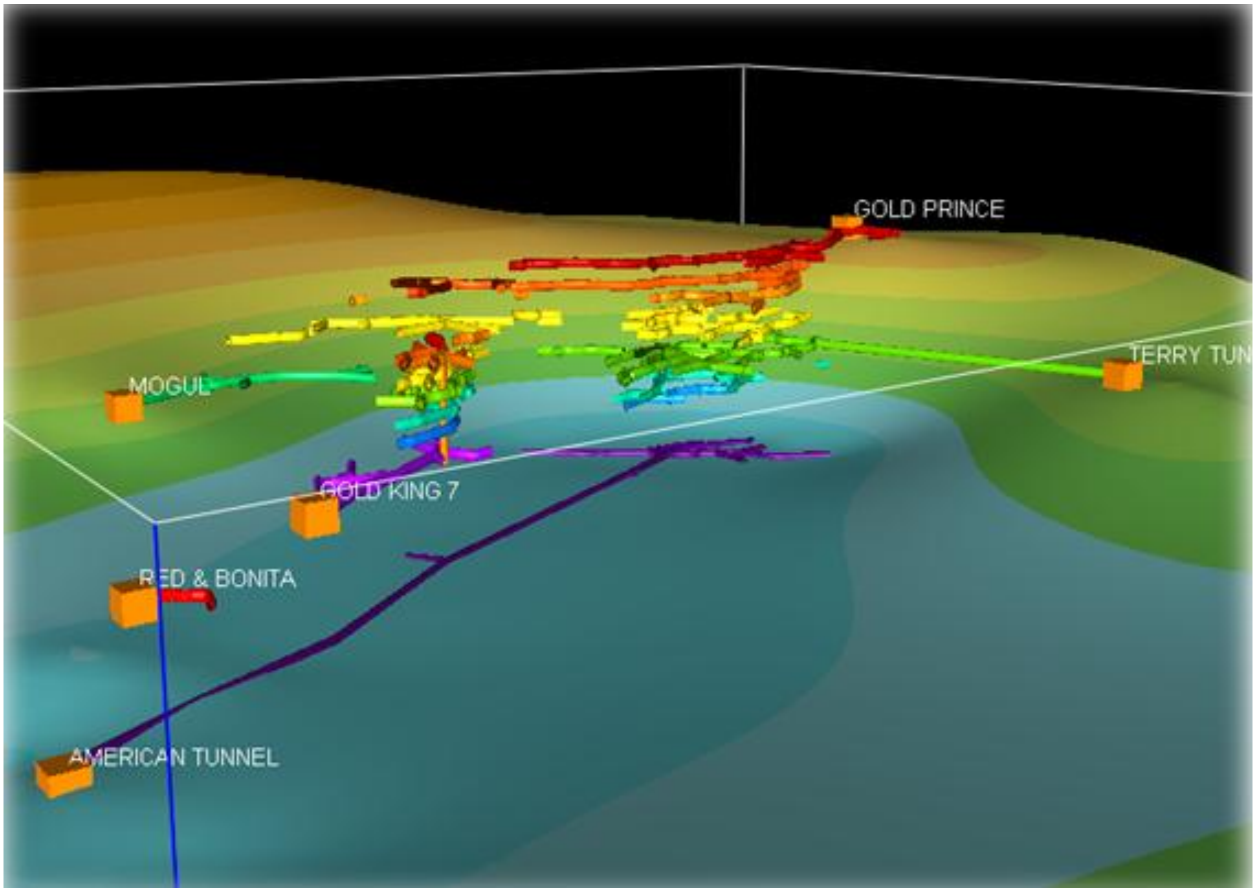

GOLD PRINCE
TERRY TUN
MOGUL
GOLD KING 7
RED & BONITA
AMERICAN TUNNEL

Figure 6