Report of Structural Geologic Investigation

Red & Bonita Mine

San Juan County County, Colorado

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Prepared for

Animas River Stakeholders Group

Prepared by

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Introduction and Background

The Animas River Stakeholders (ARSG), Bureau of Land Management (BLM) and the U.S. Environmental Protection Agency (EPA), are cooperating in an investigation of reclamation options for controlling or eliminating acid mine drainage at the inactive Red & Bonita Mine (R&B), on upper Cement Creek, in San Juan County, Colorado. The overall goal of the work is to reduce heavy metal loading in Cement Creek and the Animas River, as measured below Silverton. The R&B portal and dump are located about ½-mile above Gladstone on the east side of Cement Creek at an elevation of 10,960 feet (Lat. N37° 53'51.3", Long. W107° 38'34.9") (Figure1). The portal is located on the "Letter B" claim, M.S.No.2045. At present, the R&B adit portal is caved at surface, and is discharging an estimated 300gpm of mine drainage. The drainage is contributing an un-quantified but significant metals load to Cement Creek.

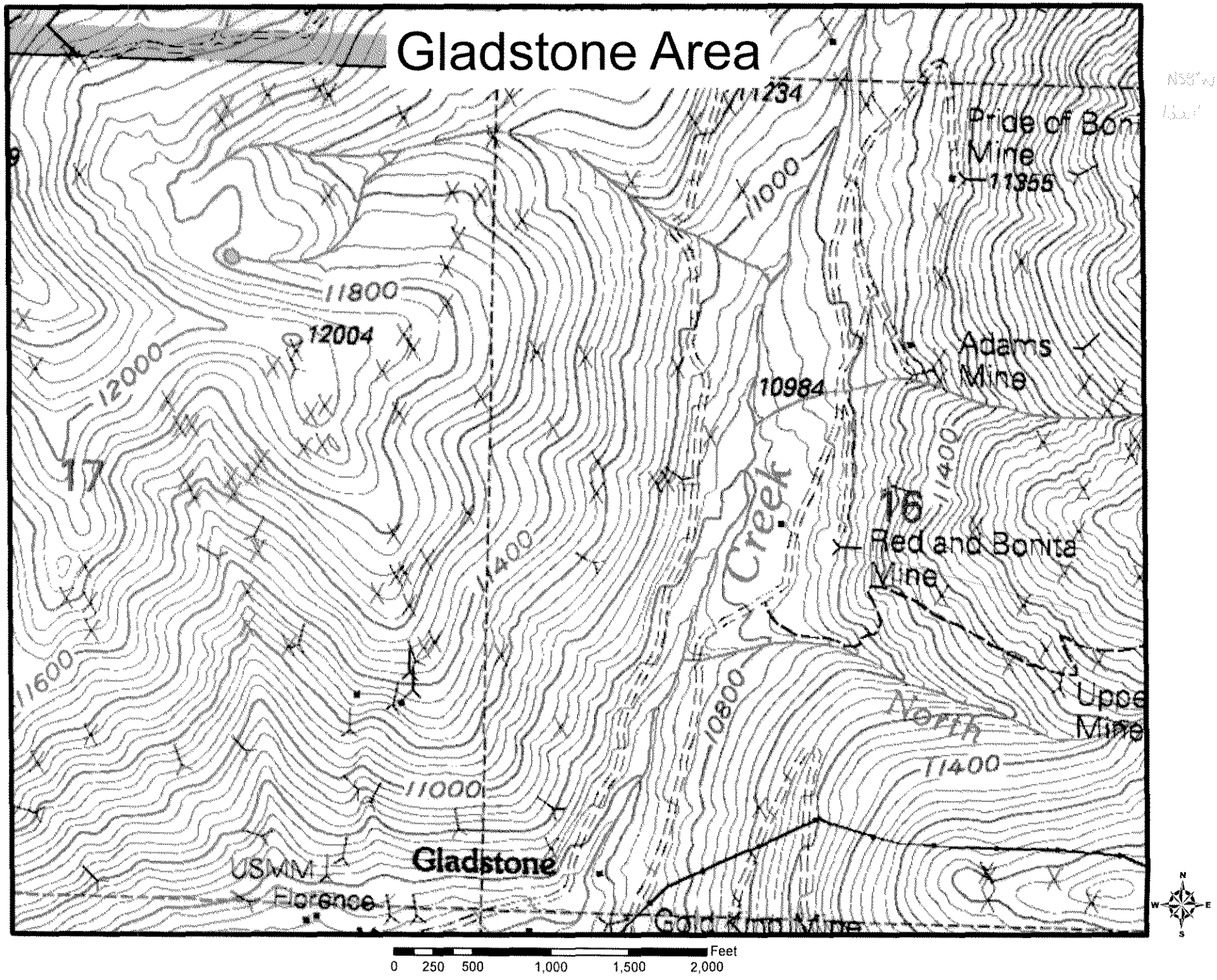
Project Objective and Methodology

One of the options being considered for water quality improvement is a subsurface hydrologic bulkhead constructed in the R&B adit to prevent acid mine discharge from the mine portal. The focus of this report is to make a preliminary assessment of the geotechnical suitability of the bedrock along the R&B cross-cut as a potential location for a bulkhead closure. Surface geologic structural analysis work was conducted at the mine in June 2007. This included analysis of joints, faults, and rock fabric associated with the bedrock in which the workings are driven, as well as a review of the available information on underground workings. Surface geologic investigations concentrated on the slopes above the workings, and in the adjacent section of the north fork of Cement Creek below the Gold King Mine. Rock structural discontinuities were located and strikes and dips of these features measured and plotted to develop a preliminary structural analysis of the bedrock. The strike and dip of joints and planar flow structure were measured in the field and analyzed using a computer program to determine if there were any preferred structural orientations in the bedrock, (anisotropy), that might create a permeability "short-cut" that could compromise the integrity of an underground bulkhead at the Red & Bonita site. A topographic transect was also reviewed to determine if a sufficient depth of cover along the adit crosscut would allow for consideration of a bulkhead approach.

Description of Geologic Units

The Red & Bonita Mine site is located entirely within Tertiary-aged rocks of the Silverton Volcanic sequence. The Silverton Volcanics is a sequence of predominantly intermediate composition lava flows and related volcaniclastic rocks that were extruded onto the underlying Eureka Tuff in later Oligocene time. These volcanic flows have been subdivided into the mapable formations exposed at the R&B site (Figure 2, Burbank and Luedke, 1964). The R&B workings are driven in the Burns Member, a sequence of light to dark-gray, thin to thick, intertounging flows and domes of porphyritic dacite and rhyodacite that crops out throughout the study area. These rocks have been propylitically altered throughout the watershed. The only other geologic units at the site consist of aprons of talus, and colluvium. The R&B portal is

FIGURE 1


Gladstone Area
11234
Pride of Bon
Mine
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Creek
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North
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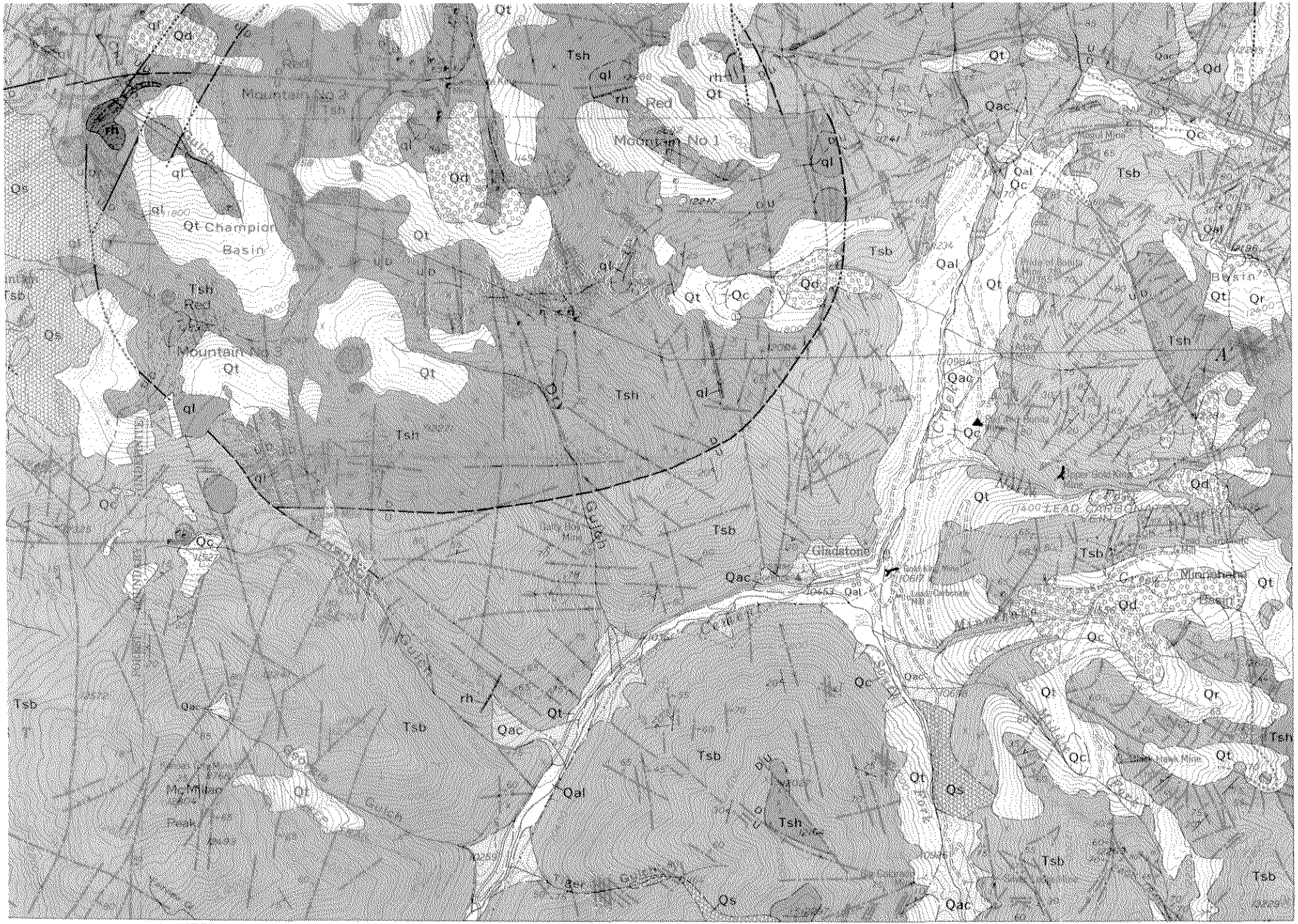

(SILVERTON)

1N

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40'

FIGURE 2. SURFACE GEOLOGIC MAP, RED & BONITA MINE AREA.
▲ INDICATES MINE LOCATION

Geology by W. S. Burbank, assisted by M. G. Barclay, F. M. Chace, M. G. Dings, R. S. Duce, E. B. Eckel, E. N. Goddard, V. C. Kelley, C. F. Park, Jr., 1929–38; V. C. Kelley, assisted by Caswell

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currently blocked at surface by caved talus and colluvial materials, loosely cemented by iron hydroxide precipitates.

Structural Geology

Structurally, the Red & Bonita workings lie entirely within the Burns Member described above. The Gold King Vein system lies 2,200 feet east of the portal, and the Bonita Fault lies 3,600 feet east of the portal (Figure 2). At least four other un-named but mapped mineralized fissures striking roughly NE-SW occur in the ground between the portal and the Gold King vein structure (Burbank and Luedke, 1964). There are also five localized, mineralized fissures exposed in the gulch below the Gold King waste dump, however, these do not appear to continue farther north into the R&B ground, and there was no evidence they are the locations of surface groundwater discharge.

Joints and flow structure (crude bedding) were identified and measured at surface on cliff faces and at the portals of adjacent prospects and mines (Table 1). The structural data was analyzed using Rock Pack III software at the Colorado Geological Survey (Figures 3 and 4). As shown in Figure 3, two preferential joint trends were detected.

TABLE 1
RED & BONITA STRIKE AND DIP DATA

Structure Type	Feature No.	Strike Azimuth°	Dip Angle°	Dip Azimuth°
Minor Joint	1	279	79	9
Minor Joint	2	275	85	5
Minor Joint	3	276	86	6
Minor Joint	4	5	81	95
Minor Joint	5	136	89	226
Minor Joint	6	40	84	130
Minor Joint	7	263	59	353
Minor Joint	8	325	84	55
Minor Joint	9	271	62	1
Minor Joint	10	41	86	131
Minor Joint	11	261	82	351
Minor Joint	12	332	76	62
Minor Joint	13	295	75	25
Minor Joint	14	275	70	5
Minor Joint	15	278	82	8
Minor Joint	16	302	84	32
Minor Joint	17	30	90	120
Minor Joint	18	115	79	205
Minor Joint	19	54	82	144
Flow Structure	1	130	33	220
Flow Structure	2	123	33	213
Flow Structure	3	134	11	224

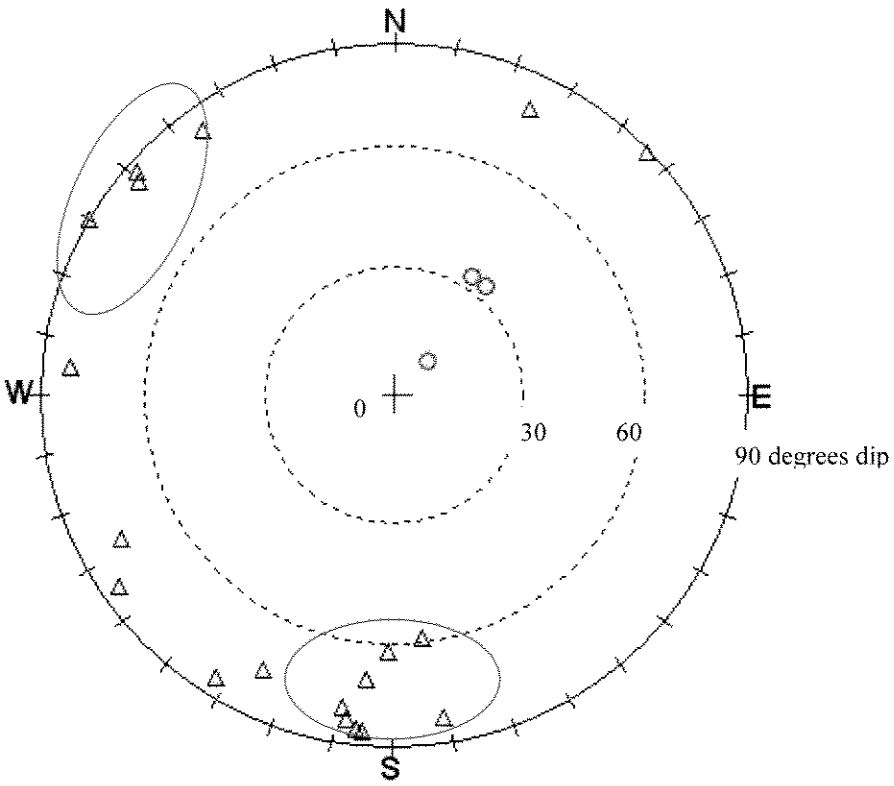


Figure 3. Pole plot of surface planar discontinuities measured around the Red & Bonita Workings. Triangles indicate poles of minor joints; circles indicate poles of flow laminations in andesite rock. The plot shows a cluster of poles to the south and a weaker set in the northwest sector, indicating two trends of anisotropy in the surface bedrock.

The southern pole cluster represents a set of joints trending roughly east-west, with dips of 60 to 89 degrees to the north. The northwest pole cluster represents joints striking roughly northeast-southwest, dipping steeply southeast. These orientations are similar to the dominant northeast-southwest anisotropy noted in the Simon Hydrosearch report prepared for the Sunnyside Mine (Stock, et. al, 1992,1993). They reported permeability greater in a northeast-southwest direction due to the dominant fracture orientation within this section of the Eureka Graben. The structural discontinuities measured in this study tend to agree with the direction of structural anisotropy as shown on published geologic maps and reports for this area near the Eureka Graben. Flow structure (crude bedding) in the andesite strikes south-east and dips gently southwest.

Rock exposed in adjacent mine workings and prospect adits is highly jointed near the portal, becoming tighter with increased distance from surface. This is common in hard rock workings in the San Juan Mountains. Rock near surface is subjected to severe chemical and physical weathering (freeze-thaw, surface infiltration). Release of overburden pressure through erosion, coupled with glacial scouring effects, normally increases fracturing and jointing of the rock mass near surface. As distance from the surface increases, joints generally become fewer and tighter with depth due to overburden pressure. This is important, because the dominant trend of anisotropy is roughly parallel to the trend of the workings in the R&B. Although the structural measurements in this study were collected from surface outcrops, they are believed to be analogous to rock fabric underground in the cross-cut section of the R&B workings. If overburden pressures are not enough to close the minor joints at mine level, a plug in the R&B workings could

be "short-circuited" by filling of these steeply dipping pathways until they "spill over" and discharge back into the workings on the other side of the bulkhead.

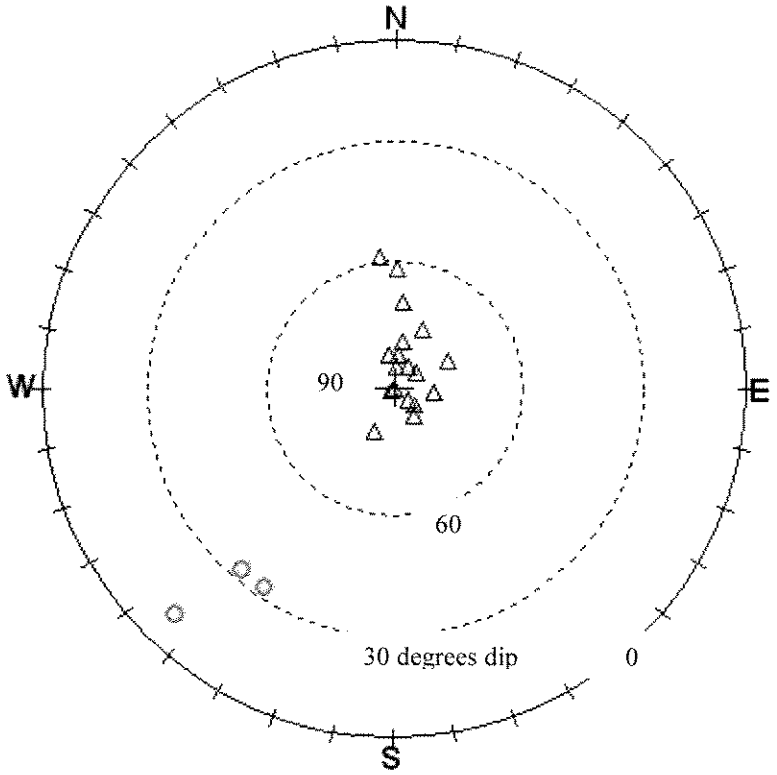


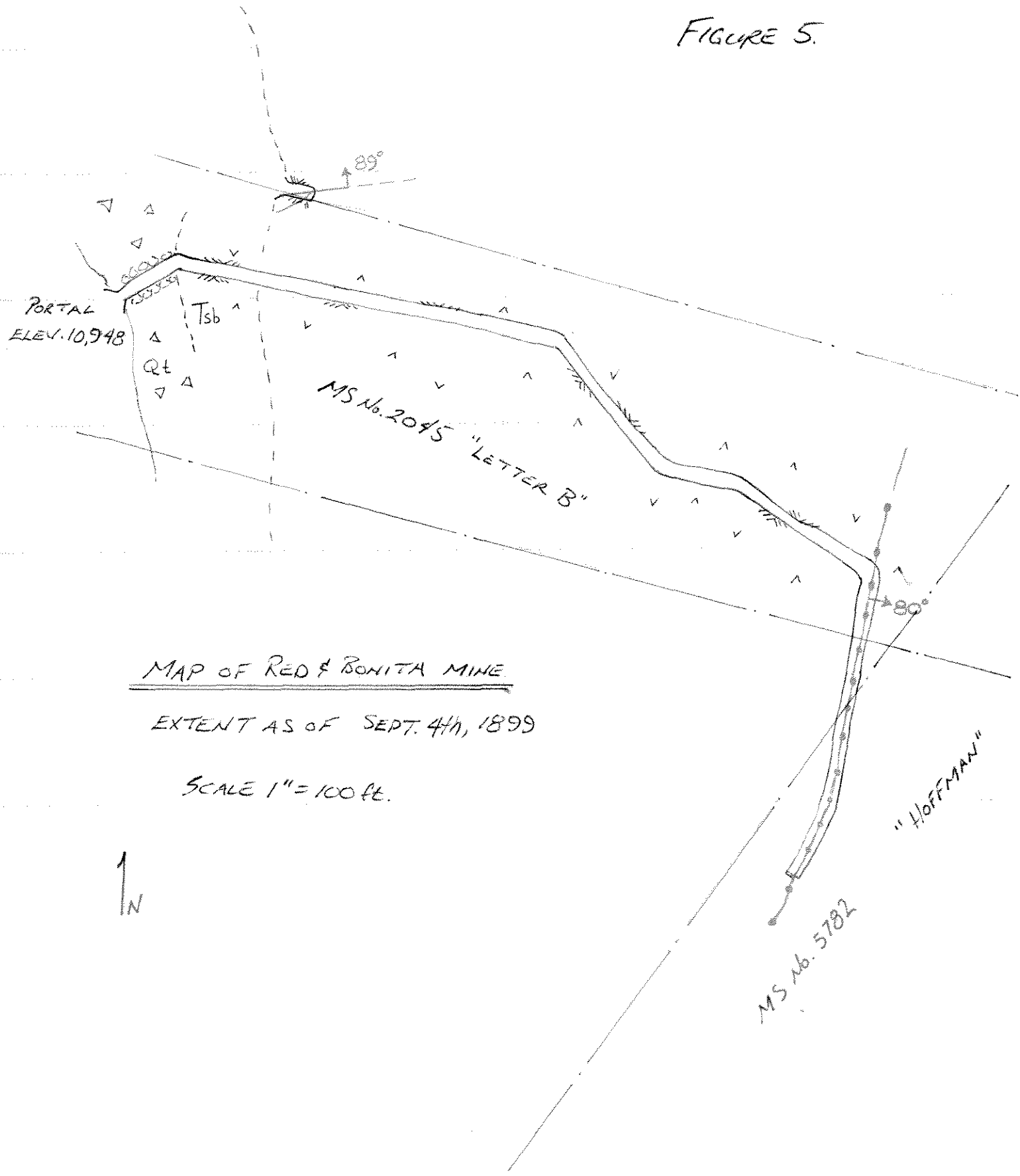
Figure 4. Dip vector plot for planar discontinuities measured on surface around the Red & Bonita workings. Triangles indicate dip of minor joints; circles indicate dips of flow laminations in andesite rock. Most joints are steeply dipping, while flow structure has shallow dips.

Mine Workings

A rudimentary layout of the R&B workings is available from an 1899 mineral survey for the adjacent American Eagle Mill Site (Fearn Engineering Services, personal communication, 2007). Based on geologic maps and the 1899 representation of the workings, the R&B adit appears to be a crosscut driven entirely in Burns Formation dacite on a roughly east-south east heading for approximately 665 feet (Figure 5). At 665 feet from the portal, the heading is believed to have intersected a mineralized fissure vein trending NE-SW on the Hoffman Lode. The workings turn abruptly SW and drifted on this structure for approximately 230 feet.

Although the 1899 map shows a total of only 895 lineal feet of workings, the size of the main dump indicates the eventual underground configuration of the mine was much more extensive. The waste dump survey completed by DMG in 1998 (Herron, et, al, 1998), estimated there were approximately 6,000 cubic yards of materials left at the portal. Back-calculating the extent of underground void from this volume using a reasonable bulking factor indicates the waste represents at least 3,560 lineal feet of 5ft. x 7ft. workings. This estimate does not include the volume of ore that was either hauled off or run through the mill. Based on these rough calculations, it is highly probable that the R&B workings were driven much farther east-ward, intersecting deeper groundwater-bearing structures between the Gold King 7-level above and the American Tunnel level below. This conjecture is supported by the fact that, after the American

FIGURE 5.



MAP OF RED & BONITA MINE

EXTENT AS OF SEPT. 4th, 1899

SCALE 1" = 100 ft.

RED & BONITA
BKS

ABOVE GLADSTONE, SAN JUAN CO. CO
A. E. LOWE
JUNE 23, 1899
10,948

MAIN
1 in = 100 ft

Tunnel level 331 lower than the R&B workings was bulkheaded, groundwater re-filling these deeper structures eventually increased the R&B portal discharge from approximately 5gpm in 1998 to over 300gpm at present time.

The R&B portal is currently caved at surface where it was timbered through unconsolidated scree and talus deposits. The 1899 mine map shows a distinct change in heading at 50 feet from the portal; this distance might represent the length of original timbered section through the surface talus deposit to the point where bedrock was encountered, and the heading was "squared up" to avoid a mixed-face condition when drilling started into bedrock. Based on the position of the outcropping rock above the portal, and the slope and a visual estimate of the thickness of the talus deposit, fifty feet or a little less is a good approximation of where solid bedrock is expected to be encountered beyond the portal.

There are no known records on the vertical extent of workings in the R&B mine. Based on historical accounts, ore found on the dump, and the fact that the mill operated intermittently for many years, it must be assumed that ore was extracted by stoping on the steeply dipping mineralized structures the workings encountered. The extent and heights of ore extraction are unknown but could be significant. Prior to opening the portal for underground evaluations, an appropriately cased and equipped drill hole should be extended into the workings within the bedrock section to measure the hydraulic head present behind the debris plug. If a significant head pressure is found, it can be bled-off by opening the pressure valve on the probe hole or drilling additional pressure-relief probe holes into the workings. Following decanting of the impounded mine pool, underground mapping is needed in the cross cut section of the workings to identify any discrete structural discontinuities, rock quality, mineralized structures, and locations of water inflow prior to any final feasibility analysis or bulkhead design.

Hydrology

The R&B site lies along the valley floor of Cement Creek, and is in an area identified as a zone of groundwater discharge to Cement Creek (Stover, 1999, Herron et al, 1998, Stock et. al, 1992, 1993,). Extensive aprons of native ferricrete deposits lie below the site on the banks of Cement Creek, indicating that groundwater with elevated iron and other metals discharged in this area long before mining occurred. Since plugging of the American Tunnel, natural springs and seeps have begun to reappear along the valley foot slopes. At present, the R&B workings are short-circuiting groundwater from the natural fracture systems they intersect directly to surface through the mine. If the R&B adit were bulkheaded deep enough such that overburden pressures are great enough to seal minor joints, it is expected the restoration of natural groundwater flow paths would result in discharge from reactivated springs and seeps in this area along Cement Creek.

Fracture permeability in the crystalline volcanic bedrock generally decreases with depth. As depth below surface increases, minor joints and fractures are made progressively tighter by increasing overburden pressure. As generally observed in the San Juans, the deeper mine workings penetrate below surface, the more likely groundwater tends to be present only where major structures are encountered. Closer to the portal, decreasing overburden pressure allows minor joints and fractures to transmit water, as is evident by the drips and drizzles entering most adits within the first couple hundred feet of surface. This near-surface "aquifer" thus consists of water-bearing interconnected fractures and joints in the andesite bedrock beneath the surface of the study area. It will be important to select any proposed bulkhead location in the R&B well beyond the zone of the near-surface saturated fractured-rock aquifer, where overburden pressures are high enough to seal minor joints from transmitting groundwater.

Depth of Cover

A preliminary cross section along the R&B workings was constructed as part of the bulkhead feasibility consideration (Figure 6). Due to the extremely steep valley walls along Cement Creek there are 400 feet of overburden at 400 feet in from the portal, and 600 feet of depth at 1,000 feet from the portal. A final bulkhead design must take into account the expected pressure head and depth of overburden available to prevent hydro-fracturing of the rock around the bulkhead. In the case of the R&B workings, it appears that sufficient cover exits to continue consideration of a bulkhead if this approach is chosen.

Conclusions

This surface geologic investigation did not indicate any significant structural or undesirable geotechnical conditions that would preclude further consideration of a bulkhead closure approach for discharge control at the Red & Bonita Mine. The bedrock in this area has dominant structural anisotropy (preferred orientation of permeability and flow direction) trending northeast-southwest dipping steeply southeast, and east-west dipping steeply north. The preferred overall groundwater flow direction is thus predicted to be toward the main Cement Creek valley, parallel to the trend of the workings, and generally not toward the adjacent lower section of the gulch below the Gold King Mine. Localized structures and joints do exist that strike in many other directions, making it imperative that a thorough structural analysis of rock exposed in the mine workings be conducted prior to a final bulkhead feasibility analysis. Additionally, if overburden pressure is not sufficient to close minor joints parallel to the trend of the workings at the selected bulkhead location, it could be "short-circuited" by filling of these steeply dipping pathways until they "spill over" and discharge back into the workings on the other side of the plug. A through investigation of formation permeability at selected plug locations should be included in any underground evaluation.

The Red & Bonita workings are driven in similar ground and structural conditions to those encountered in the American Tunnel, where bulkheads were successfully installed. The significant depth of the workings below surface at this site should provide sufficient overburden pressures for a bulkhead. The bulkhead would eliminate the present "short-circuit" movement of groundwater through the mine workings and force it back into pre-mining natural pathways. Groundwater is expected to recharge these fracture pathways and eventually find its way to surface in the valley of Cement Creek, reactivating the springs and seeps which existed prior to mining. Flooding of the R&B workings is expected to minimize ARD formation by establishing essentially anoxic conditions in mineralized areas of the mine, significantly reducing formation and transport of dissolved zinc, copper and cadmium from the mined ore bodies to surface waters.

One major concern is the unknown groundwater inter-connectivity between the R&B workings and the nearby Gold King Mine. Although there are no known man made connections such as drill holes, raises or stopes, without direct knowledge of the final extent and configuration of the workings, these types of connections could exist. It is more likely that there are at least a few deep, discrete groundwater-bearing structures that are intersected by both mines, and therefore it is possible that plugging the R&B adit level could force the local groundwater system to refill and rise high enough along these pathways such that discharge increases at the Gold King Portals.

Recommendations

Based on available underground information and surface structural observations, the following

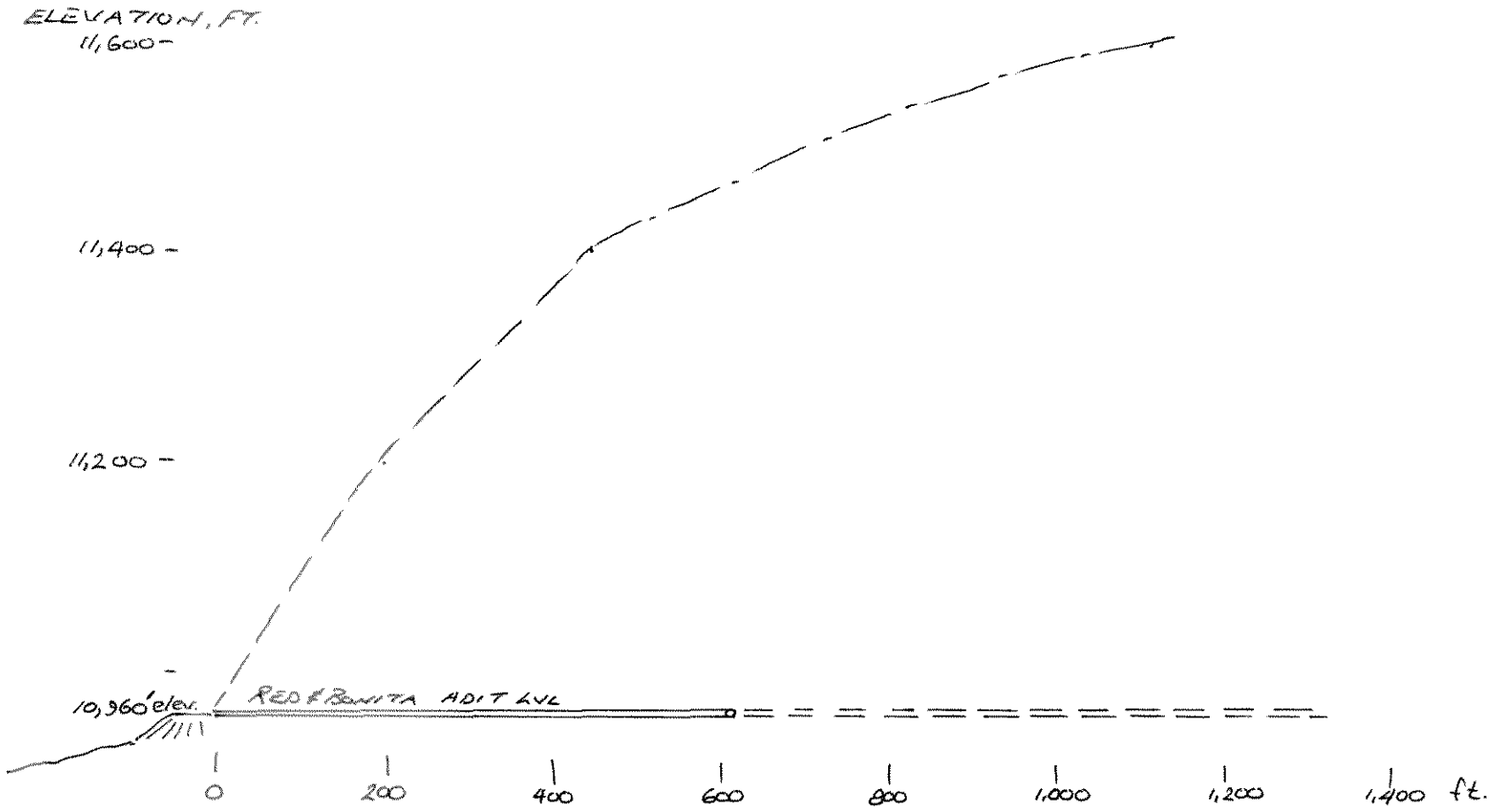


FIGURE 6. DEPTH OF COVER PROFILE ABOVE RED & BONITA ADIT

recommendations are provided for consideration in underground source control and bulkhead feasibility investigations:

1. The head pressure behind the surface portal collapse should be determined prior to any attempt to remove the portal blockage. This can be accomplished by directional drilling into the adit in the bedrock crosscut section using appropriate drill tooling, packers and pressure control methods.

2. Once the portal is opened and the mine pool decanted, a thorough geotechnical and hydrologic investigation of the underground workings should be conducted to determine an appropriate mitigation approach. Other source controls methods could include diverting any clean inflows entering the workings away from ore bodies and contaminate sources in the mine, and local controls to prevent discrete inflows from entering the workings.

3. The location of any bulkhead should be as far back from the portal and shallow fractured rock aquifer as possible, while avoiding the altered rock zones adjacent to mineralized veins. A through investigation of formation permeability at selected plug locations should be included in any underground investigations. This will determine the formation (curtain) grouting needed to seal the rock around the bulkhead. If the bulkhead is placed too close to surface, a great deal more grouting will be required to isolate the impounded water from communicating with the near-surface fractured rock aquifer, and there is a higher degree of risk that water will find a pathway around the bulkhead.

4. If a high-head condition is predicted for a bulkhead, it might be more cost effective to consider the "multiple leaky plugs" approach to save drilling and curtain grouting costs.

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