# Saguaro GeoServices, Inc.

February 8, 2010
Ref. No. 1099-09-1

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
BLM-OR Grants Pass Resource Area
2164 NE Spalding Avenue
Grants Pass , OR 97528

**ATTENTION: TIM BARNES, COR**
**SUBJECT: BULKHEAD FEASIBILITY ASSESSMENT, 520 LEVEL, ALMEDA MINE, JOSEPHINE COUNTY, OREGON**
*BLM Contract No. L10PC002969, SGS Job No. 1099-09*

Ladies and Gentlemen:

In accordance with the requirements of the subject contract, this letter report describes field investigations and engineering activities undertaken by Saguaro GeoServices, Inc. (SGS) to assess the feasibility of constructing a bulkhead within accessible portions of the 520 adit at the Almeda Mine. This report does not cover mine and ground water sampling, monitoring data, and test results and observations obtained by BLM or others. Those data need to be considered in future decisions regarding overall abatement strategies.

## EXECUTIVE SUMMARY

SGS studied the feasibility of installing a partial pressure bulkhead to limit the flow of acid mine drainage (AMD) from the 520 adit[1] at the subject mine site. SGS pressure-washed the accessible portions of the 520 adit and performed geologic and physical mapping in November 2009. Feasible bulkhead locations are limited by rock structure, adequacy of rock cover, and the presence of other workings. Nonetheless, a bulkhead in the vicinity of Station 0+75 (portal = 0+00) was found feasible. The impounded mine pool would need to be controlled to limit seepage or potential for discharge from overlying workings, but impoundment eliminates uncontrolled portal discharges and makes several treatment options possible. Limitations on mine pool elevation similarly limit the pressure demand on the bulkhead. Bulkhead design details and dimensioning would be refined later, but conceptually the bulkhead would be reinforced concrete, anywhere from 3 to 7 ft thick, keyed into rock walls that had previously been pressure grouted as part of the bulkhead construction process; and would have fixtures to provide controlled release appropriate to the overall AMD treatment scheme adopted. Mobilization, keyway excavation, grouting, bulkhead installation, sealing, plumbing and fixtures, and supporting work were estimated at the conceptual level at about $547,000, using data from the Golinsky bulkhead project completed in 2001 in northern California.

## BACKGROUND

As the result of its prior investigations (Saguaro GeoServices, Inc., 2002; Saguaro GeoServices, Inc., 2007), SGS recommended that the 520 adit be reopened so that the rock walls could be examined, and the feasibility and general characteristics of a bulkhead (plug) could be assessed. Previous work disclosed shallow overburden, a near-surface large stope[2] and the presence of a concealed adit, called the 0 level, about 30

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[1]An "adit" is a horizontal mine working open to the surface at one end. A "tunnel" is open at both ends. A "drift" is a horizontal mine opening that does not open to the surface, and commonly follows the principal mineralized trend or vein. A "crosscut" is a horizontal mine opening that connects drifts or adits, or branches off them, in a direction that cuts across the principal mineralized trend or geologic structure.

[2]A "stope" is an enlarged ore extraction working following an ore zone. Stopes tend to be irregular in shape, extend above or below mine levels, and are not developed, supported, or maintained for long-term personnel occupation.

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ft above the 520 level that also connects with the stope. The goal of mine plugging is to raise the discharge point as much as practicable from its current location close to the Rogue River floodplain. The aforementioned site conditions, together with a packer test and drill core analysis, showed that the mine pool could not be safely raised to permit year-round discharge from the 620 portal (adit opening). The resulting head would be at least 40 psi, a level that would exceed the rock vertical stress at any reasonably-feasible bulkhead location within the 520 adit between the stope and the portal, would significantly increase pressures within deeper mine levels that are shown on old maps as extending below the Rogue River floodplain, raising the question of artesian AMD seeps developing at other locations; and could discharge from the 0 level unless that opening were bulkheaded as well. The conditions of the 0 level adit and portal (opening) are unknown and no bulkheading recommendations are being made for it. Therefore SGS recommends that AMD collection and treatment occur from a collection point below the 620 level and below the 0 level as well.

In 2009, BLM obtained funding for several activities at the site. BLM engaged Mining and Environmental Services of Idaho Springs, CO (MES) to reopen the 520 adit, install support, and clear and dispose of the muck[3] and debris clogging the adit floor as far back as the stope shown on old maps as roughly 100 ft from the portal. (Another study under BLM contract is addressing recommendations for AMD treatment strategies. BLM has also engaged a contractor to conduct periodic mine water flow and chemical sampling.)

With the 520 level workings available for personnel entry, BLM contracted SGS to fulfill the following project objectives: 1) Review the reinforced interior of the 520 adit from the opening back to the stope area for geology, engineering, and hydrology features of significance relative to the possible construction of a valved bulkhead; 2) Prepare a draft report discussing the condition of the adit, geology, engineering and hydrology of the adit area, problems the BLM may encounter in the installation and operation of a bulkhead, and bulkhead design and construction criteria that need to be considered in the preparation of a contract package, including geologic and engineering considerations of rock mechanics, geology and hydrogeology impacts on the bedrock and structures. There would need to be a blow-out valve (pressure actuated release valve), and a second valve for sampling/draining; 3) Review the existing draft Almeda Mine Engineering Evaluation/Cost Analysis (EECA) bulkhead alternative report, prepare recommendations for changes, discuss the proposed EECA bulkhead alternative changes and the draft adit report with the BLM, and prepare a cost estimate for the EECA bulkhead alternative (incorporating Contractor changes); 4) Prepare a final report covering the adit investigation and the EECA bulkhead alternative cost estimate.

## LOCATION AND MINE HISTORY

The Almeda Mine is an underground gold and base metal mine located in Josephine County, southwestern Oregon, about 17 miles northwest of Grants Pass on the north bank of the Rogue River (Figure 1, next page). The property is across the Rogue River from the Galice Road. The bridge across the river to the mine was washed away by floods in the early 1920s. The mine is currently accessible by rafting across the river or by a circuitous route on logging roads.

The Almeda mine exploited a small volcanogenic massive sulfide deposit that is part of a regional mineralized system called the “Big Yank Lode” or “Big Yank Ledge”. Mineralization occurs as (1) extensive, disseminated, low-grade gold in intensely silicified and pyritized metavolcanic breccia and (2) overlying stratiform massive sulfide and barite lenses. Production was primarily prior to 1917. There was very little production between 1917 and 1942 and the property was closed in 1943 under War Production Board Order. Other than exploration, there has been no mining activity on the property since.

The Almeda Mine consists of a series of adits and stopes, connected by crosscuts and raises, driven in the hillside from elevations over 300 ft above, and reportedly over 400 ft below, the Rogue River level. Large open stopes are documented on the maps and drawings of the underground workings. In many cases the distances from the stope perimeter to the ground surface is less than 100 ft and may be closer to 50 ft.

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[3]“Muck” in mining terminology refers to earth materials loosened from the mine surfaces, and can be waste rock, ore, or soil.

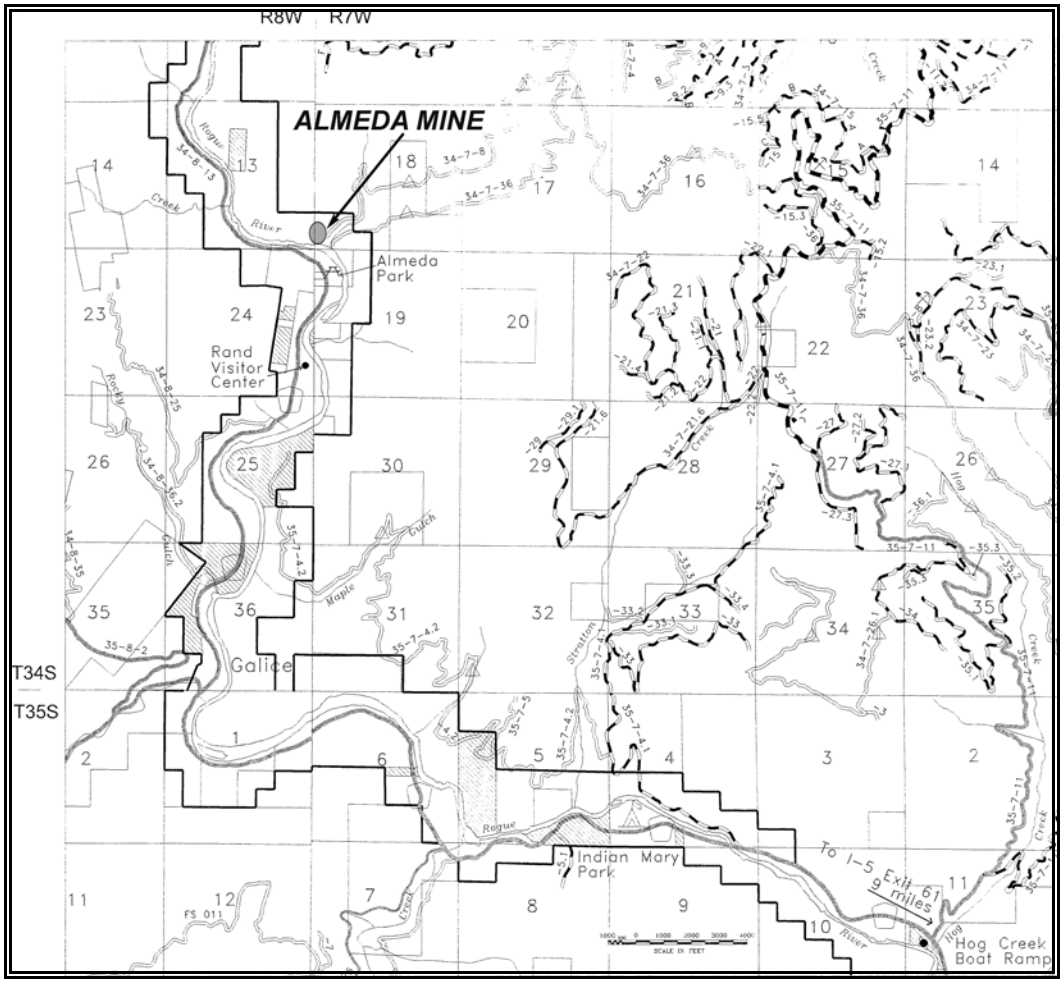


**Figure 1** – *Almeda Mine Location map, west of Merlin, OR*

Libbey (1967) states that the mine was last investigated below the "River Level" in the 1930s and early 1940s when the mine was dewatered. Those lower workings are now flooded. Of the eight adits, only the 520 or "River Level", the West 620, and the 794 adits have been open since the1930s. Due to the dangerous and inaccessible condition of the workings, comprehensive verification of mine maps and records is not possible without extensive rehabilitation.

Figure 2, published by Libbey, shows a fairly large stope about 120 ft from the portal of the 520 level. There is a dead end crosscut to the left about 100 ft from the portal. On Libbey's map the stope connecting with the 520 level is also shown to connect with the "No. 0" or "0 level". The elevation of the 0 level is not labeled on any of Libbey's maps. During the 2005 SGS drilling investigation, the crown[4] of the 0 level was intercepted between the 520 level and the 620 level, at about 35 ft above the invert of the 520 level. The 0 level portal is now covered with dump material; the portal location is not exactly known. According to the maps, the stope intersects the 0 level about 80 ft inside the 0 portal, which as shown on the maps may have been partly timbered in dump material. There is evidence that the 520 level portal which was also timbered in dump material, experienced some scouring by flood waters. It is not known if flooding has reached the 0 level portal; such flood action might result in the retreat of the adit opening.

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[4]The roof of an opening is referred to as the "crown" in tunneling and the "back" in mining, but in this report the terms are used interchangeably. In mining as in tunneling, the sides of an opening may be referred to as the "ribs" and the floor the "invert".

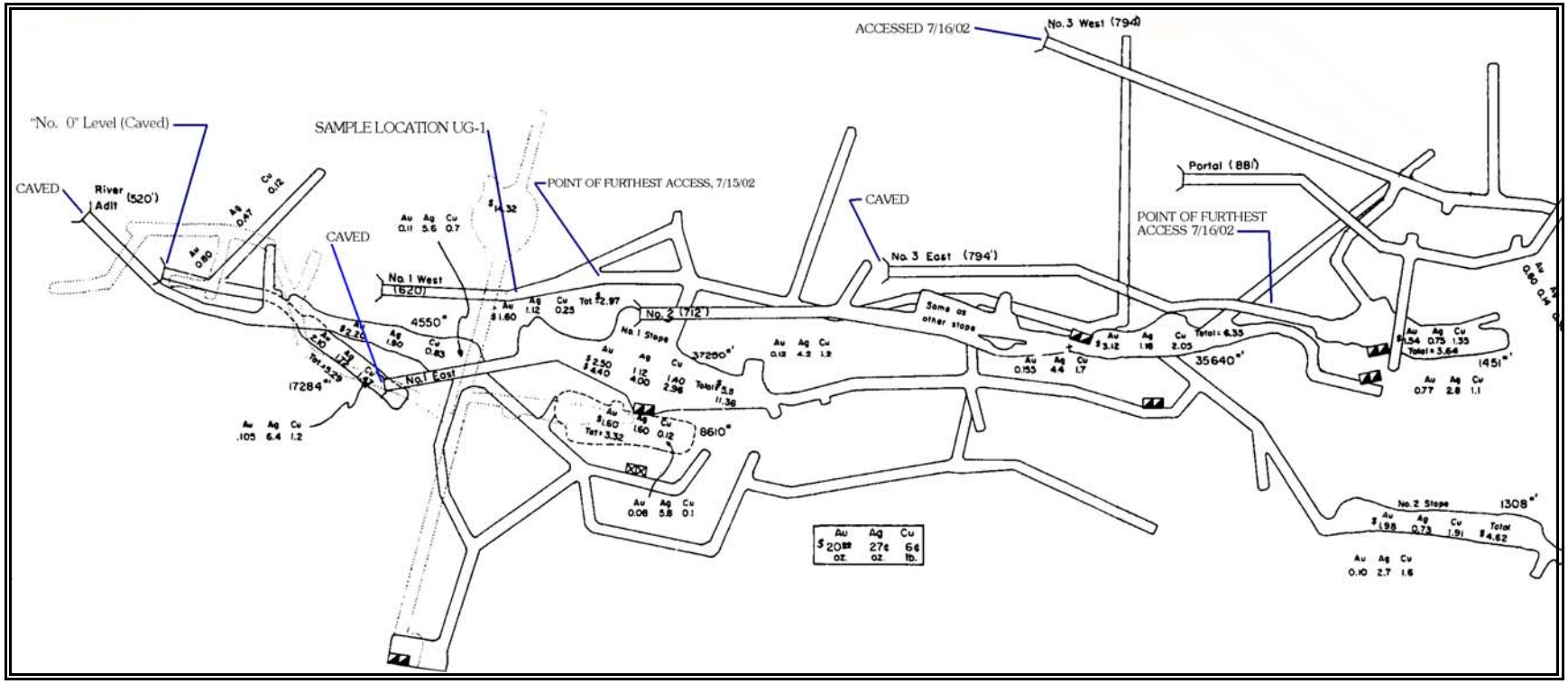


**Figure 2:** *General mine map (after Libbey, 1967, Figure 11). Grade annotations are those of Libbey. North is to the right. The 520 portal is at extreme left and the stope in question can be seen as the southernmost widened perimeter expressed on both the 520 Level and the 0 level.*

## APPROACH

Project Personnel and Equipment

The adit reopening was finished in early November 2009. SGS personnel traveled to the site on November 15, 2009 and completed underground site activities on November 17. The SGS field team consisted of Robert Cummings, P.E., Principal Geological Engineer, and Brad Herbert, R.G, Senior Engineering Geologist. Tim Barnes, P.G. was present at the site throughout SGS' field activities, serving as BLM COR.

Prior to SGS' arrival at the site, MES had cleared the 520 adit back to the stope and the SE crosscut with mechanical equipment (Bobcat), and the portal had been supported with steel sets and guardrail lagging (Figure 3). Further inside the mine, rock bolts (split sets) had been installed as needed along the remainder of the cleared portions of the adit. Because MES was tasked only with clearing the adit for safe passage of technical personnel, considerable loose muck and crusty mineral precipitate remained on the adit surfaces and obscured the visual examination of rock conditions.

**Figure 3** – *2009 rehabilitated portal of the 520 (left) and the same site in 2005 (right)*

SGS used a trailer-mounted pressure washer to clean the adit walls for geologic inspection (Figure 4). Because BLM disallowed the use of water from the Rogue River for pressure washing applications, and because there were no other, nearby sources of fresh surface water suitable for pressure washing, the mine drainage was used. MES had constructed a settlement basin for the portal discharge, and installed a four-inch HDPE overflow line from the settlement basin to a small take-out pool in the limestone drainage channel, about 100 feet away from the portal. SGS pumped AMD from the pool, through a one-inch polyethylene pipeline to the 200-gallon storage tank on the pressure washer. In this way the mine drainage was continually recycled for pressure washing applications, with no net discharge. Because it was powered by a gasoline engine without an exhaust scrubber, the pressure washer had to remain at least 30 ft outside the portal at all times to prevent carbon monoxide accumulation underground. 150 ft of high-pressure hose delivered the pressurized fluid into the mine. The AMD used in pressure washing operations was neutralized periodically, by adding powdered lime at the settlement pond and the take-out pool. Initially the water used was fairly clear, but shortly after washing operations began, the water returning to the pressure washer tank became turbid and orange in color.

**Figure 4** – *2200 psi pressure washer*

Pressure washing applications (Figure 5, next page) took about six hours to sufficiently expose the geologic conditions between the portal and the stope. Gage pressures on the pressure washer were closer to 1,700 psi than the rated 2,200 psi in large part because of line losses. Below the high water mark on the ribs (walls), the most recent deposits adhering to the adit ribs were found to be soft, and were fairly readily removed by

the pressure washer. Older and harder deposits found underneath them, as well as deposits across the back (roof), close to and just above the high water mark, proved to be much harder and more difficult to remove. Complete removal of all of the mineral encrustation and precipitate was not feasible. For geologic mapping, remaining encrustation was chipped away as needed.

**Figure 5** – *Pressure washing operations*

Initial Reconnaissance

The first step in the underground reconnaissance was to check the air quality. This was accomplished by taking measurements with a QRAE-II air sampling pump. The air sampler was left in place at the mouth of the stope and was in operation at all times when SGS was working underground. Air quality was consistently good, with no detected carbon monoxide or hydrogen sulfide. Oxygen levels of 20.9% were recorded, which is equivalent to ambient air. The "good" air can be attributed to the proximity to the surface and would not be found in deeper portions of the mine that lack active air circulation. Thereafter, a reconnaissance of the adit was made (see OBSERVATIONS section following).

Geologic Mapping

For geologic mapping, SGS first set control points and established the stations within the 520 adit. An origin point was marked by an orange paint dot at the approximate center of the first steel set in the portal. *This has not been related to BLM's coordinate system for the site, nor have the monitor wells been surveyed relative to the site coordinates, therefore the location of the geologic mapping relative to the surface must be considered approximate.*

Control for the geologic mapping was established using conventional underground mapping techniques. The general trends of the adit and the 0+45 right crosscut (BLM referenced as SE crosscut) were mapped based on four survey reference line segments set up by the field team. Within the adit, old wooden dowels remaining in the back (roof), proved to be convenient locations to establish the survey control points. A person stood at each end of a survey reference line segment such that his head lamp was directly below the survey control point. Then a bearing was taken, relative to true north, on the opposing person's head lamp. The bearings were compared. In each case, the bearings were found to be in agreement within 1°. Distance control was established by stretching a fiberglass tape tightly and measuring between each survey control point. The control points 1 through 4 are shown on the geologic map in Appendix A, and are described in Table 1.

**TABLE 1 – SURVEY LINE SEGMENTS**

| SURVEY CONTROL POINTS | LINE SEGMENT AZIMUTH[1] | LINE SEGMENT DISTANCE[2] (FT) | COMMENT |
|---|---|---|---|
| 1 to 2 | 041 | 43.7 | portal (1) to dowel (2) at 0+45 right crosscut |
| 2 to crosscut end | 145 | 27.0 | dowel (2) to end 0+45 right crosscut |
| 2 to 3 | 019 | 80.7 | dowel (2) to borehole B1C (3) |
| 3 to 4 | 000 | 113.3 | B1C (3) to first stull (timber) (4) |

[1]Brunton Compass accuracy, looking into the mine
[2]Fiberglass tape (from portal reference point 1)

A third person then marked numbered stations at 10 foot intervals and unnumbered slashes at 5 foot intervals on each rib (wall) with orange paint. To map the rib configuration, perpendicular distances from the survey reference line to each side was measured at waist height at every 5 foot interval as well as at other significant variations in the mine ribs. In this manner, stationing and mine rib topography were recorded from the portal to station 1+10, beyond which the adit was impassable in deep wet muck.

Geologic mapping was conducted after the adit survey was completed. Mapping of geologic features was carried out by Mr. Brad Herbert using accepted industrial underground mine mapping techniques (Peters, 1978). All features were measured by station, with left and right referenced as one faces inby[5]. Continuous individual fractures and shears were mapped as joints, and more continuous, major discontinuities with possibilities of significant offset were mapped as faults. Lithology was generally visible on the ribs where it had been exposed by pressure washing. Because the crown areas remained mostly covered by mineral encrustation, lithology was exposed by chipping away the encrustation as needed.

The crosscut to the left of approximate station 0+95, denoted "0+95 left" in this report, was not mucked out, and therefore could not be measured or mapped in quantitative detail. Similarly, geologic mapping was not possible past approximate station 1+10 because of the limits of muck removal.

Mr. Cummings assessed the adit walls using rock mass classification techniques according to the Geomechanics (RMR) System of Bieniawski (1989). The Geomechanics classification system relies upon six parameters that can be visually ascertained: intact rock strength (estimated in the field by rock hammer blows), RQD (assessed in the field by empirical correlation with fracture density), discontinuity spacings, discontinuity condition (pertaining to the most unfavorably-oriented discontinuities), ground water condition, and favorability of the orientation of discontinuities.

Mr. Cummings also developed a photographic log of the adit. Photographs were taken with a wide-angle (28 mm) lens, at each 10-foot station, looking down the tunnel, first in the inby direction and then the outby direction. Spot photographs, taken face on, of specific geologic conditions and, later, conditions at the recommended bulkhead location were also shot.

## OBSERVATIONS

### General Mine Conditions

Several horizontal lines of staining and AMD deposits can be seen along the adit ribs (Figure 6). The deposits were left by standing water impounded behind the plugged adit portal. The different levels probably represent fluctuations in infiltration and/or past stages of plugging at the 520 portal.

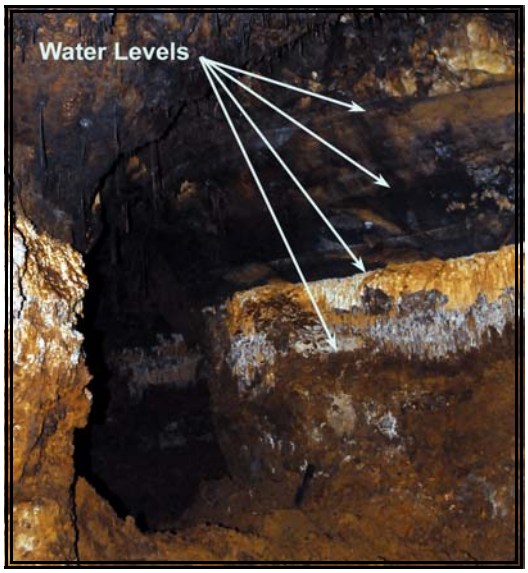

**Figure 6** – *Stope and 0+95 area exhibiting multiple water marks on ribs*

Ground conditions were found to generally be good. Very little scaling (removing loose rock) appeared to have been necessary when the adit was reopened. The adit cross-section is nominally 5.5 ft wide by 7.5 ft high, with vertical ribs, a flattened arch crown, and relatively little overbreak. MES supported the portal area with steel sets comprised of vertical H-beam posts and horizontal H-beam caps, backed by W-beam (similar to roadway guard rail) along the ribs and back. Along the right side, the steel sets extend from the portal

[5]In mining, the inby direction is away from the portal, more particularly, in the direction of intake ventilation airflow. Outby is opposite to inby. "Right" and "left" directions are always in the sense of an observer looking in the inby direction.

in about 15 ft. Along the left side, the steel sets extend only 5 ft in. Between five and 15 ft on the left side, the caps are attached at the left quarter arch to steel pads held in place with split set rock bolts. The remaining portions of the rehabilitated adit were supported with split set bolts, reportedly 4 ft long on 2-3 ft centers (variable, depending on rock structure). Wooden 6 in. x 6 in. stulls (supporting timber) were found that extend across the crown at intervals; these appeared to have been installed for the purposes of hanging utilities, rather than ground support.

The first 40 to 50 feet of the adit is quite wet, with many dripping zones. Such zones are uncommon in the crosscuts and along the reach of the adit between the first crosscut and the stope except for some occurrences of iron stalactites that tend to follow the more continuous faults and fracture zones. None of the rock is completely dry.

At about station 0+45, an intersection is encountered where a crosscut to the right extends to the southeast that is approximately 25 ft long. It is referred to in this report as the 0+45 right crosscut. The crosscut is narrower than the main adit but has a high arched crown. There is no evidence that this crosscut connects to any other workings. Opposite the crosscut, a short stub-out exists along the left rib; it was not cleaned out by MES, but appears to be about 5 ft in length.

At approximate station 0+55, what appears to be a concrete doorframe was encountered. The doorframe was constructed of cast-in-place concrete that is roughly trapezoidal in cross-section: the concrete is thicker at the base where it contacts the wall rock. A block out is visible around the former door perimeter, where a wooden jam probably existed. Neither the door nor its hinges remain. A badly corroded remnant of a two-inch pipeline penetrates the concrete frame at the right quarter arch--it was probably to deliver compressed air. Remnants of the wooden form work can still be found, as well as traces of the rags that were stuffed between the form work and the rock surface when the concrete was poured. A couple of soundings with a rock hammer disclosed that the outermost inch or so of the concrete is badly softened and decomposed, but the internal concrete appears to be intact, although not particularly strong. The purpose of the doorway is not known. It may have been for ventilation control or flood protection.

The monitor well casing for B-1C was intercepted at station 0+80.5, almost dead center in the adit crown. The slotted casing was removed by MES, leaving about 6 inches of the PVC casing extending down from the back (roof).

The 0+95 left crosscut is shown on the old maps and extends to the left, in a west-northwesterly direction, for about 30 feet. This crosscut was not mucked out by MES, so its examination entailed crawling across the thick accumulation of saturated, stiff mud and mineral precipitate that extend to within a few feet of the back (Figure 7). Because of the difficult access, this opening was not measured accurately so its representation on SGS' maps should be considered approximate.

**Figure 7** – *0+95 left crosscut, still mostly full of muck*

The 0+95 left crosscut marks a widened part of the workings that merges with the southernmost limit of the stope shown on the old maps. A small (3 x 5 ft) pillar – not shown on Libbey's map (see Figure 2) – supports the widened section. The back gets higher north of 0+95 as the workings transition into the stope. Beyond approximate station 1+20, the stope includes heavy (12 in.) timber posts that hold up a mucking platform comprised of 6 in. round timber resting on 12 in. timber caps. There is evidence that the mucking platform was originally covered with canvas. The stope walls can clearly be seen extending steeply upward from the mucking platform.

The dimensions of the stope, and the possible penetration of the 0 level, cannot be seen because of the mucking platform. The stope does appear to vary in width. The planimetric (horizontal) relationship between the stope expression at the 0 level and the 520 as shown on the old maps indicates a dip to the west, but the limited view available from the 520 suggests that at least parts of it dips to the east. In viewing the stope, it appeared to extend to a width of 8-12 ft but it may be wider beyond. The main brow of the stope, at roughly station 1+05, rises sharply from about 8 ft by the pillar, to over 15 ft before rising even more sharply into portions of the stope that are not visible. The maximum height could not be determined. Green copper mineralization is evident on the stope brow.

By standing at the pillar and looking ahead into the stope, it was just possible to see a short section of the casing for monitor well B-2 (Figure 8). It was not possible to get accurate distance or direction measurements to the B2 well casing.

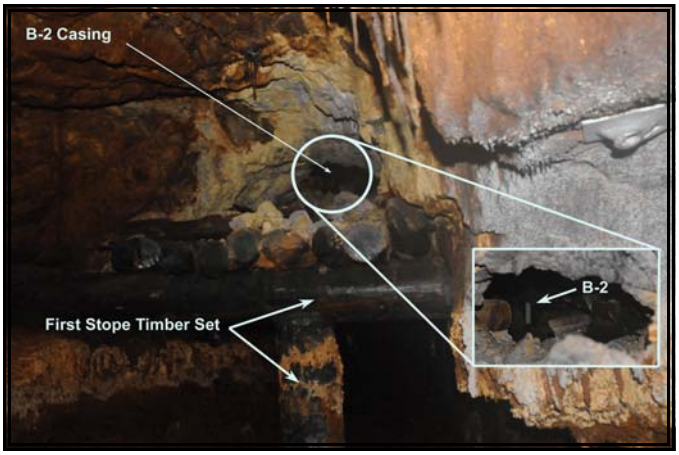


**Figure 8** – *View of B2 casing looking ahead from approximate station 1+00*

**Figure 9** – *Ore chute (center) within the 520 level stope*

About 15 ft past the start of the timber section is an ore chute (Figure 9) extending up into the stope on the left side. Efforts to reach it were prevented by the instability of the saturated mud, mineral precipitate, and the presence of wood debris.

The timber in the stope area appears to be saturated, but intact. It is still serving its intended function, but the black slimy surface and presence of oxygen may signal deterioration. No attempt was made to sound the timber or disturb it in anyway so as to judge its effectiveness. MES did not remove invert muck and debris from the timber section. Figure 10 shows what would be involved to do this. Removal of this muck would entail some presently-unwarranted risk of disturbing the timber.

Appendix B shows the approximate position of the mapped workings with respect to surface features.

**Figure 10** – *Closeup of muck, debris and precipitate filling the stope at least to the height of the timber, ahead of Station 1+20*

Geologic Mapping

The geologic map resulting from SGS' field work is displayed in Appendix A. For comparison, the inset shows the mapping reported by Libbey (1967) that was attributed to Herbert (1953). It is readily apparent that the terminology for the rock types is different now than it was when Herbert performed his examination in 1953. The reliability of the Herbert mapping is not known, but because Herbert oversaw extensive activity within the 520 level it is likely that the mapping represented his first-hand observations. (There are no reported geologic maps from Yates' examination in the 1930s.)

The most striking feature disclosed by the geologic mapping is the very strong north and north-northeast trending structural fabric. Additional fracture sets are oriented roughly east-west, and northwest-southeast. Between stations 0+50 and 1+00, the adit follows near-vertical, north-northeast, axis-parallel structures that appear to offset slivers of barite-altered tuff, bleached and altered slate (Galice formation), and small zones of intermediate volcanic rocks. The slate is densely fractured, but the fractures tend to be tight. The primary concern from a bulkheading standpoint is the longitudinal, near-vertical fracturing. It must be anticipated that other fractures of similar orientation and character exist in the rock to either side of the adit, and that these generally north-south fractures will be crossed by others belonging to the northwest and east-west sets. Fractures bounding the mineralization in the stope area also followed the north-south trend.

The north-south structural fabric is consistent with the observations of the differing rock types seen when comparing the logs of drill holes B1A, B1B, and B1C. Drill hole B1A, which passed through the rock mass a few feet west of the left rib, at approximate station 0+80, encountered primarily diorite porphyry, although the adit rib at this location exhibits Galice slate and some barite-altered diorite. Drill hole B1B, which passed through the rock a few feet east of the right rib, opposite approximate station 0+80, encountered primarily Galice slate at the corresponding adit depth. Between these, drill hole B1C, which intersects the adit, passed through formations of altered slate and massive barite. Therefore, significant contrasts in lithology and alteration, which were noted in the east-west direction among those three drill holes, are also reflected in the adit geology.

Where observed, the fracturing is mostly planar and rough, with fillings of clay and oxide not more than a few millimeters thick. It was not possible to comprehensively examine fracture fillings. Where the wall rock was well-exposed by pressure washing, the fracture fillings were also removed by the washing process. In the 0+95 left crosscut, some open fractures were encountered, one of which as noted on the geologic map was open almost 0.25 inch (~6mm).

Collectively, the mapping indicated the presence of fracture permeability pathways that link the accessible portions of the adit and areas, such as the crosscut opposite station 0+95 and the upper portions of the stope, that would become inundated after bulkheading.

## Rock Mass Classification

As described earlier, the Geomechanics classification system relies upon six parameters that can be visually ascertained: intact rock strength (estimated in the field by rock hammer blows), RQD (assessed in the field by empirical correlation with fracture density), discontinuity spacings, discontinuity condition (pertaining to the most unfavorably-oriented discontinuities), ground water condition, and favorability of the orientation of discontinuities. Ratings are on a scale of 0-100, with the higher values indicating better rock mass quality. Orientation ratings are discount factors; in this case the greatest discount was applied in instances where fractures were oriented parallel to the adit axis, with steep dips.

Rock Mass classification (RMR) values of rock exposed in the adit ranged between 29 and 52, with the lowest values occurring in the general vicinity of the stope, and the highest values occurring in the harder, less-fractured rock closer to the portal (Table 2, next page). The rock mass in the vicinity of the recommended bulkhead location, about 0+75, received a rating of 40, indicating fair to poor rock conditions. Most of the fracture fillings were noted to consist of weathered wall rock and clay. Most of the fracture apertures (opening or gap) were noted as ranging between closed and about 0.1 inch (3 mm), the average being about 0.05 inches (1 mm) of aperture or less.

## Rock Mass Strength

The rock mass strength under different confining stress conditions can be estimated using the Hoek-Brown criterion (Hoek et al.,1995) which results in stress-strain curve and a Mohr-Coulomb envelope for the rock mass. The calculations involve a parameter called the Geological Strength Index (GSI). For better-quality

rock masses (RMR values greater than 25) the GSI is calculated as the RMR minus five rating points. Other parameters used in the Hoek-Brown calculation include $m_i$, a value related to the lithology (assumed to be that of slate); the unconfined compressive strength (assumed to average 7000 psi); and a value related to the degree of blasting disturbance (assumed to be 0.9, intermediate between fully controlled presplit blasting/mechanical excavation and typical tunnel blasting).

**TABLE 2 – 520 ADIT ROCK MASS CLASSIFICATIONS**

| REACH | FRACTURE CONDITIONS | WATER CONDITIONS | RMR RATING |
|---|---|---|---|
| 0+10 - 0+20 | rough, weathered, moderately continuous, ~.05-.1 in (1-3 mm) apertures | dripping | 46 |
| 0+20 - 0+30 | rough, weathered, moderately continuous, ~.05-.1 in (1-3 mm) apertures | dripping | 52 |
| 0+30 - 0+40 | rough, weathered, moderately continuous, <.05 in (<1 mm) apertures | dripping | 52 |
| 0+40 - 0+50 | moderately continuous, <.05 in (<1 mm) apertures, slightly rough, slight weathering | dripping | 36 |
| 0+50 - 0+60 | moderately continuous, <.05 in (<1 mm) apertures, slightly rough, slight weathering | damp | 38 |
| 0+60 - 0+70 | moderately continuous, <.05 in (<1 mm) apertures, fillings <.05 in (<1 mm), slightly rough, slight weathering | damp | 36 |
| 0+70 - 0+80 | continuous fracturing, <.05 in (<1 mm) apertures, slightly rough, slight weathering | damp | 40 |
| 0+80 - 0+90 | moderately continuous, ~0-.05 in (0-3 mm) apertures, slightly rough, <.2in (<5 mm) clay fillings, slight weathering | wet | 37 |
| 0+90 -1+00 | continuous, ~.01-.05 in (1-3 mm) apertures, .2 in (5 mm) fillings, smooth-slightly rough, weathered | damp | 29 |
| 1+00 - 1+10 | moderately continuous, slightly rough, clay fillings to .2 in (5 mm), weathered | damp to wet | 31 |

For present purposes the Hoek-Brown criterion was applied for a tunnel case, assuming an effective depth of 40 ft (approximate perpendicular distance to the surface, including the dump material, from the bulkhead location). The parameters obtained are as follows:

| | |
|---|---|
| rock mass cohesion: | 9 psi |
| rock mass friction angle: | 40.5° |
| rock mass tensile strength: | negligible |
| rock mass unconfined compressive strength: | 34 psi |
| rock mass modulus of deformation: | 27,000 psi. |

Figure 11 (next page) shows the parameters and the resulting strength envelope. The strength envelope and stress-strain curve allows estimation of rock deformation and failure likelihood under the stresses imposed by a bulkhead.

The rock mass strength calculations according to the Hoek-Brown criterion are for homogeneous rock masses – in other words, the distribution of discontinuities imparts generally uniform behavior at the scale of the structure or system of interest. Where specific, individual geologic structures may have significant geotechnical impact, those structures should be considered individually. Accordingly, the geologic mapping was examined for potential sources of slippage (wedges or plane fractures) at the recommended bulkhead location. The mapping did not disclose discrete fractures at the recommended bulkhead location that could serve as releasing surfaces for bulkhead failure in shear.

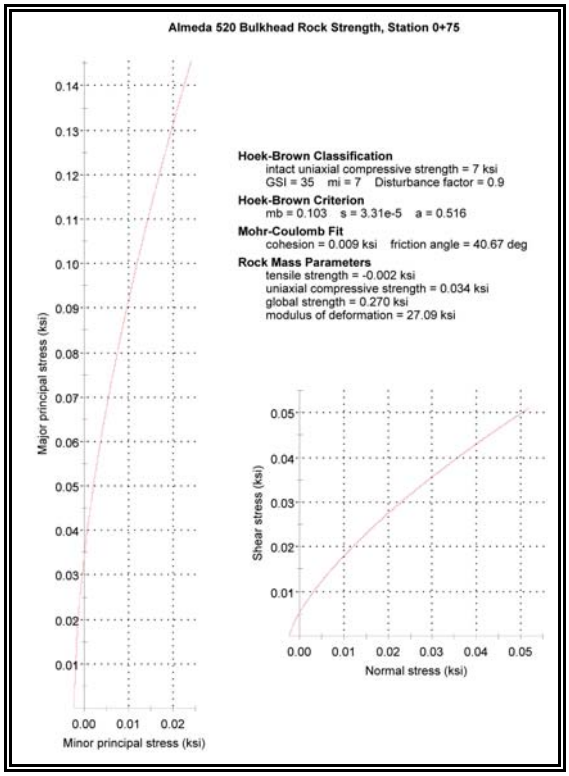


**Figure 11** – *Estimated rock mass strength of 520 Level walls at proposed bulkhead site 0+75*

## DISCUSSION

### Selection of Bulkhead Site

Construction of a partial-pressure diversion bulkhead in the 520 adit is feasible, although the sparse overburden cover and the presence of longitudinal fracturing increase the potential for seepage. The presence of the stope limits the choice of location, so the geologic conditions must be addressed through engineering design. The rock is strong enough to support a limited-pressure bulkhead, so the primary design concern is to limit water pressure behind the bulkhead that could result in excessive seepage and compromise the rock mass strength.

It is not feasible to place a bulkhead within the stope itself, and placing the bulkhead inby the stope would allow too much AMD to pass into the adit between the bulkhead and the portal. Therefore the bulkhead must go between the stope and the portal. The preferred bulkhead location is at approximate station 0+75 (Figure 12, next page).

The rationale for selecting this location is to position the bulkhead under as much cover as possible without encroaching too much on the stope. Close to the stope, the adit is taller and therefore the bulkhead would be much larger; and flow pathways from the stope to the adit outby the bulkhead would be short. Bulkhead locations further into the mine than about station 0+85 would put the bulkhead quite close to the 0+95 left crosscut, where a large span, small pillar, and short potential leakage pathways around the bulkhead may exist. A location inby station 0+75 also would put B1C in front of the bulkhead where it could present a leakage pathway and would be useless for mine pool monitoring. Bulkhead locations further toward the portal would have less overburden thickness which results in lower stresses across fractures, tending to lower the resistance to fracture flow. The wet/dripping conditions seen from the portal to roughly station 0+45 evidence hydraulic communication with the surface. It would be desirable to put as much distance as practicable between this weathered zone and the impoundment area behind the bulkhead. Between stations 0+60 and 0+70 the local geology is favorable regarding the occurrence of crosscutting fractures but the presence of longitudinal faults and the contact between the Galice formation and the barite-altered tuff along the right quarter arch is a significant potential leakage pathway. Additional potential leakage pathways exist through the mine floor at this location.

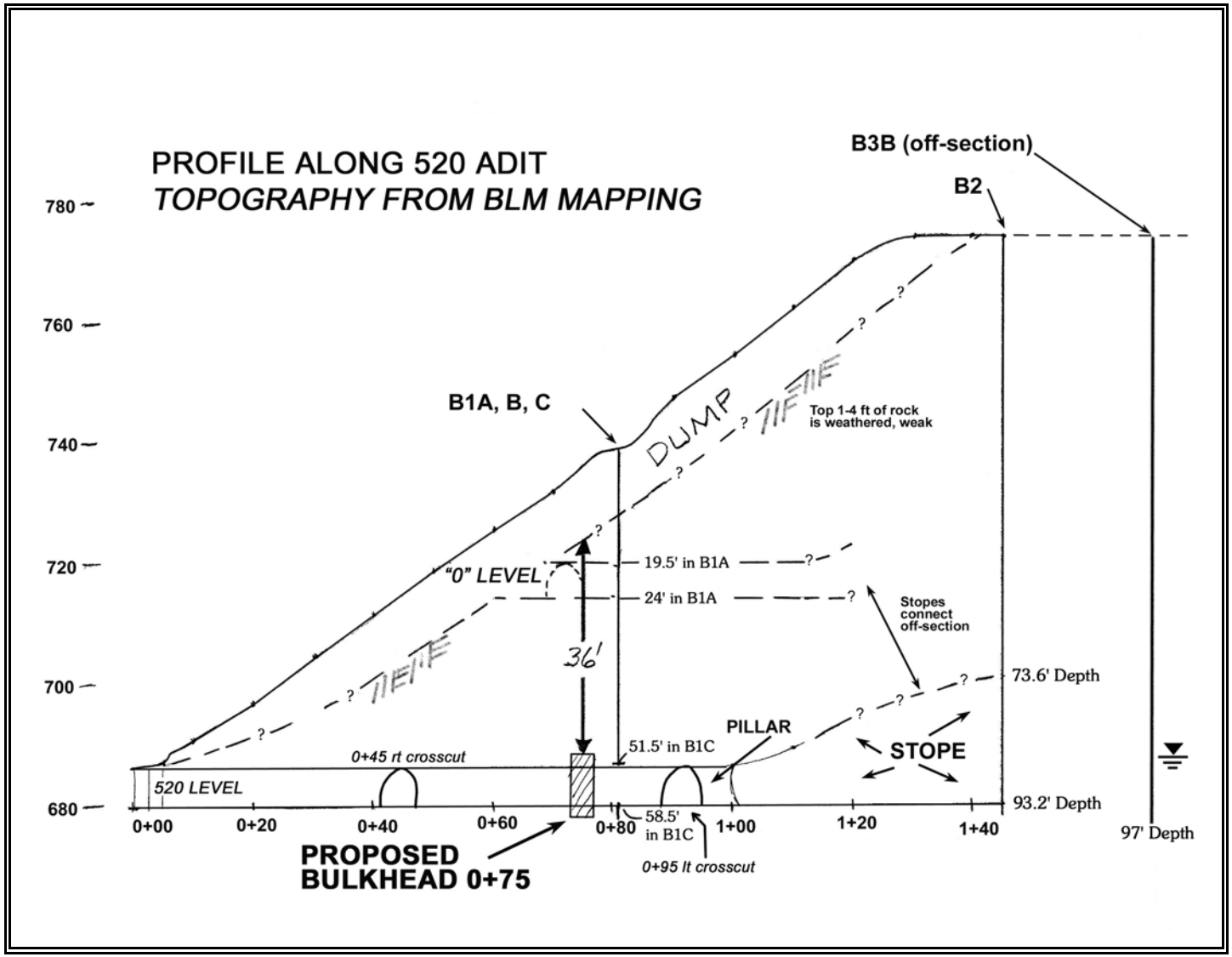


**Figure 12** – *Profile section along 520 Level centerline showing proposed bulkhead position*

Therefore the best location for a bulkhead appears to be at station 0+75. A bulkhead location at station 0+75 puts the faults occurring crossing the adit at station 0+68 and station 0+71 outby the bulkhead rather than through it. At 0+75, over excavation would be required for the bulkhead. On the right rib a small overbreak zone exists on a dipping fracture. The left rib would also need to be overexcavated to get the bulkhead abutment behind a long fracture zone that is parallel to the drift along the left rib. Figure 13 shows the mine conditions at the proposed bulkhead location.

**Figure 13** – *Views of proposed bulkhead location, 520 Level, 0+75*

Seepage Considerations

Leakage pathways will be along faults and fracture networks. The untreated permeabilities of such features can only be estimated from available data. Permeability testing conducted in borehole B1A demonstrated that the rock mass permeability increased by an order of magnitude if the hydrostatic pressure (pressure caused by weight of water) approached the lithostatic pressure (pressure caused by weight of rock). At hydrostatic pressures considerably below lithostatic, however, the rock mass permeability measured was moderate. During the permeability test, flow rates occurring at pressures approximately half of lithostatic were steady-state at about 0.05 gallons per minute. (Extrapolation of these values to mine-scale seepage estimates would require calculation of appropriate rock mass permeability values and applying these to the estimated saturated perimeter of the mine pool.) At the bulkhead level, the confining stress (adjusted for the fact that the ground surface slopes) would be approximately 24 psi. Maintenance of a mine pool level around elevation 710 (approximately 20 ft above the adit crown at the proposed bulkhead location of 0+75) would restrict the maximum pressure head on the bulkhead to about 12 psi, which is about half the lithostatic confining stress.

Some idea of the permeability of the Galice slate can be gained by consideration of the drilling records from borehole B3B (roughly EL 773 – boreholes have not been surveyed so actual elevations are not available)

drilled in 2003. After a long of day of drilling, the drill core barrel was left in the hole for retrieval in the morning. The hole was at its final depth of 98 ft BGS (approximate EL 675 at the bottom– refer to Figure 12) and the water level was about 5 ft below the collar, or about EL 768. When the crew returned to the hole in the morning, the top of the core barrel was not in water. Since the core barrel height is around 8 ft, the water level dropped at least 85 feet overnight. The estimated lateral (horizontal) distance from the bottom of the hole along a possible flow pathway to a seepage point at the slope toe in the bedrock surface below the dump would be at least 120 ft. No significant, individual open fractures were identified, but the slate was found to be generally fractured throughout the recovered core with one especially notable breakout between 50 and 60 ft BGS. B3B was completed as a monitoring well; our understanding is that B3B readings average about 11 feet of water in the bottom, with minor fluctuations, which would put the water level at about EL 686, slightly (less than 10 ft) above the invert elevation of the 520 level some distance away. Moreover, it was reported to SGS that this water level did not drop when the mine was reopened and the standing water in the adit was released (Tim Barnes, personal communication, 2009). No permeability measurements were conducted in drill hole B3B, but it seems fair to assume that drainage through the fractures in slaty cleavage occurs fairly readily. Therefore, for bulkheading, permeability pathways involving the slate should be addressed with grouting from within the 520 adit.

Stage grouting from within the adit is therefore recommended, between approximate stations 0+70 and 0+80, radially in all directions. Grouting will lengthen seepage paths around the bulkhead more than can be done with a keyway alone. The initial grout hole spacings should be approximately 3 feet, but secondary grouting applications within the primary grouting should be on half spacings, for an average spacing of around 1.5-2 feet. Drilling of grout holes can be accomplished using jack leg drills. For planning purposes, it should be assumed that the pre-grouting holes would be at least 15 feet long in the ribs and 20 feet long in the crown and invert.

It is sometimes advisable to shotcrete the surfaces of mine openings behind bulkhead seals. The shotcrete layer can provide a barrier to impede the impounded water from passing directly into fractures in the shotcreted zone behind the bulkhead. In this case the accumulation of encrustation would first have to be removed from all rock surfaces to be shotcreted. A couple of additional days of pressure washing and likely manual removal would be required. In addition, the 0+95 left crosscut should be mucked out, cleaned, pressure washed, and shotcreted. Conceptually, the shotcrete should consist of a minimum of 4 inches of wet mix shotcrete, with the addition of polyethylene fibers to improve durability. It is highly important that the rock surfaces be free of woody debris, mud, loose rock, scale, and mineral encrustation, not only on the crown and ribs, but also on the invert, before shotcrete is applied.

Boreholes B1A and B1B may present vertical leakage pathways which should be addressed. The holes were abandoned with bentonite hole plug, but it is not known whether hole plugging was effective in borehole B1A because it penetrated the 0 level. Positioning grout holes close to the projected location of the drill holes may allow grout to communicate with the holes and fill them.

At the selected location, drill hole B1C will be immediately behind the bulkhead. This is by design, so that the water pressure can be monitored both in the drill hole, as well as with gauges on the bulkhead plumbing. However, to avoid potential leakage pathways up the drill hole and over the top of the bulkhead, a durable plastic casing should be cemented in place.

The bulkhead itself should be provided with blockouts for contact grouting after the concrete has cured.

Estimated Bulkhead Loads and Deformations

Over excavation into solid rock would be needed to form a keyway all around the bulkhead structure. Assuming that the nominal dimensions of the existing perimeter are roughly 7.5 feet high by 5.5 feet wide, and allowing for 1 foot of overbreak all around, over excavation of 3 feet (maximum) for a keyway would yield roughly 80-100 ft.$^2$ of bearing surface. Maintenance of the mine pool level at a height not greater than 20 feet above the adit crown will impose an average hydrostatic pressure at bulkhead mid-height equal to roughly 24

feet of head, or approximately 10.5 psi. This hydraulic pressure distributed over the exposed area at the rear of the bulkhead will impose roughly 85 kips (kip =1,000 pounds) of horizontal hydraulic load on the bulkhead, which will be transferred to the keyway walls. Using the estimated 34 psi rock mass unconfined compressive strength and accounting for the development of hydrostatic pressures in the keyway equal to the impounded head, the effective strength under 24 feet of head is roughly 34-10.5=23.5 psi. The available effective resisting force provided by the bulkhead embedment comes to roughly 338 kips, for a safety factor of roughly 4.0 (338/85). Less keyway depth (the minimum should be 1.5 ft) could be accepted if side friction on the bulkhead is also considered. A more complete rock mechanics analysis should be performed to support final bulkhead design. The required safety factor should be selected according to the confidence in the design parameters but should not be less than about 2.0.

The projected average stress imposed by the bulkhead on a 3 ft keyway is, according to the above assumptions, 85 kips per 100 ft.$^2$, or roughly 5.9 psi. The estimated modulus of deformation of the rock adjacent to the bulkhead location is 27,000 psi. A very simplified deformation analysis using this parameter results in an estimate of the strain (dimensionless) which is the quotient of the average stress and the modulus of deformation, of 0.000219. Presuming the depth of loading influence to be equal to the keyway depth and taking no account of stress decay with distance from the loading surface or shear strain resistance along the length of the bulkhead (conservative) the elastic rock mass deformation within the keyway, taken in a direction perpendicular to the axis of the bulkhead, comes to approximately 0.000219 x 36 in. = 0.008 in. A calculated deformation of 0.03 in. or less would be unlikely to dilate nearby fractures enough to result in noticeably higher seepage.

Bulkhead Conceptual Design

For conceptual planning purposes, the bulkhead used for the Tunnel 2 impoundment at the Golinsky mine project in northern California can be used as a model of what would be proposed at Almeda. The Golinsky mine bulkheads were heavily reinforced, cast-in-place concrete, approximately 3 feet in overall thickness (Figure 14). The pressures at Almeda would be a little less and the thickness would be a little greater

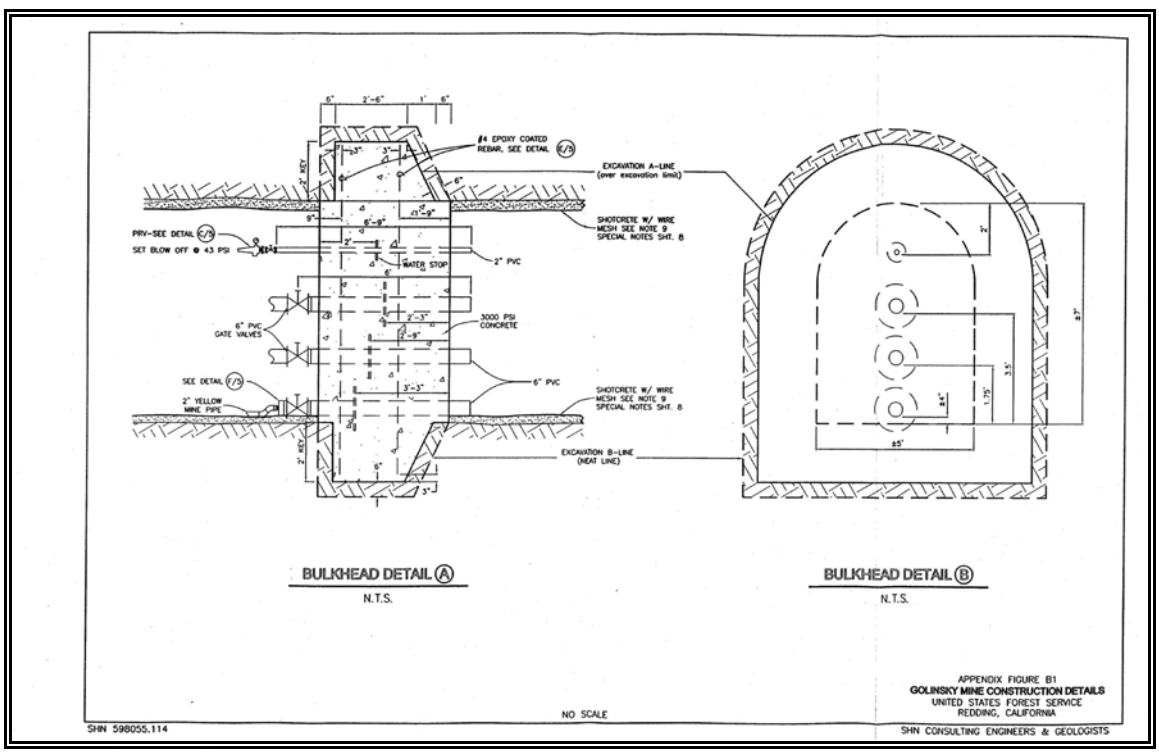


**Figure 14** – *Cast-in-place concrete bulkhead used for Tunnel 2 at the Golinsky Mine*

(estimated at 5 ft) for keyway constructibility purposes. Actual bulkhead dimensions would be determined during final design. Other bulkhead construction parameters including reinforcement, keyway details, grouting pattern, and depth of over excavation, are a matter for final design. Similar to the Golinsky bulkheads, the bulkheads at the Almeda project would be outfitted with primary and secondary relief valves, the primary valves consisting of a pressure-sensing valve to maintain the mine pool within design limits, backed by a main shutoff valve that could be activated to permit replacement of the pressure sensing valve. If a pressure - sensing valve requires electronic components, these should be proven for long-term applications in unattended wet and corrosive environments; otherwise, a manual gate valve should be used with settings obtained by trial and error. Hydrostatic pressures behind the bulkhead should be measured and recorded by pressure sensors installed in the valves and in B-1C. Valves of choice are constructed of nylon or similar corrosion-resistant material. The detailed specifications and sourcing for the valves would be resolved during final bulkhead design.

Accompanying the main bulkhead installation should be a cofferdam, constructed where the adit opens into the stope. The long-term purpose of the cofferdam would be to prevent debris, sludge and precipitate from accumulating against the rear of the main bulkhead, thereby preserving the metering function of the bulkhead during the design life of the facility, and assuring that excessive sludge and debris loads are not imposed on the bulkhead. The short-term purpose of the cofferdam is to prevent mine drainage from entering the main bulkhead construction area. It is very important to construct the main bulkhead as much as possible in the dry. Mine drainage would be impounded behind the cofferdam and routed through a diversion pipe past the bulkhead to the portal. All bulkhead penetrations would be affixed with water stops. As the bulkhead is completed, the diversion pipe, now passing through the bulkhead, would be cast into the bulkhead concrete in a similar manner to the other pipes. The cofferdam would be built across the adit floor, out of grouted, reinforced concrete masonry units (slump block) to within 2 ft of the adit crown so as to provide the maximum sludge impoundment but still permit personnel to exit over the top of it after sealing the back side. The contact points between blocks will not be sealed, except for the bottom 1-2 ft where drainage must be impounded during bulkhead construction. During bulkhead construction mine drainage would pass through the cofferdam through a pipe located close to the base, so the cofferdam need not resist unbalanced hydrostatic pressures during the bulkhead construction period. After the bulkhead is complete the bypass pipe and other pipe valves are closed and the mine pool forms behind the bulkhead. During mine pool fill up, leakage through the cofferdam block structure must be permitted so that the fluid levels on either side of the cofferdam remain equal. The only unbalanced load on the cofferdam should be from the accumulation of debris. These loads would not be high but should be accounted for in cofferdam design.

Bulkhead Operations

A diversion bulkhead in the 520 adit would make possible other options to control AMD release by serving one or both of two purposes:

1. Impound water in order to facilitate treatment within the mine pool;
2. Develop a source of pressure so mine water can be conveyed elsewhere for final treatment and release.

It is not recommended that the mine pool level be allowed to rise above the 0 level. The maximum mine pool elevation should allow room for annual fluctuation of the mine pool without overflow through the 0 level. If overflow from the 0 level is allowed, it would be advisable to place a diversion dam within the 0 level (possibly by remote injection of foam) and drill back through it to install a pipe to convey the overflow down the face of the dump, where it can be controlled and treated.

By impounding drainage behind a 520 bulkhead, a number of possible AMD handling options arises. Initially, the concept would be to apply neutralizing agents, either through the borehole B2 penetration into the stope (which may require agitation to assure that the reagent accesses the entire impounded volume) or outside the impoundment, for example using the 0+45 right crosscut (which could be enlarged for the purpose) to house a reagent dosing system.

In-pool dosing (behind the bulkhead) may be feasible, but would have to be supported by estimates of the rate of sludge production within the mine pool until the sludges back up against the bulkhead. The effectiveness of dosing within the static mine pool would also have to be determined. Dosing through B2 or a new, dedicated hole into the stope would be preferable to dosing through B1C which would result in sludge accumulation right behind the bulkhead piping system. B1C should be maintained as a monitoring well.

One advantage of dosing the AMD outby the bulkhead is that the resulting sludges would exit the mine along with the neutralized AMD, where they could be captured in a settlement pond for periodic collection and disposal. Moreover, the reagents would be applied to a dynamic system and may be more efficient than if added to a static mine pool. If reagents are added to the pipeline outby the bulkhead, the reagent dosage should be optimized for the flow rate, which the dosing system must be able to sense as the flows change due to regulation of the mine pool level. There are possibilities that the head developed by the bulkhead could be utilized to assist in the regulation of the reagent dosing.

During the period of dosing, additional studies could be conducted to investigate the possibility of diverting the AMD outflow to a passive treatment facility, such as a biocell or artificial wetland. To keep the flows fairly consistent, thereby improving effectiveness, enough AMD needs to be impounded that delivery will not cease during the dry months, but at the same time the pressures generated by storage of AMD during wet months must not exceed the design criteria of the system. While AMD is being treated, data on the relationship between seasonal precipitation, mine pool elevation, and bulkhead outflow volume could be studied to determine the optimum rate of year round release to a passive treatment facility. Figure 15 (Appendix B) shows the inferred position of the rehabilitated underground workings (locations are not validated by survey and are only approximate) as well as the flood levels shown on BLM mapping as provided to SGS. Specifically, the concept would be to back up AMD underground, to the minimum acceptable elevation above the Rogue River flood plain and to permit flows to be captured, controlled and treated in a facility sufficiently above Rogue River flooding. Assume for example that the 20 year flood is selected as a design basis. The 20 year flood is approximately at elevation 695, so regulating the mine pool at, for example, EL 700-705 would allow a constant delivery of AMD to a biologic passive treatment facility sited at EL 700, just above the 20 year floodplain, maintaining approximately 20 ft of head above the 520 invert and adequate (at least 10 ft) room between the mine pool and the 0 level.

## RECOMMENDATIONS

Construction of a partial-pressure bulkhead, designed with pressure-regulating valves to control the mine pool elevation below EL 715, appears feasible. With respect to the foregoing discussion which provides more details, the general sequence of the installation would be as follows.

1. Cement a corrosion-proof casing into borehole B1C.

2. Construct a small upstream diversion(station 100+00 -105+00) to temporarily capture and pipe mine drainage around the shotcrete work area.

3. Clean all rock surfaces, including the invert, between the bulkhead area and 0+95 of the adit, as well as the back, ribs and invert of the 0+95 left crosscut and apply a minimum of 4 in. of fiber-reinforced shotcrete all around. Shotcrete test panels should be created, cored, and checked for permeability to assure that the method of shotcrete application is suitable.

4. Carry out a pre-grouting operation over an interval of about 15 ft centered on the bulkhead centerline. Grout holes should generally be radial to the adit, 15-20 feet in length, on 4 foot centers for primary grouting and on half centers for secondary grouting. Grout holes in the crown areas should be collared slightly off center to improve penetration of the near-vertical, continuous fractures. Grout should utilize microfine cement. It is not necessary to hold grout pressures to less than lithostatic; it is preferable to improve grout migration by utilizing pressures that are 10-25% above lithostatic so long as grout invasion into the stope, the 0 level, or the adit itself is avoided.

5. Construct a diversion dam of grouted, reinforced slump block across the mouth of the adit where it enters the stope area, at about station 0+88. The slump block should be placed on a bed of thick, strong mortar or grout that is in direct contact with clean rock, all across the adit floor and up the sides. Reinforcement should be drilled and grouted into the adit invert. The block up to the diversion pipe top height should be sealed to direct all flow and seepage into the pipe. Blocks above that elevation should be grouted and reinforced but loose-fitted (1/8 in. gaps) to allow water percolation during mine pool filling.

6. Excavate the keyway to a depth of 1.5-3 ft circumferentially all around the bulkhead location. Extremely light blasting (small holes, detonating cord) or propellant systems may be used so long as relief is provided along the keyway bearing surface (the side toward the portal) by line drilling, but be sure that excessive loosening of the rock does not occur past the final contour. The final 6 in. should be excavated using spades, chipping hammers, or similar mechanical means. The plans should specify the allowable excavation limits (minimum and maximum) over which concrete quantities will be paid.

7. Provide epoxy coated, grouted dowels radially all around the bulkhead centerline, with 5 ft of embedment, and 1 foot of reveal into the keyway. Dowels should be spaced not more than 3 ft apart, and should be placed using centralizers to assure that the dowels are fully encapsulated by cement grout, and that no steel contacts the rock at any point. This will both secure the bulkhead and provide attachment points for bulkhead reinforcing steel.

8. Construct the bulkhead. The bulkhead should be constructed such that it covers and seals against the shotcrete in place on the upstream side. Integral water stops should be provided at all points where pipes pass through the bulkhead. If individual pours are necessary that may result in cold joints they should be affixed with water stops. Detailed specifications for reinforcement, tying of reinforcement, mixing and placement of concrete, mixing and placement of shotcrete, and so forth would be developed during design. Leave all discharge valves open.

9. After the concrete has reached its full design strength, drill for contact grouting through the grout ports in the bulkhead, and pressure-grout the bulkhead perimeter.

10. After the contact grout has cured, close the discharge valves in sequence, and monitor the buildup of pressures behind the bulkhead.

The plans and specifications should be sealed by an engineer registered to practice in the appropriate jurisdiction in Oregon.

## POTENTIAL ISSUES

Problems that may arise during the installation and operation of the bulkhead relate chiefly to unforeseen geologic conditions (permeability pathways) and issues stemming from the bulkhead construction.

As discussed in this report, the Galice appears to be fairly permeable. There is also a strong geological discontinuity trend that could link the mine pool impoundment to the surface over a fairly short distance. The trend is oriented at a steep angle to the hillside so it may present a direct pathway from the mine pool to the surface. Because of the mineral encrustation in the adit, it was not possible to view and evaluate all portions of the rock discontinuities at the bulkhead site. There is the possibility that discontinuities within or close to the adit perimeter can have an unforeseen effect on rock mass permeability. Flow can occur through the rock-fabric-scale discontinuities (slate cleavage, foliation, or short fractures) or along discrete faults or fracture zones that have not been detected, or both, and that have not been completely grouted or are beyond the limits of grouting. The mine pool may, therefore, be self-draining to some extent. Limiting the impounded head, and pursuing a careful grouting program, will reduce unintended seepage.

If grouting prevents seepage around the bulkhead as intended, and if major permeability conduits are not intercepted by the mine pool, the mine pool will rise and be limited by bulkhead valve release, or because flow occurs out the 0 level. A constant rate of bulkhead valve release would be expected to result in mine pool height fluctuation because inflows to the mine vary seasonally. (The magnitude of seasonal variation should be determined by monitoring a full annual cycle of precipitation events and unregulated mine outflows; after this is done the optimum release rate can be estimated.) With a bulkhead in place that regulates outflow according to a pre-set, constant valve setting, there is a possibility that exceptionally wet periods will cause excessive mine pool rise, leading to excessive seepage or flow out the 0 level. To avoid the detrimental effects of fluctuating hydrostatic pressures, it is preferable to maintain the pool at a fairly consistent elevation by adjusting flow, as long as facilities outby the bulkhead can tolerate the flow fluctuations.

Management of the bulkhead should include monitoring of the mine pool elevation and the bulkhead valve releases, as well as systematic observation of seepage zones. It would be advisable to defer construction of any facilities outby the bulkhead that require a particular flow or pressure until an understanding is gained on the permeability performance of the rock mass and the seasonal fluctuations. During this time, injection of reagents into the mine pool may be a worthwhile strategy.

If the bulkhead construction encounters difficulties the result will be impeded bulkhead performance. The most common are:

1. Excessive grout takes, because of grout losses to the ground surface, adjoining workings, or excessive pressures resulting in widespread hydrofracturing.
2. Inadequate ring grout coverage because of grout spacings that are too wide, grout that is mixed too thick, improper grout pressures, or grout losses. In the present case the small opening dimensions will limit the length of drill steel that can be used for grout hole drilling, which will add difficulty to the grouting operation.
3. Interruption of the bulkhead concrete pour, resulting in an unintended cold joint that is not affixed with water stops and that will be difficult to effectively grout; or poor concrete quality (honeycombing, laitance, weakness).
4. Ineffective rock and site preparation, resulting in loose rock, open fractures, flowing water in the concrete pour zone, contaminants at the concrete-rock interface, and other issues that promote seepage around the bulkhead.
5. Improper selection of bulkhead materials, piping, valves, and other hardware.
6. Insufficient contact grouting after bulkhead placement, which can result from, among other things, compensating for too-wide contact hole spacings with excessive grout pressures that hydrofracture the rock or shotcrete layer.

In this case, the remoteness of the site, the very limited staging area, the narrow roads, and the time involved in providing materials, equipment, and labor should be taken carefully into account with thorough planning.

Sincerely,
**SAGUARO GEOSERVICES, INC.**

Robert A. Cummings, P.E.
Principal Geological Engineer
President

*enc:* *References*
*Appendix A: Geologic Map, 520 Level*
*Appendix B: Site Arrangement*
*Appendix C: Conceptual Opinion of Probable 520 Bulkhead Construction Costs*

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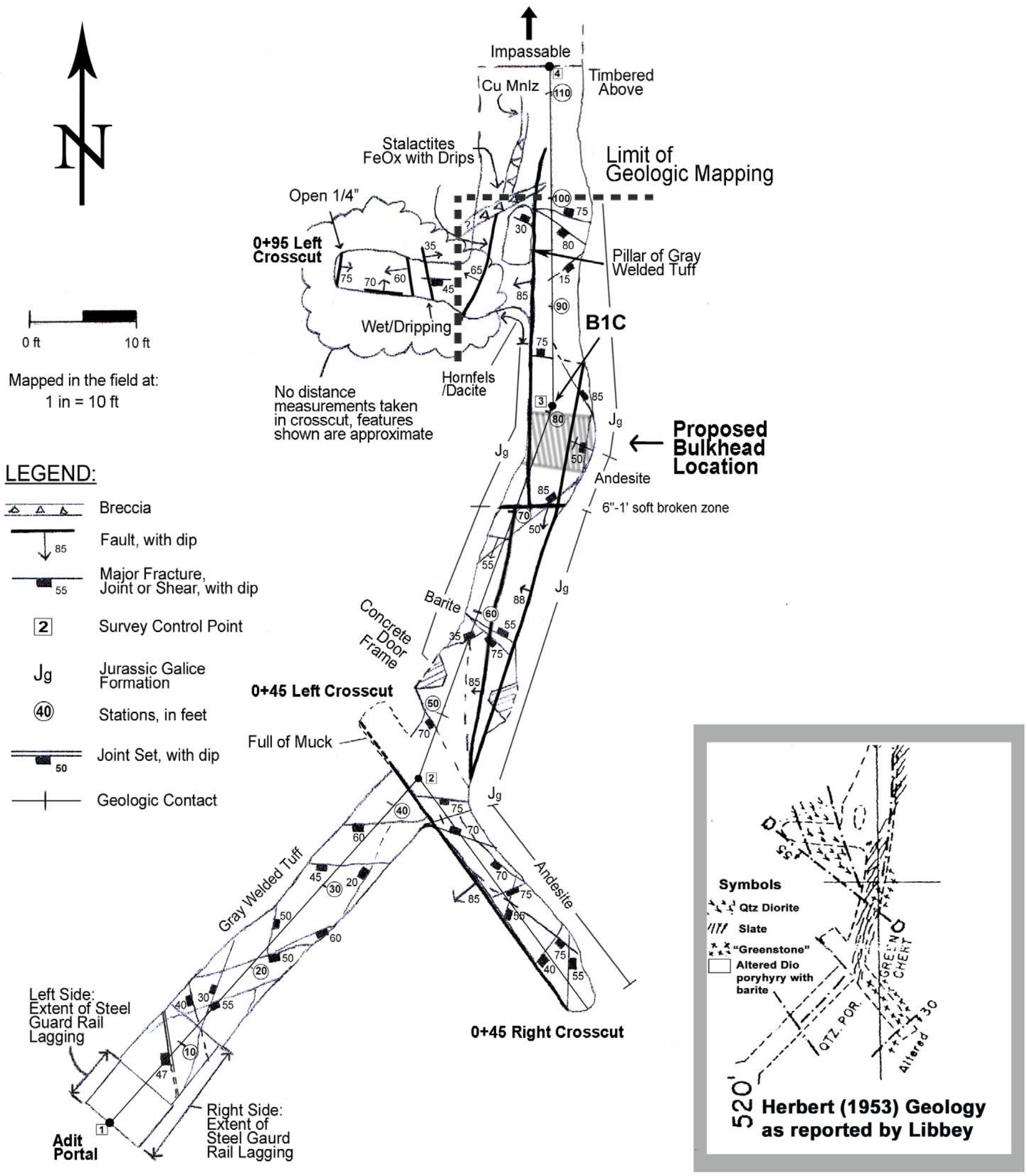
## APPENDIX A
## 520 ADIT GEOLOGIC MAP

*"APPENDIX A – Almeda 520 Level Map.pdf"*

# APPENDIX A




**ALMEDA 520 ADIT**
**GEOLOGIC MAP**
**RAC/BH**
**SGS PROJECT 1099-09**
**NOVEMBER 2009**

**APPENDIX B**
**520 ADIT RELATIVE TO SITE SURFACE FEATURES**

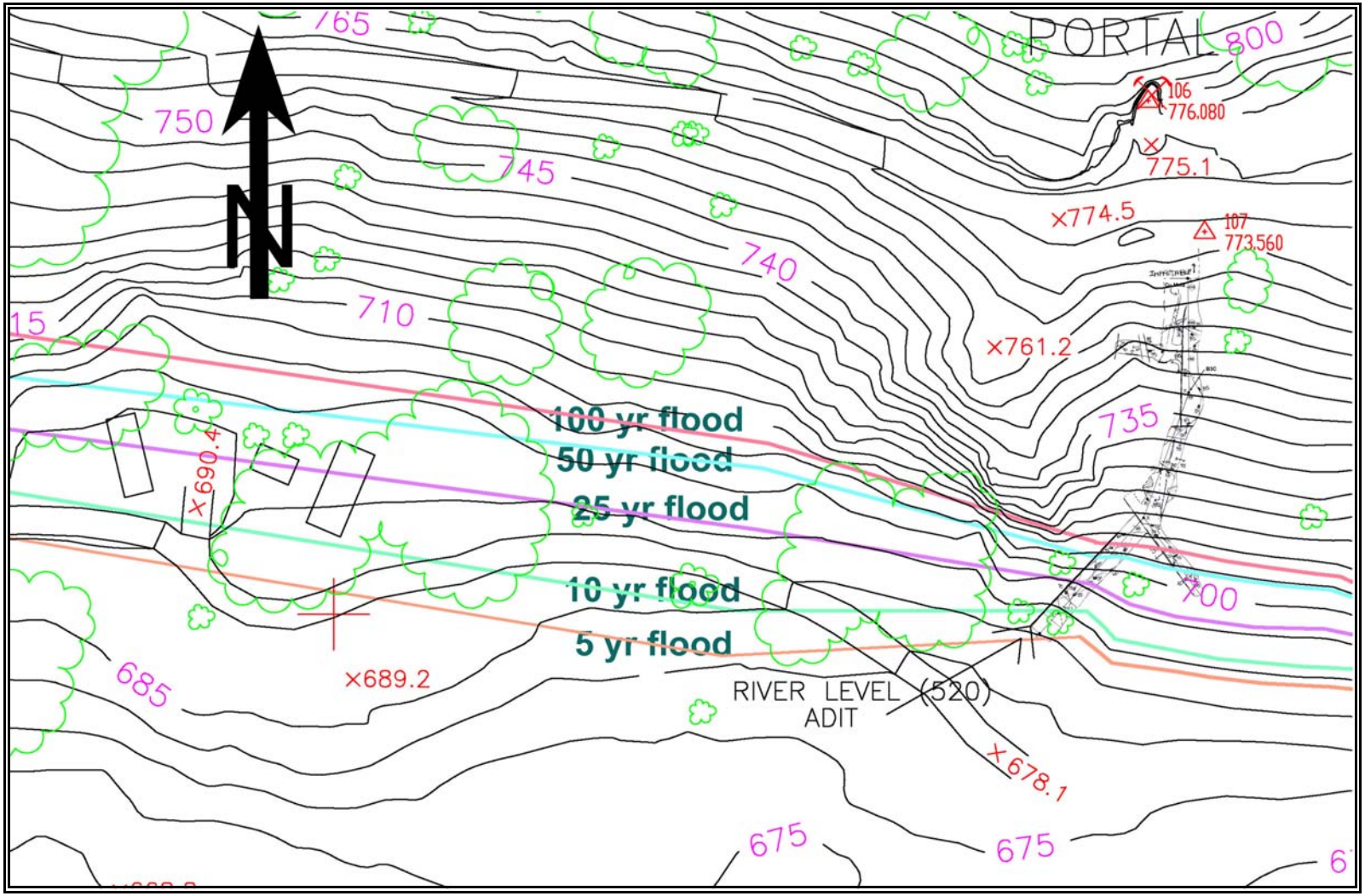



**Figure 15** – *Approximate position of the mapped portions of the 520 level relative to potential downstream treatment locations, with flood levels (from BLM 2002 mapping) shown*

## APPENDIX C
## CONCEPTUAL OPINION OF PROBABLE 520 BULKHEAD CONSTRUCTION COSTS

SGS prepared a preliminary, conceptual-level (plus or -25%) opinion of likely bulkhead construction costs.

### BASIS OF COST CALCULATIONS

The Almeda 520 bulkhead project is different from other, deeper mine sealing projects, in that the bulkhead itself needs only to withstand moderate hydrostatic pressures (less than about 50 psi); ring grouting, bulkhead sealing, and mine pool management are important to reduce the emergence of seepage at the surface. The site is in a rugged area, where equipment and heavy loads will be hauled in on both improved and unimproved dirt roads, some of which are quite narrow and steep near the mine. The import and deployment of materials and supplies will reflect the costs attendant to the difficult access conditions.

Rather than use generic industry unit cost information (site-adjusted averages for concrete, steel reinforcement, rock scaling, shotcrete, and so forth) or costs pertinent to conventional more-accessible deep-mine bulkheads, SGS forecast the conceptual Almeda construction costs by adapting the bid prices for the Golinsky bulkhead project in northern California, completed in 2001 by the Shasta-Trinity National Forest. The Golinsky project, described by SGS in a previous report (SGS, 2007) also is a low-pressure bulkhead application under shallow cover in a rugged area with limited access. For the Golinsky project, SGS reviewed the available construction records and adapted costs from the bid tabulation and the cost details presented by the eventual contractor.

These Golinsky mine bulkhead cost data required adaptation for use in the Almeda conceptual cost calculations, for the following reasons.

1. Unlike the Almeda site, there is no road access to the Golinsky mine openings, which may only be reached by helicopter or by foot. This aspect certainly increased the Golinsky bid prices, although the archival data do not permit calculation of the percentage of increase. Massive, heavy items were probably the most affected (concrete, for example, was brought in by helicopter in large sacks, and mixed on site). Access issues probably constitute the greatest overall cost impact through the Mobilization item. Mobilization items such as site improvements (ladders, stairs, trail improvements, water system, and so on) and the marshalling of equipment at the portals (drills, mixers, mucking equipment and so on) would have been heavily dependent on high-cost helicopter and labor hours. Access-related cost impacts will exist at the Almeda site, where the delivery of materials and equipment will also be time-consuming and expensive, although to a lesser degree.

2. There were two adit bulkheads (“55 level” and “Tunnel 2") installed at the Golinsky; the Almeda 520 project will entail only one, so to an unknown extent, there may have been economies of scale on the Golinsky project that will not be applicable at the Almeda project.

3. The 55 level bulkhead constructed at the Golinsky project is in a much taller adit than the 520 adit at Almeda. The "Tunnel 2" adit dimensions at Golinsky are similar to those of the 520 adit at Almeda, so SGS considered the Tunnel 2 bulkhead costs to be more relevant to the Almeda 520 project.

4. Rock involved in the Tunnel 2 bulkhead at Golinsky consisted of a fractured volcanic assemblage where long, near-vertical discontinuities parallel to the adit axis were not as hydraulically important as they appear to be in the Almeda 520 adit.

5. Much of the ring grouting called for in the Golinsky construction documents was not performed, due to technical problems, and the contractor received a unit price adjustment for the reduced quantity. On the other hand, for reasons that are not well described in the construction report, the contractor performed considerably more tunnel excavation (apparently from the adit invert) than was called for in the construction documents. Because these circumstances are not forecast in the Almeda 520 project, SGS considered the resulting as-built cost structure to be less useful than the bid prices.

6. The Golinsky contract was let in late 2000 but the Almeda bulkhead construction may not take place until late 2011 or 2012, so a cost escalation was required. SGS considered that the costs used in the bids may have reflected the bidders' 1999 internal costs. According to federal government statistics, the inflation rate between January 1999 and December 2009 was 31.44%. The average annual rate of inflation was therefore approximately 3.7% over those nine years. An additional 3.7% per year for 2010, 2011, and 2012 yields an *escalation factor* on the Golinsky prices, January 1999 through December 2012, of 43%. Assumption of a different inflation schedule would of course change the unit prices.

SGS considers that the similarities between the Golinsky and Almeda 520 bulkhead projects outweigh these differences. In forecasting the costs, these differences were accounted for using judgment. Although the Almeda project will not be as affected as the Golinsky by the cost impacts of access and site location, SGS considers the Golinsky unit costs, with some adjustments, to be sufficiently comparable to the Almeda bulkhead situation as to fall within the accuracy implied by a conceptual cost estimate. At worst the Golinsky costs would form a conservatively appropriate basis for forecasting the Almeda costs.

Where the Golinsky items of work were considered reasonably applicable to similar activities that will be required at the Almeda site, SGS forecast the corresponding Almeda unit prices by applying the above inflation rate to the average Golinsky bid price attributable to the three lowest Golinsky bidders. This was considered a more realistic approach than simply adopting the unit price structure proposed by the successful contractor, who may have unbalanced his bid, but also excludes certain very high unit prices extended by the highest bidders, which may be unrealistic. As noted above, these unit prices may account for issues related to access and transportation of materials, personnel, supplies, and equipment that are mostly, but perhaps not fully, realized at the Almeda site.

## UNIT COST ITEMS

The following cost elements were considered.

### 1. Mobilization

Mobilization consists of the marshaling of personnel and equipment from the point of origin (contractor office, vendor facility, etc.) to the site; submittal of necessary preliminary documents and permits; set up of site offices and equipment (water handling, compressor, power as might be required, and so on).

### 2. Demobilization

Demobilization will include the removal of personnel, equipment, and so forth from the site area, as well as site clean up.

### 3. Site Improvements and Grading

It is considered that some minor improvements will be needed to the roadway between the 620 portal and the 520 work area, and that some grading in front of the 520 work area will be necessary to stage the lay down of reinforcing steel, mixing of concrete and shotcrete, and so forth. More extensive improvements would be desirable but may not be feasible for environmental or cultural reasons.

### 4. Rock Mass Grouting

This includes ring grouting of drill holes around the bulkhead location. Ring grouting assumed 15 ft long drill holes in the back and floor and 20 ft long holes in the ribs, averaging 1.5 foot centers, comprised of 4 rings, spaced at 4-5 feet apart.

5. Bulkhead Keyway Excavation

Mechanical or extremely light blasting will be used to excavate a key way all around the bulkhead location ranging between 1.5 and 3 feet deep.

6. Keyway Scaling

This item would include scaling ordered by the site engineer, within the bulkhead keyway and immediately behind it.

7. Bulkhead Installation

This item would be a lump sum cost for the placement of reinforcing steel and mass concrete, to the dimensions required by the contract documents. It would also include such incidental items as water handling, AMD diversion and removal from the invert, including a cofferdam; concrete testing and quality control, and other matters related to the actual installation of the concrete bulkhead. The Golinsky Tunnel 2 bulkhead was taken as13 $yd^3$ of concrete, based on the design quantities in the Golinsky plans; the actual quantity was more like 18 $yd^3$. The Almeda bulkhead is estimated to require about 21 $yd^3$ of concrete, so the Golinsky bulkhead lump-sum price was factored accordingly.

8. Shotcrete

Shotcrete is recommended behind the bulkhead location and in the station 95 left crosscut. This item is assumed to include mucking of the station 95 left crosscut and cleaning of the rock surfaces in it and the adit sections back to the mouth of the stope; and placement of 4 inches of fiber mesh-reinforced shotcrete on the ribs, back, and invert.

9. Bulkhead Sealing

This item includes contact grouting of the bulkhead perimeter, and other grouting and sealing activities that may be required once the concrete bulkhead is in place. The Golinsky prices were again adjusted life a factor equal to the ratio of the two bulkhead volumes.

10. Plumbing and Fittings

This item includes the installation of the valves, gauges, and piping sufficient to connect the valves and gages to the bulkhead. It does not include piping to connect the bulkhead installation to other facilities that might be installed underground, or at the portal.

11. Operation and Maintenance Plan

The contractor would submit a written operations and maintenance (O&M) plan giving instructions to the BLM on the function and maintenance of the valves, gauges, and other features.

12. Quality Control Plan and Environmental Compliance

The contractor will be required to submit for approval, and implement, a quality control plan relating to the materials of construction, installation, and final hardware. In addition, a program similar to that which was required for the adit reopening will need to be developed and implemented to control environmental impacts attended to the bulkhead construction.

## SUMMARY OPINION OF PROBABLE CONSTRUCTION COST

Mobilization: the average mobilization cost entered by the three lowest bidders for the Golinsky project, times escalation at 43%, less 25% to account for differences in access and efficiency: $200,000

Demobilization: 25% of mobilization: $50,000

Site Improvements and Grading: two days of small dozer, plus operator, supervision, and support: $3,000

Rock Mass Grouting: average cost extended by the lowest three Golinsky bidders, times escalation at 43%, for the Tunnel 2 project only. $80,000 (estimated total 1,120 l.f. drilling)

Bulkhead Installation: average Tunnel 2 lump sum cost extended by the lowest three Golinsky bidders, times escalation at 43%, times a volume correction factor (21 $yd^3$ /13 $yd^3$): $87,000

Shotcrete: the average cost per square foot for Golinsky Tunnel 2 shotcrete as extended by the three lowest Golinsky bidders, times escalation at 43%, applied over a perimeter area equal to that of 65 total feet of 5 x 7 drift, plus 20% to account for rock irregularity and overbreak: $56,000.

Bulkhead Sealing: average lump-sum price extended by the lowest three Golinsky bidders, times escalation at 43%, multiplied by a scale factor (21 $yd^3$ /13 $yd^3$) to account for the differences in bulkhead volume: $13,000

Plumbing and Fittings: average lump-sum price extended by the lowest three Golinsky bidders, times escalation at 43%: $5,000

Operation and Maintenance Plan: same rationale as above: $5,000

Quality Control Plan and Environmental Compliance: average lump-sum price extended by the lowest three Golinsky bidders, times 2 (to account for the additional political and scientific complexity associated with the Almeda site), times escalation at 43%: $17,000

*Total Conceptual Estimated Cost*: $545,000

Suggested Allowance for Engineering: 15%.