WALKER MINE PROJECT
FINAL
FEASIBILITY AND DESIGN REPORT
CONTRACT NO. 4-051-150-0

Prepared for

California Regional Water Quality Control Board

Central Valley Region

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

I STATEMENT OF PROBLEM

The Walker Mine discharges acid- and heavy metal-laden water from an adit and mine waste dump into Dolly Creek which is a tributary to Little Grizzly Creek. The discharge from the mine is reported to have totally eliminated aquatic life in Dolly Creek, and in Little Grizzly Creek for a distance of approximately ten miles downstream from the mine.

The primary goal of the California Regional Water Quality Control Board (the Board) is to restore Little Grizzly Creek and Dolly Creek to a condition capable of supporting a diversity of aquatic life.

The first objective of the studies forming the subject of this report is to evaluate the effectiveness and feasibility of sealing the Walker Mine adit in such a manner as to prevent a direct discharge of acid- and heavy metal-laden water from the underground workings. The second objective is to design and estimate construction costs for such a seal, should it prove to be warranted.

II SCOPE OF WORK

A. Feasibility

Steffen Robertson and Kirsten's (SRK) studies have been directed towards evaluating the feasibility of sealing the actual and potential portals through which acid mine drainage (AMD) might discharge by:

1) Performing a hydrologic assessment of the underground mine and its environs;

2) Examining available maps of the underground workings, surface features, and fault systems;

3) Examining available data to assess general groundwater movement and the potential for the escape of mine waters through surface springs or seepage; and

4) Identifying possible alternative outlets for mine water, when it is prevented from following its present course by sealing of the 700 Level Adit.

B Design Criteria

1) Concrete bulkheads have been designed to seal the main Access Adit on the 700 Level and to minimize the potential for the escape of mine water through other outlets.

Site selection for seals was made to:

- Minimize the potential for seepage around the seal;
- Maximize the structural integrity of the seal; and
- Permit future replacement of the seal, if necessary.

2) Seal design has taken into account:

- The maximum possible head of water to be held behind the seal;

- Installation of pipes through the seal to permit future dewatering of the mine in case that should become necessary;

- Materials and construction techniques appropriate to the environment in which the seal is to be located, and the objective of a design life in excess of 100 years; and

- Installation of a pressure gauge to monitor the head of water behind the seal.

C. Reporting

All feasibility studies and plug design will be submitted to the Board for review and approval.

D. Construction

Following the Board's approval of plug feasibility and design, and authorization for construction, the approved structures will be installed.

III STUDIES AND CONCLUSIONS

Data available from the Board's records and previous studies were evaluated, and related to current conditions through site visits during the weeks of September 17, 1984 and June 17, 1985. The physical conditions of accessible underground workings on the Main 700 Level from the portal to the Piute Section (a distance of approximately 8,000 ft.) were observed, and all accessible surface outlets from the mine workings were visited. Potential sources of surface inflows to the mine were also observed.

The results of site observations indicated that a single concrete bulkhead plug in the 700 Level Adit, at a point close to the South Orebody workings, would effectively stop the discharge of AMD from the Walker Mine Adit. Minor improvements and additions to the existing system of diversion ditches, around surface subsidence over the underground workings, would further minimize inflow of water to the workings.

Consideration was given to the possibility that water would rise in the mine workings behind the proposed plug and might eventually discharge through the next-lowest outlet, the Piute Shaft Landing Tunnel. The studies described in this report demonstrate the strong probability that water would not rise to the level of the Piute Shaft Landing Tunnel: equilibrium between inflow to the workings and outflow as recharge to the groundwater system would probably be reached below that level.

The cost of constructing an internal plug to compartmentalize the mine workings and protect against the remote possibility that water might rise to a level at which it could discharge, was found to be unjustifiable. Insurance against any possible discharge through the Piute Shaft could be provided by monitoring the level of water in the mine workings. If, at any time in the future, as a result of excessive precipitation or snowmelt, the water should approach the overflow level, a controlled flow of AMD could be released through a valve in the 700 Level Adit plug, treated to acceptable standards, and discharged into Dolly Creek. The costs of proposed remedial measures, and of rejected alternative courses of action were estimated. A treatment system was found to be more cost efficient than the alternative of an internal plug.

IV RECOMMENDATIONS

The following course of action is recommended:

1. Rehabilitate and extend the existing diversion ditches around surface subsidence sinkholes, to minimize inflow of surface water to the underground mine workings.

2. Conduct a water flow and quality balance survey along the 700 Level Haulage and Adit, through the abandoned plant site area, and along Dolly Creek to its confluence with Little Grizzly Creek.

3. Install a single plug in the 700 Level Adit approximately 2,700' from the portal.

4. Monitor water levels in the mine workings by means of gauges reading pressure behind the plug.

5. Prepare a contingency plan for future construction and operation of a small treatment plant at the 700 Level Adit Portal, to treat AMD that might have to be discharged periodically (in the order of ten or more years after installation of the plug) to relieve any excess buildup of water that might threaten to overflow out of the Piute Shaft.

V COSTS

The cost of the recommended course of action, in 1985 dollars to the nearest $500, would be:

Rehabilitation of Diversion Ditches	$ 14,000
Water Balance Survey	6,500
Main Adit Plug Construction	150,000
Discharge Treatment Plant Specifications	6,500
Total Initial Cost of Abatement	$177,000

Future work associated with the recommended course of action would be:

Routine Monitoring	$ 1,000/year
Maintenance of Diversion Ditches	2,500/year
Total On-going Cost of Abatement	$ 3,500/year

Possible future costs could include:

Build Discharge Treatment Plant	$250,000
Operate Discharge Treatment Plant	5,000/year

The additional cost of rejected precautions, over the recommended course of action, is estimated as:

Internal 712/Piute Plug (minimum)	$227,000
Piute Landing Tunnel Plug	23,000
Sawmill Adit Plug	20,000
Total Cost of Rejected Precautions	$270,000

1.0 INTRODUCTION

1.1 Location and History

The Walker Mine is an inactive copper mine located some 20 miles east of Quincy, in Plumas County, California, approximately 20 miles by road from Portola. Access is by well-graded gravel road through the Plumas National Forest from California Highway 70 at Portola. Situated in hilly country at an altitude of between Elev. 6,000 and 7,000 ft, the mine site is subject to heavy snowfall in winter and is generally inaccessible to motor vehicles between November and April.

Copper ore was first discovered at the Walker Mine site in 1904. Production commenced in 1916, continuing until 1932 and again from 1935 to 1941, when it was closed down by the operator, Walker Mining Company, a subsidiary of Anaconda Copper Company. Mining started on the 200 Level (approximately 6,670 ft elevation) near the outcrop of the Central Orebody, but the Main Haulage Tunnel on the 700 Level (approximately 6,200 ft elevation) was driven in the early 1920's. The Main Access Adit on the 700 Level was driven as an adit from the millsite at Dolly Creek, cross-cutting north by northeast some 3,000 ft to intersect the South Orebody. From there, the haulage was driven north by northwest, following the vein through the Central, North, 712 and Piute Orebodies. Approximately 10,000 ft from the portal, the Piute Shaft was raised in the vein from the 700 Level to surface in 1927/28. The portal of the 700 Level Main Access Adit remains the lowest point at which the underground workings reach the surface.

No stoping was done below the 700 Level until the 1930's. The deepest level from which ore was mined was the 1000 Level (approximately 5,720 ft elevation) and the deepest exploration winze was sunk to below the 1200 Level (approximately 5,400 ft elevation) on the Central Orebody.

A total of 5,319,000 tons of ore was mined between 1916 and 1941, from which 83,890 tons of copper were recovered (an average recoverable grade of 1.58% Cu with 0.03 oz/ton gold and 0.68 oz/ton silver recovered as by-products).

Soon after cessation of mining in November, 1941, all the mining equipment was removed and the surface plant was dismantled. When mineral processing stopped, the neutralizing effect of the water discharged from the plant was lost and the acid mine drainage (AMD) water flowing from the main Access Adit Portal on the 700 Level began to affect the Dolly Creek and the Little Grizzly Creek. Increasing concern over the detrimental effects of the AMD prompted the California Regional Water Quality Control Board (the Board) to commission several investigations, including the studies forming the subject of this report.

1.2 Statement of the Problem

The Walker Mine discharges acid- and heavy metal-laden water from an adit and mine waste dump into Dolly Creek which is a tributary to Little Grizzly Creek. The discharge from the mine is reported to have totally eliminated aquatic life in Dolly Creek downstream from its confluence with mine drainage water, and in Little Grizzly Creek downstream from its confluence with Dolly Creek for a distance of approximately ten miles downstream from the Walker Mine.

The primary goal of the Board is to restore Little Grizzly Creek and Dolly Creek to a condition capable of supporting a diversity of aquatic life.

The first objective of the studies forming the subject of this report is to evaluate the effectiveness and feasibility of sealing the Walker Mine adit in such a manner as to prevent a direct discharge of acid- and heavy metal-laden water from the underground workings. The second objective is to design and estimate construction costs for such a seal, should it prove to be warranted.

1.3 Scope of Work

In terms of Contract No. 4-051-150-0, signed on August 20, 1984, and the subsequent order to proceed given on September 5, 1984, Steffen Robertson and Kirsten (Colorado) Inc. (SRK), has pursued the following scope of work:

A. Studies have been directed towards evaluating the feasibility of sealing all actual and potential portals through which AMD might discharge by:

1) Performing a hydrologic assessment of the underground mine and its environs;

2) Examining available maps of the underground workings, surface features, and fault systems;

3) Examining available data to assess general groundwater movement and the potential for the escape of mine waters through surface springs or seepage; and

4) Identifying possible alternative outlets for mine water, when it is prevented from following its present course by sealing of the 700 Level Adit.

B. Design Criteria

1) Concrete bulkheads have been designed to seal the main Access Adit on the 700 Level and to minimize the potential for the escape of mine water through other outlets.

The selection of sites for seals has been made to:

- Minimize the potential for seepage around the seal;
- Maximize the structural integrity of the seal; and
- Permit future replacement of the seal, if necessary.

2) Seal design has taken into account:

- The maximum possible head of water to be held behind the seal;
- Installation of pipes through the seal to permit future dewatering of the mine in case that should become necessary;
- Materials and construction techniques appropriate to the environment in which the seal is to be located, and the objective of a design life in excess of 100 years; and
- Installation of pressure gauges to monitor the head of water behind the seal.

C. Reporting

This report has been prepared to detail the observations and conclusions arising from the feasibility studies, and to specify the design of the proposed bulkhead plug.

D. Construction

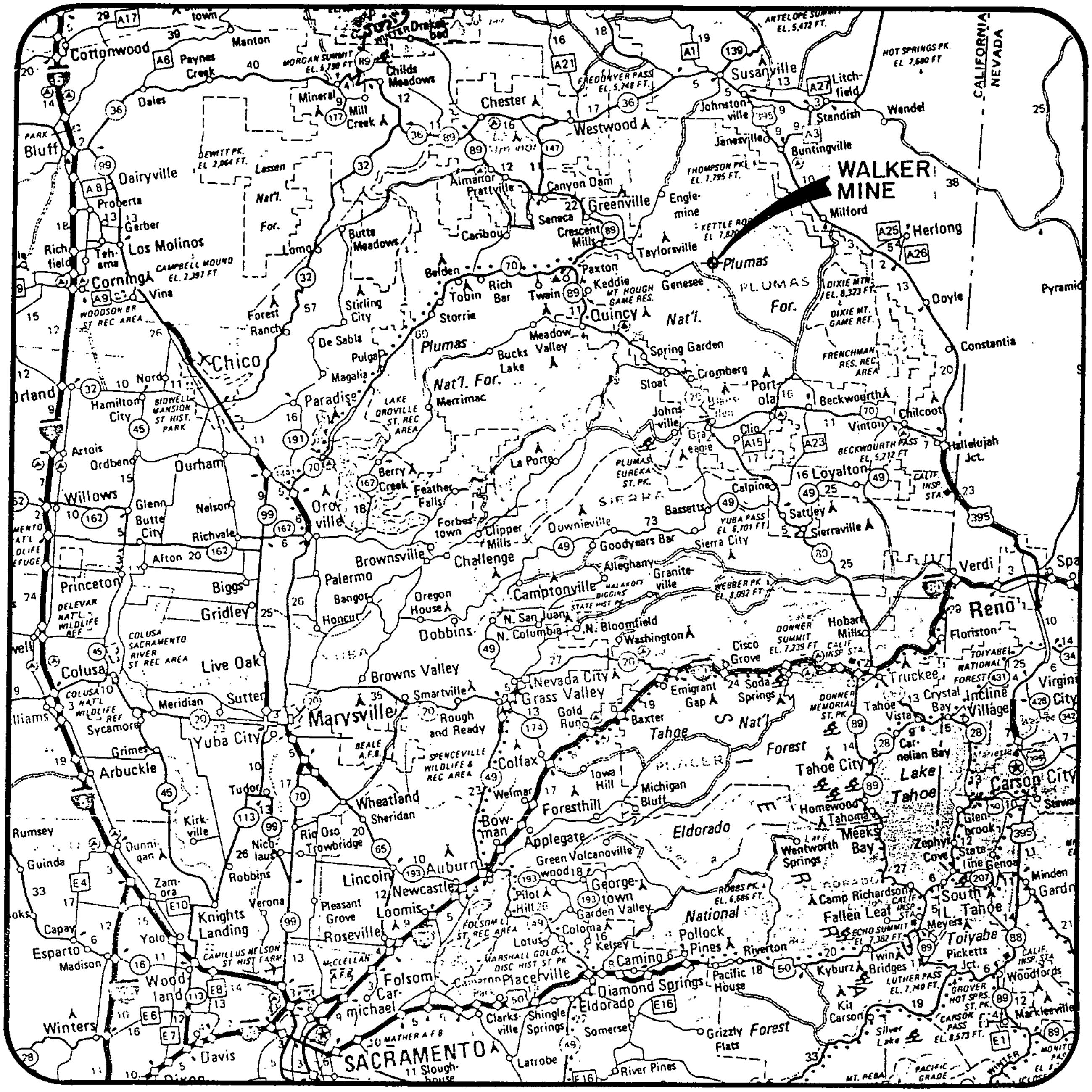
Following the Board's approval of plug feasibility and design, and authorization for construction, the approved structures will be installed.

1.4 Constraints

It must be emphasized that many of the opinions and conclusions recorded in this report are subjective and based on professional judgement. Assumptions have had to be made on the basis of limited or nonexistent data, to serve as a base on which professional experience and judgement can develop logical courses of action or events.

Certain information, such as underground plans showing the final extent of the mine workings and the locations of potential points (such as air raises or adits) for egress of water rising in the old workings, were not initially available. Research through the California Division of Mines and Geology discovered a vertical projection of the mine workings used to indicate ventilation flows at the time of an underground fire in 1940. Though incomplete and not necessarily indicating the full extent of the workings when mining stopped in 1941, this drawing has been used in the evaluation presented in this report.

Information regarding water flows and quality, both in surface streams and from the 700 Level Access Adit Portal, has been drawn from available sources. Time and restricted access have not permitted complete physical verification, but indirect checks have been applied. Water flows from the 700 Level were estimated by indirect measurements during the field visit by SRK in September, 1984 and June, 1985.



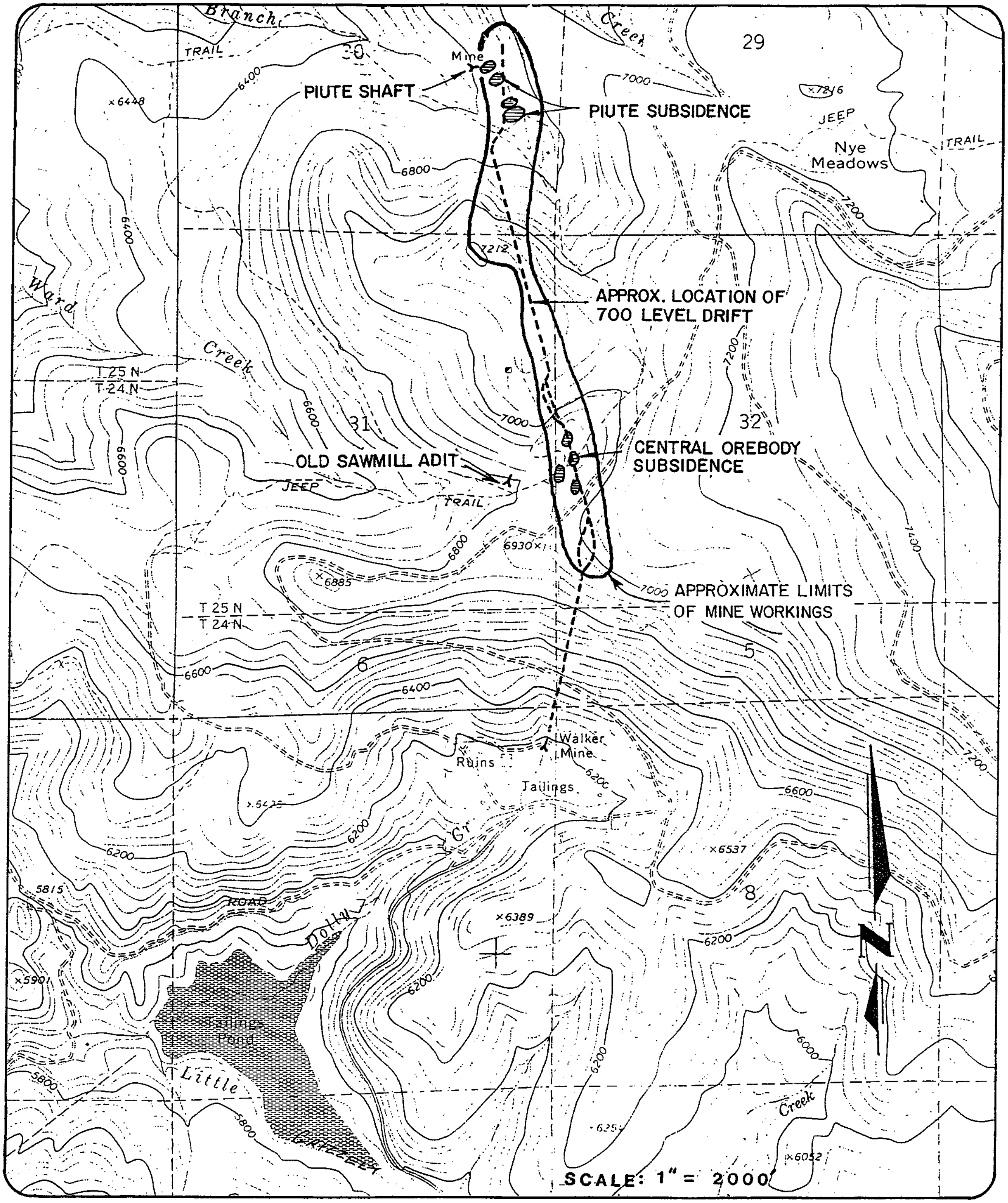
0 20 40

APPROX. SCALE IN MILES

N

LOCATION OF MAP ABOVE

PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 1
DATE 3 / 85		PROJECT LOCATION
REVISION NO. 0		



PROJECT NO.	PREPARED BY:	FIGURE 2
06901	STEFFEN ROBERTSON & KIRSTEN	SITE PLAN AND TOPOGRAPHY
DATE 3 / 85	Consulting Engineers	
REVISION NO. 0		

FIGURE 2

SITE PLAN AND TOPOGRAPHY

2.0 STUDIES AND RESULTS

2.1 Site Visits

Unexpected delays were experienced by the Board in obtaining rights of access to the mine following signature of their contract with SRK. On September 5, 1984, a court order for entry onto the property was obtained, allowing SRK to examine the site and the accessible parts of the underground workings of the Walker Mine during a ten-day period between September 17 and 26. A site visit was arranged for the week of September 17 to enable all key members of the team to make a quick visual inspection of the mine workings and their environs.

Prior to the site visit, members of SRK's project team met with officials of the Board in Sacramento and studied the Board's project files relating to the Walker Mine. A composite underground plan of the main working levels at the Walker Mine, (at a scale of 1" = 200') was obtained, but no vertical projections or cross sections of the underground workings were available.

The 700 Level Main Access Adit was examined from its portal to the northern end of the Central Orebody workings. Data collected included:

- Observation and assessment of rock mass classification, noting evidence of permeability and orientation of fissures;
- Observation of the quantity and quality of water flow in the 700 Level tunnels at various locations from the Central Orebody workings to the adit portal;
- Measurement of tunnel profiles at selected alternative locations for a bulkhead seal in the 700 Level Main Access Adit, close to its intersection of the South Orebody; and

- Assessment of the transport and utility facilities available for construcion of a bulkhead seal.

All subsidence areas on surface were visited, as were the collars of the Main and Piute Shafts, and the portal area of the Sawmill Adit.

The effects of mine drainage from the Walker Mine 700 Level Adit were observed in the Dolly and Little Grizzly Creeks, and the tailings impoundment was examined visually. No evidence was found of seepage of mine drainage through outlets other than the 700 Level Adit, but it was recognized that this did not mean that seepage might not occur at other times of the year, at the same time in other years, or in other places.

Subsequent to the site visit, plans or other records concerning the underground workings and geology of the Walker Mine were sought from the Anaconda Minerals Company but, despite their generous cooperation, none could be found. However, valuable information in the form of a 1" = 200' scale vertical projection of the mine workings as of April, 1940 (shortly before the final cessation of operations) was obtained through the California Division of Mines and Geology.

Delays in obtaining access to the site did not allow more than a single cursory examination before the onset of winter prevented further access. This factor, combined with a paucity of documentary evidence of underground geological and mining features, and limited records of water flows and quantities up and downstream of the mine workings, forced the project team to base its preliminary conclusions on circumstantial evidence to a greater extent than it considered ideal.

Conclusions, drawn from available data and observations made during the first site visit led to a maximum security recommendation in SRK's Draft Feasibility and Design Report presented in February 1985. This recommendation required the installation of a second, internal plug, between the 712 and Piute Sections, in addition to a main plug in the 700 Level Adit. This requirement was based on concerns that water, held back by a single plug in the main adit, might rise to a level at which it could overflow through the Piute shaft and pollute the hitherto uncontaminated catchment of Ward Creek. The high degree of uncertainty attached to this possibility mandated a very conservative approach.

The Regional Board suggested a second visit to further investigate several specific questions they presented in a letter to SRK dated May 31, 1985. It was considered that the information gathered would permit SRK to attach a higher degree of confidence to their recommendations.

A court order was obtained on June 13, 1985 permitting SRK to enter the mine between June 17 and June 31, 1985. After two days of delay awaiting the owner's representative who held the keys to the property and the adit door, forced entry was made on June 18, 1985.

The team made a one-day underground inspection on June 19, 1985, the last day available in the team's schedule. It took over 3 hours to reach the Piute Orebody Section along the 700 Level haulage, and about 2½ hours to return by the same route .

Tunnel dimensions were measured, and rock quality observed, at the site selected for a possible internal plug between the 712 and Piute Sections. The selected site was flooded to a depth of about 3'-6".

Approximate measurements of water flow rates were made where flow was sufficiently channelized to be measurable, to estimate a flow profile along the 700 Level haulage. The locations of major inflows to and losses from the haulage were listed.

The nature and volume of sludge, fallen timbers and rockfall in the haulage were observed and related to the work that would be required to remove them.

The presence or absence of rail track was checked by probing with a steel rod. The track's condition was noted at the few points where it was exposed and could visually be inspected.

Branches of the 700 Level haulage that could have led to another connection between the 712 and Piute Sections were checked and found to dead-end. The possibility of a connection at a higher level could not be checked as access into the 712 Orebody workings through the collapsed northern most stope drawpoint chute was considered unsafe on examination. In subsequent conversation with the owner's representative, Mr. Donato, he confirmed that he had descended through the Piute Shaft and workings to the 700 Level haulage, but had not ventured into the flooded part leading southward to the 712 Section. He had returned to surface up the Piute Shaft, checking the workings at each level for a connection to the 712 Section. No connection was found.

In addition to their underground inspection, SRK's engineers examined the diversion works around the sinkholes above the mine workings.

2.2 Hydrology

2.2.1 Introduction

This section of the report sets out the findings of a study of the hydrological effects of plugging the main access adit of the Walker Mine.

The mine has been generating and discharging acid drainage since its closure in 1941. The copper carried by the water has reportedly rendered the receiving streams (Dolly Creek and Little Grizzly Creek) essentially barren of aquatic biota for about 10 miles downstream. In order to mitigate this impact, the Regional Board has proposed to install a plug in the mine portal. This section of the report comments on the effectiveness of this action to:

- Provide an immediate relief from the contaminated flow from the mine; and
- Build up the water level in the mine, thus reducing the volume of material capable of generating AMD,

and indicates the general order of magnitude of the effects to be expected following the installation of the mine plug. The anticipated results of this action are assessed in terms of:

- Effectiveness in achieving long-term improvement in water quality in the vicinity of the mine; and

- Extent and likelihood of possible undesirable side effects, and steps that can be taken to mitigate them.

2.2.2 Available Information

This study was performed entirely on the basis of existing information, together with field trips to the site in September, 1984 and June, 1985. The documents available were:

- Composite plan of the main levels of the mine, at a scale of 1" = 200', dated August 1, 1941;

- Vertical projection of mine workings at a scale of 1" = 200', as of early 1940;

- Report on "Plans to Proceed Toward Abatement of the Water Pollution Problems Incident to Water Emanating from the Walker Mine, Plumas County," California Division of Mines & Geology, August, 1972;

- Report on "Evaluation of Water Pollution Sources and Development of Conceptual Pollution Abatement Plans, Walker Mine, Plumas County, California", D'Appolonia Consultants, December, 1979;

- Water quality data from Conoco, for 1976 and 1977 (Pine, 1979), 1980 and 1981 (Hart, 1980 & 1981); and

- Water quality data from the California Regional Water Quality Control Board, Central Valley Region for 1977 and 1978 (Matteoli, 1977, and 1978; and Croyle 1985).

While this database is limited, particularly with respect to flows, it is considered to be adequate for the present evaluation. Little independent checking of the data was possible in the time available; however, consistency checks have been made when possible and some information has been omitted as a result.

2.2.3 Setting

2.2.3.1 The Mine

The Walker Mine is located in Plumas County, California as shown in Figure 1. The workings strike approximately north-south, over a distance of nearly 1½ miles. The tabular orebody, 10 to 100 ft thick, was mined at an average stoping width of 35 ft, dipping to the east at about 60^{o} to 70^{o}. The mine excavations extended from surface above elevation 7,000 ft to below elevation 5,400 ft. A section through the mine is shown in Figure 4.

Rock containing sub-economic grades of copper was not mined, and remained in place. A study done during World War II estimated about 4 million tons of copper-bearing rock remained in the mine area. Subsequent exploration by several mining companies has failed to identify sufficient reserves to justify reactivation of mining.

The volume of voids resulting from mine excavations was estimated as a function of location based on Figure 4. In absence of transverse sections of the workings, an average stoping width of 35 ft was assumed throughout. The volume of rock excavated from the mine is estimated to be about 5,319,000 tons of ore plus an estimate of 680,000 tons of waste rock. Visual inspection of the mine suggested that the mine is still very stable and it is likely that little collapse of the hanging wall has taken place since the mining operation. It is assumed that the effective volume of the voids caused by mining is equivalent to the volume of rock excavated, i.e. some six million tons of rock or 543 million gallons of water.
The estimated void volumes are shown in Table 1.

TABLE 1
ESTIMATE OF VOIDS AS MINED

SECTION	VOID VOLUMES (MILLION GALLONS)			
	Above 6600'	6200'-6600'	Below 6200'	Total
Piute	-	88	19	107
"712"	6	57	-	63
North	57	76	57	190
Central	44	63	50	157
South	-	13	13	26
Totals	107	297	139	543

2.2.3.2 Hydrology

The mine is located in the catchment area of Little Grizzly and Ward Creeks, both of which flow north to Indian Creek (Figure 2). Flow from the mine currently discharges out through a 3,000-ft long adit (700 Level Access Adit) at about the 6,200 elevation to the south of the mine. This flow varies considerably over the year, as shown in the data for 1978 (Figure 5). Much of the portal flow is believed to originate as surface flow, which is captured by sinkholes which connect the mine to the South and Middle Forks of Ward Creek. Remedial actions and diversions in recent years have probably reduced the peak flow below that shown in Figure 5.

Water from the adit flows into Dolly Creek, which flows to Little Grizzly Creek, which in turn flows to Indian Creek. Average flows in these creeks have been calculated to be of the order of 1.7 cubic feet per second per square mile of catchment (1.2 gpm/acre - Table 1 D'Appolonia, 1979).

2.2.3.3 Water Quality

The quality of water in local streams which are unaffected by the mine is excellent. The flow from the portal is, however, of low pH and high in copper and other dissolved metals, as shown in Table 2.

There is a seasonal variation in the copper concentrations measured in the water flowing from the portal of the mine. The available data are plotted in Figure 6. It is of interest to note that the copper concentration is highest during periods of greatest flow. This is a result of the spring flushing of acid generated in the mine all winter, which has a lower pH and a higher copper content than the flow later in the year. It is noteworthy that the total dissolved solids (TDS) of the mine water is low, indicating a low residence time in the ground and suggesting that the greater part of the flow is derived from surface inflow.

TABLE 2

TYPICAL SELECTED WATER QUALITY PARAMETERS

(Kaback, June, 1978)

Parameter	Unit	Portal	Streams
Ca	mg/l	24.5	5.8
Na	mg/l	2.7	2.8
K	mg/l	1.6	0.7
Mg	mg/l	6.4	2.2
SO_4	mg/l	146	5
HCO_3	mg/l	0	23
CO_3	mg/l	-	-
pH	Units	4.1	7.6
NO_3	mg/l	4.5	0.7
NH_3	mg/l	0.01	0.01
Cl	mg/l	1	-
Cu	mg/l	29	0.03
Zn	mg/l	0.93	0.01
Fe	mg/l	1.0	0.15

2.2.3.4 Flows Within the Mine

During the initial site visit, the flows in the southern part of the mine were measured using the floating object method. The results of these measurements are presented in Table 3a.

TABLE 3a

ESTIMATED MINE FLOWS (SEPTEMBER 20, 1984)

Location	Flow (GPM)	Comment
Between North and Central Orebodies	174	Location just south of north end of Central orebody
At junction of portal adit and the Central Orebody	229	-
At portal in timbered section	116	-

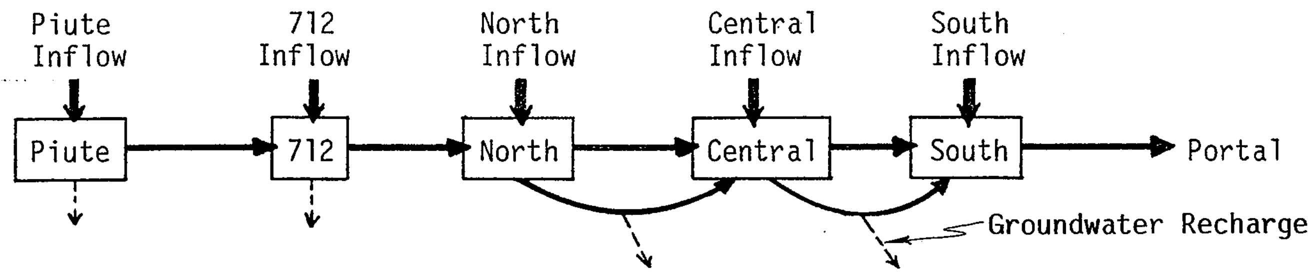
Based on these measurements, it was concluded that:

1. At the time there was apparent flow continuity in the southern portion of the mine, and
2. There appeared to be some flow loss along the portal adit.

Accordingly, it was considered wise to locate any adit plug remote from the portal. In addition, a more detailed flow survey was proposed to better defined in-mine flow.

During the second site visit, a portable direct-reading flow meter was used to determine flow velocity at points where the cross-sectional area of the channel could be estimated reasonably. Where no appropriate channel sections existed, flows were estimated by eye.

The results are presented in terms of flow from blocks of the mine, as indicated in the following sketch:



The results of the rough measurements are presented in Table 3b.

TABLE 3b
ESTIMATED MINE FLOWS (June 19, 1985)

Location	Flow (GPM)	Comment
Between Piute and 712 orebodies	130	Rough measurement.
Within 712 orebody	100	Visual estimate.
Flow on 700 Level at south end of North orebody	270	Rough measurement; does not include above 230 gpm, as this was observed to flow into lower mine workings.
Flow on 700 Level at south end of Central orebody	60	Rough measurement; does not include upstream flows, which entered lower workings.
Flow on 700 Level at south end of South orebody	215	Rough measurement.
Discharge from portal	275	Rough measurement.

Based on this set of readings (which do not cover the entire mine area due to measurement difficulties and shortness of time), it is concluded that, in all likelihood, the flows entering the mine exceed the flow entering the mine adit from the workings, suggesting a deep point of egress of inflow water within the mine.

2.2.4 Evaluation of Current Conditions

2.2.4.1 Conceptual Flow Model

In order to have a means of evaluating the probable behavior of the mine after remedial action, it is necessary to develop a conceptual model of the flow behavior of the mine system. The inflowing water is made up of the following components:

1. Surface water inflow. This enters from sinkholes near the Piute and Central orebody areas. As it is close to its source, quality is expected to be excellent.

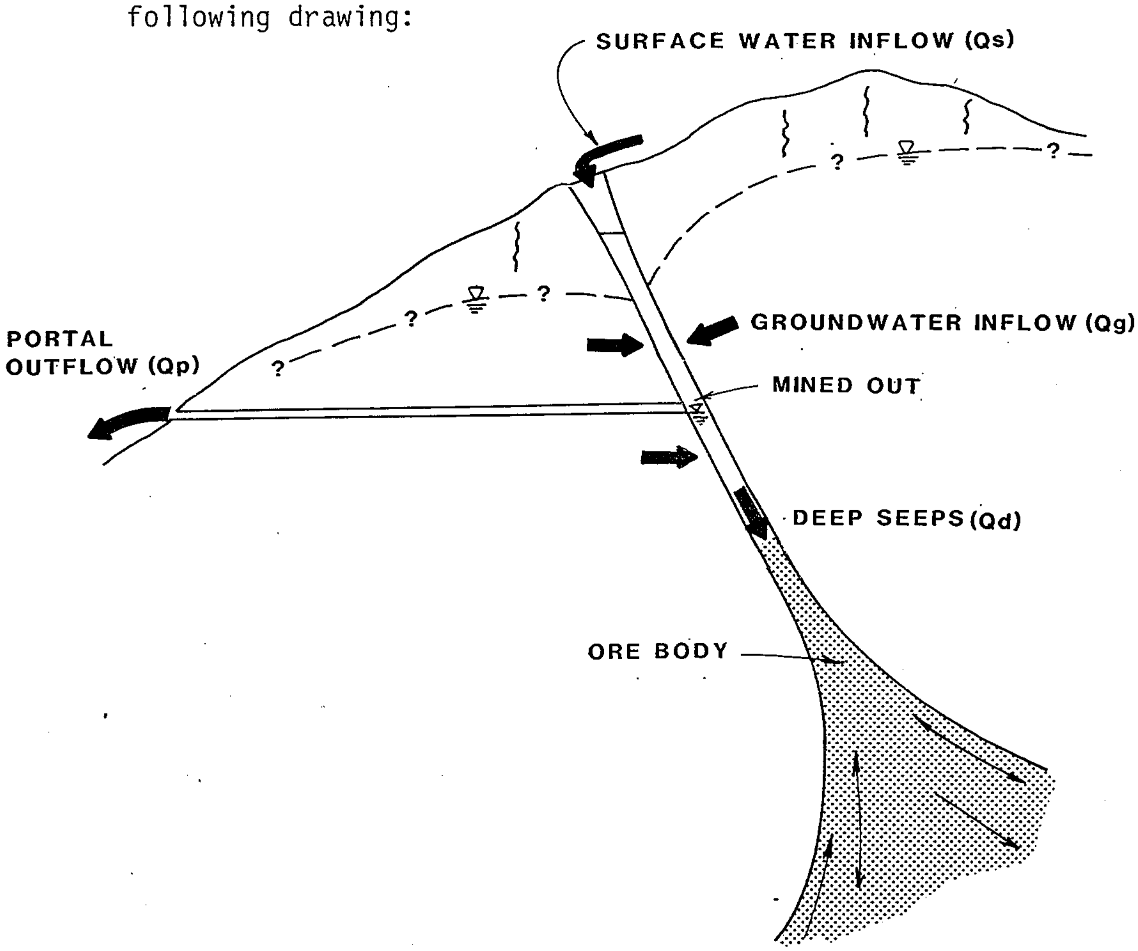
2. Groundwater inflow. The drainage of the mine has caused a groundwater sink in the vicinity of the mine. Local groundwater of (likely) moderate TDS and low metal content is flowing into the mine.

The outflowing water is made up of essentially two components:

1. <u>Flow from the portal</u>. This is essentially an overflow from the mine void, at the elevation of the intersection of the portal adit and the mine.

2. <u>Discharge to deep groundwater system</u>. As noted above, it is entirely possible that there is a deep conduit for flow from the mine. This conduit could allow discharge of water from the mine to the deep bedrock flow system via open pathways through the rock.

The total flow system is shown schematically in the following drawing:



Clearly the relationship between the flows shown for the steady state condition is

$$Q_s + Q_g = Q_p + Q_d$$

2.2.4.2 Groundwater Inflow to Mine

The portion of the measured flow due to groundwater influx to the mine is difficult to evaluate. The minimum low flow from the mine is an indication of the minimum groundwater inflow rate, on the assumption that there is no other outflow from the mine, and that the inflow from surface sources is negligible during low flow periods. The minimum inflow reported is zero (California Division of Mines and Geology, 1972) and 50 gpm (Kaback, 1979). That the flow due to groundwater is small, is further suggested by the low TDS of the Adit flow discussed in Section 2.2.3.3.

It is possible to check the reasonableness of this range of low flows. The groundwater inflow estimate can be used to back-calculate the average hydraulic conductivity of the host rock. Simple evaluation, based on Darcy's law, produces an average hydraulic conductivity of 10^{-5} cm/sec or less. Based on the observations of the rock mass made during the site inspection, this hydraulic conductivity is reasonable for the rock penetrated by the mine.

2.2.4.3 Surface Water Inflow to the Mine

The recorded flow from the mine adit has been as high as 3,000 gpm in the spring. This flow is presumed to be essentially surface water flow. This presumption may be checked by comparison with stream flows in the areas of the sinkholes above the mine.

The peak flow in 1978 presumably resulted from some stream capture at sinkholes in the Middle and South Forks of Ward Creek. As shown on Figure 7, the catchment area to the sinkholes at the Piute Shaft area is 234 acres, while that to the central orebody sinkholes is about 212 acres. Applying flow/drainage relationships based upon local soil, vegetation, precipitation and runoff data, the total estimated average flow in these streams at these locations is given in Table 4.

This figure (525 gpm) compares well with the computed average flow of about 420 gpm in 1978, prior to much of the recent stream diversion activities.

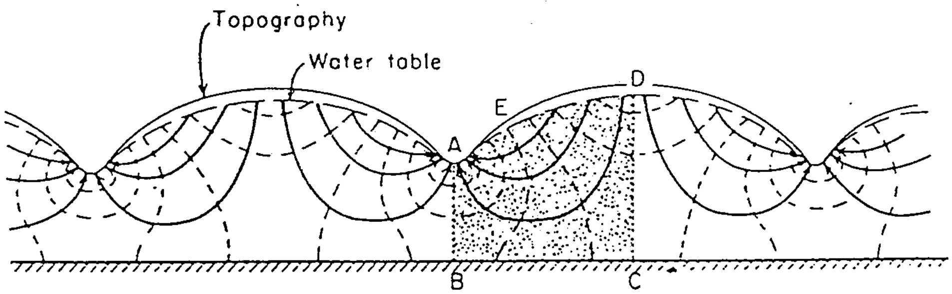
TABLE 4
AVERAGE ANNUAL FLOW TO SINKHOLES (GPM)

LOCATION	PIUTE	CENTRAL	TOTAL
Area (Ac)	234	212	546
Rate (GPM/Ac)	1.2	1.2	1.2
Flow (GPM)	275	250	525

2.2.4.4 Discharge to Deep Rock System

As noted above, it appears that more water currently flows into the mine than flows out via the 700 Level Adit. This suggests that water is being lost to the deep groundwater system using the mine as a conduit.

This process is possible under the following scenario. The area around the mine has high topographic relief. The current water level in the mine is Elev. 6,200 ft. The level of Grizzly Creek (about 2½ miles to the southwest) is around Elev. 5,000-5,500 ft, some 700-1,200 ft lower. The level of Indian Creek, some five miles to the northwest, is about Elev. 3,000 ft, some 2,400 ft lower. The hydraulic gradient to these two possible regional groundwater receptors is about 0.1. Based on the evaluations of Toth et al (1963), it has become clear that deep groundwater circulation patterns differ from shallow patterns, because heads at depth are less dramatically influenced by topography. This effect is illustrated below by a figure from Freeze and Cherry.



GROUNDWATER FLOW NET IN A TWO-DIMENSIONAL VERTICAL SECTION THROUGH A HOMOGENIOUS, ISOTROPIC SYSTEM BOUNDED ON THE BOTTOM BY AN IMPERMEABLE BOUNDARY (after HUBBERT, 1940)

Accordingly, it is possible to have head conditions in the Walker Mine area which cause groundwater inflow to the mine near the surface, and flow out of the lower portions of the mine to the deep groundwater system.

It is possible to obtain an appreciation of the possible flow ranges which might occur by back-analyzing flow from the mine using some assumptions:

1. The head at an elevation of 4,000 ft (3,000 ft below surface at the mine) is 5,000 ft elevation (about half way between the mine water head and that at Indian Creek.
2. Flow is down the orebody fault zone only.
3. The fault zone in which flow occurs is 40-ft wide and 6,000-ft long.
4. Flow is downward.

Using these assumptions, the flows which result out of the mine are:

Hydraulic Conductivity (cm/s)	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}
Flow (gpm)	0.2	2	20	200	2000

A typical hydraulic conductivity for fractured rock is in the range of 10^{-4} cm/sec to 10^{-5} cm/sec. This suggests a reasonable flow estimate for present discharge from the mine to deep groundwater is about 20-200 gpm, which is in the same order as groundwater inflow to the mine.

2.2.5 Summary of Present Mine Flow System

A summary of the estimated mine inflow and outflow system is as follows:

Component	Winter (min)	Spring (max)
Surface Water	0	3000
Groundwater	50-200	50-200
Total Input	50-200	3050-3200
Deep Flow	20-200	20-200
Portal Flow	0-50	3000
Total Output	20-250	3020-3200

As can be seen, this is roughly in balance.

2.2.6 Evaluation of Remedial Actions

2.2.6.1 Do Nothing Alternative

In this alternative, the mine is allowed to flush of its own accord. Based upon continuing leaching of broken ore left in stopes and mineralized wall rocks fractured by mining, as little as 100,000 tons would continue to produce acidic, copper-bearing water at a concentration of 3 mg/l (Figure 6) for over a century. It appears clear that acid drainage can be expected to continue for a long time if unabated.

2.2.6.2 Effects of Installing a Seal in the 700 Level Access Adit

The proposed action is to install a seal in the main access adit which will cause the water level to build up in the mine. The mine water buildup will continue until inflow is equal to outflow in the mine system. The most probable effect of the water level rise in the mine will be to reduce groundwater inflow and increase the deep groundwater outflow. It is expected that the equilibrium water level will be considerably below the Piute Shaft outlet so no direct egress of the mine water to the surface is expected. The level to which the water will rise is a very strong function of the success of diverting surface water away from the Piute and Central Orebody sinkholes; therefore, it is difficult to estimate the final level. In addition, this level will fluctuate in the mine on a seasonal basis.

It is possible, but extremely unlikely, that there is no significant deep groundwater discharge from the mine. If this extreme condition were to occur, the water level would probably rise to the next exit from the mine (apparently the Piute Shaft at elevation 6,600 feet), or until the inflow is equalled by the outflow from the mine into the containing host rock.

The minimum time that it would take for the water level to rise up to the level of the Piute Shaft Landing Adit can be estimated by assuming no flow from the mine into the rock, and this calculation is presented below:

Volume to be filled = 297,000,000 gal (Table 1)
Time at 420 gpm = 1.3 years
Time at 50 gpm = 11.3 years

It would appear that refill to the level of the Piute Shaft collar could take between 5 and 10 years, given reasonable success diverting flows around the sinkholes, and given the extreme assumption of no groundwater outflow within the mine workings.

Flow could possibly occur from the Piute Shaft area under this scenario. This flow is expected to be no higher than 10 gpm because the head driving the inflow of groundwater would reduce as the water level rose in the mine workings, provided the diversion of the South Fork of Ward Creek around the Central Section sinkhole area was adequately maintained.

This flow would probably be of a similar quality to the water currently discharging from the main adit, as acid generation will continue in the un-submerged parts of the North, Central and 712 Orebodies, and it is mainly this water which would pass down through the 700 Level haulage connection and flow out of the Piute Shaft.

2.2.6.3 Additional Plugging to Isolate Piute Section

An alternate remedial strategy to avoid flow from the Piute Shaft after sealing the main portal is to isolate the Piute Section. This could be achieved by plugging the only connecting drift between the Piute and

712 Sections on the 700 Level at Elev. 6,200 ft. This could be done in two ways:

1. Before sealing the main adit, using conventional methods. This would require rehabilitating the 700 Level haulage to the plug location and installing the plug. It would provide a positive seal in this location.

2. After sealing the main adit, using a seal implaced via boreholes. This would be done from surface, and might be less effective than the conventional seal due to extreme difficulty of hitting the small target drift and ensuring an effectively watertight seal.

If a plug were successfully emplaced in this location, and if inflows were not balanced by net flows recharging the groundwater systems, the entire mine would likely refill with water, thus eliminating further acid generation through exclusion of oxygen.

2.2.7 Conclusions

The conclusions of this hydrologic evaluation are:

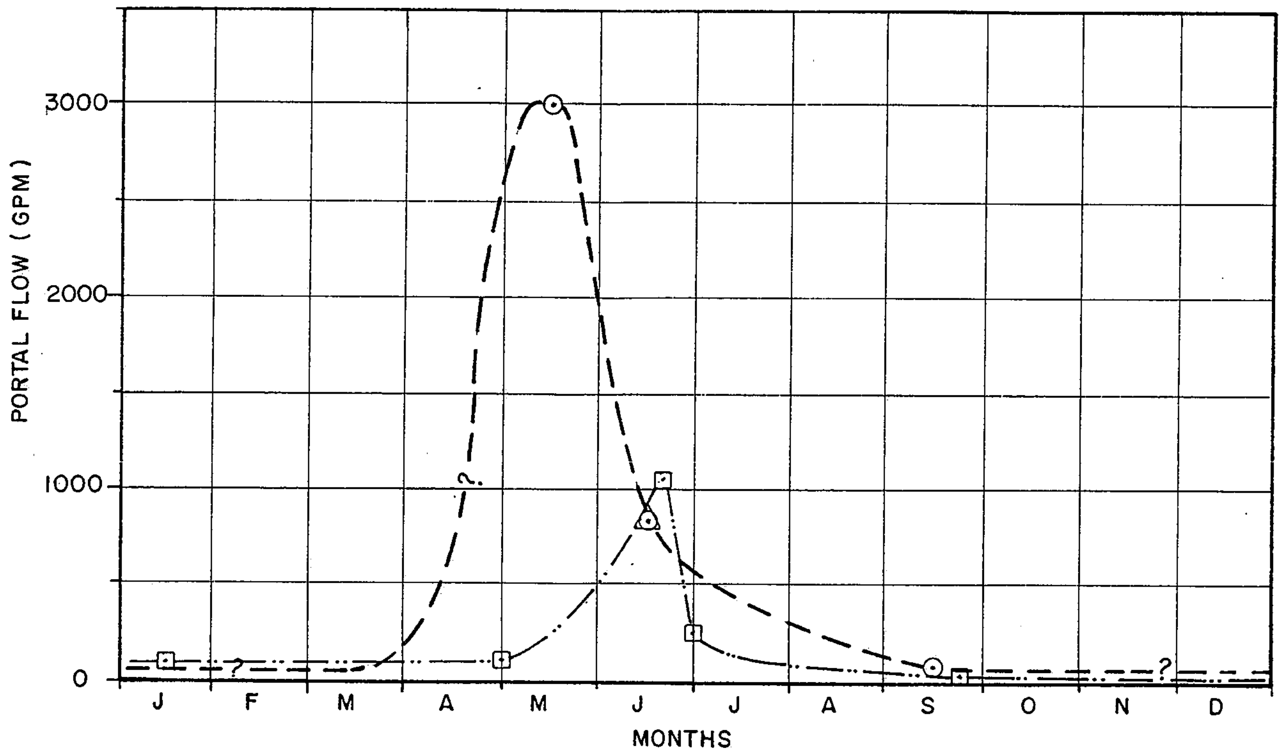
1. Sealing the main 700 Level Adit of Walker Mine will effectively remove the main source of copper contamination from Little Grizzly Creek, assuming there are no other, as yet unidentified outlets. The possibility of seepage of acid mine water from the flooded workings to surface in the catchment of Dolly Creek is considered to be extremely remote.

2. There is only a remote chance that a small flow of acidic water containing dissolved copper could ultimately occur from the Piute Shaft area, as a result of the single-plug strategy.

3. The remote chance of possible flow from the Piute Shaft could be minimized, and probably eliminated, by emplacement of another seal to separate the main mine from the Piute Section in addition to diverting surface water from the mine. This precaution would be extremely expensive, and is considered to be unjustified in view of alternative precautions and the low risk of flow.

4. Observations indicating a significant recharge of the groundwater system through outflow from the mine workings add substantially to confidence that equilibrium will be reached before the level of water in the mine workings rises to the level of the Piute Shaft Landing Tunnel (6,585 ft elevation).

5. The magnitude of the outflow inferred from the lower workings suggests a deep groundwater flow path from the mine. The orientation of regional faults (which appear from underground observation to be aquacludes) runs perpendicular to the direct path from the workings to the valley of the Little Grizzly Creek, and would tend to inhibit flow in this direction. Visual observation revealed no seepage into the valleys of the Dolly or Little Grizzly Creeks which could be identified as groundwater recharged from the Walker Mine workings.

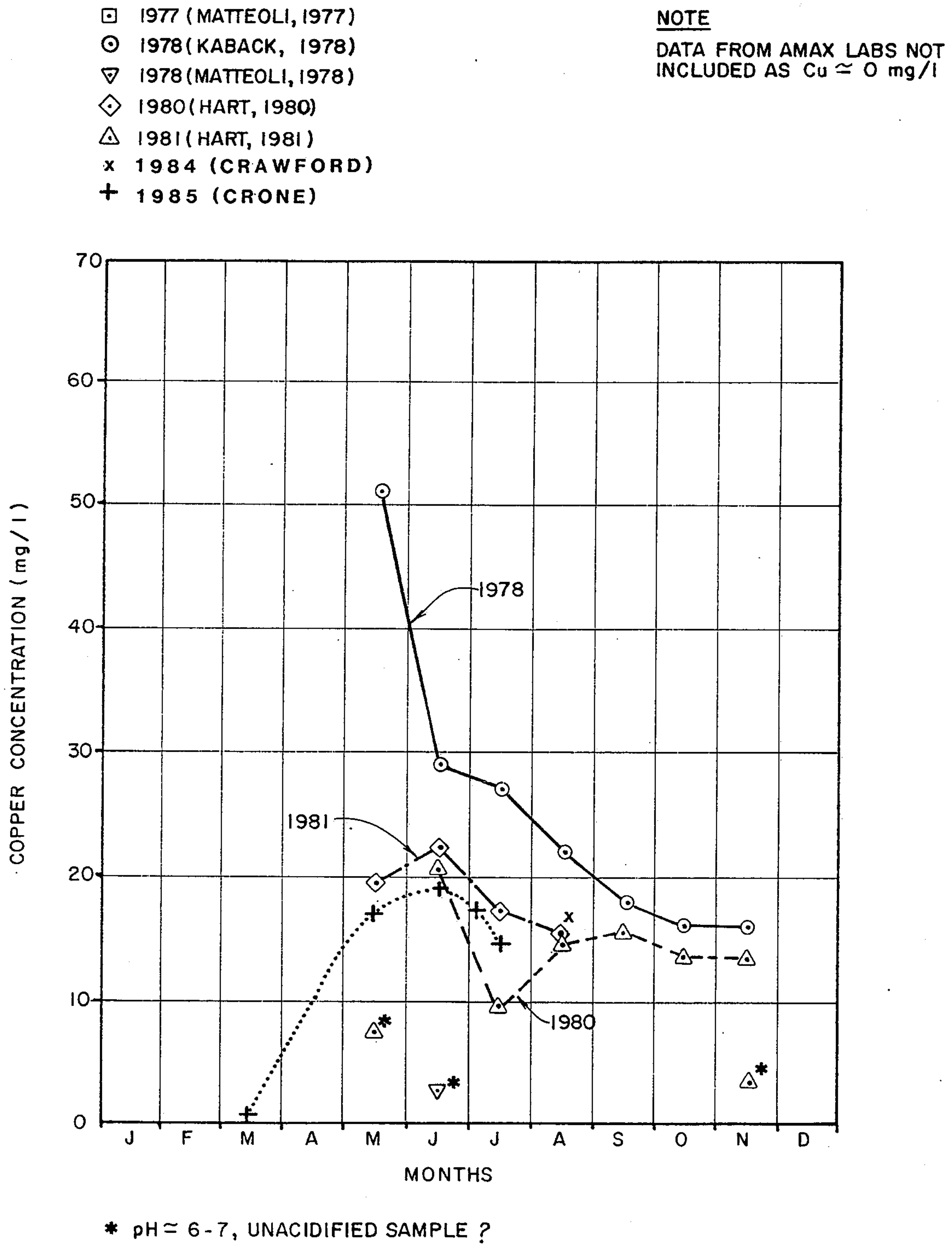


⊙ 1978 (KABACK, 1978)

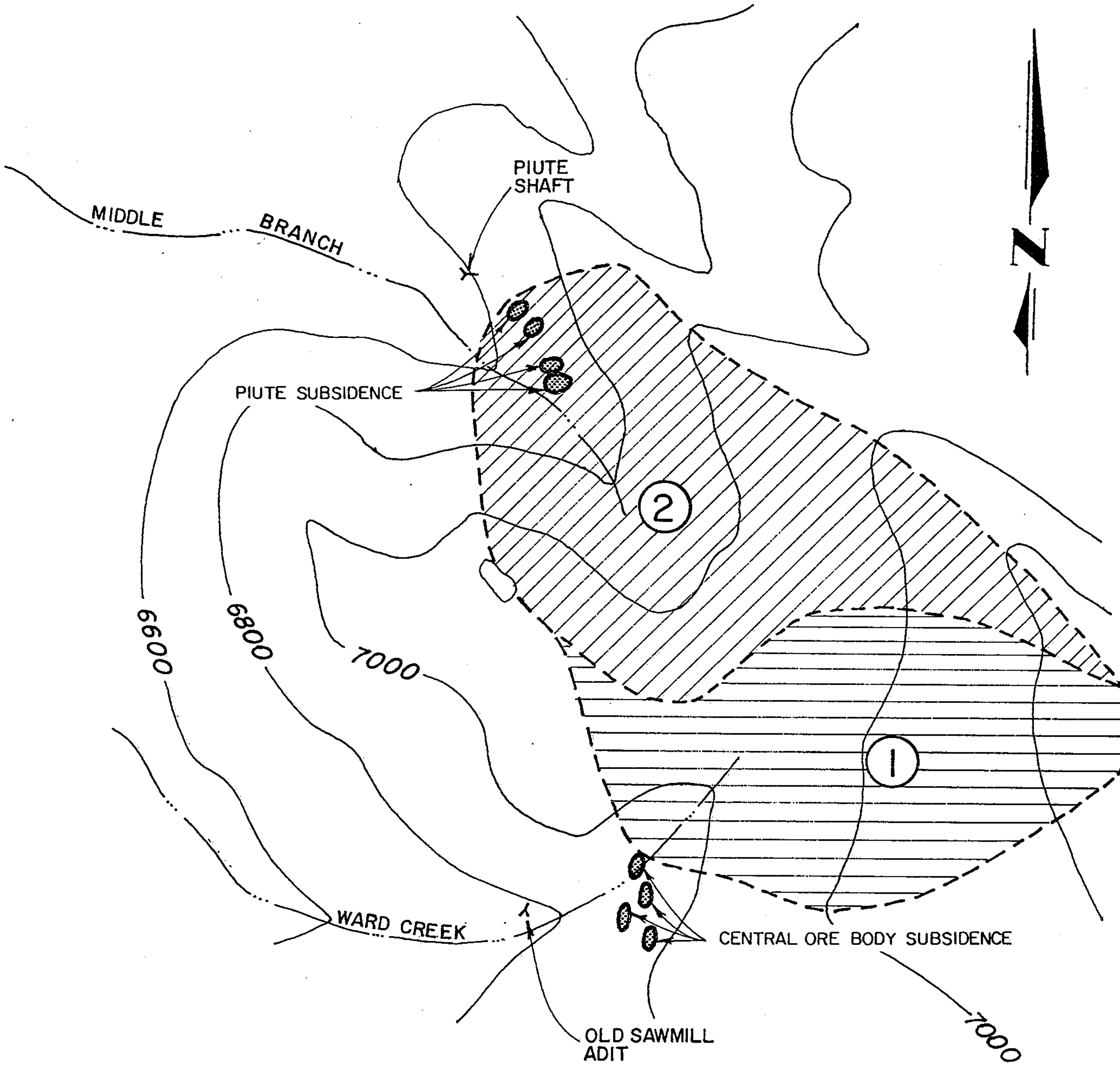
△ 1978 (MATTEOLI, 1978)

⊡ 1985 (CROYLE, 1985)

PROJECT NO. 6901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 5
DATE 3/85		MINE OUTFLOWS
REVISION NO. 0		



PROJECT NO. 6901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 6
DATE 3 / 85		COPPER CONCENTRATION FROM PORTAL
REVISION NO. 0		



AREA (1) = 212 ACRES

AREA (2) = 234 ACRES

PROJECT NO. 6901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 7
DATE 3/85		CATCHMENT AREAS
REVISION NO. 0		

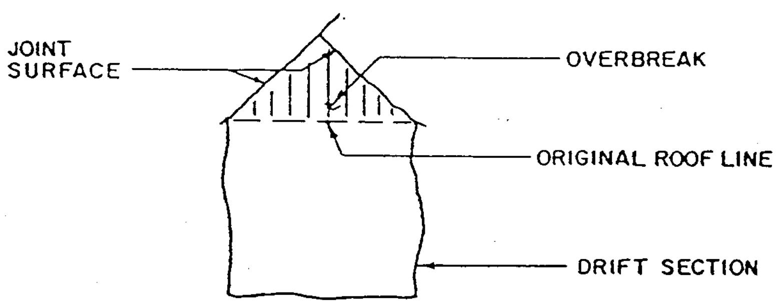
2.3 Geology and Geotechnical Considerations

2.3.1 Condition of Main Access

The main access drive was examined in order to determine its condition and its suitability as a site at which to install a bulkhead. Figure 8 shows schematically the main drive.

The first 1,300 ft of the drive from the mine portal is heavily supported. Timber square sets on approximately 3 ft centers are used, together with timber lagging. The surrounding ground is highly weathered granodiorite which has, in places, a soil-like consistency.

Beyond 1,300 ft from the portal, ground conditions are excellent. There is no installed support, little indication of blast damage, and no indication of any stress-induced failure. Due to the blocky nature of the ground, overbreak had been experienced during the original driving. The overbreak was generally in the roof as shown below:



The overbreak was a result of falls of ground along intersecting joint planes. The nature of the overbreak indicates a general lack of confinement on the rock mass which, in turn, implies that a high in situ stress field does not exist.

A number of faults and shear zones were observed. These zones generally transect the drift at approximately right angles. The zones consisted of a composite of sheared and altered granodiorite and clay gouge. Due to the presence of the clay gouge, it is considered that such zones will act as regional groundwater barriers.

With the exception of the poor ground adjacent to the mine portal, the main access drift was essentially dry.

2.3.2 Rock Mass Classification

2.3.2.1 General

In order to summarize key geological and geotechnical data and to provide a tool for decision making during design, a system of rock mass classification and rating has been used. This type of classification makes use of measurable parameters in an attempt to minimize judgemental bias. This gives an effective quantitative method of rock mass description. The suggested method of rock mass description developed by the International Society for Rock Mechanics (1977), lists the following parameters:

- Number of joint sets;
- Orientation;
- Spacing (block size);
- Condition of joint walls;
- Joint roughness;
- Joint persistance;
- Joint opening; and
- Water seepage.

All of these parameters can either be directly measured or scaled against carefully calibrated descriptive scales.

To summarize these parameters into a single value, a rock mass classification system is used. The system considered appropriate to the bulkhead design at the Walker Mine was developed by Barton et al. (1974) and subsequently modified by Kirsten (1983). Rock mass quality (Q) is related to the parameters described above by the following expression:

$$Q = \frac{RQD}{Jn} \cdot \frac{Jr}{Ja} \cdot \frac{Jw}{SRF}$$

where RQD is the Rock Quality Designation, a measure of joint spacing, Jn the number of joint sets present, Jr the joint roughness, Ja joint alteration, Jw a measure of water pressure, and SRF a measure of the in situ stress condition.

2.3.2.2 Rock Mass Rating

Two important parameters relating to bulkhead design are rock mass strength, which in part will control the position and length of the bulkhead, and rock mass permeability, which will control the risk of leakage past the bulkhead. These parameters are both functions of rock mass quality.

An initial rock mass quality rating has been estimated from a number of observations and measurements carried out in the main access drive. Figure 9 shows the results of the observations made in granodiorite (the dominant rock type) while Figure 10 shows the results obtained in the hornfels schists that occur adjacent to the orebody. The figures give the ratings obtained using the Q-system proposed by Barton et al (1974). For corroboration purposes, the CSIR system developed by Bieniawski (1973) was also undertaken.

The ratings from both systems indicated that the rock mass in the main access drive (granodiorite) can be regarded as good quality (Q-system) or very good quality (CSIR-system). The hornfels schists adjacent to the orebody are of slightly lesser quality, being rated as fair quality (Q-system) and good quality (CSIR-system).

The ratings estimated are in agreement with the observed conditions of the main access drive and the footwall drives visited which have stood unsupported for periods in excess of 40 years without deterioration.

2.3.3 Site Characterization

2.3.3.1 Geology

The Walker Mine is situated in a series of metasediments that have been metamorphosed by the intrusion of the Sierra Nevada Batholith. At the southern end of the mine, the hornfels and intruding diorite are unconformably overlain by flat-lying volcanic and clastic rocks.

The ore deposits consist of a series of vein-like pods with mineralization occurring in or adjacent to granitoid veins in hornfels and diorite. Major ore minerals include chalcopyrite, pyrrhotite, pyrite, cubanite, magnetite and sphalerite.

Structures in the mine area include cleavage, joints, and faults. The D'Appolonia report (1979) states that the orientation of cleavage in the hornfels above the mine is northwest-trending and dips 53^{o} to the southwest (approximately the same strike as the orebody). Jointing was observed in the main access drive and generally two sets, in addition to the cleavage, are present. Faulting is also evident in the main access drive and, according to the D'Appolonia report (1979), has been mapped on surface. The dominant fault set trends north to northwest and dips 50^{o} to 80^{o} east to northeast. A subordinate and apparently conjugate set trends northeast to east and dips 50^{o} to 80^{o} southeast to south. A more complete description of regional and local geology is given by D'Appolonia (1979).

2.3.3.2 Material Properties - Strength

The bulkhead and the surrounding rock can be regarded as a discontinuum consisting of a series of blocks of intact rock and concrete, separated by various planes of weakness. The behavior of this system will be controlled by both the strength and deformation moduli of the intact material and the strength and stiffness along the planes of weakness.

Values for these various components of strength have been evaluated from a number of simple field observations and measurements and from published data.

Intact Rock Strength

Intact rock strength was estimated from a series of simple field measurements. These indicated that the uniaxial compressive strength of the granodiorites is in the range of 22,000 to 29,000 psi. The hornfels schist is weaker with an estimated uniaxial compressive strength in the range of 12,000 to 17,000 psi.

A cross-check on these estimated strengths was carried out with the aid of the relationship between uniaxial compressive strength, vertical stress and tunnel condition given by Hoek and Brown (1980). The relationship is shown in Figure 11. The access tunnel and the footwall drifts were found to be in a stable condition (i.e. p_2/σ_c = 0.1 in Figure 11). It has been assumed that the vertical stress is equivalent to the overburden load of approximately 1,450 psi. Entering this value on Figure 11 and projecting up to the p_2/σ_c = 0.1 line, the minimum uniaxial compressive strength can be read off. This value is 16,000 psi and compares well with estimates done from field measurement.

Rock Mass Strength

Hoek (1983) has developed a failure criterion that can be used to predict rock mass strength. A series of approximate equations were derived that allow Mohr's strength envelopes to be constructed for different rock types and quality.

The rock mass classification outlined in the previous section was used to determine the appropriate strength equations as shown in Figure 12. From these equations, failure envelopes were constructed and are shown in Figure 12 for both the granodiorite and hornfels schist.

Strength at Rock-Bulkhead Interface

The strength along the rock/bulkhead contact is dependent upon the following parameters:

- Rock/concrete frictional and adhesion properties;

- The roughness and size of asperities along the rock surface;
- The condition of the rock; and
- The stress acting across the contact.

Strength estimates have, therefore, been based upon a series of field observations and tests, and published data.

The roughness and size of asperities found along a potential shear surface have a major influence on the shear strength of that surface. Patton (1966) has demonstrated that the roughness angle (i) can be combined with the base friction angle ($Ø_b$) of the surface to obtain an estimate of the peak frictional strength available along the surface.

Observations in the main access drift indicate that at least two orders of asperities exist. These are illustrated in Figure 14. The first order asperities reflect the roughness along individual joint planes and have been termed the roughness factor. The second order of asperities are at a greater scale and arise due to the intersection of joints with different orientations. This has been called the step factor.

For failure to occur along the rock/bulkhead interface, the following sequence of events must take place:

- The base frictional properties between the concrete and the rock must be exceeded;

- Shear through or dilation over the first order asperities (roughness factor); and

- Shear through or dilation over the second order asperities (step factor).

The peak strength of the contact (τ_p) is, therefore, a function of

$$\tau_p = f\ (\tau_b, \tau_r, \tau_s)$$

where τ_b is the strength component attributable to the base frictional properties, τ_r the strength component attributable to the roughness factor and τ_s the strength component attributable to the step factor.

An estimate of base frictional strength of the two principal rock types can be made from published data. Figure 15 shows a composite of results obtained by Einstein et al, 1979. The granodiorite rocks fall within the Group IV rock (Figure 15) while the hornfels schist falls within the Group III rock (Figure 15).

From Figure 15, it is estimated that the base frictional strength of the granodiorite is 30^o and that of the hornfels schist 25^o.

A number of observations were made underground on joint roughness. These observations indicate that some 2^o can be added to the base frictional strength to account for surface roughness.

As can be seen from Figure 14, the walls of the access drive comprise a series of large rock steps. The average relief change over one of these steps is approximately 8 inches. Any shear surface along a bulkhead/rock contact must either pass through the rock mass or dilate over the step. To account for this effect, the peak frictional strength can be increased. Based upon results given by Robertson (1971), it is considered that 15^{o} can be added to the base friction angle to account for the stepped rock surface.

Based upon the above discussion, the peak frictional strength available along the rock/bulkhead is estimated to be:

$$\tau_p = \tau_n \tan (30^{o} + 2^{o} + 15^{o}),$$

where τ_n is the normal stress acting across the contact.

2.3.4 Bulkhead Design

2.3.4.1 Location

Two bulkhead positions have been considered. The first is in the main access drive and is intended to block the main discharge point of mine water. However, this will in turn cause the mine water to backup within the old workings until it might eventually issue out of the Piute Shaft. In order to minimize the consequences of this, a second bulkhead could be located between the 712 Orebody and the Piute Orebody. As indicated in Section 2.2.7.3, the installation of an internal plug is not recommended. Consideration of its technical feasibility and the cost of its construction is necessary for an effective evaluation of its merits on a cost/benefit basis.

The approximate locations of the two bulkheads is shown in Figures 3 and 4. The main bulkhead is positioned approximately 2,700 ft from the mine portal. Figure 16 shows the profile of the roof, floor and walls. The position was specifically chosen for its geometry; the narrowing of the drive at that point will greatly enhance the stability of the bulkhead.

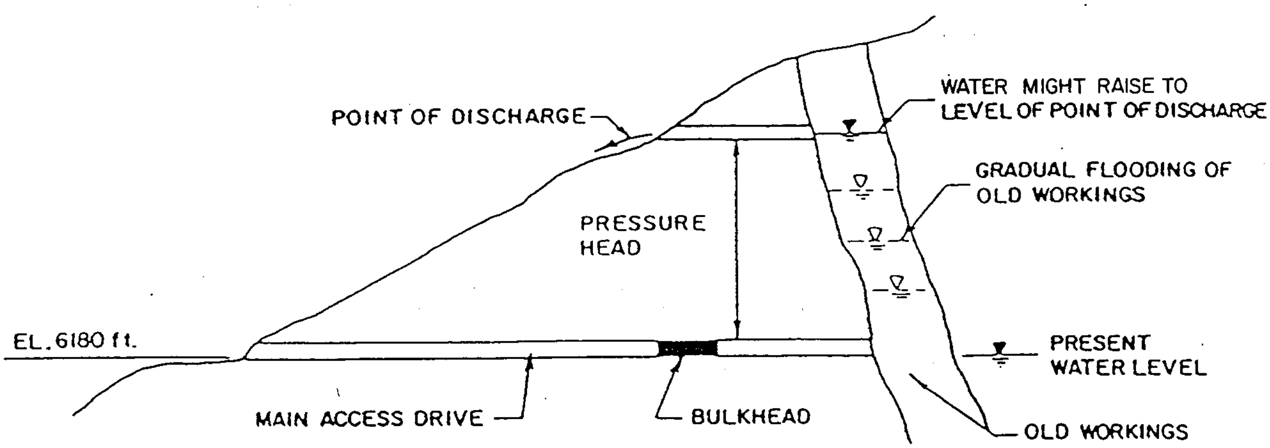
2.3.4.2 Design

The stability of a bulkhead will depend upon several factors. These include:

- The water pressure applied to the bulkhead;
- The strength of the bulkhead;
- The strength of the surrounding rock; and
- The strength along the bulkhead/rock interface.

Pressure on Bulkhead

The water pressure on a bulkhead is dependent on the head of water maintained behind it. As the flow of water is stopped by the bulkhead, the water will gradually back up through the mine until equilibrium is reached or a higher exit point is encountered. The difference in elevation between the higher exit point and the bulkhead elevation represents the pressure head the bulkhead has to resist. This is shown on the following drawing.



Two bulkhead locations have been studied, namely the main bulkhead and the Piute bulkhead. Examination of old mine records and plans indicate that with only the main bulkhead in place, the next point of egress for mine water will be the Piute Shaft. The difference in elevation between the Piute Shaft Landing Tunnel and the main bulkhead is approximately 390 ft. However, with both the main and Piute bulkheads in place, the point of egress for water contained between the two bulkheads will be the Old Sawmill Adit where it exits from the caved area above the Central Orebody. The pressure head in this instance is 570 ft. It should be noted that the water contained beyond the Piute bulkhead could still exit from the Piute Shaft.

For design purposes, it has, therefore, been assumed that the higher head acts against both bulkheads. In addition, a factor of safety of 2.5 has been applied to this head giving a design pressure head of 1,400 ft.

Bulkhead Dimensions

The water retained behind a bulkhead exerts a load on the bulkhead. This load is transferred to the surrounding rock in the form of shear stresses. It has been assumed, for design purposes, that the stress distribution is uniform over the length of the bulkhead.

Based upon the above assumptions, the bulkheads can be dimensioned by using the following relationship (Garret and Pitt, 1961):

$$l = \frac{p \cdot a \cdot b}{2(a + b)\, f_s}$$

where:

p = pressure applied to the bulkhead

a = width of bulkhead

b = height of bulkhead

l = length of plug

f_s = safe average shear stress

The two bulkheads would be placed in approximately 12 ft x 12 ft drifts. By using the pressure head established in the previous section, the relationship can now be written as:

$$l = \frac{1400 \times (0.434)\ (12 \times 12)\ (12 \times 12)}{2\ (12 + 12)\ (12)\ fs}$$

$$= \frac{21874}{f_s} \text{ units in } \frac{\text{lb/in}}{\text{lb/in}^2}$$

F_s, the safe average shear stress can be estimated from Section 2.3.3.2, Material Properties. In this section, it was shown that, due to the roughness and stepped nature of the tunnel walls, any shearing along the bulkhead/tunnel interface will result in either dilation over the surface or shear through the rock mass.

The shear strength of the rock mass can be estimated from the curves shown in Figure 13. For design purposes, it has been assumed that there is little or no normal load acting across the bulkhead/rock interface. The design shear stress used is, therefore, the intercept on the shear stress axis. By using the value at $\sigma_n = 0$ (i.e. assuming no normal load across the interface; a conservative assumption), the estimated length of the bulkheads is:

granodiorite = 10 ft

hornfels schist = 14 ft

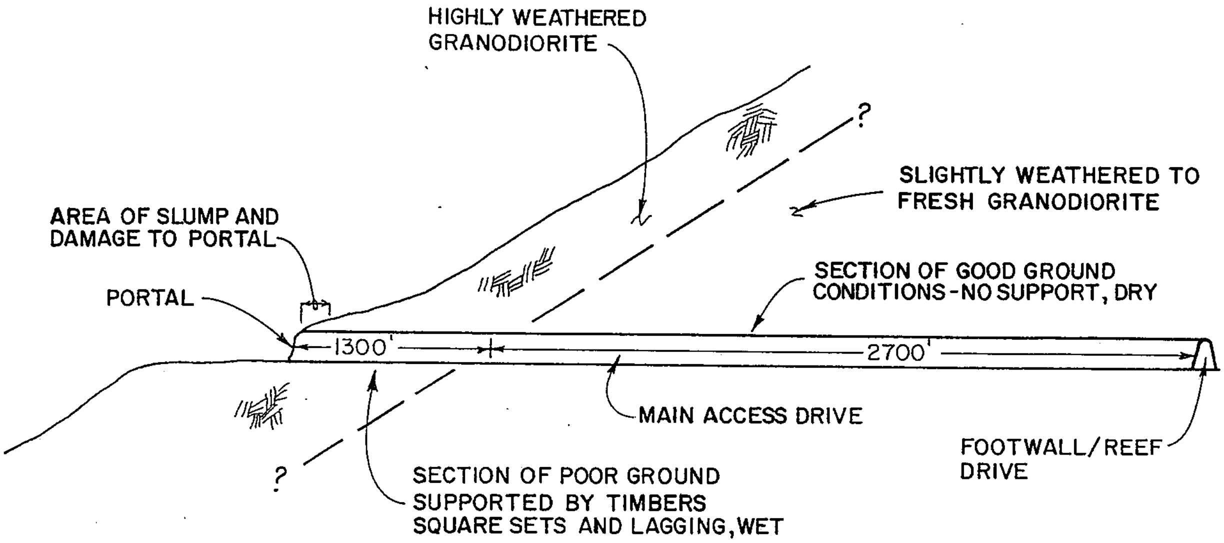
If dilation occurs, shearing has to occur within the plug. Therefore, a similar exercise was carried out by using an appropriate f_s value for concrete. The strength of concrete was taken as 2000 psi at 28 days. Some 10 ft of bulkhead length was found to be sufficient to preclude shear failure through the concrete. Therefore, to ensure the stability of the bulkhead, minimum bulkhead lengths of 10 ft in fresh granodiorite rocks and 14 ft in hornfels schists are required.

Practical experience gained in high pressure bulkheads used in South African gold mines has indicated that it is generally more difficult to stop leakage around a bulkhead than to make it strong enough to resist thrust. Recommendations put forward by Cummins and Given (1973) indicate that the pressure gradients along the plug should be moderate and experience has proven that gradients of up to 40 psi per ft are effective (though in a number of cases, gradients of up to 400 psi per ft have been achieved). By using the design pressure head of 1,400 ft (608 psi), the bulkhead length necessary to obtain the required pressure gradient is 15 ft. This value is in excess of the length necessary for bulkhead stability. It is, therefore, recommended that both the main bulkhead and the Piute bulkhead be 15-ft long.

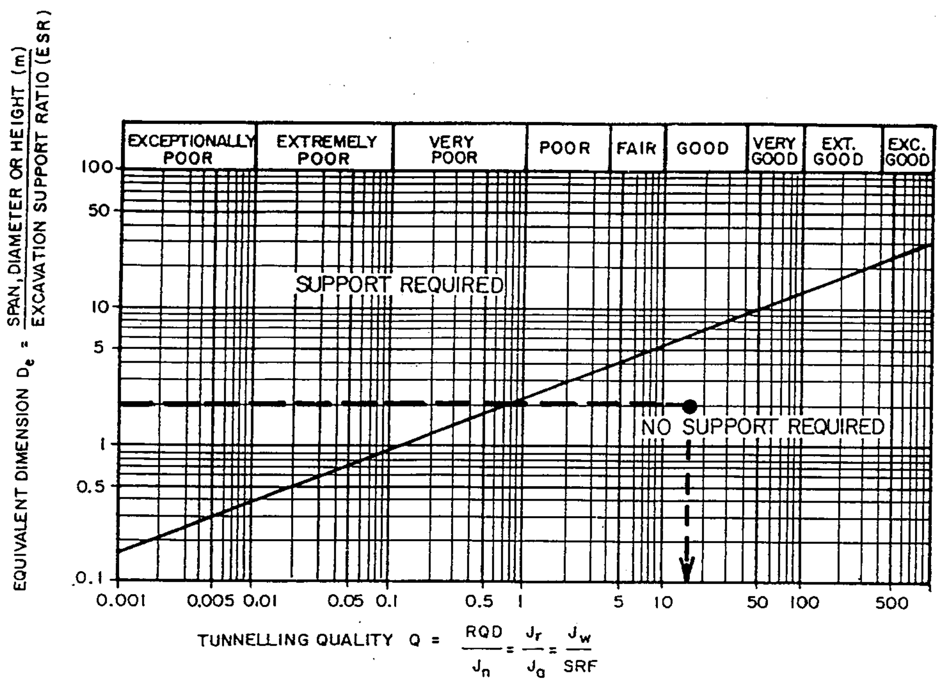
2.4 Results

Observations on surface and underground at the Walker Mine provided substantial confirmation of hydrological and geotechnical data derived from previous reports, relevant literature and the SRK team's past experience. Confidence in the available and derived data was sufficient to permit design and specification of the concrete bulkheads considered as seals in the 700 Level tunnel between the Piute and 712 Sections, and in the Access Adit close to its intersection of the South Orebody.

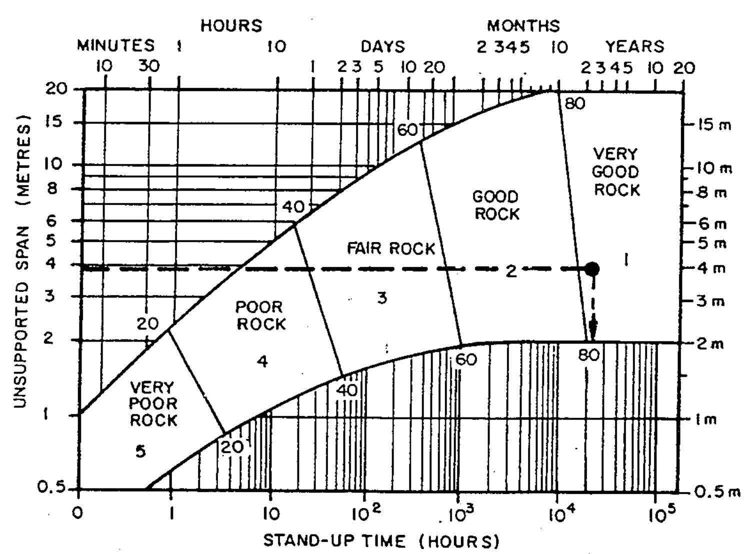
Observation of the condition and dimensions of the 700 Level Adit provided sufficient information to permit fairly accurate (-10% to +25%) estimates of construction costs for the proposed main (Adit) bulkhead seal. The 700 level Haulage had not been cleaned beyond the South Orebody at the time of the site visits, but the work required to clear it sufficiently to permit access for construction of an internal plug between the 712 and Piute Sections was estimated on the basis of visual inspection on June 19, 1985.



PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 8
DATE 3/85		MAIN PORTAL SECTION
REVISION NO. 0		



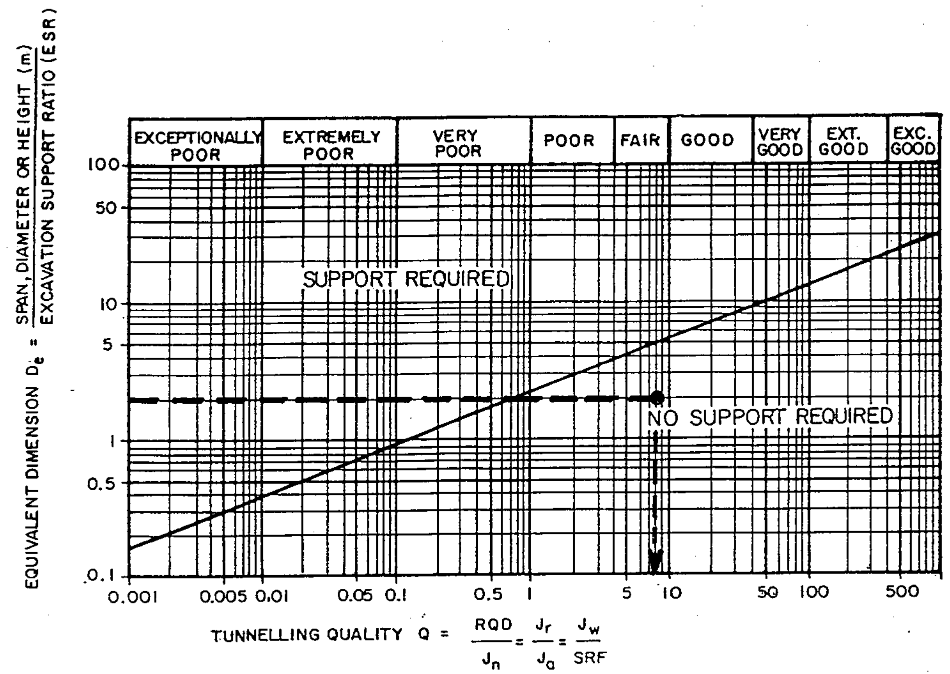
Q =17



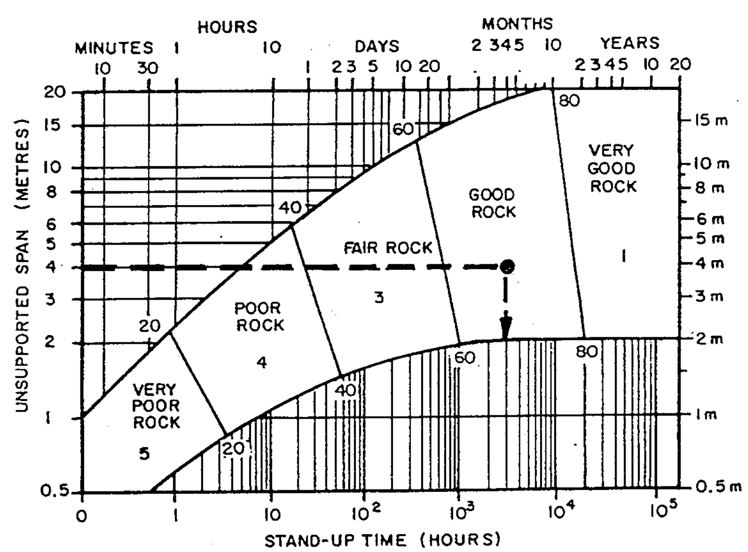
RMR = 81

CSIR Classification System		NGI Classification System	
Parameter	Rating	Parameter	Rating
Strength	12	RQD	100
RQD	20	Joint Set No.	6
Spacing	20	Joint Roughness No.	1.0
Condition	20	Joint Alteration No.	1.0
Groundwater	7	Joint Water Reduction	1.0
Orientation	—	Stress Reduction	1.0
Rock Mass Rating (RMR)	81	Tunneling Quality (Q)	17
Comments			

PROJECT NO. 06901	PREPARED BY STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 9
DATE 3/85		TYPICAL ROCK MASS CLASSIFICATION RATING FOR GRANODIORITE
REVISION NO. 0		



Q = 8



RMR = 64

CSIR Classification System		NGI Classification System	
Parameter	Rating	Parameter	Rating
Strength	7	RQD	70
RQD	15	Joint Set No.	9
Spacing	20	Joint Roughness No.	1.0
Condition	15	Joint Alteration No.	1.0
Groundwater	7	Joint Water Reduction	1.0
Orientation	—	Stress Reduction	1.0
Rock Mass Rating (RMR)	64	Tunneling Quality (Q)	8
Comments			

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DATE 3/85
REVISION NO. 0

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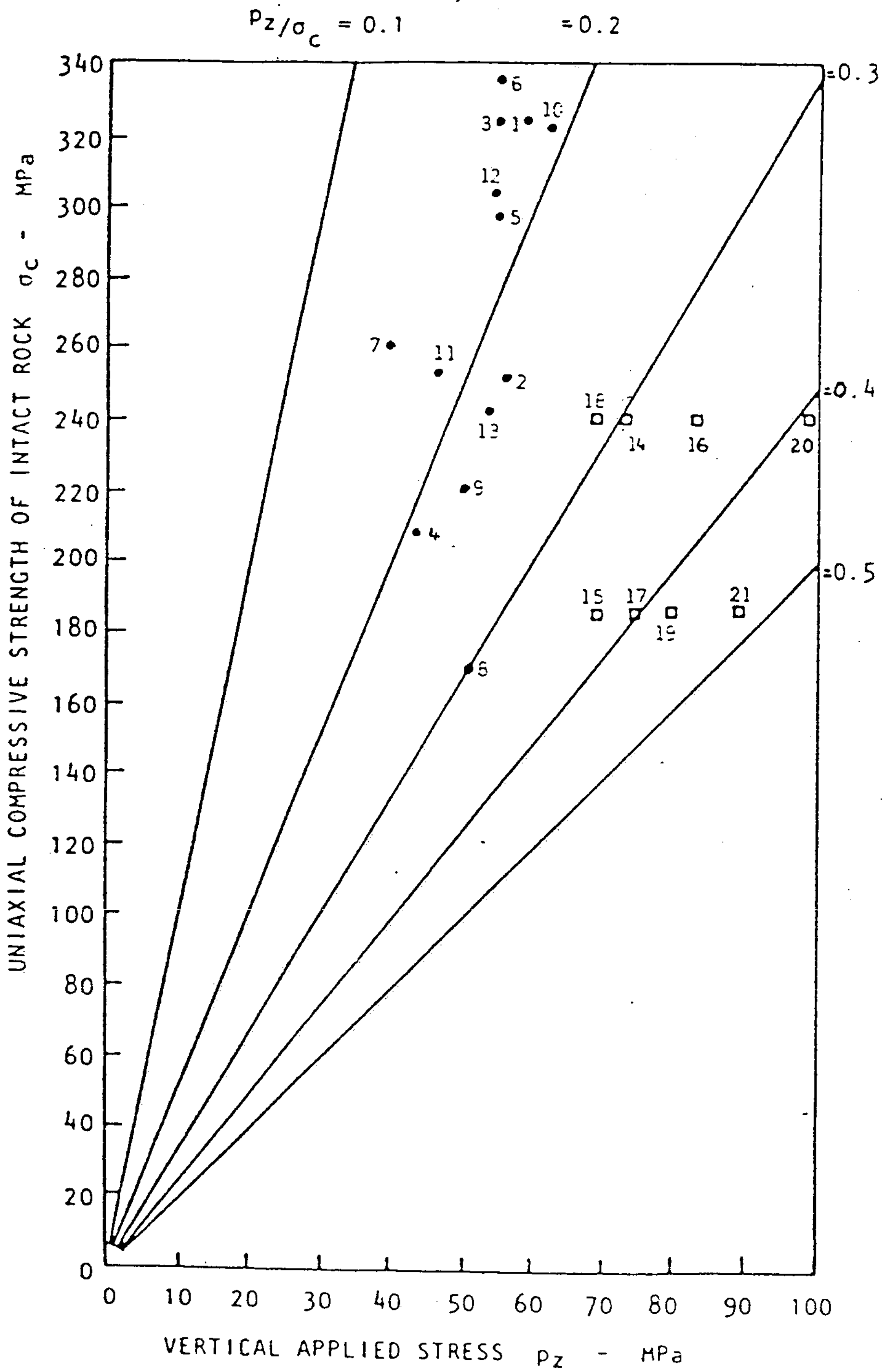
Consulting Engineers

FIGURE 10

TYPICAL ROCK MASS CLASSIFICATION RATING FOR HORNFELS SCHIST



p_z/σ_c = 0.1 - stable unsupported tunnel.

p_z/σ_c = 0.2 - minor side-wall spalling.

p_z/σ_c = 0.3 - severe sidewall spalling.

p_z/σ_c = 0.4 - heavy support required.

p_z/σ_c > 0.5 - possible rockburst conditions.

NOTE: 1 MPa = 145 PSI

PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 11
DATE 3/85		COMPRESSIVE STRENGTH vs. APPLIED STRESS FOR SQUARE TUNNELS
REVISION NO. 0		

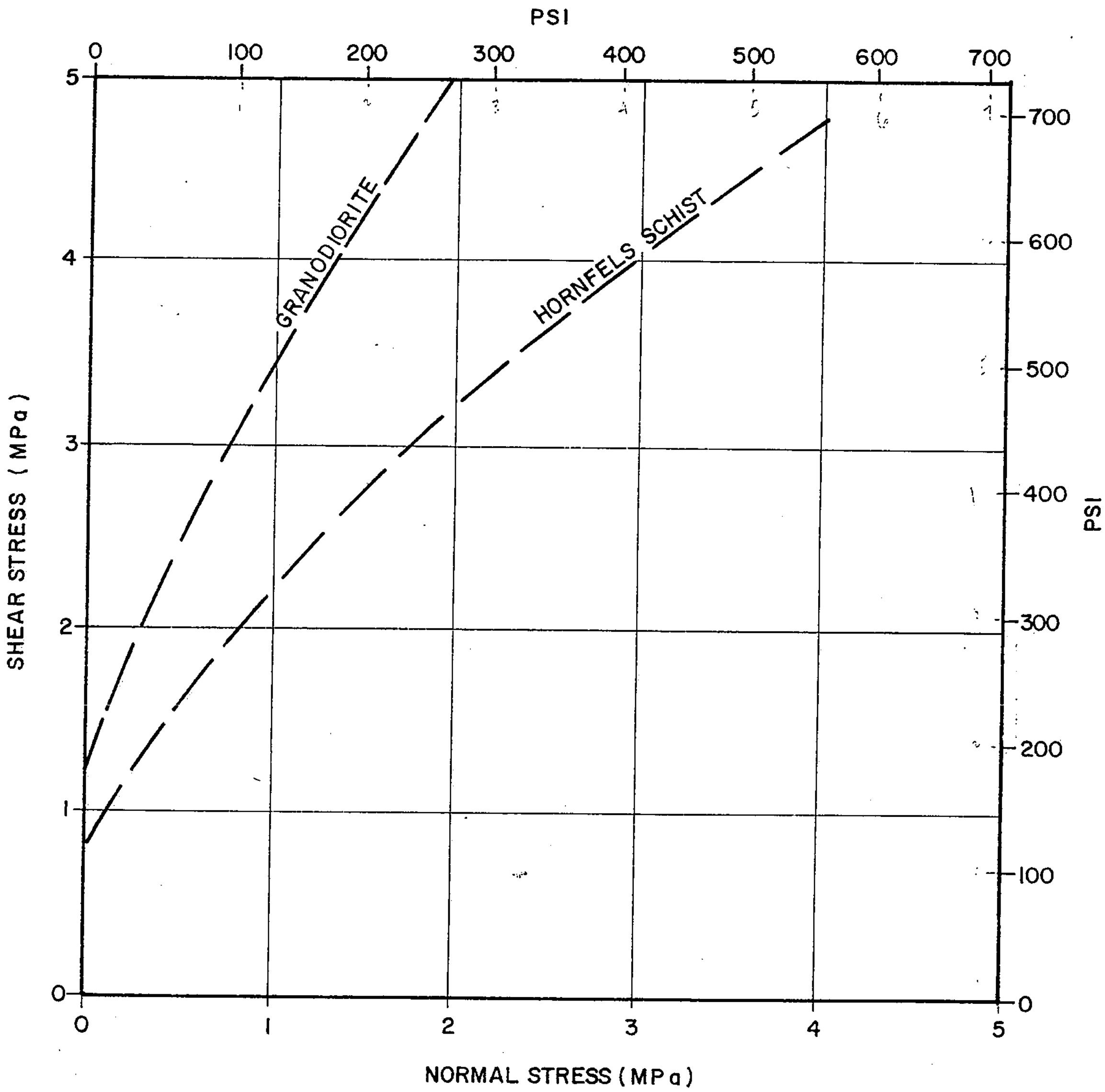
APPROXIMATE EQUATIONS FOR PRINCIPAL STRESS RELATIONSHIPS AND MOHR ENVELOPES FOR INTACT ROCK AND JOINTED ROCK MASSES

	CARBONATE ROCKS WITH WELL DEVELOPED CRYSTAL CLEAVAGE *dolomite, limestone and marble*	LITHIFIED ARGILLACEOUS ROCKS *mudstone, siltstone, shale and slate (normal to cleavage)*	ARENACEOUS ROCKS WITH STRONG CRYSTALS AND POORLY DEVELOPED CRYSTAL CLEAVAGE *sandstone and quartzite*	FINE GRAINED POLYMINERALLIC IGNEOUS CRYSTALLINE ROCKS *andesite, dolerite, diabase and rhyolite*	COARSE GRAINED POLYMINERALLIC IGNEOUS AND METAMORPHIC CRYSTALLINE ROCKS *amphibolite, gabbro, gneiss, granite, norite and quartz-diorite*
INTACT ROCK SAMPLES *Laboratory size rock specimens free from structural defects* *CSIR rating 100+, NGI rating 500*	$\sigma_{1n} = \sigma_{3n} + \sqrt{7\sigma_{3n} + 1.0}$ $\tau_n = 0.816(\sigma_n + 0.140)^{0.658}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{10\sigma_{3n} + 1.0}$ $\tau_n = 0.918(\sigma_n + 0.099)^{0.677}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{15\sigma_{3n} + 1.0}$ $\tau_n = 1.044(\sigma_n + 0.067)^{0.692}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{17\sigma_{3n} + 1.0}$ $\tau_n = 1.086(\sigma_n + 0.059)^{0.696}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{25\sigma_{3n} + 1.0}$ $\tau_n = 1.220(\sigma_n + 0.040)^{0.705}$
VERY GOOD QUALITY ROCK MASS *Tightly interlocking undisturbed rock with unweathered joints spaced at ±3 metres* *CSIR rating 85, NGI rating 100*	$\sigma_{1n} = \sigma_{3n} + \sqrt{3.5\sigma_{3n} + 0.1}$ $\tau_n = 0.651(\sigma_n + 0.028)^{0.679}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{5\sigma_{3n} + 0.1}$ $\tau_n = 0.739(\sigma_n + 0.020)^{0.692}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{7.5\sigma_{3n} + 0.1}$ $\tau_n = 0.848(\sigma_n + 0.013)^{0.702}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{8.5\sigma_{3n} + 0.1}$ $\tau_n = 0.883(\sigma_n + 0.012)^{0.705}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{12.5\sigma_{3n} + 0.1}$ $\tau_n = 0.998(\sigma_n + 0.008)^{0.712}$
GOOD QUALITY ROCK MASS *Fresh to slightly weathered rock, slightly disturbed with joints spaced at 1 to 3 metres.* *CSIR rating 65, NGI rating 10*	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.7\sigma_{3n} + 0.004}$ $\tau_n = 0.369(\sigma_n + 0.006)^{0.669}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{1.0\sigma_{3n} + 0.004}$ $\tau_n = 0.427(\sigma_n + 0.004)^{0.683}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{1.5\sigma_{3n} + 0.004}$ $\tau_n = 0.501(\sigma_n + 0.003)^{0.695}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{1.7\sigma_{3n} + 0.004}$ $\tau_n = 0.525(\sigma_n + 0.002)^{0.698}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{2.5\sigma_{3n} + 0.004}$ $\tau_n = 0.603(\sigma_n + 0.002)^{0.707}$
FAIR QUALITY ROCK MASS *Several sets of moderately weathered joints spaced at 0.3 to 1 metre.* *CSIR rating 44, NGI rating 1.0*	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.14\sigma_{3n} + 0.0001}$ $\tau_n = 0.198(\sigma_n + 0.0007)^{0.662}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.20\sigma_{3n} + 0.0001}$ $\tau_n = 0.234(\sigma_n + 0.0005)^{0.675}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.30\sigma_{3n} + 0.0001}$ $\tau_n = 0.280(\sigma_n + 0.0003)^{0.688}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.34\sigma_{3n} + 0.0001}$ $\tau_n = 0.295(\sigma_n + 0.0003)^{0.691}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.50\sigma_{3n} + 0.0001}$ $\tau_n = 0.346(\sigma_n + 0.0002)^{0.700}$
POOR QUALITY ROCK MASS *Numerous weathered joints spaced at 30 to 500mm with some gouge filling / clean waste rock* *CSIR rating 23, NGI rating 0.1*	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.04\sigma_{3n} + 0.00001}$ $\tau_n = 0.115(\sigma_n + 0.0002)^{0.646}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.05\sigma_{3n} + 0.00001}$ $\tau_n = 0.129(\sigma_n + 0.0002)^{0.655}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.08\sigma_{3n} + 0.00001}$ $\tau_n = 0.162(\sigma_n + 0.0001)^{0.672}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.09\sigma_{3n} + 0.00001}$ $\tau_n = 0.172(\sigma_n + 0.0001)^{0.676}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.13\sigma_{3n} + 0.00001}$ $\tau_n = 0.203(\sigma_n + 0.0001)^{0.686}$
VERY POOR QUALITY ROCK MASS *Numerous heavily weathered joints spaced less than 50mm with gouge filling / waste rock with fines* *CSIR rating 3, NGI rating 0.01*	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.007\sigma_{3n} + 0}$ $\tau_n = 0.042(\sigma_n)^{0.534}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.010\sigma_{3n} + 0}$ $\tau_n = 0.050(\sigma_n)^{0.539}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.015\sigma_{3n} + 0}$ $\tau_n = 0.061(\sigma_n)^{0.546}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.017\sigma_{3n} + 0}$ $\tau_n = 0.065(\sigma_n)^{0.548}$	$\sigma_{1n} = \sigma_{3n} + \sqrt{0.025\sigma_{3n} + 0}$ $\tau_n = 0.078(\sigma_n)^{0.556}$

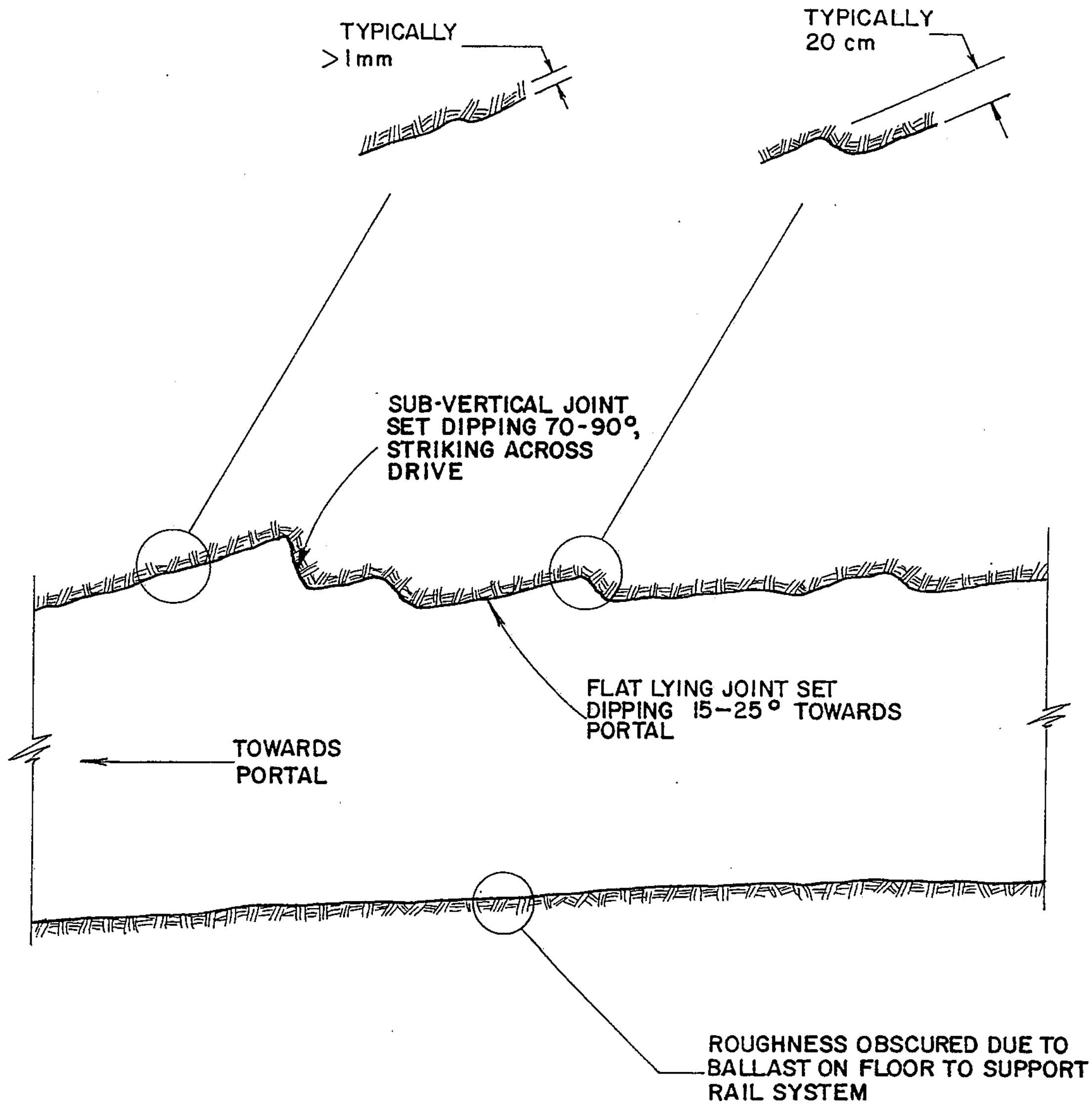
LEGEND

- HORNFELS SCHIST
- GRANODIORITE

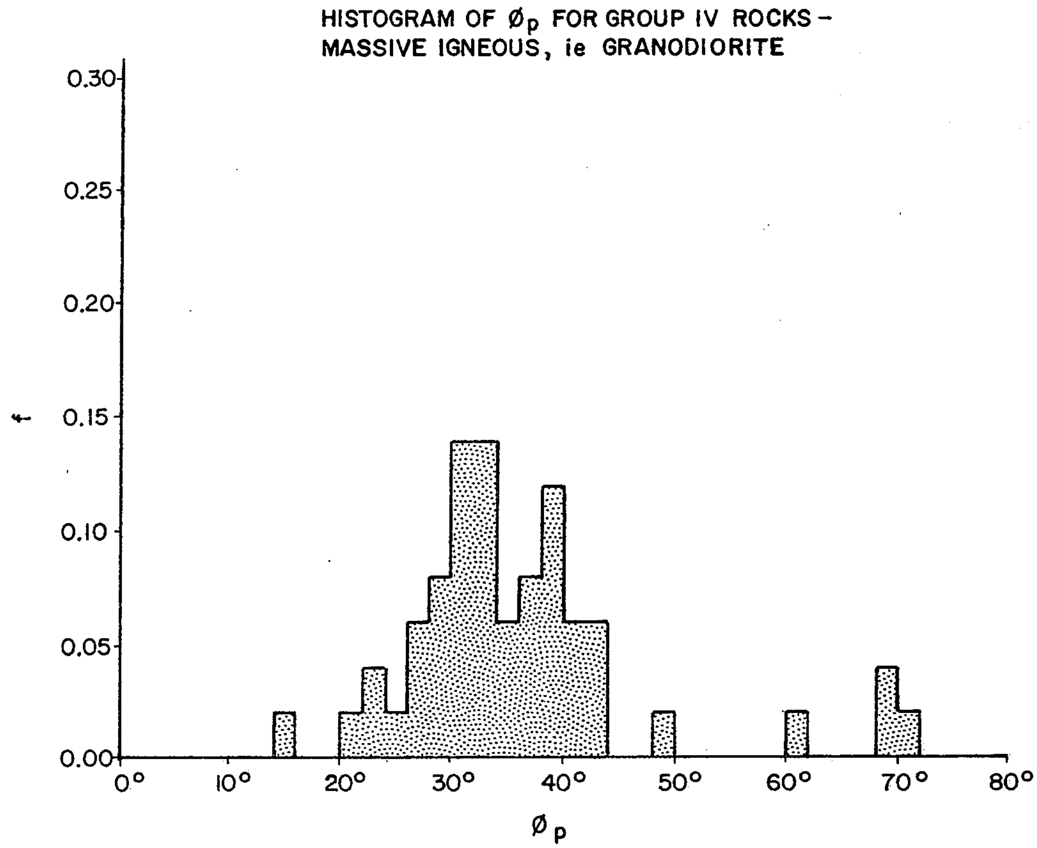
PROJECT NO. 06901	PREPARED BY	FIGURE 12
DATE 3 / 85	STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	PRINCIPAL STRESS RELATIONSHIPS
REVISION NO. 0		

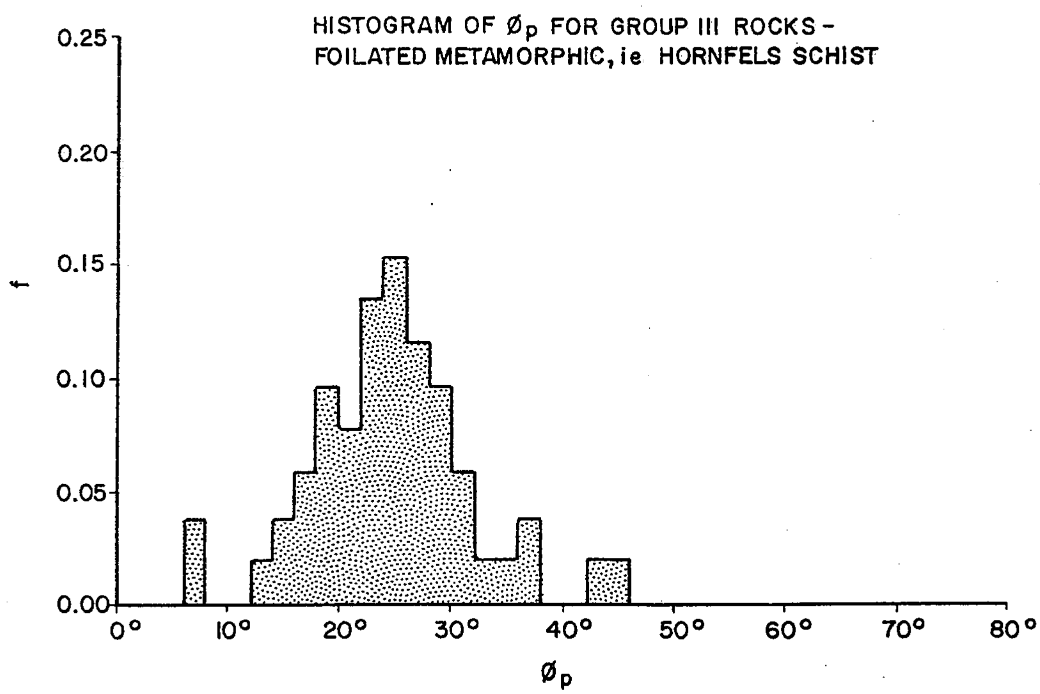


PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 13
DATE 3/85		ESTIMATED SHEAR STRENGTH OF ROCK MASS
REVISION NO. 0		

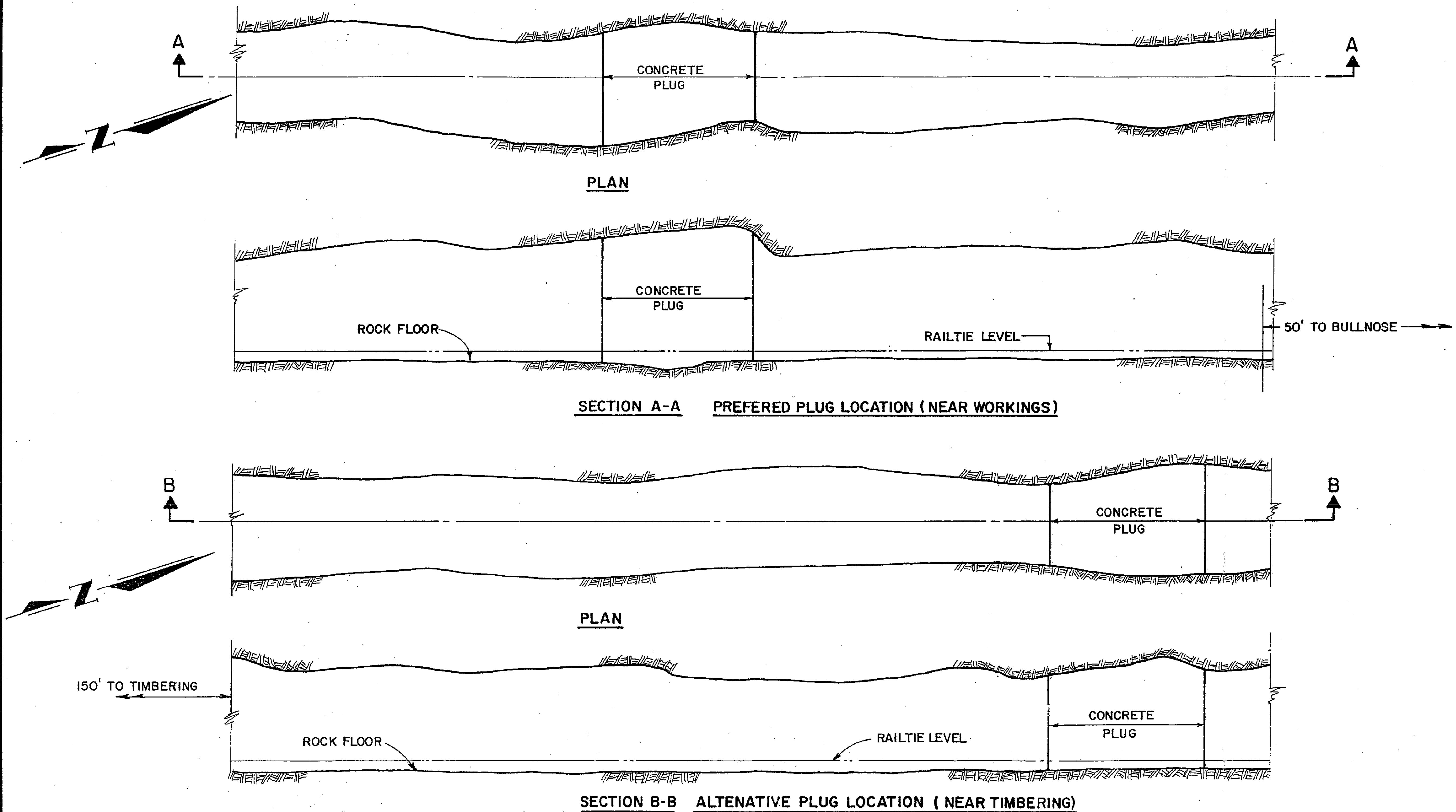


PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 14
DATE 3/85		VERTICAL SECTION THROUGH MAIN ACCESS DRIFT SHOWING ASPERITIES
REVISION NO. 0		



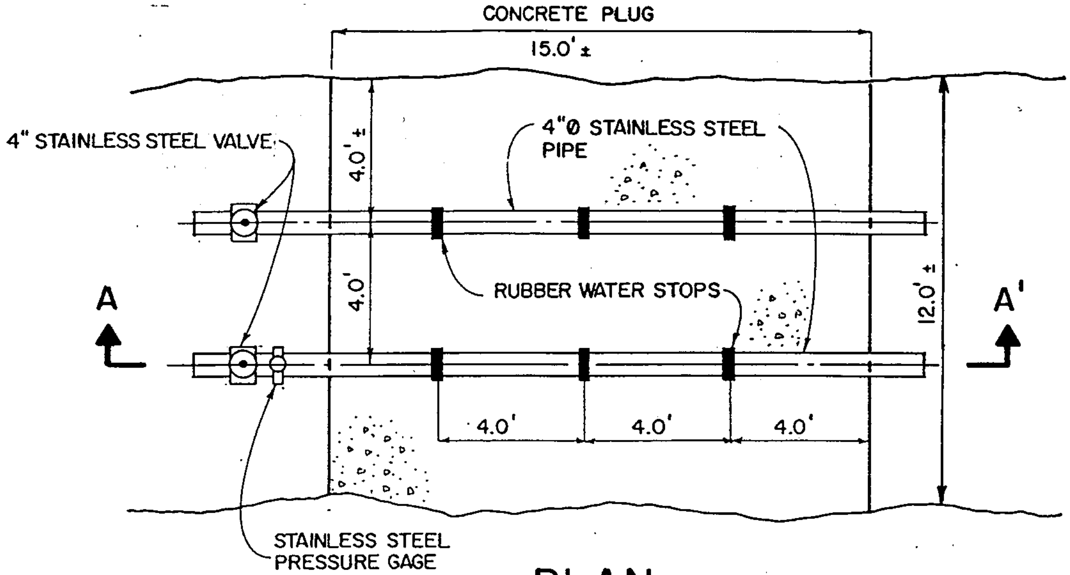


PROJECT NO. 06901	PREPARED BY: STEFFEN ROBERTSON & KIRSTEN Consulting Engineers	FIGURE 15
DATE 3 / 85		DISTRIBUTION OF PEAK FRICTIONAL STRENGTH
REVISION NO. 0		

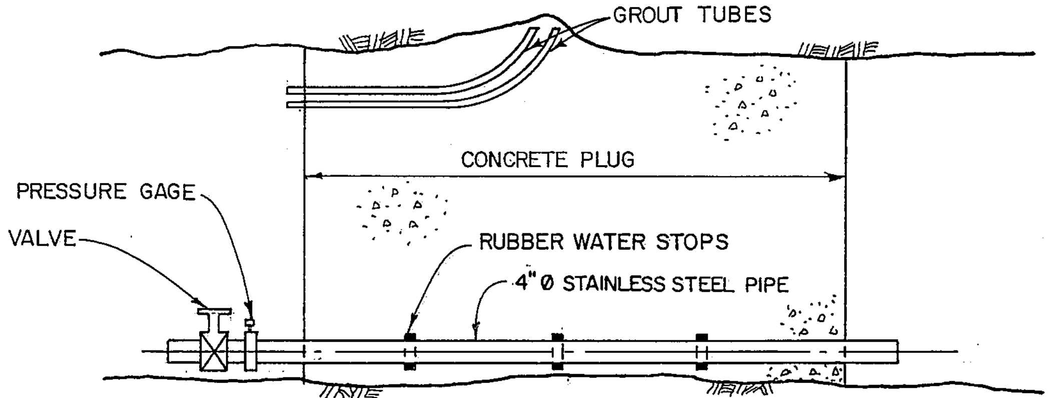


ROCK FLOOR CONFIGURATION ESTIMATED

PROJECT NO. 06901	PREPARED BY	FIGURE 16
DATE 3/85	STEFFEN ROBERTSON & KIRSTEN	MAIN ADIT PLUG LOCATIONS
REVISION NO. 0	Consulting Engineers	PLAN AND SECTIONS



PLAN



SECTION A-A'

PROJECT NO.	PREPARED BY:	FIGURE 17
06901	STEFFEN ROBERTSON & KIRSTEN	TYPICAL DRAIN PIPE DETAILS
DATE 3/85	Consulting Engineers	
REVISION NO. 0		

3.0 PLUG SPECIFICATION AND CONSTRUCTION CONSIDERATIONS

3.1 Plug Specifications

The sections below summarize materials to be used in the construction of the plug. Discussions on the proposed mix design are presented in Appendix I. Technical specifications for bid purposes are presented in the attached addendum to this report.

3.1.1 Location and Dimensions

Main Adit Plug at approximately 12,950 N, 11,420 E
Plug Length = 15 ft
Piute Plug at approximately 18,600 N, 10,000 E
Plug Length = 15 ft

3.1.2 Site Preparation

The plug site shall be cleaned and prepared to ensure an adequate bond between the rock and concrete surfaces. Methods of site preparation shall be proposed by the contractor and approved by the engineer prior to construction. The cleaned and prepared surface shall be approved by the engineer prior to placement of concrete.

Access to the sites may require additional site preparations for transporting construction materials. This shall be done on an as-needed basis. Such site work need not be to the extent of maintaining permanent access, but shall be such that safe working conditions are established.

3.1.3 Formwork

The formwork for the bulkheads shall be constructed of good quality material and in such a manner as to provide a good seal for containment of the concrete and any grout that may be injected. The design of the formwork shall be sufficient to withstand the fluid pressure of the concrete and any increased pressures due to grouting or concrete placement. The formwork will be subject to the engineer's approval prior to placement of the concrete.

3.1.4 Concrete

The concrete used to form the plugs shall be a 3,000 psi, 28-day strength mix. The mix shall use fine aggregate of the gradation and durability as specified in ASTM C 33-82 and C 117-80. The cement shall be sulfate-resistant Portland cement. Slump shall be 4 to 7 inches (see Appendix 1). Water used in the mix shall be of good quality so as not to degrade the concrete. Mine and mine drainage waters are not acceptable for use in the concrete mix. The mix design and admixtures are presented in Section 4.4 of the Addendum.

Concrete delivery and placement shall be according to ASTM and ACI standards. Under no circumstances shall delivery scheduling or placement methods be such that a cold joint shall be formed in the plug. If necessary, curing retards may be included in the mix design.

3.1.5 Piping and Valves

Two drainage pipes through the main adit plug shall each be 4-inch diameter schedule 40 stainless steel pipe. The valve(s) shall be of a corrosion resistant metal as specified in Section 4.5 of the Addendum or equivalent. Placement of the pipe shall be of good standard practice. Minimum clearance around the pipe shall be 12 inches.

A stainless steel screen shall be placed around the upstream end of the pipes. The screen shall have 3/4-inch opening. Placement and anchoring shall be determined as part of construction.

Piping for grout tubes shall consist of flexible nylon, PVC, or HDPE tubing.

3.1.6 Grouting

Grouting shall be done in areas of overhangs or protrusions to provide a tight seal between the rock and concrete. Grout tubes shall be placed such that air entrapment does not occur in the voids. A return line shall be installed at each location to provide a means of determining total void filling with grout. Placement of the grout lines is subject to the approval of the engineer.

Grouting may not be done within the first seven days after concrete emplacement. Grout pressures shall not exceed 1,500 psi. The grout shall be a neat mix of sulfate-resistant Portland cement. Chemical grouts may be used upon approval by the engineer.

3.1.7 Monitoring

Monitoring pressure head behind the in place plug in the main adit shall be done by means of a direct-reading pressure gauge inserted in one of the drainage pipes. In the event that an internal plug is constructed, pressure head in the Piute Section will be measured by an open standpipe piezometer installed from the surface or by a piezometer or vibrating wire piezometer installed during construction. Provisions for installation shall be included at the time of construction.

3.1.8 Operation

The discharge valves shall be locked at all times, except during operation or testing by authorized personnel. Upon completion of operation or testing, the operator shall check to see that the valves are locked prior to leaving the site. Operation and testing shall be done only by authorized personnel of the California Regional Water Quality Control Board Central Valley Region.

Prior to opening a valve, all personnel and equipment shall be clear of the line of discharge. This a high pressure system and will discharge at a high velocity and pressure. The valves shall be opened and closed at a slow and constant rate.

A warning sign shall be posted at the valves listing the above procedures.

3.2 Discussion of Alternatives

Effective permanent abatement of the flow of AMD from the Walker Mine could require up to four stages of control measures, each stage increasing the degree of confidence in the effectiveness of the solutions to the problem. These stages and comments on the rationale behind their conception are:

1. Installation of a concrete bulkhead plug in the 700 Level Main Access Adit.

   This measure will effect an immediate halt to the contaminating emissions from the mine, but, in the absence of any additional precautions, the halt might be only temporary. If water in the workings was able and permitted to rise until it could overflow through the

Piute shaft, the problem might simply be transferred from Dolly Creek to the Middle Fork of Ward Creek after a hiatus of up to ten years. The means by which such a transfer can be avoided are detailed in Section 5.2.

The optimum site for this plug is in the Access Adit, as close to the mine workings as possible. This site is indicated in Figures 3 and 4, and detailed in Figure 16. An alternate, less favorable site has been identified closer to the portal, about 250 ft from the end of the timbered section of the adit. This site could be used to replace the original bulkhead should that ever become necessary.

2. Establishment of diversion ditches above subsidence slumps over the Central and Piute Orebodies.

Evidence derived from examination of seasonal flow records for the 700 Level Adit suggest that a large part of the outflow of AMD consists of surface runoff, principally spring snowmelt which enters the mine workings through subsidence slumps. Adequate control of this inflow, combined with stoppage of the outflow by means of a plug in the 700 Level Adit, could allow the inflow of groundwater to reach equilibrium at a level below the next point of egress above the 700 Level, i.e. the Piute Shaft Landing Tunnel.

Much of the excavation necessary to divert flows in the upper catchment of the South and Middle Forks of Ward Creek around subsidence slumps has been done. A conservative estimate of the cost of additional upgrading of the diversion system has been based on observations on site during June, 1985. Unlike the concrete bulkhead plug, the diversion ditch system will require periodic inspection and maintenance, which might be timed to coincide with availability of personnel and equipment near the site.

3. Isolation of the Piute Section of the mine workings.

Isolation could be achieved by construction of a concrete bulkhead plug in the 700 Level Haulage between the Piute and 712 Sections. The site of this plug is indicated in Figures 3 and 4. Its effect would be to compartmentalize the mine workings and permit groundwater to reach equilibrium at different levels in two separate sections of the mine workings, probably below the level at which water would overflow to surface from the flooded workings.

Construction of an internal (Piute) plug would be undertaken through the 700 Level Adit and Haulage. This would require rehabilitation of the haulage for a distance of about 6,000 feet to the extent that the rail track was clear and sound enough to permit passage of a locomotive and flat cars or concrete mixer cars for about 20 trips during plug construction. The alternative of gaining access to the internal plug site through the Piute Shaft has been rejected on the basis of evident unsafe conditions close to the collar, and Mr. Donato's reported observation of the severe deterioration and collapse of timbering in the shaft. Rehabilitation would be both slower and more expensive than cleaning out the 700 Level Haulage. Remote placement of a grouted plug through surface boreholes has been rejected because an effective seal could not be assured without thorough preparation of the rock surface at the plug site, and this would require almost as much rehabilitation work in the 700 Level Haulage as would be needed for conventional construction.

There is an indication on one sketch, prepared to indicate ventilation flows during an underground fire in the Walker Mine in 1940, that there might be a second drift on the 700 Level, parallel to the Main Haulage connecting the 712 and Piute Sections. Underground inspection does not support this possibility.

The very high cost of isolating the Piute Section is considered excessive in view of the low risk that it might be required, and the availability of other, lower-cost alternatives (see Section 2.2).

4. Construction of a seal in the Old Sawmill Adit.

This adit is the highest artificial outlet for water from the mine workings below the large openings provided by subsidence slumps over the Central Orebody. As such, it is the highest point at which a seal could be attempted in the event that groundwater did not reach equilibrium level at a lower elevation following isolation of the Piute Section. It is considered very unlikely that groundwater inflow could cause an overflow from the flooded mine workings through the slumps. Only under exceptional circumstances would heavy surface inflows raise the water level in the flooded workings to overflow level, and then only brief flows of minimally contaminated water could be expected to enter Ward Creek.

The Old Sawmill Adit Portal appears to have collapsed naturally and would probably permit passage of water overflowing from the mine workings. Insufficient information is available to design or estimate accurately the cost of a seal in this adit should it be needed some twenty years or so after construction of the 700 Level plugs.

3.3 Construction Consideration and Cost Estimate

3.3.1 Construction Considerations

It is generally more difficult to stop leakage past a bulkhead than it is to make the bulkhead strong enough to resist the total thrust due to hydrostatic pressure. Even if an impermeable plug or seal is effectively placed within the tunnel opening, the permeability of the contact between the plug material and the surrounding rock can be a weak link in the total performance of the plug. It has been noted in South Africa that leakage is likely along the floor and the roof, even at low pressure, where mud and air pockets commonly weaken the concrete-rock contact. This type of behavior has likewise been observed in tunnel plug construction at the Nevada Test Site. Construction practices have been developed to circumvent such undesirable behavior.

Several things can be done to reduce the likelihood of leakage along the plug perimeter. The first step in obtaining a good contact between the plug material and the surrounding rock is to have the rock thoroughly cleaned after final excavation and before placement of the plug material. This involves not only cleaning of the rock surface, but also spraying the rock surface with a concrete adhesive or a sodium silicate grout material and then spraying a fine-grained angular sand upon this adhesive material. It has been found that such a pre-treatment of the rock surface enhances and promotes the final bond between the concrete plug and the surrounding rock.

During actual placement of the concrete, bulkheads must be constructed at the two ends of the plug. These bulkheads must be strong enough to withstand the pressure of the fluid concrete. Provisions must be made prior to concrete placement to allow air escape at the upper portion of the zone to be filled with concrete. It has been found useful, when topping off the concrete plug, to drill two six-inch diameter holes from outside of the bulkhead to the uppermost point of the void to be filled with concrete. Small pipes are then grouted into these two holes. As a topoff mechanism, the uppermost portion of the concrete is grouted by injection of grout in one of the two topoff pipes until grout flows from the second topoff pipe. At this point, the ejection pipe is shut off with a valve, the pressure on the injection pipe is increased to some predetermined value and then it is shut off. It has been found in tunnel plug construction practice, that placement of concrete at a minimum slump of 7½ inches increases the workability and flow characteristics of the fluid concrete within the tunnel plug forms. Even so, additional provisions must be made to promote the complete flow of concrete against both the tunnel form and the rock surface, to eliminate the possibility of honeycombing and void development at the concrete-rock interface.

It has been found in both South Africa and Nevada Test Site practices that leakages around tunnel plugs can be sealed acceptably by at least one stage if not multiple stages of grouting. The critical points to grout are at the top of the structure where topoff procedures may possibly not have completely filled the void, and the lower portion of the structure where sediment may have been allowed to collect. In grouting these areas, grout holes approximately two feet apart and intersecting the rock-concrete interface are suggested. This pressure grouting has been accomplished at pressure levels of a few hundred psi in South Africa.

It is extremely important that horizontal cold joints in the concrete plug be avoided by all means. Such cold joints can be crucial to the permeability of the concrete plug, and can make the entire plug ineffective if permeability through the plug is allowed. It has also been suggested that standard commercial grade expansive agent additives be employed to promote expansion of the concrete during curing, and thus to help seal any voids that may have a tendency to develop. Placement of plugs up to 30 ft long at the Nevada Test Site has not experienced any problems in thermal cracking and associated crack permeability. It should be noted however, that in these plugs concrete is placed at temperatures no higher than 55^{o}F. This procedure ensures that all hydration takes place within the forms, and that excessive temperatures do not develop.

Due to the chemistry of the mine waters that the bulkheads are intended to confine, sulfate resistant cement should be used in construction. In addition, it is recommended that a 3000 psi, 28-day strength concrete be used.

3.3.2 Cost Estimates

The level of accuracy of cost estimates is approximately -20%, +32%.

A. MAIN ACCESS ADIT PLUG

Activity Description	Labor	Equipment	Materials	Sub-Contract	Total
1. Mobilization	3,900	1,800	-	6,200	11,900
2. Site Service	5,300	8,700	-	-	14,000
3. Site Preparation	14,400	6,600	-	-	21,000
4. Plug Construction	15,700	7,300	36,600	-	59,600
5. Demobilization	6,600	3,000	-	6,100	15,700
6. Diversion Works	-	-	7,500	5,400	12,900
7. Management/Q-C	14,300	-	-	-	14,300
TOTAL	60,200	27,400	44,100	17,700	149,400
Plus 10% Contingency					14,900
Estimated Construction Cost					$164,300

For budgeting purposes:

- Total Estimated Construction Cost = $165,000
- Duration of Construction Activities = 35 days or 6 weeks

Activities itemized in the Cost Estimate include:

1. Transport of personnel and equipment from source to site, and set up.
2. Installation or extension of compressed air and water lines, ventilation fan and ducting, and rail track on surface, as well as generator, compressor and pumps.
3. Construction of cofferdam and bypass pipe, lifting track at plug site, excavation of invert, and barring/hammering/washing entire plug site to sound, clean rock. Best quote for concrete batched at portal is $180.00 per cu yd for 100 cu yd required.
4. Construction of bulkhead formwork, installation of reinforcing, pipes, valves and instrumentation, and grouting.
5. Stripping pipelines (fan and ducting left in place) and removal of equipment and personnel.
6. Five days of dozer work with supporting hand labor, and approximately 300 cu yd riprap.
7. Site supervision, inspection and certification by professional engineers.

B. PRELIMINARY AND ONGOING COSTS

1. Water Balance Survey:

Engineering time	$ 4,300
Equipment and materials	1,000
Travel and subsistence	1,200
Total estimated cost	$ 6,500

2. Discharge Treatment Plant Specifications:

Engineering time	$ 6,500

3. Routine Maintenance:

Inspection and gauge reading	-	(Board staff)
Equipment	$ 2,000	
Labor	500	
Materials (riprap, etc)	1,000	
Total estimated cost	$ 3,500/year	

C. ADDITIONAL COST FOR INTERNAL/PIUTE PLUG

(Assumed constructed immediately prior to Main Adit Plug)

Rehabilitation at 700' Level Haulage	$130,000
Concrete at Portal	17,000
Plug construction	60,000
Contingency @10%	20,000
Total estimated cost	$227,000

D. COST OF PLUGS IN MINOR ADITS

(Assumed constructed immediately after the Main Adit Plug)

1. Piute Landing Tunnel Plug:

Site Access and Cleanup	$ 12,000*
Plug construction	11,000
Estimated cost of plug	$ 23,000

2. Old Sawmill Adit Plug:

Site Access and Cleanup	$ 9,000*
Plug Construction	11,000
Estimated cost of plug	$ 20,000

*Tentative estimates as portals are caved.

E. POSSIBLE FUTURE TREATMENT PLANT.
(Subject to B.2)

1. Construction of a facility for short-term treatment (estimate) $250,000

2. Operation of AMD treatment facility, allowing for materials and minimal supervisions $ 5,000/year

4.0 MONITORING

Three factors relating to the effectiveness of abatement procedures at the Walker Mine will have to be monitored:

- The water level in the flooded mine workings and, hence, the rate at which the workings fill up following installation of a seal;
- The development of surface springs or seepage indicating escape of mine waters; and
- Precipitation, in order to determine a relationship between rainfall, snowmelt, rate of filling of mine workings, and possible surface seepage.

4.1 Water Level in Mine Workings

Continuous pressure head readings will be taken at the main adit plug to monitor water level. This will be accomplished by the remote continuous recording station specified in Section 4.7 of Addendum 1 to this report. Data should be collected from the recording as near to quarterly as possible. As the adit will be a dead-end after installation of the plug, the remote reading and recording instruments will be set inside the portal immediately inside the steel door so observers will not need to enter the adit. The instrument station will be set sufficiently far back from the door to avoid adverse effect on the power supply due to low temperatures during the winter months.

4.2 Surface Springs and Seepage

During the construction period, a survey of seeps, springs, and drainage channels (wet or dry) will be made around the area of the mine. Following completion of the main plug, these areas should be inspected visually on a quarterly basis to see that no new seeps are developed as the mine fills. If additional seepage is noted at any time, water quality samples should be taken to assess the impact of the mine filling on that water source. In addition, quarterly observations of the mine adit to check leakage from around the plug should also be made.

4.3 Precipitation and Temperature

A rain gauge and temperature recorder should be installed between Middle and South Forks of Ward Creek. Data from these recorders should be collected during the scheduled site visits. This data would then be used to compare the mine filling with precipitation/snow to the extent to which mine filling can be related to direct infiltration. It can also be used to determine the effectiveness of the installed diversion system and whether or not modifications or remedial work are warranted.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Observations

5.1.1 Achievement of Primary Objective

The installation of a concrete bulkhead seal in the main 700 Level Access Adit to the Walker Mine at an elevation of approximately 6,200 ft is technically feasible, and would be effective in sealing off the main source of copper contamination to the Dolly and Little Grizzly Creeks, assuming there are no other hitherto unidentified outlets below the level of the Piute Shaft Landing Tunnel (approximately 6,585 ft elevation).

5.1.2 Potential Adverse Effects

Under present conditions of incomplete control of spring runoff entering subsidence sinkholes over the Central and Piute Orebody workings, there is a remote possibility that the back-up of water caused by a seal in the main Access Adit at the 700 Level could rise to the level of the Piute Shaft Landing Tunnel within 10 years. A reduced flow of AMD, of a quality similar to that presently flowing from the 700 Level Access Adit, would then discharge through the Piute Shaft into the Middle Fork of Ward Creek. It is very unlikely that the average volume discharged would be more than 10 gpm.

5.1.3 Mitigation of Adverse Effects

Rehabilitation and regular maintenance of a system of diversion ditches, designed to keep surface runoff in the catchments of the Middle and South Forks of Ward

Creek out of the subsidence slumps, and consequently out of the mine workings, would substantially increase the time it would take to flood the old workings up to the level at which discharge could occur. This remedial action could be expected also to reduce the probability of any flow out of the Piute Shaft to insignificant levels. See Section 5.2.(5) for further possible precautions.

5.1.4 Maximum Security Option

In addition to installation of a primary seal in the main 700 Level Access Adit and establishing effective diversion ditches around slumps, isolation of the Piute Section by installing a concrete bulkhead in the 700 Level haulage (the only connection between the Piute Section and the remainder of the mine to the south) could be expected to reduce the volume of any possible outflow of AMD through the Piute Shaft by about 90%.

The mine workings in the Piute Section would flood to the level of the natural water table. Only snowmelt or rain in the immediate catchment of the Piute subsidence slumps would enter the workings and, if the water table was close to overflow level, run out of the Piute Shaft Landing Tunnel at approximately 6,580 ft elevation. Minimal mixing with and contamination by the stagnant water in the flooded Piute workings would occur.

The South, Central, North and 712 sections of the mine would also flood to the level of the natural water table in each section. If this level should be above the Old Sawmill Adit (6,770 ft elevation at its intersection with the mine workings), it might be necessary to clean out this adit portal and install a bulkhead capable of withstanding the maximum head of 110 ft of water that would be developed if the workings were to fill with water to the level of the subsidence slumps above the Central Section workings. As in the case of the Piute Section described above, only local snowmelt or rain runoff could be expected to enter the upper part of the workings and possibly overflow, without significant contamination by the stagnant water in the mine workings.

The time required for flooding in the mine workings to reach equilibrium in this worst-case scenario is estimated to be in excess of 15 to 20 years after two bulkhead seals had been installed.

5.1.5 Critical Appraisal of Maximum Security Option

Rehabilitation of the 700 Level haulage to gain access to the site of a possible internal plug would be more expensive and time-consuming than expected prior to visual inspection. Costs have been estimated on the basis of sluicing sludge with a jet of water pumped from flooded lower workings. Suspended solids would settle in the large sump of the Central and South Orebody workings below the 700 Level. Any residual turbidity emerging from the adit would be settled in the existing ponds below the portal.

Items leading to higher costs included:

a) Sludge cover on the floor of the haulage, which was generally deeper than expected, up to 18 inches in places.

b) The collapse of timber stope draw point chutes which has caused significant blockages with 30 to 50 tons of rock and timber lying in the haulage at four points, which would require tedious hand labor for clearing.

c) Deterioration of timber sets, which has exposed potentially dangerous bad ground at two locations and would require re-timbering to permit safe passage of personnel and equipment.

d) Clearing of timber and other materials buried in the sludge, which would require considerable manual labor.

e) Track in sections of the haulage that pass over shafts or rock-passes, which is supported on timber that might not now support the weight of a locomotive and concrete cars without reinforcement.

f) Rails that showed signs of corrosion and were absent over several hundred feet through the Central Section.

g) 5 x 10 ton Bilby-type mine cars parked in the haulage in the North Orebody Section, which would have to be removed. The condition of their wheel bearings could not be determined.

h) Collapse of the northern-most stope drawpoint chute in the 712 Orebody Section (Chute No. 208), which has almost blocked the haulage with 150 to 200 tons of broken rock and timber. Stulls and platforms loaded with broken rock could be seen in the open stope above the drawpoint, making conditions hazardous for removal of the blockage.

i) It was possible to crawl over the blockage at drawpoint No. 208 and continue northward on the 700 Level haulage. Up to 3'-6" of a thick, opaque, azure blue colloidal suspension was backed up behind the blockage. The volume held back was estimated at 90,000 to 100,000 gallons.

The investigating team did not proceed more than 300 ft beyond the No. 208 drawpoint, but selected and measured tunnel dimensions at a suitable site for a plug about 150-ft north of No. 208 drawpoint. The time required for taking measurements, the 39^{0} F "water", and the need to return to the portal within the predicted 5½ to 6 hours precluded further progress into the Piute Section.

Accurate measurement of water flow in the 700 Level haulage was not possible. A portable direct-reading flowmeter was used to determine flow velocity at points where the cross-sectional area of the channel could be estimated reasonably. From these measurements it was inferred that, of about 560 gpm flowing into the workings above the 700 Level, less than 300 gpm were being discharged through the main 700 Level Adit. The balance is presumed to return as recharge to the groundwater system.

Observation of the rock mass quality between the 712 and Piute Orebodies and calculation of the permeability of the pillar between the stoped out areas in these orebodies indicate that, although a plug in the 700 Level haulage between the 712 and Piute Sections would initially halt a potential 10 gpm outflow through the Piute Shaft, a flow of up to 1 gpm could be established through the pillar after a few years.

5.2 Conclusions

1. Installation of a plug in the 700 Level Adit, some 2,700 ft from the portal, would stop the discharge of Acid Mine Drainage (AMD) from the Walker Mine.

2. Water backed up in the mine workings would probably reach equilibrium below the 6,500 ft elevation, as the increasing head could be expected to increase the rate of recharge of the groundwater system.

3. Recharge of the groundwater system would be dispersed over the full strike length of the workings, maximizing the attenuation effect on AMD re-entering the surrounding rock mass. No seepage has been located which can be identified as a point at which water recharged from the mine workings eventually reaches surface.

4. The cost of rehabilitation of the 700 Level haulage and installing an internal plug between the 712 and Piute Section is considered excessive for insurance against the low risk of AMD emission through the Piute Shaft (see Section 3.2 (3)).

5. A more cost-effective back-up to a single plug in the 700 Level Adit would be:

   a) Rehabilitation and maintenance of diversion channels around surface sinkholes, to minimize inflow of runoff from rain or snowmelt.

   b) Regular monitoring of water level in the mine workings, by means of pressure gauges at the plug with remote-reading facilities at the portal.

   c) The facility to open valves on the 4-inch diameter pipes through the plug, to relieve any excessive build up of water in the workings. Two 4-inch diameter pipes, 30 ft long, could pass over 2,400 gpm under 400 ft head, equivalent to the peak expected instantaneous rate of inflow.

d) Adequate notice of impending overflow of water accumulating in the mine, through the Piute Shaft, would be available to permit construction of a small treatment plant at the portal of the 700 Level Adit.

By these means, the small and short-duration release of any possible excess inflow into the mine could be neutralized without risk of contaminating an unaffected catchment (Ward Creek).

e) The cost of such a treatment facility (should it ever be needed) would be less than the total cost of the internal plug and would be deferred for probably not less than ten years (see Section 3.3).

f) This proposal provides for a means to direct any possible emission of AMD from the Walker Mine, under controllable conditions, through a neutralizing facility, provided the build up of water pressure behind a plug did not divert excessive quantities of AMD through natural outlet(s), which could deliver it to surface without adequate natural attenuation of its acid and metal content.

6. Installation of a plug in the main adit of the Walker Mine need not necessarily sterilize the mine for future exploitation. Should it become feasible at some future time to mine the known mineral resource, the valves on pipes through the plug could be opened and the mine water drained in less time than it took to enter the workings. The workings could be drained at a controlled rate during the period required to plan mining operations and secure the relevant permits. The AMD could be treated at a rate of, say, 500 to 800 gpm and discharged to surface waters. It is not possible to comment on or endorse the economic feasibility of such a course of action without knowledge of the potential ore reserves.

5.3 Recommendations

Immediately:

1. Undertake minor rehabilitation of diversion channels around Central Orebody sinkholes;

2. Undertake minor rehabilitation of diversion channels around the southern sinkholes above the Piute Orebody and establish a diversion channel around the northern end; and

3. Conduct a flow and water quality balance study on water movements from the mine workings above 700 Level, along 700 Level Haulage and Adit, entering and leaving the workings below 700 Level, and in the Dolly Creek from the mine portal to its confluence with Little Grizzly Creek.

Then, subject to the findings of 3:

4. Install a single plug in the 700 Level Adit approximately 2,700 ft from the portal;

5. Monitor water levels in the mine workings by means of gauges reading pressure behind the plug; and

6. Prepare a contingency plan for future construction and operation of a small treatment plant at the 700 Level Adit Portal, to neutralize AMD that might have to be discharged periodically (several years after installation of the plug) to relieve any excessive build up of water that might threaten to overflow out of the Piute Shaft.

Note: Implementation of Item 3 would require:

a. Channelization of drains and construction of simple flow measurement stations at up to six points in the 700 Level Haulage and Adit;

b. Establishment of up to five flow measurement stations between the 700 Level Adit portal and the Dolly Creek's confluence with Little Grizzly Creek; and

c. Careful measurement of water flow quantity and quality at each measuring station, to determine the entire flow pattern between Walker Mine workings above 700 Level and Little Grizzly Creek.

6.0 GLOSSARY

Where used in this report, the following terms will be defined as follows:

Adit: A horizontal or nearly horizontal passage driven from the surface for the working or drainage of a mine;

Aquaclude: A geologic formation that prevents the passage of gound water in significant amounts;

Asperities: Protrusions forming roughness or jaggedness on the surfaces of the walls, roof and floor of a tunnel/adit;

Bulkhead: (i) A wall or partition erected to resist ground or water pressure; (ii) A tight partition of wood, concrete or metal used for retainment of fluids in a tunnel or channel; also used for protection against gas or fires in mines;

Bullnose: The narrow-angled corner formed where the walls of two tunnels intersect at less than 90^0;

Haulage: Underground level either along and inside an orebody or closely parallel to it, usually in the footwall. On this level, the mineral drawn from stopes is transported to a shaft for hoisting or to surface through an adit. Haulage ways include levels and connecting passage ways (crosscuts) and are also used to transport supplies, waste rock, and for movement of personnel;

Portal: Any entrance to a mine, more usually the surface entry to an adit; and

Stope: An excavation from which ore has been extracted in a series of steps usually applied to steeply inclined or vertical veins.

APPENDIX I
CONCRETE MIX DESIGN RECOMMENDATIONS

by
Mr. Robert F. Adams, P.E.
Consulting Concrete Engineer

ROBERT F. ADAMS, P.E.
CONSULTING CONCRETE ENGINEER
5971 ANNRUD WAY
SACRAMENTO, CA 95822

(916) 428-9121

NOV - 1985

12 NOVEMBER 1985

Mr. Don Poulter
Steffen Robertson & Kirstan
7510 W. Mississippi Ave., Suite 210
Lakewood, CO 80226

Dear Mr. Poulter:

Subject: Concrete for Tunnel Plug, Walker Mine
Your Project No. 06901

I have reviewed your Draft Final Feasibility and Design Report for the Walker Mine pollution abatement project. You requested that I furnish my recommendations for concrete for the tunnel plug, the key feature of this project. This reports my recommendations for materials for concrete and concrete for the tunnel plug. A discussion gives the reasons for some of the recommendations and other matters pertaining to construction of the tunnel plug.

The low pH 4.1 of the acid mine water makes the concrete requirements of more concern than usual. Had the pH been above 5, there would have been less concern.

MATERIALS FOR CONCRETE

Aggregate shall meet the requirements of ASTM 633 for use in a severe weathering region. The sand shall be a natural sand. The coarse aggregate shall be a crushed limestone Size 57 (1 inch to No. 4) or Size 67 (3/4 inch to No. 4). The amount of flat and elongated particles in the coarse aggregate not exceed 15 percent. (Corps of Engineers Test CRD-C119). The sand and coarse aggregate may be rejected if the specific gravity, saturated surface dry basis, is less than 2.60.

Portland Cement shall be Type II, low alkali, meeting the requirements of ASTM C150.

Pozzolan shall be Class N,, natural or F, fly ash, meeting the requirements of ASTM C618. If a fly ash, Class F, pozzolan is used, the ignition loss shall be less than one percent.

Air Entraining Admixture shall meet the requirements of ASTM C260.

Water Reducing-Retarding Admixture shall be an unmodified lignosulfonate meeting the requirements of ASTM C494, Type D, supplied as a 40 percent solution.

Silica Fume shall be EMSAC F-100 as supplied by Elkem Chemicals, Inc., Pittsburgh, Pennsylvania.

Water- Use good quality water for mixing water. Do not use mine water. Sulfates should not exceed 1500 ppm and chlorides should not exceed 2000 ppm. The water should not contain oil or material that would affect the setting of portland cement.

CONCRETE PROPORTIONS AND PROPERTIES

Cement Content:

Portland cement - 450 pounds per cubic yard
Pozzolan - Class N - 150 pounds per cubic yard
or Class F - 200 " " " "

Air Content: 5+1 percent

Slump: 4 to 7 inches

Water-Reducing Admixture: Use 8 fluid ounces of water-reducing admixture per 100 pounds of cementing material.

Silica Fume: Use EMSAC F-100 at dosage of 2 gallons per 100 pounds of portland cement.

Design Strength of Concrete: 3000 psi at 28 days. (The strength of concrete as specified above should far exceed the design strength under normal conditions.)

DISCUSSION

The following gives some of the reasons for some of the above recommendations and other discussion and recommendations pertaining to the job.

Low permeability of the concrete is one big factor in reducing aggressive chemical attack on concrete such as that caused by sulfates and acids. Lower permeability is achieved by lower water-cement ratio (which means higher cement content, other things being equal), air entrainment, use of pozzolans and use of silica fume (a rather special pzzolan).

The rather low sulfate content of the mine water, 146 ppm (in your Table 2) does not justify the use of Type V portland cement, a premium price cement. The use of Type II portland cement with pozzolans provides protection from sulfates, if needed, equivalent to a Type V portland cement alone, except in the most severe sulfate conditions.

The use of a limestone coarse aggregate is recommended as a sacrificial aggregate for the acid water. Limestone coarse aggregate is frequently used in concrete pipe for sanitary sewers where acid conditions sometimes form. The closest commercial source of limestone coarse aggregate known to me is Sierra Rock Co., Placerville, a distance of about 150 miles from the jobsite.

Another advantage to limestone aggregate concrete is that it has a lower coefficient of thermal expansion, hence less thermal volume change.

The tunnel plug, being 12 by 12 by 15 feet in section is "mass concrete" for which there is sometimes concern about temperature rise in the concrete and temperature differences which sometimes cause cracking. It is believed that with the cement contents recommended there will be no problem because the concrete is placed against rock in a rather stable temperature environment and is not exposed. Another reason for using a pozzolan is to lower the temperature rise of the concrete substantially.

My recommendations have included the use of silica fume, a "super" pozzolan which reduces the permeability of concrete by up to two orders of magnitude. Silica fume is recommended because of this, and your report notes a 100 year expected life for the job. Unfortunately, the particular silica fume recommended is rather expensive and will increase the cost of the concrete some 30 to 50 dollars per cubic yard, a small amount considering the total cost of the job and believed to be justified for this job. (See attached sales literature for EMSAC silica fume.)

Your report mentions the use of an expansive agent in the concrete. This has not been recommended because the expansion comes at the wrong time in this kind of job. This in grout would be OK. The use of shrinkage-compensating cement has not been recommended either because of some problems with this cement.

The closest ready mix producer is in Portola, some 25 to 30 miles away - over a dirt road part of the way at least. If concrete is to come from this source, the cement, pozzolan and admixtures should not be added until the ready mix truck gets to the jobsite. It would seem very desirable to bring in a very small portable batch plant to batch at the jobsite. Such plants are available in the area.

Your report mentions rock cleanup prior to concreting. This is a must. The floor particularily should be cleaned of all loose rock, mud, debris, etc. etc.

It is suggested that vibration of the concrete in the lower portion of the plug be required, particularly on the floor and against rock and forms and around the pipe - and lower slump concrete, 4 to 5 inches, can and should be used here. In the crown, more slump is required - 5-1/2 to 7 inches slump.

The pump slickline should be kept buried in the crown, pumping to refusal to fill in the arch as well as possible, and backing out the slickline as the arch is filled.

Grouting the arch will be necessary. And from your experiences, grouting the sides appears to be necessary also. It is suggested grouting wait at least a month to allow the plug to cool and stabilize dimensionally. The peak temperature might occur at about 5 to 7 days.

Wood forms would be better than steel forms because they would provide more insulation.

Limited trial mixes should be made to establish a recommended starting mix. This should be done after the Contractor has selected his material sources.

Job inspection and quality control should be done to insure that the requirements of the specifications are followed and that good construction practices are followed. Most importantly, the air content of the concrete should be controlled by tests.

This report was reviewed by a colleague, Mr. Lewis H. Tuthill who concurred with my recommendations.

Please advise if you have any questions or I can furnish further information or help.

Sincerely,

Robert F. Adams

Robert F. Adams, P. E.

Some Addresses

Source of EMSAC F-100. Hill Brothers Chemical Co., 410 Charcot Avenue, San Jose, CA 95131. Phone 408-263-3131

Small jobsite concrete plant - Engineered Concrete Placement, Box 51333, Middletown, CA 95461, Phone 707-987-0151.

Source of Class N Pozzolan - Lassenite Industries, Inc., produced this at Hallelujah Junction about 35 miles East of Portola. Believe this still being produced. Office for this company now believed to be in Oroville, or Yuba City, California. Phone might be 800-221-3134.

Limestone Aggregate - Sierra Rock Co., 1845 Quarry Road, Placerville, CA 95667, Phone 916-622-8571.

White Cap Ready Mix, Portola, Bob Higgins, 916-832-4225

ADDENDUM 1
TO
WALKER MINE PROJECT
FINAL
FEASIBILITY AND DESIGN REPORT
CONTRACT NO. 4-051-150-0

WALKER MINE PROJECT
700 LEVEL ADIT PLUG
AND
SURFACE DIVERSION DITCHES
TECHNICAL SPECIFICATIONS

Prepared for:

California Regional Water Quality Control Board
Central Valley Region
3201 S Street
Sacramento, California 95816

Prepared by:

Steffen Robertson and Kirsten (Colorado) Inc.
3232 South Vance Street, Suite 210
Lakewood, Colorado 80227

November, 1985

TABLE OF CONTENTS

Page No.

TABLE OF CONTENTS (con't)

1.0 INTRODUCTION

1.1 General

In the following paragraphs, technical specifications are presented for the various work items noted. Specific items concerning contractual agreements, environmental controls, and health and safety requirements that must be complied with by the Subcontractor, have not been included as part of these specifications.

The work to be performed under these specifications is the construction of a concrete plug with drains in the 700 Level Adit of the Walker Mine, diversion of mine waters during plug construction, remedial work on the diversion ditches around the subsidence above the Piute and Central Orebodies and construction of a new ditch around the Piute Orebody. Also included in the work is the reclamation of the disturbed areas resulting from the construction of these facilities. This includes the replacement or repair of portal doors which are currently in place.

The structures specified herein are to be constructed to the lines and grades shown in the construction drawings to meet the technical requirements in these specifications.

While every effort has been made to have specifications and construction drawings free of error and ambiguity, the Subcontractor is responsible for bringing any such points to the attention of the Owner's representative before execution of the work to allow correction and/or interpretation.,

For any discrepancy or ambiguity in the specifications, construction drawings, codes, standards, or regulations, it is the intent of these specifications that the most restrictive interpretation shall apply unless intepreted otherwise by the Engineer.

1.2 Definitions

a) "Agency", when referred to, shall be understood to mean a duly authorized representative of the California Regional Water Quality Control Board - Central Valley Region.

b) "Engineer", when referred to, shall be understood to mean a duly authorized representative of Steffen Robertson and Kirsten (Colorado) Inc. (SRK); SRK is a subcontractor to the Agency.

c) "Contractor", when referred to, shall be understood to mean the party which has executed a contract agreement for the work with the Agency.

d) "Regulatory Agencies", when referred to, shall be understood to mean duly authorized representatives of such public agencies that have jurisdiction over this project in addition to the Agency.

e) "Drawings", when referred to, shall be the 06901 series drawings for Contract No. 4-051-150-0.

1.3 Permits

All permits required to execute and complete the work under these specifications shall be the responsibility of the Contractor. This includes, but is not limited to permits required for 1) mobilization and demobilization of equipment of the site, 2) execution of underground work, and 3) access and clearing for construction of the diversion ditches, and 4) any permits required by Regulatory Agencies.

The Agency will provide the permit for right of entry to the property on which the mine portal is located.

2.0 CONTRACTOR'S RESPONSIBILITY

The Contractor shall carefully examine all of the technical specifications and construction drawings, and the site of the work. He shall fully inform himself as to the character of all conditions at the site, local and otherwise, affecting the execution of the work, including those conditions to which Federal, State, and local safety and/or health laws and regulations may be applicable. Failure to comply with the requirements of this section shall not relieve the Contractor of responsibility for complete performance of the work.

It shall be the sole responsibility of the Contractor to determine and satisfy himself, by such means as he considers necessary or desirable, as to all matters pertaining to this work including, but not limited to:

- The location and nature of work;
- Climatic conditions;
- The nature and conditions of the terrain;
- Geologic conditions at the site;
- Transportation and communication facilities;
- Location and nature of construction materials available for use in the work;
- Other construction or operation in the project area that may be underway simultaneously with the construction work for the adit plug or diversion ditches; and
- All other factors that may affect the cost, duration, and execution of the work.

Before accepting the work, the Contractor shall acknowledge in writing that he has inspected the site and determined the characteristics of the work and the conditions indicated above.

Technical and other information relating to the site of the work is available in the following reports:

1) "Walker Mine Project, Feasibility and Design Report", Contract NO. 4-051-150-0 (SRK, 1985); and
2) Open file data through the Agency.

This report and data are provided for the Contractor's information and convenience. Neither Agency nor SRK will assume any responsibility for the Contractor's interpretation of, or conclusions reached from, examination of such data.

The performance of items specified to be submitted for review and comment by the Engineer remain the responsibility of the Contractor.

3.0 INSPECTION OF WORK

Full-time inspection of all construction activities under this work shall be as defined in the contract documents between the Agency and their subcontractors. Inspection of all work shall be carried out by the Engineer while such work is in progress. Notwithstanding such inspection, the Subcontractor shall be held responsible for the acceptability of the finished work.

The Engineer and/or his representatives shall at all times have access to the work whenever it is in preparation of progress. The Contractor shall fully cooperate with the Engineer to facilitate inspection. The Contractor shall give the Engineer ample notice of readiness of the work for inspection to see that the work is performed in accordance with the requirements set forth in the technical specifications and construction drawings. All work done by the Contractor shall meet the approval of the Engineer, but the detailed manner and methods of doing work shall be the responsibility of the Contractor.

If any work should be covered up without prior review or consent of the Engineer, it must, if required by the Engineer, be uncovered for examination and be properly restored at the Contractor's expense.

It is the intent of these specifications that all materials will be inspected and tested by the Engineer before final acceptance of the work. Test data will be made available to the Contractor for inspection at his option. Any part of an item of work which is found not to comply with the specification requirements or which is improperly located or constructed shall be removed and replaced to the satisfaction of the Engineer, at the Contractor's expense.

4.0 PLUG SPECIFICATIONS

4.1 Plug Location and Dimensions

The plug shall be located as shown in the drawings. The approximate coordinates of the plug center are 12,950 N, 11,420 E. The actual location will be field sited by the Engineer. The plug site shall be surveyed and recorded by a Contractor for the Agency. The plug shall be 15 ft in length.

4.2 Site Preparation

4.2.1 Access

Access and remedial work required to maintain access to the plug site during construction shall be the responsibility of the Contractor. Ventilation in the adit and working area shall remain in-place and in working order upon completion of construction. All work shall be done in accordance with the required mine health and safety regulations.

4.2.2 Mine Water Diversion

Mine waters running through the plug site shall be diverted such that the plug (including form work) is constructed in the dry. The diversion system shall be maintained until such time that water against the plug will not adversely effect the completion of the concrete placement. The method of diversion and schedule shall be submitted to the Engineer for approval prior to construction. Such approval does not relieve the Contractor from the responsibilities for the performance or adequacy of the diversion system.

4.2.3 Plug Site

The plug site shall be cleared and prepared to ensure an adequate bond between the rock and concrete plug. All loose rock within the plug site shall be spawled off to sound, intact rock. The rock surface shall be cleaned of all loose and fine materials. Limits of the site preparation shall extend a minimum of 5 ft past either end of the plug limits.

Methods of site preparation shall be proposed by the Contractor and submitted for review and comment by the Engineer. This in no way relieves the Contractor from his responsibility to accomplish the required site preparation in an efficient and timely manner. The prepared site shall be approved by the Engineer prior to placement of concrete.

4.3 Formwork

The formwork for the bulkheads shall be the responsibility of the Contractor. It shall be constructed of good quality material and in such a manner as to provide an efficient seal for containment of the concrete and any grout that may be injected. The design of the formwork shall be in accordance with ACI 347, "Recommendated Practice for Concrete Formwork", and of sufficient strength to withstand the fluid pressure of the concrete and any increased pressures due to grouting or concrete placement. A reference design is provided in the drawings.

The Contractor shall be responsible for the design and safety of form work. Completed forms in place will be approved by the Engineer prior to concrete placement to check all lines, grades, and tolerances as shown in the drawings. A reference design showing drain pipe locations is provided in the drawings.

4.4 Concrete

4.4.1 General

Contained in the following sections are concrete materials specification, recommended mix specifications, and handling requirements for the concrete plug. Concrete mixing, delivery and placement shall be in accordance with ACI Standards and Specifications.

The selected method and procedures for mixing, transportation and placing the concrete shall be submitted to the Engineer for review and comment prior to construction mobilization.

All material testing shall be done to ASTM specifications where applicable or unless otherwise specified. Under no circumstances shall delivery scheduling or placement methods be such that a cold joint will be formed in the plug.

The Contractor shall locate and supply all materials and equipment necessary for this work, including water, concrete aggregate, additives, and vehicles for transport of concrete to the plug location. Once all materials have been located, the Contractor shall prepare a trial mix for testing to check the adequacy of the mix design. The mix design and test results shall then be submitted to the Engineer prior to construction.

Before any concrete is placed, the mix design shall have been approved by the Engineer, formwork and the prepared site shall have been inspected by the Engineer, and tests of all materials and mechanical operation of all equipment shall have been completed.

4.4.2 Applicable Codes of Specifications

The following publications of the latest edition are a part of this specification, except as noted within this specification.

American Society for Testing and Materials

ASTM C-31	Specification for Making and Curing Concrete Test Specimens in the Field
ASTM C-33	Specification for Concrete Aggregates
ASTM C-39	Test for Compressive Strength of Cylindrical Concrete Specimens
ASTM C-94	Specification for Ready-Mixed Concrete
ASTM C-143	Method of Test for Slump of Portland Cement Concrete
ASTM C-150	Specification for Portland Cement
ASTM C-171	Specification for Sheet Materials for Curing Concrete
ASTM C-172	Method of Sampling Fresh Concrete
ASTM C-231	Test for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C-260	Specification for Air Entraining Admixtures for Concrete
ASTM C-309	Specification for Liquid Membrane - Forming Compounds for Curing Concrete
ASTM C-494	Specification for Chemical Admixtures for Concrete

American Concrete Institute Publications

ACI 211.1	Recommended Practice for Selected Proportions for Normal and Heavy Weight Concrete
ACI 214	Evaluation of Strength Test Results of Concrete
ACI 304	Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete
ACI 306	Recommended Practice for Curing Concrete
ACI 309	Recommended Practice for Consolidation of Concrete
ACI 311	Recommended Practice for Concrete Inspection
ACI 347	Recommended Practice for Concrete Formwork

4.4.3 Cement

Cement shall be an approved brand of Portland Cement complying with all the requirements of ASTM C-150, Type II.

4.4.4 Water

The water used for mixing concrete will be clean and free from oils and other substances deleterious to concrete. Sulphates shall not exceed 1,500 ppm and chlorides shall not exceed 2,000 ppm. Mine water is not acceptable for use in the concrete mix.

4.4.5 Concrete Aggregates

Aggregate shall meet the requirements of ASTM 633 for use in a severe weathering region. The sand shall be a natural sand. The coarse aggregate shall be a crushed limestone Size 57 (1 inch to No. 4) or Size 67 (3/4 inch to No. 4). The amount of flat and elongated particles in the coarse aggregate not exceed 15 percent. (Corps of Engineers Test CRD-C119). The sand and coarse aggregate may be rejected if the specific gravity, saturated surface dry basis, is less than 2.60.

4.4.6 Admixtures

The following admixtures shall be used in the design mix:

1. Pozzolan shall be Class N, natural or F, fly ash, meeting the requirements of ASTM C618. If a fly ash, Class F, pozzolan is used, the ignition loss shall be less than one percent.
2. Air Entraining Admixture shall meet the requirements of ASTM C260.
3. Water Reducing-Retarding Admixture shall be an unmodified lignosulfonate meeting the requirements of ASTM C494, Type D, supplied as a 40 percent solution.
4. Silica Fume shall be EMSAC F-100 as supplied by Elkem Chemicals, Inc., Pittsburgh, Pennsylvania, or equivalent.

4.4.7 Curing Aids and Coating

All materials used for curing shall conform to ASTM C-309. All materials used for coating shall conform to ASTM D-977. These apply to the front face of the plug once the formwork is removed.

4.4.8 Handling and Storage of Materials

4.4.8.1 Aggregate

Stored aggregate shall be handled in such manner as to prevent segregation of sizes and to avoid the inclusion of dirt and/or foreign materials in the concrete. Material shall be removed from stockpiles in approximately horizontal layers.

4.4.8.2 Cement

Cement in sacks or barrels shall be stored under a weather-tight cover with the floor raised at least one-half foot above the ground. Cement that has hardened or partially set shall be removed from the site and not used.

Bulk cement shall be stored in airtight and weatherproof bins with access for inspection.

4.4.9 Proportioning

It is the intent of this specification to secure, for every part of the work, concrete of homogeneous structure which, when hardened, will have the required strength, impermeability and resistance to chemicals and weathering.

Proportions shall be selected to produce concrete with a minimum 28-day compressive strength of 3,000 psi. The recommended design mix is as follows:

1. Cement Content:
   Portland cement - 450 pounds per cubic yard
   Pozzolan - Class N - 150 pounds per cubic yard
   or Class F - 200 pounds per cubic yard
2. Air Content: 5 + 1 percent
3. Slump: 4 to 7 inches (see Appendix I of SRK Feasibility and Design Report for explanation).
4. Water-Reducing Admixture: Use 8 fluid ounces of water-reducing admixture per 100 pounds of cementing material.
5. Silica Fume: Use EMSAC F-100 at dosage of 2 gallons per 100 pounds of Portland cement.

4.4.10 Batching of Concrete Mixture

The measurement of materials for concrete batching shall be in accordance with ASTM Specification C-94, Sections 6 and 7. After the equipment is set in operating position, the batching plant shall be inspected by an authorized agency and scales checked for accuracy. An inspection seal or tag properly documented shall be attached to the equipment.

4.4.10.1 Cement and Aggregate Measurements

The Contractor shall measure cement and aggregate by weighing only. Weighing shall be accurate to within 1.0 percent of the required weight. Cement may be measured in standard bags, however, no fraction of a bag shall be used unless weighed.

4.4.10.2 Water Measurement

The Contractor shall measure the water by volume or by weight. The device for the measurement of the water shall be readily adjustable and under all operating conditions shall have an accuracy within 1.0 percent of the quantity of water required for the batch.

4.4.10.3 Moisture Content

The Contractor shall provide a moisture meter to measure the amount of free water in fine aggregates within 0.3 of a percent. The Contractor shall compensate for varying moisture contents of fine aggregates and change batch weights of materials if necessary before batching.

4.4.10.4 Admixture Measurement

Admixtures shall be used strictly in accordance with manufacturer's recommendations. All admixtures shall be added to the concrete mixture with dispensing equipment furnished by the manufacturer.

4.4.10.5 Batching Plant

Bins

Bins with adequate separate compartments for fine aggregates and for each required size of coarse aggregate shall be provided in the batching plant. Each compartment shall be designed to discharge efficiently and freely into the weighing hopper. Means of control will be provided so that, as the quantity desired in the weighing hopper is approached, the material may be added slowly and shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully.

Scales

The scales for weighing aggregates and cement shall be of either the beam type of the springless dial type. Scales shall be accurate within 1.0 percent under operating conditions.

4.4.11 Mixing and Transportation of Concrete

Concrete shall be mixed and transported in equipment approved by the Engineer in a manner which will deliver uniform and homogeneous concrete to the forms. Mixing and transporting shall be in accordance with the appropriate ACI and ASTM codes. Revisions to applicable codes to accomodate field conditions shall be approved by the Engineer prior to construction.

4.4.11.1 Mixing Equipment

Mixers may be stationary mixers or truck mixers. Agitators may be truck mixers or truck agitators. Truck mixers shall be equipped with revolution counters and water meters. Stationary mixers shall be equipped with a timing device that will not permit the batch to be discharged until the specified mixing time has elapsed.

Each unit shall have attached thereto, in a prominent place, a metal plate or plates on which are plainly marked, the various uses for which the equipment is designed, the capacity of the drum or containers in terms of volume of mixed concrete and the speed of rotation of the mixing drum, blades, or paddles.

4.4.11.2 Mixing and Delivery

Concrete shall be mixed and delivered alongside the forms by one of the methods listed below. It should be noted that transport equipment from the portal to the plug site will be rail mounted.

Central Mixed

The materials completely mixed in a stationary mixer and transported to the delivery point in a truck agitator, a truck mixer operating as a truck agitator, a non-agitating truck approved by the Engineer or by pumping through a pipeline.

Shrink Mixed

The materials partially mixed or blended in a stationary mixer and the mixing completed in a truck mixer enroute to the job. This shall only be allowed provided the stationary mixer is located at the mine portal.

Transit Mixed

The materials placed into the truck mixer and all mixing done in the truck mixer.

4.4.11.3 Control

The Engineer will make slump tests from

samples taken at approximately the one-quarter and three-quarter points of the load. When the above pairs of slumps differ by more than two inches, the truck or agitator shall not be re-used until the condition causing the non-uniformity has been corrected.

The Engineer will make air content measurements at the beginning and approximately the one-half points of the load. When the air content is measured to be outside the limits of the specified content, the remainder of the load shall be refused. Subsequent loads will be tested prior to placement, and as above, to see that the problem has been corrected.

4.4.11.4 Retempering

Water shall not be added to mixed batches of concrete to increase the slump without specific written approval of the Engineer.

4.4.12 Testing of Concrete

The following tests will be performed by the Engineer on work performed under this Specification.

4.4.12.1 Strength Tests

During the course of construction, tests will be made to determine whether the concrete, as being produced, complies with the standards of quality specified in Section 4.4.9. The actual testing will be performed by an approved testing laboratory.

Preparation of Test Specimens

The concrete for test specimens will be sampled in accordance with ASTM C-172. The specimens will be cast and cured in accordance with ASTM C-31 and will be tested in accordance with ASTM C-39. Each test specimen will be tagged with the location of the sampled batch in the structure, the mix proportions or number, the slump and the type and brand of cement.

Number of Test Specimens

Not less than three (3) test specimens will be made for each 40 cubic yards, or portion thereof, of concrete placed in any one shift.

Age of Test Specimens

One or more test specimens will be broken at seven (7) days and the remaining specimens will be broken at twenty-eight (28) days.

4.4.12.2. Slump Tests

Slump tests will be made in accordance with ASTM C-143.

4.4.12.3 Tests for Entrained Air

The entrained air content of fresh concrete will be determined in accordance with ASTM C-231.

4.4.13 Enforcement of Strength Requirements

4.4.13.1 Definition of Failure

Cast Specimens

The test specimens cast in the field shall be considered to have failed the strength requirements when the average of all the strength tests or the average of any five consecutive strength tests is less than the specified strength or when more than one test in ten has an average value less than 90 percent of the specified strength. A strength test shall be the average strength of at least two companion cylinders.

Cored Specimens

The concrete represented by cored specimens shall be considered to have failed the strength requirements when the average strength of three specimens falls below 85 percent of the specified strength.

4.4.13.2 Failure of Test Specimens

When test specimens are made, cured, and tested in accordance with Section 4.4.12 of this specification, fail as defined above, the Engineer may require the following action be taken:

Testing of Cored Specimens

Specimens shall be secured, prepared and tested in accordance with ASTM C-42.

The Engineer will specify the location where each core specimen shall be secured. No more than three cores shall be taken from each portion of the structure for which cast test specimens have failed, as defined in Section 4.4.13.1 above.

Cored specimens shall be tested no later than sixty (60) days after the concrete was placed unless otherwise approved by the Engineer.

Where cored specimens fail as defined in Section 4.4.13.1 above, the Contractor shall strengthen or replace the structure in accordance with a plan approved by the Engineer.

4.5 Piping

Two drain pipes through the concrete plug shall be installed as shown in the draings. The pipes shall be 4-inch diameter stainless steel pipes. The values shall be as specified in the drawings or equivalent. The valve types and materials are subject to approval by the Engineer prior to installation.

Rubber water stops shall be placed around the pipes as shown in the drawings. If pipe connections are required within the concrete plug, they shall be threaded joints unless otherwise approved by the Engineer. Pipe connections shall be sufficiently tight to withstand up to 600 psi pressure.

4.6 Grouting

Grouting shall be done in areas where ever needed to provide a tight seal between the rock and concrete. Grout tubes shall be placed such that air entrapment does not occur in voids. A return line shall be installed at each location to provide a means of determining total void filling with grout. Placement of the grout lines is subject to the approval of the engineer.

Grouting may not be done within the first seven days after concrete emplacement. Grout pressures shall not exceed 1,500 psi. The grout shall be of a neat mix using sulfate resistant Portland cement. Chemical grouts may be used upon approval of the Engineer.

4.7 Instrumentation

A pressure gage shall be installed on one drainpipe and connected to a data logger as shown in the drawings. The equipment required is specified below. Installation and connection of the equipment shall be done as specified by the supplier. Routing of the readout lines shall be such as to protect them from damage.

The instrumentation installed shall be as listed below or equivalent. The supplier of the equipment itemized below is available upon request.

- Wekslar Gage - No. AA4-4-2
- TERRATRAC Model T/1015 Data Logger with 2,000 reading capacity; int. clock; in portable heavy-duty, gasketed case; battery-pak; signal connectors.
- Extended Operation Battery Pack (6 mo. of daily readings)
- Battery Charger (120VAC)
- HP-41CX Advanced Calculator (with programming for Interrogation; Extended Memory Module; HP-IL Module)
- Precision Pressure Transducer (SENSOMETRIC Series 97, 250 psig)

- Instrument Signal Cable (non-direct burial, 3 conductor and 100% shield)

Unless otherwise arranged and agreed to by the Agency, the Contractor shall be responsible for the selection, procurement and installation, operation of the above or equivalent instrumentation system.

Also, the Contractor shall be responsible to see that the instrumentation system is maintained in good condition and is properly operating at the time of acceptance of the work by the Agency. The Contractor shall also provide an operating warranty of the equipment for one full year following acceptance of the work by the Agency.

4.8 Cleanup

All materials used during construction and not built into the plug shall be removed from the adit and portal area, including the formwork at the face of the mine plug. Any support placed in the adit by the Contractor will be left in place.

The portal, the portal doors, and immediately surrounding area shall be left in a safe and operable condition. Reclamation of disturbed areas outside the portal shall consist of removal of all equipment and unused or discarded materials. The site shall be graded to re-establish original drainage conditions.

5.0 DIVERSION DITCHES

5.1 Scope

The work under this specification includes clearing, grubbing, and excavation for a diversion ditch as shown in the drawings, and remedial work for existing ditches.

5.2 Definitions

1) Clearing is defined as the cutting near ground level of trees and brush, and the removal of such cut material along with downed timber, rotten wood, rubbish, any other vegetation, and objectionable material.

2) Grubbing is defined as the removal from below the surface of the natural ground of stumps, vegetation, and roots 1-inch diameter and larger.

3) Excavating is defined as the removal of soil, soil-rock or rock materials within the limits shown on the construction drawings or specified by the Engineer.

5.3 Clearing and Grubbing

5.3.1 General

Clearing and grubbing shall be done along the alignment of new diversion ditches. Only clearing shall be done along access routes to the work area. Clearing along access shall be kept to a minimum. Prior to clearing, access routes shall be approved by the Engineer and the Regulatory Agencies.

5.3.2 Protection

1) Trees and vegetation beyond the specified limits for the diversion ditch and access route shall not be removed or damaged without the approval of the Engineer.

2) Beyond the clearing and grubbing limits, the following activity is not permitted:

a) Compaction of root area by moving trucks or heavy motor equipment, or by storage of heavy equipment, supplies, gravel, and earthfill.
b) Damage by trucks and motor equipment bumping into trees, leaning equipment, lumber, pipes, and other supplies against trees.
c) Nailing or bolting objects to trees, using trees as temporary support posts, power poles, or sign posts.
d) Strangling trees by tying ropes, guy wires, power lines to trunks or large branches of trees.
e) Poisoning trees by pouring paint thinner, paint, solvents, oil, gasoline, dirty water, and other expendable materials on or around trees and roots.
f) Burning of foilage and branches by burning trash under trees or so near that wind-blown heat damages tree leaves.
g) Cutting of roots by utility ditching, foundation digging, placement of curbs and benches, and other miscellaneour excavation.
h) Damaging of branches and foliage by temporary overhead power and telephone lines, swinging of power crane booms, cherry pickers, or driving too-tall van trucks under trees.

i) Cutting off branches, to allow for construction, by improper pruning methods such as peeling bark down the truck.

5.3.3 Extent of Removal

Clearing and grubbing shall be done for a maximum distance of 5 ft beyond the limits of the ditch excavation and grading; and 3 ft beyond the limits required for equipment access.

Blasting of stump removal shall not be permitted.

5.3.4 Disposal

a) If applicable, branches and brush shall be put through a chipper and the residue spread in designated areas to retard erosion and provide for dust control.
b) Larger trees and limbs shall be disposed of as proposed by the Contractor and approved by the Engineer, or as specified in a separate contract with the Agency.

5.3.5 Timing

Clearing and grubbing shall not be permitted during the rainy season unless proper sediment control structures have been installed to limit erosion and to prevent an increase in sediment loads in the streams. All runoff and sediment control measures shall be submitted to the Engineer in detail for comment and review. All waters discharged from the sediment control area shall be in compliance with State of California water quality control standards and discharge permit requirements.

5.4 Riprap Materials

Riprap may be required to provide protection against excessive erosion of the diversion ditches. It is anticipated that this material will be available from a local supplier. Suitable material may exist outside the mine portal and could be used subject to the Engineer's approval.

Riprap shall be as specified below.

Riprap with $*d_{50}$ = 6 inches

Intermediate Rock Dimension	Percent smaller than given size by weight
24 inch	100
15 inch	70-100
12 inch	40-60
9 inch	20-40
6 inch	10-20
2 inch	2-10

$*d_{50}$ = median particle size

5.5 Riprap Bedding Material

Riprap bedding material is not anticipated to be available at the site and will be obtained from commercial sources. Samples of the materials proposed for bedding shall be provided for testing and approval by the Engineer prior to use. Specifications for bedding are listed below.

Riprap Bedding Material

U.S. Standard Sieve	Percent Finer by Weight
3 inch	90-100
3/4 inch	20-90
No. 4	0-20
No. 200	0-3

5.6 Existing Ditches

Existing ditches requiring remedial work shall be regraded to their original geometry. Areas showing excessive erosion shall be regraded and protected from addtional erosion. Details for such protection are shown in the drawing.

Areas requiring additional work shall be field located by the Engineer in conjunction with the Contractor.

Acceptance of the completed work shall be subject to the approval of the Engineer.

5.7 New Ditches

New ditches to be installed shall be excavated and graded to the lines and grades or shown in the drawings. Areas which may be susceptible to excessive erosion under normal flow conditions will be protected as shown in the drawings.

Final alignment of the diversion ditch(es) will be field located and approved by the Engineer.

STEFFEN ROBERTSON AND KIRSTEN
Consulting Engineers

January 23, 1986
Project No. 06901

California Regional Water Quality Control Board
Central Valley Region
3201 "S" Street
Sacramento, California 95816

Attention: Mr. William Marshall, Contract Manager

RE: EVALUATION OF FLOW IN WALKER MINE - ADDENDUM TO FINAL REPORT FOR CONTRACT NO. 4-051-150-0

Dear Bill,

Enclosed is the report on the evaluation of flow in the Walker Mine. This report is an addendum to the final feasibility study and design report for plugging the Walker Mine which was prepared under Contract No. 4-051-150-0.

The report presents a summary of the field data collected and laboratory tests conducted for the flow evaluation study. The data was interpretated by Adrian Brown and the conclusions were presented to and discussed with the project team prior to finalizing this report. The conclusions are unchanged from those forwarded to you in our December 12, 1985 letter and preliminary report.

Sincerely,

STEFFEN ROBERTSON AND KIRSTEN
(COLORADO) INC.

Colin C. Smith

Colin Smith
Project Manager

CS/gg

Encl.

3232 South Vance Street, Suite 210, Lakewood, Colorado 80227, U.S.A.
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Other offices in: U.S.A., Canada, United Kingdom and Africa

FLOW EVALUATION WITHIN THE WALKER MINE
ADDENDUM REPORT TO WALKER MINE PROJECT
FINAL FEASIBILITY AND DESIGN REPORT
CONTRACT NO. 4-051-150-0

Prepared for:
California Regional Water Quality Control Board
Central Valley Region
3201 S Street
Sacramento, California 95816

Prepared by:
Steffen Robertson and Kirsten (Colorado) Inc.
3232 S. Vance Street, Suite 210
Lakewood, Colorado 80227

January, 1986

1.0 INTRODUCTION

On December 6, 1985, an inspection of the Walker Mine was made by Steffen Robertson and Kirsten (SRK) staff for the purposes of evaluating the mine flow system and of resolving the question as to whether there is currently any water which flows into the mine that does not pass out through the portal adit. This information is critical to the prediction of the post-sealing performance of the mine, particularly with respect to the question as to the likelihood of copper-laden water from the mine ever entering the Ward Creek catchment via the Piute Shaft.

The personnel participating in this phase of the work and the preparation of this report were Adrian Brown and Mark Logsdon of Terra Therma, Inc. and Colin Smith, associate consultants to SRK. As geohydrologist on the team, Adrian Brown was the lead engineer responsible for the data interpretation and preparation of this report.

2.0 ACTIVITIES

The mine was visited on Friday, December 6, 1985. The SRK team entered the adit at about 1000 hours and progressed from the portal to the rockfall between the Piute and 712 sections, taking water quality samples and flow measurements at appropriate locations on the way. The party returned to the portal at about 1715 hours. The water samples were filtered that evening, and carried to Denver the following morning for analysis.

3.0 RESULTS

3.1 Field Measurements

The results of the field measurements of flow and water quality are summarized on Table 1.

TABLE 1
SUMMARY OF RESULTS OBTAINED FOR FLOW ON THE 700 LEVEL

LOCATION	FLOW (gpm)	TEMP (^{o}C)	pH (units)	COND (umho)
Flow in the adit	21	7.3	5.25	340
South end of South orebody	1	5.9	3.29	289
South end of Central orebody	41	4.0	6.23	221
South end of North orebody	55	3.7	8.40	208
South end of 712 orebody	46	3.4	8.28	231
South end of Piute orebody	40	3.4	8.58	198

The pH results are questionable due to a malfunction of the pH probe resulting from the difficult conditions encountered underground. It should be noted that other readings were taken during the trip; the values presented above are the key values with respect to the question which was of primary interest during this visit.

The water level in the lower workings was visible at a few locations, and the distance below track grade was measured using a tape at these points. The results are indicated in Table 2.

TABLE 2
ELEVATIONS OF WATER LEVELS IN WORKINGS BELOW THE 700 LEVEL

LOCATION	CHAINAGE (feet)	TRACK ELEVATION (feet)	DEPTH TO WATER (feet)	WATER ELEVATION (feet)
North end of adit	-1900	0.0	0.0	0.0
Center of Center Orebody	- 500	7.0	5.0	2.0
Center of North Orebody	800	13.5	14.5	-1.0

Note: Elevations are relative to the elevation of the north end of adit. Elevation of the track is computed on the assumption that the track gradient is 0.5 percent. This is the gradient computed from plans.

Given the relatively low precision of the measurements, it is considered that the water elevations are the same; that is, the water level in the South, Central, and North orebody workings below the 700 level is the same, and is about equal to the elevation of the adit discharge point.

3.2 Laboratory Results

Seven water quality samples were collected in conjunction with the flow measurements in the mine, and a water quality sample of the outflow from the adit was also collected. Table 3 presents the laboratory analytical data for the samples.

All eight samples were analyzed for pH, specific conductance, and TDS, as indicators of the overall chemistry, and for copper (Cu), the heavy metal of principal concern. The water exiting the adit was analyzed for a full suite of major and minor species, primarily to allow correlation of these data with other sampling sessions. Copies of the laboratory report are attached.

TABLE 3

WATER QUALITY DATA, WALKER MINE - DECEMBER, 1985

PARAMETER	UNITS	SAMPLE NUMBER AND LOCATION							
		1	2	3	4	5	6	7	8
		S. end South ext.	S. end Central	S. end North	Inflow from roof, S. end North	S. end of 712	N. end of 712	S. end of Piute	Outflow from adit
pH	umho/cc	4.05	7.41	7.46	3.44	7.21	7.58	5.43	5.31
Conductivity	mg/l	346	242	217	436	222	203	167	256
TDS	mg/l	235	88	153	244	155	149	117	195
Alkalinity	mg/l $CaCO_3$				<1		73	11	12
Ca	mg/l				17		25	13	23
Mg	mg/l				5.5		5.1	3.1	6.2
Na	mg/l				1.87		3.6	1.81	3.1
K	mg/l				2.21		1.11	1.51	1.39
HCO_3	mg/l				<5		72	<5	<5
CO_3	mg/l				<1		<1	<1	<1
OH	mg/l				<.5		<0.05	<0.05	<0.05
SO_4	mg/l				135		45	73	111
Cl	mg/l				.5		0.5	0.5	0.6
Al	mg/l								0.4
As	mg/l								<0.01
Ba	mg/l								<0.1
Cd	mg/l								<0.01
Cr	mg/l								<0.01
Cu	mg/l	11.5	.33	.54	12.1	.73	1.00	10.4	8.7
Fe	mg/l				12.1		<0.05	0.21	0.10
Pb	mg/l								<0.01
Mn	mg/l				5.3		0.90	1.59	2.52
Hg	ug/l								<0.3
Ni	mg/l								<0.05
Se	mg/l								<0.01
Ag	mg/l								<0.01
Zn	mg/l				.96		0.24	0.40	0.65

4.0 DISCUSSION

These results quite clearly indicate that water which enters the mine does not all leave by the adit. The main inflow at the time of the visit was from the Piute area. In the 712 mine section, and to a lesser extent in the North orebody, there was some evidence of inflow from above. However, the two largest of the observed flows were measured and found to be of the order of 2 gallons per minute. It is estimated that, at the time of the visit, less than 10 gallons per minute of flow was observed coming from the workings above 700 level adit. There may, however, have been inflow to this level in sections which were not visible to the party, due to being in other segments of the drive system.

The available maps of the mine indicate that there is no mined connection between the Piute and the 712 orebody below the 700 level. Similarly, there is no known connection between the 712 orebody and the North orebody below the 700 level. Thus, it is not surprising to find that the flow on the 700 level increases from the south end of the Piute orebody to the south end 712 orebody.

There is believed to be connection below the 700 level between the North, Central and South orebody workings. The flow values reflect this, as the flow in the drain on the 700 level reduces in this stretch, presumably because of leakage to the lower workings. During the recent inspection trip, the flow could be seen to be disappearing from the 700 level adit drain into the lower workings at a number of locations, particularly in the South orebody area. The drain was essentially dry at the point where the 700 drive intersects the exit adit. Flow in the exit adit comes from the south extension, and is presumably return flow from the deeper mined area, which collects water from the entire mine.

The water level information indicates that there is a connection between the North, Central and South orebody workings below the 700 level. Water is presumably flowing into the lower workings from the 700 level, and moving towards the adit exit through the conduits provided by the workings. This effect did not appear to be significant in the North orebody at the time of the visit. However, on the previous visit where this location was inspected, a considerable flow was observed to be dropping into the deeper portion of the North orebody workings at the location where the water level was measured this time.

The chemical parameters indicate regular changes from the input areas to the outflow areas. As the field readings were taken in winter, the water was entering the mine colder than the mine rock temperature. As a result, the water was warmed by the rock, which clearly shows in the field results.

The laboratory values for conductivity (and related TDS) are consistent with the field measurements - both generally increased from inflow to outflow points within the mine. The laboratory pH values (which were not subject to the vicissitudes of measurement under highly adverse field conditions) have a very strong correlation with TDS ($r = -0.78$). The correlation is even higher for copper, the metal of greatest interest ($r = -0.96$) for zinc and sulfate, the correlation factors are -0.93. These correlations clearly indicate that the dissolved load of the waters, particularly the concentrations of heavy metals is dependent primarily on pH.

The correlation of copper concentration with pH offers a ready explanation for why flow from the mine to the natural groundwater system has not introduced significant quantities of copper into the surface water system. The acid drainage in the mine system is the result of oxygenated waters reacting with the sulfide ores. When the water in the mine system flows out of the mine workings and into the country rock, it flows away from the concentrated sulfide zone, and along many flow paths through the granodiorite (and potentially other units) before it discharges to surface waters. During this flow, the acid produced in the ore zone is neutralized by water-rock reactions (primarily with the feldspars), and the copper initially carried in solution is precipitated and/or scavenged by clays, oxyhydroxides, and other phases that are present in the country rock.

The importance of the observation that there is a loss of a considerable amount of water from the mine to the groundwater system under natural conditions is as follows:

1. The loss from the mine will presumably increase as the mine fills after flooding, due to the higher driving head;
2. The increased flow loss from the mine makes it highly unlikely that water will ever rise high enough in the workings to cause a discharge from the Piute area, and into the presently unaffected catchment of Ward Creek; and
3. The losses have presumably been going on since the closing of the mine, and to date there is no evidence of a stream of copper-laden water egressing from the groundwater system to the surface water system via the natural flow system. Based upon the data collected in the mine, it is expected that as the water enters the groundwater, it is neutralized and the copper is precipitated from solution. Therefore, no increases in copper-ladened waters are expected to occur in the surface water system as a result of plugging the mine.

5.0 CONCLUSIONS

The conclusions of the evaluation are as follows:

1. The flow in the mine is a clearly identifiable hydraulic and geochemical system; water moves from the 700 level drive to the lower workings where it can, and discharges from the deep workings to the deep groundwater system, to the adjacent downgradient mine workings (when they are connected), or to the main exit adit and thence to the portal;
2. There is clearly loss of water from the mine which is a result of discharge of water from the deep mined workings to the natural groundwater system. At the time of the visit, about 40 percent of the influent water was appearing at the proposed plug location as flow in the adit drain, and approximately 60 percent of the inflow to the mine was discharging into the bedrock from the deep mine workings;

3. Based on these results, it is considered highly unlikely that copper-rich water could flow from a plugged mine to the catchment of Ward Creek via the Piute Shaft; and
4. There is a low probability that copper from the mine will emerge from the groundwater system once a plug has been installed in the mine and the water pressure in the mine has increased. In fact, the production of acid drainage will gradually decrease in importance to the extent that inflow of oxygenated surface water can be reduced (by reducing the flow into the surface shafts, particularly the Piute) and as the water stored in the plugged mine consequently becomes less oxidizing over time.

CORE LABORATORIES, INC.
ANALYTICAL REPORT

ANALYTICAL REPORT

W85884

TERRA THERMA INC.

CORE LABORATORIES, INC.
ANALYTICAL REPORT

CLIENT IDENTIFICATION

JOB NO.:16307-W35884
COMPANY: TERRA THERMA, INC.
JOB/GROUP REMARKS:

IDENTIFICATION	IDENTIFICATION
1) 1285-04	2) 1285-06
3) 1285-07	4) 1285-08
5) 1285-01	6) 1285-02
7) 1285-03	8) 1285-05

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 1	W85884 - 2	W85884 - 3	W85884 - 4
SAMPLE ID:	1285-04	1285-06	1285-07	1285-08
SAMPLE REMARKS:				
DATE/TIME SAMPLED	12-06-85/1415	12-06-85/1515	12-06-85/1530	12-06-85/1730
DATE/TIME RECEIVED	12-09-85/	12-09-85/	12-09-85/	12-09-85/
DATE/TIME ANALYZED	12-10-85/	12-10-85/	12-10-85/	12-10-85/
CHEMIST: RIF/DRH				
LOCATION: AURORA, CO				
LAB pH (@ 25 deg. C)	3.44	7.58	5.43	5.31
LAB COND. (as umhos/cm @ 25C)	436	203	167	256

--ALL VALUES REPORTED ON A DISSOLVED BASIS (MG./L.) UNLESS INDICATED OTHERWISE

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85881 - 1		W85884 - 2		W85884 - 3		W85884 - 4	
SAMPLE ID:	1285-04		1285-06		1285-07		1285-08	
SAMPLE REMARKS:								
MAJOR CATIONS								
CALCIUM (Ca)	17	(0.85)	25	(1.25)	13	(0.65)	23	(1.15)
MAGNESIUM (Mg)	5.5	(0.45)	5.1	(0.42)	3.1	(0.26)	6.2	(0.51)
SODIUM (Na)	1.87	(0.08)	3.6	(0.16)	1.81	(0.08)	3.1	(0.13)
POTASSIUM (K)	2.21	(0.06)	1.11	(0.03)	1.51	(0.04)	1.39	(0.04)
SUM OF MAJOR CATIONS (me/l)		(1.44)		(1.86)		(1.03)		(1.83)
SUM OF TOTAL CATIONS (me/l)		(2.69)		(1.93)		(1.44)		(2.27)
MAJOR ANIONS								
BICARBONATE (HCO3)	<5	(0.00)	72	(1.18)	<5	(0.00)	<5	(0.00)
CARBONATE (CO3)	<1	(0.00)	<1	(0.00)	<1	(0.00)	<1	(0.00)
HYDROXIDE (OH)	<0.5	(0.00)	<0.5	(0.00)	<0.5	(0.00)	<0.5	(0.00)
SULFATE (SO4)	135	(2.81)	45	(0.94)	73	(1.52)	111	(2.31)
CHLORIDE (Cl)	0.5	(0.01)	0.5	(0.01)	0.5	(0.01)	0.6	(0.02)
SUM OF MAJOR ANIONS (me/l)		(2.82)		(2.13)		(1.53)		(2.33)
SUM OF TOTAL ANIONS (me/l)		(2.82)		(2.13)		(1.53)		(2.33)

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 1	W85884 - 2	W85884 - 3	W85884 - 4
SAMPLE ID:	1285-04	1285-06	1285-07	1285-08
SAMPLE REMARKS:				
GENERAL PARAMETERS				
TOTAL DISSOLVED SOLIDS (CALC.)	244 (193)	149 (118)	117 (106)	195 (158)
*TOTAL ALK. (pH 3.7 as CaCO3)	<1	73	11	12

*--FILTERABLE

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 1	W85884 - 2	W85884 - 3	W85884 - 4
SAMPLE ID:	1285-04	1285-06	1285-07	1285-08
SAMPLE REMARKS:				
DISSOLVED METALS				
ALUMINUM (Al)				0.4
ARSENIC (As)				<0.01
BARIUM (Ba)				<0.1
CADMIUM (Cd)				<0.01
CHROMIUM (Cr)				<0.01
COPPER (Cu)	12.1	1.00	10.4	8.7
IRON (Fe)	12.1	<0.05	0.21	0.10
LEAD (Pb)				<0.01
MANGANESE (Mn)	5.3	0.90	1.59	2.52
MERCURY (Hg)--ug./l.				<0.3
NICKEL (Ni)				<0.05
SELENIUM (Se)				<0.01
SILVER (Ag)				<0.01
ZINC (Zn)	0.96	0.24	0.40	0.65

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 5	W85884 - 6	W85884 - 7	W85884 - 8
SAMPLE ID:	1285-01	1285-02	1285-03	1285-05
SAMPLE REMARKS:				
DATE/TIME SAMPLED	12-06-85/1100	12-06-85/1210	12-06-85/	12-06-85/
DATE/TIME RECEIVED	12-09-85/	12-09-85/	12-09-85/	12-09-85/
DATE/TIME ANALYZED	12-10-85/	12-10-85/	12-10-85/	12-10-85/
CHEMIST: RIF/DRH				
LOCATION: AURORA, CO				
LAB pH (@ 25 deg. C)	4.05	7.41	7.46	7.21
LAB COND. (as umhos/cm @ 25C)	346	242	217	222

--ALL VALUES REPORTED ON A DISSOLVED BASIS (MG./L.) UNLESS INDICATED OTHERWISE

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 5	W85884 - 6	W85884 - 7	W85884 - 8
SAMPLE ID:	1285-01	1285-02	1285-03	1285-05
SAMPLE REMARKS:				
GENERAL PARAMETERS				
TOTAL DISSOLVED SOLIDS	235	88	153	155

CORE LABORATORIES, INC.
ANALYTICAL REPORT

7-JAN-86

TERRA THERMA, INC.

RESULTS OF WATER QUALITY ANALYSIS
ON SAMPLES COLLECTED AT LOCATION:

JOB NO. 6307-	W85884 - 5	W85884 - 6	W85884 - 7	W85884 - 8
SAMPLE ID:	1285-01	1285-02	1285-03	1285-05
SAMPLE REMARKS:				
DISSOLVED METALS				
COPPER (Cu)	11.5	0.33	0.54	0.73