Working Document 033001/2

ANVIL RANGE MINING COMPLEX CONCEPTUAL CLOSURE PLAN

Prepared for:

Anvil Range Mining Corporation

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Prepared by:
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August 1996

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Project No. 033001

August 21, 1996

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Copy by Fax

Attention: Kurt Forgaard
President and CEO

Dear Mr. Kurt Forgaard

Re:. Updated version of Anvil Range Conceptual Closure Plan

Please find enclosed two copies of the second draft of the conceptual closure plan for the Anvil Range Mining Complex. Two copies are being couriered out today directly from our office to Mr. Norm Anderson in Vancouver and Mr. Dan Yoon in Toronto.

As outlined in an earlier fax, the following changes and additions have been made to the last draft of this report issued June 13, 1996:

- chapter 8: Faro Closure Plan
- chapter 9: Vangorda and Grum Closure Plan
- chapter 10: Post-closure water treatment
- chapter 14: Costing
- Appendix A, B, C, and D

Please recognize that this document is a draft version for discussion purposes only.

Yours sincerely,

ROBERTSON GEOCONSULTANTS INC.

Christoph Wels

Christoph Wels, Ph.D.
Senior Hydrogeologist

cc. Dan Yoon, Norm Anderson, Eric Denholm

Anvil Range Mining Complex
Conceptual Closure Plan

Table of Contents

Anvil Range Mining Complex
Conceptual Closure Plan

June 1996

1. The Anvil Range Mining Complex

1.1 Location and Description

The Anvil Range Mining Complex, currently owned and operated by Anvil Range Mining Corporation, is located near the town of Faro, approximately 200 km NNE of Whitehorse, the capital of Yukon Territory. Figure 1-1 shows the general location of this mining operation, while Figure 1-2 and 1-3 show the location of mines, mill and tailings facilities. The operations are located in the vicinity of the headwaters of Rose Creek, a tributary of Anvil Creek, and Vangorda Creek, all of which are tributaries of the Pelly River.

The Anvil Range Mining Complex consists of the Faro mine site located approximately 20 km NW of Faro, and the Vangorda Plateau mine site located approximately 13 km SE of Faro. The Faro mine site includes the Faro Pit and Dumps, mill facilities as well as a series of tailings impoundments (Fig. 1-2). The Faro Pit was mined out in August, 1992. The Vangorda Plateau mine site includes the Vangorda Pit and Dumps, the Grum Pit and Dumps as well as the water treatment facilities (Fig 1-3). Currently Grum Pit, and from time to time the Vangorda Pit, are being excavated and ore is being hauled on a haul road from the Vangorda Plateau to the Faro mine site for milling. Tailings are currently deposited in the mined out Faro Pit. The concentrate is then trucked to Skagway, Alaska, for shipment to overseas markets.

1.2 History of Development and Ownership

The Vangorda deposit, the initial mineral discovery in the Anvil Range, was first drilled by Prospector Airways, a predecessor of Kerr Addison Mines, between 1953 and 1955. However, the Faro lead-zinc deposit, discovered in 1964, was first developed and brought into production by Anvil Mining Corporation in 1969, initially producing 5,000 tonnes of ore per day. The Anvil operation was amongst the major world producers of lead and zinc concentrates. In 1975 Anvil Mining Corporation was reorganised to form Cyprus Anvil Mining Corporation (CAMC). In 1979 CAMC purchased the Kerr Addison mineral deposits and claims including Grum, Vangorda and Swim. However, until June of 1982 when CAMC terminated its mining and milling operations, all mining was confined to Zones I and II of the Faro open pit.

During the 18 years of mining CAMC and its predecessor mined approximately 35 million tonnes of ore, generated 10 million m^3 of tailings, and stripped 62 million m^3 of waste rock which was stored in the Faro waste dumps. Further waste stripping operations at the Faro Pit were carried out between June 1983 and October 1984, with about 7.4 million cubic metres of waste being removed.

Curragh Resources Inc. (CRI) restarted the Faro mining and milling operation in June, 1986 and continued to mine Zone I and III of the Faro open pit at a rate of approximately 13,500 tonnes of ore per day. Open pit mining was augmented by underground mining under the east wall of the Zone I and III pit, starting in 1989. From 1986 through 1992, Curragh mined an estimated 23.4 million tonnes of ore, generated 6 million m^3 of tailings, and stripped 30 million m^3 of waste rock in the Faro open pit which was stored in the waste dumps and the Vangorda haul road. CRI also mined 1.8 million tonnes from an underground mine accessed through the Faro Pit mine. CRI initiated development of the Grum and Vangorda ore deposits. By 1992, when Curragh Resources Inc. went into receivership, the Vangorda open pit was nearly fully developed, and 5.7 million tonnes of ore had been mined and overburden rock had been stripped at the Grum location.

In November 1994 the property was bought by the current owner, Anvil Range Mining Corporation, and waste rock stripping in the Grum pit commenced in January 1996. Full processing of ore from Grum began in August 1995. Anvil has mined approximately 5 million tonnes of ore to date.

1.3 Background to the Closure Plan

An Integrated Comprehensive Abandonment Plan (ICAP) for the Faro site has been required by the Yukon Water Board as a condition of licence IN89-001 to ensure that all elements of the mining and milling complex are considered, and provided for, in a comprehensive closure plan, and to closure standards which they consider appropriate for 1996. The following design standards and/or environmental requirements for the Faro site which must be according to licence IN89-001 substantially change the viability of previous closure plans:

- the maximum credible earthquake (MCE);

- the probable maximum flood (PMF); and,
- CCREM water quality standards at some point in Rose.

Similarly the Vangorda-Grum mine sites' water licence require submission of a detailed abandonment plan. The above noted criteria have not been incorporated into the requirements for the Vangorda-Grum plan. The required dates of submission of these two plans were December 31, 1994, and July 15, 1994, respectively. Due to the shut-down of the Faro mine and mill complex from April 1993 - November 1994, it was not possible to submit these plans. Anvil Range Mining Corporation took over the Faro complex in November 1994 and after review of the situation proposed to prepare one comprehensive closure plan incorporating both the Faro and Vangorda-Grum sites. It proposed to submit this plan in November 1996 Anvil has made application to the Yukon Territory Water Board to modify both its water licences to incorporate that deadline.

1.4 Key Closure and Environmental Reports

A considerable amount of information related to the Anvil Range Mining Complex has been generated as a result of studies and reports completed from 1973 onwards. Over twenty related reports have been reviewed during the preparation of this Final Closure Plan (see reference section). Many of the ideas and data discussed in this Conceptual Closure Plan were originally presented in one of the following seven reports:

Faro Mine Tailings Abandonment Plan, by Klohn Leonoff Ltd., September, 1981.

Faro Mine Abandonment Plan, Curragh Resources Inc., April, 1988.

Other Facilities Abandonment Plan, Curragh Resources Inc., June, 1989.

Vangorda Plateau Development - Water License Application, by Curragh Resources Inc., December, 1989 (SRK No. 60609).

Down Valley Tailings Impoundment Decommissioning Plan, by Steffen, Robertson and Kirsten, April, 1991 (SRK No. 60635).

Water Recycle and Tailings Deposition Plan, Kilborn Inc., June, 1991.

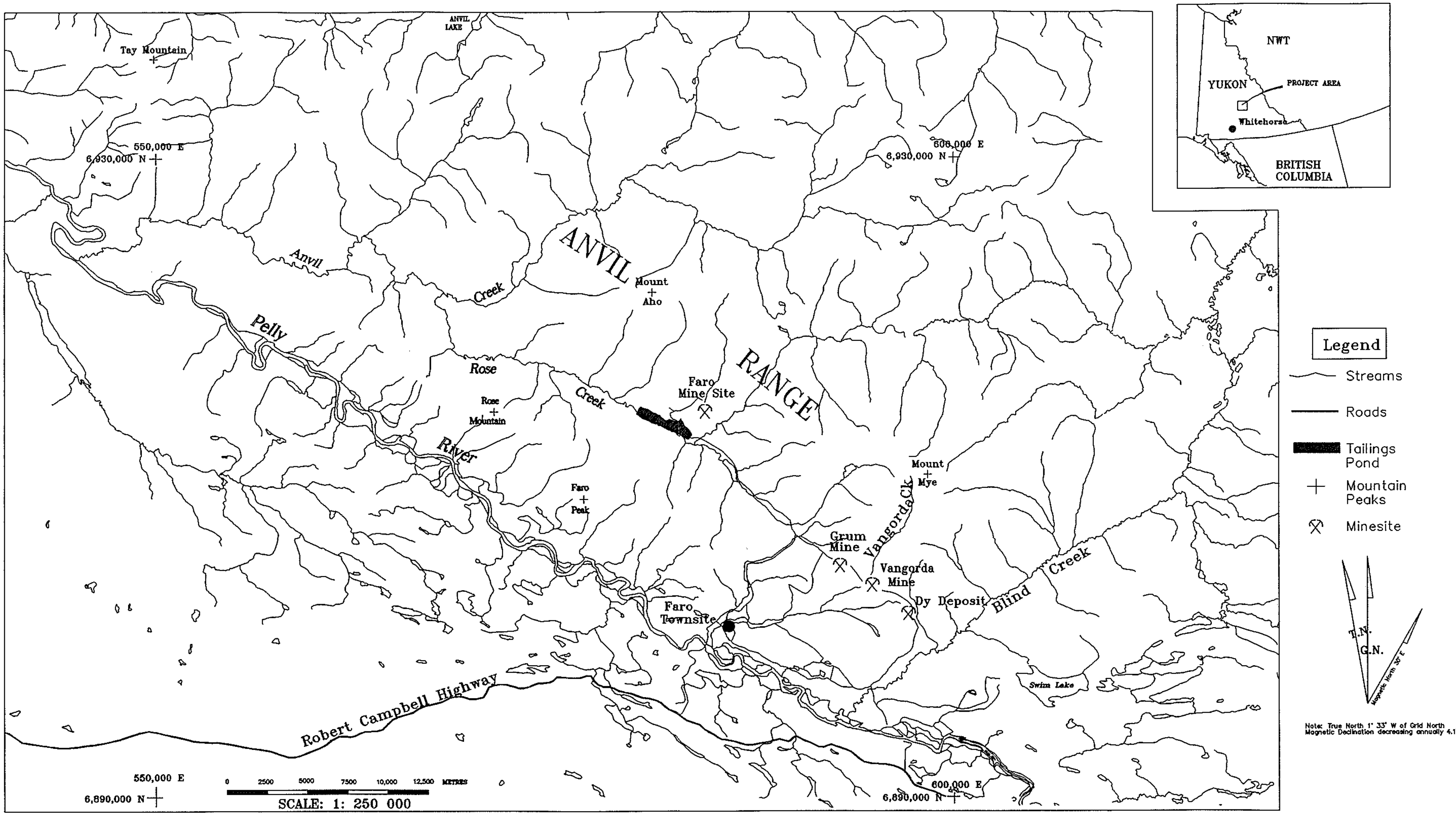
Summary Report on Schedule D to Water License #IN89-001, Faro Mine, Yukon, by Steffen, Robertson and Kirsten, August, 1992 (SRK No. 60648).

Faro Decommissioning Overview of the Environmental Plans, Curragh Resources Inc., Dec. 1991

Proposed Modifications to the Grum Waste Rock Dump, Anvil Range Mining Corporation, Feb., 1996.

Construction Report Vangorda Rehabilitation PWGSC Project 760831, Vangorda Plateau, *Faro Mine, Yukon Territory*, Steffen, Robertson and Kirsten, Nov., 1994.

Modification of the Vangorda Waste Dump Design, Curragh Inc., circa 1992.



Notes: Map derived from 1:250,000 scale
NTS Mapsheet 105 K
North American Datum 1927
Transverse Mercator Projection

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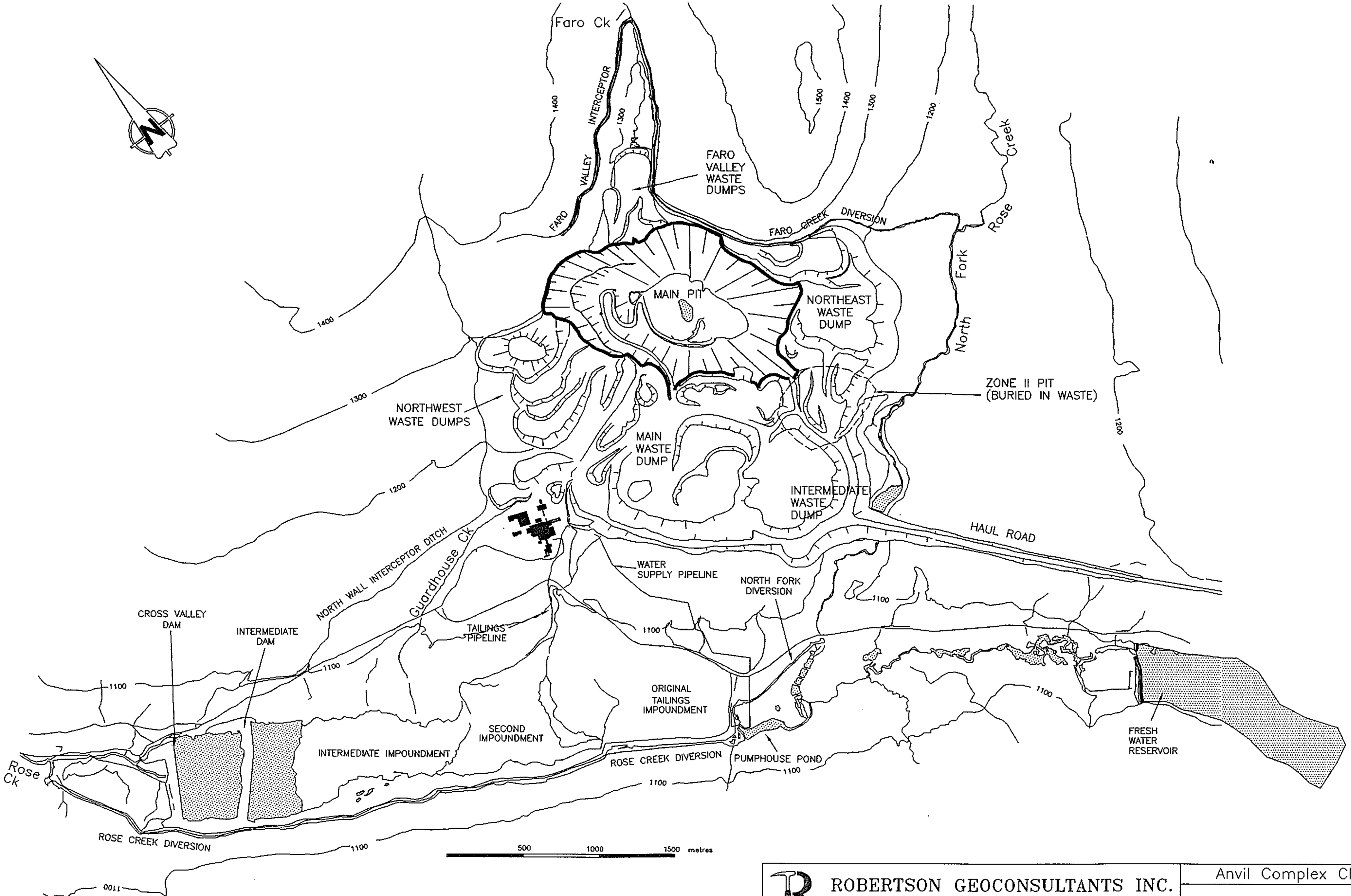
Anvil Complex Closure Plan

REGIONAL OVERVIEW

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		1-1



Notes:
Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour Interval 100 m
Universal Transverse Mercator Projection

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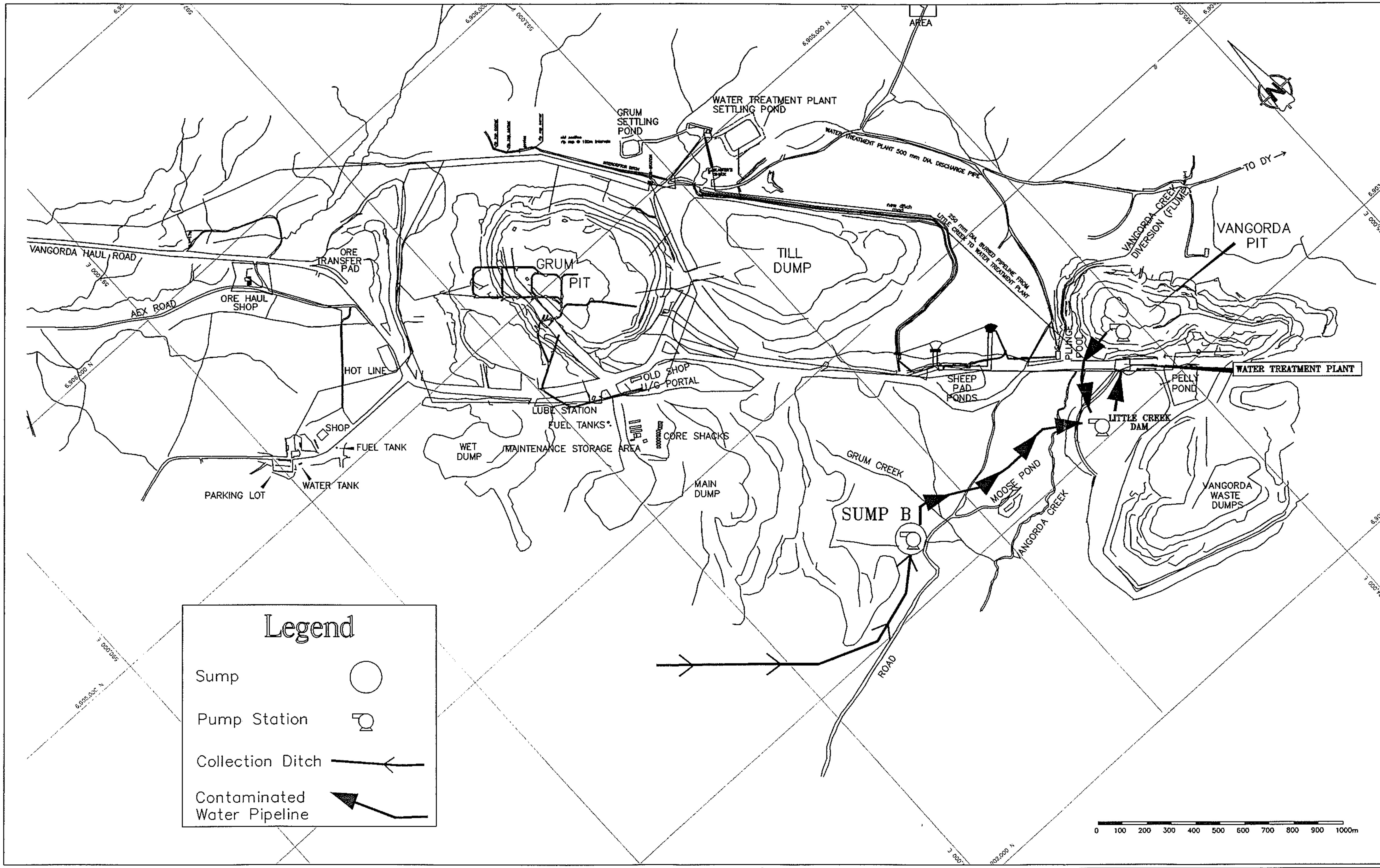
Anvil Complex Closure Plan

Faro Overview

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		1-2



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Anvil Complex Closure Plan

Vangorda Plateau Overview

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		1-3

2. Closure Plan Philosophy

2.1 Philosophy and Approach

In the mid to late 1960's, when the Faro lead-zinc deposited was first identified, the general public had little involvement with, or appreciation of, the mining industry. The technological advances of the time focused on improving production, reducing costs, and improving worker safety. Recognition of the potential environmental impact of mining operations was only beginning to develop.

Since the early 1960's, there have been significant advances made by the industry in the integration of environmental management practices into mining operations. Over the past 40 years, there have been well publicised, major failures in mines around the world have resulted in deaths both of workers and the general public. These failures attracted international attention, and resulted in public inquiries which highlighted the need to predict and control these physical failures.

In terms of environmental impact, the other major area of concern that has long been recognized is the oxidation and leaching of metals releasing contaminants into receiving waters. In the past 15 years, there have been remarkable advances in the technology both to predict and control these reactions, and the resultant potential adverse impacts on water quality. The Faro mine, under the operation of Curragh Resources, participated in some of the early research on acid mine drainage prediction and control for both waste rock and tailings.

For the mining industry, much of the applied technology has only been available in the past 15 years or less - mines in production before this time were not generally designed or operated with this awareness of environmental management. The Anvil Range complex is one such site, where mining began in the late 1960's and has continued with intermittent shutdowns to this day. Thus, approaching closure, these sites must assess the environmental impact and develop plans for closure that address not only current, but past, operational practices. Clearly the funds available for closure are not unlimited; the assessment of environmental impact and closure requirements must look at the components of the site and the site as a whole (an "integrated" or comprehensive plan) and must select measures and allocate resources to address the major issues of environmental impact.

All countries are increasing their environmental protection requirements and adopting more stringent standards. Globally, there is a trend towards "Designing for Closure" with environmental protection and closure measures being designed into existing mine operations, and being mandatory for opening new mines. Closure plans have been developed for various aspects of the Anvil Range Mining Complex under different operators. This plan represents the first, comprehensive closure plan for the Faro, Vangorda and Grum mines. Under Anvil Range, progressive reclamation is part of the Vangorda Plateau mine operations and will increasingly be so, once this comprehensive closure plan is accepted for the three mining areas of the complex.

The Ontario Ministry of Northern Development and Mines has produced a guideline for the "Rehabilitation of Mines - Guidelines for Proponents" (October 1994) which discusses some of the philosophy and technology for closure planning. The general principles of closure planning which are used throughout the international mining industry are summarized below, and are also discussed in the above reference.

As a mining company or regulatory authority considers the "acceptable" closure of a mine, there are some hard facts that must be faced; there are some mines from which we can never "walk away" - to achieve an acceptable environmental impact from the closed out mine, there may be a requirement for long term care or maintenance. Clearly this is the least desirable state of closure, and one which would only be faced at an older operation which was not designed for closure and is facing problems such as acid mine drainage or unstable major structures requiring continued maintenance.. The Anvil Range Mining Complex, with the longer term potential for oxidation and acid rock drainage is probably a site that will require long term care - either active care in terms of treatment or passive care in which at least periodic treatment, monitoring and maintenance is required. These terms are described more fully in the Ontario Guidelines.

In planning for closure, there are three key aspects that must be considered in determining if the site requires active care, passive care or is potentially a "walk-away" solution:

- protection of public health and safety;
- alleviate or eliminate environmental damage; and,
- allow a productive use of the land in its original condition or an acceptable alternative.

These are often broadly discussed as the "impact" or environmental impact of a site or a closure plan. For each of the considerations of impact there are three technical aspects that must be considered:

Physical Stability: buildings, structures, workings must be stable and "must not move". In the Ontario Guidelines the description is provided, "Physical structures such as crown pillars, pit slopes, underground openings, tailings dams and spillways must be stable to eliminate any hazard to public health and safety... " to which could be added ...or the terrestrial or aquatic receiving environment.

(Geo)chemical Stability: metals and "other" contaminants must be stable, that is, must not leach and/or migrate into the receiving environment, or, as described in the Ontario Guidelines for Closure, "Surface waters and groundwater must be protected against adverse environmental impacts resulting from mining and processing activities."

Land-use "In a closed out conditions the rehabilitated site should be compatible with the surrounding lands." (Ont. Guidelines).

Thus the major topics that would be addressed in any closure plan would include:

- naturally occurring physical hazards;
- level of environmental impact or benefit and the associated costs;
- expected post-operational use of the mine site and the compatibility with the land surrounding the site;

- traditional and current use of the land;
- conditions prior to mining.

To address these topics and technical areas in a logical manner for each site component, the following flowsheet was developed for the preparation of this Closure Plan:

History of Site Development

- understand history
- identify all site components and receiving environment

Characterization of

- physical development
- water chemistry, geology
- sources of water quality contaminants
- public health and safety concerns

Implementation

- reclamation during operation e.g. Vangorda dump
- revise operating plans to include closure measures
- continue to contribute to closure fund during operation
- monitor, particularly at areas which are "closed"

2.2 Objectives for this Plan

It is an objective of all closure plans to achieve 'walk away' conditions such that no long term monitoring or maintenance will be required following mine closure. Such a condition cannot be achieved at the Anvil Range complex within reasonable economic criteria. Thus it becomes an objective for the Closure Plan to minimize the amount of post closure monitoring and maintenance to the extent reasonably achievable considering incremental costs for incremental reductions in active care requirements and environmental risk.

The assessment criteria, as to what constitutes 'a reasonable level of post closure active care, costs and environmental risk' will differ for Anvil Range, the Yukon Water Board and other intervening parties in the permitting process. Assessments of the appropriate criteria must be made and presented in the Closure Plan to form a basis for decision making. The rapid changes that are being experienced in Canada in the application of environmental criteria for mining projects results in considerable uncertainty as to the acceptability of many criteria, particularly those involving on-going active care and risk of environmental impacts.

Selection of inadequately 'low' criteria may result in the rejection of the Closure Plan or the imposition of additional and stringent closure requirements in the permits. Selection of 'high' criteria may result in closure costs which are not economically achievable. The selection of criteria are therefore a balance between financial capability and the cost of reducing requirements of future active care and of future risk to the environment. In the development of the Closure Plan, the consultants will provide assistance and guidance to the best of its ability to assist Anvil Range in their selecting of the criteria for discussion with the Technical Advisory Committee and regulatory authorities.

3. Regional Setting

Note: for each of the sections in this chapter there will probably be a Technical Appendix containing the key data.

The following sections which describe the "natural" environment are necessary for the closure plan both to determine the objectives for closure - that is, what issues are sensitive/priorities, and to determine the standards that should be aimed for at closure - that is, we don't need to make things "cleaner" than they were before mining started.

3.1 Location and General Property Description

To be extracted from existing reports.

3.2 Geology

This section will explain the mineralogy and geochemistry of each of the major ore and waste rock types of the district. The purpose will be to provide a framework for understanding the static and kinetic geochemical rock test work described in Chapter 4. A brief discussion of structure will be included to provide a basis for understanding the hydrogeological setting. This will be summarized from existing reports, however, new work will be required for the seismic evaluation.

3.2.1 Regional Geology

3.2.2 Ore Deposit Geology

3.2.3 Rock Sampling Program

This section will describe the samples collected and indicate what the samples represent for interpretation purposes. Most samples collected are mixed materials from the dumps in contrast to previous sampling which focused on fresh drill core of pure rock types. Details of samples will be included in a technical appendix. Specific details relevant to specific dumps or pits will be further discussed in Chapter 4.

3.2.4 Rock Testing Program

This section will describe the laboratory static and kinetic tests done to characterize acid generation and leachable metal load. The section will contain a brief description of methods and a detailed description will be included in a technical appendix. A summary of the results will be provided in this section with complete details in the technical appendices. This section will introduce the test program and results, but Chapters 4, 8, 9 and 10 will deal with loading implications and prediction of future performance of the rock types.

3.2.5 Seismic

This section will assess the maximum credible earthquake (MCE) on the basis of a new analysis of regional fault patterns by a specialist.

Studies in progress:

- *Phase I seismic assessment by Bruce Geotechnical*

Additional investigation requirements:

- *possibly Phase II seismic assessment by Bruce Geotechnical*

Information requirements from Anvil:

- *see Section 4.1*

3.3 Soils

This section will be extracted from existing reports, primarily those done by Kerr Addison for the Grum development. This section will discuss soils, landforms, and vegetation maps plus using some air photos.

Additional investigation requirements: ?
Studies in progress: none
Information requirements from Anvil:

- *Kerr Addison/Montreal Engineering Grum Report on Biophysical Studies*
- *black and white air photos*

3.4 Vegetation

This section will be extracted from existing reports.

Additional investigation requirements: ?

Studies in progress: none

Information requirements from Anvil:

- *Kerr Addison/Montreal Engineering Grum Report on Biophysical Studies*
- *colour air photo coverage (1979)*

3.5 Wildlife

This section will be prepared with assistance from Grant Lortie. The text will document:

- species, abundance, diversity
- seasonal land use
- pre-mining wildlife
- summary of studies and considerations for wildlife in design and construction of Vangorda Plateau
- effect of mining operations and, consequently, considerations for closure

Additional investigation requirements: none

Studies in progress: information review by G.L.

Information requirements from Anvil:

- Kerr Addison/*Montreal Engineering Grum Report on Biophysical Studies*
- Sheep Reports - MacLeod, etc.

3.6 Climate

This section will largely summarize work which was undertaken in past studies. The main source of information will be a detailed assessment of the climate of the Faro mine site conducted in 1990 as part of the decommissioning study for the Down Valley Tailings Impoundment.

The climatic data available in 1990 were adequate to provide a reasonably accurate assessment of the mine site climate. No revisions to this 1990 study are necessary as no new climatic data have been collected at the mine site over the past six years. The Closure Plan report will contain estimates for the following climatic parameters:

- air temperature;
- precipitation (for both average and extreme conditions);
- snowpack;
- evapotranspiration; and,
- lake evaporation.

3.7 Hydrology

The most recent assessment of the hydrology of the Faro mine site was conducted in 1990, as part of the decommissioning study for the Down Valley Tailings Impoundment. At that time, few measurements had been made of the flows in the mine site streams. To estimate the magnitude of these flows, reliance had to be largely placed on the data collected by the Water Survey of Canada (WSC) at their network of regional streamflow gauging stations.

Various techniques were used to transfer these data to ungauged points on the mine site streams. These transferred data likely provided the best estimates of mine site streamflow that could be made at the time. However, two weaknesses existed in the database used to conduct the 1990 hydrology study. Firstly, most of the WSC stations were sighted on large rivers, with catchments one to three orders of magnitude larger than those commanded by the mine site streams. Secondly, stations some distance from the mine site (i.e., over 100 km away) had to be utilized in order to provide sufficient data to perform the hydrological assessment.

In the intervening period since the last hydrology study was completed, the streamflow monitoring network in the vicinity of the Faro mine site has been significantly enhanced. These enhancements have been realized by both the mine and the government. In the case of the mine, automatic water level recorders were installed at three key points around the mine site. Furthermore, spot flow measurements (made by a current meter) were taken on a more frequent basis than in the past.

The government monitoring network was improved by the addition of three new stations in close proximity to the mine site. These are:

- 09BC005 Tay River near the mouth;
- 09AH005 Drury Creek at km 469 Robert Campbell Highway; and,
- 29BC005 Blind Creek near Faro.

The first two stations were installed by the Water Survey of Canada (WSC) while the remaining one was established by DIAND.

With this improved streamflow monitoring network, we will be able to refine our understanding of the mine site hydrology because:

- we now have more stations in close proximity to the mine site; and
- a greater proportion of the gauging stations now measure flow from small catchment areas (i.e., < 300 km^2).

A hydrological study incorporating the improved streamflow database is now underway. Much of the work to date has been focused on assembling and processing the available data. Many of the collected streamflow records were found to contain gaps of missing data. These gaps were "patched" using correlations with the records of neighbouring streamflow stations. A detailed account of the patching process was presented in a memorandum prepared for the Closure Plan.

The prime objective of the hydrology study will be to characterize the flows in the mine site streams during average, drought, and flood conditions. A selection of the types of flow statistics which will be provided in the Faro Closure Plan report are listed below:

- the long-term average annual and monthly flows;
- the 200-year peak instantaneous flow; and,
- the 100-year, 1-day minimum annual flow.

3.8 Hydrogeology

The study region is underlain almost exclusively by mixed crystalline rocks of low permeability which do not support deep regional groundwater systems. Instead, most groundwater in this region is confined to local shallow aquifers in surficial deposits of glacial till and fluvial sands and gravel. These surficial deposits are distributed irregularly within the region typically comprising thin deposits in the upland areas and thicker deposits in the valleys. These shallow groundwater systems are annually recharged during spring runoff and intense summer rain storms and discharge in near-by creeks and streams.

As a result of short flow paths the shallow groundwater has a low solids content and its water chemistry is similar to that of surface water in the area. In contrast, deep groundwater within the bedrock is typically of poor water quality (acidic water containing sulphides and base metal) in particular when it has been in contact with orebodies.

Data on pre-mining hydrogeology is limited to the borehole drilling program performed by International Water Supply Ltd in Rose Creek Valley to determine the properties of the valley aquifer as well as drilling and pumping at Grum and Vangorda to dewater the area before and during pit excavation.

RGC has obtained all records of IWS study in Rose Creek Valley and several Piteau reports on dewatering the Grum Pit. However, little is known about the situation at Vangorda (any information on old drilling records, pump rates during dewatering etc.)

Most of the recent data on hydrogeology has been collected at the Faro mine site. Several monitoring boreholes were installed in compliance with different water licenses in the Down Valley Tailings area (Midnight Sun, 1981 and ??) and at the toe of the Main waste dump near the "sulphide cells" (EBA Engineering, 1989). These monitoring wells have since been monitored for water level and water quality. In 1990, SRK dug several shallow pits along the toes of the Northwest, Main, and Northeast waste dumps and sampled shallow groundwater for water quality. Prior to backfilling, a standpipe was placed in these pits. However, these standpipes were not included into the routine monitoring program and recent inspection suggests that they are of limited use today.

Most recently, the Zone II pit area was studied by drilling deep and shallow boreholes and installing multi-level piezometers for water quality monitoring (SRK, 1994). Several of these boreholes are now being monitored for water quality and water level.

As outlined in earlier memos to Anvil it is important that water levels in Faro Pit, Zone II pit, and surrounding boreholes be monitored as the Faro pit is filled with tailings to detect any potential seepage from Faro pit to Zone II or even North Fork Rose Creek early on. RGC will need this data to verify and/or update the groundwater model developed for this area.

Current data on the hydrogeology at the Grum/Vangorda is relatively sparse. Several groundwater monitoring wells were installed downstream of the Vangorda waste dump by Midnight Sun in 1994. However, these monitoring wells were sampled infrequently after installation. At the Grum site several boreholes were drilled in the immediate vicinity of the Grum Pit as part of the on-going dewatering system. Anvil Range is currently monitoring groundwater levels in these boreholes (and pumping rates) on a bi-weekly to monthly basis.

Information requirements from Anvil:

- RGC has no records of water quality and water levels measured downstream of the Vangorda dumps (DIAND?). We understand that ANVIL is keeping a record of water levels and volumes pumped during dewatering at Grum (and Vangorda?) pits. RGC requires these records for estimating groundwater inflows and length of time needed for pit flooding. Any records of groundwater quality at Grum and Vangorda. Any maps of depth of overburden for the Vangorda Plateau area?
- original topography map, Lockwood, 1964, Faro area;
- overburden depth map/drill holes, Faro area;
- zone 2 pump records;
- Vangorda pit recharge records;
- Grum dewatering well data.

3.9 Water Quality

The database of water chemistry monitoring over the past 10 years of operation has been compiled in spreadsheet format, and used for the majority of these evaluations. Some the data were provided in electronic form (DIAND database) while most had to be entered.

These data represent a considerable accumulation of information, and some limit had to be set as to the information to enter into the database, if not already in electronic form. In some cases, the period of record spans a longer time period than 10 years. These data have been considered in the evaluation of trends in water chemistry and geochemistry over time, but have not always been included in the electronic database.

Considerable effort was put into compiling this database into a convenient and useful format - both for the closure plan and for existing operations, to continue to monitor trends in water chemistry. The database management program "EQWin" developed by Teck Corporation for their mine sites was used to assemble the database and do statistical and trend analyses of the data, and prepare figures for presentation in this report.

Appendices will contain summary tables for key locations along with graphs of selected parameters.

3.10 Aquatic Resources

This chapter, and the chapters on rock testing and site water chemistry, are probably the most important chapters of the closure plan. The protection of water quality and therefore of aquatic resources tends to be the single largest issue for either closure or opening of a mine. Zinc is also one of the biggest issues in terms of fish because it is relatively mobile (chemically) and available over a wide range of water chemistry conditions - i.e. wide range of pH and alkalinity values encountered in natural waters.

The yardstick that tends to be used by regulatory authorities for water quality are the CCREM guidelines, and specifically those for the protection of aquatic life which specifies a maximum value of 0.03 mg/L total Zn as the limit. These have been specified as the criteria that must be achieved in Rose Creek for closure and, we suspect, may be the requirements for other areas as well. To achieve these limits would have significant technical and cost implications for the closure plan. It is in Anvil's interest to product site specific evidence; these guidelines are too low.

It is important to discuss in some detail is that there is documented evidence of fish in waters with zinc concentrations greater than the CCREM limit, in the area of the mine. In 1992, the regulatory authorities and Curragh Resources initiated a study into these waters, and the fish populations. This was the start of the Technical Advisory Committee supervised investigation work carried out by an independent fisheries consultant. The major work done was a test on the response of the stream community (benthic invertebrates and periphyton, but not fish) to additions of small amounts of zinc magnesium mesocosm. The work showed tolerance to zinc many times greater than CCREM guidelines, but more follow up work was called for.

Unfortunately the study was never completed, and only a draft report issued in 1993. It is strongly recommended that Anvil re-initiate this program with the government. Evidence, from an "independent" study group, that there can be a healthy benthic community in waters with elevated metal concentrations (compared to closure licence requirements) would be strongly in Anvil's favour when designing and negotiating for closure criteria.

3.10.1 Fisheries

This chapter will summarize the fisheries investigations to date and highlight the aspects relevant to closure:

- species, abundance, diversity for each drainage and/or watershed;
- sensitive areas or species and therefore priorities for closure;
- changes over time;
- relate fisheries to water chemistry for each drainage and/or watershed;
- aspects to consider during the actual closure activities; and,
- long-term implications of closure measures - e.g. results of changes in creek diversions etc.

This section will be compiled from existing reports done for Rose, Anvil, Vangorda, and Blind Creeks.

Additional investigation requirements: re-initiate the Mesocosm investigation
Studies in progress: none
Information requirements from Anvil:

- *reports on all fisheries work by Derdes and earlier; probably available in Whitehorse office.*

3.10.2 Benthic Invertebrates

This section is related to both the fisheries and the sediment studies, and is related to the evaluation of environmental impact on the receiving waters. Benthic studies have been done in the major creeks for many years at the site. This chapter summarizes those studies, discussing the points that are relevant to closure, similar to fisheries above. Benthic results may be useful in placing environmental risk of structural failure in context since there was a major tailings discharge in the mid 1970's. It may be possible to document a gradual recovery of the ecosystem.

Additional investigation requirements: none specific to closure
Studies in progress: none specific to closure; however, sampling will be done in Rose Creek and Anvil Creek this year which could provide useful information on ecosystem recovery.
Information requirements from Anvil: none

3.10.3 Sediment Studies

This section is related to primarily to the benthic investigations and is related to the evaluation of environmental impact on the receiving waters. Sediment studies have been done in conjunction with benthic studies for several years at the site (but not as long as the benthics). This chapter summarizes those studies, discussing the points that are relevant to closure, related to the benthic studies above. Sediment investigations may also be useful in addressing transport of fines and/or tailings and the resultant impact (or lack thereof), e.g. as a result of the tailings migration downstream of the impoundment as a result of the spill in the mid 1970's.

Additional investigation requirements: none specific to closure

Studies in progress: none

Information requirements from Anvil:

- *information on tailings spill - time,*
- *volume of tailings and water spilled,*
- *mechanism of spill - dam breach, piping?*

3.11 Land Use

One of the aspects of the Impact Assessment in this closure plan is an evaluation of the impact of the closure on the local community and related issues for the local environment. Two of the three main issues with respect to closure planning are based on the projected land use; public safety and land use. The goal of the closure plan would be to return the land to "...use which is the same as or commensurate with the use prior to mining..". This former and future of the land is discussed in this chapter.

The most significant issues will probably be the maintenance of the roads and access to the area for recreational land users, and the control of inadvertent access to open pits etc.

We have assumed that reclamation of the town, its' municipal infrastructure (water supply, sewage, garbage disposal) as well as the power and transportation infrastructure of claims is beyond the scope of this plan.

3.11.1 Historic

With reference to the Ross River Dene Land Use and Occupancy study.

3.11.2 Current

Current land use is mainly mining with limited recreational hunting and considerably reduced subsistence hunting and trapping.

Additional investigation requirements: none specific to closure

Studies in progress: none

Information requirements from Anvil:

- *commitments made to local communities with respect to jobs, roads, services;*
- *current and future responsibilities and ownership of access roads versus YTG responsibilities. This should probably be in the form of a map showing road, surface, distance and responsibility for maintenance now and in future;*
- *any commitments made regarding Faro townsite.*

4. Mine Components - Faro

Chapters 4, 5, and 6 describe the components of each of the three mines of the Anvil Range Complex. The purpose of the chapter is to set the stage for the closure measure's section by characterizing the components, defining key issues, and providing a best guess of how the component will evolve if left as is. In some cases, a more detailed description of the component may be provided in a subsequent chapter if more appropriate for discussion of closure measures or impacts.

- List of components and for each a discussion of:
  - location
  - history of development and use
  - size and configuration (tonnage, planimetric area, constituents)
  - catchment, local water courses i.e. "zone of influence"
- Drawings

4.1 Mine Workings

4.1.1 History of Development

Brief discussion - dates, tonnage, development of Zone I, III, and II pits, backfilling of Zone II pit, tailings deposition in Main pit. Also need to mention the underground workings in the Faro pit and possibly the sulphate reduction scheme.

4.1.2 Main Zone Open Pit

4.1.2.1 Pit Geology

Overall geology and rock types have already been discussed in Section 3.2. This section will focus more on proportions at this site and local distributions. This section is critical to the estimation of long-term water chemistry in the open pit, and therefore to decisions discussed in the closure section. The two aspects to be discussed with respect to closure are:

- rock types and surface area of exposure in the pit walls, based on geologic mapping and bench plans for the ultimate pit limits; and,
- structural - for discussions of stability, estimation of broken rock on benches, and for modelling of groundwater inflow and seepage.

4.1.2.2 Structural Geology and Physical Stability

A brief section - depending on the decisions made regarding the Faro Creek Diversion which would be the key stability issue related to the pit. Probably not too important, except as relates to groundwater seepage and the water balance, and to the stability of exposed walls above final flooded elevation in pit.

4.1.2.3 Water Balance and Pit Geometry

The topics addressed in this section are:

- hydrology;
- water level in pit and influence of flooded elevation(s) to groundwater flow;
- height capacity curve which is required for estimation of available storage volume, plug dam requirements;
- groundwater inflow;
- groundwater seepage (Zone II pit) - a major issue;
- capacity required to retain flood or failure events.

4.1.2.4 Geochemistry

This section will address the potential both for alkali and contaminant release from the wall rock, the waste rock and the tailings in the pit. It is critical to the decision about the closure measures for this site in that:

- if it can be shown from the geochemical testing and water balance/chemistry modelling that the pit can achieve an acceptable discharge limit then the pit would not become a contaminated water storage area, there would be no reason to maintain the Faro Creek Diversion, and the treatment requirements for the site would be greatly reduced; or,
- if, as is generally expected, the pit water would not be acceptable for discharge without some treatment this determines the closure requirements for many of the other Faro site components as discussed further in the closure chapter. The prediction of the pit water chemistry then becomes critical to the estimation of water treatment requirements, lime (or alternative treatment reagent), volume of sludge generation, and ultimately the financial requirements for "perpetual" treatment.

Either way, this prediction of water chemistry for the Main Pit is key to the closure plan.

4.1.2.4.1 Current

- Current and historic water chemistry - both surface water and groundwater
- Predictions based on waste rock testing
- Relate this geochemistry to the pit wall geology, which will form the basis for the water chemistry predictions.

Some of the key questions to be discussed for determination of closure measures and therefore herein are:

- What is main source of loading that has consumed alkalinity from the tailings?
- Quantify current and future loading from exposed pit walls.
- What is happening (geochemically) in Zone II?
- Is it going to get worse - and how much?
- Contribution of contaminants from Valley Dam to pit water. Would this loading be the "make or break" in terms of achieving acceptable water chemistry in the pit in the long term?
- If treatment is required we will need to evaluate the option of pumping from Zone II pit to maintain a water level that will prevent discharge.

4.1.2.4.2 Composition

- Discussion of geochemistry of waste rock in pit.
- Discussion of pit wall rock geochemistry.

4.1.2.4.3 Geochemical Testing

4.1.3 Open Pit - Zone 2 including dumps

4.1.3.1 Geology

As above for Main Zone Pit.

4.1.3.2 Physical Stability

Maybe only relevant for dumps within the pit but some discussion of the fractured sill between the pit and the north fork of Rose Creek may be warranted.

4.1.3.3 Water Balance

This section may be done as part of the Main zone pit, but there are some distinct issue to address for this pit:

- hydrology and effects of dumps in retaining water, evaporation, runoff;
- groundwater inflow and influence of change in flooded elevation in main pit;
- groundwater seepage and influence of change in flooded elevation in main pit;
- differentiate the waste rock that drains into pit from NE dumps that drain away from pit.

4.1.3.4 Geochemistry

The items address in this section include:

- geochemistry of waste rock deposited in pit;
- current and historic water chemistry - both surface water and groundwater;
- predictions for future leaching and oxidation based on waste rock testing;
- calibration of geochemical test results to the monitoring data (pumping, groundwater, receiving waters).

This section will conclude with a prediction of the metals loadings to the pit water and, combined with the Main Zone pit work, estimate of the longer term water chemistry in the pit water and (any) seepage.

Additional investigation requirements: none specific to closure
Studies in progress: none
Information requirements from Anvil:

- *decision and/or design constraints on plug dam. This decision relates to both the decision on reprocessing of tailings, and to the potential use of the pit for water storage prior to treatment and/or treatment sludge storage;*
- *for each of the Main Zone and Zone II pits require the pit geology plans, and the geology bench plans for the ultimate pit limits;*

- *general description of the geology and structure of each of the pits - probably can be extracted from existing reports;*
- *rate of water level rise during shutdown and tailings deposition - and also pumping records from Zone II pit;*
- *any other water chemistry data from sampling in the pit;*
- *volume of tailings solids and water placed in pit;*
- *information on solids geochemistry of tailings put in pit, including amount of lime added during flotation, sulphide content, any metal oxides in ore?*
- *chemistry of water pumped from Zone II pit.*

4.2 Waste Rock Dumps

The Faro waste dumps are well recognized by the regulatory authorities as the largest (potential) source of long term metal loads for the site. While the tailings are obviously of concern, it seems to be agreed that the tailings will continue to leach metals. But the progression of the tailings oxidation can be more readily modelled than rock dumps, and mitigation options are more effective and practical. The tailings have been studied, modelled, monitored and water treated for many years. In contrast, the waste dumps have not in the past been studied in much detail, and there are few places at which dump drainage can be clearly identified and monitored. Thus there is not only the concern that the dumps will get worse over time (because there is no clear understanding of how far along the acid generation and metal leaching processes have proceeded), there is also the concern that the drainage may "escape" detection. Therefore the issues for closure associated with the waste dump are large:

- have dumps gone as "acid" as they will go? i.e. how far along on the acid generation curve;
- how much water actually flows through the dumps i.e. infiltration, evaporation and channelling, plus question of field saturation. This will be related to both hydrologic balance and particle size;
- where does the dump drainage report to the receiving environment - and how would it be collected (assuming collection and treatment is required);
- Is it possible to isolate certain dumps (or areas of the dumps) which are the main sources of acidity and metals. The related question to this is to

determine where these dumps drain; what is, and has been, the contribution of this drainage to the pit?

The comments in this section apply to all similar sections relevant to waste dumps and to some extent to pit wall rock that follow.

4.2.1 Faro NW Dumps

4.2.1.1 Description

Details of development, construction and composition specifically relevant to geochemistry and to the predictions of water chemistry and therefore the closure measures.

4.2.1.2 Physical Stability

Referring to current conditions, existing reports, identify potential concerns including seismic, hydrologic events.

4.2.1.3 Hydrology and Drainage

Discussion of water flow, infiltration, residual moisture capacity, drainage flowpath and discharge to the receiving environment.

4.2.1.4 Geochemistry

4.2.1.4.1 Current

Based on results in surface water quality monitoring stations and groundwater wells downstream. This assessment is both to identify the metals of concern for the dump, and to understand the extent to which oxidation, acid generation and metal leaching/precipitation have developed in the dump and along the flowpath.

4.2.1.4.2 Composition

Geology/mineralogy, reference to appendix for details on rocks

4.2.1.4.3 Geochemical Testing

This section summarizes key results used as input to the long-term predictions of water chemistry and to the evaluation of the geochemical stability of the component. The testing also relates back to the assessment about the extent to which processes have developed in the dumps.

4.2.1.4.4 Predictions of Water Chemistry

This section presents the model for current geochemistry and drainage, with discussions of future drainage chemistry if no remediation. It is important to present detailed predictions for the closure case. The results of current water quality monitoring will be used primarily to calibrate predictions made from the results of the lab tests.

4.2.2 Faro Creek Valley Dump

4.2.2.1 Description

Composition of the dump as well as description of the surface to set stage for purpose and extent of closure measures.

4.2.2.2 Physical Stability

Composition of the dump as well as description of the surface to set stage for purpose and extent of closure measures.

4.2.2.3 Hydrology

Additional considerations for this section include the flux and therefore the contaminant loadings for:

- additional surface water flow from Old Faro Creek plus diversion drainage;
- groundwater flux at interface, and flows through waste rock versus through original ground.

4.2.2.4 Geochemistry

As above.

4.2.3 Faro Main and Intermediate Waste Dumps

4.2.3.1 Description

Location, size, geometry, period of development, particularly with reference to sulphide cell and cover.

4.2.3.2 Physical Stability

Refer to current conditions, existing reports, identify potential concerns including seismic, hydrologic events.

4.2.3.3 Hydrology

Where does water drain - surface versus groundwater.

4.2.3.4 Geochemistry

Key points included in this section are:

- sulphide cells - design and construction;
- current "impact" based on results in surface water quality monitoring stations and groundwater wells downstream;
- composition - geology/mineralogy, reference to appendix for details on rocks;
- geochemical testing results, reference to appendix for details on testing results;
- model for current geochemistry and drainage, with discussions of future drainage chemistry if no remediation. It is important to present (and do) detailed predictions for the closure case only. The current situation will be used more to calibrate predictions made from the results of the lab tests.

4.2.4 Faro NE Dumps

With notes as above for dumps.

4.2.4.1 Physical Stability

4.2.4.2 Hydrology

4.2.4.3 Geochemistry

4.2.4.3.1 Current

4.2.4.3.2 Composition

4.2.4.3.3 Geochemical testing

4.2.4.3.4 Predictions of Water Chemistry

Additional investigation requirements: none specific to closure
Studies in progress: kinetic geochemical testing
Information requirements from Anvil:

- *as-built reports for waste dumps, geotechnical inspections, possibly require a survey of the sulphide cell area and cover - maybe old air photos*
- *pre-mining maps for drainage divides*
- *air photos of various ages for development of dumps*
- *update mapping (survey or air photo) of final dump configuration*

4.2.5 Near Pit Dumps ("Ranch" area dumps)

Dumps on southwest side of Faro Pit are partly in the pit, but would be above eventual flooded level. These may pose a water quality concern.

4.2.5.1 Description

Size as well as general description

4.2.5.2 Geochemistry

4.2.6 Low Grade Stockpiles (A and C)

Two large stockpiles beside former main ramp entrance to Faro Pit will require discussion as they represent a significant potential contaminant source.

4.2.6.1 Description

Emphasize size as well as general description.

4.2.6.2 Geochemistry

4.3 Rose Creek Tailings Facility

4.3.1 *Studies to date*

The tailings facility has long been the main subject of discussion for the Faro closure. The existing studies regarding closure will be summarized. It was originally intended to keep this section very brief, and emphasize the closure option of tailings reprocessing. Discussions with the TAC committee and their consultants though has emphasized the need to review the geochemical predictions, and the closure options for this plan.

4.3.2 *Description of Facilities*

4.3.3 *Geochemical Characterization*

This section on characterization of the tailings however will be brief, referring the reader to existing documents which have been submitted to the government.

Additional discussion in this section will focus in review of the water chemistry data for any changes that have occurred.

4.3.4 *Hydrogeology and Hydrology*

Discussion will focus on the physical stability of the tailings dams, given that reprocessing is the current selected option and on the water chemistry and contaminant loading issues related both to recovery of tailings for reprocessing and to the tailings that would remain in the facility.

Additional investigation requirements:

- *method for recovery of tailings*

Studies in progress:

- *reprocessing feasibility*

Information requirements from Anvil:

- *reprocessing feasibility*
- *discussion of amount of tailings that would be recovered*
- *design, as-built and inspection reports on tailings dams and on groundwater monitoring wells (Golder tailings dam inspection report from 1995?)*

4.4 Faro Pit Tailings Facility

- *General description of the pit tailings capacity of pit, composition, etc.*

4.5 Water Management Structures

In contrast to the above discussions of the mine workings and the dumps, the description of the structures that are used for water management must address primarily the physical aspects:

- design events and capacity for extreme events;
- design and construction;
- spillways;
- freeboard;
- monitoring and maintenance requirements particularly in the longer term - based in part on current experience.

The chemical or geochemical issues are generally related to the final flowpath of the water, both at closure and as a result of a failure of the structure - e.g. if Rose Creek were to flow through the tailings, a certain contaminant load would be added to the Creek waters, or if Faro Creek were kept diverted and the diversion failed, the water would enter the pit.

4.5.1 Faro Creek Diversion

4.5.1.1 Setting

4.5.1.2 Hydrology (Capacity?) and Design Events

4.5.1.3 Physical Stability

4.5.2 Rose Creek Diversion

4.5.2.1 Hydrology and Design Events

Probably can use existing reports.

4.5.2.2 Physical Stability

Probably can use existing reports plus any assessment and engineering required for extreme events.

4.5.3 Fresh Water Reservoir

This discussion will be extracted from existing reports.

Additional investigation requirements: none specific to closure

Studies in progress: PMF review

Information requirements from Anvil:

- *design and as-built reports for above structures*
- *inspection reports*
- *maintenance records?*

4.5.4 North Wall Interception

4.5.5 Zone II Well

4.6 Mill and Pipelines

This section will be a general description of the site.

4.6.1 Buildings and Equipment

4.6.2 Stockpiles Near Mill

- *oxide fines*
- *Skagway sediments*
- *other stockpile bases*

4.6.3 Loadout and Surrounding Area

4.6.4 Water Supply, Pumphouse, Pumphouse Pond, North Ford Diversion

4.6.5 Tailings Pipelines/Drop Boxes

Additional investigation requirements: none specific to closure

Studies in progress: none

Information requirements from Anvil:

- *plan of plant site layout with facilities labelled, particularly items noted above in table of contents;*
- *water control, oil/fuel etc. disposal within shops;*
- *inventory of fuel, oil, storage tanks - age, volume, buried or surface;*
- *list of reagents used for processing, in laboratory;*
- *estimate of surface area of buildings, description of construction materials and surface area of concrete slabs/foundations;*
- *list of major equipment (or plan of mill showing equipment). It is not necessary to have detailed list - only major equipment that would require $ for removal at closure. Also comment on equipment/facilities that could be sold or salvaged at closure.*

4.7 Infrastructure

4.7.1 Roads

4.7.2 Borrow Areas and Other Disturbed Land

These areas can be very important to address in a closure plan, as the area often represents wildlife habitat. Compared to many closure activities, reclamation of borrow areas can be a low cost item with very high benefits in terms of acceptance of the plan.

4.7.3 Buildings and Equipment

4.7.4 Shops - main plus lube shack

4.7.5 Fuel, oil storage facilities

4.7.6 Power

Additional investigation requirements: none specific to closure

Studies in progress: identification of extent and use of borrow areas.

Information requirements from Anvil:

- *any descriptions available of borrow areas - or plans (1979 ortho photo maps and newer photos) showing these areas. It would be useful to identify old borrow areas to document how they "recover" and therefore limit the amount of reclamation work that may be required.*
- *water control, oil/fuel etc. disposal within shops;*
- *inventory of fuel, oil, storage tanks - age, volume, buried or surface;*
- *estimate of surface area of buildings, description of construction materials and surface area of concrete slabs/foundations.*

5. Mine Components - Vangorda

5.1 History of Development

Brief summary of pit and dump development, discussion of the shut-down and subsequent pumping, 1995/96 mining, closure activities on dump during shutdown.

5.2 Open Pit

The key issues for closure associated with the Vangorda open pit will be water quality and the related question of diversion of Vangorda Creek, and control of access or physical stability. The water quality issues will arise from loadings from the pit wall rock primarily. If Vangorda Creek is allowed to flow through the pit, the water quality discharging from the pit would probably have to meet CCREM standards as it is a receiving water. If the Creek can be kept hydraulically separate from the pit waters, then it may be possible to argue that the pit water chemistry could have a higher zinc concentration than CCREM, based on it being an effluent rather than a receiving water.

5.2.1 Geology

- rock types with pit wall mapping;
- structural - to be used for discussions of stability and of groundwater inflow and seepage;
- minerology of ore, particularly with respect to apparent rapid oxidation.

Once again, the geology of the pit walls is critical to the estimation of pit water chemistry. Thus accurate mapping information is required.

5.2.2 Physical Stability

Probably not too important, except as relates to groundwater seepage and the water balance, and to the stability of exposed walls above final flooded elevation in pit, and stability of the Vangorda Creek diversion if retained.

5.2.3 Water Balance

The importance of this chapter is providing the basis for estimating the amount and sources of water flowing into, and out of, the pit. These estimates are then used to estimate the contaminant loading and pit water chemistry. The topics addressed include:

- hydrology - including mention of Vangorda Creek Diversion, discussion of rate of rise of water during shutdown and pumping;
- height - capacity curve and determination of final flooded elevation;
- groundwater inflow - volume and source;
- groundwater seepage - volume and outlet.

5.2.4 Geochemistry

Topics addressed include:

- seep sampling data;
- pit water chemistry during flooded period related to the sources of contaminants - i.e. stockpile, oxidized area;
- predictions based on waste rock testing;
- relation of this geochemistry to the pit wall geology, which will form the basis for the water chemistry predictions.

5.3 Vangorda Creek Diversion

Most of this discussion is extracted from the existing design and as-built reports.

5.3.1 Hydrology (Capacity?) and Design Events

5.3.2 Physical Stability

5.4 Waste Dump

Again, most of this discussion is extracted from existing reports - IEE, Water Licence Application, Design Modification Report, 1994 As-Built Report (SRK) and documents from receiver.

5.4.1 Background

5.4.2 Closure to date

5.4.3 Physical Stability

5.4.4 Water Balance

5.4.5 Geochemistry

5.4.6 Water Quality

This section will primarily address the water quality monitoring from the dumps, and the use of these data to calibrate the water quality predictions for the other dumps. The government are well aware of the predictions for these dumps, and of the apparent underestimation of the rate and extent of oxidation or metal leaching from the Vangorda dump. This discrepancy can, in part, be explained by the addition of the oxide fines to the dump for the sulphide area. However, the release of metals from the phyllites will require most careful evaluation.

An additional issue to be addressed is that of the receiving environment for the drainage from the dumps - specifically, does it report to groundwater, thickness of underlying till etc.

Additional investigations:

- *review of dump inspection reports to evaluate physical stability issues with respect to pore pressures in embankments, as well as any evidence of ongoing deformation that might affect integrity of coves.*

Information required from Anvil:

- *geology and bench plans showing ultimate pit limits (including current mining);*
- *pit height/volume curve at ultimate pit limits;*
- *information on water levels and rate of rise in the pit during shutdown, and during the interruption to pumping when the treatment plant was shut down;*
- *discussion of the oxide fines stockpile - will it be removed?*

6. Mine Components - Grum

6.1 History of Development

6.2 Open Pit

The main closure issues for the Grum pit are relatively minor compared to the other two pits. Topics of interest will be water quality as a result of the flooded sulphides in the pit, the water balance as it relates to the potential to use the pit to store water and/or treatment plant sludges, and the safety issue of long-term control of access to the pit.

6.2.1 Geology

Discussion:

- rock types with pit wall mapping;
- emphasize that sulphides isolated to lower elevations;
- structural - primarily for groundwater inflow and seepage;
- plan of ultimate pit limits and wall rock geology as for other pits and comment on any underground workings.

6.2.2 Water Balance

- hydrology;
- groundwater inflow and seepage;
- flooded elevation, time to flooding.

6.2.3 Geochemistry

- groundwater well sampling data - can be used to discuss inflow water chemistry;
- effect of backfilled sulphide waste on water chemistry;
- predictions based on waste rock testing, and related to the pit wall geology.

6.3 Grum Dump

6.3.1 Design and Development

6.3.2 Physical Stability

From existing reports, including recent changes in design.

6.3.3 Geochemistry

This section will be an important part of the closure plan discussions, more so than originally intended, as a result of changes to the design and the ensuing discussions with the regulatory authorities. The issue will be the requirement for the internal till covers - and therefore the prediction of dump water chemistry. Modelling of the Grum Dump water chemistry will be required; both because the design changed, and because the methods for estimating dump water chemistry have changed. This model will be applied to all the dumps and calibrated against Vangorda dump observations.

6.4 Crushing and Grinding Mill at Grum

- *if pit in place*

6.5 Slurry Pipeline

- *if pit in place*

6.6 Haul Road

May be included with the Faro discussion in terms of geochemistry. Or else could just refer to the common sections from the Faro chapter but with appropriate water chemistry data from Vangorda side.

6.7 Little Creek Sump

6.8 Current Water Treatment Plant - closure

6.9 Infrastructure

6.9.1 Roads, Borrow Areas and other Disturbed Land

6.9.2 Buildings and Equipment, Power

6.9.3 Shops, fuel and oil storage

6.9.4 Pipelines, Water Management

Additional investigation requirements:

- *dump seep sampling*

Studies in progress:

- *identification of extent and use of borrow areas;*
- *geochemical testing*
- *cover material testing - i.e. alternative to till*

Information requirements from Anvil:

- *plan of ultimate pit limits with wall rock geology*
- *discussion of slot cut and therefore elevation of invert for pit*
- *discussion of plans for mining underground insofar as it affects closure-Champ?*
- *any descriptions available of borrow areas - or plans showing these areas;*
- *water control, oil/fuel etc. disposal within shops;*
- *core shed?*
- *inventory of fuel, oil, storage tanks - age, volume, buried or surface;*
- *estimate of surface area of buildings, description of construction materials and surface area of concrete slabs/foundations.*

7. Site Water Chemistry

This chapter will discuss the summary of site water chemistry data by showing the water balance figures, with contaminant loading calculations (based on the 1991 closure plan spreadsheet but with recent chemistry and streamflow data).

The single most important issue for the closure plan is the quality of water draining from the Anvil complex following closure and its impact on the receiving streams. Thus the initial data gathering efforts have concentrated on geochemical characterization of the site waste deposits (mine rock and tailings) and definition of the surface and groundwater release pathways. This information has been used to develop a preliminary understanding of the long term geochemical behaviour of the contaminant sources and hence of the likely long term loads to the receiving water.

In the absence of any long term controls on acid generation and acid rock drainage the contaminant load to the environment from the various contaminant sources is very large. Extensive and very effective control measures are required to protect receiving waters. Control measures ranging from 'source control' (control of acid generation or migration from its point of origin) to 'interception and treatment' can be considered. If source control is inadequate then it must be supplemented with collection and treatment. Source control helps to reduce the quantity and quality of contaminated drainage that must be collected and treated, hence also reduces treatment costs and environmental risk, particularly the risk that treatment requirement will grow beyond capability of the system put in place.

From evaluation of the existing data, appreciation of the likely long term contaminant loads, and the ability to apply source control, it is concluded that a combination of source control and collection and treatment will be required. It is necessary to establish where, and to what extent, each should be applied before the geometry and geochemical conditions applicable to each source, migration path and collection system can be defined. Such a definition is necessary before the individual source terms and contaminant pathways can be defined, allowing a determination of rates of contaminant generation, loads to interception systems, and residual environmental impacts and risk.

7.1 Site Water Balance

One objective of the Faro Closure Plan study is to prepare water balances for the Faro and Vangorda Plateau mine developments. Work on this task is in progress. To date, most of the effort has been spent on gathering and processing the flow data required to prepare the water balances, as described above in Section 3.7. However, some work has also been directed at designing an easily-understood presentation for the water balances. It is proposed to present them in graphical form as "box and stick" diagrams. Figure 7-1 shows a draft version of the "box and stick" diagram proposed for illustrating the overall water balance of the Faro mine development. A similar diagram will be prepared for the Vangorda Plateau Development.

A variety of symbols will be used in the "box and stick" diagrams to represent the various components of the water balances. Boxes with a single outline will be used to represent individual subcatchments while boxes with double outlines will represent water treatment plants and ore-processing operations. Circles will denote changes in storage of water within important reservoirs at the mine site (e.g., the Fresh Water Reservoir and the Main Pit). Lines and arrows will show the movement of water between the various system components.

Flow magnitudes for the water balances will be assessed in one of two ways. The preferred way will be to use the record of observed flows collected at the site of interest (if available). These will be patched where necessary to infill gaps of missing data. Where no flow measurements are available for a particular site, estimates of flow will be made using a technique known as regional analysis. Essentially, this technique involves transferring data from a gauged site to an ungauged site. This is done by developing empirical relationships which relate measured flows to catchment physical characteristics. For example, average annual runoff could be related to the average elevation of the catchment which generates the runoff. Such a relationship would then form the basis for approximating the average annual flow at ungauged sites.

Balances will be done for seasons to be worked out on further review of data. Balance will be completed for Mean Annual Flow and a low flow period to be specified. A variety of parameters will be modelled as discussed below.

7.2 Faro Site, Rose Creek and Anvil Creek

7.2.1 Water Balance for Faro Site

7.2.2 Historical Data Review for Faro Site

7.2.3 Contaminant Loading

- Water balance figure with current metal loadings at key stations, for key metals (As, Cd, Co, Cu, Ni, Pb, Hg, Zn) plus parameters specific to component or where necessary to understand calculations e.g., sulphate, Ca, Mg, Na etc.;
- Discussion of current sources of loading and therefore the components which are critical to closure, and therefore for which more detailed predictive work is done.
- "Rating" of current and potential loadings to put in perspective the different sources - which are the most critical sources, predictions for changes over time, variability, sensitivity to errors in estimation.

7.3 Vangorda Plateau Site, Vangorda Creek

Details for each section as above.

7.3.1 Water Balance

7.3.2 Historical Data Review

7.3.3 Contaminant Loading

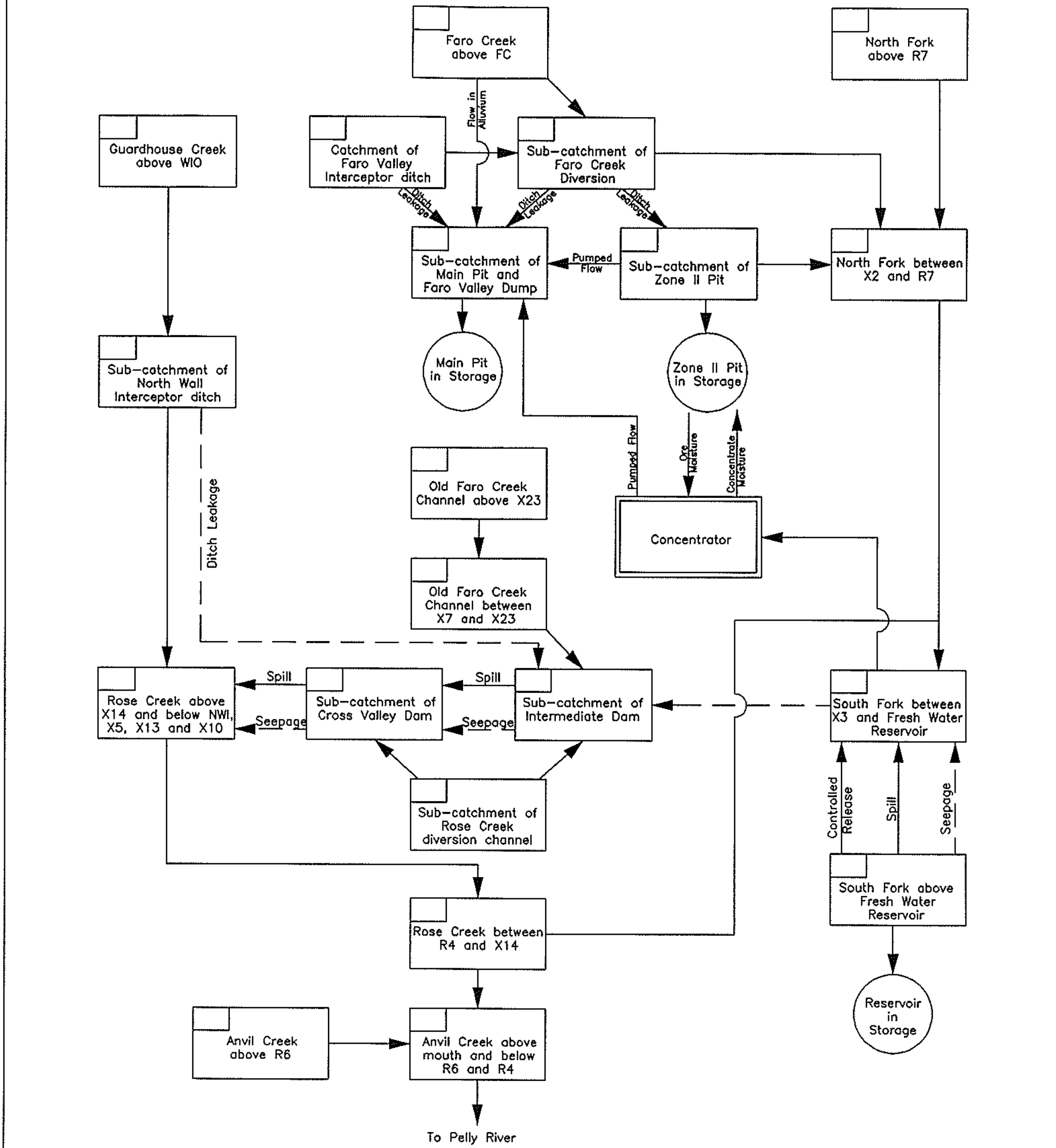
Additional investigations:

Studies in progress:

- *complete data compilation*
- *data presentation and trend analysis*
- *map compilation with watersheds for graphical presentation of data*

Information required from Anvil:

- *purchase copy of EQWin from Teck so that it can be used for the data presentation in the plan*
- *data on water quality monitoring in digital form for Annual Reports from 1990 to 1994.*



ROBERTSON GEOCONSULTANTS INC.

Consulting Geotechnical and Environmental Engineers

Anvil Range Mining Corporation

Anvil Complex Closure Plan

Proposed Schematic Representing the Faro Minesite Water Balance

PROJECT NO.	DATE	APPROVED	FIGURE
033001	July 1996		7-1

\FARO\completed\7-1Water-Balance Tue Aug 20 15:28:30 1996 Drawn: L. du Toit

8. Faro Closure Plan

This and the following two chapters present options currently under consideration for closure measures covering each component of each mine site. The final report will deal with a brief discussion of the options considered and reasons for rejection, but will focus more on the actual selected set of closure measures. In the final report each component will follow the organization.

- *closure issues*
- *closure measures*
- *predicted performance and assessment of risk*
    - *physical stability*
    - *geochemical and water quality*

For the purposes of this report only the options will be discussed. The purpose of the section at this stage of development of the closure plan is to consider the available options, their pros and cons, and their interrelationships in order to select the best option on which to base further development of the closure plan. Any additional options that merit discussion should be brought forward at this time for consideration.

A selected option has been noted for each component. This is based on the consulting teams' current understanding of the issues, the site, expected performance of the proposed measures and their probability of acceptance by the regulatory authorities. The selection is made to focus discussion and other options could result from discussion with the Anvil Management team. The purpose of this section is to arrive at a final choice; not to justify the current selection. In the end the Anvil management team must be comfortable with and support the selected options if the closure plan is to be viable.

8.1 Mine Workings

The main geochemical issue associated with the closure of the Faro open pits is the chemistry of the water in the pit and, more importantly, eventually decant from the pit. As discussed earlier, the criteria for the quality of this drainage would be either:

- CCREM - probably required if the Faro Creek reports to the pit as the pit water would essentially be a receiving water as opposed to a mine effluent:

- CCREM or slightly less stringent if the pit is discharging only groundwater infiltration and precipitation waters to the receiving environment.

The sources contributing metals, acidity and/or alkalinity to the pit water (as discussed in Sections 4.1.2 and 4.1.2.4 would include:

- the waste rock and the tailings in pit;
- pit wall rock and loose rock on benches;
- Faro Creek Valley Dump;
- Faro Creek Diversion; and,
- drainage from Main, Intermediate and possibly NE dumps (Zone II pit).

The physical stability issue for the closure of the Main Zone Pit would be associated with the stability of the pit wall in the area of the Faro Creek Diversion, and the potential for failure of the diversion into the pit in the event of failures in the wall. An additional safety concern would be to reduce the risk of inadvertent access to the pit.

8.1.1 Main Zone Open Pit

8.1.1.1 Closure Issues

- *prediction of water quality in pit by assessment of loadings from pit walls and other sources such as peripheral dumps;*
- *stability of northeast wall and implications for Faro Creek diversion;*
- *impact of tailings on pit water quality;*
- *physical stability of closure structures.*
- *water balance and storage needs;*
- *practicality of required structures and long-term.*

8.1.1.2 Closure Measures

Option 1 - Selected:
Use Faro Pit as Contaminated Water Storage Reservoir Facility and Upgrade Faro Creek Diversion

In this selected option, Faro Pit will be used as the primary contaminated water storage facility for the Faro site. This option is selected primarily as it is anticipated that the water quality in Faro Pit will not, over the long term, achieve a water quality which would allow untreated water discharge (see Option 2). If water from the pit must be treated prior to discharge then the pit can be effectively used as part of the interception and storage system for contaminated drainage from Faro Valley Dump, contaminated seepage from the Faro Creek diversion and Faro waste rock dumps draining to the pit. It also serves as a secure contaminated water storage facility (satisfying design requirements for the MCE and PMF) to which to pump contaminated water from other collection facilities (e.g. Zone 2 dewatering pump; possibly collection at toe of dumps).

The post-closure water management for this option is summarized in Figure 8-1a. The water treatment plant will be located at the Faro mill site. A smaller contaminated water storage reservoir (~200,000 m^3) will also be built in the Faro Creek Valley near the treatment plant (Fig. 8-1a) to avoid pumping contaminated toe seepage back into Faro pit. This "Sidehill Dam Reservoir" will receive all of the contaminated seepage collected from the toes of the rock dumps which either drains directly into the reservoir or is pumped from Sump 1 and Sump 2 (Fig. 8-1a). In addition, contaminated water from the Faro Pit water will also be pumped to this reservoir to provide a single feed line to the treatment plant and to provide the potential for pre-treatment (e.g. liming) prior to treatment in the plant. The same pipeline may be used to pump contaminated water from this reservoir back to the Faro pit if the storage capacity of this reservoir is temporarily exceeded.

Since Faro Pit is used as a contaminated water storage reservoir all inflows to the pit should be minimized. Hence the existing Faro Valley interceptor and Faro Creek Diversion will be maintained (Fig. 8-1a). As permanent structures, both will have to be upgraded, however, to carry the probable maximum flood (PMF). A profile of the upgraded Faro Creek Diversion (G-H) is shown in Figure 8-3a. Cross-sections of the diversion in rock and soil are shown in Figure 8-3f. No provisions have been made thus far for lining the Faro Creek diversion. The cost of lining the ditch should be compared with the potential savings in treatment costs due to reduced leakage into the Faro pit. Provisions are made, however, to excavate a new section further upslope by-passing a short reach along the unstable North-East pit slope (see Fig. 8-1a for approximate location and Fig. 8-3e for a profile of this "by-pass" C-D).

A plug dam will be needed to provide sufficient storage capacity in Faro Pit to accomodate relocated and/or re-processed tailings and contaminated water. In addition, the plug dam would be designed to provide sufficient freeboard to hold runoff from Faro Creek, in the event of a failure of the Faro Creek diversion. A review of the existing geotechnical information suggests that the maximum water level in the pit should be maintained at or below an elevation of 3835' UTM to ensure the stability of the plug dam. A detailed geotechnical field investigation is required to confirm this assumption. The conceptual design of the plug dam is shown in plan view in Fig. 8-3d and in profile and section in Figure 8-3c.

The water level in the Faro pit will be controlled by pumping to the sidehill dam reservoir. The actual operating water level would be significantly lower than 3835' UTM to allow for live storage and some flood contingency. At this stage the flood contingency in Faro pit is designed for the full PMF event (~7m storage) thus reducing the requirements for a spillway from Faro pit. Hence, in this selected option only an emergency spillway has been assumed at the North abutment of the plug dam which is designed to carry a 500 year event into the North Fork of Rose Creek (see Fig. 8-1a). A sensitivity analysis may be required to weigh the benefit of more storage in the pit (for tailings) against the cost of a larger spillway.

Option 2 - Alternative for Consideration:
Clean up pit water to discharge quality - Re-establish Faro Creek through Pit

This alternative would be applied if it could be demonstrated that the water quality in Faro Pit would reach a discharge standard (say 0.3 mg/l zinc) within a relatively short period after closure (say 10-20 years). Reclamation measures required would include:

i) Measures reducing contaminant yields to pit
- remove Faro Valley dump from bottom of Faro Creek Valley;
- relocate all in-pit waste to a level which would be flooded including waste and stockpiles around pit (if not processed);
- install plug dam to achieve high flooded level minimizing sulphide wall rock exposure;
- intercept contaminated drainage from Faro dumps and pump to alternative storage facility; and,
- add excess lime to pit water as it rises to neutralize initial acidic loads from stored acidic products in waste rock and pit walls.

ii) Measures increasing dilution in pit (once pit water is close to discharge quality)
- relocate Faro Creek to its old channel to drain into Faro Pit.

The post-closure water management for this option is summarized in Fig. 8-1b. It is anticipated that the water quality in Faro Pit will not achieve discharge water quality at least for the next 10-20 years. In other words, initially the same quantities will be treated requiring the same water treatment plant as in option 1 (Fig. 8-1b). However, in an effort to improve pit water quality there will be no pumping of contaminated water to the pit from other sources (i.e. Zone 2 and toe sumps). A larger "Sidehill Dam Reservoir" with a capacity of ~1,000,000 m^3 is required to collect contaminated seepage from the various sumps and the Zone 2 pit (Fig. 8-1b). In addition, a new "Faro Valley Sump" would be built in the Faro pit below the Faro Valley Dump to intercept some of the seepage originating from the Faro Valley Dumps. This water would be pumped to the Sidehill Dam Reservoir via a pipeline running along the NW perimeter of the Faro pit (Fig. 8-1b).

As long as Faro Pit water has not reached discharge water quality (say 20 years) the existing Faro Valley interceptor and Faro Creek diversion will be maintained (Fig. 8-1a). However, an upgrading of these structures is not required since they are only interim control structures. Once Faro pit water has improved to discharge quality the existing Faro Creek diversion will be abandoned and a new diversion excavated along the North side of Faro valley (Fig. 8-1b). From the pit perimeter of the North wall Faro Creek is allowed to spill into Faro pit. The profile of this relocated diversion (E-F) is shown in Figure 8-3e. As a permanent structure this relocated diversion will be sized to carry the PMF (see Figure 8-3f for typical cross-sections of the diversion in rock and soil). Preliminary calculations suggest that a relocation of Faro Creek into its original streambed in the Faro valley (even after removal of the Faro Valley dump) would be prohibitively expensive considering the control measures required to prevent erosion of the streambed during flood events.

As in the previous option, a plug dam will be needed to provide sufficient storage capacity in Faro Pit to place relocated and/or re-processed tailings and contaminated water. Again, the maximum water level in the pit should be maintained at or below an elevation of 3835' UTM to ensure the stability of the plug dam. The conceptual design of the plug dam is the same as in the selected option 1 (see Figures 8-3d and 8-3c).

The emergency spillway discussed in the selected option will not be adequate in option 2 since Faro Creek will be routed through the pit requiring a permanent outlet structure ("Faro pit spillway"). In this option the Faro pit spillway is located near the SW access ramp and runs passed the mill site into Guardhouse Creek (Fig. 8-1b). As a permanent structure this Faro pit spillway is designed to carry the PMF (see Fig. 8-3a for profile (A-B) and Figure 8-3b for typical sections). The invert of the spillway is located at an elevation of 3835' UTM (no live storage and flood contingency required with a permanent outlet structure).

Option 2 was not selected for two reasons. First, detailed comparison of the costs for implementing option 1 and option 2 indicate that the "clean pit" option is significantly more costly, despite the lower operating costs in the future (see chapter 14 and App. D), mainly due to the high costs of moving Faro Valley Dump and building a large contaminated water storage reservoir. Second, it is anticipated that the water quality in Faro Pit will not achieve discharge water quality for many years carrying a high risk of future treatment costs despite large initial capital costs, such as removing Faro Valley dump. In addition, the higher water level in the Main pit increases the potential for seepage to Zone 2 pit and seepage in the shallow fractured bedrock zones, increasing the potential for contaminated groundwater migration and loads to Rose Creek.

Safety and Control of Access to Pit

For each of these measures, there is still a requirement to control inadvertent access to the pit, by both recreational users of the land and by wildlife. Given the large perimeter of the pit and the depth of snow that can occur, it is not practical to rely on a constructed fence or signs for year-round control of access. The most practical measure appears to be a combination of this, and constructed berms of rock.

All road access to the pit will be blocked by waste rock berms and, in the short term while access to the pit for sampling is required, gates. The pit walls are generally stable, with the exception of a section of the north (east?) wall of the pit. Thus, in the precipitous but stable areas of the pit, rock berms will be constructed from waste rock. Along the west wall, access to the upper benches will be limited by rock berms, but no berms are required around the pit perimeter in this area. Contouring of the Faro Valley Dump would be sufficient to control access in the western north wall of the pit. In the area of the north wall which is subject to failures, estimates would be made of the projected failure planes and access to this area controlled by berming off the road. At the eastern extent of the pit, access is limited because of the rock piles to a single road which will be blocked. Signs and gates will be used in the plant area at the southern perimeter of the pit.

8.1.2 Open Pit - Zone 2 including dumps

8.1.2.1 Closure Issues

- Contaminant loading from waste rock in Zone 2 pit
- Contaminant/alkali loading from wall rock
- Influence of the old "washout" material
- Seepage from Zone 2 to North Fork of Rose Creek
- Seepage from main pit to Zone 2 pit

8.1.2.2 Closure Measures

The available options for Zone II appear to be limited. To avoid seepage from the pit into the north fork of Rose Creek it will be necessary to continue the current practice of pumping water from the pit using the well through the waste rock. The plan must allow for potential increase in pump capacity and eventual replacement of the pump and probably also the well.

8.2 Waste Rock Dumps

The issues associated with the waste dumps are primarily geochemical, related to the predicted chemistry of the drainage from the dump and the requirements for control of this drainage water.

8.2.1 Faro Creek Valley Dump

8.2.1.1 Closure Issues

- contaminant loading to Faro Pit Water
- routing of Faro Creek water through the dump area

8.2.1.2 Closure Measures

Option 1 - Selected:
Re-contour Upper Surface and Establish Vegetation in-situ
The upper surface of the dumps will be recontoured to promote effective drainage and minimize infiltration and erosion. Side slopes will be left at the angle of repose. A thin layer (30 cm) of non acid generating waste, till or alluvial gravel might be placed on the acid generating waste where slopes are less than 3:1 to assist in the establishment of vegetation, although this must be evaluated within the geochemical modelling in progress. Contaminated run-off and seepage will drain to Faro Pit where it will be collected and treated prior to discharge.

Option 2 - Alternative for Consideration:
Relocation
This option would remove all of the Faro Valley waste rock and place it on the upper surface of other acid generating portions of the Faro mine waste dumps. It might be necessary to reclaim the original ground surface by adding finely crushed limestone to neutralize stored acidity and re-establish vegetation.

The selection of this alternative is substantially dictated by the selection of the closure option for Faro Pit. If pit water is not treated then drainage from the Faro Valley Dump would be collected and treated - rather than discharging into the pit. Otherwise, the dump would be relocated to preserve pit water quality.

Option 3 - Selected:
Contouring of Roads and Ditches
Associated with the Faro Valley Dump are roads and diversion ditches which would require closure measures for both physical and geochemical stability. A portion of the road and diversion ditch was constructed and repaired with acid generating rock, which would be removed and deposited with the Faro Valley Dump material. Ditches not in use would be breached so as not to be preferential flowpaths, which could be of concern under high flow conditions.

8.2.2 Faro Main, Intermediate, NE, NW Waste Dumps

8.2.2.1 Closure Issues

- flow path of seepage from dumps;

- percolation of water through dumps;
- contaminant loading to surface and ground water from oxidation of dumps and resulting metal leaching;
- prediction of extent of long term acid generation;
- physical stability of selected dump faces.

8.2.2.2 Closure Measures

Option 1 - Selected:
Re-contour Upper Surface
The upper surface of the dumps will be graded to avoid ponding and minimize infiltration and erosion. Side slopes will be left at the angle of repose.

Contaminated surface drainage will be channelled by surface ditches to storage ponds for pumping to the main contaminated water reservoir (potentially Faro Pit). Contaminated shallow groundwater will be collected in shallow ditches installed at the toe of dumps where such seepage occurs, drained to collection sumps and pumped to the contaminated water reservoir.

Contaminated deep groundwater will be recovered where the flux is demonstrated to be sufficiently large to be a threat to the down-gradient environment. Recovery will be by deep dewatering wells.

Option 2 - Alternative for Consideration:
Re-contour Upper Surface and Establish Vegetation In-situ
This alternative would encompasses the same remedial action as described in the above selected option. In addition, a thin layer (30 cm) of non acid generating waste, till or alluvial gravel will be placed on the acid generating waste where slopes are less than 3:1 to assist in the establishment of vegetation.

This alternative would be selected only if it can be demonstrated that the establishment of vegetation significantly reduces infiltration and the load of contaminants to the receiving surface and/or groundwater systems. Given the historic land use of the site area the cost of placing covers purely for the establishment of vegetation is not considered appropriate.

Option 3 - Alternative for Consideration:
Re-contour Dumps and Cap with Low Permeability Cover
All waste dumps from which water of unacceptable discharge quality drains to either surface or groundwater would be re-contoured to slopes of 3:1 or flatter and a low permeability cover incorporating either a clay layer or a geosynthetic membrane would be constructed to minimize infiltration. This alternative would rely on the cover to reduce infiltration sufficiently to avoid having to collect and treat either surface run-off or seepage.

This alternative was not selected as it would be very expensive, particularly since there are no economic clay sources available. Thus any covers constructed solely of available local materials would not inhibit infiltration to the extent that collection and treatment could be avoided. The cost of installing a geosynthetic membrane is very large and it would have to be replaced every 150 years or so.

8.2.3 Near Pit Dumps ("Ranch Dump")

8.2.3.1 Closure Issues

- contaminant load to Faro pit water
- extent of continued acid generation

8.2.3.2 Closure Measures

Option 1 - Selected Options
Leave as is and treat water that accumulates in Faro Pit - this is linked to selection of pit options.

Option 2 - Alternative
If pit water quality is to be maintained at discharge levels, then these dumps would have to be relocated by pushing below eventual pit water level or moving to other sulphide bearing rock dumps with controlled water collection.

8.2.4 Low Grade Stockpiles (A&C)

8.2.4.1 Closure Issues

- contaminant loading to ground water and potentially to Faro pit water;
- extent of continued acid generation;
- current contained soluble metal load.

8.2.4.2 Closure Measures

Option 1 - Selected Option

During operations, screen and process coarse material in Faro Mill; dispose of fine material in Faro pit.

Option 2 - Alternative

Leave as is; collect water for treatment.

Option 3 - Alternative

Move entire stockpile into Faro Pit for disposal with tailings.

8.3 Rose Creek Valley Tailings Facility

The closure of the Faro tailings facility must address issues of both physical and chemical stability, as discussed in Section 4.3. These issues include:

- oxidation and metal release from tailings solids;
- stored oxidation products in tailings (namely dissolved zinc);
- potential for transport in, and contamination of, underlying groundwater in intervening period prior to reprocessing;
- method for removal of tailings solids and associated water quality control measures;
- storage and water quality control from tailings which are left in impoundment;
- physical stability of remaining dams; and,
- hydrology as it relates to remaining dams and to the Rose Creek Diversion.

8.3.1 Closure Measures

Option 1 - Selected:

Relocate Tailings from Original and Second Tailings Impoundments to Faro Pit; Some Redistribution of Tailings behind Intermediate Dam

Only those tailings from the Original and Second Tailings Impoundments will be relocated to the Faro Pit. Embankment soils which are contaminated with sulphide tailings would be removed and placed behind the Intermediate Dam or in the pit. It is proposed for consideration that these soils could be used as capping material over acid generating portions of the Faro waste dumps, although the materials handling costs and potential leaching concerns (at least in the short term) may rule out this option.

The tailings upstream of the Intermediate Dam will be redistributed slightly to move tailings from the higher portions of the beach into the pond area to achieve a level tailings surface. It may be necessary to also remove some tailings from this pond to maintain the required freeboard without raising the Intermediate Dam.

The polishing pond behind Cross Valley Dam will be drained and any sludges and contaminated soils removed and used as capping material on acid generating portions of the Faro Dumps or placed into Faro Pit. The Cross Valley Dam would be breached and soils so excavated would be used as a buttress to Intermediate Dam to improve its long term and seismic stability.

The operating level for water behind Intermediate Dam will be three meters above the tailings elevation to ensure adequate depth for acid generation control and a flow depth during flood events which would not be erosive to the tailings. Materials from the breaching of Cross Valley Dam will be used for the raising of Intermediate Dam, if necessary. Rose Creek will be relocated to the original channel under Original and Second Tailings Impoundments and then through Intermediate Dam. A new massive roller compacted concrete spillway structure would be constructed to safely pass the PMF over Intermediate Dam.

This option was selected because it is the most effective considering both environmental impact and cost. However, there is a long term risk associated with the stability of the Intermediate Dam and it's spillway. Should the dam breach or the spillway wash out, the tailings stored behind the dam could be washed down Rose Creek. Therefore, the stability of the Intermediate Dam will have to be demonstrated prior to implementing this option. It is anticipated that unless there are additional geotechnical data available regarding the foundation conditions and dam construction that some additional field investigations may be required for this dam, if this option is selected.

It is critical to this closure plan that a decision be made by mid-July regarding the tailings reprocessing and/or relocation viability. If a "no-go" decision is made, there would considerable geotechnical field investigations required to design an alternative, in-place tailings closure option. This closure plan document would not discuss the mechanics of tailings recovery, nor the processing of the tailings, nor the feasibility. This is to be provided by Anvil Range - perhaps as a technical appendix to the closure plan documents.

Option 2 - Alternative for Consideration:
Relocate All Tailings to Faro Pit, Re-establish Rose Creek Channel
All tailings (from Original and Second Tailings Dams as well as behind Intermediate Dam) would be dredged and relocated to the Faro open pit, provided there is sufficient capacity in the Faro Pit, or it can be created at reasonable cost. Embankment and foundation material contaminated with sulphide tailings will be excavated and placed behind the Cross Valley dam. Alternatively, it may be considered for use as capping material for acid generating waste dumps, as mentioned above. All embankment sections crossing the original stream channel of Rose Creek would be breached to slope angles providing long term stability and Rose Creek will be relocated back into its original stream channel. The tailings may or may not be treated to recover concentrate during tailings relocation.

This alternative was not selected since it is considered less effective in terms of both environmental impact and cost (with or without reprocessing). The benefit of complete tailings relocation has to be weighed against a higher water level in Faro Pit (to submerge all tailings) resulting in higher potential of contaminant seepage from the Faro Pit. In addition, tailings relocated into Faro Pit take up storage capacity needed for contaminated water storage and potentially sludge disposal during water treatment.

Option 3 - Alternative for Consideration:
Composite Cover on Old Tailings and Water Cover on Intermediate Tailings by Raising Intermediate Dam

This alternative would use a water cover over the tailings in the Intermediate Dam Impoundment, and a composite soil cover (with saturated layer) over the tailings in the Original and Second Impoundments in combination with a synthetic membrane liner.

A minimum 2 m water cover would be established over the Intermediate Tailings Impoundment by raising the Intermediate Dam. The dam would be stabilized to survive the MCE and a side channel spillway build to pass the PMF. The Cross Valley Dam would be breached and a channel constructed across the floor of the polishing pond to direct spillway discharge into the original Rose Creek channel. The section of Rose Creek Diversion running alongside Intermediate Dam would be abandoned. The upstream section of Rose Creek Diversion south of the Second Tailings Impoundment, would be broadened and stabilized.

This alternative was not selected as it was concluded that current requirements for stability of the Original and Second Tailings Impoundment embankments for MCE and PMF conditions could not be achieved at a reasonable cost. Furthermore, the effectiveness of a shallow 'flooded' cover is difficult to demonstrate from available information and such a cover would require long term operations and maintenance. Under the prevailing requirements for closure it would still be considered an active system. The presence of acidic tailings in close proximity to Rose Creek will continue to pose a high risk for future releases.

Option 4 - Alternative for Consideration:
Some Relocation of Tailings from Original and Second Impoundment to Intermediate Dam Impoundment - Raising of Intermediate Dam to Flood all Tailings

A fourth alternative comprises a minimum of 2 m water cover established over all of the tailings in the impoundment area. Total flooding would be achieved by dredging parts of the Original and Second Tailings Impoundments (by suction dredging or hydraulic monitoring) and placing these behind a raised Intermediate Dam. Rose Creek would be re-routed through the tailings area to provide the water cover. The dam would have to be stabilized to MCE and PMF standards.

This is essentially the same option as was proposed in the Abandonment Plan prepared by Klohn Leonoff in 1981. It was not selected because of costs, pollution concerns, and long-term risk of Intermediate Dam failure.

8.4 Faro Pit Tailings

8.4.1 Closure Issues:

- seepage from the final impoundment;
- depth of water cover;
- stability of impounding structure(s);
- outflow structure (if needed) - prevention of seepage through dumps;
- inflow structure (if needed) - prevention of suspension of tailings;
- capacity of the pit.

8.4.2 Closure Measures

The pit issues and alternative have already been discussed at length in Section 8.1. The closure measure for the tailings is a water cover. This will effectively prevent future significant acid generation and limit contaminant migration. Seepage from the final impoundment will be a concern as noted above; however, seepage will be reduced if large amounts of tailings are placed in the pit by relocation from the Rose Creek Valley tailings.

8.5 Water Management Structures

8.5.1 Faro Creek Diversion

8.5.1.1 Closure Issues

The physical issues for closure of this structure are primarily related to physical stability, namely:

- the potential for leakage from the diversion into the original channel and/or into the pit;
- the potential for failure of the diversion as a result of pit slope failure;
- longer term requirements for maintenance; and,
- the design capacity for the structure.

The geochemical concerns are primarily related to the consequences of the above potential failures, e.g. the increased contaminant loading to the pit as a result of leakage from the diversion through the Faro Valley Dump.

8.5.1.2 Closure Measures

Will depend on the decision regarding the Faro Main Zone Pit.

8.5.2 Rose Creek Diversion

Several of these sections are only relevant if the diversion is to be maintained.

8.5.2.1 Closure Issues

The issues related to closure of this structure are primarily related to physical stability; maintenance and design capacity and depend on the selected closure measure for the tailings impoundment.

8.5.2.2 Closure Measures

Option 1 - Selected:

Upper Section in Original Stream Channel - Lower Section Flows through Intermediate Impoundment

After removal of tailings from Original and Second impoundments, Rose Creek will be restored to its original channel to flow into the water cover zone (minimum 3 m deep) over the tailings remaining behind Intermediate Dam. The Intermediate Dam will be stabilized and raised using material from the breaching of Cross Valley Dam to provide the minimum cover and a massive roller compacted concrete spillway would be installed to pass the PMF on the right abutment. Cross Valley Dam will be breached and Rose Creek restored to its original channel downstream of this breach.

The diversion structure itself will be backfilled and/or contoured so as not to present a safety hazard or preferential flowpath for drainage, which could result in erosion of the structure or adjacent structures.

Option 2 - Alternative for Consideration:

Restore Rose Creek to Original Stream Channel

After removal of all tailings from the Rose Creek valley Rose Creek would be returned to its original stream bed.

While this would be the preferred option for Rose Creek considered in isolation, it is not appropriate for the Selected Option for tailings relocation.

Option 3 - Alternative for Consideration:
Upgrade Rose Creek Diversion
This alternative would call for an upgrading of the existing Rose Creek Diversion. Measures would include widening of the current upper section of the diversion (cutting into hillslope) and placement of embankment material between Second Tailings Impoundment and upper section of Rose Creek Diversion to pass the requirements for stability during a PMF event.

The existing diversion dyke at the south-west corner of the Second Tailings Embankment would be breached, allowing Rose Creek to flow through the flooded Intermediate Impoundment. The section of the diversion running alongside the Intermediate Dam Impoundment would be abandoned.

The ranking of the above three alternative options follows from the selection of the tailings dam remediation alternatives.

8.5.3 Fresh Water Reservoir

8.5.3.1 Closure Issues

- overwintering fish habitat created by reservoir;
- risk of failure and resulting risk to downstream structures.

8.5.3.2 Closure Measures

Option 1 - Selected
The dam of the freshwater reservoir will be partially breached and stabilized in accordance with the previous closure plan or partially breached to preserve over-wintering habitat.

Option 2 - Alternative
Completely breach the dam so that no reservoir is left eliminating risk of failure but also eliminating fish habitat.

Option 3 - Alternative
Upgrade dam to pass PMF and survive MCE. Would be prohibitively expensive in light of the fact that reservoir would have no purpose other than fish habitat.

8.6 Mill and Pipelines

8.6.1 Closure Issues

- public safety;
- aesthetics;
- contaminant loads from metal bearing soils;
- contaminant loads from hydrocarbon contaminated soils;
- chemical disposal.

8.6.2 Closure Measures

The mine and mill buildings and equipment have significant salvage value. An estimate of the salvage value and disassembly and demolition costs will have to be made. However it is our judgement, based on decommissioning experience at other mine and mill sites, that the salvage value may be similar to the costs of the decommissioning and cleanup of these facilities. It is therefore assumed that the demolition, decommissioning and cleanup of the mill and mine site facilities will be approximately equal to income realized from the salvage values. Any building rubble and non-salvageable material from the Faro Mine Site and Grum Mine Site would be placed into the Faro and Grum Pit, respectively.

The time of decommissioning will depend to a great extent on the re-processing of the tailings from the Down Valley Tailings Impoundments. It is anticipated that some of the re-processing would be done parallel to processing of new ore from the Grum Pit to avoid a delay in decommissioning due to a delayed re-processing of old tailings alone.

Existing pipelines should be to the greatest extent possible re-used for site maintenance after closure, e.g. as pipelines for management of the contaminated water and water treatment system(s). Those pipelines not needed for further site maintenance would also be decommissioned.

All buildings not salvaged or scrapped would be demolished and burned or buried. Tanks for fuels would be emptied and removed or backfilled. All metal contaminated soils would be removed to the pit, or covered as required. Hydrocarbon contaminated soils would be excavated and land farmed to allow volatilisation of contaminants.

8.7 Infrastructure

8.7.1 Closure Issues

- public safety;
- restoration of productive wildlife habitat;
- restoration of land use;
- local contaminant remediation (mainly hydrocarbon).

8.7.2 Closure Measures

8.7.3 Haul Road and North Fork Rock Drain

8.7.3.1 Closure Issues

- plugging of the rock drain in the long term;
- backing up water into Zone II pit;
- re-establishing fish passage in North Fork.

8.7.3.2 Closure Measures

Option 1 - Selected:
Breach Rock Drain, Re-contour and Re-vegetate Haul Road
The road embankment will be breached at the rock drain to allow free drainage of the currently ponded North Fork Rose Creek. The discharge channel will be designed as a wide rip-rap stabilized channel (current rock size should be sufficient) with relatively low gradient. This will maintain fish habitat conditions as they currently exist.

Areas of the haul road will be resloped as required to 3:1 to improve ease of access over the haul road, and safety berms will be pushed down. The surface of the road will be scarified to encourage revegetation.

Option 2 - Alternative for Consideration:
Maintain Rock Drain
The rock drain would be maintained. This was not selected as the long term performance of the rock drain is uncertain and there is concern that water could back up into Zone II of long-term permeability is not maintained.

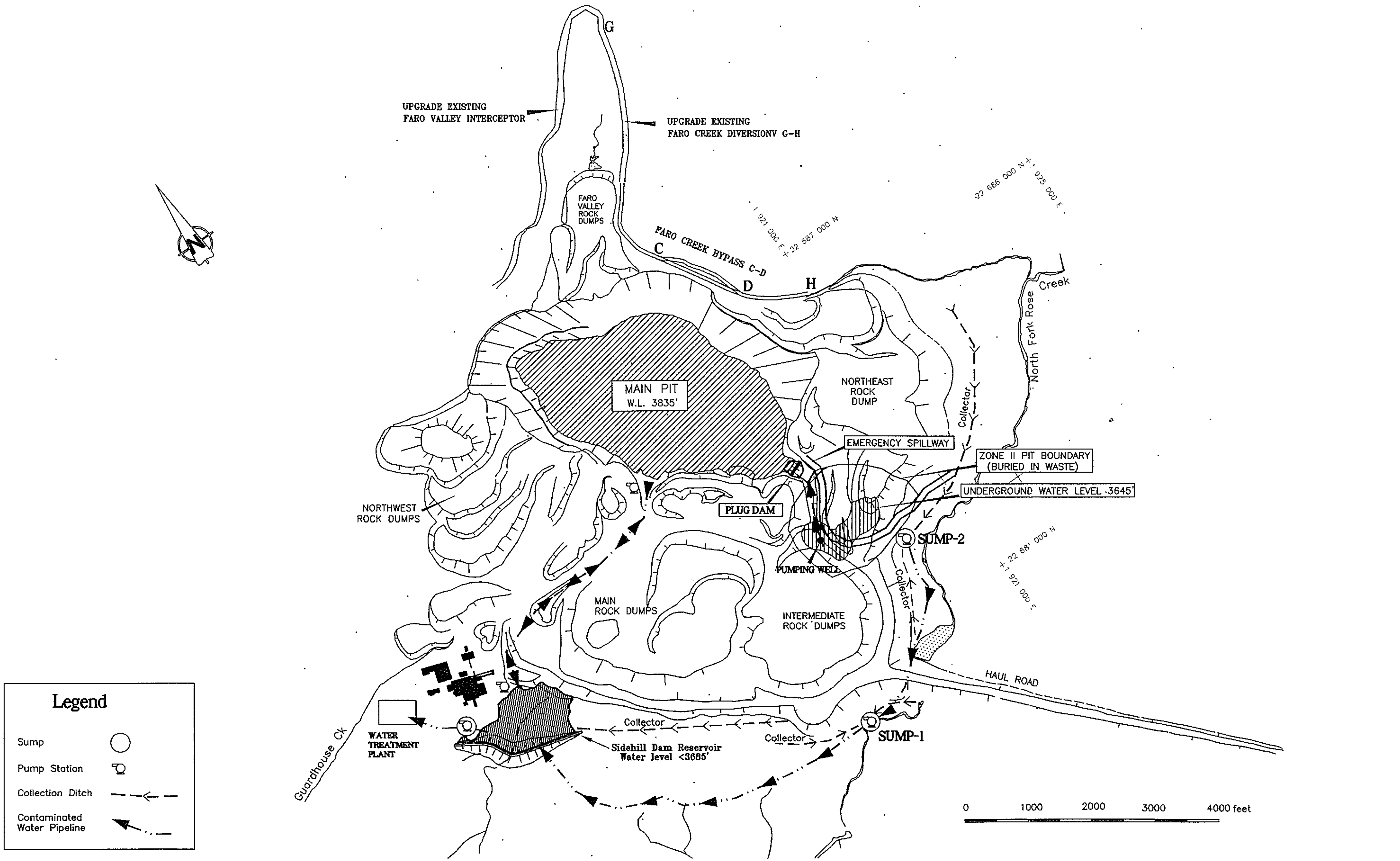
Option 3 - Alternative for Consideration:
Remove Part of Haul Road and Consolidate with Dumps

Those portions of the haul road identified as containing potentially acid generating waste rock would be excavated and this material consolidated with the acid generating waste rock in the Faro dumps. This alternative was not selected as there is very little potentially acid generating rock in the haul road and drainage from these small amounts are not expected to have significant environmental impact.

The infrastructure items include the water supply system, small haul roads, and various smaller items (e.g. explosives shop, pump house, lube shacks etc..).

The small haul roads require only minor reshaping at local spots, removal of culverts and establishment of erosion resistant surface drainage, road scarification and revegetation. All smaller building items will be demolished and building rubble placed in Grum and/or Faro Pit.

An important closure item under infrastructure is the reclamation of borrow areas, particularly in the Rose Creek Valley. Closure measures are relatively simple requiring local resloping and revegetation.



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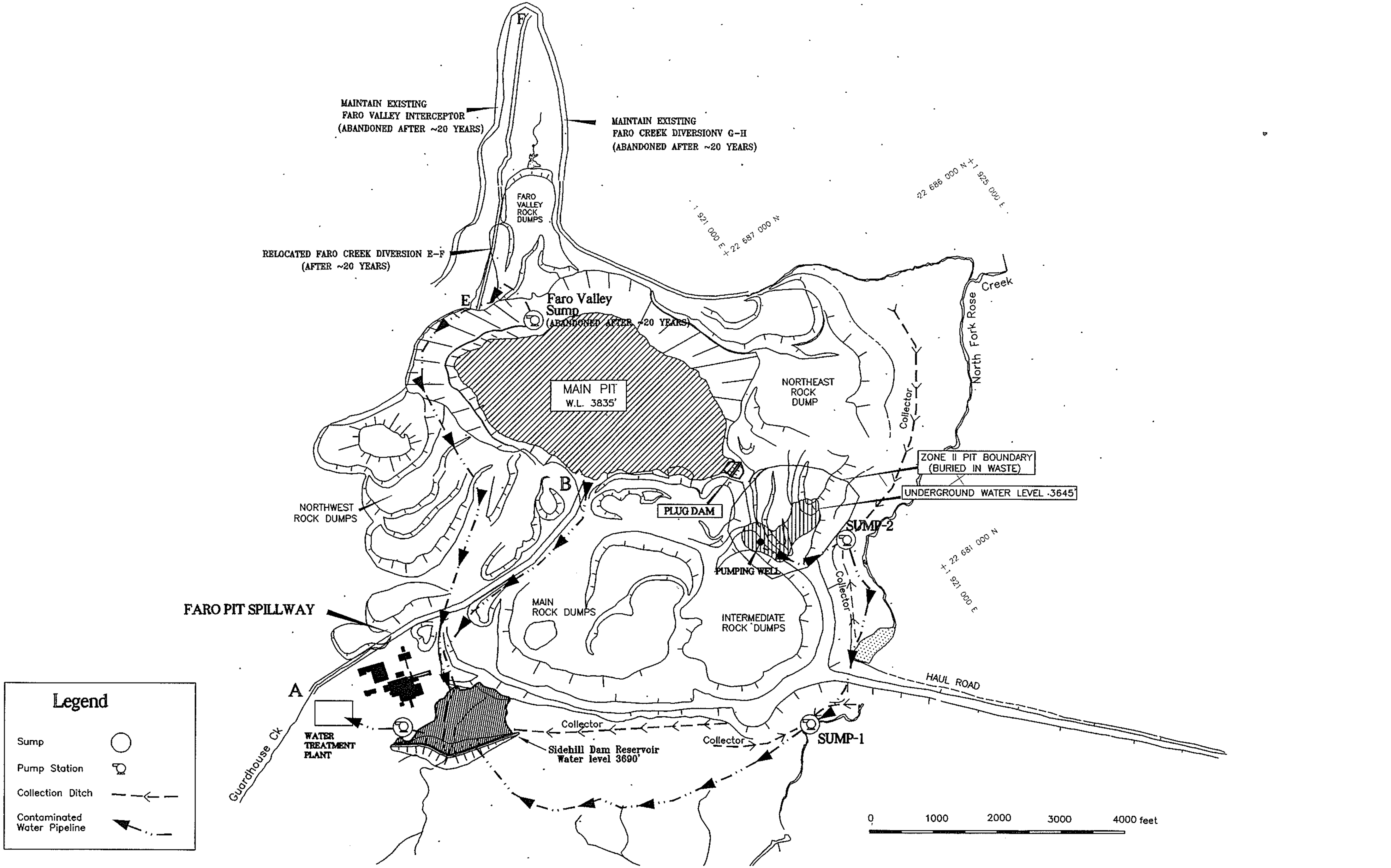
Anvil Complex Closure Plan

FARO - WATER MANAGEMENT

Option 1 - Contaminated Pit

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-1A



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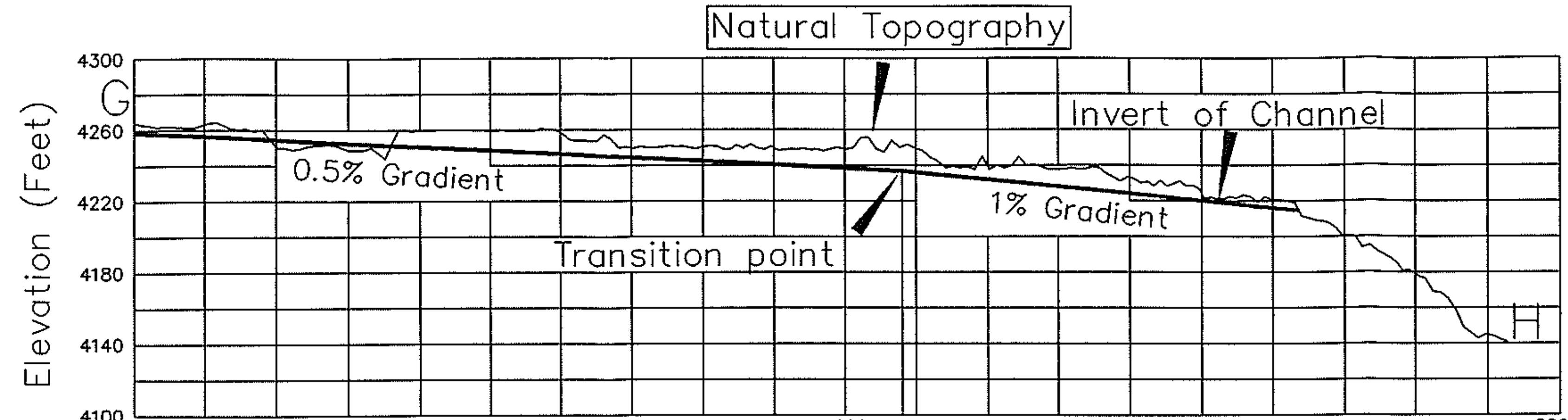
Anvil Complex Closure Plan

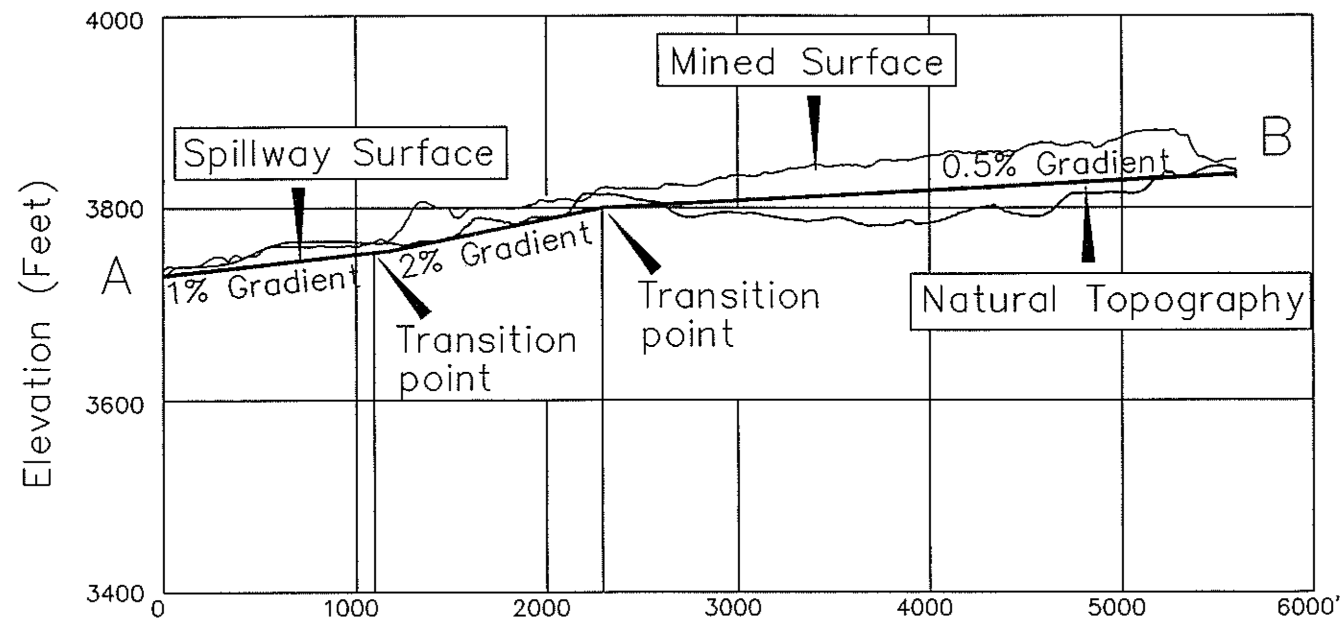
FARO - WATER MANAGEMENT

Option 2 - Clean Pit

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-1B



Profile G–H



Profile A–B

NOTES:
VERTICAL TO HORIZONTAL SCALE 10:1
ALL ELEVATIONS & DISTANCES ARE IN FEET
SEE FIGURES 8–1A & 8–1B FOR LOCATION PLAN

SCALE: 1"=1000'

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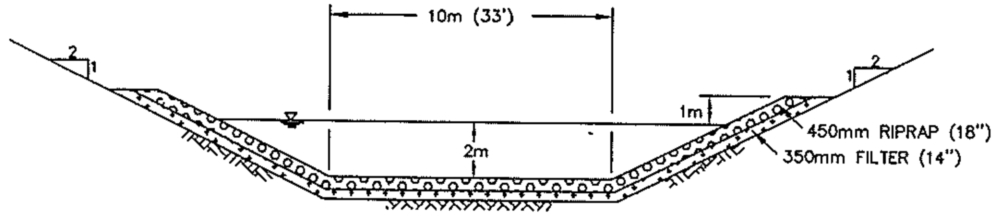
Anvil Complex Closure Plan

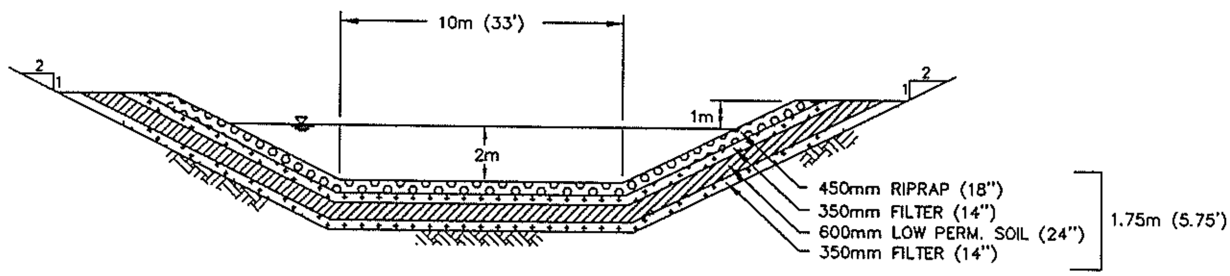
Profiles for Spillway A-B and Collector G-H

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8–3A

CLEAN WATER OPTION: FARO CREEK RUNS THROUGH PIT AND DISCHARGES INTO SPILLWAY AT MAIN HAUL ROAD PASSING ALONG NORTHSIDE OF MILLSITE.



SECTION A : ASSUMED DESIGN SECTION IN NATURAL GROUND



SECTION B : ASSUMED DESIGN SECTION IN MINE ROCK FILL

LEGEND:

- RIPRAP
- FILTER
- LOW PERM. SOIL

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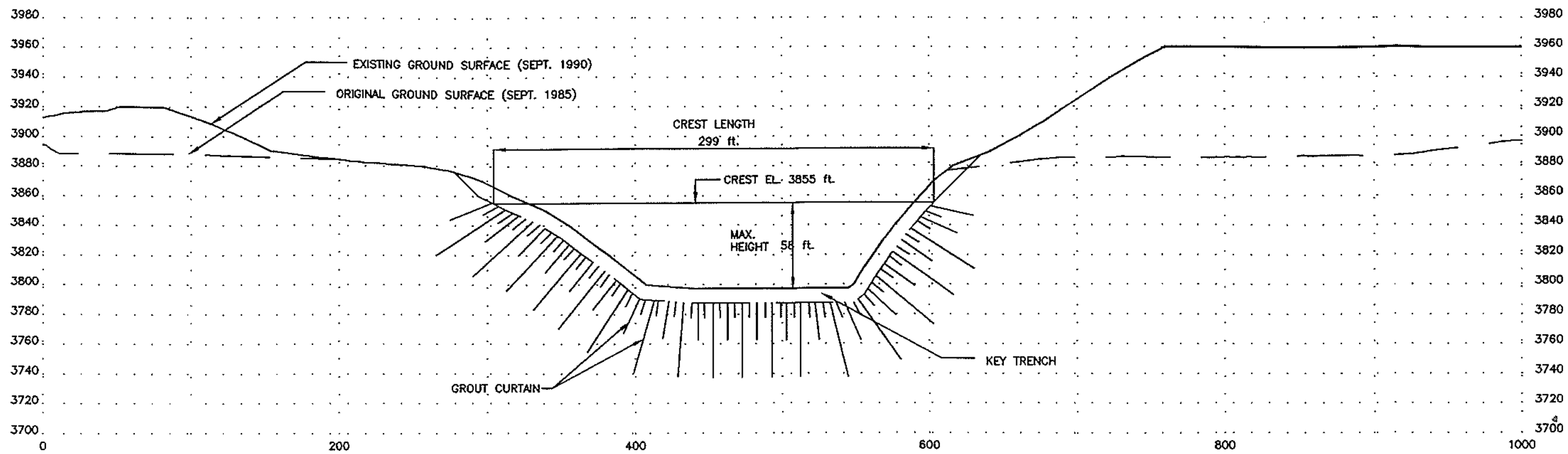
Anvil Complex Closure Plan

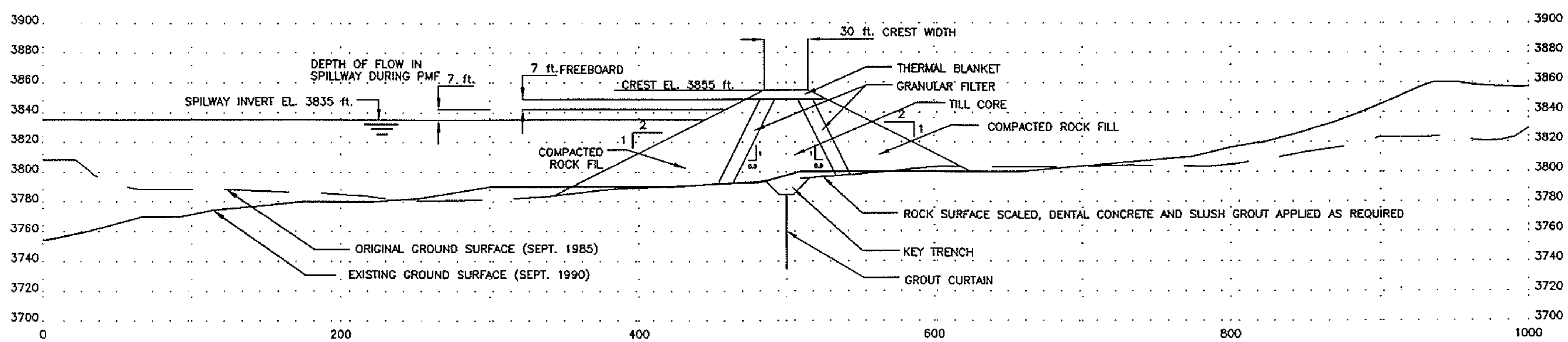
FARO PIT SPILLWAY TYPICAL SECTIONS

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-3B

C:\Pierre\Faro\title-Faro-Spillway Wed Aug 21 13:32:57 1996 Drawn: P. Rasoldier



PROFILE ALONG CENTRELINE (A–A)



TYPICAL SECTION (B–B)

NOTE: SEE FIGURE 8-3D FOR PLAN VIEW

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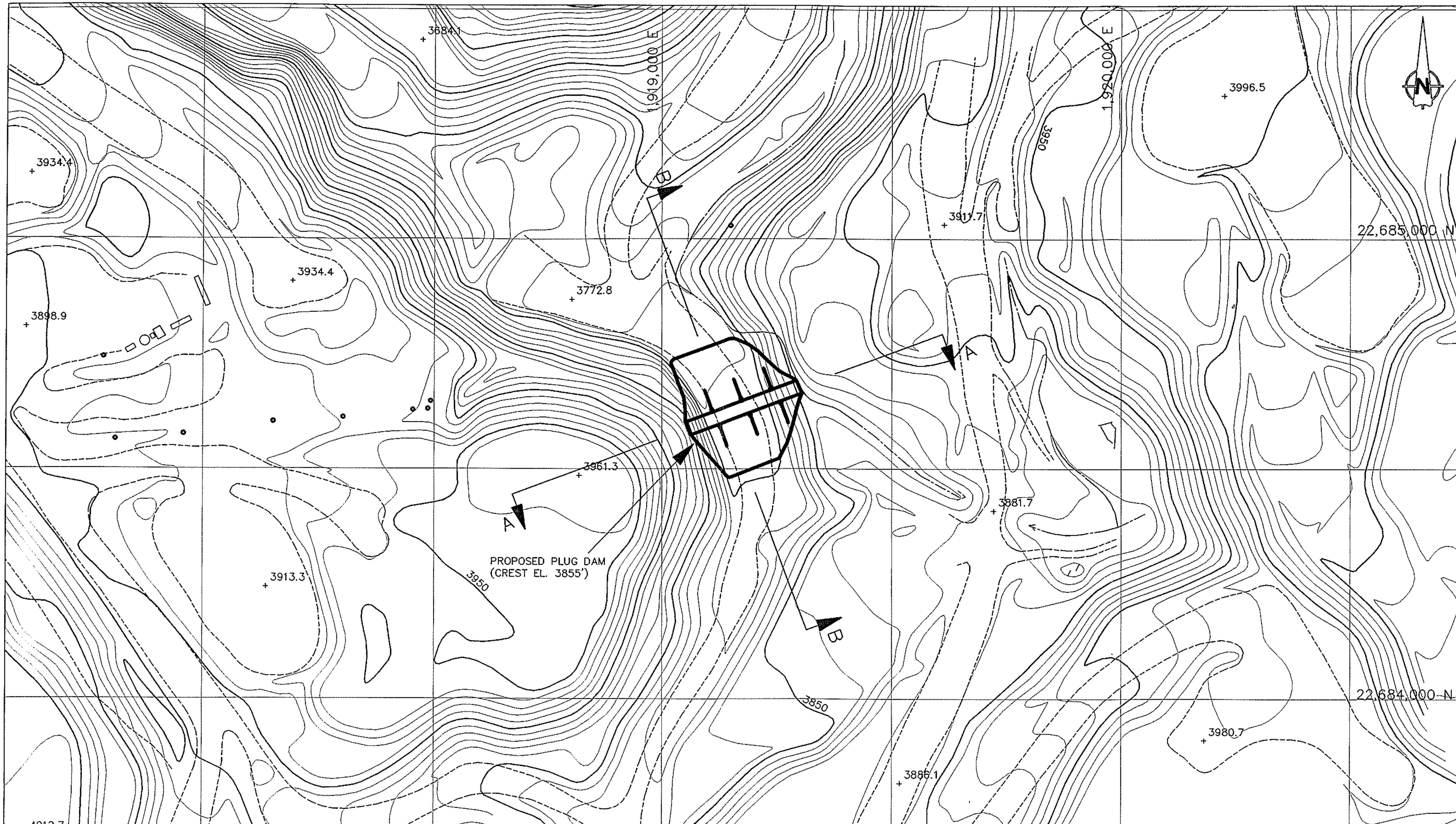
Anvil Complex Closure Plan

FARO PIT PLUG DAM SECTIONS

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-3C



SCALE: 1"=200'

NOTE: SEE FIGURE 8-3C FOR TYPICAL SECTIONS

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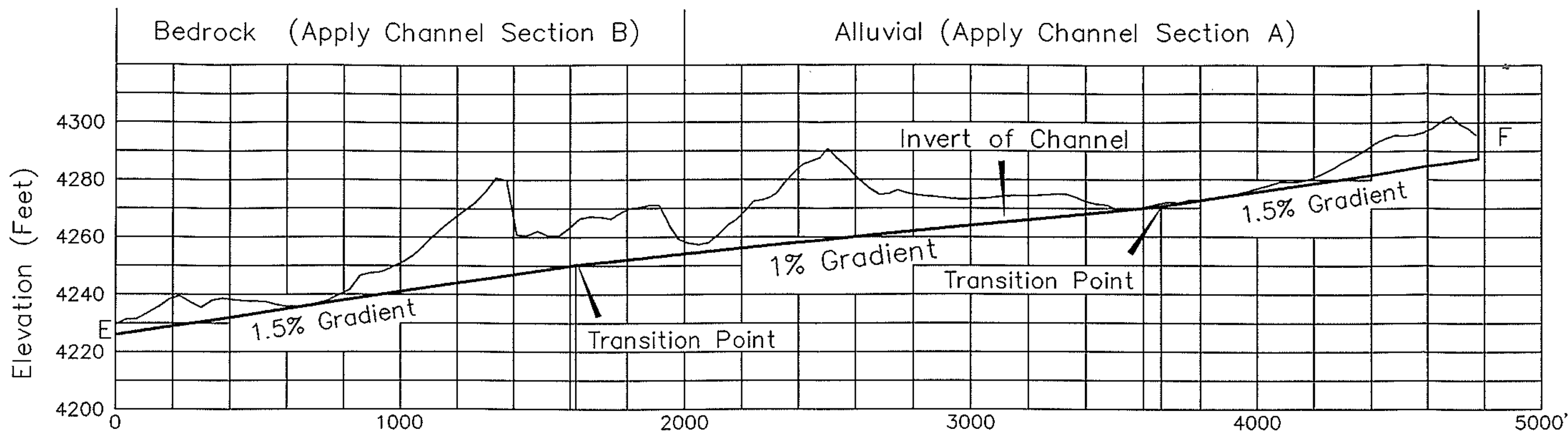
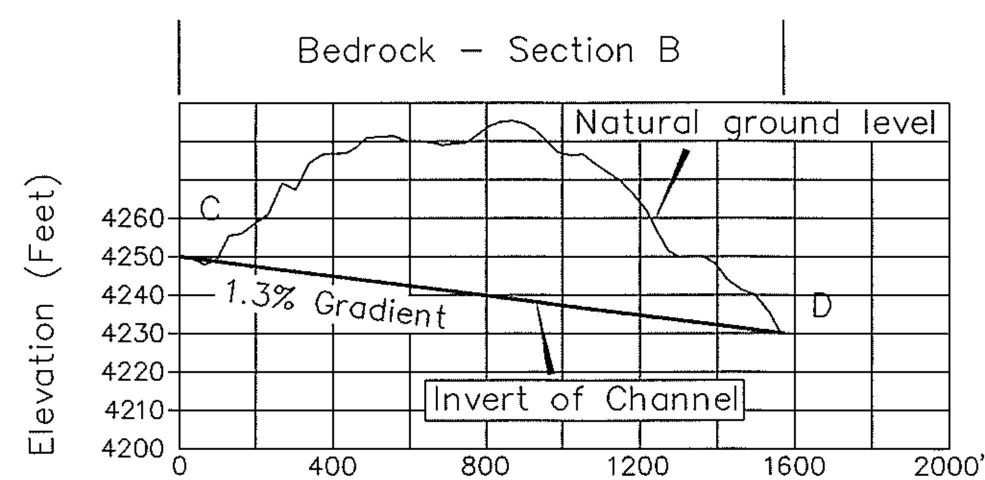
Anvil Complex Closure Plan

FARO PIT PLUG DAM PLAN

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-3D



Profile E–F



Profile C–D

NOTES:
VERTICAL TO HORIZONTAL SCALE 10:1
ALL ELEVATIONS & DISTANCES ARE IN FEET
SEE FIGURES 8–1A & 8–1B FOR LOCATION PLAN

SCALE: 1"=500'

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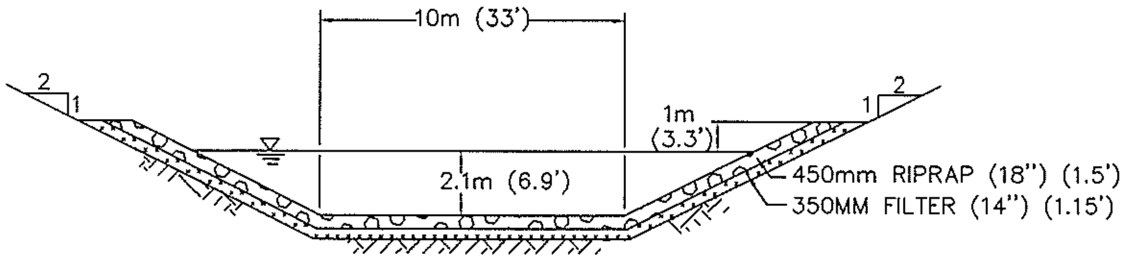
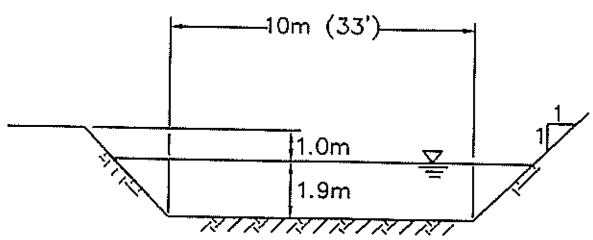
Down Valley Tailings Impoundment

Profile for Channels C-D and E-F

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8–3E



TYPICAL SECTION IN SOIL
SECTION A



TYPICAL SECTION IN ROCK
SECTION B

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Anvil Complex Closure Plan

FARO CREEK DIVERSION COLLECTION DITCH SECTIONS

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		8-3F

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9. Grum and Vangorda Closure Plan

9.1 Closure Issues

The closure issues for Vangorda were anticipated to a large degree in the project design and the preparation of the IEE and Water Licence Application documents. At that stage predictions were made of the environmental impact at closure for the selected closure measures. These predictions, for both Vangorda and Grum, are being reviewed by the regulatory agencies as these properties go through production and closure and will be compared to the measures and predictions in this closure plan. Therefore, this plan must, to some degree, review these predictions and commitments and discuss areas where there are changes. It must also compare predictions to the short track record of performance of the Vangorda dumps.

The two areas where there are differences, and which will therefore be the subject of discussion with respect to closure are:

- the predictions for drainage water quality from the Vangorda dump; and,
- the changes to the design of the Grum dump, particularly the expansion of the sulphide cell area and the "optional" internal till covers.

The other major issues with respect to geochemistry and water quality include:

- water treatment plant;
- Vangorda pit water quality;
- Vangorda Creek Diversion. The considerations are similar to the Faro Creek Diversion. If the Creek passes through the pit, the discharge water standards would probably be CCREM. If the Creek is maintained separate from the pit waters, it may be possible to argue for higher zinc concentrations being acceptable in the discharge.

The main issues with respect to physical stability will be control of access to the pit, and the design and stability of the Vangorda Creek Diversion.

The closure issues associated with the Grum development are similar to those discussed above for Vangorda and are related primarily to the waste dump and to a lesser extent to pit water quality and final flooded elevation. Minor issues include the closure required for the haul road, infrastructure and removal of stockpiles.

The options described in the New Grum Dump submission including resloping and revegetation of the till dump, till cover on the sulphide cell, and collection and treatment provision for waste dump seepage will apply. Low grade stockpiles will be removed to Faro for processing or hauled to Grum pit for disposal. The Grum pit will be allowed to flood, and overflow from the pit will existing through the slot cut to Grum Creek.

A preliminary design of the post-closure water management at Grum/Vangorda has been completed (Appendix B). Figure 9-1a shows the approximate locations of the collection ditches, sumps, pumps and pipelines after closure. Note that the collection ditch for the Vangorda dump is already in place draining seepage from this dump by gravity into Little Creek sump. Flow records provided by ARMC indicate that this collection ditch is collecting much lower seepage volumes than are expected to drain from these rock piles. It is conceivable that much of the seepage is flowing underneath the collection ditch. It is recommended that the existing groundwater wells be monitored routinely to assess the movements of contaminants downstream via subsurface flow paths.

A conceptual design and costing of the required water management structures (diversion ditches, sumps etc.) for the Grum/Vangorda mine site is currently in progress.

9.2 Vangorda Open Pit

9.2.1 Closure Issues

Issues:

- Flooded elevation
- Contaminant/alkali loading from wall rock under water
- Contaminant/alkali loading from wall rock exposed above the water level
- Vangorda Creek and Diversion

- Potential seepage into Dy portal

9.2.2 Closure Measures

Option 1 - Selected:
Backfill Vangorda Pit with Waste Rock and Route Vangorda Creek Over the Fill
The pit would be back-filled to the long-term water level waste rock during excavation of Grum Pit. At closure, the Vangorda Pit will be allowed to flood to its natural groundwater level by groundwater seepage. As much as possible, acid generating waste will be deposited at depth in the pit, below the flooded water level rather than in the sulphide cell on the waste dump.

As in the current closure plan, partial till covers will be placed as required to limit flushing of the exposed pit walls which are a contaminant source. A thin cover would be placed on the backfill to encourage revegetation of the area and limit erosion.

Vangorda Creek will then be re-routed into its original stream channel with provisions for an armoured stream channel across Vangorda Pit to minimize both infiltration into the pit and the erosion and transport of fines in the Creek. The water level in the pit will be controlled by a well with a water level control, and pumping of the pit water either to the treatment plant or directly to discharge.

This option has been selected since it presents a low risk to the environment both in terms of acid generation and stability (no risk of structural failure). This option would be more cost effective than alternative 1 if back-filling can be incorporated into current mining activity (excavation) at the Grum site.

A variant of this option would involve placing a few meters of fill between the pit wall and backfilled rock in order to reduce oxygen penetration into the sulphides of the pit wall.

Option 2 - Alternative for Consideration:
Flood Vangorda Pit and Re-establish Vangorda Creek through Pit,
Collect and Treat Contaminated Water
This alternative would be applied if the selected option is not cost-effective and reclamation measures could be implemented which would be sufficient to ensure that the water quality in Vangorda pit would reach a discharge standard (say 0.03 mg/L zinc)

within a relatively short period after closure (say 10 years). Reclamation measures required would include:

i) Measures reducing contaminant yields to Vangorda Pit
- install till cover to acid generating portions of pit wall;
- relocate all in-pit waste to a level which would be flooded;
- install plug dam to achieve high flood level minimizing sulphide wall rock exposure;
- intercept contaminated drainage from Vangorda dumps and pump to alternative storage facility;
- add excess lime to pit water as it rises to neutralize initial acidic loads from stored acidic products in waste rock and pit walls;
- securely plug Dy ramp portal if developed in pit wall.

ii) Measures increasing dilution in pit
- relocate Vangorda Creek in its old channel to drain into Vangorda pit;
- excavate exit for Vangorda Creek by breaching haul road and removing culvert.

This alternative does not make use of the pit as a disposal facility of submerged acid generating waste rock and would only be considered if the selected option is not cost-effective. In order to protect the environment from an initial flush of contaminated water it is proposed that the Vangorda Creek diversion will be maintained for a few years until the success of the flooding of Vangorda Pit and the achievement of adequate water quality can be demonstrated.

Option 3 - Alternative for Consideration:
Use as Contaminated Water Storage Reservoir

Vangorda Pit would be used as a contaminated water storage facility for the Grum and Vangorda mining area. Contaminated water from all contaminated water sources in this area are drained or pumped to Vangorda Pit. Water is evacuated from Vangorda Pit and pumped to the chosen treatment plant (either Grum or Faro mine site) and treated prior to discharge. The water level in the pit would be maintained at a level sufficiently low (if pit storage capacity allows) that a plug dam is not required thus preventing water decanting over the rim or discharging to shallow permeable groundwater channels. It will be necessary to maintain the Vangorda Creek diversion to avoid treating unnecessarily large volumes of water. Should the diversion fail, the pit would capture the flow as long as sufficient capacity is provided; thus it should not be necessary to design for PMF or MCE assuming resources to repair the diversion are available in the plan.

This option would be most advantageous if the water quality in Vangorda Pit will not, over the long term, achieve a water quality which would allow untreated water discharge. If water from the pit must be treated prior to discharge then the pit can be effectively used as part of the interception and storage system for contaminated drainage from the Vangorda and Grum dumps and contaminated seepage from Vangorda Creek diversion to the pit. It serves as a secure contaminated water storage facility (satisfying the design requirements for the MCE and PMF) to which contaminated water from other collection facilities in this area could drain or be pumped. The capacity of the pit can be used for seasonal storage allowing the optimization of the water treatment plant operation (constant, paced or seasonal). It may also be considered to deposit the sludges produced during water treatment in the Vangorda pit.

Option 4 - Alternative for Consideration
Combination of above alternatives
This alternative combines partial backfilling of the pit with using part of the pit for contaminated water storage. It would prove to be the most practical option if it is shown, as expected, that the pit water chemistry would not be suitable for untreated discharge.

In this option, the pit would be partially backfilled, and Vangorda Creek re-established on the top of the fill, close to its' original course. The rest of the pit would be used for water storage, on conjunction with the treatment plant, prior to water treatment and discharge. The partial till covers on the southeast pit upper walls that were included in the original closure plan would be used.

This alternative has the advantages of providing storage for some wastes, storage for contaminated water, and reduces the engineering requirements for upgrade and maintenance of the Vangorda Creek Diversion.

9.3 Vangorda Creek Diversion

9.3.1 Closure Issues

The closure issues associated with the current structure are primarily related to the capacity to handle extreme events, and the requirements for monitoring and maintenance of the structure in the long term.

If the diversion is routed through the pit, there will be a change in the downstream hydrology, i.e. Vangorda Creek. Maybe not significant, but must be discussed.

9.3.2 Closure Measures

The measures will depend on those selected for the Vangorda pit and are discussed above.

9.4 Vangorda Waste Dump

Those options described in the Vangorda Plateau Closure Plan, and modified by Curragh in 1991, will apply.

9.4.1 Closure Issues

- continued acid generation;
- contaminant leaching by percolating waters;
- permeability of soil in dump base;
- stability of embankment;
- effect of resloping and cover to date.

9.4.2 Closure Measures

The dump has been partly build according to the design of the original 1988 closure plan which was modified in dump volume. This resulted in a higher dump and since till was insufficient to apply the original design to the enlarged dump, a revised type of till cover was proposed.

The dump slopes would be resloped to 3 H to 1 V and a 2 m thick cover of compacted till would be placed on the slopes. The original 3 m thick compacted till cover (in 3-1 m lifts) would be placed over the dump top after regarding of the existing waste rock.

The purpose of the till cover was to reduce (but not eliminate) percolation through the dump, to reduce oxygen penetration into the dump, and to provide a suitable substrate for revegetation.

An alternative for this plan is to move oxide fines currently within the dump footprint to a site such as the Vangorda Pit in order to reduce contaminant loading from the dump. These fines appear to be the source of very high Zn, Cu, Ni, SO_4, and low pH from drain #6.

9.5 Grum (and Champ) Open Pits

9.5.1 Closure Issues

- maintenance of water quality during flooding;
- acid generation from pit wall sulphides;
- flooded level of pit;
- pit geology;
- long term water quality with respect to sludge disposal.

9.5.2 Closure Measures

The Grum pit will be allowed to flood at closure. Current understanding of the pit geology indicates all sulphides will be below the flooded level thus continued acid generation from pit walls will not be an issue. Pit water quality during filling will be a significant challenge which may require liming to overcome.

It is proposed to dispose of long term water treatment sludges in the Grum Pit. This will also raise water quality issues.

9.6 Grum Dumps

9.6.1 *Closure Issues*

- water quality of dump seepage;
- continued acid generation from sulphide cell;
- inhibition of seepage water by external and/or internal till covers;
- acid generation from "non-sulphide" portion of dumps;
- erosion from dumps, particularly till dump;
- restoration of wildlife habitat - sheep migration corridor.

9.6.2 *Closure Measures*

The till dump will be resloped to 3 H to 1V and planted with grass to reduce erosion. There are no chemical water quality issues provided the limited phyllite in the dump is neither acid generating nor exposed on the dump face.

The main and southwest dumps incorporate the concept of localisation of sulphide material and collection of contaminated seepage. The main dump contains a sulphide cell which would be covered to reduce (but not eliminate) seepage. Contaminated water would be collected for treatment.

The main and southwest dumps will be revegetated once all stockpiles are removed to Faro mill for processing or to the Grum Pit for storage.

The ore transfer pad would similarly be cleaned of all stockpiled material and revegetated.

9.7 Little Creek Sump and Pipeline

9.7.1 *Closure Issues*

This structure currently lacks a spillway which will be required for closure if not sooner. The stability of this small dam will have to be assessed with respect to appropriate criteria. The risk from failure of this structure is much lower than the Faro structures, thus PMF and MCE would not be appropriate.

9.7.2 Closure Measures

Retain as a water management sump depending on the Vangorda Pit options and water treatment options selected. If not required then the dam should be breached and accumulated precipitates or fines removed to Vangorda Pit.

9.8 Current Water Treatment Plant

9.8.1 Closure Issues

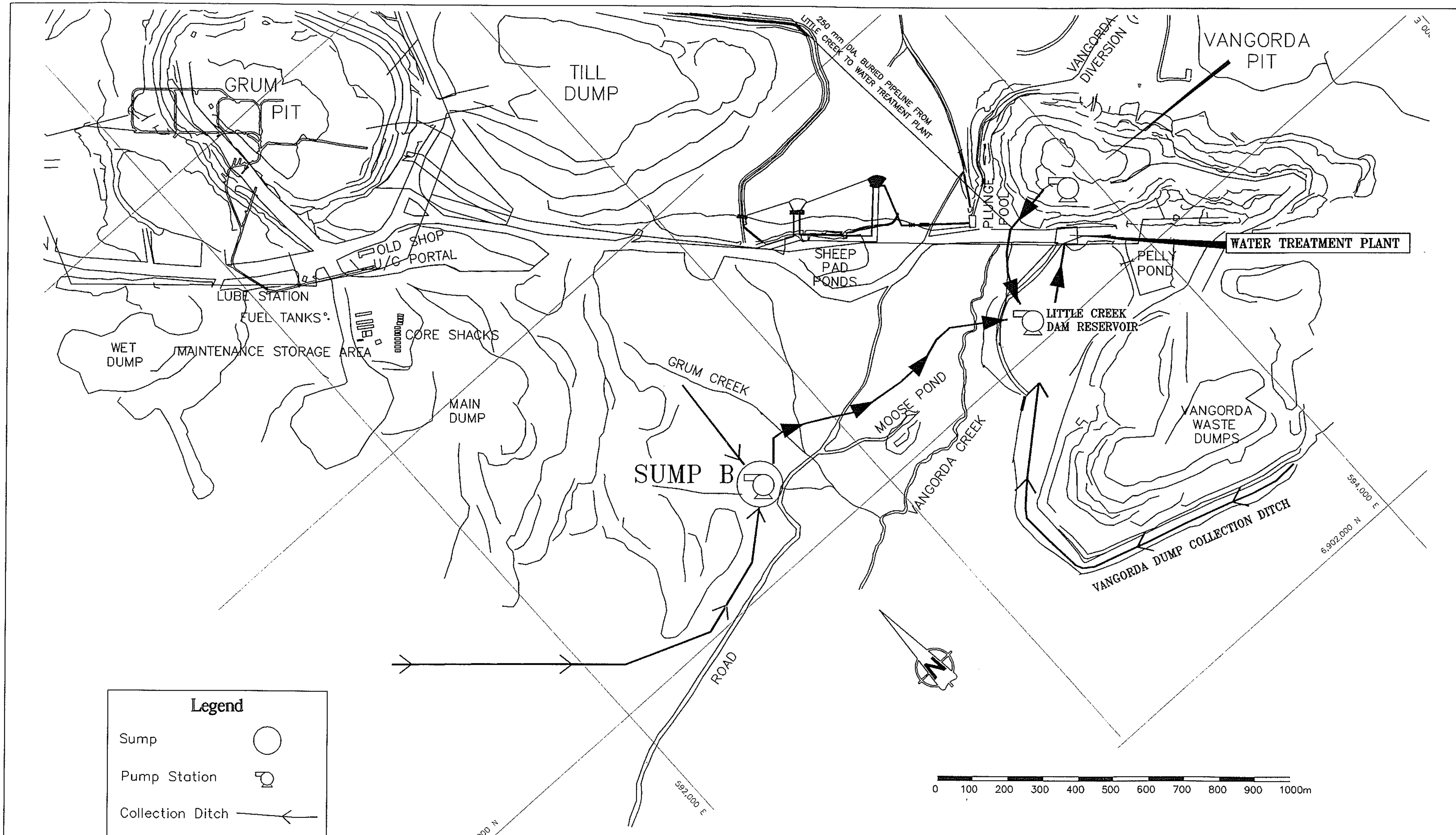
- use of plant in closure plan
- sludge disposal from current settling pond
- long term stability of settling pond

9.8.2 Closure Measures

The plant may be dismantled and moved to a more convenient site depending on the water treatment option selected.

Sludges may be disposed of in the Grum Pit.

The pond will be breached to prevent water accumulation following closure of the plant and removal of all sludges.



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Anvil Range Mining Corporation

Anvil Complex Closure Plan

Vangorda/Grum Water Management

PROJECT NO.	DATE	APPROVED	FIGURE
033001	August 1996		9-1A

10. Post-Closure Water Treatment

A review of post-closure water treatment options for the Anvil Range mining complex has been completed by H.A. Simons (Appendix A). This draft report describes various options of treatment plants differing in capacity, location and type of treatment process (straight line plant (LDS) versus high density sludge (HDS) process). In addition a brief discussion on alternative treatment processes and sludge disposal is given. A summary description of the various options and the associated capital and operating costs are presented in Table A1 of Appendix A.

Table 10-1. Comparison of Costs for Various Options of Post-Closure Water Treatment.

	Option 1: LDS/200gpm near Little Creek Dam & HDS/2500 gpm at Faro mill site	Option 2: HDS/3000gpm near Little Creek Dam	Option 3: HDS/3000gpm at Faro mill site
Total Capital Cost (August 96 $)	$11,600,000	$11,300,000	$11,200,000
Annual Operating Costs ($ /a)	$556,000 per year	$541,000 per year`	$489,000 per year
Net Present Value			
at 4%	17,925	17,454	16,706
at 8%	15,023	14,629	14,102
at 12%	13,114	12,770	12,376

A summary of the costs (capital and operating costs as well as net present value) for the three options currently considered for post-closure water treatment (see section 10.3) is given in Table 10-1.

10.1 Water Management Systems

The anticipated post-closure collection system of contaminated water for the Faro site and Grum/Vangorda site are summarized in sections 8.1 and 9.1, respectively. The pumping system required to pump contaminated water from the various sumps to the water treatment plant at the Faro and Grum/Vangorda site is shown in Figures 8-1a/b and Figures 9-1a, respectively. The design specifications and associated capital costs for the pipeline system and unit costs for operating the required pumps are summarized in Tables 1 to 3 of Appendix B.

A preliminary evaluation of generating hydro-electric power using Rose Creek and the Intermediate Dam impoundment as a storage reservoir indicates that this system would generate sufficient power (~600 kw output) to meet the mine's demand for the water pumping (<350 kw) and water treatment (<300 kw) during years of average and greater than average runoff (Appendix B). During years of low runoff some back-up form of power (from the grid or diesel electric) would be necessary.

10.2 Water Treatment Process

Currently lime treatment appears to be the practical alternative. The high density sludge (HDS) process is generally favoured over the low density sludge (LDS) process considering its greater efficiency in metal removal, significantly lower sludge volume production, and greater chemical stability of the sludges produced.

10.3 Closure Measures

Option 1 - Selected:
Separate Treatment Plants for Grum/Vangorda and Faro Mine Sites
The contaminated waters from the Grum/Vangorda and Faro mine sites will be collected and treated separately in lime treatment plants at those two sites, respectively. Little Creek Sump will be the local contaminated water storage facility for contaminated water collected at the Grum/Vangorda Mine Site. The Faro Pit and/or the Sidehill Dam reservoir will be the local contaminated water storage facilities for water collected at the Faro mine site. Sludges from the two treatment plants will be deposited in the Grum (or Grizzly) and Faro underground workings, respectively. The LDS plant at Grum/Vangorda will require a sludge settling pond (the existing settling pond may be used).

The existing LDS treatment plant at Vangorda/Grum will be relocated to a site close to Little Creek Dam, i.e. at a much lower point on the property to minimize pumping requirements. Considering the additional cost, a conversion to a high density sludge (HDS) process is not considered at this stage. Sludge volumes are relatively small (~1700 m^3/a w/ LDS) and there is ample capacity for storage of sludges in the Grum (or Grizzly underground workings). The design capacity of this plant has not been finalized. Should the review of the hydrology data indicate that the capacity of the existing plant is excessive and could be significantly down-sized (e.g. 1000 gpm capacity) then construction of a new HDS plant should be considered.

At the Faro site a new HDS treatment plant with a capacity of 2500 gpm will be constructed. Here the anticipated sludge volumes are sufficiently high (2100 m^3/a w/ HDS or ~11300 m^3/a w/ LDS) to warrant the higher capital costs of building an HDS plant considering the limited storage capacity in the Faro underground workings (100,000 to 250,000 m^3).

The capital and operating costs for this selected option are shown in Table 14-1. Although this option has slightly higher costs (in net present values) than the alternative options it was selected since it does not involve pumping contaminated water between the Faro and Grum/Vangorda mine site.

Option 2 - Alternative for Consideration:

One Central Treatment Plant at Current Grum Mine Site - Sludge Disposal in Grum Underground Workings

A new, larger treatment plant (3000 gpm capacity) will be built at a location near Little Creek Dam at the Grum/Vangorda site. This treatment plant will treat water from both Grum/Vangorda and the Faro mine sites. Little Creek Dam will be the primary contaminated water storage facility for all contaminated water collected at the Grum/Vangorda Mine Site. The Faro Pit will be the primary contaminated water storage facility for the Faro site. Contaminated water will be pumped from Faro pit to Little Creek Dam using a large pipeline (possibly along the haul road).

The anticipated sludge volumes in this larger plant with combined flows from Faro and Grum/Vangorda are sufficiently high (2,500 m^3/a w/ HDS or ~13000 m^3/a w/ LDS) that the additional capital cost for an HDS system is warranted considering the limited storage capacity in the Grum underground workings.

The capital and operating costs for this alternative option are shown in Table 14-1. Despite the slight cost savings of this option over the selected option it was not selected because the long pipeline from Faro to Grum/Vangorda is considered a substantial risk from an operations point-of-view (e.g. freezing; rupture of pipeline) carrying the potential of future costs not accounted for in the current cost estimates.

Option 3 - Alternative for Consideration:

One Central Treatment Plant at Faro Mine Site - Sludges deposited into Faro underground workings

A new, high capacity (3000 gpm) HDS lime treatment plant will be built at the Faro mill site. The Faro Pit would be the primary contaminated water storage facility for both the Faro and Vangorda Plateau mining areas. All contaminated water collection facilities would drain to storage sumps from which contaminated water would be pumped to Faro Pit (including a long pipeline from Grum/Vangorda to Faro operating seasonally). All sludges would be deposited into the Faro underground workings and later potentially at depth into the Faro pit.

The anticipated sludge volumes in this larger plant with combined flows from Faro and Grum/Vangorda are sufficiently high (2,500 m^3/a w/ HDS or ~13000 m^3/a w/ LDS) that the additional capital cost for an HDS system is warranted considering the limited storage capacity in the Faro underground workings (100,000 to 250,000 m^3).

The capital and operating costs for this alternative option are shown in Table 14-1. This third option offers slight cost savings over option 2 since the volumes of contaminated water to be pumped over the several kilometre long pipeline between Grum/Vangorda and Faro are smaller. Although this option represents the least expensive option it was not selected since the long pipeline from Faro to Grum/Vangorda is considered a substantial risk from an operations point-of-view (e.g. freezing; rupture of pipeline) carrying the potential of future costs not accounted for in the current cost estimates.

The ranking of the above alternative options depends to a great extent on the ranking of remedial options for Faro, Grum and Vangorda Pits. The selection presented here assumes that Grum Pit would be the best storage reservoir for sludge disposal (largest storage capacity, low contamination, alkali water, low inflow).

11. Environmental Impact

Once the closure measures have been selected then the source terms, migration (release) pathways and discharge loadings and concentrations must be determined to establish that discharge criteria and downstream water quality can be achieved. These will be evaluated using the contaminant loading balances presented earlier, and adjusted for post-closure conditions.

Impacts considered would be:

- aquatic Impacts
    - contaminant loading after closure
    - predicted concentration in receiving waters
    - comparison to guidelines for aquatic protection
- terrestrial impacts
- land use impacts
- socio-economic impacts

12. Monitoring and Maintenance

This chapter will provide a summary of monitoring and maintenance work required as part of the closure measures.

13. Closure Schedule

The scheduling of the closure measures will be developed after initial discussions with Anvil Range on the selection of alternative closure measures. The schedule would address progressive reclamation, which is believed to be important to both the acceptance of the plan by the regulatory authorities and to the viability of the closure implementation for Anvil Range. It would also show the schedule for the post-operational decommissioning measures, and monitoring and maintenance schedules.

14. Costing

Among the various closure measures those related to the Faro mine workings (section 8.1) involve the greatest engineering effort and constitute the greatest individual costs of the various closure measures. Given the importance of these measures a detailed costing of the two alternative options for the Faro pit, i.e. "contaminated pit" versus "clean pit" has been completed. The detailed costing table showing assumed unit prices and quantities is given in Appendix D. Here the results are briefly summarized.

Table 14-1 compares the capital and operating costs of the major closure measures for the two option of the Faro open pit: "Contaminated Pit" (Selected Option 1) versus "Clean Pit" (alternative option 2). Note that unit prices have not been finalized which may influence the total costs but has probably little influence on the comparison of the two options.

Table 14.1 Capital and Operating Costs for closure measures at Faro mine site.

Items	Option 1: "Contaminated Pit"	Option 2: "Clean Pit"
Capital Costs (Aug 96 $)		
Water Treatment Plant at Faro mine site	$ 6,700,000	$ 6,700,000
Contaminated Water Storage Reservoir ("Sidehill Dam")	$ 2,200,000	$ 4,000,000
Contaminated Water Collection System (ditches, sumps, pumps, pipelines)	$ 1,200,000	$ 1,400,000
Plug Dam in SE corner of Faro Pit	$ 900,000	$ 900,000
Spillway structure from Faro pit	$ 500,000	$ 2,700,000
Faro Creek Diversion Structures	$ 2,400,000	$ 1,700,000
Relocate Faro Valley Dump	N/A	$ 6,200,000
Total Capital Costs (including 20% contingencies)	$ 16,700,000	$ 28,300,000
Annual Operating Costs ($ per year)		
treatment plant	$/a 390,000	$/a 260,000
power for pumping	$/a 108,000	$/a 56,000
Total Operating Fund Costs (Aug 96 $)	$ 15,000,000	$ 9,500,000
Grand Total Liability Costs	$ 31,700,000	$ 37,800,000

The capital and operating costs of various options of post-closure water treatment are described in detail in Appendix A and are summarized in chapter 10.

This section must be completed with the assistance of Anvil Range in terms of both scheduling and costing. Anvil Range will be required to select unit costs appropriate for the operation for closure activities, as identified in the next draft of this closure plan report.

APPENDIX A

Review of Post-Closure Water Treatment Options at Anvil Range Mine

August 19, 1996

Prepared by

SIMONS
Environmental

Table of Contents

1.0 BACKGROUND

H.A. Simons Ltd was retained by Robertson Geoconsultants Inc. to outline conceptual post-closure water treatment options for the Anvil Range Mine Site. The options evaluated to date including descriptions, capital costs, operating costs and NPV calculations, are presented in the attached tables. The original terms of reference assumed that two separate treatment plants would be constructed - one at Faro and a second a Vangorda/Grum. After a preliminary review of operating and capital costs, two additional options involving combined treatment of water from Faro and Vangorda/Grum water at either Vangorda or the Faro sites were added. In addition to a review of the treatment plant options, discussion is also provided on other issues associated with water treatment including the use of Faro pit for an in-pit treatment system, review of general treatment process options, evaluation of treatment of tailings during discharge to Faro Pit and review of sludge volumes and management issues.

It is emphasized that the comments and costs included in this report are of a conceptual level of accuracy only, and do not include water collection costs upstream of the three pits, Faro, Grum and Vangorda. The primary purpose of the exercise was to develop comparative data, and it is considered that the document develops realistic comparisons.

2.0 TREATMENT PLANT AT GRUM/VANGORDA

The current water treatment plant at Vangorda plateau is a straight lime neutralization plant (SLN) that uses a pond to settle solids, producing a low-density sludge (LDS). The basic plan at present is to re-locate this plant to Little Creek Pond near Vangorda Pit (which will be used for water management and equalization). Sludge would be collected in a new settling pond and pumped to either Grum or Vangorda Pit every 2 or 3 years. For purposes of comparison, four scenarios have been developed for treatment at the Vangorda/Grum site. These options, listed in the attached tables as options V-1 through V-5, can be described as follows:

V-1	Existing LDS Plant -Relocated to Little Creek Pond - 2000 gpm
V-2	Upgrade of relocated LDS plant to HDS process - 2000 gpm
V-3	Construction of new HDS Plant at Little Creek Pond - 2000 gpm
V-4	Construction of new HDS Plant at Little Creek Pond - 1000 gpm

The attached tables summarizes the key physical and operating features of each option as well as their respective capital and operating costs.

Operating conditions and costs are based on the following assumptions:

1. The reagent consumption estimates are based on assumed conservative influent chemical characteristics summarized in Table 1. These characteristics assume higher contaminant levels than are currently experienced on average and are higher than the values in Table 2 below.

2. The table describes the power demand for each scenario, for both the operating and non-operating plant modes.

3. The table displays the annual power usage for each scenario, and shows the plant consumption separate from the pumping usage. The pumping estimates include only these pumps which transfer water from the pits (the "water management facilities") to the plants; the estimates do not include pumping costs related to any water collection systems at either site.

4. Lime consumption estimates are based on the assumed water chemistry presented in Table 1 (which are conservative).

Table 1

Feed Characteristics for Treatment System Evaluation at Vangorda and Faro

		Vangorda	Faro
pH		6.2	7.0
TEMP	C	4	
COND	uS/cm	1500	3500
COLOUR	TCU		
TURBIDITY	FTU	50	
SUS.	mg/L	200	10
DISS.	mg/L	2000	5000
ALK	mg/L as CaCO3	100	270
NH3	mg/L	5	0.50
HARD	CaCO3	300	
Al	mg/L	5	0.10
As	mg/L	0.05	0.10
Ca	mg/L	250	600
Cd	mg/L	0.05	0.02
Cr	mg/L	0.05	0.00
Cu	mg/L	0.05	0.02
Fe	mg/L	10	5
SO_4	mg/L	300	3000
Mg	mg/L	100	345
Mn	mg/L	20	20
Ni	mg/L	2	1
Pb	mg/L	0.2	0.10
Sb	mg/L	0.05	0.05
Zn	mg/L	50	100

5. Supplies include analyses, operator and maintenance supplies

6. The operating cost estimates are based on the following unit values.

Lime CaO	$195/tonne
Flocculant	$3 /kg
Power	$0.082/kWh
Labour	$45 /hour Supervisor
	$29 /hour Operator
	$30 /hour Maintenance

Sludge Handling and Disposal Cost $3.50 /tonne
Based on HDS at 35% Solids
and LDS at 8 % Solids

2.1 Vangorda Water Chemistry

The current feed water characteristics for Vangorda are provided in Table 2. The feed to the water treatment plant will be generated from a combination of three sources.

1) seepage collected from the Grum waste dump

2) seepage collected from the Vangorda waste dump

3) ground water pumped from the Vangorda pit

Typical effluent data for the existing treatment plant and the Permit criteria are also provided in the Table 2 for comparative purposes.

Table 2 **Typical Influent and Effluent Characteristics and Permit Criteria at Vangorda**

Parameter	Influent	Effluent	Permit
pH	7.7	9.1	>6.5
NFR	15	5	15
Alkalinity	150	100	
NH_3	2	2	3.5
SO_4	500	500	
Total Metals			
Aluminum	0.3	0.03	
Arsenic	0.05	0.02	0.05
Antimony	0.05	0.02	0.10
Cadmium	0.03	0.002	0.02
Chromium	0.002	0.002	
Cobalt	0.2	0.05	
Copper	0.1	0.02	0.20
Iron	2	0.3	
Lead	0.05	0.03	0.20
Manganese	6	1.5	
Mercury	<0.03	<0.03	0.005
Molybdenum	0.002	0.002	0.50
Nickel	0.2	0.01	0.50
Selenium			0.05
Silver	<0.03		0.10
Zinc	20	0.3	0.50
Toxicity LC_{50}			100%

The feed to the Vangorda treatment plant has a neutral pH and contains significant concentrations of zinc, some iron and manganese and minor amounts of other metals. Feed water chemistry can be expected to vary with respect to metals concentrations during operation, however it is assumed that the water will remain neutral to alkaline during active operation due to residual alkalinity in the waste rock.

The current treatment plant operates in compliance with the permit with some minor exceptions due to loss of suspended solids which can result in a minor exceedence in some metals. It is uncertain whether there will any further requirements for increasing permit limits at closure, potentially there could be some limitation placed on the release of manganese.

2.2 Expected Performance After Closure for LDS System and HDS

It is anticipated that the re-located LDS treatment plant could perform adequately after closure based on the following assumptions:

- Permit criteria remain unchanged
- Influent chemistry does not change dramatically i.e. - alkaline conditions, low levels of contaminants, absence of other metals of concern such as Cd, Pb etc.
- Current methods of handling and storing sludge are acceptable.

The current treatment system produces a low density sludge which is settled and dewatered using a pond. This practice is acceptable as long as loadings are low and the costs associated with transferring the sludge either to Grum or Vangorda pit are acceptable.

2.3 Advantages of an HDS System at Vangorda

The installation of an HDS plant at Vangorda would produce a dense sludge which will reduce handling requirements and costs associated with sludge disposal. Sludges produced by the HDS process versus the LDS process also tend to be more stable, both physically and chemically. This may be an advantage if this is an issue that influences disposal options and long-term liability. In addition an HDS system should be capable of achieving lower effluent specifications than is current achieved (if this became a requirement after closure). If future permit specifications require removal of Mn to limits in force in some jurisdictions (i.e. 1.0 mg/L)., it is unlikely that it could be achieved with an LDS system. HDS systems can be operated to oxidize and precipitate Mn. It is important to note that current limits for Cu, Ni, Pb and Zn are above concentrations that would normally be expected to cause non-compliance with the toxicity requirement. Operation of the LDS system near these limits would likely result in non-compliance with respect to toxicity. HDS plants tend to register more efficient lime utilization than LDS plants but this is may not be a significant factor in this case due to the relatively low estimated lime consumption at Vangorda. A process flowsheet for an HDS System is enclosed.

2.4 Flows - Vangorda

The flows at Grum/Vangorda for the purpose of this comparison have been estimated at 600,000 m^3/y equivalent to an average continuous annual flow of 300 USgpm.

2.5 Capital Cost Estimates - Vangorda

The Capital Cost Estimates for the four treatment options at Vangorda, including plant feed systems, from the attached Table, can be summarized as follows

V-1 Existing LDS Plant -Relocated to Little Creek Pond - $3.6 million

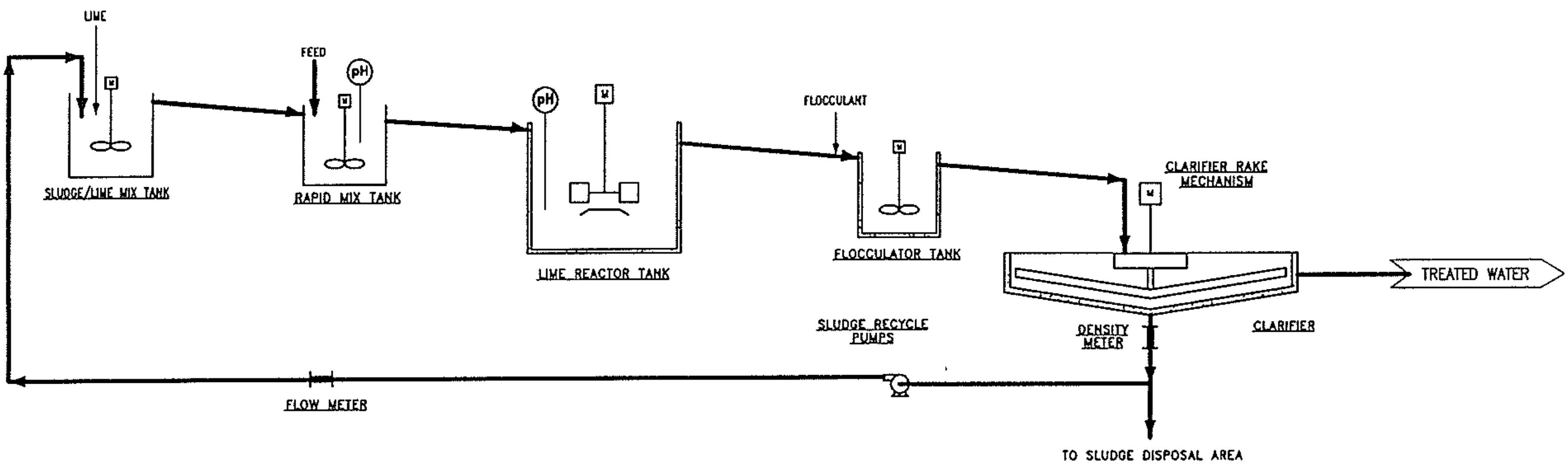
V-2 Upgrade of relocated LDS plant to HDS process - $4.3 million - equivalent to an incremental cost of $0.7 to upgrade from LDS to HDS

V-3 Construction of new HDS Plant at Little Creek Pond - $5.3 million

V-4 Construction of new HDS Plant at Little Creek Pond with a design flow of 1000 gpm - $3.6 million

2.6 Power Requirements - Vangorda

As noted above, a preliminary-level estimate has been made for power demand and usage for each scenario; the figures include all pumping costs from the pits (the water management vehicles), but exclude water collection costs upstream of the three pits.



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ANVIL RANGE MINING CORP.
FARO, YUKON

SIMONS

FARO WATER TREATMENT PLANT

PROCESS FLOWSHEET SCHEMATIC

ACCT. No.	DWG. NO.	REV.
-	DWG	REV

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2.7 Sludge Generation

Estimated sludge generation at Vangorda will be 148 tonne/y on a dry weight basis, based on the influent chemistry presented in Table 1. The estimate is sensitive to flow rates and water chemistry - mainly carbonate, zinc and iron. The quantity of sludge generated would increase dramatically if carbonate content increases.

LDS (V-1) would produce 1855 tonne/y of sludge on a wet basis - equivalent to 1686 m^3 while HDS would produce 424 tonne/y , equivalent to 314 m^3.

2.8 Discussion

The lowest capital costs are for V-1 and V-4 at $3.6 million. The plant costs for V-1 are less than V-4 but V-1 has higher costs for sludge transfer and storage due to the low density sludge produced. Operating costs are similar for all options. V-4 is the most attractive option due to the production of dense sludge but it is important to note that due to its lower capacity V-4 would operate for a longer term each year than V-1, assuming storage is provided.

3.0 FARO TREATMENT PLANT

A new water treatment plant will be required at Faro. The design and configuration of this plant will be dependent on which closure options are selected. Tailings from processing Grum/Vangorda ore are currently being backfilled to Faro pit. After closure tailings from the Rose Creek tailings facility will be re-processed and discharged to Faro pit. These tailings although not acidic do contain some leachable zinc that would report to the pit water during re-processing. In addition it is recognized that the pit contains leachable zinc in oxidized waste rock within the pit and in the pit wall. Two basic options are being considered for Faro Pit.

Option 1 - Use Faro Pit as contaminated water reservoir taking advantage of natural attenuation of zinc through carbonate precipitation and other mechanisms. The pit would be used to collect seepage. In pit treatment systems using lime, limestone or soda ash could be considered to reduce contaminant concentrations prior to either treatment in a conventional plant or use of passive systems such as wetlands, or limestone trenches. Only a small equalization pond would be required since the pit itself would provide a substantial amount of equalization.

Option 2 - Isolate Faro Pit from sources of contamination and attempt to improve water quality over time (20 year) such that direct discharge to the environment is feasible. The O/F from the pit would require treatment prior to release during this interim period. A large equalization pond would be required to buffer seasonal flows . Seepage would have to be collected and pumped to the equalization pond.

3.1 Faro Water Chemistry

The predicted water chemistry at Faro for the purpose of this comparison is provided in Table 1. This is a conservative estimate of influent chemistry to ensure that estimates for lime consumption and sludge generation are also conservative.

3.2 Evaluation of Treatment Alternatives

3.2.1 Ion Exchange

At this point the use of ion exchange as a long-term treatment option for this type of effluent has not been demonstrated, although a number of studies have indicated that it may be economic in certain site-specific situations with the recovery of a marketable product. Lab studies would be required to demonstrate feasibility and estimate costs. Operating complexity associated with resin regeneration and the treatment and disposal of brine solutions containing high metals concentrations in most cases make ion exchange un-attractive. In addition resin fouling from the presence of iron and organics compounds can reduce resin re-use and increase costs.

3.2.2 Wetlands

These systems are usually only attractive when used for small flows or for polishing. A considerable amount of space is required and operation is restricted to frost free periods. It in likely that this alternative could be used to replace a conventional treatment system especially at the flows anticipated at Faro. However it may have some use in the future to treat small seeps that appear seasonally.

3.2.3 Limestone Trenches

Zinc can be removed at neutral pH in the presence of carbonate. Limestone, either in a treatment plant or a passive system such as a limestone trench has been investigated and proven partially successful (The author has direct experience with limestone treatment). Limestone may release sufficient carbonate into solution at higher than ambient temperatures to precipitate zinc. However the kinetics of dissolution appear to be slow at the low temperatures that normally occur at mine sites - this make this a slow process relative to lime. The quantity of limestone required becomes large in this case relative to the volume of water treated. The use of limestone trenches or other means of contact may be attractive as either a roughing or polishing step but this is unlikely to replace conventional treatment at the current flows anticipated at Faro. The use of pulverized limestone in a treatment plant where a high degree of agitation is provide has proven feasible at bench scale to remove zinc (in high by contaminated samples) but lab testing under expected ambient condition of water temperature and chemistry at Faro would be required. The use of pulverized limestone as an alternative to quick lime may have some advantage in terms of operating costs, although the quantity of sludge generation would increase thereby increasing sludge disposal costs.

3.2.4 Addition of Lime/Soda Ash to Tailings

The Faro tailings are partially oxidized and contain some dissolved zinc. When these tailings are pumped to the Faro Pit, lime and or soda ash could be added to the tailings to both depress soluble zinc and add alkalinity to the pit water to precipitate zinc in the water column. Tests would be required to determine if this measure has any advantages. Based on experience, the quantity of reagent required could be high. In addition, a high level of mixing would be required to maximize reagent utilization. If soda ash addition proved effective at low dosages, this option could be feasible otherwise it is unlikely that the quantity of lime added to precipitate zinc associated with the tailings would be less than that required to treat water once the water in the pit has stabilized.

3.2.5 In-Pit Treatment

This option would involve the treatment of pit water through a simple lime neutralization system followed by deposit back in the pit for settling. This measure could effectively treat the water and overtime reduce the contaminant level in the pit water but it is unlikely that sufficient mixing could be provided between the lime slurry being added and the pit water to precipitate additional metals though indirect contact. This option requires some cost estimation work to determine whether it is worth considering further for Vangorda.

3.2.6 LDS vs HDS

An LDS system at Faro would have a lower capital cost that an HDS system however on an overall basis when operating costs and NPV are considered it is certain that an HDS system will be favoured. The same advantage for the HDS system outlined would apply to the Faro site with the added advantage that the higher LDS sludge volumes that would be generated at Faro would render it more costly to operate than HDS due to sludge disposal costs.

3.4 Capital Cost Estimates - Faro Treatment Plant

The Capital Cost Estimates for the two treatment options at Faro, including plant feed systems, from the attached tables, can be summarized as follows:

F-1 HDS Plant -for 2500 US gpm, operating 8 months/year - $8.0 million
F-2 HDS Plant -for 5000 US gpm, operating 4 months/year - $13.1 million

4.0 COMBINED TREATMENT OPTIONS

Capital and operating cost estimates for combined water treatment plants at either Vangorda or Faro are presented in the attached tables.

Option C-1 is based on construction of a 3000 gpm HDS plant to be constructed at Vangorda. In this option Faro's drainages would be pumped to the Vangorda Pit for storage prior to treatment, and high density sludge would be pumped to either Vangorda or Grum pits for permanent storage. The cost for this option, including the pipeline, is less than the combined costs of the best options for the individual plants at the Faro and Vangorda sites - both in terms of capital and operating cost.

Option C-2 is based on construction of a 3000 gpm HDS plant at Faro. Water from Grum and Vangorda would be pumped to the Faro Pit for storage prior to treatment in a single plant near the Faro Millsite. The pumped volume of C-2 is one quarter of the volume of C-1.

4.1 Capital Cost Estimates - Combined Treatment Plant

The Capital Cost Estimates for the two combined treatment options, including plant feed systems, from the attached tables, can be summarized as follows:

C-1 HDS Plant -for 3000 US gpm, operating 8 months/year - $11.3 million (plant at Vangorda).

C-2 HDS Plant -for 3000 US gpm, operating 8 months/year - $11.2 million (plant at Faro).

5.0 SLUDGE DISPOSAL OPTIONS

Sludge generated by the current LDS plant at Vangorda is primarily a lime precipitate containing mainly zinc but also iron and other metal hydroxides. These hydroxides are chemically stable at the pH at which they are produced. However deviation from this pH can result in instability. For example if pH drops to say 8, zinc hydroxide solids can solubilize and release zinc into solution. The theoretical solubility of zinc as its hydroxide at pH 8.0 is approximately 1 mg/L. The release of zinc from this type of sludge would not necessarily occur however if the sludge contain significant percentages of gypsum, ferric hydroxide or carbonate. Hydroxides are not the stable form of the these metals in equilibrium with carbon dioxide in air.

The selection of sludge disposal methods and disposal site will depend on behavior and long-term stability of under ambient environmental conditions, i.e. contact with air, precipitation, freeze/thaw cycles, moisture content etc. Testing of sludge is essential to make these decisions. Some sludges from straight lime neutralization processes are chemically stable and can be deposited in a sub-aqueous environment without concern that contaminants will re-solubilize. These sludge often contain gypsum and/or ferric hydroxide but carbonates may also be present. Alternatively some sludges from LDS systems are unstable and not acceptable for sub-aqueous disposal. These types of sludge need to be isolated in impoundments. Exposure of these types of sludges to air should increase in stability with time due to the absorption of CO_2 from the air which results in the formation of $CaCO_3$ and other metals carbonate precipitates in the sludge. HDS sludges tend to be more stable than equivalent LDS sludges due to the formation of crystalline minerals which incorporate metals and the absorption of CO_2 if aeration is involved. However as mentioned above testing is essential for HDS sludges as well as LDS sludges.

At this point there a number of alternatives available for sludge disposal at Faro as follows:

- in pits,
- in separate impoundments,
- or on the waste dumps.

None of these options can be ruled out without some testwork and review of sludge disposal objectives.

Final selection of the sludge disposal methods will be dependent on the following factors:

1) long-term stability
2) capital and operating costs
3) assessment of potential liability and risks, and finally
4) assessment of beneficial uses.

6.0 RECOMMENDATIONS

This report is based on conceptual-level information, and the cost estimates, in absolute terms, are considered to be at an order-of-magnitude level of accuracy. However, the relative accuracy of the estimates is somewhat more reliable, since these estimates were developed on comparative basis. The capital and operating cost estimates, plus NPV indicate that a combined plant has a NPV which is 10 percent more favourable, than an NPV based on two separate plants at Faro and Grum/Vangorda.

The cost and NPV data included in the attached "Comparison of Treatment Options" provide a sound comparative basis to proceed forward. We recommend the following approach be adopted:

1. Select a "Faro" option and develop to a prefeasibility level of accuracy.

2. Select a "Grum/Vangorda" option and develop to a prefeasibility level of accuracy.

3. Select a "Combined" option and develop to a prefeasibility level of accuracy.

4. Conduct water management studies in parallel to the above work.

5. After completion of the above scoping studies, select a "Best-value" option, for advancement to Feasibility Study stage.

Submitted:

T.W. Higgs

T.D. Lee

Attachment
"Comparison of Treatment Options" (3 pages)

TABLE A-1

COMPARISON OF TREATMENT OPTIONS

Anvil Range Mine
B242A -- 19 Aug 1996

	V-1 LDS/2,000 gpm (Existing facility, moved to Vangorda)	V-2 HDS/2,000 gpm (Existing, relocated, converted to HDS)	V-3 HDS/2,000 gpm (New HDS Plant)	V-4 HDS/1,000 gpm (New HDS Plant)	F-1 HDS/2,500 gpm (New HDS facility @ Faro mill site)	F-2 HDS/5,000 gpm (New Faro plant, seasonal operation)	C-1 HDS/3,000 gpm (New HDS @ Vangorda, P/L from Faro pit)	C-2 HDS/3,000 gpm (New HDS @ Faro, P/L from Grum Pit)
	Operates 4 months/yr	Operates 4 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr
1. PHYSICAL FEATURES								
1.1 Water Management	In Vangorda Pit, plus Little Creek Pond. Grum drainages pumped to Vangorda Pit via existing pipeline.	In Vangorda Pit, plus Little Creek Pond. Grum drainages pumped to Vangorda Pit via existing pipeline.	In Vangorda Pit, plus Little Creek Pond. Grum drainages pumped to Vangorda Pit via existing pipeline.	In Vangorda Pit, plus Little Creek Pond. Grum drainages pumped to Vangorda Pit via existing pipeline.	Faro Mill and Mine area drainages will be collected and transferred into Faro Pit.	Faro Mill and Mine area drainages will be collected and transferred into Faro Pit.	Faro Mill and Mine drainages will be collected in Faro Pit, and transferred each summer to Vangorda Pit. Grum drainages will be pumped to Vangorda Pit in existing pipeline.	Faro Mill & Mine area drainages will be collected and transferred into Faro Pit. Vangorda & Grum drainages will be pumped to Faro Pit each summer, on a 4-month campaign basis.
1.2 Plant Location	Near Little Creek Pond, west of Vangorda Pit.	Near Little Creek Pond, west of Vangorda Pit.	Near Little Creek Pond, west of Vangorda Pit.	Near Little Creek Pond, west of Vangorda Pit.	On the current Faro Mill site.	On the current Faro Mill site.	Near Little Creek Pond, west of Vangorda Pit.	On the current Faro Mill site.
1.3 Plant Feed System	Grum drainages will be transferred to Little Creek Pond via existing pipeline system. New pumps in Little Creek Pumphouse will feed Treatment Plant.	Grum drainages will be transferred to Little Creek Pond via existing pipeline system. New pumps in Little Creek Pumphouse will feed Treatment Plant.	Grum drainages will be transferred to Little Creek Pond via existing pipeline system. New pumps in Little Creek Pumphouse will feed Treatment Plant.	Grum drainages will be transferred to Little Creek Pond via existing pipeline system. New pumps in Little Creek Pumphouse will feed Treatment Plant.	A pumping system will withdraw water from Faro Pit and deliver it to the Treatment Plant.	A pumping system will withdraw water from Faro Pit and deliver it to the Treatment Plant.	Grum and Faro drainages will be transferred to Vangorda Pit, then pumped to Little Creek Pond. New pumps in Little Creek Pumphouse to feed plant.	A pumping system will withdraw water from Faro Pit and deliver it to the Treatment Plant.
1.4 Plant Description	Simple Lime Neutralization system, within a building. Effluent flows by gravity to Clarification Pond.	Parts of the existing LDS facility will be incorporated into a new HDS facility.	The existing LDS plant (east of Grum Pit) will continue to operate while a new HDS facility is constructed by Little Creek Pond.	The existing LDS plant (east of Grum Pit) will continue to operate while a new HDS facility is constructed by Little Creek Pond.	A new 2,500 gpm HDS Plant will operate for eight months of each year.	A new 5,000 gpm HDS Plant will operate for four months of each year.	The existing LDS plant (east of Grum Pit) will continue to operate while a new HDS facility is constructed by Little Creek Pond.	The existing LDS plant (east of Grum Pit) will continue to function while a new 3000 gpm HDS facility is constructed by Faro Pit.
1.5 Treated Water Discharge	Decant from new Clarification Pond flows directly to Vangorda Creek.	Directly from Plant to a new diffuser in Vangorda Creek.	Directly from Plant to a new diffuser in Vangorda Creek.	Directly from Plant to a new diffuser in Vangorda Creek.	Treated water will be piped to a new diffuser in Rose Creek.	Treated water will be piped to a new diffuser in Rose Creek.	Directly from Plant to a new diffuser in Vangorda Creek.	Treated water will be piped to a new diffuser in Rose Creek.
1.6 Sludge Storage	In bottom of Clarification Pond; remove every 2 or 3 years, to new Sludge Storage area.	Pumped on a batch basis from the Treatment Plant to a perched storage area within Vangorda Pit or Grum Pit.	Pumped on a batch basis from the Treatment Plant to a perched storage area within Vangorda Pit or Grum Pit.	Pumped on a batch basis from the Treatment Plant to a perched storage area within Vangorda Pit or Grum Pit.	The sludge will be pumped to a new sludge pond, where it will dewater and dry; the drainages will return to Faro Pit.	The sludge will be pumped to a new sludge pond, where it will dewater and dry; the drainages will return to Faro Pit.	Pumped on a batch basis from the Treatment Plant to a perched storage area within Vangorda Pit or Grum Pit.	The sludge will be pumped to a new sludge pond, where it will dewater and dry; the drainages will return to Faro Pit.

TABLE A-1

COMPARISON OF TREATMENT OPTIONS

Anvil Range Mine

B242A -- 19 Aug 1996

	V-1 LDS/2,000 gpm (Existing facility, moved to Vangorda)	V-2 HDS/2,000 gpm (Existing, relocated, converted to HDS)	V-3 HDS/2,000 gpm (New HDS Plant)	V-4 HDS/1,000 gpm (New HDS Plant)	F-1 HDS/2,500 gpm (New HDS facility @ Faro mill site)	F-2 HDS/5,000 gpm (New Faro plant, seasonal operation)	C-1 HDS/3,000 gpm (New HDS @ Vangorda, P/L from Faro pit)	C-2 HDS/3,000 gpm (New HDS @ Faro, P/L from Grum Pit)
	Operates 4 months/yr	Operates 4 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr
2. OPERATING FEATURES								
2.1 Sludge D/W tonne/yr	148	148	148	148	1,026	1,026	1,174	1,174
2.2 Sludge W/W tonne/yr	1,855	424	424	424	2,933	2,933	3,357	3,357
2.3 Sludge Volume m^3/yr	1,686	314	314	314	2,172	2,172	2,486	2,486
2.4 POWER DRAW kW								
Operating Mode	115	160	160	120	175	235	190	190
Non-Operating Mode	35	48	48	48	70	70	76	76
2.5 POWER USAGE kWh/a								
Plant	540,200	747,500	747,500	840,900	1,226,400	1,095,000	1,331,500	1,331,500
Pumping	174,300	174,300	174,300	174,300	217,800	217,800	1,503,000	874,400
TOTAL	714,500	921,800	921,800	1,014,200	1,443,200	1,312,800	2,835,000	2,205,900
2.6 Design Flow gpm	2,000	2,000	2,000	1,000	2,500	5,000	3,000	3,000
2.7 Average Flow gpm	300	300	300	300	1,250	1,250	1,550	1,550
2.8 Lime Consumption t/a	133	116	116	116	711	711	827	827
3. CAPITAL COST SUMMARY (Aug 96 $)								
3.1 Water Collection	not included	not included	not included	not included	not included	not included	not included	not included
3.2 Water Management	50,000	50,000	50,000	50,000	700,000	800,000	2,300,000	2,300,000
3.3 Infrastructure	215,000	215,000	225,000	215,000	305,000	320,000	235,000	305,000
3.4 Plant Feed System	100,000	100,000	100,000	70,000	400,000	600,000	170,000	170,000
3.5 Treatment Plant	785,000	1,685,000	2,175,000	1,385,000	2,615,000	5,030,000	3,055,000	2,935,000
3.6 Treated Water Transfer	150,000	100,000	100,000	80,000	200,000	250,000	90,000	210,000
3.7 Sludge Transf. & Storage	700,000	250,000	250,000	200,000	180,000	200,000	350,000	180,000
SUB-TOTAL	2,000,000	2,400,000	2,900,000	2,000,000	4,400,000	7,200,000	6,200,000	6,100,000
3.8 Construction Indirects	700,000	800,000	1,000,000	700,000	1,500,000	2,500,000	2,100,000	2,100,000
3.9 Engineering Indirects	300,000	400,000	500,000	300,000	800,000	1,200,000	1,100,000	1,100,000
TOTAL	3,000,000	3,600,000	4,400,000	3,000,000	6,700,000	10,900,000	9,400,000	9,300,000
Owner's Contingency	600,000	700,000	900,000	600,000	1,300,000	2,200,000	1,900,000	1,900,000
GRAND TOTAL	3,600,000	4,300,000	5,300,000	3,600,000	8,000,000	13,100,000	11,300,000	11,200,000

TABLE A-1

COMPARISON OF TREATMENT OPTIONS

Anvil Range Mine

B242A -- 19 Aug 1996

	V-1 LDS/2,000 gpm (Existing facility, moved to Vangorda)	V-2 HDS/2,000 gpm (Existing, relocated, converted to HDS)	V-3 HDS/2,000 gpm (New HDS Plant)	V-4 HDS/1,000 gpm (New HDS Plant)	F-1 HDS/2,500 gpm (New HDS facility @ Faro mill site)	F-2 HDS/5,000 gpm (New Faro plant, seasonal operation)	C-1 HDS/3,000 gpm (New HDS @ Vangorda, P/L from Faro pit)	C-2 HDS/3,000 gpm (New HDS @ Faro, P/L from Grum Pit)
	Operates 4 months/yr	Operates 4 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr	Operates 4 months/yr	Operates 8 months/yr	Operates 8 months/yr
4. OPERATING COST SUMMARY (Aug 96 $)								
4.1 Reagents	27,976	24,584	24,584	24,584	146,874	146,874	171,458	171,458
4.2 Power	58,589	75,588	75,588	83,164	118,342	107,650	232,470	180,880
4.3 Labour	38,570	38,570	38,570	77,630	71,630	27,200	82,650	82,650
4.4 Supplies	38,857	35,857	35,857	42,163	42,163	37,720	42,265	42,265
4.5 Sludge Disposal	6,493	1,484	1,484	1,484	10,264	10,264	11,748	11,748
TOTAL (rounded)	167,000	176,000	176,000	223,000	389,000	330,000	541,000	489,000
5. NET PRESENT VALUE								
5.1 Capital Cost	3,600,000	4,300,000	5,300,000	3,600,000	8,000,000	13,100,000	11,300,000	11,200,000
5.2 Operating Cost	167,000	176,000	176,000	223,000	389,000	330,000	541,000	489,000
5.3 Net Present Value								
at 4%	5,493	6,267	7,210	6,197	12,432	16,500	17,454	16,706
at 8%	4,616	5,315	6,207	5,087	10,407	14,458	14,629	14,102
at 12%	4,037	4,682	5,527	4,370	9,077	13,035	12,770	12,376

SIMONS

APPENDIX B

Hydro-electric Power and Contaminated Water Pumping System

1.0 Hydro-electric Power Generation

1.1 Description of System

The hydro-electric system would use storage in the reservoir behind the Intermediate Dam after removal of tailings to regulate the flows in Rose Creek, which would be used to generate electrical power. The powerhouse would be located a short distance below the existing Cross Valley Dam, which would provide a static head of approximately 30m (98 feet), and a net head at the turbines after allowing for friction losses in the penstock of approximately 27m (88 feet). The penstock would be 1.22m (48") in diameter and approximately 1,000m long. The penstock alignment would be along the north side of the present tailings impoundment.

In making a preliminary estimate of the hydro-electric potential, the following assumptions have been made:

- Hydro power would only be generated during the six month period May to October inclusive. (Flow regulation over a twelve month period would be impractical as it would require over 14m of active storage).

- During the six month period power would be generated at a constant rate.

- The surface area of the reservoir behind the Intermediate Dam will be approximately 1.9 sq. kilometres.

- The unit runoffs during a mean annual runoff year and the drainage areas of the sub-catchments to Rose Creek above the Intermediate Dam are as given on Figure 4.1, and the monthly flow distribution and the monthly lake evaporation are as given in Table 4.1 in the SRK Report "Tailings Disposal in the Faro Pit" dated June, 1991.

- Overall efficiency of the turbines and generators would be 85 percent.

Typical annual operating costs for the system would be about 2 percent of the capital cost.

1.5 Estimated Power Costs

Assuming an interest rate of 7 percent and an amortisation period of 25 years, the cost of generating power is estimated at $0.089 per kwh.

2.0 Contaminated Water Pumping System

The general layout of the sumps, pumping installations, and pipelines delivering contaminated water to the water treatment plant are shown on Figure 8-1a (Faro "Contaminated Pit"), Figure 8-1b (Faro "Clean Pit"), and on Figure 9-1a (Grum / Vangorda).

Tables 1, 2, and 3 for the Faro "Contaminated Pit", Faro "Clean Pit", and Vangorda receptively list the estimated flows, pipeline lengths and sizes, pumping heads, pump power requirements, pump horsepowers, and pipeline costs for the two Faro alternatives and Vangorda. The cost of the pumping installations has not been included.

The total estimated power requirements for the contaminated water pumping systems are as follows:

Faro "Contaminated Pit"	290 kw	389 HP
Faro "Clean Pit"	151 kw	202 HP
Vangorda	28 kw	38 HP

To the above power requirements must be added the power requirements of the water treatment plants. However it seems apparent that the hydro-electric power system outlined above would produce sufficient power to meet the mine's demand for the water pumping and treatment systems during years of average and greater than average runoff. During years of low runoff some backup form of power (from the grid or diesel electric) would be necessary.

It should be noted that in practice the power demands for the water pumping and treatment systems will to a large extent mimic the runoff hydrographs, and that therefore the power demand will not necessarily be constant as assumed above. Varying the power generated to follow both the inflows to the reservoir and the varying power demand could therefore allow more efficient utilisation of the available water, provided the turbine and generator set design output is increased to meet the fluctuating demand.

Table 1: ANVIL RANGE MINING COMPLEX - PUMP SUMMARY

FARO - OPTION 1 - "CONTAMINATED PIT"

PIPELINE FROM	PIPELINE TO	Q M3/ YEAR	LENGTH	DIAM.	STATIC HEAD	FRICTION HEAD	TOTAL HEAD	PUMP KW	PUMP HP	EST PIPELINE COST
Zone 2	Pit	140,000	1500'	4"	205'	23'	228'	16.2	21.8	27,000
Sump 2	Sump 1	95,000	3500'	4"	170'	20'	190'	6.9	9.2	35,000
Sump 1	SH Dam	175,000	6200'	6"	125'	20'	145'	9.7	13.0	93,000
Main Pit	SH Dam	1,041,000	4800'	8"	23'	17'	40'	15.8	21.1	96,000
SH Dam	WTP	1,516,000	1500'	10"	40'	22'	62'	35.6	47.7	39,000
								84.2	112.9	
SH DAM Wet Yr. Overflow	Main Pit Wet Yr. Overflow	300,000 M3/month	4800'	10"	223'	79'	302'	206	276	124,800
		Alternate		12"	223	33'	256'	175	234	168,000
									August 1996	

Table 2: ANVIL RANGE MINING COMPLEX - PUMP SUMMARY

FARO - OPTION 2 "Clean Pit "

PIPELINE FROM	PIPELINE TO	Q m3/ YEAR	LENGTH	DIAM.	STATIC HEAD	FRICTION HEAD	TOTAL HEAD	PUMP KW	PUMP HP	EST PIPELINE COST
Zone 2	Sump 2	140,000	1800'	4"	210;	15'	225'	21.5	16.0	32,500
Sump 2	Sump 1	235,000	3500'	6	170'	20'	190'	16.9	22.6	52,500
Sump 1	SH Dam	315,000	6200'	8"	125'	15'	140'	16.6	22.3	124,000
Main Pit	SH Dam	421,000	4800'	6"	23'	13'	36'	5.7	7.7	72,000
Pit Sump	SHD	480,000	8600'	6"	280'	19'	299'	54.3	72.8	238,000
SHD	WTP	1,516,000	1500'	10"	40'	22'	62'	35.6	47.7	39,000
								150.6	201.9	
									August 1996	

Table 3: ANVIL RANGE MINING COMPLEX - PUMP SUMMARY

GRUM / VANGORDA

PIPELINE FROM	PIPELINE TO	Q m3/ YEAR	LENGTH	DIAM.	STATIC HEAD	FRICTION HEAD	TOTAL HEAD	PUMP KW	PUMP HP	EST PIPELINE COST
PIT	LC DAM	300,000	1312	6"	33'	7'	40'	4.5	6.1	21,000
SUMP B	LC DAM	280,000	2953	6"	23'	232'	46'	4.9	6.5	45,000
LC DAM	WTP	610,000	565	8"	75'	6'	81'	18.7	25	14,000
								28.1	37.6	
									August 1996	

FIGURE 1:
REGULATED FLOW FOR POWER GENERATION
INTERMEDIATE DAM

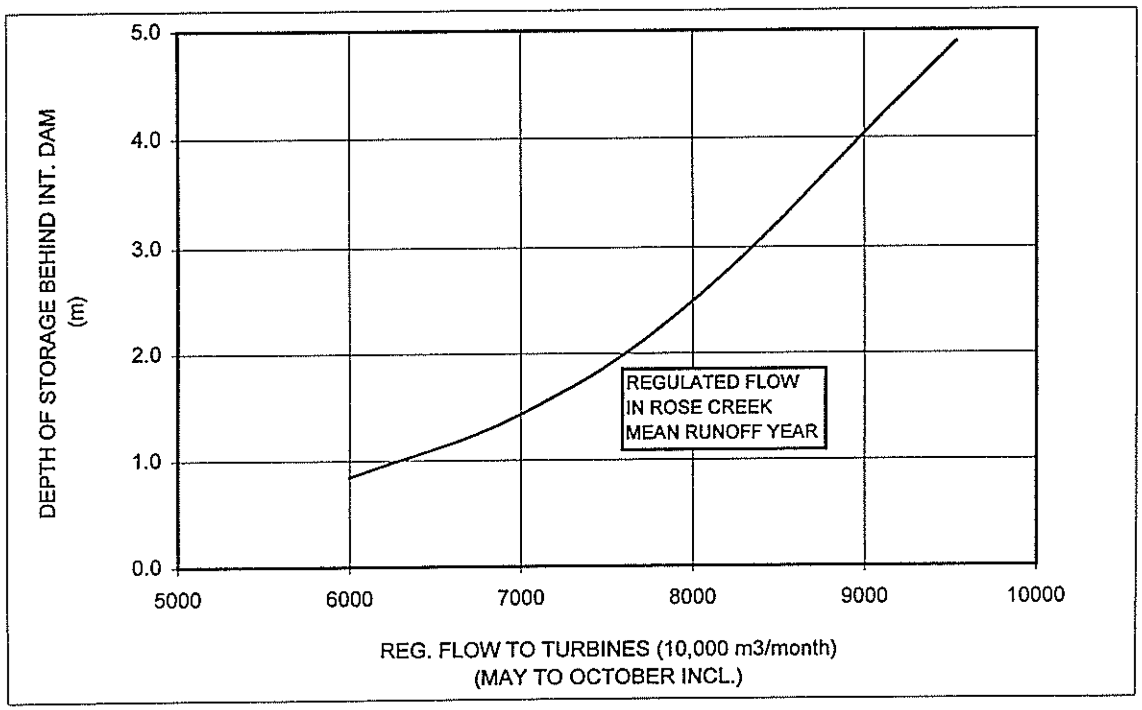
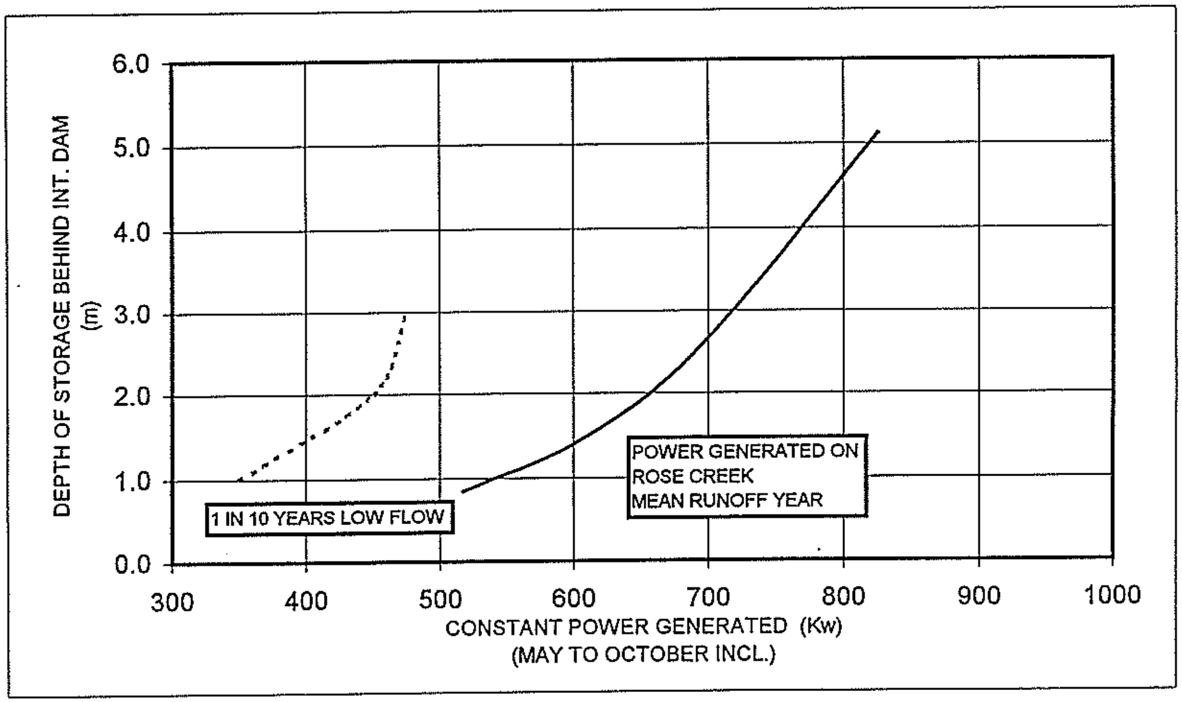


FIGURE 2:
POWER GERERATED FROM ROSE CREEK
INTERMEDIATE DAM



APPENDIX C

SEISMIC GROUND MOTION ESTIMATES
ANVIL RANGE MINING COMPLEX
FARO, YUKON

Introduction

Closure plans for the Anvil Range Mining Complex, Faro, Yukon require consideration of the ability of water storage dams and tailings embankments to withstand seismic ground motions. Probabilistic estimates of seismic ground motions corresponding to selected return periods (or probabilities of exceedance) were made at the site. The following describes the criteria for estimation of ground motions, the estimation procedure, and presents the results.

Criteria for Ground Motion Estimation

The Canadian Dam Safety Association Dam Safety Guidelines (CDSA, 1995, Section 5.0) specify the following criterion for estimation of the ground motions:

> Dams shall be designed and evaluated to withstand ground motions associated with a Maximum Design Earthquake (MDE), without release of the reservoir.
>
> Selection of the MDE for a dam shall be based on the consequences of dam failure.

The above criterion was developed for application to water storage dams. However, Section 11.0 of the Guidelines specify that tailings dams shall meet the same requirements. The last sentence above implies that the MDE ground motions should increase with increasing severity of the consequences (or risks) associated with failure of dams or embankments. Table 5-1 of the Guidelines provides specific criteria for derivation of MDE ground motions. A copy of this table is given below.

USUAL MINIMUM CRITERIA FOR DESIGN EARTHQUAKES
(from Table 5-1 of CDSA, 1995)

Consequence Category	MAXIMUM DESIGN EARTHQUAKE (MDE)	
	Deterministically Derived	Probabilistically Derived Average Return Period (years)
Very High	MCE[1]	10,000
High	50% to 100% MCE	1,000 to 10,000
Low	-	100 to 1,000

[1] Maximum Credible Earthquake

The description of consequence categories is given in Section 1.4 of the Guidelines. In the case of the Anvil Range Mining Complex, failure of the dams or embankments could result in release of acid water and tailings and considerable damage to the river environment and fisheries. Such consequences are considered "Very High" and therefore the average return period of ground motions derived by a probabilistic method should be 10,000 years.

Although probabilistic estimates of ground motion are made herein, a comment concerning the term "Maximum Credible Earthquake" and deterministic estimates is in order. The MCE is basically an earthquake magnitude. In the Guidelines, the MCE is defined as the largest reasonably conceivable earthquake that could occur under the presently known or interpreted tectonic framework. Once the magnitude of the nation. The rates of exceedance of particular ground motion values are computed by simple counting. A computer program, called *McHazard*, was written to perform these calculations.

Ground Motion Estimates at Faro

A recent GSC Open File report describes the development of new seismic hazard maps of Canada (Adams et al, 1996). Two seismic zonations are proposed for Canada: the H (for Historical) and the R (for Regional). Each of these zones is assumed to be an equally valid interpretation of the seismological observations and data. The H and R zonations for western Canada as well as the location of Faro are shown on Figures 1 and 2, respectively.

The following zones were used to estimate ground motion at Faro:

H Zonation	R Zonation
MCK - Mackenzie Mountains	MMB - Mackenzie Mountains
SYT - Southern Yukon	SOY - Southern Yukon

Other zones are considered to be too distant to have much effect on the ground motion at Faro. Zone geometries, parameters of the magnitude recurrence equation, and maximum magnitudes for each zone were obtained from the Open File report. Probabilistic estimates of peak ground acceleration were then made for each zonation.

The attenuation relationship used by GSC for western Canada is that derived by Boore et al (1993). This relationship computes peak ground acceleration on a rock site given earthquake magnitude and distance from the site. The relationship was derived using strong motion data recorded in California and it is assumed that the relationship describes ground motion attenuation in western Canada (where no data are available). From the point of view of seismic wave propagation, the structure of the two regions is similar, (i.e., mountainous terrane composed of geologically young rocks) and it is reasonable to assume that ground motion attenuation is similar in both regions.

The resulting seismic hazard curves, which relate values of peak ground acceleration to exceedance probability or return period, are shown in Figure 3. The approach recommended by GSC is to adopt the larger estimate. Thus, if the selected return period is 10,000 years, the curve for the R zonation should be used. From this curve the peak ground acceleration corresponding to a 475 year return period is approximately 0.05g and that corresponding to a 10,000 year return period is approximately 0.13g. Note that these values apply to rock sites.

The Tintina Fault

Figure 4 shows the locations of earthquake epicenters recorded in southwestern Yukon during 1980-1991. This figure is taken from a paper by Lowe et al (1994) who discuss geological and geophysical data used to interpret the tectonics and geology of the region. Seismic activity in the region is concentrated in southwestern Yukon and there is a general decrease in activity to the northeast. Of particular interest is seismic activity along the Tintina fault which is close to Faro. Numerous small ($M<4$) events occur west of the fault, while immediately east of the fault there is little seismic activity. There is little seismic activity along the trace of the fault. This is consistent with the geophysical data presented by Lowe et al (1994) which show that the fault separates two regions with distinct physical properties: a relatively homogeneous region to the northeast and a more heterogeneous region to the southwest in which considerable strain is built up and sometimes released as earthquakes.

The offsets of major geological features along the fault indicate that about 450 km of displacement has occurred on the fault since Late Cretaceous time (70 million years ago). However, there is no evidence of more recent displacement along the Tintina fault and the fault is not included as an earthquake source zone in either the H or R zonations given in the GSC report, i.e., the fault is not considered active and no maximum magnitude has been defined for the fault. Thus, it is unrealistic to consider a deterministic estimate of seismic ground motion at Faro in which an earthquake is assumed to occur on the Tintina.

References

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CDSA, 1995. *Dam Safety Guidelines.* Canadian Dam Safety Association.

Lowe, C., Horner, R. B., Mortenson, J. K., Johnston, S. T., and Roots, C. F., 1994. New geophysical data from the northern Cordillera: preliminary interpretations and implications for the tectonics and deep geology. *Canadian Journal of Earth Sciences,* 31, 891-904.

APPENDIX D

Facility: Faro Pit					
Option 1: Use Pit as Contaminated Water Storage Reservoir; Maintain Faro Creek Diversion					
Item Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Total Cost**
Build Plug Dam on South-East Corner					
Foundation Preparation	lump sum			$100,000	
Slush grouting; dental concrete	lump sum			$250,000	
grout curtain	lump sum			$250,000	
place till core	m^3	$3.00	16,500	$49,500	
place filter soil	m^3	$5.00	9,000	$45,000	
place rock fill	m^3	$6.00	34,500	$207,000	
Subtotal					$901,500
Upgrade Faro Creek Diversion (current alignment) to pass PMF					
excavate soil	m^3	$3.00	51,000	$153,000	
excavate rock	m^3	$6.00	150,000	$900,000	
excavate rock for by-pass failure area	m^3	$6.00	103,000	$618,000	
place filter soil	m^3	$5.00	7,200	$36,000	
place rip-rap	m^3	$12.00	8,600	$103,200	
Subtotal					$1,810,200
Upgrade Faro Valley Interceptor (current alignment) to pass PMF					
excavate soil	m^3	$3.00	125,000	$375,000	
place filter soil	m^3	$5.00	10,000	$50,000	
place rip-rap	m^3	$12.00	10,000	$120,000	
Subtotal					$545,000
Build Emergency Spillway from SE of Faro Pit to North Fork Rose Creek					
excavate rock in abutment of plug dam	m^3	$6.00	50,000	$300,000	
excavate channel in Haul Road	m^3	$3.00	20,000	$60,000	
place rip-rap in channel	m^3	$12.00	10,000	$120,000	
Subtotal					$480,000
Build Sidehill Dam Reservoir w/ small storage capacity (0.2 million m3)					
Clearing and Grubbing	m^2	$1.00	75,000	$75,000	
Foundation Stripping	m^3	$3.00	40,000	$120,000	
line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	75,000	$1,125,000	
Fill Placement	m^3	$3.00	300,000	$900,000	
Subtotal					$2,220,000
Contaminated Water Collection Ditches (assume depth of 5m)					
excavate collector ditches in overburden	m^3	$3.00	192,000		$576,000
Build & Equip Sump 1 (assume depth of 5m)					
excavate sump in overburden	m^3	$3.00	6,000	$18,000	

line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	1,200	$18,000	
install pump w/ pump house	lump sum			$40,000	
Subtotal					$76,000
Build & Equip Sump 2 (assume depth of 5m)					
excavate sump in overburden	m^3	$3.00	7,500	$22,500	
line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	1,500	$22,500	
install pump w/ pump house	lump sum			$40,000	
Subtotal					$85,000
Contaminated Water Pipelines from Sumps & Pit to Treatment Plant					
capital cost of all pipelines	lump sum				$415,000
Build HDS Treatment Plant w/ 2500 gpm capacity at Faro Mill Site					
construction cost	lump sum				$6,700,000
TOTAL					$13,808,700
Engineering and Contingencies (20%)					$2,761,740
TOTAL CAPITAL COST- OPTION 1 FOR FARO PIT					$16,570,440
					=========
Post-closure Annual Operating Costs					
annual operating cost for treatment plant	lump sum			$389,000	
annual pumping costs	kwh	$0.09	1,269,500	$107,908	
				$496,908	
TOTAL OPERATING FUND COST (assume 30 yrs)					$14,907,225
fund for annual costs (assume 30 yrs)					
CLOSURE LIABILITY- OPTION 1 FOR FARO PIT					$31,477,665
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Facility: Faro Pit					
Option 2: Clean Pit Water over ~20 years; Then Re-establish Faro Creek through Pit					
Item Description	**Unit**	**Unit Cost**	**Quantity**	**Cost**	**Total Cost**
Build Plug Dam on South-East Corner					
Foundation Preparation	lump sum			$100,000	
Slush grouting; dental concrete	lump sum			$250,000	
grout curtain	lump sum			$250,000	
place till core	m^3	$3.00	16,500	$49,500	
place filter soil	m^3	$5.00	9,000	$45,000	
place rock fill	m^3	$6.00	34,500	$207,000	
Subtotal					$901,500
Relocate Faro Valley Dump to Rock Dump downstream of Faro Pit					
excavate, haul and dump rock waste	m^3	$2.40	2,600,000		$6,240,000
Relocate Faro Creek Diversion to North Wall of Faro Valley after ~20 years					
excavate soil	m^3	$3.00	310,000	$930,000	
excavate rock	m^3	$6.00	95,000	$570,000	
place filter soil	m^3	$5.00	6,000	$30,000	
place rip-rap	m^3	$12.00	16,500	$198,000	
Subtotal					$1,728,000
Build Spillway from SW access ramp of Faro Pit to Guardhouse Creek to pass PMF					
excavate soil (including waste rock)	m^3	$3.00	753,500	$2,260,500	
place filter soil	m^3	$5.00	27,500	$137,500	
place rip-rap	m^3	$12.00	19,500	$234,000	
place low-permeability soil	m^3	$5.00	16,500	$82,500	
Subtotal					$2,714,500
Build Sidehill Dam Reservoir w/ large storage capacity (1.0 million m3)					
Clearing and Grubbing	m^2	$1.00	125,000	$125,000	
Foundation Stripping	m^3	$3.00	80,000	$240,000	
line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	125,000	$1,875,000	
Fill Placement	m^3	$3.00	575,000	$1,725,000	
Subtotal					$3,965,000
Contaminated Water Collection Ditches (assume depth of 5m)					
excavate collector ditches in overburden	m^3	$3.00	192,000		$576,000
line collection ditches (not suggested)	m^2	$15.00	1,920,000	$28,800,000	
Build & Equip Faro Valley Sump (temporary)					
build sump structure on Faro Pit bench	lump sum			$50,000	
install pump w/ pump house	lump sum			$40,000	
Subtotal					$90,000

Build & Equip Sump 1 (assume depth of 5m)					
excavate sump in overburden	m^3	$3.00	6,000	$18,000	
line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	1,200	$18,000	
install pump w/ pump house	lump sum			$40,000	
Subtotal					$76,000
Build & Equip Sump 2 (assume depth of 5m)					
excavate sump in overburden	m^3	$3.00	7,500	$22,500	
line sump w/ HDPE 80 & bedding/cover	m^2	$15.00	1,500	$22,500	
install pump w/ pump house	lump sum			$40,000	
Subtotal					$85,000
Contaminated Water Pipelines from Sumps & Pit to Treatment Plant					
capital cost of all pipelines	lump sum				$415,000
Build HDS Treatment Plant w/ 2500 gpm capacity at Faro Mill Site					
construction cost	lump sum				$6,700,000
TOTAL					$23,491,000
Engineering and Contingencies (20%)					$4,698,200
TOTAL CAPITAL COST- OPTION 1 FOR FARO PIT					$28,189,200
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Post-closure Annual Operating Costs					
annual operating cost for treatment plant	lump sum			$389,000	
annual pumping costs	kwh	$0.09	660,000	$56,100	
				$445,100	
TOTAL OPERATING FUND COST (assume 30 yrs)					$13,353,000
fund for annual costs (assume 30 yrs)					
CLOSURE LIABILITY- OPTION 2 FOR FARO PIT					$41,542,200
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