Gartner Lee

Faro Mine Site - Phase I Environmental Site Assessment FINAL REPORT

Prepared For:
DIAND – Waste Management Program

Prepared By:
Gartner Lee Limited
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GLL 99-913

March, 2001

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DIAND – Waste Management Program
Room 345 – 300 Main Street
Whitehorse, Yukon
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Attn: Brett Hartshorne

Dear Brett:

Re: Faro Mine Complex – Phase 1 Environmental Assessment Final Report

The Gartner Lee project team is pleased to provide you with the Final Report on the Faro Mine Complex Phase 1 Assessment. We have incorporated comment received from your review along with those generated by a peer review by the project team.

I would like to thank you for your patience and cooperation on the complex undertaking. We have enjoyed working with you on this project, and hope that this report meets your current needs. If you have any questions, or wish to discuss the findings of this report, please do not hesitate to call Gartner Lee Limited at 633-6474.

Yours very truly,
GARTNER LEE LIMITED

Leslie Gomm
Senior Environmental Engineer

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1 Introduction

Gartner Lee Limited, with Mehling Environmental Management Inc., BCG Engineering Inc. and Sheila C. Greer, has completed a Phase 1 Environmental Site Assessment (ESA) of the Anvil Range Mining Complex in south-central Yukon Territory. The mining complex consists of the Faro mine site, which was in production from 1969 to 1992, and the Vangorda Plateau mine site, which was in production from 1986 to 1998. Production was halted several times in the past due to low metal prices or changes in ownership. The present owner, Anvil Range Mining Corporation (ARMC), is currently in receivership. Production has ceased and the mine sites are in care and maintenance status. This study represents a preliminary environmental assessment of the operation, land and waters of the Anvil Range Mining Complex, and is being conducted on behalf of the Department of Indian and Northern Development (DIAND) Contaminants/Waste Program. The goal of this project is to provide an initial inventory of environmental liabilities in support of the devolution of mineral resources in the Yukon from the Government of Canada to the Government of the Yukon Territory.

1.1 Overview of the Anvil Range Mining Complex

The Anvil Range Mining Complex is located approximately 200 km NNE of Whitehorse, the capital of the Yukon Territory, as shown in Figure 1.1. The Faro mine site, which includes the mill and tailings facilities, is located approximately 15 km north of the town of Faro. The Vangorda Plateau mine site is located approximately 9 km northeast of the town of Faro and can be reached by a 13 km haul road from the Faro mine site. The Faro Mine was one of the largest open-pit lead and zinc mine of its day and was later also mined underground, starting in 1989. The Faro Mine was first operated by the Anvil Mining Corporation in 1969, then taken over by the Cyprus Anvil Mining Corporation in 1975. Ownership changed again when Curragh Resources restarted operations in 1986. Anvil Range Mining Corporation, the current owner, acquired the property in 1994.

The first exploration work was conducted on the Vangorda Deposit between 1953 and 1955 by Prospector Airways, a predecessor of Kerr Addison Mines. The deposit was considered to be too small and remote to be mined at that time. The Faro Deposit was discovered in 1964 and brought into production in 1969 by Anvil Mining Corporation.

The Faro and associated ore bodies are Sedex type deposits which consist of gently dipping stratiform massive sulphide zones that have been offset by faults. Quartz and pyrite are the dominant minerals of these ore bodies. The secondary minerals are sphalerite, galena, pyrrhotite, chalcopyrite and marcasite. The surrounding rock consists of altered phyllites and schists. There is an associated calc-silicate or calcareous rock unit in these deposits as well as a baritic unit.

1.2 Regulatory Framework

The Faro mine site occupies mineral leases leased from the Government of Canada under the Yukon Quartz Mining Act. These leases are listed in Section 4.1. The Vangorda Plateau mine site occupies mining claims but no federal or territorial leases.

Water use, tailings disposal and effluent discharge at the Faro and Vangorda mine sites are governed by two separate Water Licenses. These Water Licenses were regulated under the Northern Inland Waters Act until 1992 when the Act was changed to the Yukon Waters Act. Water Licenses are granted by the Yukon Territory Water Board under these acts. The licence for the Faro mine site is QZ95-003 (formerly IN89-001) and the licence for the Vangorda Plateau mine site is IN89-002.

Anvil Mining Corporation began operations at the Faro mine site in 1966, with ore production beginning in 1969. At that time there was no regulatory regime in place in the Yukon for mine production. The first water license was issued to Cyprus Anvil Mining Corporation in February of 1975 for the Faro mine and mill site. This license included a clause requiring the submission of an abandonment plan. The original water license was renewed on December 1st, 1979 and was set to expire on November 30th, 1984.

In September of 1980, Cyprus Anvil requested an amendment to their water license to include permission to expand the Rose Creek Tailings Facility by building the Intermediate and Cross Valley Dams, pending the submission of an acceptable abandonment plan. The amendment was granted by issuing a new water license in March 1982 that included the required abandonment plan for the Rose Creek Tailings Facility. This new water license was set to expire in March 1989. Due to low metal prices, the mining operations shut down in June of 1982 and did not resume until 1986.

Curragh Resources Inc. took over the Faro mine site in October 1985 but could not take over the liability of $51,000,000 for reclamation included in the abandonment plan. An emergency amendment was granted on October 4th 1985, which assigned the water license to Curragh Resources and stipulated that Curragh Resources submit a new abandonment plan by December 1986.

Two amendments to this water license were requested and granted on November 18th 1988 and September 22nd 1989 respectively. The latter was a Renewal Interim Order of the water license with an expiry date of January 31st 1990. Curragh Resources then applied for a new water license which was granted on December 21st 1989 after a Water Board hearing was held on a proposal to include a Trust Fund clause in the water license to build up $7,500,000 over 25 years of mine life for reclamation. This fund was based on 25 cents per ton of concentrate shipped over the life of the mine. This water license also had a clause that required the licensee to submit a detailed abandonment plan by March 31st 1991. Subsequently, Curragh Resources applied for a water license for the Vangorda Plateau mine site, which was granted in September 1990 and included a security and reclamation agreement. This license is valid until December 31st 2003.

The first amendment to Curragh Resources' Faro mine site water license was made in October 1991 to allow the use of the Faro Pit for tailings disposal. The next amendment included the Trusteed Environmental Fund, which took care of the transfer of $368,229.24 into the fund and implementation of the above monies.

In 1992, DIAND began the scoping for the Integrated & Comprehensive Abandonment Plan (ICAP) for Faro and Vangorda Plateau mine sites. Curragh Resources produced an abandonment plan with various options and introduced an option that was incorporated in amendment #3, which was approved in July 1993. This alternative required a final abandonment plan to be produced within two years of the expiry of the water license in January 1997.

Curragh Resources Inc. shut down the mine in December of 1993. DIAND assessed abandonment issues and environmental liabilities on the different abandonment options, which varied from $88,000,000 to $110,000,000 for implementation.

The Faro and Vangorda Plateau water licenses were assigned to Anvil Range Mining Corporation on November 8th 1994 including the provisions for security funding. Anvil Range Mining Corporation signed a Reclamation Security Agreement with the Government of Canada' s Minister of DIAND which provided for reclamation funding based on metal prices and mining revenues.

In March of 1995, Anvil Range Mining Corporation set up a Reclamation Trust Indenture and signed an Economic Agreement with Ross River Dena Development Corporation. An application for a new water license was submitted to the Water Board in August of 1995. A series of brief amendments (nos. 4 to 7) to the Faro mine site water licence were issued which extended the term of the existing licence (IN89-001) for brief periods until a new licence (QZ95-003) was issued in January 1998. The new licence has an expiry date of December 31, 2003, which corresponds to the expiry date of the Vangorda Plateau water licence. Licence QZ95-003 includes some re-organization of the reclamation security funds and the introduction of the Reclamation Trust Indenture.

When operations at the Faro and Vangorda mine sites were shut down in February 1998 and the Mine went into receivership, an abandonment plan had still not been approved. Anvil Range Mining Corporation filed an Integrated Comprehensive Abandonment Plan (ICAP) with the Yukon Territory Water Board in November 1996 but this document was not approved. The current water licences (Faro QZ95-003 and Vangorda Plateau IN89-002) serve to operate the mine sites in shut down mode until a decision is made regarding the fate of the Faro and Vangorda Plateau mine sites. There are some closure measures for various components of the mine sites written into the water licences.

Table 1.1 summarizes all operators of the Faro and Vangorda Plateau mine sites, water licenses held and amendments made, as well as the start and expiry dates of all licenses and amendments.

Table 1-1 Chronology of Operators, Water Licenses and Amendments

Operators	Water License / Amendment #	Date	Expiry Date
Cyprus Anvil Mining Corp.	Y-2L3-0005	Feb 4, 1975	Nov 30, 1979
	Y-2L3-2098	Dec 1, 1979	Nov 30, 1984
	Y-2L3-2226	Mar 24, 1982	Mar 24, 1989
Curragh Resources Inc.	YIN85-05AL (amendment to Y-2L3-2226)	Oct 4, 1985	Mar 24, 1989
	YIN85-05A (amendment to Y-2L3-2226)	Sep 21, 1987	Mar 24, 1989
	Amendment # 88-1 to YIN85-05A	Nov 18, 1988	Mar 24, 1989
	Amendment # 89-1 to YIN85-05A	Sep 22, 1989	Jan 31, 1990
	IN89-001 (Faro)	Jan. 23, 1990	Jan 30, 1997
	IN89-002 (Vangorda)	Oct. 25, 1990	Dec 31, 2003
	Amendment # 1 to IN89-001	Oct. 2, 1991	Jan 30, 1997
	Amendment # 2 to IN89-001	Dec.11, 1991	Jan 30, 1997
	Amendment # 3 to IN89-001	Jul. 23, 1993	Jan 30, 1997
Anvil Range Mining Corp.	IN89-001 & IN89-002 assigned to Anvil Range Mining Corporation	Nov 8, 1994	Jan 30, 1997
	Submitted Application QZ95-003 to YTWB	Aug, 1995	
	Amendment # 4 IN89-001	Sept. 9, 1993	Jan. 30, 1997
	Amendment #5	Jan. 8, 1997	May 30, 1997
	Amendment # 6	May 28, 1997	Sept. 30,1997
	Amendment # 7	Oct. 7, 1997	Dec. 31, 1997
	QZ95-003 (amendment to IN89-001)	Jan. 30, 1998	Dec 31, 2003

The new licence (QZ95-003) was sent by the water board to the Minister for signing in November 1997 but it did not take effect until signed by the Minister in January 1998.

1.3 Objectives

Protocols established in published federal and territorial guidelines for decommissioning industrial properties prescribe a phased approach for identification and management of contaminated sites (CCME 1991 and Yukon Government 1996). The first phase of the environmental site investigation process consists of a review of all available information relating to historic and current mine site operations to identify issues and areas of potential environmental concern.

The overall objective of the environmental site assessment at the Anvil Range Mining Complex is to assess previous mining operation practices for the purpose of identifying significant and potentially significant environmental liabilities. In short this will provide a ***snap shot*** of current site conditions to assist with the devolution process.

The specific objectives for the Phase I environmental site assessment of the Anvil Range Mining Complex are:

- To determine and document past activities and historical land uses which may have impacted site conditions;
- To assess and summarize recent and current site activities and adjacent mine related land uses which may be impacting, or have the potential to impact, site conditions;
- To identify contaminant sources and discharge points;
- To provide DIAND with an assessment of environmental liabilities at the mine site;
- To define the significance of the potential contaminant sources;
- To summarize the information in a status report and database;
- To provide the Ross River Dena Council with training opportunities;
- To ensure that the community of Ross River is consulted with respect to this project, and upon approval from the DIAND, presented with the results of the Phase 1 assessment.

1.4 Scope of Work

The scope of work for the Phase 1 ESA included the following tasks:

Task 1: Desktop review of site specific background information, historical information and regulatory information.

Task 2: Interviews with Ross River Dena Council members, as part of the community consultation. Interviews with former DIAND Water Resources and mine personnel were also conducted.

Task 3: Preliminary site inspection, including inspection of buildings, site conditions, mining locations, tailings impoundment and other facilities. Limited soil, water, and rock sampling was conducted.

Task 4: A review and preliminary impact assessment of traditional land use and heritage resources in the study area.

Task 5: Documentation and reporting to provide an assessment of the environmental liabilities associated with land use activities at the Faro mine.

1.5 Report Structure

The following report summarizes the work carried out, results, conclusions and recommendations for the Phase 1 Environmental Site Assessment of the Anvil Range Mining Complex:

- **Section 1** (this section) provides a brief introduction and outlines the objectives of the work carried out as part of this project.
- **Section 2** provides an assessment of traditional land uses and heritage/archeological resources in the Faro Mine and Anvil Range area.
- **Section 3** presents the environmental setting of the area.
- **Section 4** presents the land tenure and mining history.
- **Section 5** provides an overview description of the mine development and operation.
- **Section 6** is a summary of the site inspection and document review findings.
- **Section 7** presents a summary of the soil, water and rock sampling conducted at the site.
- **Section 8** presents the conclusions from the project and provides a list of recommendations.

Site Name: Faro Mine
File Name: FIG1.WOR

Gartner Lee Limited

Scale: 1: 6,000,000

DIAND Contaminants/Waste Program

Faro Mining Camp
Phase 1 Environmental Site Assessment
Project Location Map

Project No: 99-913
Date Issued: March 2001

Figure 1.1

2 Traditional Use and Heritage/Archaeological Resources

This section has two purposes. The first is to assemble data on First Nations traditional use of and heritage resources located in the Anvil Range Mining Complex area. The second is to consider how these resources have been or may have been impacted by the mine development and operation.

As discussed elsewhere in this section, no consideration was given to impacts on heritage resources or on traditional uses of the mine area prior to development. Consequently, base-line information on traditional use and heritage resources in the Faro and Anvil Range area prior to mine development was not assembled.

In this section, consideration of the mine's effect on traditional use is largely based on an earlier, retrospective study completed by anthropologist Martin Weinstein. To verify if the results of the Weinstein study, interviews were conducted with members of the Ross River Dena community.

The absence of pre-development comparative data has made it difficult to determine how mine development and operation has affected heritage resources. As a result, only general suggestions regarding the impact of mining can be offered.

2.1 Definitions

2.1.1 Traditional Use

Under the Canadian Environmental Assessment Act (CEAA) and related legislation, traditional use is considered when reviewing the potential socio-economic impacts of a proposed development. Traditional use refers to First Nations activities such as hunting, trapping, fishing, and gathering of plant resources.

Social activities such as gatherings, teaching of skills and cultural values, are also part of traditional use activities. This is an important consideration, as it is also now recognized that for First Nation societies, hunting and harvesting activities are not just the means to make a living. Land use and animal harvesting are also critical elements of satisfaction and giving meaning to one's life (Usher and Weinstein, 1991).

Traditional use is most commonly established through the mapping of traditional use sites and areas. Traditional use sites are geographically defined places, on land or water, where such activities take place (i.e. hunting locale, berry picking area, game lick, campsite). These sites may lack the physical evidence of human-made artifacts or structures, yet maintain cultural significance to a living community of people. Trails and travel routes would also be considered traditional use areas.

Traditional use sites are usually documented through oral, historical and archival sources. A summation of the various types of traditional use activities of the Ross River Dena and how these have changed during the past century can be found in Weinstein (1992:49-67).

The Faro Mine development and operation has had other social and economic impacts on the Ross River First Nations community besides impacts on traditional use activities. Various reports have discussed the broader impacts of mine development on the Ross River First Nation community (Dimitrov et al., 1984; Miller, 1972; Reid, Crowther and Partners, 1983; Sharp, 1977; Weinstein, 1992). Readers should note that older socio-economic impact assessment studies (i.e. Reid, Crowther and Partners, 1983) did not consider hunting, fishing and gathering as economic activities, as production was not geared to a market.

While such broader socio-economic impacts are beyond the scope of the present analysis, they are significant and must be acknowledged. They include such things as increased rates of alcoholism, violence, sexual exploitation, premature deaths, and the transformation of the community.

The cumulative socio-economic impact of various mine developments on the Ross River community is also acknowledged, but not addressed here.

2.1.2 Heritage Resources

The term heritage resource most often is used to refer to material remains that relate to human history. Of present concern are locale-specific resources where artifacts or structures are found. Natural landscape features, such as legend places and named places that are of historic or cultural significance can also be considered heritage resources even though they may not have material remains. This is because they have heritage value to a group, such as the First Nations, who have traditionally lived in the area.

Archaeological sites are the most commonly recognized heritage resources in Yukon. They are an important part of the Yukon's human history record, since for the Territory's First Nations, they represent the material remains of their ancestor's way of life in pre-contact or prehistoric times. Some prehistoric sites include above ground structures such as caches and hunting blinds.

Historic sites, featuring buildings or structures, have also been documented in the Yukon Territory. The upper cut-off or most recent date for historic sites varies, but currently the Heritage Branch of the Yukon Territory Government is using a date of ca. 1950. Historic sites most often consist of above-ground remains or structures, while other historic sites are largely known through buried remains,

The Yukon Land Claim formally recognizes First Nations interests in the region's archaeological and heritage sites. Under the terms of the Yukon Land Claim agreement, First Nations own all heritage sites on Settlement Lands and own all artifacts from sites that have a direct connection to their history. In the Yukon Territory, a definition of heritage resources also potentially includes paleontological sites. There are no known paleontological sites in the Faro Mine area.

2.1.3 Study Area

The geographic area of concern is broadly defined as the Anvil Range area, north of the Pelly River and Campbell Highway, west of the Ross River, and east and south of the Tay River. Thus, it includes the mine sites, the Faro townsite area and various roads on the north side of the Pelly River. The area also includes an extensive amount of surrounding country, including the Rose, Anvil and Vangorda Creek basins, as well as major parts of the Blind Creek and Tay Creek drainages.

A broadly defined study area was necessary for the following reasons:

(1) the resources upon which traditional land use is based (i.e. caribou, sheep, moose) and which have also been affected by the mine development, can be widely scattered across the landscape, not necessarily localized in their distribution.

(2) traditional land use has been affected by the extensive mineral staking activity that has taken place in the greater Faro area (Weinstein, 1992).

2.2 Literature Review

2.2.1 Traditional Use

There are a number of sources for information on traditional First Nations use of the Anvil Range area. The limitations of these sources will be briefly mentioned, before reviewing the types of information on hand.

There are some data in the Council for Yukon Indians (CYI) Resource Atlas for map sheet 105K Tay River that was assembled in the 1970s for land claims purposes. The location of sites is known to be very approximate and the explanatory information is basic. Nonetheless, it is the oldest set of land use information with any significant level of locational detail. A listing of the cabin and gravesite locations noted in the CYI Resource Atlas is listed in Table 2.1. An anthropology thesis (McDonnell, 1975) concerning the Ross River and Kaska people refers to traditional land use activities, especially hunting, in the general area north of the Pelly River and east of the Ross River. This study helps outsiders understand organizational principles of Kaska social groups, the importance of food and resource sharing within Kaska society and how and why family groups moved throughout the course of a year. It does not feature detailed traditional land use data, showing the areas used, which families were using these areas, when they were using them and for what purposes. Nor does it consider in any detail of how land use patterns changed for the Ross River people with the opening of the Faro mine.

Table 2-1 Council for Yukon Indians Land Use Data

#	Location	Description
G-1	Pelly River, at Blind Creek area	Gravesite, there are 6 to 7 people resting here
G-2	Pelly River, below Rose Mountain	Gravesite, there are several people resting here
C-1	Cabin, mouth of Tenas Creek, on Pelly River	Arthur John, fishing and trapping
C-2	Cabin, Pelly River, below Rose Mountain	Sid Atkinson, old trapping cabin
C-3	Cabin, Pelly River, below Rose Mountain	Rose cabin, built by a white man
C-4	Cabin, Pelly River, at Van Gorder Creek	Arthur John, trapping
C-5	Cabin, Pelly River, at Blind Creek	Hoole McLeod and Jack Sterriah
C-6	Cabin, Pelly River, at Grew Creek	Jack Ladue, located on Blind Creek
C-7	Cabin, Blind Lake	Arthur John
C-8	Cabin, Blind Lake area	4 cabins, located on the mountain creek, the people used to hunt sheep from these cabins
C-9	Cabin, Orchay Lake	"Old Jules" very old site
C-10	Cabin, lake on Orchay system [Ta\ges Lu\ge; ']	Trapping
Source: CYI Resource Atlas, files RRDC Land Claims Office		

Aboriginal language toponyms, or place names, are another significant data source. Place names often encode historical information and are also an important source of traditional land use data, as key land use and important resource locales are usually named (Andrews, 1990; Cruikshank, 1990; Greer, 1990; Hanks and Winters, 1983). Toponymic data for map sheet 105K Tay River has been published (Kaska Tribal Council, 1997; Moore, 1999), and is reproduced in Table 2.2. This list of names shows the Kaska familiarity with the Anvil Range study area.

Table 2-2 Kaska Place Names, Anvil Range Area (Map Sheet 105k).

Béde Lūgé´ or Méde Lūgé	Lake, at 62°13'N 132°46'W; one of sources of Blind Creek; means fish food
Dech´ ue Kį´	Mountain, at 62°18'N 132°53'W; means porcupine den
Desdele Mené´	Series of lakes called Swim Lakes on map; means red sucker lakes
Desdele Chō Mené	Laforce Lake, at 62°41'N 132°22'W; means big red sucker lake
Dzeh Tsedle Chō	Mountain, Mount Kulan on maps, at 62°20'N 132°32'W; roughly means bigger standing alone mountain
Dzeh Tsedle Zǫ́ze	Mountain, at 62°16'N 132°34'W; roughly means smaller, standing alone mountain; hunters were usually successful here

Dzeł Jedé or Hés Jedé	Mountain, at 62°28'N 133°07'W; means old mountain, refer to the quality of the rocks on the mountain
Dū Néstlōn	Olgie Lakes on maps, at 62°05'N 132°30'W; means lots of islands lake
Dū Ese	Lake at 62°20'N, 132°13'W; also known as Poison Lake; means numerous scattered islands.
Eghá´ Dā́ óli	Blind Lake, at 62°17'N 132°25'W; means hair floating, referring to moose hair in lake
Ekį´	Hill on north side of Pelly River opposite Ross River townsite; means food cache.
Elḗs Tué	Creek originating north of Mount Mye, flowing east then northeast into Tay River, between 62°23-28'N 132°05-44'W; name means lick creek, referring to sheep lick that the creek passes by.
Elḗsgā	Mountain at 62°24'N 132°58'N; small mountain south of the creek by the sheep lick
Eyān Lué	Lake at 62°08'N 132°01'W; means downstream people/enemies lake, referring to long ago battle
K´ ésk´ ale Hés	Mountain at 62°25'N 133°27'W, named Mount Aho on recent maps; means ptarmigan mountain.
Łą̄ Nenesjā	Mountain, at 62°35'N 133°50'W; refers to hunting sheep by chasing them to ledge
Kuk´ éh Lūgé	Lake, at 62°35'N 132°31'W; means next behind fish
Kuk´ éh Lūgé Hés	Mountain, at 62°32'N 132°25'W; means next behind fish lake mountain
Kut´ ā̂gé	Tenas Creek on maps, between 62°08-10'N 132°20'W; means cut in, referring to the deep and narrow channel cut by the river
Men Tēle	Lake at 62°11'N 132°14'W, known as Big Orchay Lake; means flat lake.
Mésgą̂ T`oh	Hill at 62°02'N 132°20'W; means raven's nest
Néghā Tsí	Mountain at 62°33'N 133°50'W; means wolverine head
Tāges Lūgé	Lake at 62°09'N 132°20'W; means middle or in between fish lake
Tédāgi Lūgé	Small lake at 62°05'N 132°44'W; means fish lake on the hill.
Tédāgi Tué	Creek at 62°04-04N 132°44'W; name comes from the name of the lake above
Tsē Nehts´ at	Mountain at 62°26'N 132°13'W; meaning of name is unclear, but has something to do with rock
Tū Degā	Lake at 62°33'N 132°12'W, also known as Connolly Lake; means white water, referring to windy conditions on the lake

Tsē Zūl	Mount Mye at 62°18'N 133°06'W; means hollow rocks
Ugetś enéhtēts	Mountain at. 62°45'N 132°50'W; means some one camped on it
Yādōye Menė́	Lake at 62°23'N 132°02'W; meaning of name is unclear, but has something to do with sky
Yādōye Hés	Mountain, at 62°25'N 132°05'W; meaning of name is unclear, but has something to do with sky
Source: Kaska Tribal Council 1997. Note: some of the Kaska place names in Weinstein (1992) differ from those above; the above list is more reliable as these names have received detailed study by a linguist.	

2.2.2 Weinstein Impact Assessment

In considering the effect of the Anvil Range Mining Complex on the traditional land use of the Ross River Dena, the most important source is a report by anthropologist Martin Weinstein (Weinstein, 1992). Described as "an attempt at a retrospective assessment of impacts to the Ross River Band's land use due to the mining development" (Weinstein, 1992:5), the report is a relatively detailed look at a complex and poorly documented issue. The report examined how the establishment and operation of the Faro Mine has affected the subsistence economy of the Ross River people. Subsistence economy is defined as "food production (hunting, fishing and plant gathering); fur production; the use of natural materials as tools, for structural purposes; and non-food resources; the distribution and consumption of these resources; and the set of social relations, specific to native communities, through which the production, distribution and consumption of these resources are organized" (Weinstein, 1992: 16).

In the Weinstein study, land use at different periods is mapped to build a composite picture of changes to use of the area during the second half of the 20th century. Due to a lack of other information sources, re-call information was the major way by which land use data were gathered. Many members of the Ross River community, representing a range of ages, completed extensive questionnaires on individual land use patterns during the 1980s and early 1990s. Detailed maps of land use activities and patterns for 1990 were assembled. The study also incorporated in-depth map data collected during an earlier land use and occupancy study of the Ross River traditional use area (Dimitrov et al., 1984).

The Weinstein report includes thorough discussions of several topics that are key to understanding Kaska land use in the Faro area, including:

- an introduction or orientation to the land use history of the Ross River Dena over the past century. This includes consideration of how they have been affected by such things as rising and falling fur prices, the opening and closing of fur trade posts, and the construction of the Canol Road.
- a discussion of the Kaska system of land and harvesting access. This review shows that the Kaska system is a flexible one that is based on notions of sharing and mutual aid and ensuring the needs of the community are met. Rules for access and land use are based on social affiliation, with informally

defined limits. The consequence of this system is that it is hard to identify individuals and families who were, and who were not, affected by the development.

- a discussion of the importance of detailed knowledge of the land and its resources in the subsistence economy of the Kaska people. This section of the report includes a summation of the extensive Kaska ecological knowledge of Mount Mye region, including a discussion of the habitat and behavior of key species such as sheep, caribou, moose and whistler/marmot.
- locational data on cabins, salmon fishing camps, and main trails in the Faro study area that were used prior to mine development. Locations for hunting camps or "dry meat camps" as Weinstein refers to them, as well as other fish camps, are only generally described. This data is summarized in Table 2.3, Table 2.4 and Table 2.5.

Table 2-3 Cabins – Pre Mine Development (Weinstein, 1992: 81).

Location	Description
Mouth of Blind Creek, on the Pelly River	Associated with Blind Creek salmon fishery; cabins belonging to Jack Sterriah and Old Man Jules; latter now decayed.
Present Faro Bridge Site, on the Pelly River	At the time of Faro fire, 3 cabins, belonging to Joe Ladue, Joe Etzel, Arthur John. After fire, cabins rebuilt by Lydia Glada, Gordon Etzel and Arthur John.
Fish Hook, near mouth of Anvil Creek on the Pelly River	Home base for the Ladue family; cabins belonging to Arthur John, Peter Ladue, Jack Ladue and Joe Ladue.
Swim Lake	There had been a complex of 3 cabins at Swim Lake, but they were destroyed during a fire. Mid-century, tent camps in area.
Blind Lake	Cabin belonging to Joe Ladue.
Tay Lake	Three cabins, belonging to Jack Ollie, Arthur John and Jack Sterriah.
Poison Lake	Two cabins, belonging to Jack Sterriah and Long Hair John.
Lake Near Tenas Creek	Cabin belonging to Duck Johnnie.
Near Tenas Creek	Cabin belonging to Old Johnnie.
Northeast slope of Mount Mye	Cabins belonging to Long Hair John and Jack Sterriah.
West slopes of Dzeł Jede; (mountain north of Mt. Nye, spelled Ktl Jhet by Weinstein)	Cabins belonging to Joe Ladue and Pat Pelly.
Laforce Lake	Cabin belonging to Jack Ollie.

Table 2-4. Fish Camps – Pre Mine Development (Weinstein, 1992).

Location	Description
Blind Creek	Salmon fishing; used extensively by Hoole McLeod and family, Joe Ladue and family, Sid Atkinson and family, Oldman Jules and family, Arthur John and family, Jack Ladue and family, Jack Sterriah and family, Alec Shorty and family, Jack Ollie and family, and Skumballah Jack.
Faro Bridge Site	Salmon fishing
Old Rose	Salmon fishing

Table 2-5. Trails – Pre Mine Development (Weinstein, 1992: Figure 9).

Anvil Creek, from mouth at Pelly River to Rose Creek
Anvil Creek, upstream from junction with Rose Creek
Rose Creek, upstream from mouth at Anvil Creek, southeast and over to Blind Creek
Pelly River, downstream from Pelly, north through valley on west side of Mount Mye to upper Anvil Creek
Pelly River, near Faro, north over Mount Mye and continuing north to upper Anvil Creek and DzeÂ Jede area
Blind Creek, from near mouth on the Pelly, up the south face of Mount Mye and north to upper Blind Creek area
Blind Creek, upstream to Swim Lakes and northeast to Blind Lakes area and beyond
Swim Lake, southeast to Orchay Lakes, to Tenas Creek

According to Weinstein (1992), prior to the development of the Faro Mine, the Anvil Range study area was one of two "core" land use areas utilized by the Ross River people. The other is further to the east, in the Pelly Banks/Pelly Lakes/Frances Lakes area. He writes:

> *The Mye Mountain/Blind Creek area of the band's traditional lands were one of two major core use areas. The nature of habitat and resources within the band's territory required seasonal relocations of harvesting groups. Some groups had to walk considerable distances between seasonal harvesting areas. The Mye Mountain/Blind Creek area was a rare locale; the complete mix of animals and productive habitat required for the Kaska method of making a living from the land were contained within this limited space. Because of the abundance of the resources, the area was well known within the band. People from other regions were often invited and encouraged to join the Mye Mountain/Blind Creek harvesting groups." (Weinstein, 1992: 154).*

Several key resources were drawing the Ross River people to the Anvil Range area. These include:

- **Salmon**: Fish camps were located on Blind Creek, around where the Faro bridge is located today, in the Rose Slough area below Rose Mountain, and at Fish Hook, which is near the mouth of Anvil Creek. Of these four fish camps, the largest was on Blind Creek. Here fish traps were placed in the creek so that large quantities of chinook salmon were harvested during their annual salmon run. According to the Kaska Tribal Council (1997: 362), Joe Ladue was the last Ross River community member to put a fish trap in Blind Creek, although the year is not stated.

- **Sheep**: Various places around Mount Mye were known as important sheep hunting areas. This includes the animal lick that is located between Blind and Vangorda Creeks, south of Mount Mye, and animal lick or licks up the tributary of Blind Creek that flows from northeast of Mount Mye.

- **Caribou**: The Anvil Range and Mount Mye area has two types of caribou, a resident population which summers here, and migratory herds which summer in the Mackenzie Mountains and move south to the Pelly drainage area for the winter.

- **Moose**: This important species can be found across the Faro study area. They are located in the flat lands down by the lakes for most of the year but move up to the alpine zone in late summer.

- **Fur-bearers**: Trapping activities tended to focus on valley bottom areas of the Pelly River and Blind, Anvil and Rose Creeks. Cabins at such places as Fish Hook, the Faro Bridge, Blind Creek, Swim Lake and Blind Lake were used as bases from which trapping and hunting activities took place.

In assessing changes to this pattern of use of the Faro/Anvil Range area by the Ross River Dena, Weinstein (1992) then considers a number of important factors. These include:

- the Kaska response to the different phases of the project. This section includes a good summation of the history of the Faro Mine, and notes, for example, that families continued to use the area throughout the development phase of the project.

- how Kaska perception of resource quality affects their use of a resource. Traditional foods were abandoned because they were perceived as contaminated by toxic substances, whether or not they actually were. This section includes a summation of the various environmental problems (tailings spills, habitat disturbance, etc.) that have occurred in the mine area.

- how resource abundance has changed in the development area due to the mine, and the consequences of these shifts for the Kaska.

- problems with authority over the area, as the Ross River people were informed they were no longer allowed to hunt in the area, or were harassed about their guns, etc.

- the conflicts with other resources users (i.e., recreational hunting and fishing) that the Ross River people have experienced.

- vandalism that occurred to Kaska property such as cabins, trap lines, etc.

The conclusions of the Weinstein study are discussed in Section 2.4.

2.2.3 Registered Heritage Sites

Two databases containing heritage site information were consulted, the CHIN (Canadian Heritage Inventory Network), which is the register for archaeological sites and is maintained by the Canadian Museum of Civilization (available at the Yukon Heritage Branch), and the Yukon Historic Sites Inventory database which is maintained by the Yukon Heritage Branch.

There are no registered archaeological sites within the Anvil Range study area (i.e., between 62°05' to 62°40'N and 132°05' to 132°50'W). Archaeological sites are known around the Ross River settlement and elsewhere along the Campbell Highway. A lack of registered sites in the study area does not mean that sites may not have been affected by the Faro development, as no site inventory and assessment work was completed prior to mine development. This issue is considered further below.

A number of sites are registered in the Yukon Historic Sites Inventory database, which are within the study area. These Sites are listed in Table 2.6.

Table 2-6 Study Area Historic Sites Registered in the Yukon Historic Sites Inventory

YHSI #	Name/Label	Location	Description/Comment*
105K/03/001	Pelly River Cabin Remains	Pelly River at Blind Creek	Believed to be associated with nearby Sawmill
105K/03/002	Pelly River Sawmill Remains	Pelly River at Blind Creek	Heavy timber frames
105K/03/003	Blind Creek Cabin & Dog Houses	Pelly River at Blind Creek	Abandoned; may have belonged to either Joe Ladue or Jack Sterriah
105K/03/004	Sawmill Buildings	Pelly River at Blind Creek	Equipment shed, 2 residence buildings
105K/03/005	Pelly River Foundation	Pelly River at Blind Creek	Related to lumbering, milling activities
105K/03/006	Blind Creek Grave Site	Pelly River at Blind Creek	5 standing grave fences, and "as many as 25 grave mounds"
Source: Yukon Heritage Branch, Historic Sites Office. * Note: little or no oral history research regarding these sites has been completed.			

Note that this list represents only the registered sites. There may well be others that have been affected by the Faro development. No site inventory and assessment work was completed prior to the mine development, nor has any systematic effort been made to document First Nation's historic sites in the area since that time. This issue is considered further below.

2.3 Community Interviews

2.3.1 Interview Method

A series of interviews were held with selected elders of the Ross River Dene community in Ross River in December of 1999. The purpose of these interviews was to confirm if the findings of the Weinstein study were still considered valid, and to record any additional information regarding land use in the area that individuals wanted to offer. It was also hoped that the interview sessions would give insight into the heritage site potential of the Anvil Range area. Past heritage studies have shown the close link or correspondence between traditional First Nations land use sites and heritage site locations in the Yukon (Gotthardt, 1993; Greer, 1997).

Field research in the Faro and Anvil Range area to document traditional use sites and heritage sites would have been desirable, but was not possible given the winter project season.

Staff of the Ross River Dene Council Land Claims office suggested individuals who would be appropriate to interview. Sessions were held, over a three day period, with Robertson Dick, Charlie Dick, Grady Sterriah, Betty Souza, Doris Bob, Doris Etzel, Gracie Tom, Tootsie Charlie, Mary Charlie, Robert Etzel, Frank Shorty and Margaret Shorty. Regrettably, Arthur John Sr. whose family traditionally used the Faro/Anvil Range area, and who has continued to use it himself, was not available for an interview.

Greg McLeod and Alex Shorty, who were assisting Gartner Lee Limited with other aspects of the Anvil Range Mining Complex Environmental Site Assessment, arranged the interviews. They also sat in on most of the interview sessions, which took place in Ross River Dene Council Land Claims office. Topographic and computer generated maps were used as research aids and for documenting spatial information. Most of the interview sessions were tape-recorded. Notes were taken for interviews that were not tape-recorded.

An open-ended format was employed in the interview sessions. The elders were asked to discuss their use of and their knowledge of important resources in the Anvil Range area. They were also asked about their knowledge of heritage sites in the region, such as hunting blinds, hunting fences, graves, campsites and caches. Considerable information was offered on land use and heritage sites in other parts of the traditional territory as well. Information on traditional use and heritage sites in the Ketza mine area was documented during these same sessions.

Most interview sessions lasted between one and three hours. The longest sessions were with Grady Sterriah and Charlie Dick. The bulk of the information recorded on the Faro/Anvil Range area came from Mrs. Sterriah, Robert Etzel, and Charlie Dick.

A rough, not verbatim, transcript of the interview sessions and the notes taken has been prepared (Greer, 2000). This set of notes includes latitude and longitude co-ordinates for the data provided.

2.3.2 Interview Results

New information on the role of the Ross River Dena in the mineral discovery that led to the Faro mine development was recorded during the interview sessions. Mrs. Grady Sterriah recounted a family story about the discovery.

> *When he knew he was dying, my Daddy's Dad showed Daddy (Jack Sterriah) where he had found a special, heavy type of rock. My Daddy's Dad wanted him to know about it. He (grandfather) predicted that something to do with that funny rock was going to happen in the future. Then, in 1960s, Kulan came around. He stayed with the people, made friends. Kulan said he's prospecting and he's going to help people who know this special rock, who help him find it. They trusted him, so Daddy told Arthur John to make a map to show Kulan that place that his dad had shown him. Then Arthur John took him to that place. After that, Kulan gave Daddy grocery, case by case. We don't what's going on - then we heard. [Mrs. Grady Sterriah with Sheila Greer, December 2, 1999; paraphrased].*

Mrs. Sterriah concluded the story by adding, "that's how things got away" referring to how the Ross River Dena lost control of their lands. Feelings of injustice over the Faro discovery, and the fortunes that were made by some, while Kaska people lost so much, continue to be strongly felt.

The interview sessions confirmed the significance of the Faro area in the subsistence economy of the Kaska people. The importance of the Blind Creek valley, as a travel route, and for accessing important hunting areas was mentioned. One source referred to the many old stumps one could see in the Blind Creek area, as evidence of how heavily used the area was. The salmon fishery at Blind Creek was recounted in detail. Similarly, people talked about the numerous lakes east of Mount Mye (Blind Lake, Swim Lakes, Tenas Lake, Orchay Lakes, etc.) as being important fishing lakes and areas for hunting and trapping.

Looking downstream from the Faro mine site, the importance of the locale known as "Fish Hook" at the mouth of Anvil Creek, prior to mine development, was also mentioned. Fish Hook was the base camp of the Ladues from which they hunted and trapped in the surrounding area including Anvil Creek and Rose Creek.

During the interview sessions, no attempt was made to confirm the location of the cabins documented by Weinstein (1992), or in the CYI Resource Atlas data. Nonetheless, the information shared suggested that the Kaska people had many cabins in the Anvil Range study area.

Two gravesite locales were reported within the study area. One is the Blind Creek graveyard, which is registered in the Yukon Historic Sites Inventory as #105K/03/006. A second gravesite was also mentioned but its location is not certain. It was identified as the place where Jack Sterriah's father was buried, and reported as being on Jackfish Lake, which is also known as Johnson Lake, and near the airport. Two different lakes, however, were indicated on the recording map as being Jackfish/Johnson Lake. Further research is therefore needed to confirm the location of this gravesite. Note that another gravesite location in the study area is indicated in the CYI Land Use data, where a grave is reported along the Pelly River below Rose Mountain (see Table 2.1). Yet another gravesite was mentioned in the 1999 interviews, but it is located well away from the mine area, north of Orchay Lakes.

Great concern was also expressed during the interviews over the quality of the environment in the mine area and in the basin downstream from the mine. Individuals recounted having seen or killed diseased animals (moose, beaver) in the area. The lack of fencing around tailings ponds was seen as particularly dangerous for animals.

2.3.3 Summary of Community Interviews

1. No information came forward in the December 1999 interviews that would contradict Weinstein's summation of traditional use by the Ross River Dena of the Faro area prior to the development of the mine. The Anvil Range was an important land use area, especially for certain Ross River Dena families. Here they were able to obtain a wide variety of resources, including salmon, moose, sheep, caribou and marmots, as well as berries and other plants.

2. No information came forward in the December 1999 interviews which would contradict Weinsteins' summation of how traditional use of the Faro area has been affected by the development and operation of the mine. As discussed below, the Ross River people have largely, but not entirely, stopped using the area.

3. The available land use evidence suggests that the Anvil Range area has heritage site potential. There likely are both archaeological and historic period sites here that have not been documented. Some heritage sites may already been destroyed or damaged by the mine development.

2.4 Impact of Mine Development

2.4.1 Impact on Traditional Land Use

The Weinstein study shows that the geographic distribution of the contemporary land use patterns of the Ross River people has changed as a result of mine development. It indicates that some individuals, whose family lands were located in the mine and town development areas, have shifted their primary harvest effort to other accessible western areas of the band's territory (Weinstein, 1992: 148, Figure 27). Though connection to the Mye Mountain/Blind Creek areas are still powerfully felt by the people with historic family ties to that country, the move to other areas was an economic necessity. The author writes:

> *People persisted in the use of the Faro area for harvesting, but the intensity of use changed as harvesters encountered the impacts of the development: problems of restricted access and firearms use prohibitions; declines in local animal populations which resulted from disturbance, habitat loss and degradation, and increased competition from recreational hunters and fishers; fears of health risks from consumption of wild meat exposed to toxic substances; and increased amounts of disturbance. Disturbance ranged from simple curiosity of Faro residents, for whom the activities of Ross River Indians on the land were interesting anachronisms, to the malicious destruction of trapping sets, poaching of furs, theft of gear and vandalism of cabins.* (Weinstein, 1992: 156)

The study offers quite specific examples as to the effect of the mine on subsistence or traditional use activities. For example, it is noted that areas downstream of the mine and townsite, such as Fish Hook, were largely abandoned for fish harvesting, as the condition of the fish downstream was now suspect. The use of the traditional productive fisheries at Swim Lakes declined because that area was being used by Faro residents and the Ross River people avoided such conflicts (Weinstein, 1992: 146). Hunting in the area has largely been abandoned, due to the concerns over the quality and safety of the meat of the animals frequenting the tailings ponds and related features. The exception to the pattern of abandonment is trapping which has continued to a limited extent in the mine development area by a few individuals.

Those families for whom the Mye Mountain/Anvil Creek/Blind Creek areas were primary resource lands at the time of the development were most heavily affected by it. These families included the direct descendents of: Selkirk Billy, Aklack, Billy Atkinson, Long Hair John, Gumbala, Nahlier, Pat Johnnie and Sue Bill. During the period immediately prior to mine construction, Joe Ladue, Hoole McLeod, Jack Sterriah, Old Man Jules and Jack Ollie's wife and some of their family members regularly trapped in the affected area (Weinstein, 1992: 88).

Weinstein (1992) concludes, however, that given the Kaska system of land tenure and use, all Ross River Dena families were in some way affected by the Faro mine development.

The Weinstein report recommends compensation for the Ross River people, for the impacts they have suffered as a result of the Faro mine development as they were dispossessed of their lands. The report also offers recommendations for future developments to avoid similar negative effects on the harvesting economy of other Indian groups. These recommendations include controlling pollution, which leads to the abandonment of foods because of perceptions of toxic contamination; controlling disturbances of the bush and animals; and not opening up First Nations harvest areas to recreational hunting and fishing. The report notes that the creation of new roads is not benign, but has severe consequences. In the Mount Mye area, the existing trail system was severely affected by road development.

This examination of the effects of mine development on the traditional use of the Ross River people concurs with the conclusions and recommendations of the more extensive Weinstein study.

2.4.2 Impact on Heritage Sites

Although no heritage sites are on record for the study area, it cannot be stated that heritage sites were not affected by the development. The Anvil Range is not well known archaeologically and no effort has been made to document sites there. The exact location and condition of only one of the several gravesites reported in the study area is known, for example. The other gravesites may have already been damaged or destroyed.

As noted above, the traditional land use data assembled in the Weinstein report, and confirmed in the December 1999 interviews suggests that the Anvil Range area has a potential for heritage sites. Given that the Faro area was not checked for sites prior to development, it is recommended that a post-development heritage impact assessment be undertaken, to document existing sites before they suffer further damage through such things as artifact collecting and erosion.

3 Environmental Setting

3.1 Topography, Vegetation and Climate

The Anvil Range Mining Complex is located within the Yukon Plateau (North) Ecoregion, within the Pelly River Ecoregion. This region is characterized by discontinuous, widespread permafrost (Robertson Geoconsultants Inc., 1996a). The Faro mine, mill, tailings pond and water supply reservoir are all located in the Rose Creek Valley. The majority of this valley is forested but adjacent ridges above 1200 m are alpine tundra (Robertson Geoconsultants Inc., 1996a). The Grum and Vangorda developments are located in an area known as the Vangorda Plateau. This plateau is characterized by a gently rolling topography with significant forest cover. The major drainage on the Vangorda Plateau is Vangorda Creek.

The mean annual temperature at the site is -3.4°C based on data collected at the Anvil climate station located at the mine site. July is the warmest month with a mean temperature of 11.5°C while January is the coldest month with a mean daily temperature of -19.8°C. The mean annual precipitation at the Anvil climate station is 368 mm, comprising of 167 mm as rainfall and 179 mm snowfall as water equivalents. This amount of precipitation is typical of the dry interior Yukon climate.

3.2 Wildlife and Fisheries Resources

3.2.1 Sheep

Sheep Mountain, located about 10 km west of the town of Faro, contains a population of thinhorn sheep, both Fannin and Stone, which pass through the Vangorda Plateau mine site during their fall (September) and spring (June) migrations. The area south of the mine site at Sheep Mountain is used as a winter range and contains several mineral licks which are very important to the health of the sheep (Schweinsburg, 1991). The Mount Mye area to the north of the mine site is used as summer habitat. Figure 3.1 shows key wildlife habitats, predominantly sheep, as identified in the Yukon Key Wildlife Habitat Inventory (1999).

The Grum and Vangorda Pits are located in the middle of the traditional migration routes used by sheep in mid-September to reach vital winter forage sites and in mid-May/June to return to their summer range on Mt. Mye. A study by Schweinsburg (1990) found that despite the increased mining activities in the area, sheep will stick to their traditional routes rather than finding alternate ways around the activity, indicating some habituation and learning by the sheep.

The sheep population in the area has apparently remained the same since 1981 although population and productivity counts of sheep on both winter and summer ranges from 1980 to 1990 show that reproduction is excellent and lamb mortality is low (Schweinsburg, 1990). The close proximity of the town of Faro, the mine sites and easy access roads have been linked to illegal hunting activities, which have been quoted by Mr. Schweinsburg as one explanation for preventing sheep from increasing in numbers. He also recommends further studies and more detailed monitoring of the habitat use by the sheep population. The finite availability of winter forage is also recognized as a limiting factor as regards the size of the herd.

The most recent sheep survey was conducted from October 1999 to April 2000 to assess the numbers of sheep utilizing the winter range habitat. The numbers of sheep counted have neither significantly increased nor decreased over the last ten years, which would indicate a fairly stable sheep population (Mychasiw, pers. comm., 1999).

3.2.2 Moose

In the area of Faro and Vangorda, moose occur in fairly low numbers, possibly due to developments in the town of Faro and the Faro and Vangorda mine sites. It is believed, however, that the Pelly River flood plain provides a good winter range for moose (Robertson Geoconsultants Inc., 1996a).

The Department of Renewable Resources initiated the first moose survey of this area in December of 1997 due to local concerns about moose harvest levels. The Game Management Subzone (GMS) 4-45, north of the town of Faro was found to have a very high moose abundance, one of the highest in the Yukon, which makes them vulnerable to over-harvesting (Ward, 1997).

A second survey, carried out in November 1998, was expanded to include several areas adjacent to GMS 4-45. Results confirmed the high density counts from the previous survey and concerns for over-harvesting were supported by facts such as fewer moose seen near easily accessible corridors than in more remote locations of the survey area and relatively few bulls were observed during both surveys. (Ward, 1998) The latest survey conducted December 1999, which monitored population composition and trends, found similar moose abundance and composition to the previously conducted surveys. Hunting pressure seems to be increasing and there is still cause for concerns over high harvest levels (Ward, 1999).

3.2.3 Caribou

The Tay River woodland caribou herd is about 4,000 animals strong and is known to utilize the Anvil Range, including Mt. Mye, as part of their summer range (Robertson Geoconsultants Inc., 1996a).

The Department of Renewable Resources started an inventory of the Tay River herd in March of 1989. 23 caribou were captured and fitted with radio collars to determine the herd's range, seasonal movements and estimate population numbers. The town of Faro and the Faro Mine site lie on the southern end of the herd's range and a 1991 caribou census study located a concentration of caribou within 10 km of Faro. Harvest of the Tay River herd is mostly limited by access and is presently within sustainable numbers (Kuzyk et al, 1997).

3.2.4 Fish and Benthos

The two main drainages at the Anvil Range Mining Complex are the Vangorda Creek drainage, and the Rose Creek/Anvil Creek drainage (Robertson Geoconsultants Inc., 1996a). The habitat characteristics for various reaches of the creeks was classified by P.A. Harder and Associates in 1987 for the Vangorda drainage and in 1988 for the Anvil/Rose Creek drainage (Robertson Geoconsultants Inc., 1996a).

The lower reaches of Vangorda Creek near the Pelly River are used as rearing habitat by chinook salmon, arctic grayling and other species with chinook salmon being the dominant species. Metal analysis of fish tissue from Vangorda Creek showed that mercury levels were below the EPA guideline from 1975 to 1977 (Robertson Geoconsultants Inc., 1996a). The concentrations of some metals (copper, lead and zinc) appeared greater in 1992 than from 1975 to 1977 although a direct comparison of the results is not possible because of different sampling methods (muscle tissue versus whole tissue analyses).

A study by in 1996 found stream conditions in Vangorda Creek comparable to pre-development inspections with the exception of added fines in the gravel and an unstable beaver dam behind which silt has been accumulating (Robertson Geoconsultants Inc., 1996a). The culvert at the Faro town road and waterfalls in each of the main and west forks represent physical barriers to chinook salmon migrating upstream in the drainage.

The Faro mine site drains directly into Rose Creek, which flows into Anvil Creek, which is tributary to the Pelly River. The dominant fish species in the Anvil/Rose Creek drainage is arctic grayling. Some use of lower Anvil Creek by juvenile chinook salmon has also been observed although salmon species have not been observed in Rose Creek. Upper Anvil Creek, above Rose Creek, has very few fish. In lower Rose Creek, more recent fisheries surveys indicate that fish are largely absent in the lower creek areas whereas some fish populations were generally reported in older surveys (Robertson Geoconsultants Inc., 1996a). This apparent decrease in fish use may be related to historical mine related events including tailings spills and periodic discharges of non-compliant effluent. The North Fork Rose Creek haul road causeway prevents any upstream movement of fish beyond this location. The most productive fish habitat in the Anvil/Rose Creek drainage is the South Fork of Rose Creek, which includes overwintering habitat that was created by construction of the freshwater reservoir early in the life of the mine.

Metal analysis of fish tissue from Anvil and Rose Creeks (Robertson Geoconsultants Inc., 1996a) showed that mercury levels were below the EPA guideline in 1975 and 1976 but that one sample in 1992 was greater than the EPA guideline at 0.8 ppm (versus the EPA guideline of 0.5 ppm). The concentrations of some heavy metals were generally found to have higher concentrations in the liver than in muscle tissue. The concentrations of some metals, particularly lead and zinc, appeared greater in 1992 than in 1975. However, due different analysis methods (muscle tissue versus whole tissue analyses including liver), a direct comparison of all of the results is not possible (Robertson Geoconsultants Inc., 1996a).

Some species of benthic organisms are sensitive to contaminants in the water and are used as indicators of the general health of the water. Natural fluctuations that occur in benthic diversity and abundance due to factors such as climate, stream flow and life cycles of the organisms must be considered when interpreting benthic abundance or variability data. The sampling method used must also be considered. Benthic invertebrate studies have been ongoing in the Anvil/Rose Creek drainage since 1973 and in the Vangorda drainage since 1975 (Robertson Geoconsultants Inc., 1996a). The current water licences require sampling of benthic species every second year in each of Rose and Vangorda Creeks.

Monitoring stations in Rose Creek downstream of the tailings ponds showed much lower diversity, as measured by number of species, and abundance of benthic organisms in the 1970's and 80's as compared to background monitoring stations. Studies from 1990 to 1998 indicate that benthic communities have increased both in numbers and variety (Robertson Geoconsultants Inc., 1996a).

The information for Vangorda Creek suggests that benthic productivity at the background location upstream of the mine site is generally lower than that at downstream locations and this is likely attributable to physical conditions at the upstream location. Benthic productivity is generally good throughout the lower sections of the creek downstream of the mine site (Robertson Geoconsultants Inc., 1996a).

Stream sediment investigations have been performed in Vangorda Creek from 1991 to 1995 and were performed in Rose Creek in 1973 and 1983 (Robertson Geoconsultants Inc., 1996a). The current water licence for the Vangorda Plateau mine site requires that stream sediments be sampled every second year in conjunction with benthic monitoring programs. The information for Vangorda Creek indicates that the concentrations of some metals (copper, lead and zinc) are greatest immediately downstream of the mine site. These concentrations are generally lower farther downstream in lower Vangorda Creek, although they remain elevated above background.

The information for Rose Creek indicates that the levels of copper, lead and zinc in stream sediments downstream of the mine were higher in 1983 compared to 1973 (Robertson Geoconsultants Inc., 1996a). It is important to not that after 1973, two large spills occurred, tailings slurry and copper sulphate, which would have had a direct impact on the level of metals in the sediment.

3.3 Regional Geology

The bedrock geology of the area loosely termed the "Anvil District" is in part made up of sandstone, siltstone and shale, all of which may be calcareous. Some intrusive and extrusive volcanic rocks are also found in the district. The sedimentary sequence is approximately 5 Km thick, and was deposited in a deep water environment off the ancient coast of North America approximately 430-510 million years ago. These sediments have been intruded by a younger (65-136 million year old) Anvil Plutonic and Dyke Suite of granitic and dioritic rocks respectively. The heat and pressure caused by the intrusion of plutons (granite plugs) and dykes caused regional metamorphism, folding and faulting of the sediments.

The Mt. Mye and Vangorda Formations, which host the Anvil District mineralization, are found within this metamorphosed package of sedimentary and volcanic rocks. The bulk of the lead-zinc-silver-barite mineralization occurs within a 150 m section in the uppermost Mt. Mye Formation. The bottom portion of the Vangorda Formation consists of graphitic and calcareous phyllites.

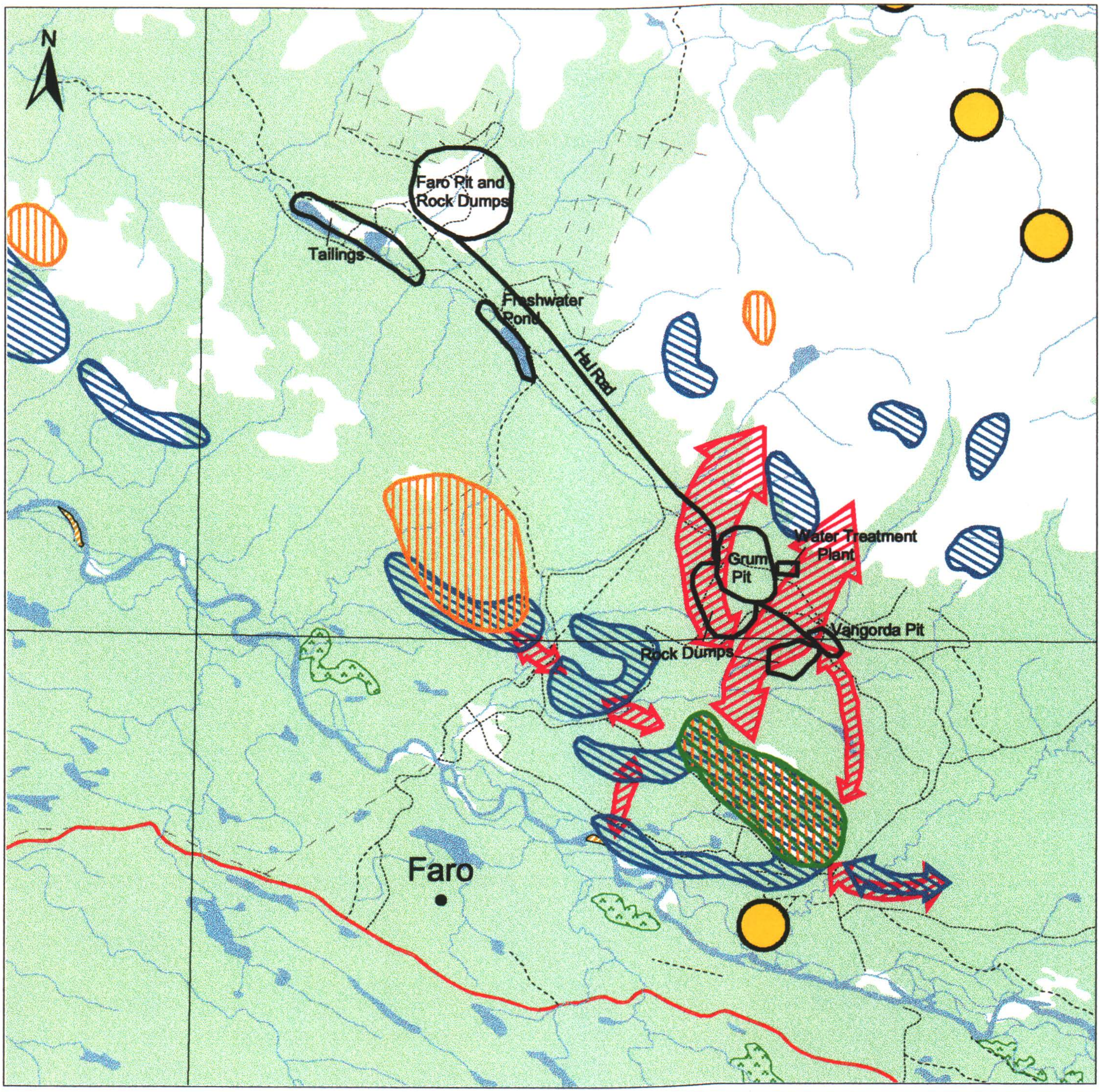
Mineralization in the Anvil District consists of sediment hosted, massive pyritic sulphide ores consisting of iron, lead, zinc, copper and silver bearing minerals such as sphalerite, galena, pyrrhotite, chalcopyrite, magnetite, arsenopyrite and marcasite, along with barite and quartz.

3.4 Regional Hydrogeology

The Anvil Range Mining Complex area is underlain by low permeability bedrock. Higher permeability is associated with fractures and fault zones that are structurally controlled and may act as deep groundwater conduits. Higher permeability is also associated with weathering of the bedrock surface. The regional deep groundwater flow direction is unknown.

The area has an undulating bedrock surface, which is overlain by glacial till and alluvial sediments. These form shallow aquifers that are discontinuous and irregular. In the upper slopes of the valleys, these deposits are relatively thin with groundwater flow being confined to coarser material at base of the surficial sediments and highly weathered bedrock surface. Groundwater flow direction is controlled by the bedrock topography. The valley floors contain thick deposits of alluvial sands and gravels, which form the larger aquifers.

Several previous hydrogeological investigations have been conducted at the mine sites, primarily to assess the dewatering of the pits or for the construction of the tailings dams. Groundwater quality studies have also been conducted for the waste rock dumps, tailings ponds and the North Fork Rose Creek area. This is discussed in more detail in Section 6.



Faro Key Wildlife Habitat Areas

Faro Mine Site Assessment

Legend
- Thinhorn Sheep (early winter rutting)
- Thinhorn Sheep (spring lambing)
- Thinhorn Sheep (winter range)
- Thinhorn Sheep (migration corridor)
- Mineral Lick

Scale 1:150 000

2000 0 2000 4000 Meters

Yukon Albers Equal Area projection

Drawn By: K. Svec and N. Guy
Site Name: Faro / Vangorda Mine
Project: 99-913
Date: 23 March 2000

DATA SOURCE:
Key Habitats Areas compiled by Fish and Wildlife Branch of Yukon Renewable Resources at 1:250,000.

Figure 3.1 Gartner Lee Limited

4 Land Tenure and History

4.1 Land Tenure

4.1.1 Faro Deposit

For greater security of tenure, the area of the Faro Deposit is currently held by 12 mineral leases under the *Yukon Quartz Mining Act*. These leases are due to expire on November 16th, 2009 and are listed in Table 4.1. All 12 mineral leases are currently held in the name Anvil Range Mining Corporation.

Table 4-1. Mineral Leases Granted under the Yukon Quartz Mining Act for Faro Deposit.

Lease No.	Grant No.	Claim Name	Ownership	Expiry Date	Lot No.
3427	92225	FARO 39	Anvil Range Mining Corporation	2009.11.16	39
3428	92227	FARO 41	Anvil Range Mining Corporation	2009.11.16	41
3429	92228	FARO 42	Anvil Range Mining Corporation	2009.11.16	42
3430	92229	FARO 43	Anvil Range Mining Corporation	2009.11.16	43
3431	92230	FARO 44	Anvil Range Mining Corporation	2009.11.16	44
3432	92231	FARO 45	Anvil Range Mining Corporation	2009.11.16	45
3433	92232	FARO 46	Anvil Range Mining Corporation	2009.11.16	46
3434	92239	FARO 53	Anvil Range Mining Corporation	2009.11.16	53
3435	92240	FARO 54	Anvil Range Mining Corporation	2009.11.16	54
3436	92241	FARO 55	Anvil Range Mining Corporation	2009.11.16	55
3437	92242	FARO 56	Anvil Range Mining Corporation	2009.11.16	56
3438	94573	WHI 8 FR	Anvil Range Mining Corporation	2009.11.16	90

There are no current Land Use Permits over the mine site and surrounding area as none are required within the municipality of the Town of Faro.

There are four federal land leases at the Faro site under the *Territorial Lands Act*:

- #1646 Map Sheet 105K6 – pit, dumps, plant site, tailings impoundments
- #1690 Map Sheet 105K6 – freshwater reservoir
- #1777 Map Sheet 105K6 – Faro Valley rock dump
- #4945 Map Sheet 105K6 – NE rock dump

The rest of the Faro Deposit and surrounding area is held by mineral claims under the *Yukon Quartz Mining Act*. This package includes the following Quartz Claims:

- FARO Claims registered to Anvil Range Mining Corporation, expiry March 1st 2001 to November 16th, 2009
- BILL Claims registered to Pelly River Mines Ltd., expiry March 1st, 2001
- WHI Claims registered to Anvil Range Mining Corporation, expiry March 1st, 2001.
- ED Claims registered to Anvil Range Mining Corporation, expiry March 1st, 2001.
- LO Claims registered to Pelly River Mines Ltd., expiry March 1st, 2001.
- GAL Claims registered to Anvil Range Mining Corporation, expiry March 1st, 2001 to March 1st, 2002.

4.1.2 Grum Deposit

The area of the Grum Deposit is currently held by at least 28 mineral leases under the *Yukon Quartz Mining Act*. These leases are due to expire between June 1st, 2006 and August 21st, 2015 and are listed in Table 4.2. All 28 mineral leases are currently held in the name Anvil Range Mining Corporation. There are no surface leases registered under the *Territorial Lands Act* associated with the Grum Deposit. In November 1995 several surface leases were applied for, but to date, none have been granted.

The rest of the Grum Deposit and surrounding area is held by mineral claims under the *Yukon Quartz Mining Act*. This package includes the following Quartz Claims:

- MIAMI Claims, registered to Glamis Gold Inc., expiry March 1st, 2001.
- TIE Claims, registered to Pelly River Mines Ltd., expiry March 1st, 2001.
- SUN Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2001 to March 1st, 2002.
- CHAMP Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2006 to December 5th, 2011.
- RICH Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2001 to March 1st, 2006.
- SALLY Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2006.
- JACK Claims registered to Anvil Range Mining Corporation, expiry March 1st, 2006.

- ELLE MAY Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2006 to January 25th, 2008.
- ROCKY Claims, registered to Anvil Range Mining Corporation, expiry January 28th, 2006 to June 1st, 2006.

Table 4-2. Mineral Leases Granted under the Yukon Quartz Mining Act for Grum Deposit.

Lease No.	Grant No.	Claim Name	Ownership	Expiry Date	Lot No.
3204	66741	FIRTH 6	Anvil Range Mining Corporation	2006.01.28	76
3205	66743	FIRTH 8	Anvil Range Mining Corporation	2006.01.28	75
3206	66760	CHUCK 1	Anvil Range Mining Corporation	2006.01.28	68
3207	66761	CHUCK 2	Anvil Range Mining Corporation	2006.01.28	69
3208	66764	CHUCK 5	Anvil Range Mining Corporation	2006.01.28	67
3209	66765	CHUCK 6	Anvil Range Mining Corporation	2006.01.28	72
3210	66766	CHUCK 7	Anvil Range Mining Corporation	2006.01.28	73
3211	66767	CHUCK 8	Anvil Range Mining Corporation	2006.01.28	74
3195	70440	BIX 2	Anvil Range Mining Corporation	2006.01.28	77
3196	70441	BIX 3	Anvil Range Mining Corporation	2006.01.28	78
3335	66702	CHAMP 3	Anvil Range Mining Corporation	2008.01.25	62
3336	66703	CHAMP 4	Anvil Range Mining Corporation	2008.01.25	61
3337	66704	CHAMP 5	Anvil Range Mining Corporation	2008.01.25	64
3338	66705	CHAMP 6	Anvil Range Mining Corporation	2008.01.25	63
3329	66680	ELLE MAY 1	Anvil Range Mining Corporation	2008.01.25	58
3330	66681	ELLE MAY 2	Anvil Range Mining Corporation	2008.01.25	52
3331	66682	ELLE MAY 3	Anvil Range Mining Corporation	2008.01.25	59
3434	92239	GRUM 1	Anvil Range Mining Corporation	2009.11.16	53
3435	92240	GRUM 2	Anvil Range Mining Corporation	2009.11.16	54
3436	92241	GRUM 3	Anvil Range Mining Corporation	2009.11.16	55
3437	92242	GRUM 5	Anvil Range Mining Corporation	2009.11.16	56
3499	66706	CHAMP 7	Anvil Range Mining Corporation	2011.12.05	120
2125	77899	HANK 2 FR	Anvil Range Mining Corporation	2015.08.21	79
2126	77900	HANK 3 FR	Anvil Range Mining Corporation	2015.08.21	80
2127	77901	HANK 4 FR	Anvil Range Mining Corporation	2015.08.21	81
2128	77902	HANK 5 FR	Anvil Range Mining Corporation	2015.08.21	82
2129	77903	HANK 6 FR	Anvil Range Mining Corporation	2015.08.21	83
2130	77904	HANK 7 FR	Anvil Range Mining Corporation	2015.08.21	84

4.1.3 Vangorda Deposit

The area of the Vangorda Deposit is currently held by 12 mineral leases under the *Yukon Quartz Mining Act*. These leases are due to expire between January 28th, 2006 and January 25th, 2008 and are listed in Table 4.3. These 12 mineral leases are currently held in the name Anvil Range Mining Corporation.

Table 4-3. Mineral Leases Granted under the Yukon Quartz Mining Act for Vangorda Deposit.

Lease No.	Grant No.	Claim Name	Ownership	Expiry Date	Lot No.
3197	66673	ROCKY 2	Anvil Range Mining Corporation	2006.01.28	51
3212	66674	ROCKY 3	Anvil Range Mining Corporation	2006.06.01	49
3213	66675	ROCKY 4	Anvil Range Mining Corporation	2006.06.01	50
3214	66676	ROCKY 5	Anvil Range Mining Corporation	2006.06.01	47
3327	66677	ROCKY 6	Anvil Range Mining Corporation	2007.08.01	48
3215	66678	ROCKY 7	Anvil Range Mining Corporation	2006.06.01	45
3328	66679	ROCKY 8	Anvil Range Mining Corporation	2007.08.01	46
3198	66684	WYNNE 1	Anvil Range Mining Corporation	2006.01.28	53
3332	66685	WYNNE 2	Anvil Range Mining Corporation	2008.01.25	57
3199	66686	WYNNE 3	Anvil Range Mining Corporation	2006.01.28	54
3333	66687	WYNNE 4	Anvil Range Mining Corporation	2008.01.25	56
3334	66688	WYNNE 5	Anvil Range Mining Corporation	2008.01.25	55

There are no surface leases registered under the *Territorial Lands Act* associated with the Vangorda Deposit. A surface lease was applied for in November of 1995 but has not been granted to date.

The rest of the Vangorda Deposit and surrounding area is held by mineral claims under the *Yukon Quartz Mining Act*. This package includes the following Quartz Claims:

- ROCKY Claims, registered to Anvil Range Mining Corporation, expiring January 28th, 2006 to August 1st, 2007.
- GALE Claims, registered to Pelly River Mines Ltd., expiry March 1st, 2005.
- ALICE Claims, registered Anvil Range Mining Corporation, expiry March 1st, 2006.
- WYNNE Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2006 to January 25th, 2008.
- TIM Claims, registered to Anvil Range Mining Corporation, expiry March 1st, 2006.

4.2 Site History

The initial mineral discovery in the Anvil Range was the Vangorda Deposit, first drilled between 1953 and 1955. It was the Faro Deposit, discovered in 1964 that was brought into production by Cyprus Anvil Mining Corporation in 1969. Additional deposits were subsequently discovered in 1964 (Swim), 1973 (Grum) and 1976 (Dy/Grizzly). The development history of the major deposits is outlined below.

4.2.1 Faro Deposit

A plan map of the Faro mine site, which includes the location of the open pits, waste rock dumps, mill, tailings facility and freshwater reservoir is shown in Figure 4.1.

The Faro Mine began production in 1969 at 5,000 tonnes of ore per day. In 1970 production increased to 6,000 tonnes per day. In 1974, a mill expansion allowed an increase in ore production to 9,300 tonnes per day. In 1975, Anvil Mining Corporation was reorganized to form Cyprus Anvil Mining Corporation. In 1979, Cyprus Anvil purchased the Kerr Addision mineral deposits and claims including Grum, Vangorda and Swim. Also in 1979, Cyprus Anvil discovered and acquired the Faro No. 2 zone, adjacent to Faro No. 1 Zone, resulting in additional ore reserves. Exploitation of the No. 2 Zone was initiated soon after and was completed in 1981. Cyprus Anvil then embarked on a program of expansion to bring the Vangorda Plateau deposits (Vangorda and Grum) into production to supplement the Faro Mill feed.

Due to depressed base metal prices, debt load due to expansion, failure to strip waste in advance, low productivity and high costs, Cyprus Anvil ceased production in 1982.

Open pit waste stripping (7.4 million m^3) was carried out between June 1983 and October 1984 in the Faro open pit. This helped overcome one of the previously mentioned obstacles to productivity. The property was shut down and remained idle until the operation was acquired by Curragh Resources in November 1985.

The mine facilities were reactivated in December 1985 and waste stripping in the Faro Pit commenced in January 1986 for a mill start up in June 1986. Mining was conducted primarily in Zone III of the Faro Pit with remnants being mined from Zone I. The production rate was 13,500 tonnes per day.

4.2.2 Vangorda Plateau Deposits

The Vangorda Plateau mine site consists of the Vangorda Pit and Dump, the Grum Pit and Dumps, the Water Treatment Plant and Grum Pit offices, shops and miscellaneous buildings, as shown in Figure 4.2.

The Vangorda Deposit was discovered in 1953 and drilled several times between then and the late 1980's when it was finally developed for production. At the same time as Vangorda was discovered, two small occurrences, Champ and Firth, were found. In 1973, the Grum Deposit was found between these two minor occurrences. During the years 1975 to 1977, extensive work programs were carried out at Grum to define the ore deposit. This work included an underground exploration program. The deposit was accessed by a ramp from a portal elevation of about 1265 m and twin declines followed the ore zone for 700 m, with extensive definition drilling done from these declines. There has been no underground exploration at the Vangorda Deposit.

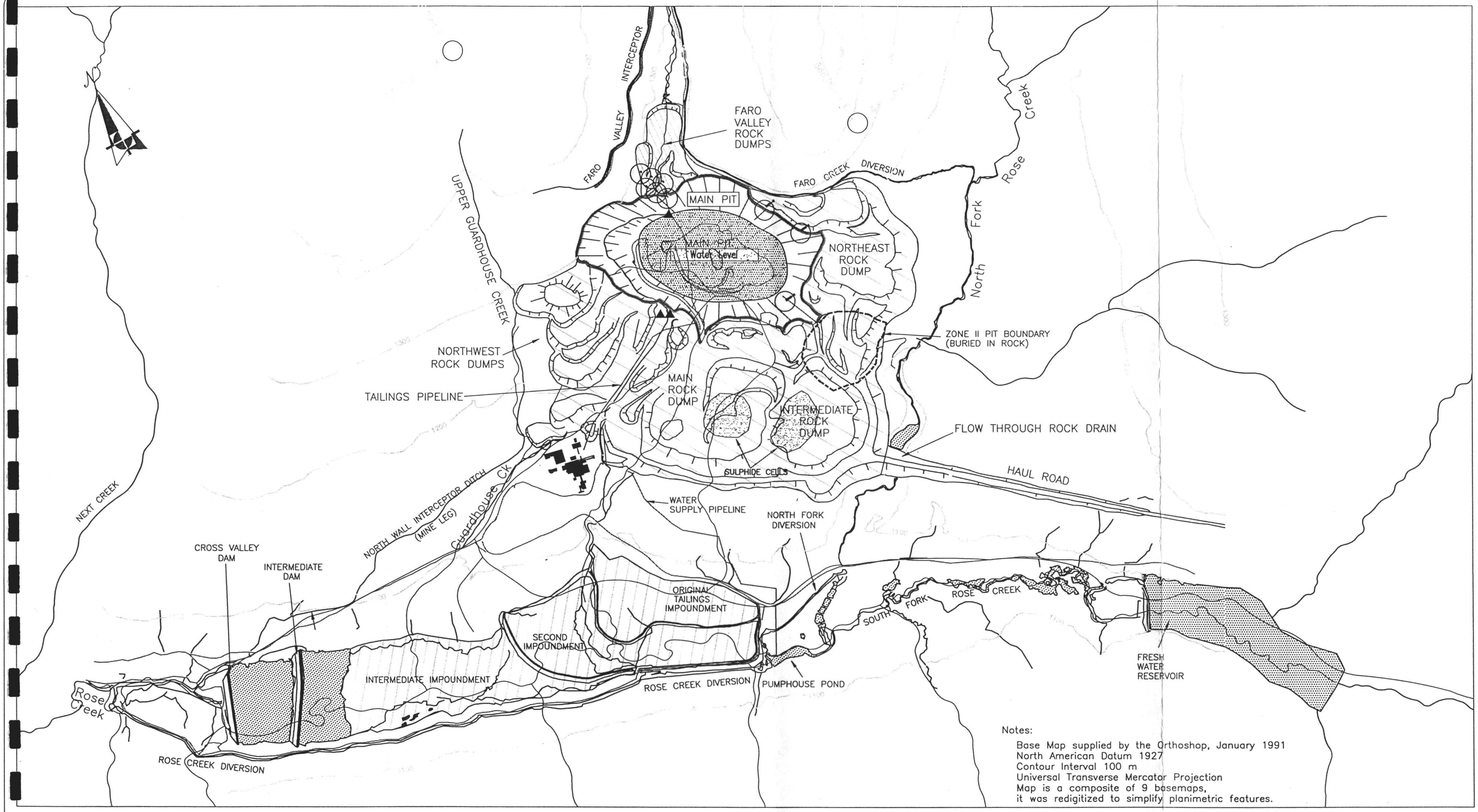
The Vangorda Plateau mine sites were first developed in 1988 when efforts to de-water the overburden of the Vangorda and Grum Deposits began. Several drainage ditches were dug and Doal Lake (actually a shallow pond) was drained. Stripping at the Grum site began first, with the wet soils from the vicinity of Doal Lake being placed in the wet dump, located immediately southwest of the pit area.

Mining on the site got off to an erratic start due to production difficulties with the other mining sites in the area. Mining of the Vangorda Deposit began in 1990 following issuance of a water license. Between 1990 and 1993, Curragh Resources mined 5.7 million tonnes of ore from the Vangorda Pit and several times that amount of waste rock. The Vangorda Pit was redesigned shortly after mining began, resulting in a larger pit. Combined with a lessening in the amount of till being excavated for cover material due to iron contamination of the basal till, this led to a redesign of the waste dumps and the covers proposed for the dumps.

By 1992, when Curragh Resources went into receivership, the Vangorda Pit was nearly fully developed and stripping had begun on the Grum Deposit. Stripping was carried out intermittently at the Grum Deposit, resulting in the excavation of approximately 22 million tonnes of glacial overburden and rock. Only 52,000 tonnes of ore was mined from the Grum Pit by Curragh Resources.

The site was under temporary closure from 1993 to late 1994. During this time, DIAND undertook construction of the Vangorda Rock Dump collector ditch and re-sloped a small portion of the rock dump. A 2 m thick till cover was placed on half of the area re-sloped. Five groundwater wells were placed below the toe of the rock dump during the shutdown.

Anvil Range Mining Corporation took over the mine site in November 1994 and resumed pre-production stripping at Grum. The Grum Overburden Dump was completed and dumping was concentrated on the Grum Main and Southwest Dumps. The Grum Dumps were reconfigured in response to higher than anticipated amounts of sulphide bearing material. Anvil Range Mining Corporation completed mining of the Vangorda Deposit in 1998. The Company went into receivership in 1998.



LEGEND

Data Source: Robertson Geoconsultants Inc.

Scale 1:25,000

0 250 500 1000 1500 m

Scales

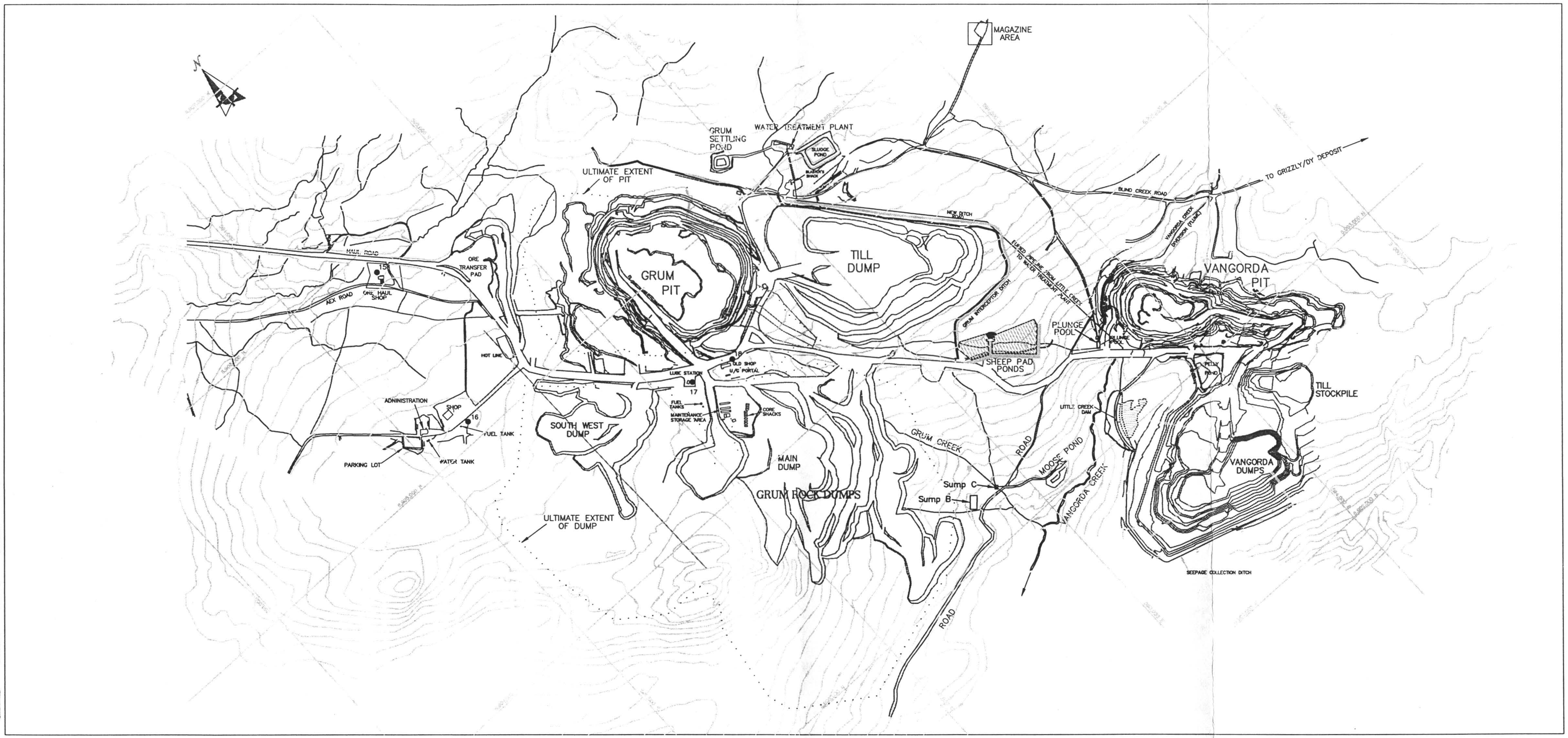
Designed By:	D.L.	Drawn By:	D.L.
Checked By:	F.K.P.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Faro	File Name:	fig4_1.dwg

DIAND Waste Management Program

Overview of Faro Mine Site

Gartner Lee Limited

Figure No. 4.1



LEGEND

Data Source: Robertson Geoconsultants Inc.

Scale 1:100,000

0 333 667 1000 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16/01	Project No.	99-913
Site Name:	Vangorda Plateau	File Name:	fig4_2.dwg

DIAND Waste Management Program

Overview of Vangorda Plateau

Gartner Lee Limited

Figure No. 4.2

5 Mine Development and Operation Description

5.1 Faro Deposit

5.1.1 Faro Deposit Geology

The geology of the Faro Deposit has been described in detail by both Wallinger (1978) and Robertson Geoconsultants Inc. (1996a). The Faro mine site is bounded by the main stem of Rose Creek, the North Fork of Rose Creek, Next Creek and the southwest contact of the Anvil Batholith. The area is unusual in that the grade of metamorphism is higher than most other mining areas in the district, though typical for areas near the Anvil Batholith contact.

On the uplands adjacent to the Rose Creek Valley, bedrock is discontinuously covered with a veneer of morainal and colluvial deposits which increase in thickness towards Rose Creek. The valley is filled with a complex assemblage of fluvial, glacial and lacustrine deposits. Bedrock in the valley bottom is overlain by a complex of fluvial and glaciofluvial sands and gravels. Maximum thickness of the sand and gravel is 35 to 40 m.

The zinc-lead-silver massive pyritic deposits of the Anvil District occur in a Cambrian metasedimentary, metavolcanic terrain on the south-western slope of the Anvil Range in the Selwyn Basin of Central Yukon. The Faro Deposits occur in a unit of middle amphibolite facies pelitic schists overlain conformably by calc-silicate phyllites. The massive sulphide ore zones are stratabound by a quartzitic horizon and strataform with respect to the dominant foliation in the host rocks. The ores had a granular texture averaging about 70% sulphide minerals, with quartz or barite the most common non-sulphide gangue minerals present. The average grades were 3.4% lead, 5.7% zinc, and 30% iron, with 42 grams of silver per tonne. The average specific gravity was 4.16.

In the central portion of the deposit, pyrite occurred commonly as coarse porphyroblasts (to 5 mm), with inclusions of sphalerite and galena, in a fine grained matrix of sphalerite, galena and minor chalcopyrite.

At the margins of the deposit, pyrrhotite formed fine-grained aggregates with veinlets and fine disseminations of chalcopyrite, sphalerite and galena. Other primary sulphides present in minor or trace amounts were tetrahedrite, bournonite and arsenopyrite. Marcasite and magnetite were important secondary minerals with anglesite, geothite and gypsum occurring sparingly. A zone of low-iron, disseminated galena and sphalerite ores in a gangue of seritic or graphitic quartzites enveloped the massive sulphide zone.

5.1.2 Faro Pit and Waste Dumps

The Faro Deposit was described as an ellipsoidal somewhat tabular mass having a major axis of 1,220 m and a minor axis of 370 m. The vertical thickness was up to 100 m. The ore zone was covered by waste rock and alluvium up to a depth of 170 m.

Stripping of the pit began in 1968 and commercial milling of ore began in September 1969. The initial production rate was 5,000 tonnes of ore per day, increasing to 6,000 tonnes in 1970 and 9,300 tonnes in 1974. The Faro Pit was mined as a conventional truck and shovel operation. Initially 58.5 tonne trucks were utilized, these were replaced with 108 tonne trucks in 1977.

The first pit mined was Zone I, from which waste rock was dumped in the Faro Valley and Northwest Dumps (Figure 4.1). The pit was initially developed as a narrow, northwesterly elongate cut into the hill slope northwest of Faro Creek. The pit was then broadened to the southwest in the early 1970's, with the waste dumped to the west side of the Northwest Dumps and into the west Main Dump. The pit was extended to the southeast across Faro Creek following establishment of the initial Faro Creek diversion in the mid 1970's. Waste rock was deposited in the Main Dump and also the Northeast Dumps, which were started at that time. Zone I was mined into the early 1980's and was essentially completed by Cyprus Anvil. Curragh Resources mined several small remnants of ore from the pit walls between 1986 and 1992, with waste dumps internal to the pit. Cyprus Anvil deposited several million tonnes of oxidized ore from Zone I (and Zone II) near the mill.

In the late 1970's and early 1980's, Zone II was mined and the Intermediate Dumps were started. It is believed that during the initial stripping of oxidized ore, metal enriched overburden and sulphide waste rock from the Zone II Pit were deposited on the Intermediate Dump. Thus the lower lift of this dump can be expected to contain a significant storage of soluble metal.

Faro Zone III was a down-dropped block of ore, which required considerable stripping of waste rock. This stripping was begun by Cyprus Anvil in the mid 1970's, in conjunction with mining of Zone I, using the Northeast Dumps. During the mid 1980's shutdown, Cyprus Anvil conducted a major stripping effort, with waste rock being deposited in the Main and Intermediate Dumps. The southeast slot access to the Zone III Pit was developed at that time. Clean calc-silicate and schist waste from the Zone III stripping was segregated on top of the east Main Dump for possible use in dam raising at a later date. Waste from the Zone III stripping was also deposited by Cyprus Anvil in the mined-out Zones 2 Pit and in the Intermediate Dump.

Curragh Resources mined primarily in Zone III where considerable stripping was required. During Curragh's tenure, waste rock from the Faro mine site was deposited in the Main and Intermediate Dumps and the Zone II Pit. Curragh Resources deposited most of their sulphide waste in a cell on the upper lift of the Intermediate Dump, but later also deposited sulphides on top of the clean calc-silicate and schist placed by Cyprus Anvil on the upper lift of the Main Dump. Calc-silicate breccia, stripped from Zone III, was used for the North Fork of Rose Creek rock drain. Schist, calc-silicate breccia and minor quantities of intrusive material was also used to build the haul road to Vangorda Plateau and a haul road to the mill on the southwest side of the Main and Intermediate Dumps. Rock placed in the haul road southeast of the North Fork of Rose Creek was derived from stripping in Zone III and was hauled through the south slot access. Thus, the southeast section of the haul road is believed to be constructed of clean non-sulphide waste rock, as that was all that was reportedly being mined in that part of the pit at the time. Curragh Resources also placed a considerable amount of waste rock, much of which was sulphide bearing in the previously mined portions of the Zone I and Zone III Pits. The Ramp Zone, a small extension of Zone II, was mined by Curragh Resources in 1986 and then backfilled. The Ramp Zone was immediately southwest of the southeast slot access to the Zone III Pit. Thus the pit wall between the slot and the Ramp Zone is thin. Sulphide material was also dumped over the southwest pit with the intention that it would be pushed down into the pit later.

Curragh Resources deposited low-grade ore (3 to 5% lead and zinc) in two stockpiles, A and C, beside the main haul road from the Zone I Pit. Curragh Resources processed the oxidized ore stockpiled by Cyprus Anvil after screening out the fine fraction of the ore. The oxidized fines are still present near the mill in active fresh ore stockpiles (see Section 7.4.5.1).

Curragh Resources mined 1.7 million tonnes of ore from a room and pillar underground mine developed through a portal into the southwest wall of the Faro Pit. All openings into this mine were internal to the Faro Pit and are now flooded. Before flooding, Curragh Resources prepared the underground workings for possible use in future water treatment.

Tailings deposition into the mined out Faro Zone I and 3 Pits began in August 1992 and continued until closure in 1998. The reported ore, waste and tailings for the Faro mine site are presented in Table 5.1.

Table 5-1. Reported Ore, Waste and Tailings Tonnage (1973 – 1992)

Year	Reported Tonnage
1973	80 Million tonnes (65-70%) pyrite and 4% pyrrhotite)
1975	46 million tonnes
1981	57 million tonnes 3.4% Pb, 5.7%Zn, 37.5g/t Ag.
1982	Mined ore, 35 million tonnes.
1982	Waste rock mined, 62 million m^3.
1982	Tailings generated, 10 million m^3.
1983 – 1984	Further 7.4 million m^3 waste stripped.
1986 – 1992	Ore mined, 23.4 million tonnes
1986 – 1992	Waste stripped, 30 million m^3
1986 – 1992	Tailings generated, 6 million m^3.

5.2 Vangorda Deposit

5.2.1 Vangorda Deposit Geology

The Vangorda Deposit is a small deposit for this area and has a number of characteristics that make it unusual. These include:

- Shallow depth and greater weathering
- Abundance of barren foot wall sulphides
- Degree of development of strongly altered phyllites

The Vangorda Deposit was relatively close to the ground surface and was more affected by weathering than the other ore deposits of the district. The top 6 to 10 m of the deposit was moderately oxidized and contained cyanide soluble copper, which interfered with the selective flotation of lead and zinc in the mill. This material was placed in the Vangorda Dump on the sulphide cell side of the dump. Later the material was screened and the coarse fraction sent to the mill (since it was less oxidized). The fine fraction of this oxidized ore remains in the dump and is referred to as "oxide fines" or "baritic fines."

The thickest part of the ore body occurred below a ridge of highly compacted till east of Vangorda creek. This till was used to construct the berms around the periphery of the Vangorda Dump. The basal 1 to 5 m of the till is commonly stained and cemented by iron oxides thought to be derived from oxidation of the ore and/or sulphides associated with graphitic rock. This material was rejected for use in construction of the till berms as it was thought likely to be charged with soluble metals.

The proximity of the deposit to the surface may have had other implications for the geochemical behavior of the Vangorda sulphides. Marcasite associated with pyrrhotite is described in polished section of many ore types at Vangorda. It is suspected that the presence of marcasite is due to surficial weathering. The apparent rapid oxidation of the Vangorda sulphides and formation of extensive white powder on rock surfaces during periods of dry weather is possibly due to weathering of marcasite.

The Vangorda Deposit consisted of one major sulphide horizon, the "main horizon", located about 50 to 120 m beneath the basal carbonaceous member of the Vangorda Formation. The host rocks for the deposit were dominantly non-calcareous phyllites, probably part of the Mt. Mye Formation. However, formational assignments near this deposit were ambiguous, largely due to the strong wall rock alteration developed around the deposit. Most phyllites, especially in the main horizon footwall, were bleached, locally silicified and/or chloritic and sulphide bearing.

A number of thin horizons occurred above the main horizon. These horizons were too thin or of too low a grade to be economically mineable, with the exception of the south-east end of the deposit where the ore horizons were shallow, resulting in a low stripping ratio.

The Vangorda Deposit consisted of the same sulphide rock types as the other Anvil District deposits. Two rock types were particularly prominent. The footwall of the main horizon of the deposit was an assemblage of sulphide-rich quartzite, quartz bearing semi-massive sulphides and massive pyrite, which was referred to as the "foot-wall pyritic quartzite". The rocks of the foot-wall pyritic quartzite grade downwards from the pyrite - quartz rocks over an interval of 50 to 100 m into flaggy, moderately hard, siliceous phyllite and, ultimately, into soft non-siliceous altered phyllite. Parallel to this downward decrease in silica in the foot-wall pyritic quartzite is a downward decrease in the abundance of sulphides from massive barren pyrite (with over 80% pyrite) at the top, through quartz-rich semi-massive sulphide (with approximately 50% pyrite), to weakly pyritic altered phyllite (with a few % pyrite) at the base. Most of the sulphides in the quartzite were pyrite, however pyrrhotite was generally present and locally abundant or dominant in this footwall zone. Magnetite was unusually well developed in the footwall pyritic quartzite. The footwall pyritic quartzite contained only minor lead and zinc but had copper (approximately 0.2%) and gold (approximately 0.75 g/t) grades similar to high-grade lead-zinc ore. Most of this unit was sulphide waste, based on the lead-zinc content, and mining of this material was minimal except as required to gain access to deeper high-grade baritic sulphides of the main horizon. Since the copper and gold grade of this material suggests possible milling at some point, this material has been segregated on the north side of the Vangorda Dump.

The main horizon massive sulphides that overlie the pyritic quartzite were commonly baritic and rich in lead and zinc. The contact between the high-grade ore and underlying barren footwall was usually sharp and visually obvious. Of the mineralization that exceeded 5% lead and zinc at Vangorda, 90% was barite bearing massive sulphides.

The Vangorda Deposit occurred in the hinge of a large second phase fold. However, there was considerable uncertainty in the details of fold morphology. The deposit was elongated in the north-west to south-east direction, parallel to the second phase fold axis, and has been traced over an area of 1300 m by 200 m.

The north-west half of the deposit plunged about 10 degrees towards the north-west but the south-east half was sub-horizontal. An axial planar foliation dips shallowly toward the south-west but was locally quite variable. This foliation was the dominant plane of failure for the host rocks of the deposit and was a principal factor in the slope stability of pit walls.

The deposit is truncated by a steep normal fault at its north-west end. Steep normal or transcurrent faults offset the ore. These faults were late stage post-folding and post-metamorphism structures.

Due to the overall southwest dip of the ore body the north east pit walls have well developed exposures of the foot wall pyritic quartzite and are strongly acid generating. The opposite walls, which consist of various altered phyllites and thin sulphite bands, must also be considered acid generating, but not as strongly acid generating as the rocks in the northeast wall. In the deeper part of the pit, the sulphides do not extend all the way up the pit walls, thus there is potential to completely flood the sulphides to reduce oxidation. A major fault is found at the northwest end of the Vangorda Pit. This fault truncated the ore body and juxtaposed the black graphitic phyllite of the basal member of the Vangorda Formation against the ore body. These graphitic rocks are well developed in the pit wall and the Vangorda Creek Diversion rock cuts. The graphitic rocks contain minor pyrite and seepages from them are iron rich.

All phyllites mined from the Vangorda Pit were altered and many contain at least minor pyrite or pyrrhotite with relatively little calcite. For this reason all phyllites from the Vangorda were considered acid generating and placed in the southwest portion of the bermed Vangorda Dump. As in all of the Anvil Range deposits, the dominant meta-sedimentary phyllites contain layers of mafic meta-igneous intrusives. At the Vangorda Deposit, the meta-intrusives are altered like the phyllites and may thus have more leachable Nickel and Cobalt, elements that are normally enriched in mafic rocks.

5.2.2 Vangorda Pit and Waste Dumps

The Vangorda Pit is 1,150 m in length, 200 to 350 metres wide and up to 100 metres in depth. The longitudinal axis of the pit is approximately northwest / southeast with the deepest portion to the northwest end of the pit. The southeast half of the pit is a narrower slot about 200 m wide and only 50 m deep. Access to the pit was by a ramp with the entrance at the southeast end of the pit that led to the deeper northwest pit where the thickest ore was mined. Vangorda Creek originally passed directly over the thickest part of the ore body and had to be diverted to mine the pit.

The northeast pit wall is mostly in massive and disseminated sulphide bearing rock. Due to the plunge of the deposit and offset by faults, the northwest part of the deposit is deeper. Consequently the pit is considerably broader there and remnant sulphide exposures on the pit walls are correspondingly deeper. The upper northeast walls are weakly altered phyllites of the Mt. Mye Formation that pose no significant acid generation concern. The southwest pit walls are mostly phyllites, however, in the slot area there are minor sulphide lenses interlayered with the phyllites. In the deeper part of the pit there are no known sulphides in the phyllites. The northwest end of the pit is in black carbonaceous phyllite with moderate to weak acid generation potential and low base metal sulphide content. The weathering of these rocks appears to be the source of iron in the ferricrete at the base of the till. Seepage from the black carbonaceous phyllite was not high in zinc or other metals.

Two small rock dumps were placed in the pit by Anvil Range Mining Corporation on either side of the haul road near the pit entrance. The size of these dumps is not well known, but there are probably not more than a few 10's of thousands of tonnes in each. The rocks are likely to be mixtures of 50% sulphides and 50% phyllites.

The Vangorda Pit walls have experienced local instability. In particular, the northwest end of the pit, which is in the carbonaceous phyllites and is near several faults, has experienced wall failures, which forced the diversion channel to be moved soon after construction. This immediate area appears to have stabilized, however, ongoing movement is occurring on the southern walls of the pit. The northeast walls, particularly the northeast wall in the slot area, do not appear to be unstable.

5.3 Grum Deposit

5.3.1 Grum Deposit Geology

The Grum Deposit, with mineable reserves of approximately 25 million tonnes, was much larger than the Vangorda Deposit and has a number of unusual characteristics that make it unique. Particularly outstanding are:

- The high proportion of disseminated sulphide ore types compared to massive ores
- The generally weak alteration overprint
- The complex, large scale, fold structure

The sub crop of the ore deposit is covered by up to 100 m of till and better-sorted glacio-fluvial silts, sands and gravels. The material fills a buried channel trending north-south through the pit area. There have been no notable weathering features encountered at Grum.

The Grum Deposit consists of three to five highly contorted layers of massive and disseminated sulphide mineralization within a 150 m thick section of barren phyllite. The most important mineralized horizon occurs just beneath the basal carbonaceous member of the Vangorda Formation. There are thin low-grade horizons with the Vangorda Formation and more important horizons in the upper part of the Mt. Mye Formation.

A feature unique to the Grum Deposit among the district deposits is the relative abundance of quartzose ore types, particularly carbonaceous pyritic quartzites which comprise about 50% of the reserves above 4% lead and zinc. Other ore types are similar to those occurring in the other deposits of the area. Thick sections of barren pyritic quartzite and barren massive pyrite, such as found at the Vangorda Deposit and the Faro Deposit, are not conspicuous at the Grum Deposit. Altered phyllites are also not prominent at the Grum Deposit, and where present, they contain relatively little sulphide. The sulphide waste at the Grum Deposit thus tends to consist of low grade ore types mixed with phyllites rather that the phyllites themselves.

At the Grum Deposit, the Vangorda Formation consists of soft, highly fissile, calcareous phyllites. Mafic meta-igneous rocks in the Grum area are volumetrically minor and tend to be highly foliated chlorite phyllite rather than blocky, massive greenstones that typify the Vangorda Formation elsewhere. Carbonated versions of these chloritic phyllites are widespread near the ore and commonly these pale coloured muscovite – ankerite rich rocks contain bright green minerals similar in appearance to fuchite. The basal carbonaceous member of the formation thickens across the deposit from about 10 m in the north-east to as much as 80 or 100 m south west of the deposit. The sulphide horizons appear to be associated with the northeast pinch-out of this unit. Immediately above the main ore horizon, the carbonaceous rocks are soft, highly sheared and gouged. Elsewhere they are moderately hard, highly fractured, black siliceous phyllites. The Mt. Mye Formation consists of soft phyllites that are distinguished from those of Vangorda Formation by being non-calcareous and less distinctly banded. The phyllites at the Grum Deposit are not as strongly altered as at the Vangorda Deposit and many are strongly calcareous. Consequently an effort was being made to separate the phyllites from acid generating rocks in order to concentrate the acid generating material in a place in the dumps where drainage control could be provided with greatest effectiveness.

There are no significant post-metamorphic dykes at Grum. The Anvil Batholith crops out 1.5 km north-east of the deposit but is separated from it by major faults. The Batholith is unrelated to the deposit and does not appear to have significantly affected it.

The ore horizons at the Grum Deposit are contorted into a complex, shallowly northwest plunging polyphase fold structure. Prominent S-shaped folds are second phase structures. They are superimposed on a larger Z-shaped first phase fold. The dominant plane of fissility or cleavage in the phyllites at the Grum Deposit is axial planar to the second phase folds and dips shallowly (10 degrees to 30 degrees) generally to the southwest. This fissility is a major factor in assessing slope stability for the pit. The overall deposit elongation parallels the axial direction of the second phase folds (315 degree trend, 11 degree plunge).

There are several important faults at the Grum Deposit. The largest displacements occur on moderately dipping (35 degree to 45 degree) structures that truncate the deposit at both its northwest and southeast ends but do not crop out in the pit. The rocks of these faults vary from intact fault rock with characteristics identical to the enclosing phyllites to approximately 3 to 10 m thick intervals of gouge and surrounding fractured rock. A steeply north-west dipping fault set trending about 060 degrees, passes between sections 68W and 72W and down drops the deposit about 60 m on the north-west. A myriad of smaller steeply dipping faults were mapped underground by Kerr Addison, and by later operators in the pit, which trend 080 degrees on average. Joints mapped underground and on surface tend to strike 060 degrees and dip sub-vertically.

5.3.2 Grum Pit and Waste Dumps

The Grum Deposit consists of several horizons that form a complex fold pattern as already discussed in Section 5.3.1. Due to the local geometry of the deposit, there are two separate zones that comprise the surface mineable Grum Deposit. These are the "Main" zones, which was to be mined in the "IV" pit, as outlined in the original project proposal, and an additional zone to the southeast known as the Champ Zone. The Champ Zone is so close to the main deposit that the two pits merged and became one overall pit. In addition to open pit mining, plans called for underground mining to be carried out from the bottom of the Grum Pit in the final stages of the operation and in the years immediately following. The details of the potential underground follow-up to the surface mining phase were never defined. Underground mining may be carried in the same manner as at the Faro Deposit where the structure was followed down plunge from the pit bottom.

The Grum Pit is large and is being developed in a number of stages. The pit design is under evaluation and is not yet finalized, however for the purposes of this report, the Champ Zone extension of the Grum IV Pit is included, despite there not yet being a decision to mine this area. The implications of not mining the Champ Zone area are minimal, as there would be no significant changes to the closure plan without this zone.

The Grum Pit will be 1100 m long, 700 m wide and up to 200 m deep. A new access slot is being excavated at the southeast end of the pit and ultimately the Champ zone would be mined southwest of this access slot. The invert (lowest point on the crest of the pit wall) of the pit with the slot access will be in the range 1230 to 1235 m elevation, approximately 30 m lower than the previous pit design. The total pit size is unchanged from the original proposal since the extra stripping required in the access slot area slot is compensated for by stripping that will be avoided in the main pit. The total volume of the Grum Pit without the Champ Zone will be 42.6 million m^3 at closure. The pit will be 4.4 million m^3 larger with the Champ Zone being mined. The mining of the Champ Zone is irrelevant to the elevation of the pit invert.

The bulk of the rock waste already excavated or to be excavated from the Grum Pit is phyllite, either calcareous or non-calcareous. There will be relatively little sulphide waste rock. Most of the waste rock to be excavated from the Champ Zone Pit will be calcareous phyllite along with a small amount of sulphide waste. The bulk of the sulphide mineralization in the pit walls is relatively deep and there will be no exposure of sulphides above flooding level, assuming the pit is flooded to it's invert.

There is an existing set of underground workings at the Grum Deposit, which have largely been intersected by the open pit. The portal for the access ramp to these workings is at approximately 1260 m elevation, thus there is no concern for water flow from these workings because water will flow from the underground workings into the open pit. Future underground workings would also not provide a potential pathway out of the pit as the portal would be established in ore in the pit and follow the pit down plunge to the northwest.

5.4 Vangorda Plateau Haul Road

The Vangorda Plateau Haul Road is a heavy haul road developed for use by 154 tonne off highway trucks hauling ore from the Ore Transfer Pad to the Faro mill, a distance of 13 km. The road extends an additional 3 km past the transfer pad along the south side of the Grum Pit to the pit entrance on the south side of the Vangorda Pit. The road was built by Curragh Resources starting in October 1986 and was completed in 1989. There has been significant upgrading of the road surface over the years.

The road surface is approximately 30 m wide and there is a 2 m high safety berm on either side of the road. The bulk of the road was built as a fill road. There are two minor cut areas, one on the east side of the West Fork of Vangorda Creek and the other on the west side of the South Fork of Rose Creek. The road was built largely from mine waste rock selected for non-acid generating characteristics. The central 2 km of the road was built from locally borrowed surficial deposits. Most of the rock on the Faro side of the haul road (8 km) is schist with lesser calc-silicate and minor intrusive, all from the Faro Pit. The rock on the Vangorda Plateau side is calcareous phyllite from the Grum Pit.

The haul road crosses several major streams including the north and south Forks of Rose Creek as well as the West Fork and main stem of Vangorda Creek. The North Fork of Rose Creek crossing is a rock drain as described in Section 6.1.4. A second, smaller rock drain crosses Reservoir Creek, a tributary to the fresh water reservoir. The other crossings are corrugated metal pipes of 600 to 1600 mm diameter, 600 mm overflow culverts exist at most crossings. Culvert crossings were sized for a 1:25 year return period flood and were not designed to allow for fish passage. The two largest fills over these culverts are the West Fork of Vangorda Creek and the main stem near the Vangorda Pit. Side slopes are 2 horizontal to 1 vertical for sections built from overburden and 1.5 horizontal to 1 vertical for sections built from pit rock.

5.5 Ore Processing

The Faro Mill was designed to produce lead and zinc concentrate. The concentrator began operation in September 1969 with a capacity of 5,000 tonnes of ore per day. This was increased to 6,000 tonnes in 1970, 9,300 tonnes in 1974 and 13,500 tonnes in 1986. The following sections describe the Mill facilities and ore processing.

5.5.1 Primary Crushing

The Primary Crusher was originally fed directly by dump trucks hauling from the pits. During the mining of the Grum Deposit, tractor/trailer combinations were used to haul the ore to the crusher. Difficulties dumping the trailers necessitated the use of a coarse ore stockpile adjacent to the crusher. The ore was then fed to the crusher by a front-end-loader. The crusher was modified in January 1997 to again allow dumping of ore into the crusher.

The primary crusher is a 1.37 m x 1.88 m gyratory crusher, crushing to minus 15 cm. The crusher discharge was screened, with the minus 1.27 cm material conveyed directly to the fine ore bins and the oversize material was conveyed to the coarse ore storage building, which had a live capacity of 14,400 tonnes.

There is crushed ore remaining in the coarse ore building, approximately 8000 to 10,000 wet metric tons.

5.5.2 Fine Crushing

Ore was withdrawn from the bottom of the coarse ore storage by vibrating feeders and fed by conveyor to the 17.8 cm Symons standard secondary crusher set at 3.175 cm. The crushed product was screened, with the minus 1.27 cm material conveyed to the fine ore bin and the oversize material fed to the two

17.8 cm Symons shorthead tertiary crushers set at 0.95 cm. The discharge from the tertiary crushers was screened, with the undersize material conveyed to the fine ore bin and the oversize material recycled. The fine ore bin consists of four circular silos each with a capacity of 1,550 tonnes.

5.5.3 Grinding

Feed from the four fine ore bin silos was delivered to three parallel grinding circuits. Each circuit consisted of a rod mill, ball mill and a tertiary ball mill.

5.5.4 Flotation

The original plant design required the feed to the flotation section to be 70% finer than 74 microns (200 mesh) and substantial regrinding was required in the flotation section in order to obtain concentrate grades.

Initial plant operation yielded metallurgical results that were considerably inferior to those predicted by the feasibility study. This led to considerable circuit modifications and reagent testing, with little change in results. The commencement in the production of a bulk lead/zinc concentrate in 1970, in addition to the lead concentrate and zinc concentrate, did not yield an improvement in metallurgy. Metal recoveries in the early years were low, reported as 76% for lead and 66% for zinc in 1970, increasing to 83% and 80% respectively in 1976. (These recoveries do not account for zinc in the lead and lead in the zinc). The metallurgical balance from 1975 is shown in Table 5.2.

Table 5-2. Metallurgical Balance of Ore Processing for 1975 (Wallinger, 1978).

Product	Short Dry Tons	Assays, %			Distribution, %		
		Pb	Zn	Fe	Pb	Zn	Fe
Mill Feed	3,225,223	4.03	5.41	32.87	100.00	100.00	100.00
Lead Conc.	145,453	66.89	5.07	6.37	74.90	4.23	0.87
Zinc Conc.	230,494	2.04	50.80	10.78	3.62	67.13	2.34
Bulk Conc.	77,113	18.37	29.34	15.53	10.91	12.97	1.13
Final Tailing	2,772,163	0.50	0.99	36.58	10.57	15.67	95.66

It can be seen that the tailings include almost 11% of the lead, 16% of the zinc and 96% of the iron.

Processing of ore from the Vangorda Plateau deposits post 1992 presented additional challenges. Lead and zinc concentrates were produced at that time. The metallurgical balance from 1996 is shown in Table 5.3.

Table 5-3 Metallurgical Balance of Ore Processing for 1996 (ARMC, pers. comm., 2000)

Product	Tonnes	Assays, %			Distribution, %		
		Pb	Zn	Fe	Pb	Zn	Fe
Mill Feed	4,487,873	3.08	5.18	15.54	100	100	100
Lead Conc.	174,217	60.74	8.44	6.14	76.6	6.3	1.5
Zinc Conc.	323,707	2.70	51.07	8.19	6.3	71.1	3.8
Final Tailing (calculated)	3,989,949	0.6	1.3	16.6	17.1	22.6	94.7

5.5.5 Dewatering

The lead and zinc concentrates were thickened in four large rake thickeners, using Percol 351 (1975) as a settling aid, followed by filtering through disc filters.

The concentrates were dried in five rotary kilns. Four of these kilns were originally coal fired. The coal was mined near Ross River and hauled to the mill as required. The other kiln was originally oil fired. All of the kilns were converted to combination oil and propane burner systems in late 1995 and completed early 1996.

The rotary kiln dryers were equipped with wet scrubbers and an exterior discharge with the discharges and filtrates pumped to the appropriate thickeners.

Concentrates were conveyed to the storage building where they were discharged onto piles. Originally a front-end loader was used to load the 30-ton truck-mounted containers which were transported to the railway in Whitehorse. Following closure of the railway, the concentrates were trucked to Skagway, Alaska using tractor-trailer combinations with a capacity of about 50 tons ("muffin trucks"). These trucks were loaded through a conveyor/bin system, with the trucks weighed during loading on a horizontal truck scale.

5.6 Tailings Disposal & Water Management

During the period of operation from 1969 to 1992, tailings from the Faro Mill were deposited in three impoundments in the Rose Creek Valley (Figure 4.1). These consist of the Original Impoundment, the Second Impoundment and the Intermediate Dam Impoundment, which are described in detail below.

5.6.1 Original Tailings Impoundment

This impoundment is located on the north side of Rose Creek at the mouth of the old Faro Creek channel It was initially developed by raising a 7.5 to 9 m high waste rock starter dyke. The initial decant system consisted of a vertical riser leading to a 1.2 m diameter pre-stressed concrete pipe culvert placed in the space of the starter dyke. The starter dyke was raised in the winter of 1969 using un-compacted pit run waste rock with no impervious core. Dyke raising continued each summer until 1975, when a breach of the dyke occurred. It was estimated that 247,000 m^3 of frozen slurry, containing approximately 12,300 m^3 of tailings solids, had been deposited between the tailings impoundment and the mouth of Rose Creek (Robertson Geoconsultants Inc., 1996a).

5.6.2 Second Tailings Impoundment

The Second Impoundment was constructed in 1974 by building a second dam outside of the perimeter of the original dam using spilled tailings. Construction on this impoundment began in 1974 and was completed in 1975 after the breach in the original tailings impoundment. The second tailings impoundment consists of a west dam, with a height of nearly 27 m and an east dam, with a typical height of 4.3 m. The Original and Second Impoundments are currently filled with tailings and no longer impound water.

5.6.3 Intermediate Dam Impoundment

The Intermediate Dam was built downstream of the Second Impoundment across the valley of Rose Creek. This third impoundment, which is referred to as the Intermediate Dam Impoundment, contains seepage water, supernatant and tailings solids. Water is impounded against the upstream face of the intermediate dam. Water is passed by syphon or spillway from the Intermediate Dam into a polishing pond that is contained by the Cross-Valley Dam. The Intermediate Dam was initially constructed in 1981 and was raised in 1988, 1989 and 1991 to a maximum vertical height of approximately 34.4 metres (Robertson Geoconsultants Inc., 1996a). The dam is a zoned earthfill dam and includes a low permeability core.

5.6.4 Cross Valley Dam

The Cross Valley Dam was constructed during 1980 and 1981 to a maximum vertical height of approximately 19 metres (Robertson Geoconsultants Inc., 1996a). The dam is a zoned earthfill dam with a low permeability core. A granular toe drain was added in 1991. Its purpose was to create a polishing pond for water discharged from the Intermediate Dam before being released into Rose Creek. The polishing pond does not hold tailings, but lime treatment sediments can be observed on the north shore near the outlet of the Intermediate Dam spillway. Water is discharged via syphon pipes or spillway into Rose Creek.

5.6.5 Rose Creek Diversion

The North and South Forks of Rose Creek converge at the upper end of the tailings facility and are contained and diverted south of the tailings facility via the Rose Creek Diversion channel. The upper portion of the diversion was built in 1974 in conjunction with the construction of the Secondary

Impoundment. The diversion channel was extended in 1980 and 1981 as part of the construction of the Intermediate Impoundment (Robertson Geoconsultants Inc., 1996a).

5.6.6 Faro Pit Tailings Facility

The Faro Pit was used between August 1992 and April 1993 and again from August 1995 until shutdown in 1998 for tailings deposition from the Grum and Vangorda ore deposits. (Robertson Geoconsultants Inc., 1996a)

Since the shutdown in 1998 a dewatering program has been conducted at the main pit in order to maintain the in-pit water level within an acceptable range. Inflow to the main pit comes from several sources, such as rock dump seepage, surface run-off, groundwater inflow and water pumped from the Zone II pit. The water level management plan is to draw down the main pit water elevation during the summer such that the water is not projected to rise to a critical elevation prior to the start of the following season. (Anvil Range Mining Corporation, 1998)

In Spring 1999 one recycle pump was in operation intermittently to pump water from the main pit to the mill for mixing of lime prior to discharge into the Intermediate Pond Overflow. Natural runoff from the Intermediate Pond was then treated with lime in the spillway between the Intermediate Pond and the Cross Valley Pond and the treated water was discharged from the Cross Valley Pond into Rose Creek. Beginning in mid-June, one recycle pump was in operation 24 hours a day and the Faro pit water was being treated with lime at the mill before going to the Intermediate Pond. Additional lime was also being added at the spillway between the ponds. (ARMC, pers. comm., 1999)

5.7 Vangorda Water Treatment Plant

The Vangorda Water Treatment Plant (WTP) was constructed in 1989/90 during the initial development of the Vangorda Plateau mine site (Figure 4.2). During mine operations from about 1990 to 1993 and from 1995 to 1998, the plant was used to treat water from the Grum Pit, Vangorda Pit and Little Creek Dam. Water from the Grum Pit was pumped to the WTP via the Grum Pit water holding pond. Water was pumped from the Vangorda pit into Little Creek Dam where it mixed with runoff from the Vangorda rock dump and the mixed water was then pumped directly to the WTP via a long (>2 km) buried pipeline. The treatment process was conventional lime treatment with flocculant addition. Effluent exiting the WTP passed through a clarification pond prior to discharging into Vangorda Creek.

The WTP has not been operated during the current mine shut down that began in February 1998. Runoff water has been allowed to accumulate in the Grum and Vangorda Pits and runoff water from Little Creek Dam has been pumped into the Vangorda Pit.

The water level in the Vangorda Pit is predicted to reach an elevation where active intervention is desired by 2001 or 2002 (ARMC, pers. comm., 1999). The water level in the Grum Pit is not expected to reach an elevation where active intervention is desired for many years due to lower inflows as compared to the Vangorda Pit.

5.8 Freshwater Reservoir

Fresh water for the mill complex is taken from Rose Creek. The fresh water supply system consists of:

- A freshwater reservoir
- A pumphouse pond and pumphouse
- The North Fork Rose Creek Diversion, and
- A supply line from the pumphouse to the mill

The main source of fresh water is the water supply reservoir located in the South Fork of Rose Creek, which supplies water to the pumphouse year round. In addition, the reservoir supply capacity is supplemented by the North Fork of Rose Creek. A series of groundwater wells near the pumphouse have been used to provide additional water during the winter.

The freshwater reservoir, located 4 km south of the Faro mine site, was constructed in 1969. The reservoir is 1400 m long and 400 m wide and is designed to hold 5.8 million m^3 of water. Also during 1969, a pumphouse pond was constructed by building a small dam in the Rose Creek channel just downstream of the confluence of the North and South Fork of Rose Creek. A pumphouse supplied water from this pond to the mill via a 2 km long insulted steel pipe.

Construction of the Second Tailings Impoundment in 1974 necessitated raising the tailwater elevation at the pumphouse dam. This required diversion of the North Fork of Rose Creek and rebuilding of the pumphouse and pumphouse pond dam.

Since 1997, the mill fresh water supply has been primarily obtained from reclaim water from the Faro Pit, reducing freshwater requirements to about 5% of the previous requirement; approximately 95% of the operating water requirement was supplied from the Faro Pit reclaim system.

5.9 Electrical Power

Electrical power is supplied to the Faro site via a 38 kV power line connected to the Whitehorse Aishihik Faro Grid. There are transformers at the Faro mill to step the power down for local distribution on site. A standby EMD diesel generator is available to supply basic power needs in case of an emergency, but is not of a sufficient size to provide power for operation of the mill. A 27 kV overhead power line runs from the Faro mill site to the Vangorda Plateau area. This line feeds a 4160 V distribution system for the Grum and Vangorda mine sites.

5.10 Buildings and Equipment

5.10.1 Faro Mill Site

The following facilities are located at the Faro mill site (Figure 5.1):

- Primary crusher and coarse ore storage
- Mill and concentrate loadout
- Offices and warehouses
- Heavy duty equipment repair shops
- Guardhouse and administration building
- Tire shop and light vehicle repair shops

A list of major stationary equipment for the mill is shown in Table 5.3. In addition, a lube station, core shacks and explosives magazines are all located near the Faro Pit. Other buildings not located directly at the mill site include the copper sulphate plant, the bulk Explosives Plant and the Pump House, located on the mine access road.

5.10.2 Vangorda Plateau

The following facilities are located at the Grum and Vangorda mine sites:

- Grum office/dry complex
- Grum shop building
- Water Treatment Plant
- Grum exploration portal buildings
- Old exploration camp
- Grum ore haul contractors office and shop
- Explosives magazine
- Grum lube/fuel building

5.10.3 Ore Storage

During mining operations there were two main ore storage areas, the Mill ore storage pad, adjacent to the primary crusher building, and the Grum ore storage pad, located above the Grum Pit and adjacent to the Vangorda Plateau Haul Road. Ore was hauled from the Grum Pit by the pit haul trucks and stockpiled on Grum ore storage pad. The ore was then re-loaded into the contractor tractor/trailer trucks for hauling to the mill for processing. There were several stockpiles at the Grum storage pad with low-grade ore being separated from normal grade ore. Remnants of the low-grade stockpiles remain on the pad.

At the Faro Mill, ore from Grum was normally dumped directly into the crusher. However, a storage pad was used to stockpile mill feed when the crusher was not operating and also when dumping problems occurred with the tractor/trailer trucks. This stockpiled ore was re-handled to the crusher with a large front end loader or a truck/loader unit.

Coarse ore (crushed) and fine ore storage locations are discussed in Section 6.3.1. There are also a number of low grade and oxide ore storage locations within the waste dumps adjacent to the mill and Faro Pit, which are discussed in Section 6.1 to 6.3.

Table 5-4. List of Major Stationary Equipment (Robertson Geoconsultants Inc., 1996a).

Primary Crusher Plant
Primary Crusher, Allis Chalmers 54" X 74" gyratory
Apron Feeder
Oil lubrication system for above
2 Double Deck Vibrating Screens
Coarse Ore Storage
Syntron feeders
Coarse ore storage 16,000 tons live capacity
Mill Complex
a) Fine Crushing
1 Standard 7 ft Symons Cone Crusher (Secondary)
1 Single Deck Vibrating Screen
2 Short Head 7 ft Symons Cone Crushers (Tertiary)
2 Single Deck Vibrating Screens
b) Grinding Bay
3 Hardinge 9 ft X 12 ft Rod Mills (450 Hp each)
3 Hardinge 9 ft X 12ft Ball Mills (450 Hp each)
6 Krebs Cyclone Clusters
1 Allis Chalmers 13.5 ft X 22 ft Ball Mill (2500 Hp)
NOTE: There is a lubrication system for each Rod and Ball Mill including Regrind Mills.
c) Floatation Circuit
15 Denver Pb Roughers and Scavengers
3 Zn Conditioning Tanks
30 Denver Zn Roughers and Scavengers
30 Hardinge 9 ft X12 ft Pb Regrind Mill (450 Hp)
26 1st Pb Cleaners
13 Pb Retreatment
12 2nd Pb Cleaners
10 3rd Pb Cleaners
1 Hardinge 9 ft X 12 ft 1st Zn Regrind (450 Hp)

1	Retreatment Conditioning Tanks
13	Zn Retreatment
22	2nd Zn Cleaners
12	3rd Zn Cleaners
4	Zn Cleaners
d)	**Thickening /Clarifying/Tanks**
	75 ft diameter. Centre Rake Drive Eimco Thickener (Pb)
1	90 ft diameter. Eimco Thickener (Zn)
1	65 ft Zn Clarifier
1	Pb Clarifier
	Stock Tanks (1 Pb, 1 Zn)
e)	**Filtering**
6	Peterson Disk Filters (2Pb, 2Zn, 1 Bulk, 1 Extra)
f)	**Drying**
1	Standard Steel Oil Fired Rotary Kiln
4	Coal Fired Rotary Kilns (converted to propane)
g)	**Miscellaneous**
3	Hot Water Boilers
3	Air Compressors
Coal Handling Facility	
1	Coal Breaker
Concentrate Storage	
1	Shed, Capacity 7000 tons
Warehouse and Shop Facilities	
1	Repair Shop with 10 bays for mobile equipment (including 2 lubrication bays)
1	General Shop 13,4000 sq. ft housing:
1	electric shop
1	welding bay
1	carpenter shop
1	machine shop
1	Warehouse Facilities 18,000 sq. ft (plus 4,000 sq. ft of second floor office space)
1	Wabco Repair Shop with 6 bays 10,000 sq. ft
Major Overhead Cranes (located at)	
a)	Primary Crusher Plant
b)	Secondary/Tertiary Crushing
c)	Grinding Bay
d)	Mobile Equipment Repair Shops
Emergency Power	
	EMD Generator

5.11 Petroleum Products: Storage, Use and Dispensing

The primary fuel storage and dispensing locations are as follows:

- Gasoline – tanks and dispensing pumps are located adjacent to the Faro main gate guardhouse and adjacent to the Grum maintenance shop.
- Diesel – storage adjacent to the mill emergency generator.
- Diesel – storage and dispensing from the fuel/lube buildings at the Faro Pit and Grum Pit.
- Diesel – storage and dispensing at the Faro freshwater pumphouse.

5.12 Mill Reagents: Storage, Use and Dispensing

Mill reagents (except lime) are stored, mixed and dispensed from the reagent building adjacent to the mill. Bulk lime is stored in bulk in a silo located in the southeast corner of the mill building. A list of reagents used is presented in Table 5.4. Soda Ash and Z-11 were not used in the process from the start up by Anvil Range in 1995 to shutdown in 1998.

Table 5-5. Reagents used in 1975 and from 1995 to 1998.

Reagent	Kg/ton (1975)	Kg/ton (1995-98)
Sodium cyanide	0.105	0.088
Soda ash	1.1	
Lime	0.755	0.978
Copper sulphate	0.315	0.575
Z – 11	0.225	
MIBC	0.01	0.018
Dow 1012	0.004	0.012

Legend:

Scale 1:500 (approximate)

0 5 10 20 30 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.00	Project No.	99-913
Site Name:	Location	File Name:	fig5_1.dwg

DIAND Waste Management Program

Building Locations Around Mill Area

Gartner Lee Limited

Figure No. 5.1

6 Facility Evaluation and Records Review

The Gartner Lee Limited team conducted a preliminary site inspection of the Anvil Range Mining Complex site from September 21 to 23, 1999. Mr. Eric Denholm of Anvil Range Mining Corporation assisted the Gartner Lee team by conducting a tour of the mine site and providing historic and current information on mine site conditions and operations. The overall objective of the Phase 1 environmental site assessment was to identify the areas and issues of potential environmental concern on the basis of the type of mine site activity, the location of the source area, migration pathways and potential impacts to the receiving environment.

A preliminary assessment of chemical contamination, consisting of a limited soil sampling program, was conducted in conjunction with the site inspection at the Faro mine site. The soil sampling program was intended to provide contaminant concentration data in areas of potential environmental concern, particularly where petroleum hydrocarbons have been stored, dispensed and disposed. Soil samples were analyzed to determine concentrations of petroleum hydrocarbon parameters. Selected samples were also analyzed to determine metal concentrations.

6.1 Site Inspection – Faro Mine Site

The Faro Mine site is outlined in Figure 4.1. Photographs from the site visit are attached in Appendix A. The Faro mine site consists of the Faro Main Pit and the backfilled Zone II Pit. Each pit has associated waste dumps, water containment structures and water diversions. The plant site and tailings facilities are also located at the Faro Mine Site.

6.1.1 Faro Pit

Since 1992, tailings from the mill have been deposited in the Faro Main Pit (Photo 1). In 1997, after the pit filled with water and tailings to the point where active intervention was desired (approximately 50 feet below overflow elevation), Anvil Range Mining Corporation installed a system to recycle water from the pit for use in the mill rather than pumping water from the Rose Creek reservoir (Photo 2). Only potable water is currently drawn from the reservoir. The water level in Faro Main Pit is controlled by pumping to maintain the in-pit water level within an acceptable range. The pit water typically contains 2 to 3 mg/L zinc.

The Zone II Pit has been filled with sulphide bearing waste rock and acts as a collection sump for local area surface and shallow groundwater flows. The water quality in the Zone II Pit is currently at levels greater than 50 mg/L zinc. Water is pumped from the Zone II Pit into the Main Pit to prevent groundwater flowing over the southeast Zone II Pit wall (which has a lower elevation) into the North Fork of Rose Creek. During the September 1999 site visit, a pipe was observed discharging water pumped from the Zone II Pit into the Faro Main Pit along the main haul road. A plastic lip has been placed beneath the discharge to minimize erosion, but gullies were forming on the road.

Water is currently pumped from the Main Pit to the mill where lime is added in the mill's lime mix system (Photo 3). The treated water is then discharged from the mill below the main access road, into an open ditch, where it mixes with waste rock drainage flowing at about 3 to 5 L/sec. The mixed discharge flows down the ditch to discharge behind the Intermediate Dam. The water quality in the Intermediate Pond is not normally in compliance with the water licence due to waste rock seepage and runoff flowing over exposed tailings. Therefore lime slurry is added to the overflow in the spillway of the Intermediate Impoundment to treat the water.

As a result of excess water in the Rose Creek Tailings Facility in the spring of 1999, pumping of the Faro Main Pit water was delayed. In addition, ice blockage in the Faro Creek Diversion in the spring caused the diversion ditch to overflow into the Faro Pit, thus there was extra water in the pit that required pumping.

During the September 1999 site visit, it was noted that the north and northwest wall of the Main Pit were failing, probably along fault structures (Photo 4). The bottom of the pit was flooded and water was being recycled from the pit and passed through the plant for treatment.

Water quality monitoring is conducted at least monthly at the Faro Pit, the outflow from the Intermediate Impoundment, outflow from the Polishing Pond and downstream in Rose Creek.

6.1.2 Faro Waste Rock Dumps

The Faro waste rock dumps are subdivided into the Northwest, Northeast, Intermediate, Main and the Faro Valley Dumps (Photo 5). The dumps surround the open pit. The dumps were built by end dumping with trucks and then spreading the waste by bulldozer. The tops of the dumps are generally flat with the dump slope faces appearing to be at the angle of repose. There has been no attempt to flatten the slopes for revegetation. There are minor sloughs and slides on the faces of the dumps but the overall stability appears to be good. The Northeast Dump has been dumped directly onto a relatively steep, probably glacial till covered slope, above the North Fork of Rose Creek. It appears there was a slide at the dump during the early part of the operation as the toe of the dump shows bulging above the North Fork of Rose Creek. However, the dump presently appears to be stable. No signs of cracking or deformation were observed during the site visit. There is no evidence of silt working its way down from the dump and the water in the North Fork of Rose Creek is very clear.

The Faro Valley Waste Rock Dump is perched in the valley north of the Faro Main Pit (Photo 6). Seepage and runoff flows (via a waterfall) into the Main Pit. Seepage at this dump is reportedly among the worst quality water on site. The material in the dump is prone to the generation of Acid Rock Drainage (ARD). There was consideration given to relocating this waste into the Main Pit in order to submerge it below the pit water elevation. However, due to the difficulty in pushing the waste into the pit without rock hanging up on benches, this move has not been attempted. The dump appears to be physically stable.

The Northwest Waste Rock Dump is multi-level and has a flat top with long single angle of repose slopes. The dump has been placed directly on top of natural ground without stripping. There are no obvious signs of instability in the form of tension cracks, toe bulges or disturbed natural ground at the toe.

6.1.3 Faro Creek Diversion

Faro Creek initially flowed southward, through the centre of the Faro Main Pit and past the Main Rock Dump, before discharging into Rose Creek. Excavation of the Main Pit required that Faro Creek be diverted. The Faro Creek Diversion was constructed to direct the creek flow eastward along the crest of the Main Pit, past the north end of the Northeast Dump and into the North Fork of Rose Creek, down a previously existing small creek channel. The diversion channel is excavated into till and surficial sediments above the pit crest. The diversion has been upgraded through the use of culverts and liners to minimize seepage. The diversion is known to leak, but there are no present plans to repair the channel and minimize seepage.

The Faro Creek Diversion was inspected during the September 1999 site visit. The upper part of the Faro Creek diversion shows signs of decay and lack of maintenance (Photo 7). In some locations, the half culverts have separated and the blue tarp-like liner has been badly ripped (Photo 8). A minor slide has occurred on the north side of the diversion channel near where the diversion starts and directs flow from the natural creek. The failure encompasses no more than 10 - 15 m^3 of material, most of which has been eroded by the channel, but some residual ponding was evident. Several other potential areas where slides may occur were identified and observed along the backslope of the diversion channel. A slide in any of these areas could block the diversion channel and force flow into the Main Pit, necessitating the treatment of unanticipated volumes of pit water.

6.1.4 North Fork Rose Creek Rock Drain

A haul road has been constructed connecting the Vangorda Plateau mine sites with the existing mill at the Faro mine site. The haul road crosses the North Fork of Rose Creek via a rock drain constructed from waste rock. The road was built following the realization that ARD was a problem at Faro hence only 'selected non-acid generating rock' was used to build the road and the rock drain.

The rock drain was examined during the September 1999 site visit (Photos 9 and 10). The sediment load on the upstream side of the rock drain does not appear to be excessive. Consequently, the degree of siltation on the upstream face of the rock drain that could blind off the rock drain and reduce the permeability appears to be minimal.

Water levels at the toe of the rock drain fluctuate in response to the seasons. The apparent maximum water elevation based on the high water mark as indicated by floating debris, is some 3.5 meters above pond level. The maximum pond level appears to be at or above the staff gauge. The flow at the time of the site visit was clean, unimpeded, and the rock drain appears to be functioning well.

6.1.5 Faro Hydrogeology

6.1.5.1 Main Pit

The hydrogeology of the Faro Main Pit has been the subject of several previous studies. Piteau & Associates (1986) assessed the potential for dewatering the pit in the vicinity of fault zones. Steffen, Robertson and Kirsten Inc. (1994) examined the potential for seepage from the Main Pit and Zone II Pit to the North Fork of Rose Creek. Packer tests performed on boreholes indicate that the bedrock hydraulic permeabilities are in the range of 1×10^{-6} to 1.5×10^{-6} cm/s for quartz diorite and 9×10^{-7} to 2×10^{-4} cm/s for chlorite biotite schist. An intrusive horneblende biotite diorite was found to have a low hydraulic permeability at depth but was highly weathered near the surface having a hydraulic permeability of approximately 1 cm/s.

Southward striking faults, which intersect the Main Pit, have associated fracture zones that may be potential areas of groundwater seepage. This is dependent on the ability of the rock to sustain open fractures (Piteau and Associates, 1986). Many of the fractures that have been encountered are infilled with clay gouge and crushed rock, thus reducing permeability.

It is reported that in 1973, an estimated 22,700 m^3 per day of groundwater, containing 3.45 mg/L of zinc, entered the pit and was discharged into the tailings pond via an old channel.

Groundwater modeling by Steffen Robertson and Kirsten Inc. (1994) investigated three scenarios of the potential for seepage from the Main Zone Pit to the Zone II Pit and the North Fork of Rose Creek. The limited fault zone model showed that the amount of groundwater seepage entering the North Fork of Rose Creek which would by-pass pumping from the Zone II Pit to be less than 350 m^3/year. The extensive fault zone model indicated that the seepage by-passing the Zone II Pit pump and entering the North Fork of Rose Creek would be less than 2800 m^3/day (0.7 L/s).

6.1.5.2 Zone II Pit

The Zone II Pit mined an outcropping extension of the Main Zone ore body. The fault zone that offsets the orebodies is located along the west wall of the Zone II Pit and may be a significant groundwater flow path due to associated fracturing. The pit has been backfilled with waste rock using very little compaction, suggesting that the infiltration rate into the Zone Pit may be as high as 70% or 75,000 m^3/year (Robertson Geoconsultants Inc., 1996a). It is also possible that deep groundwater recharge occurs in the pit along fracture zones associated with north-south trending faults

Bedrock conditions along the southern edge of the Zone II Pit are not well known. Drilling along the southern lip of the pit encountered a chloritic biotite schist intruded by hornblende biotite diorite which is highly weathered and fractured and has a high permeability (Steffen, Robertson and Kirsten Inc., 1994). At depth, the chloritic biotite schist was found to have permeabilities of 1.6×10^{-5} to 4.5×10^{-5} cm/sec.

Historically, the Zone II Pit had poor water quality and had overflowed on two occasions (Robertson Geoconsultants Inc., 1996b). In late 1990, seepage occurred from the pit to the North Fork of Rose Creek, which is located only 120 metres to the southeast. A dewatering well was installed in 1991 to lower the water level in the Zone II Pit to below the level of the overflow, in order to limit pit overflow and groundwater seepage into the North Fork of Rose Creek.

Studies of groundwater quality have been conducted to investigate seepage from the Zone II Pit to the North Fork of Rose Creek (Steffen Robertson and Kirsten Inc., 1994; Robertson Geoconsultants Inc., 1996b). Several monitoring wells have been drilled into the overburden and underlying bedrock and have been monitored routinely. The water quality from the BH 90 series of monitoring wells (BH1, BH2 and BH4) indicate elevated zinc and sulphate concentrations with some acidic pH levels. The worst water quality is found in monitoring well BH4 which consistently has pH less than 4, zinc concentrations as high as 125 mg/L and sulphate concentrations as high as 9000 mg/L (Robertson Geoconsultants Inc., 1996a). Several other monitoring wells were drilled in this area in 1994 that indicated wide variations in groundwater quality. Monitoring well BH8 was found to have zinc concentrations of up to 158 mg/L and sulphate concentrations of 3500 mg/L, with pH ranging from 5.1 to 5.7 (Robertson Geoconsultants Inc., 1996a). BH9, BH10 A/B and BH11 had lower levels of zinc (0.03 – 4.3 mg/L) and sulphate (16 to 245 mg/L). It is unclear why water quality varies greatly in this area. It has been suggested that the high levels of zinc and sulphate are due to either the presence of outwash material derived from the Zone II ore body being encountered in some of the wells or the historic release of Zone II Pit water which has migrated down gradient (Robertson Geoconsultants Inc., 1996a).

6.1.5.3 Faro Waste Rock Dumps

The waste rock dumps at the Faro Mine site are investigated for acid rock drainage by conducting seep surveys annually around the site. Seepage can occur eastward to the North Fork of Rose Creek, southward from the Main, Sulphide Cells and Intermediate Dumps and westward to the Upper Guardhouse Creek.

Groundwater seepage from the eastern edge of the Intermediate Dump and the southern portion of the Northeastern Dump to the North Fork of Rose Creek is influenced by seepage from the Zone II Pit and has been monitored as described above. Seepage from the northern part of the Northeastern Dump is monitored by wells BH12, BH13 and BH14 which are constructed in the shallow overburden into the bedrock (Figure 6.1). The pH levels have been found to be between 6 and 7 with alkalinity of between 200 and 400 mg/L (Robertson Geoconsultants Inc., 1996a). Zinc concentrations range from <0.002 mg/L to 0.23 mg/L and sulphate concentrations range from 400 mg/L to 1000 mg/L (Robertson Geoconsultants Inc., 1996a and ARMC, pers. comm., 1999).

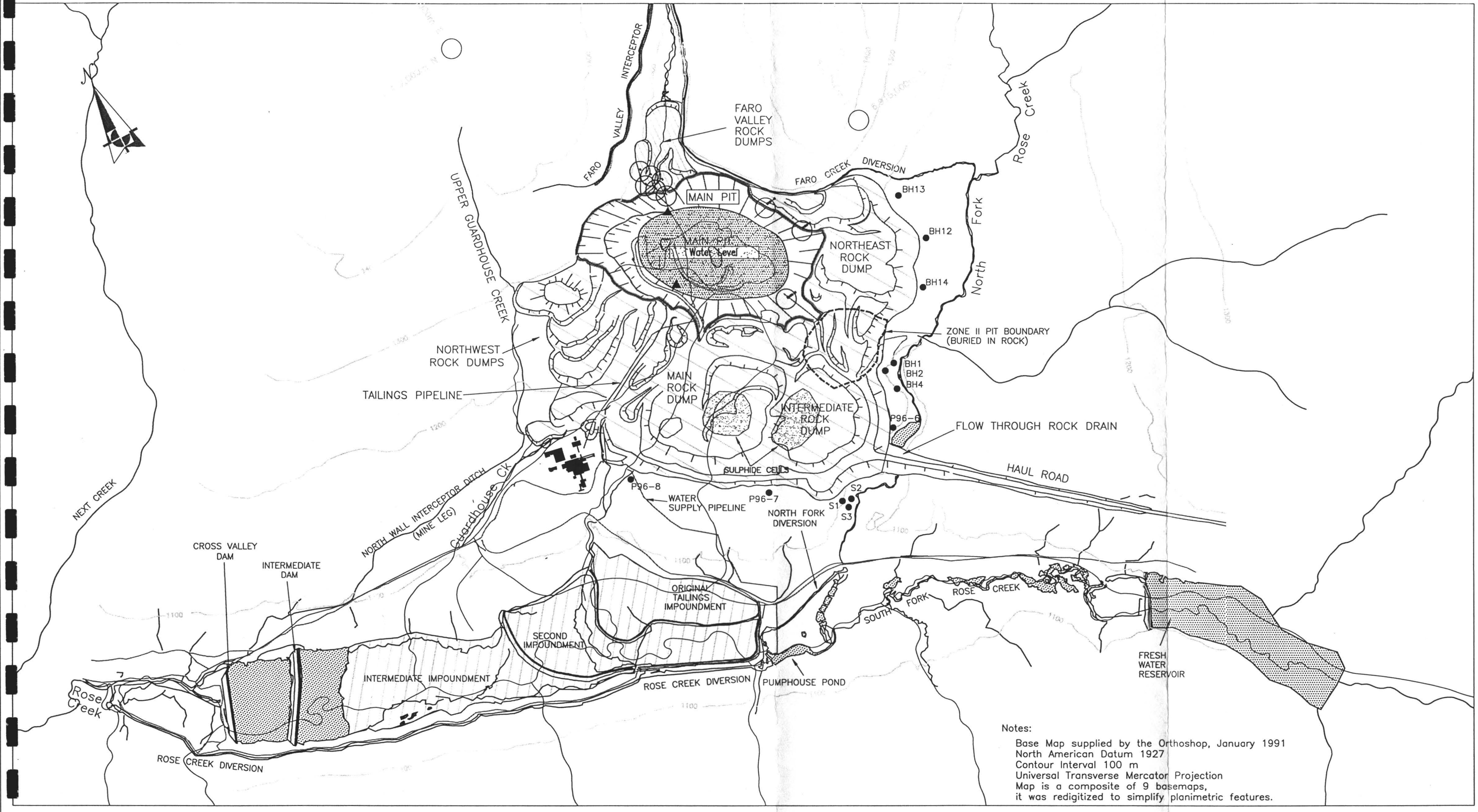
Seepage from the Intermediate Dump southward has been monitored at wells WE 2, WE 4 and BH 96-6. Monitoring wells WE 2 and WE 4 are constructed in the overburden and were found to be only slightly acidic with a pH of 6.4. Zinc concentrations ranged from 0.04 to 0.16 mg/L and sulphate concentrations ranged from 60 to 278 mg/L. BH96-6 is a deep borehole, which intersects gravel at 18 metres depth. The groundwater in the gravel layer has been found to be slightly alkaline (pH 8.0) with zinc concentrations as high as 1.3 mg/L and sulphate concentrations as high as about 425 mg/L (ARMC, pers. comm., 1999).

The area lying south of the Main, Sulphide and Intermediate Dumps is monitored for groundwater seepage by several shallow boreholes which are constructed into the overburden. Sulphate and zinc levels were found to increase ten-fold over a seven year period from 1989 to 1996 in three monitoring wells located in the area draining southeastward to the North Fork of Rose Creek (S1, S2 and S3) (Robertson Geoconsultants Inc., 1996a). In the area draining towards the Rose Creek Valley, shallow monitoring wells (including P96-7) have zinc levels near or below the detection limit, and sulphate concentrations between 53 and 882 mg/L. The area draining into the Faro Creek Valley is the main discharge for the rock dumps and groundwater is monitored in well P96-8. Zinc concentrations between 0.016 and 16.1 mg/L and sulphate concentrations as high as about 3,200 mg/L have been encountered in this monitoring well (Robertson Geoconsultants Inc., 1996 and ARMC, pers. comm., 1999).

Upper Guardhouse Creek drains the northwestern portion of the rock dumps. Test pits and shallow monitoring wells constructed at the toe of these dumps have encountered slightly alkaline groundwater with zinc concentrations of up to 0.55 mg/L and sulphate concentrations of up to 566 mg/L (Robertson Geoconsultants Inc., 1996). However, the overburden is relatively thin and most monitoring wells have encountered low levels of zinc and sulphate, suggesting that contributions of contaminants to Upper Guardhouse Creek are relatively low.

6.1.6 Faro Mine Site 1999 Groundwater Analysis

The results of the chemical analysis of groundwater sampled from monitoring wells at the Faro mine site during July and October 1999 are shown in Table 6.1. The locations of these monitoring wells are plotted on Figure 6.1. Zinc concentrations exceeding at least one of the surface water guidelines occur in nearly all of the wells. However, it should be noted that the groundwater would be diluted when discharging to a surface water body. The highest zinc concentrations are found along the old Faro Creek channel (P96-8A, P96-8B) and southeast of the Zone II Pit (BH1, BH2). High sulphate groundwater is found along the old Faro Creek channel (P96-8A, P96-8B) and south of the Sulphide Waste Dump (S1A, S2A). In some wells there are other metals whose concentrations exceed at least one of the surface water guidelines, primarily copper, cadmium and aluminum.



LEGEND

● Groundwater monitoring well sites

Data Source: Robertson Geoconsultants Inc.

Scale 1:25,000

0 250 500 1000 1500 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	F.K.P.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Faro	File Name:	fig6_1.dwg

DIAND Waste Management Program

Faro Mine Groundwater Monitoring Wells Location Map

Gartner Lee Limited

Figure No. 6.1

Gartner Lee

Table 6.1. Faro Mine Site Groundwater Quality Data

Groundwater Analysis Results (mg/L)

Station	Water Quality Guidelines		P96-6 Toe of Intermediate Dump above Rock Drain (20.85 m)		P96-7 Toe of Main Dump below Haul Road (9.90 m)	P96-8A Old Faro Creek Channel by X23 (4.87 m)		P96-8B Old Faro Creek Channel by X23 (9.30 m)		S1A South of Sulphide Waste Dump (12.80 m)		S1B South of Sulphide Waste Dump (5.37 m)	
Date	CCME [a]	YCSR [b]	04-Jul-99	30-Oct-99	31-Oct-99	03-Jul-99	31-Oct-99	03-Jul-99	31-Oct-99	03-Jul-99	31-Oct-99	03-Jul-99	31-Oct-99
Physical Tests													
pH	6.5-9..0		*5.84*	*6.05*	6.81	*6.46*	*6.28*	6.67	*6.18*	7.24	6.75	7.66	*6.28*
Sulphate (mg/L)		1000	428	341	***1606***	***2290***	***2993***	***2983***	***3218***	***2356***	***2533***	626	863
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	-	-	-	-	-	-	-	-	0.07	-	<0.05
Dissolved Metals													
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.2***	<0.05	***0.78***	***0.46***	***1.26***	***0.5***	***1.51***	***0.48***	***0.92***	***0.21***	***0.23***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	*0.071*	<0.005	*0.052*	<0.005	*0.03*	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.002***	<0.001	<0.001	<0.001	***0.014***	<0.001	***0.005***	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	*0.019*	<0.002	*0.005*	***0.042***	*0.006*	***0.044***	*0.013*	***0.04***	*0.009*	*0.016*	*0.005*
Iron (mg/L)	0.3	3	0.14	<0.01	<0.01	0.19	<0.01	0.22	0.03	0.21	0.04	0.26	0.06
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<0.01	<0.01	<0.01	*0.02*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.005	<0.005	<0.005	*0.063*	*0.135*	0.007	*0.032*	0.011	*0.045*	<0.005	<0.005
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	***0.76***	***0.41***	<0.01	***11.15***	***5.82***	***3.31***	***2.23***	***0.61***	*0.21*	*0.11*	0.03

Station	Water Quality Guidelines		S2A South of Sulphide Waste Dump (8.04 m)		S2B South of Sulphide Waste Dump (10.60 m)		S3 South of Sulphide Waste Dump (6.56 m)	BH1 SE of Zone II by NF Rose Creek (5.18 m)		BH2 SE of Zone II by NF Rose Creek (5.55 m)	
Date	CCME [a]	YCSR [b]	03-Jul-99	31-Oct-99	03-Jul-99	31-Oct-99	31-Oct-99	04-Jul-99	30-Oct-99	04-Jul-99	30-Oct-99
Physical Tests											
pH	6.5-9..0		6.76	*6.18*	6.82	*6.15*	*5.55*	-	*5.75*	*5.48*	*5.77*
Sulphate (mg/L)		1000	***1491***	***1385***	***1300***	345	***2119***	399	150	259	206
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	-	***0.47***	-	<0.05	0.17	-	<0.05	-	<0.05
Dissolved Metals											
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.38***	***0.61***	***0.37***	<0.05	***0.58***	***0.16***	<0.05	***0.1***	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	<0.001	<0.001	<0.001	<0.001	<0.001	***0.015***	***0.004***	***0.005***	***0.006***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.034***	<0.002	***0.033***	<0.002	*0.002*	*0.019*	<0.002	*0.007*	<0.002
Iron (mg/L)	0.3	3	*0.43*	<0.01	*0.31*	<0.01	0.07	*0.46*	<0.01	*0.48*	<0.01
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*0.02*	<0.01	<0.01
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.005	<0.005	<0.005	<0.005	<0.005	*0.084*	<0.005	*0.04*	0.015
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.04*	<0.01	*0.07*	*0.2*	*0.03*	***25.87***	***3.52***	***9.85***	***4.15***

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 6.1. Faro Mine Site Groundwater Quality Data cont.

Groundwater Analysis Results (mg/L)

Station	Water Quality Guidelines		BH4 SE of Zone II by NF Rose Creek (3.20 m)	BH12A NE of Zone II by NF Rose Creek (2.85 m)	BH12B NE of Zone II by NF Rose Creek (8.05 m)	BH13B NE of Zone II by NF Rose Creek (4.25 m)	BH14A East of Zone II by NF Rose Creek (6.22 m)	BH14B East of Zone II by NF Rose Creek (10.00 m)
Date	CCME [a]	YCSR [b]	30-Oct-99	30-Oct-99	30-Oct-99	30-Oct-99	30-Oct-99	30-Oct-99
Physical Tests								
pH	6.5-9..0		*5.95*	-	6.75	6.85	*5.35*	*5.79*
Sulphate (mg/L)		1000	158	259	805	603	544	***1063***
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	-	-	-	-	-
Dissolved Metals								
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	<0.05	<0.05	***0.35***	***0.05***	***0.19***	***0.75***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.003***	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	<0.002	<0.002	<0.002	<0.002	<0.002	*0.005*
Iron (mg/L)	0.3	3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	***1.34***	*0.07*	*0.23*	*0.04*	<0.01	*0.05*

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic — *results exceed CCME Aquatic Life Guidelines*

Bold, Italic — *results exceed YCSR Generic Numerical Water Standards*

6.2 Site Inspection – Vangorda Plateau

The Vangorda Plateau mine sites are outlined in Figure 4.2. Photographs from the site visit are attached in Appendix A. The Vangorda Plateau mine site consists of the Grum Pit and the Vangorda Pit. Each pit has associated waste dumps, water containment structures and water diversions. A separate water treatment plant, complete with sludge pond, is located on the northeast side of the Grum Pit immediately north of the overburden dump. Water from both sites was treated with lime at this plant.

6.2.1 Grum Pit

Grum Pit was observed during the site visit. The northeast face of the Grum Pit has a large landslide in the till overburden that overlies the bedrock (Photo 11). A diversion channel intercepts local surface flow, carries it south around Grum Pit and an overburden dump located directly to the southeast where it discharges into the 'Sheep Pad' sediment ponds prior to being directed back into the Vangorda Creek catchment. The diversion flow is limited and the ditch appears to be open and relatively stable. A waste rock dump is located directly south of the Grum Pit.

The Grum Pit has been developed in phases. The Phase 1 Pit is essentially completed but there is a 3-6 year reserve left in future phases. The Phase 1 Grum Pit has a well developed slope failure on the north east wall that appears to be a rotational failure in till. This failure limits access to the Phase 1 Pit, but access to the Phase 2 Pit can still be made on the south side. Minor stripping is required to resume mining in the Phase 2 Pit, but the till on the upper parts of the pit have to be stabilized.

An overburden dump exists southeast of the pit. The dump has been built on top of natural ground. The slopes appear to be stable at the present time and show no signs of active distress. Stepanic (1995), indicates that the glacial till originally placed in the Grum overburden dump failed as a result of placing lifts 15 m high. The height of the individual lifts was reduced to 5 m and a second bench was developed. The dump stabilized when loaded with thinner lifts. However, the actual factor of safety is likely close to unity and placement of additional waste could renew movement if not placed slowly in thin lifts.

6.2.2 Grum Underground Adit

The Grum underground adit, used for exploration, is located to the southwest of the Grum Pit. The adit is securely fenced to prevent access. In front of the adit is a settling pond used to control the sediment content of the mine discharge water. Adjacent to the adit are old shop buildings, mostly of wood construction with some steel cladding.

6.2.3 Grum Waste Rock Dumps

Relatively little sulphide bearing waste rock has come out of the Grum Pit (Photo 12). Most waste rock is 'inert' phyllite, and not mineralized. The sulphide bearing waste rock that was excavated has been placed separately in the centre of the Dump. There are plans to cover the enclosed sulphides at the end of the mine life, but the expectation is that there will be no need to cover the whole Grum Waste Rock Dump (AMRC, Per. Comm.).

The southwest portion of the Grum Waste Rock Dump drains to the west. There is no sulphide bearing waste rock stored in this portion as sulphide rich waste was placed in the main portion of the Grum Waste Rock Dump, which drains southeastward to Vangorda Creek and Moose Pond.

The Grum Waste Rock Dumps cover a large area but are relatively thin. Cracks have been observed on several levels of the main dump, apparently the result of relatively shallow sloughing of the dump face (Photo 13). There are some cracks 30-50 meters back from the crest which suggest deep-seated instabilities. However, the movement appears to be slow and the ground appears only to be creeping. It is considered that the outer edge of the Grum Waste Rock Dump is marginally stable.

Additional stability issues on the Grum Waste Rock Dump appear to be related to erosion caused by runoff cascading down off the face (Photos 14, 15 and 16). Erosion instability on the Grum Waste Rock Dump leading to sediment transport off site is a future concern.

The ditch below the Grum Waste Rock Dump is not well graded (Photo 17). Flow has ponded and broken out at 3 or 4 places along the ditch. Sediment normally caught in the ditch may eventually escape.

While monitoring of water quality is undertaken regularly, there appears to be very little collection of drainage, or monitoring of drainage in areas considered inert. If drainage from the Grum Waste Rock Dumps is not as innocuous as expected, then contaminated seepage could be escaping the dump undetected.

6.2.4 Vangorda Pit

The Vangorda Pit, located approximately 2 km southeast of the Grum Pit, is an elongated rock walled pit with significantly less till overburden than the Grum Pit (Photo 18). The pit is partially flooded. Vangorda Creek is intercepted above the pit and carried around the northwest corner of the pit in a diversion flume. The water is discharged through a plunge pool and back into the Vangorda Creek catchment on the southwest side of the pit.

The Vangorda Pit has essentially been mined out. The closure plan calls for the pit to be reclaimed as a clean water pit, with the presently diverted Vangorda Creek re-directed to flow through the pit. However, the future obtainable water quality is unknown. The pit walls appear to be friable, weak and mineralized. The walls are constantly eroding and spalling, and providing more pyritic surface areas for leaching. During operation, zinc levels in pit water were recorded between 40 and 50 mg/L. We understand that water in the pit currently has less than 10 mg/L dissolved zinc. The water quality is not presently acceptable for discharge. Consequently, there is a question as to whether or not adequate water quality for discharge can ever be obtained without treatment.

6.2.5 Vangorda Waste Rock Dump

The Vangorda Waste Rock Dump is located directly southwest of the Vangorda Pit and has been subdivided into a till stockpile and an undifferentiated waste dump (Photo 19). The Vangorda Waste Rock Dump is contained by a till berm around the downstream toe. Collection drains parallel to the south and west perimeter have been cut into the top of the till berm to convey drainage into the Little Creek Reservoir (Photo 20). The perimeter ditch shows signs of sloughing and shows places where the gradient has deviated from designs. Water is ponding at the base of the ditch. For the most part, the ditch appears to be performing adequately.

Collection ditches have also been constructed around the Vangorda Waste Rock Dump (Photos 21 and 22) to collect drainage from finger drains located under the till starter dike that extend into the waste dump. The ditches are intended to convey seepage to the Little Creek Reservoir. However, there has been less seepage than originally anticipated. It is uncertain as to why so little seepage has been collected, but suggestions have been made that water may freeze inside the dump or that evaporation out of the top of the dump is enough to eliminate seepage. A new ditch has recently been dug in a portion of the till dyke to direct ponded water to the Little Creek Dam (this appears to have been surface runoff from the phyllite section of the dump that was pooling behind the till dyke).

All Vangorda waste rock is considered potential acid generating (PAG). Half of the waste is classified as phyllites, which are considered slightly PAG, while the other half are sulphide rich rocks, which are considered to be highly PAG. The portion that is higher in sulphides lies closest to the pit (lower step), surrounded by an outer crescent of less reactive phyllites.

The closure plan for the Vangorda Waste Rock Dump calls for 3 m of compacted till as a cover. Ther may be sufficient till borrow available to build the cover, but without clear evidence of seepage, it may be desirable to review the expense of the cover (ARMC, pers. Comm.). The main rock dump is very shallow relative to the original ground underneath, although it covers a wide area. With respect to stability, the dump appears to be intact with no large-scale signs of slumping or failure.

6.2.6 Vangorda Creek Diversion

Vangorda Creek has been diverted around the Vangorda Pit (Photo 23). The diversion begins at a small dam with a culvert and a trash rack at the top end of the spillway. The water is directed into a flume consisting of a 2.4-m diameter half culvert set in a bench carved into the north side of the pit slope. Because of bends and occasional blockage, spills have been experienced and erosion has occurred at points of over topping. The culvert bedding has been locally washed away, resulting in culvert misalignment and areas where the culvert has pulled apart. Leakage from the culvert could eventually lead to saturation of the pit slope and exacerbate instability.

There has been one significant slope failure above the culvert, that resulted in impacts to the flume. In addition, icing appears to have damaged some of the horizontal struts holding the flume sides in place, and is likely to continue to do so. The flume eventually discharges into a gravel-lined channel that is the original Vangorda Creek.

Future rock falls could lead to flume damage and leaks or complete blockages could allow excess water to enter the pit and possibly lead to an overflow discharge earlier than anticipated.

6.2.7 Little Creek Dam

Seepage from the Vangorda waste dump, the till stock pile and the low-grade stockpile, is collected behind the Little Creek Dam (Photos 24 and 25) which is a water retaining structure built on a small tributary of Vangorda Creek. The dam has a crest width of approximately 6 m, a crest length of approximately 300 m and an overall height of approximately 22 m. The downstream slope is approximately 2 horizontal to 1 vertical. The dam appears to be stable with respect to overall slope stability. No signs of tension cracks or bulging of the slope were noticed during the September 1999 site visit.

In addition to seepage and runoff from the dump, mine water from the Vangorda Pit is occasionally stored in the pond and can be pumped to the Water Treatment Plant.

The spillway out of the Little Creek Dam consists of a 0.61 m diameter corrugated steel pipe (CSP) culvert which ends in a half culvert and then discharges vertically into a rip rap-lined channel prior to discharging down the hill into Vangorda Creek. Vangorda Creek passes approximately 30 m northwest of the toe of the dam and is not considered to be an issue with respect to erosion of the dam.

6.2.8 Water Treatment Plant

The water treatment plant is poorly placed to treat seepage and runoff from the Vangorda Waste Rock Dump (Photos 26 and 27). However the location was set close to the Grum Pit due, in part, to maintain a green space between the Grum and Vangorda developments is a sheep migration route. The capacity of the treatment plant (2,000 gpm or 45.4 cms) was originally sized to include runoff collected from the Grum rock dump, but this has not been needed since the Grum Waste Rock Dumps have not been found to be acid generating.

Acid rock drainage (ARD) from the Vangorda Pit and Waste Rock Dumps is transported from the Little Creek Reservoir to the water treatment plant via a 2 km long buried pipeline. The treated water is allowed to settle in a small sludge settling pond that presently contains very little sludge. The clean effluent is discharged to Vangorda Creek.

The sludge settling pond was constructed as a cut and fill lagoon in 1990, and was not in use at the time of the September 1999 site visit. The east side, and a portion of the south side, were cut into the silty clay till, at slope a of about 20 degrees. The other sides of the pond are formed by homogenous dykes and comprised of the same material. No signs of major instability were noticed on the downstream or internal faces of the sludge pond.

6.2.9 Vangorda Plateau Haul Road

The main haul road between the Faro Mine Site and the Vangorda Plateau was traversed several times during our site visit (Photo 28). The road is stable and in good condition. There are several locations where drainage has been directed over the side into local streams, carrying eroded embankment material. The drainage is controlled and the embankment itself does not appear to be destabilized or eroding prematurely.

There have been no failures or significant stability problems associated with the embankment, but because of road grades, surface runoff is locally directed over the edge of the road and into the environment. Silt and sands may be locally carried to creeks.

6.2.10 Vangorda Plateau Hydrogeology

6.2.10.1 Grum Pit

The surficial deposits at the Grum Pit range in thickness from 40 to 100 metres. They are comprised of a thick layer of low permeability till which confines a 20 to 30 metre thick aquifer of sand and gravel which is located in a bedrock depression. It is not known if this aquifer extends beyond the Grum Pit. There is also a basal aquifer present at the bedrock surface. Piezometric data indicate that groundwater flows in a southerly direction with recharge from the north. Hydrological studies of the Grum Pit have been primarily conducted for designing a dewatering system. Monitoring wells have not been constructed to investigate the quality of the groundwater seeping from the Grum Pit.

6.2.10.2 Grum Waste Rock Dumps

The Grum Waste Rock Dumps are located in areas where the colluvium is thin and underlain by impermeable bedrock. Groundwater flow is reported to be confined to thick permeable sediments, which are located in the valleys of Grum Creek. Only one monitoring well has been installed for the Grum Waste Rock Dumps (BH 96-9) which is located adjacent to a tributary of Grum Creek which drains the central portion of the dump (Figure 6.2). The overburden in this location is comprised of an upper layer of coarse sand and gravel and a lower layer of sand that is confined by a silt layer. Water sampled from these two layers do not show signs of acid rock drainage (ARD) with a pH of 8.0 and an alkalinity of 178 mg/L (Robertson Geoconsultants Inc., 1996a).

6.2.10.3 Vangorda Pit

The surficial sediments in the Vangorda Pit are comprised of low permeability silty and sandy glacial till which is underlain by a water bearing zone of sand and gravel which overlies a weathered bedrock surface. Piezometer measurements indicate groundwater flow is from northeast to southwest (Steffen, Robertson and Kirsten Inc., 1989). In the valley of Vangorda Creek, little is known about the sediments present, although they are likely highly permeable and up to 20 metres thick.

A study by Piteau and Associates (1990) of groundwater conditions in the Vangorda Pit indicated that the hydraulic conductivity of the rock is approximately 1 x 10^{-5} cm/sec. North-northwesterly faults, that are present in the pit, may provide higher permeability due to fracturing.

No monitoring wells are present for determining the quality of groundwater seeping from the Vangorda Pit.

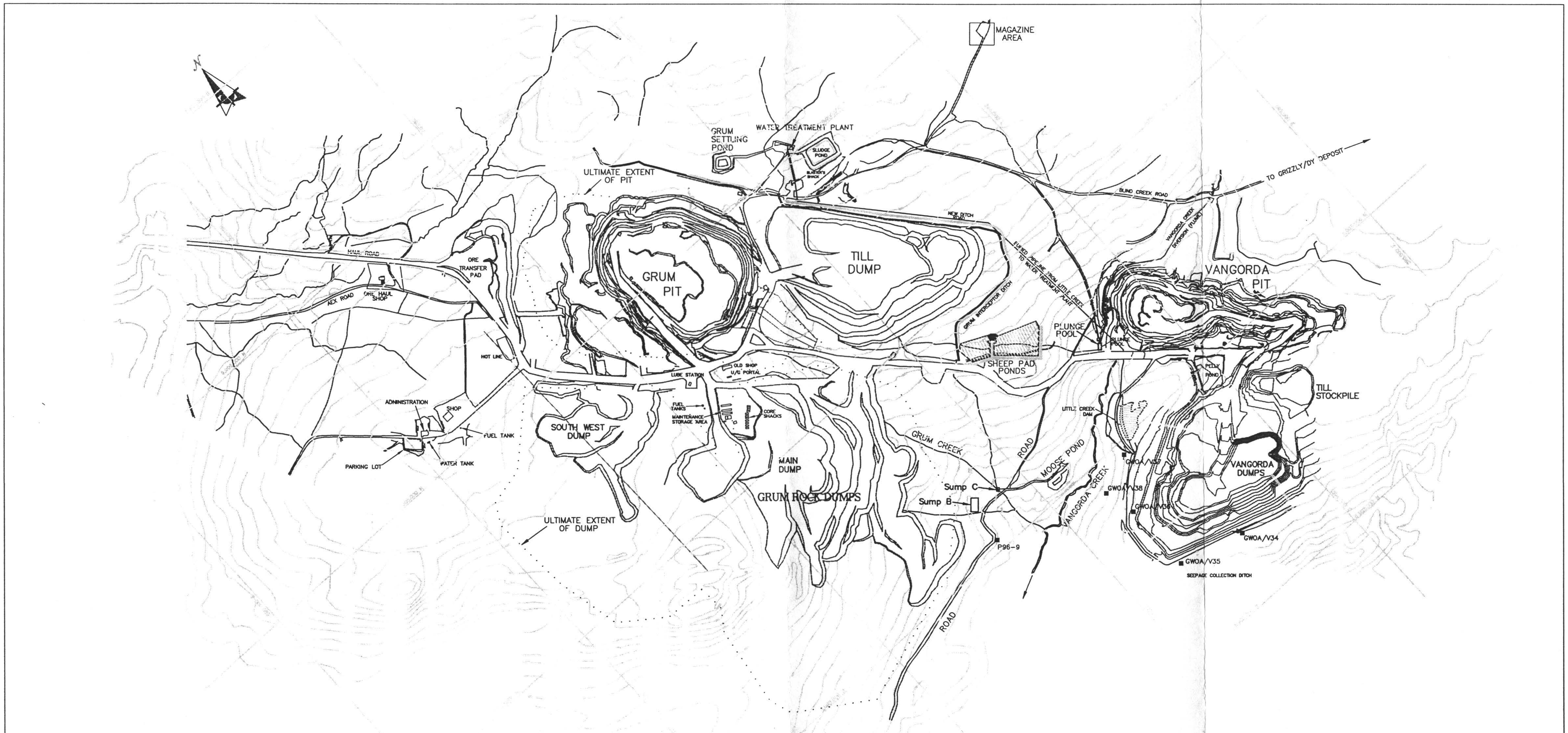
6.2.10.4 Vangorda Waste Rock Dumps

The Vangorda Waste Rock Dumps are located in an area that was overlain by low permeability compacted glacial till. Groundwater levels are generally at a depth of 8-14 m below the natural ground surface.

Monitoring wells were constructed at 14 locations at and below the toe of the Vangorda Dump between 1994 and 1996. Groundwater sampled from these monitoring wells was found to have a pH of approximately 8.0 and high alkalinities (400 – 450 mg/L), suggesting that acid rock drainage is not occurring in these areas. Sulphate concentrations were found to be slightly elevated (100 – 200 mg/L) and zinc levels were found to be near the detection limit (Robertson Geoconsultants Inc., 1996a).

6.2.11 Vangorda Plateau 1999 Groundwater Analysis

The results of the chemical analysis of groundwater sampled by the Receiver from monitoring wells at Vangorda Plateau during June and October 1999 are shown in Table 6.2. The locations of these monitoring wells are plotted on Figure 6.2. The pH levels of the water sampled are near neutral. Zinc concentrations exceeding all of the surface water guidelines occur in the Little Creek Dam water and in the Vangorda Pit ramp ditch seepage. However, zinc concentrations were found to be below the detection limit in all of the monitoring wells sampled. Copper concentrations in the monitoring wells exceeded the CCME Guidelines for the Protections of Aquatic Life. Cadmium and aluminum were also found to exceed at least one of the criteria in more than one of the wells. Since this groundwater would be greatly diluted when discharging to a surface water body, it is unlikely that this groundwater would impact aquatic life.



LEGEND

■ Goundwater monitoring well site

Data Source: Robertson Geoconsultants Inc.

Scale 1:100,000

0 333 667 1000 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Vangorda Plateau	File Name:	fig6_2.dwg

DIAND Waste Management Program

Vangourda Plateau Groundwater Monitoring Wells Location Map

Gartner Lee Limited

Figure No. 6.2

Gartner Lee

Table 6.2. Vangorda Plateau Groundwater Quality Data

Groundwater Analysis Results (mg/L)

Station	Water Quality Guidelines		V34 Groundwater Well GW94-01		V35 Groundwater Well GW94-02		V36 Groundwater Well GW94-03		V37 Groundwater Well GW94-04		96-9A Groundwater at the Toe of Grum Dump		96-9B Groundwater at the Toe of Grum Dump	
Date	CCME [a]	YCSR [b]	18-Jun-99	12-Oct-99	18-Jun-99	12-Oct-99	18-Jun-99	12-Oct-99	18-Jun-99	12-Oct-99	18-Jun-99	12-Oct-99	18-Jun-99	12-Oct-99
Physical Tests														
pH	6.5-9.0		7.85	6.79	7.21	6.77	7.29	*6.27*	7.48	*6.07*	6.96	-	7.67	-
Conductivity			-	815	-	910	-	1200	-	775	-	650	-	620
Alkalinity-Total			-	489	-	374	-	394	-	426	-	157	-	151
Sulphate (mg/L)		1000	23	26	768	142	271	313	66	62	181	168	190	167
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	0.11
Dissolved Metals														
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.06***	<0.05	***0.24***	<0.05	***0.12***	***0.11***	***0.08***	<0.05	***0.29***	<0.05	***0.17***	***0.14***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	*0.047*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.006***	<0.001	<0.001	*0.001*	<0.001	***0.005***	<0.001	***0.008***	<0.001	*0.001*	<0.001	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	*0.01*	*0.005*	***0.032***	*0.01*	*0.019*	*0.016*	*0.015*	*0.008*	*0.012*	<0.002	*0.017*	*0.004*
Iron (mg/L)	0.3	3	0.03	<0.01	0.09	0.04	0.08	0.06	0.09	0.05	0.21	0.11	0.12	0.09
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*0.01*	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.005	<0.005	<0.005	0.01	<0.005	0.017	<0.005	0.008	<0.005	0.005	<0.005	<0.005
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Station	Water Quality Guidelines		GD1 Grum Dump Toe Seep West of V15	GD2 Seep/Marsh near West End of Grum Dump Toe Road	LCD Little Creek Dam Pond Water	LCD Little Creek Dam Pond Water (Total Metals)	VGSEEP Vangorda Pit Ramp Ditch/Seepage	VGSEEP Vangorda Pit Ramp Ditch/Seepage (Total Metals)
Date	CCME [a]	YCSR [b]	03-Jul-99	03-Jul-99	18-Jun-99	18-Jun-99	18-Jun-99	18-Jun-99
Physical Tests								
pH	6.5-9.0		-	-	7.47	7.47	*6.24*	*6.24*
Conductivity			-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-
Sulphate (mg/L)		1000	578	33	299	299	***5048***	***5048***
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	***0.53***	***0.53***	***1.8***	***1.8***
Dissolved Metals								
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.22***	***0.07***	<0.05	***0.22***	***1.86***	***3.29***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	<0.001	<0.001	***0.007***	***0.006***	***2.615***	***3.144***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.021***	*0.011*	*0.004*	***0.02***	***0.498***	***0.733***
Iron (mg/L)	0.3	3	*0.53*	*0.5*	0.03	*0.36*	***344.3***	***408.6***
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<0.01	<0.01	*0.02*	***5.06***	***7.55***
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.005	<0.005	0.02	*0.044*	***4.67***	***5.398***
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	***0.063***
Zinc (mg/L)	0.03	0.3	<0.01	<0.01	***4.77***	***7.25***	***1059.5***	***1183.2***

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

6.3 Mill Site

6.3.1 Crusher and Coarse Ore Storage Building

The crusher and coarse ore storage buildings are of structural steel construction (Photo 29). The buildings are in poor condition with just enough steel siding to keep out the weather. The concrete foundations are largely below ground level.

There are several thousand tonnes (8000 – 10,000) of crushed ore in the coarse ore storage building. The ore storage pad adjacent to the crusher contains a large stockpile of mill feed from the Grum Pit. Also adjacent to the coarse ore storage building is a pile of what appears to be zinc concentrate. This could be material returned from Skagway or the Whitehorse truck terminal when mining operations ceased.

6.3.2 Mill Building

At the time of the site visit, the power had been permanently shut-off to the mill building. Due to safety concerns, a detailed inspection of the interior of the building was not undertaken. The metal fabricated mill building is constructed mainly from structural steel with lesser amounts of lumber and other building materials. Reinforced concrete has been used for foundation footings, floors and basement walls and floors. The building appears to be in reasonable shape.

Discussions with on-site personnel indicate that the mill was shut down in a professional manner. All sumps, tanks and pipelines are empty and the grinding mills are blocked and supported off their bearings. Other provisions for long term shutdown have also been put in place. All chemicals from the mill, assay laboratory and metallurgical laboratory have been removed and sold, disposed of properly or stored in the Reagent Building. One exception is that the mill lime silo is being used to mix lime for water treatment during the spring/summer pumping of the Faro Pit. There is no sodium cyanide on site and nuclear instruments in the mill have been registered with Atomic Energy Canada Limited (AECL) as per regulations.

The mill equipment is not for sale and will be kept intact. An inventory of mill equipment is listed in Table 5.3.

6.3.3 Offices and Maintenance Shops

6.3.3.1 Offices and Warehouse

The office and warehouse building is located adjacent to the mill. This building is constructed mainly from structural steel with lesser amounts of dimension lumber and other building materials. Reinforced concrete is used for foundation footings and basement walls and floors. The warehouse has a floor space of approximately 1,670 m^2 with about 370 m^2 of second floor office space. Mill and equipment spare parts remain in the warehouse. The office/warehouse is in good condition.

6.3.3.2 *Equipment Repair Shops*

This building is semi-attached to the Office/Warehouse building. The repair shop consists of 10 bays for mobile equipment including two lubrication bays. A general shop located in a 1,200 m² housing includes an electric shop, a welding bay, a carpentry shop and a machine shop. The Wabco (truck) repair shop consists of 6 bays on a 930 m² floor area. The shop building is in good condition.

The buildings are metal clad, largely structural steel construction with reinforced concrete floors at or above normal ground level.

The shops have been cleaned out. Tools and small equipment have largely been auctioned off, although some items remain to maintain and repair the remaining small fleet of mobile equipment (i.e. grader, front-end loader, backhoe and small truck). One of the bays is used for steam washing with the water draining out through the shop door and across the yard into Guardhouse Creek, or reaching the same destination through the floor drain feeding an underground pipeline.

6.3.3.3 *Tire/Light Vehicle Shop*

This steel framed and wood building sits on a concrete pad to the southwest of the main shop building. This building is in poor to average condition. The building is approximately 1,200 m² in size.

6.3.3.4 *Guardhouse and Administration Buildings*

The guardhouse is located at the entrance to the main plant site (Photo 30). The guardhouse is currently being used as an on-site office, garage, and security location. The building is in good condition.

6.3.4 Electrical Substation and Power Distribution

Power is supplied to the Faro mine site by an electrical line connected to the Whitehorse Aishihik Faro grid at the Faro townsite. The substation at the mine site has transformers to step this power down for distribution across the mine site.

The mine site has a standby diesel generator for emergency power supply that is located to the south of the mill and concentrator. The standby generator facility includes two above ground diesel storage tanks; a large primary tank (146,200 L capacity) and a small day tank (7,500 L capacity). Currently, only the large primary fuel tank is in service and this tank is used for current site activities.

6.3.5 Chemical Storage

Chemicals used in the mill process were stored and mixed in the Reagent Building located adjacent to the mill. Inventories of the mill chemicals were reduced prior to shut down and only the chemicals listed in Table 6.3 remain in the Reagent Building. This inventory has been broken down by category (frothers, collecters, and depressents) and their primary point of addition into the flotation circuit. The Unidri filter aid was used for lead and zinc dewatering and the sodium hypochloride (industrial bleach) is used to the treatment of potable water on site.

Table 6-3. Reagents Inventory.

Frothers	Quantity	Circuit
Dowfroth 1012	26 drums	Zinc
Dowfroth 250	24 drums	Zinc
Dowfroth MIBC	36 drums	Lead
Stanfroth 250	109 drums	Lead
UniFlot SP117	38 drums	Lead
Depressents	**Quantity**	**Circuit**
Unimax SD200	52 drums	Rod Mill Feed
Ferric sulphate	14 drums	Lead Regrind
Silicate of Soda	4 bags	Zinc
Zinc sulphate	10 pallets	Lead
HQS	112 drums	Rod Mill feed
Collectors	**Quantity**	**Circuit**
Areophine 3418A	1 drum	Lead
AF242	2 drums	Zinc
Reagent 200	4 drums	Zinc
Miscellaneous	**Quantity**	**Circuit**
Sodium Hypochloride	14 drums	n/a
Unidri M60 Filter Aid	33 drums	n/a

The Stanfroth drums are stored outside the building. The Receiver proposes dispose of these drums (ARMC, pers. Comm.). No chemicals remain in the mill except lime which is stored in the mill's lime silo and used for water treatment.

A 25,000 litre capacity horizontal aboveground steel tank containing glycol was located on the south side of the load-out shed. The glycol was used to spray the boxes of concentrate trucks to make dumping of the load easier. The tank is now empty and has been listed on the federal inventory of aboveground storage tanks (ASTs) at the Faro mine site. Glycol was also stored and dispensed in other areas of the mine site such as the lube shops (pit and plant site). Waste glycol is stored in a 7,500 litre capacity aboveground steel tank located on the north side of the maintenance shop. This tank has been provided with secondary containment consisting of a steel tray.

The inventory of chemicals used at the mine site included: mill reagents, laboratory chemicals and chemicals used for ancillary operational purposes such as water treatment. With the exception of the remaining mill reagents described above and lime used for water treatment, CEDA-Reactor Ltd. of Sherwood Park Alberta, was contracted to remove and dispose of all mine site chemicals in accordance with all applicable federal and territorial regulations.

6.4 Rose Creek Tailings Facility

The Rose Creek Tailings Facility is a complex structure consisting of several tailings impoundments and cells referred to as the Original Tailings Impoundment, the Second Impoundment and the Intermediate Impoundment. Downstream of the tailing ponds is a Polishing Pond contained by the Cross Valley Dam. The Rose Creek Diversion Channel carries freshwater past the tails on the left (south) side of the valley. A general layout is shown on Figure 4.1.

The entire tailings facility is underlain by sand and gravel. Samples of the porewater in the tailings and the groundwater seeping under the tailings have been taken at the downstream edge of the impoundment from groundwater wells that indicate SO_4^{-2} concentrations of about 300 mg/L. No trends for zinc are reported. Groundwater wells at the toe of the Cross Valley Dam show no significant contamination of groundwater. However, there are concerns as to whether the groundwater wells are in the correct place, and whether the tailings are buffering any generated acidity.

The individual structures are discussed from a geotechnical stability perspective below.

6.4.1 Original Tailings Dam

The Original Tailings Dam was built using upstream construction (Photo 31). There are reports of previous failures of upper tailings out of this compound into the lower tailings area, but more recent construction has covered the old dam and evidence of the failures. The original structure no longer impounds water but has a dry surface of tailings sand upstream of the dam. The area of tailings exposed behind the dam is approximately 1200 m long by 300 m wide. A test plot area has been constructed beside the access road, in the central part of the original impoundment as part of a reclamation program. However, the area has apparently been abandoned and there has been no on-going study since prior to 1994 (ARMC, pers. comm., 1999). The majority of tails appear to be oxidized orange-grey and cemented on the surface.

The Original Dam is surrounded on the upstream and downstream sides by tailings sand, and is no longer isolated as a structure.

6.4.2 Secondary Tailings Dam

The Secondary Tailings Dam, located downstream of the original dam, was built in 1974. This dam also no longer contains water but contains a relatively flat, dry tailings deposit. The upstream face of the second dam is ditched and surface water is discharged around the right (north) embankment. Rip-rap has been placed on the downstream face of the dam. The tailings area exposed upstream of the dam is 1800 m long parallel to the Rose Creek Valley and is 600 to 700 m wide at the west end and 300 m wide over the remainder of the area.

Inspections were made of both the Original Tailings Dam and Secondary Tailings Dam with respect to geotechnical stability.

The crest of the secondary dam was traversed from the upstream east end along the south perimeter until the dam turns north and traverses the Rose Creek Valley. The dam crest for the most part consists of cemented tails that have a limited catchment and hence limited erosion potential. There are no signs of cracking or erosion and the downstream slopes show no signs of bulging or other distress.

The north abutment has a channel excavated between the dam and the original ground. The channel is carrying runoff from the waste dumps and water pumped from the Faro Main Pit into the upper end of the retention pond below the secondary dam.

The tailings located in the secondary cell are dry and grey. The secondary dam has solids on the upstream face and solids at the toe of the downstream face (the upper end of the Intermediate Impoundment). The upstream face is less than 0.5 m high while the downstream face is approximately 5m high. The downstream slope of the secondary dam is 1.5 horizontal to 1 vertical and is covered with waste rock rip-rap to minimize erosion. Red seepage and tailings exist between the toe of the second impoundment dam and a road berm, which forms the north bank of Rose Creek diversion channel.

The tailings surface of both the upper and lower cells have oxidized and cemented. Dusting is a concern in some quarters and significant dust clouds occur in summer (ARMC, pers. comm., 1999). Revegetation of the crusted soil may be difficult without placement of additional soil and future wind erosion may lead to dusting.

6.4.3 Intermediate Dam

The Intermediate Impoundment is contained by natural ground on the north, the Rose Creek Diversion channel on the south, and the Intermediate Dam on the west. The beached tails that form the eastern half of the impoundment, abut the downstream toe of the Secondary Tailings Dam (Photos 32 through 34).

The Intermediate Dam has a crest elevation of 1081.7 m. The dam was raised twice from a starter dam elevation of 1068.8 m in response to the tailings storage requirements. We understand the raises were accomplished by using the downstream method. Tailings have been discharged from the upstream end, hence a water pond is present against the upstream face of the dam. A water pool about 600m long was observed ponded against the Intermediate Dam during our site visit with a typical maximum depth of 8 to 10 metres against the dam (ARMC, pers. comm., 1999). The upper end of the pond behind the Intermediate Dam has an exposed beach about 1 km long (Photo 35).

The Intermediate Dam was traversed from the north to the south side and examined in detail on both abutments. The Intermediate Dam is approximately 30 m high and 700 m long with a dam crest of approximately 6 m wide. The downstream slope is approximately 2.5 horizontal to 1 vertical. The upstream slope is approximately 1.5 horizontal to 1 vertical. During the site visit, there were no signs of dam slope instability on the downstream face or along the crest and there were no signs of settlements, cracking or exterior deformation.

Evidence of tailings from previous spills from the original impoundment was located downstream of the polishing pond in the Rose Creek Channel during our site visit. Benthos studies, routinely conducted every 2 years, indicate there is an improvement over time (see Section 3.2.4). The Yukon Territorial Government completed a fish study in 1998, but as yet the report has not been made available.

The spillway observed during our visit is on the north side of the dam and has been excavated into original ground (Photo 36). The original spillway was located on the south abutment but was relocated when the dam was raised. The present spillway contains boulders placed as energy dissipation structures. There were no signs of instability or excessive erosion along the spillway channel. Water from the Intermediate Pond is treated with lime as it passes down the spillway into the Polishing Pond. There is a lime shack located near the access road on the north side of the spillway that operates in summer when the pond is discharging through the spillway (Photo 37). The plant was not operating during our site visit.

A syphon is used to discharge water over the Intermediate Dam when the water level in the Intermediate Impoundment is below the spillway level. A temporary lime treatment plant has been used in the past on the south abutment to treat syphoned water.

A channel 3 m deep has eroded the natural ground above and slightly west of the Intermediate Dam on the north abutment above the access road (Photo 38). The channel appears to be the result of erosion from overflow or seepage from the north-wall interceptor ditch uphill of the tailings pond. The north wall interceptor ditch normally flows past the tailings impoundments and enters the Cross Valley Dam spillway and mixes with the discharge from the polishing pond. The erosion is considered minor and does not pose a threat to the dam.

Seepage from the waste rock dumps is currently directed through the main waste dump down a channel above the Original and Second Tailings Impoundments where it is discharged into the Intermediate Pond. This seepage water mixes with lime treated water from the Faro Main Pit prior to entry into the Intermediate Pond at times when the Faro pit treatment program is operating. The channel walls have been highly eroded and show signs of ongoing creep and instability. Water from the Main Pit that has been transferred through the mine and treated at the mill, is also discharged into this creek, upstream of the pH control location. The erosion will continue as water is discharged. The erosion is unsightly, but does not pose an immediate threat to the facility. Continued use of the channel will require some re-sloping and rip-rap protection.

During the summer of 1998, lime slurry was added over the 4-5 weeks when the Intermediate Impoundment was being lowered to remove water stored over the winter. This lowered zinc levels sufficiently to allow a discharge from the polishing pond. There is limited retention time available in the Polishing Pond.

In 1999, lime slurry had to be added over the entire summer (from May or early April through to early September). The ice cover in the ponds had resulted in short circuiting in both the Intermediate and Polishing ponds in the early summer, therefore the discharge went rapidly out of compliance with the water licence. To deal with this non-compliant discharge, the spillway of the Cross Valley Dam was blocked and the polishing pond water recycled to the Intermediate pond. Lime was added to the recycled water for a month before the water in the polishing pond reached compliance levels. Discharge to Rose Creek resumed in the first week in July.

During the September 1999 site visit, the zinc concentration in the tailings pond was just over 1 ppm. This was anticipated to increase to about 5 ppm zinc over the winter. In the summer of 2000, plans are to use a pump and syphon to drain water from the tailings pond, and add lime as the flow is moved into the polishing pond. Lime slurry is mixed in the mill and transported down to the Intermediate Pond spillway by tanker truck, and gravity fed into the spillway to mix with the syphoned overflow.

6.4.4 The Cross Valley Dam

The Cross Valley Dam is a water retaining structure built to contain water discharged from the Intermediate Dam. It holds no tailings, but does have sludge from the lime treatment beached on the north shore (near the right abutment) (Photo 39). During the site visit, the water level behind the Cross Valley Dam had been pumped down so that storage capacity would be available for the spring 2000 runoff.

The Cross Valley Dam is a 24.5 m high zoned earth dam and has a length of 500 m and a crest elevation of 1066 m. The dam crest is approximately 6 m wide. The downstream slope is approximately 2.5 horizontal to 1 vertical and the upstream slope is approximately 2.0 horizontal to 1 vertical. A new toe drain and a toe berm configuration was designed and constructed by Golder Associates in 1991 to reduce the heavy seepage which was observed day lighting along the toe of the dam. The work included widening of collector ditches, installation of drains, construction of berms and installation of monitoring weirs.

During the September 1999 site visit, the dam was traversed from the north to south embankment along the crest and toe. A longitudinal crack was observed along the dam crest on the south side of the dam. The south abutment was intact with no signs of distress. The cracks are several metres long with sub-rounded edges. The cracks that are obvious appear to be old and have not moved in some time. There were no signs of cracking in the central or north side of the crest. There were no signs of any cracking, slumping or toe instability along the lower part of the Cross Valley Dam during the site visit.

We understand from a review of Golder Associates documents that cracks paralleling the crest of the Cross Valley Dam have been in existence since 1987. In general, they continue to exist at the same locations, possibly becoming deeper and wider. Some instrumentation has been placed in the dam probably following initial observation of the cracks by Golder Associates, but no significant deformations have been recorded.

The upstream face of the Cross Valley Dam is covered with rip-rap (Photo 40). There is evidence of cloudy water when waves impact on the dam. It is possible that there is a filtration problem between the material forming the majority of the dam underneath the rip-rap, resulting in fine material being washed out through the large size rip-rap.

According to work by others, the permafrost beneath the Cross Valley Dam has thawed to a depth of 12 m in the foundation materials. The Cross Valley Dam and Polishing Pond are both underlain by sand and gravel. The upstream face of the dam and part of pond was blanketed with clay to extend the seepage path. Seepage from the toe of the Cross Valley Dam is collected by a granular toe drain, which was constructed in 1991. Seepage at the toe of the dam is being measured and recorded at several steel V-weirs (Photos 41 and 42). An analysis of seepage flows by Golder Associates notes that the average annual flow of 1040 IGPM for 1998 is greater than that from 1996 to1997, but generally within the decreasing trend line. There appears to be 40 L/sec seepage reported at north abutment. The seepage observed during the site visit was clean with no sediments moving and the seepage flows were limited to a couple of liters per second.

The overall dam is considered to be stable.

6.4.5 Rose Creek Diversion

The North and South Forks of Rose Creek converge at the upper end of the tailings facility and are contained and diverted south of the tailings facility via the Rose Creek Diversion channel (Photos 43 and 44). The channel is approximately 2 km long and is excavated through bedrock and glacial till. The north bank of the Rose Creek Diversion channel has been raised by a berm of borrowed sand and gravel that separates the diversion from the tailings. The diversion has been built with a low point below the secondary pond, so that any overflow from the channel would enter the pond upstream of the Intermediate Dam. There is evidence of significant slumping at several locations along the channel, probably as a result of decaying permafrost on the north-facing slope in the glacial till.

Golder Associates (1999) report that on the basis of thermistor information, much of the permafrost in the channel back slope has thawed, and as such, the possibility of excess pore pressures and the possible instabilities related to ice rich permafrost thawing has been diminished. Golder Associates note the berm crest and immediate back slope were inspected and the crest did not appear to have any signs of instability. Slope indicators along the top of the back slope indicate very limited movement except in the upper 2 m, which is probably local freeze/thaw.

The borrowed berm which separates the tailings ponds from the diversion channel is being used as an access road. There were no signs of instability observed during our visit.

The slope between the borrowed berm toe and the tailings water edge appear to be in good condition. Seepage does not appear to be uncontrolled and there are no areas of instability.

Water quality monitoring is conducted in the Rose Creek Diversion upstream and downstream of the tailings impoundment. There does not appear to be any effect of the tailings on the diversion water quality. In fact there is no indication that water is flowing from the tailings impoundment into the diversion and it is more likely that flow is the into the tailings impoundment from the higher diversion, particularly downstream of the Secondary Tailings Dam.

There has been new rip-rap added to the end of the Rose Creek Diversion, to keep Rose Creek out of the old tailings spill area. This has resulted in erosion of the downstream bank where the channel turns at right angles to enter the original stream. There appears to be 30 to 40 cm of old tailings on the surface exposed by the erosion. The diversion channel does pose a long term maintenance issue for the tailings facility. The channel will have to be maintained regularly to ensure continued service.

6.4.6 Rose Creek Valley Hydrogeology

Sediments in the Rose Creek Valley consist of up to 40 m of highly permeable sands and gravels with interbeds of silt, which overlie a low permeability bedrock surface composed of phyllite and schist. The sands and gravels constitute the main aquifer of the area. In some areas, overlying glacial till acts as a confining layer.

In 1967, the hydrogeology of the Rose Creek Valley was investigated by International Water Supply Limited to establish a water supply for the Faro Mine. Highly permeable sediments were encountered which had hydraulic conductivities of between 5×10^{-2} and 1×10^{-1} cm/sec, with the groundwater flow estimated at 3150 m^3/day above the confluence with Faro Creek (Robertson Geoconsultants Inc., 1996a).

The tailings impoundment is underlain by sand and gravel and has provided additional recharge to the valley aquifer. The hydraulic conductivities of unsegregated tailings have been found to range from 8×10^{-3} to 1×10^{-7} cm/sec, while tailings slimes have an average hydraulic conductivity of 1×10^{-6} cm/sec (Steffen, Robertson and Kirsten Inc., 1991). Infiltration from the tailings impoundment to the valley aquifer have been estimated at between 864 and 5800 m^3/day (Robertson Geoconsultants Inc., 1996a).

Groundwater quality upstream from the tailings facility in borehole P81-09 indicates background zinc concentrations of 0.03 mg/L and sulphate concentrations of 11 mg/L (Robertson Geoconsultants Inc., 1996a). Downstream of the Original and Second Impoundments, groundwater sampled from piezometer

96-5B was found to have a near neutral pH, 0.13 mg/L zinc and 767 mg/L sulphate. In the Intermediate Dam area, groundwater was found to be slightly alkaline, with zinc concentrations of below 0.04 mg/L and sulphate concentrations of up to 1048 mg/L. In the Cross Valley Dam area, zinc concentrations were found to range between 0.009 and 0.024 mg/L and sulphate concentrations of 40 to 400 mg/L (Robertson Geoconsultants Inc., 1996a).

Both Ron Nicholson of the University of Waterloo and the Department of Environment (DOE) have looked at the geochemistry of the porewater in the tailings and in the groundwater under the tailings, but the conclusions are inconsistent. At the downstream edge of the Intermediate Dam tailings impoundment, groundwater sampled from monitoring wells indicate SO_4^{-2} concentrations of about 300 mg/L, but no consistent trends for zinc. Groundwater sampled from monitoring wells at the toe of the Cross Valley Dam have not exhibited elevated SO_4^{-2} or zinc concentrations as of yet. In order to explain the low concentrations, there have been discussions as to whether the monitoring wells are in the correct place, whether the tailings are buffering any generated acidity and whether the location/development of the zinc and sulphate fronts has not yet moved past the Cross Valley Dam.

Given the relatively low levels of zinc and neutral pH encountered in the monitoring wells, groundwater seepage from the tailings facility does not appear to provide a significant load of contaminants to the aquifer.

6.4.7 Rose Creek Tailings Facility 1999 Groundwater Analysis

The results of the chemical analysis of groundwater sampled from monitoring wells at the Rose Creek Tailings Facility during June and October 1999 are shown in Table 6.4. The pH levels encountered were near neutral. Zinc concentrations exceeding at least one of the surface water guidelines tended to occur in June most likely due to the influx of spring runoff before water treatment. In contrast, only the zinc concentration measured in October for monitoring well P96-4D exceeded any of the criteria.

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Table 6.4. Rose Creek Tailings Facility Groundwater Quality Data

Groundwater Analysis Results (mg/L)

Station	Water Quality Guidelines		X16A By Rose Creek d/s of Cross Valley Dam (5 m)	X16B By Rose Creek d/s of Cross Valley Dam (30 m)		X17A d/s of Cross Valley Dam u/s of X14 across Diversion (5 m)		X17B d/s of Cross Valley Dam u/s of X14 across Diversion (20 m)		X18A North of Cross Valley Dam, Right of Access Road to X14 (10 m)	
Date	CCME [a]	YCSR [b]	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99
Physical Tests											
pH	6.5-9..0		7.13	7.79	7.38	7.56	7.45	7.55	7.52	6.93	*6.28*
Sulphate (mg/L)		1000	15	23	24	34	44	19	23	455	382
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	-	<0.05	-	<0.05	-	<0.05	-	<0.05
Dissolved Metals											
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	<0.05	***0.2***	<0.05	***0.23***	<0.05	<0.05	<0.05	***0.06***	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	***0.005***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	<0.002	*0.006*	<0.002	*0.004*	<0.002	*0.004*	<0.002	***0.02***	<0.002
Iron (mg/L)	0.3	3	<0.01	0.03	<0.01	*0.3*	<0.01	***0.4***	0.07	0.28	0.28
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	<0.01	<0.01	<0.01	***0.45***	<0.01	*0.21*	<0.01	***0.32***	0.02

Station	Water Quality Guidelines		X18B North of Cross Valley Dam, Right of Access Road to X14 (10 m)	X19A d/s of Cross Valley Dam by X13 (12 m)		X19B d/s of Cross Valley Dam by X13 (27 m)		X21B-96 Toe of Second Impoundment (15.43 m), P96-5B		X21C-96 Toe of Second Impoundment (30.18 m), P96-5C	
Date	CCME [a]	YCSR [b]	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	03-Jul-99	31-Oct-99	03-Jul-99	31-Oct-99
Physical Tests											
pH	6.5-9..0		*5.75*	7.05	6.75	7.18	*6.29*	6.98	*6.25*	6.98	7.17
Sulphate (mg/L)		1000	422	248	373	356	159	405	504	10	942
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	0.07	-	***0.83***	-	<0.05	-	1	-	***0.57***
Dissolved Metals											
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	<0.05	***0.06***	<0.05	***0.08***	<0.05	***0.08***	<0.05	<0.05	***0.33***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	***0.004***	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	<0.002	*0.01*	<0.002	***0.023***	<0.002	*0.01*	<0.002	<0.002	*0.002*
Iron (mg/L)	0.3	3	0.08	0.06	<0.01	0.06	<0.01	0.15	<0.01	0.09	<0.01
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.005	*0.043*	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	*0.029*
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	<0.01	*0.19*	<0.01	*0.13*	<0.01	<0.01	<0.01	<0.01	*0.04*

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 6.4. Rose Creek Tailings Facility Groundwater Quality Data cont.

Groundwater Analysis Results (mg/L)

Station	Water Quality Guidelines		X24A-96 North Abutment of Intermediate Dam (5.88 m), P96-4A		X24C-96 North Abutment of Intermediate Dam (15.87 m), P96-4C		X24D-96 North Abutment of Intermediate Dam (28.22 m), P96-4D		X25A-96 South Abutment of Intermediate Dam (9.65 m), P96-3A		X25B-96 South Abutment of Intermediate Dam (19.80 m), P96-3B	
Date	CCME [a]	YCSR [b]	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99	19-Jun-99	29-Oct-99
Physical Tests												
pH	6.5-9.0		6.97	*5.68*	7.05	*6.01*	6.67	***6.09***	6.88	***5.98***	7.34	6.98
Sulphate (mg/L)		1000	717	579	684	<1	***1084***	***1050***	292	294	445	408
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	-	***0.7***	-	-	-	***0.4***	-	***1.42***	-	<0.05
Dissolved Metals												
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.24***	***0.12***	***0.16***	<0.05	***0.23***	***0.39***	***0.1***	<0.05	***0.1***	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	***0.002***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	*0.009*	<0.002	***0.025***	<0.002	***0.041***	<0.002	*0.019*	<0.002	*0.019*	<0.002
Iron (mg/L)	0.3	3	0.19	0.06	0.15	<0.01	*0.44*	<0.01	0.06	<0.01	0.21	<0.01
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	0.008	<0.005	*0.027*	<0.005	*0.109*	*0.062*	<0.005	<0.005	<0.005	<0.005
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.26*	<0.01	*0.17*	<0.01	*0.17*	*0.05*	*0.07*	<0.01	*0.03*	<0.01

Notes.

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

6.5 Water Supply Dam

Photographs 45 to 48 in Appendix A were taken of the Water Supply Dam during the September 1999 site visit. Prior to 1997, only fresh water was used as process water in the mill. Approximately 440 to 570 L/s was obtained from the reservoir impounded by Water Supply Dam that was built in 1969 upstream of the tailings facility on Rose Creek as shown on Figure 4.1. The dam may not have been built according to the original Acres Engineering design, but since as-built records were not available during the site visit, the final method of construction cannot be confirmed. A review of Golder Associates inspection reports indicate that the dam consists of an impervious glacial till core surrounded by sand filters with gravel, cobble and rock rip-rap on the upstream and downstream face. It is also reported that there is approximately 1.5 meters protective gravel cap over the impervious core.

The earth filled dam is approximately 300 to 400 m long with a crest that is approximately 5 to 6 m wide. The visible upstream slope is approximately 1.5 horizontal to 1 vertical and the downstream slope appears to be in the order of 2 horizontal to 1 vertical.

A counter-weight toe berm was installed in 1989 in response to observed cracking on the crest. The lower section of the berm was built with pervious fill to afford easy exit of the seepage. Weirs were installed to measure the flow rates of seepage. Significant seepage flows were noted exiting from the toe of the dam during the site visit.

Longitudinal cracks parallel to the crest of the dam exist on the upstream face of the dam along the majority of the length. Cracks show deformations of 7.5-10 cm vertically on the upstream face and in places the cracks are up to 10 cm wide. Golder Associates, who undertake the annual inspections of this dam, believe that these cracks extend up to the top of the till core and possibly into the till core. The cracks along the crest are not considered to be an immediate threat to the structure, but could allow precipitation into the body of the dam if not graded and filled in.

A concrete emergency spillway, approximately 15 m wide, is present on the north embankment. The spillway consists of a concrete sill with steel H-beams rising on both sides. The H-beams are used to contain reservoir stop logs that are placed to fill the reservoir. No stop logs were present at the time of our site visit and water was flowing slowly over the spillway. The reservoir was initially designed to be filled each fall with enough capacity to service the mill over the winter.

In addition to the emergency spillway, low level winter discharge is accommodated though a 76 cm diameter pipe buried in the south centre of the dam. Seepage is visible at the toe discharging from and around the culvert and through the toe drain. However, there are no signs of piping, (soils moving in response to hydraulic gradient) around the culvert and the dam appears to be reasonably stable on the downstream face. ARMC has attempted an underwater inspection of the upstream part of the pipe, but the exact location of the inlet was not known at the time and the inlet was not located. ARMC plans to determine the location of the inlet and perform an underwater inspection in 2000.

The Water Supply Dam is in no immediate danger. However, following complete cessation of operations, the dam should be breached as it constitutes a potential hazard to the downstream tailing dam should the water dam be over-topped at a later date. If the dam remains in operation, the cracks on the crest should be filled with clay and the dam regraded to shed precipitation.

6.6 Explosives

Explosives used at the Faro mine consisted mainly of ANFO with lesser amounts of gel. An explosives plant, owned by Bulk Explosives Limited (BXL a subsidiary of CIL) is located along the Mine Access Road, east of the tailings impoundment. The explosives facility consists of three metal pre-fabricated buildings used for the storage of chemicals and machinery for explosives manufacture and delivery. A small lined pit, used for the extraction of copper sulphate, is located adjacent to the explosives plant. Another small plastic lined pond located outside was used as a spill basin. This pond is periodically inspected by a Faro-based employee of BXL to ensure that it does not overflow.

Discussion with Eric Denholm of Anvil Range Mining Corporation concerning the current condition of the BXL facility indicates that waste oil has been removed and the reactors (copper sulphate plant) have been drained of sulfuric acid.

The explosives plant is not owned by Anvil Range Mining Corporation although the building is on the mine lease. The building was not inspected during the September 1999 site visit.

6.7 Oil/Fuel Areas

An inventory of fuel storage tanks and their disposition was conducted at the mine site in April 1999. The inventory was conducted in accordance with regulated requirements for the registration of all fuel storage tanks on federal lands. The fuel storage tanks have been registered with the Lands Administration Department of DIAND.

Table 6.5 shows that the Faro and Grum/Vangorda mine sites contain 8 fuel storage tanks, 7 waste oil tanks and 4 glycol tanks. Currently, only two fuel storage tanks are in use at the Faro mine site. Tanks not in use have been emptied; however, the tanks have not been ballasted with an inert material such as sand and a small volume of residual fuel likely remains at the base of the tank. Diesel fuel, for use at the mine site, has been consolidated into the EMD (emergency) generator tank, which contained about 141,000 litres at the time of the site inspection. Gasoline is dispensed from the tank located adjacent to the Faro gate guardhouse.

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Table 6.5 Anvil Range Mining Complex Tank Inventory

Location	Grum Lube Shack		Grum Shop	Faro Lube Shack	Faro Plant Site	Faro EMD Primary Fuel Tank
No	1	2	3	4	5	6
Use	Glycol tanks (2)	Diesel tanks (2)	Gasoline	Diesel tanks (2)	Gasoline	Diesel
Bulk Tank Capacity (litres)	102600	387600	56200	1250200	45500	146200
Type	Vertical AST - Steel	Vertical AST - Steel	Vertical AST - Steel	Vertical AST - Steel	Vertical AST - Steel	Vertical AST - Steel
Dike/Berm	earth	earth	earth	earth	earth	earth
Secondary Containment	None	None	None	None	None	Earth dike
Installation Date	1990/91	1990/91	1990/91	unknown	unknown	unknown
Currently In Use	No	No	No	No	Yes	Yes
Note						

Location	Faro EMD Day Tank	Faro Maintenance Shops	Mill Used Oil Containers (2)	Mill Single Rectangular Waste Oil Container	Faro Mill Used Oil Tanks	Faro Mill Mobile Use Oil Tank #1
No	7	8	9	10	11	12
Use	Diesel	Waste oil	Waste oil	Waste oil	Waste oil	Waste oil
Bulk Tank Capacity (litres)	7500	20000	154000	77000	87500	7500
Type	Vertical AST - Steel	Partially Buried Horizontal Steel	Horizontal AST (rectangular) - Steel	Horizontal AST (rectangular) - Steel	Horizontal AST - Steel	Horizontal AST - Steel
Dike/Berm	Steel	none	none	none	earth	none
Secondary Containment	Steel	none	none	None	Earth dike	none
Installation Date	1998	unknown	1997	1997	unknown	1997
Currently In Use	No	No	No	Yes	Yes	Yes
Note			Installation not complete	Located within the waste oil consolidation area behind the mill		

Location	Faro Mill Mobile Use Oil Tank #2	Faro Maintenance Shops Used Glycol Tank	Faro Freshwater Pumphouse	Faro Load Out Shed	Ore Haul Contractor Shop
No	13	14	15	16	17
Use	Waste oil	Used glycol	Diesel	Glycol	Waste oil
Bulk Tank Capacity (litres)	7500	7500	4200	25000	7500
Type	Horizontal AST - Steel	Horizontal AST - Steel	Horizontal AST - Steel	Horizontal AST - Steel	Horizontal AST - Steel
Dike/Berm	none	Steel	Steel	none	none
Secondary Containment	None	Steel Tray	Steel Berm	None	None
Installation Date	1997	1997	unknown	unknown	1995/96
Currently In Use	Yes	Yes	Yes(?)	No	No
Note					Scheduled for removal to waste oil consolidation area

6.7.1 Hydraulic and Lubricating Oils

Storage and dispensing facilities for hydraulic and lubricating (lube) oils were not included in the previously described inventory. These facilities are located in two areas of the Faro mine site and one area of the Grum/Vangorda mine site:

- **Faro Shop Lube Building:** This building is located adjacent to the wash bay in the shop. Lube/oil tanks were contained inside the metal clad building on a concrete floor.

- **Faro Pit Lube Building and Tanks:** This lube/fuel building is located near the Main Pit haul road entrance. The lube and fuel facility was used for the haul trucks and other mobile equipment. It was likely constructed in the early 1970's. The building is metal clad with a concrete floor.

- **Grum Lube Building:** The lube building has been operating since the start of mining on the Vangorda Plateau. Two aboveground diesel storage tanks and two glycol storage tanks are associated with the Grum lube building.

The site inspection, conducted in September 1999, revealed several areas in the vicinity of petroleum hydrocarbon storage and dispensing facilities of the Faro and Grum sites where soil staining and hydrocarbon odors were evident. A limited soil sampling program was conducted concurrently with the site inspection in order to determine the concentration of petroleum in surficial soil samples in the vicinity of the storage and fuelling facilities. The soil sampling methods and the results of analytical testing are discussed in Section 7. Observations concerning the current condition of the fuel and lube oil storage and dispensing facilities are described below.

6.7.2 Fuel Storage and Use Sites

6.7.2.1 Faro Mill Site

A fuelling installation located across the road from the Guardhouse and Administration building contains a gasoline and a diesel fuel storage tank surrounded by an earth berm. The diesel tank is empty and has been removed from service. The gasoline tank is still in service. The site inspection revealed evidence of hydrocarbon staining and odor in surficial soils within the bermed area. Soil samples were collected in this area to determine the nature and concentration of petroleum hydrocarbon contamination.

6.7.2.2 Faro Emergency Diesel Generator and Fuel Supply

The emergency diesel generator and two associated diesel fuel storage tanks are located to the south of the mill and concentrator. The day tank was installed in 1998 and included a secondary containment tray beneath the tank (Photo 49). The tank has been emptied and is no longer in use. The primary fuel tank (Photo 50) is located to the south of the generator and day tank. A pump house, located directly adjacent to the storage tank, is required to lift the fuel up the hill to the generator. This fuel tank currently provides the only diesel storage at the mine site and is therefore used by mine personnel to fuel trucks and equipment. Visual inspection of the area showed evidence of small scale spills having occurred in the past. Soil samples were collected in this area to determine the concentration of petroleum hydrocarbon parameters in surficial soils.

The emergency diesel generator is housed in a trailer outside the electrical substation. A pool of oil was observed directly in front of the generator building (Photo 51). The oil spillage was scheduled for cleanup into drums within the next few days following our site visit (ARMC, pers. comm., 1999). Soil samples were collected in the area surrounding the oil spill to determine the concentration and approximate extent of petroleum hydrocarbon contamination.

6.7.2.3 Faro Pit Lube Building

The lube building is located near the Main Pit haul road and the diesel tanks are located on a small hill to the north of the lube building.

This lube facility has been used since the mine opened in 1969. Grease, hydraulic oil, engine oil and antifreeze were stored and dispensed from the building (Photo 52). A diesel pump station is located on the south side of the building. The diesel storage tanks are located up the hill (rock dump) to the north (Photo 53). The fuel was delivered to the pump station via gravity feed (Photo 54).

Hydrocarbon staining is evident on the concrete floor of the building and on the unpaved ground surrounding the lube shop. Four soil samples were collected in this area to determine the nature and concentrations of petroleum hydrocarbons in the surficial soil layer.

6.7.2.4 Diesel Fuel Storage and Dispensing Facilities

The diesel storage facility consists of two vertical steel diesel fuel storage tanks with a total capacity of 1.25 million litres. The tanks are contained in an unlined gravel berm. The fill nozzle is located on the west side of the berm and soil staining and associated hydrocarbon odors are evident in this area (Photo 55). Inspection of soil conditions within the bermed area also revealed areas of soil staining and hydrocarbon odors, particularly at the NE corner where the distribution line exits the berm. Soil samples were collected inside and outside the bermed area, and the results are discussed in Section 7.

6.7.2.5 Faro Historic Fuel Storage

One empty aboveground steel tank was located adjacent to the core shacks on the Mr. Mungly Rock Dump (Photos 56 and 57). Two additional tank pads were evident adjacent to the existing tank. Surficial soil adjacent to the existing tank contained a diesel odor. Hydrocarbon staining and/or odor were not observed at the other two tank pad locations. Soil samples were collected in the stained area and other locations.

6.7.2.6 Faro Freshwater Pumphouse

Diesel is stored at the freshwater pumphouse in a 4,200 L steel tank with secondary containment (Photo 58). This fuel storage facility is located down the valley from the mine site, adjacent to Rose Creek. A small volume of liquid, which appeared to be water, was noted at the base of the steel berm. A small area of hydrocarbon staining was evident in soils adjacent to the secondary containment tray. Soil samples were collected to determine the concentration of petroleum hydrocarbons in surficial samples.

6.7.2.7 Grum Ore Haul Contractor Shop

The ore haul maintenance shop is operated by a contractor and consists of 4 adjacent trailers with a cement pad fronting the trailers (Photo 59). The ground surface is unpaved around the cement pad. Remnants of a wood frame wall suggest that the cement pad was formerly enclosed and likely served as a shop. Soil staining, hydrocarbon odors and some areas of pooled hydrocarbons are evident on the ground surface surrounding the trailers and cement pad, indicating poor housekeeping practices. Anvil Range Mining Corporation staff had recently conducted soil remediation by excavating areas of pooled hydrocarbons on the east side of the trailers, where waste oil was handled (ARMC, pers. comm., 1999).

An out-of-service transformer was found on the west side of the trailers. A soil stain associated with the transformer was sampled and submitted for analysis to determine the concentration of PCBs.

While no permanent fuel tanks remain at this site, there is one temporary mobile tank being used for waste oil. The area around the shop is contaminated by petroleum products, presumably from spills over the period 1995 to 1997. The waste oil tank is scheduled to be relocated to the waste oil consolidation area at the Faro mine site.

Soil samples were collected in this area to determine the nature and concentration of petroleum hydrocarbons in surficial soils.

6.7.2.8 Grum Ore Transfer Pad

Inspection of the transfer pad area showed that several tonnes of ore remain stockpiled at this location. The area was dry with no evidence of surface runoff drainage during the site inspection in September 1999. However, the stockpiled ore represents a potential environmental concern because of the possibility for dissolution and migration of metals via surface runoff during spring melt or rainfall events.

6.7.2.9 Grum Maintenance Shop

The Grum maintenance shop is a steel clad building with a cement floor. Inspection of the area outside the building indicated generally clean soil conditions with the exception of two areas. A localized area of hydrocarbon staining was observed on the east side of the building and a small cache of used oil filters and associated soil staining was noted on the north side of the building. Samples were not collected from these areas due to the small scale and localized nature of the hydrocarbon contamination in the surficial soils.

A gasoline fuelling station and associated storage tank is located across the road from the maintenance shop. The vertical steel tank has a capacity of 56,200 L and is contained within a gravel berm. Soil samples were collected from the pump island and the fill area for the storage tank to determine the presence of petroleum hydrocarbon in this area.

6.7.2.10 Grum Lube Building

The lube building has been operating since the start of Vangorda mining. Areas of hydrocarbon staining were evident outside the lube building. A hydrocarbon sheen was noted on the surface runoff from the lube building area to the roadway to the east.

There are two diesel and two glycol storage tanks across the road from the lube building. Hydrocarbon staining is evident on the ground at the diesel fill pump. Staining was also observed within and outside of the bermed area for the storage tank.

Soil samples were collected in the vicinity of the areas of hydrocarbon staining observed during the site inspection.

6.8 Hazardous and Non-Hazardous Waste Management

6.8.1 Scrap Metal Recovery

DIAND has funded a scrap metal recovery program for the mine sites. During our site visit, material from the bone yard and electrical debris pile on the Northwest Dump was being removed for recycling.

An outdoor storage area known as the "truck laydown area" is located to the SE of the Guardhouse (Photo 60). The area is used to store steel, wire spools and out of service transformers. Three soil samples were collected in this area to determine the presence and concentration of petroleum hydrocarbons in the soil.

6.8.2 Liquid Wastes

Sewage is handled by three septic systems:

- Gatehouse
- Mill/shops complex
- Grum office/shops

The septic system for the Faro mine site is no longer operational and is located to the south of the loadout area. A secondary septic system services the Guardhouse and Administration Building. Overflow from the secondary system discharges into a ditch on the north side of the roadway. Wash bay waters also discharged directly into this ditch.

6.8.3 Landfill

The Faro Landfill is located on the shelf of the Main and Intermediate Rock Dumps (Photo 61). The initial start-up date is unknown, but thought to have been sometime early in the Mine's history. The full aerial extent of the landfill is unascertained and the current exposed site is assumed to represent a small portion of the entire historical landfill. The materials that were dumped during the earlier years of the Mine may have included tires, oils, chemicals and other hazardous materials. Since 1995, when Anvil Range Mining Corporation took over the Faro Mine site, dumping has occurred to currently accepted standards, consisting of mainly domestic garbage. Drums are cleaned and crushed before being added to the landfill and no hazardous materials are deposited. (ARMC, pers. comm., 1999)

In January of 1997 Environment Canada, Yukon Branch, Spill Reports Section, received several complaints about smoke coming from the Faro Mine Site, which turned out to be a fire in the landfill site. People were concerned about the health aspect of the smoke/haze that was hanging over the area. The fire, however, was not deemed an emergency and no immediate action was taken.

Environment Canada reported the smoke from the landfill fire to Rob McClure from the Occupational Health and Safety Board, who followed up with a site visit in February of 1997. Mr. McClure brought equipment to test the air for total hydrocarbons on charcoal. He showed Gary Heinbecker, the Safety Coordinator of the Mine at that time, how to do air sampling with the charcoal tubes and gave him information on private testing laboratories. Several samples were collected and a follow-up with lab tests on sulphur compounds was also recommended, but not done to the knowledge of Mr. McClure. (McLure, pers. comm., 1999; McLure 1997; Arrell 1997)

Mr. Dana Haggar, the present Mine Manager, could not recall if any samples had been sent to a laboratory. Mr. Haggar did recall a memo that was sent to all mine employees stating that the smoke did not represent any health hazard. However, he did not know what information this statement was based on. (ARMC, pers. comm., 1999)

6.8.4 Polychlorinated Biphenyls (PCBs)

A permitted storage facility for polychlorinated biphenol (PCB)-containing electrical equipment including small transformers and capacitors is located in a steel bin within the electrical substation compound. This facility is permitted by Environment Canada and is inspected on an annual basis. Twenty-seven used transformers, stored in a laydown area to the south of the guardhouse have been tested for PCB concentrations. This equipment was found to contain less than 50 ppm of PCB and has been designated "clean". The equipment has been labeled as non-PCB containing.

An inventory of in-place electrical equipment suspected of containing PCBs was conducted by Access Consulting Group in the fall of 1999 (ARMC, pers. comm., 1999). The study has been completed and the PCB inventory has been submitted to Environment Canada. The study identified and inventoried various types of PCB containing electrical equipment, including: fluorescent light ballasts, small capacitors on mine shovels, small capacitors installed at the motor control center (MCC) rooms for the purpose of starting motors, and lamp ballasts on drills. Ballasts of mercury vapor lamps were not found to contain PCBs. This PCB study covered the entire mine site, with the exception of pole mounted transformers. The inspection of in-service electrical equipment such as the pole-mounted transformers is scheduled for summer 2000 (ARMC, pers. comm., 1999).

6.8.5 Asbestos

An asbestos survey has not been conducted at the mine site to date.

6.8.6 Nuclear Sources

The nuclear sources on-site have been registered with Atomic Energy Canada Ltd. and are properly stored on site in the mill area.

6.8.7 Waste Oils and Lubricants

The fuel storage tank inventory identified 8 tanks that had been used to store waste oil at the Faro mine site (Table 6.5). Prior to the most recent shut down, used oil was mixed with diesel and burned in the heating plant located in the mill. The waste oil is now being collected at a centralized location on the west side of the mill complex to the south of the coal storage and identified as the "temporary drum storage" (Photos 62, 63 and 64). This area is contained within a berm constructed of soil. Significant accumulations of hydrocarbons were noted under and around the drums.

6.8.8 Ore Concentrate

Ore concentrate was observed in the concentrate storage building and in the vicinity of the concentrate load-out area (Photos 65 and 66). Soil samples were collected in the area adjacent to the load-out and concentrate storage sheds to determine the concentration and approximate extent of metal contamination resulting from this potential source area.

6.8.9 Accidental Releases

Table 6.6 summarizes the major incidents of chemical and fuel spills the Faro mine site documented in the company records from March 1975 to February 1996. This summary was taken from review of the Environment Canada, Yukon Branch, Spill Reports for the mine site. The majority of the spills reported have been associated with hydrocarbons: diesel fuel, oil, gasoline and glycol. Chemical spills such as copper sulphate have occurred both on site in the mill area as well as in the CIL compound. Other process chemical spills (cyanide, xanthate, hydrogen peroxide) have occurred in and around the reagent building. There have also been occasional spills of tailings, the most significant one occurred in 1975, when approximately 700 million litres of tailings effluent and fines were deposited downstream of the tailings impoundment in the Rose Creek Valley.

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Table 6.6 Summary of Spills (1975 - 1996)

Date	Substance	Amount	Location	Cause	Notes
09-Feb-96	Diesel Fuel	100,000 litres	Grum Fuel Tank Farm	mechnical failure	spill within secondary containment
16-Feb-96	Diesel Fuel	80,000 litres	Faro diesel bulk tank farm		spill within secondary containment
05-Jun-96	diesel fuel oil	500 litres	emergency generator north side of mill complex		
30-Sep-96	diesel	2000 litres	Grum pit ore transfer pad		put contaminated soil on Grum rock dump
04-Jan-96	diesel fuel	140,000 litres	Bulk fuel tank farm near Grum lub shop	mechnical failure	all contained in bermed area, not known if berm lined
09-Jan-96	diethylene glycol	25,000 litres	Grum mine at bulk twin glycol tanks		spill within secondary containment. Not lined. Soil placed on waste rock
11-Mar-96	gasoline	1500 litres	Grum gasoline pumping station		
03-Sep-86	copper sulfate	< 100 litres	Mill site		20% solution, went into emergency tailings then regular tailings
20-Aug-96	copper sulfate	200 kg	BXL Explosives Plant	Freshwater line failed, releasing contaminated water with residual CuSO4	most contained in building, some ponded outside
12-Dec-95	diesel	1800 litres	Grum lub shack		contained in lub shack, taken to grum waste rock dump to burn
02-Oct-95	gasoline	200 litres	Bulk Gasoline Storage near gatehouse	tank overflowed	held in permeable sand and gravel secondary containment
16-Jul-95	mine waste water	27,000 gal	dewatering line from Little Creek Pond		
29-Jun-95	copper sulfate	45,000 litres	Copper sulfate reagent tanks	clean up of reagent tanks prior to start up	5-10% CuSO4, released to tailings facility
19-May-95	cyanide	2 litres	Mill	flushing of cyanide line prior to start up	cyanide contaminated water was relased to mill floor and mixed with tailings muck- muck was place on ground just outside mill doors prior to appropriate disposal
10-May-95	mine waste water	unknown	mine water pipeline from Little Creek pond to VWTP	break in line	at haul road crossing
22-Jun-94	diesel	600 l	Water pump generating site @ Cross Valley dam	tank spill	contained in storage tank berm-soaked into berm and ground
13-Sep-93	mine waste water	72,700 litres	mine water pipeline from Little Creek pond to VWTP	pipeline rupture	migrated 200 m to Vangorda Creek diversion
26-Sep-92	diesel fuel oil	27,000 litres	Vangorda mine site		contained in bermed area
20-Jul-92	diesel	650 litres	Pelly construction tank near BXL plant	tank vandalized	burned off pooled oil, contaminated soil taken to NW rock dump

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Table 6.6 Summary of Spills (1975 - 1996) cont.

Date	Substance	Amount	Location	Cause	Notes
04-Jan-92	gasoline	1000 litres	refueling area opposite security office		10 - 20 m2 contaminated
16-May-92	glycol	100 litres	Faro reservoir, between Dam and Grum turnoff	truck turn over	
17-May-92	glycol	1250 litres	Faro road, between Grum turnoff and shooting range	truck accident	at low point near culvert, water/glycol mix ran out of tank into culver, truck leaked oil and gasoline
17-May-92	gasoline	50 litres	Faro road, between Grum turnoff and shooting range		at low point near culvert
17-May-92	hydraulic oil	50 litres	Faro road, between Grum turnoff and shooting range		at low point near culvert
16-May-92	diesel fuel	2000 litres	diesel tanks by Grum lub bay	overflowing tank	contained inside berm - 144 m2 area affected
24-Mar-92	sodium isopropyl xanthate	200 litres	Mill mixing tanks	overflow of tank	20 % solution pumped to tailings
22-Aug-91	copper sulfate	150 kg	Faro road nead Grum turnoff		on road surface
29-Aug-91	diesel fuel	4,500 litres	above ground storage tank at mill site	emergency generator tank	oil flowed down a short section of radway on east side of mill and into the old Faro Creek channel. Bulk of it went into tailings.
03-Jan-90	copper sulfate	12,000 kg	mill supply line from solution tank	line damaged	most flowed into tailings launder and pond
23-Mar-90	waste crankcase oil	500 kg	Concentrate loadout facility	4 drums ruptured	
03-Jul-90	copper sulfate	2500 kg	200 m SE of mill, upslope of tailings	80-100 25 kg bags had been discarded over a steep embankment and buried under sidecast fill	located in main drainage for faro pit abandonment plan
13-Sep-90	copper sulfate	1600 litres	Storage tank	tank leakage	19% solution flowed into flotation basement and around storage tank area
14-Sep-90	hydraulid fluid	40 litres	confluence of North fork and Rose Creeks		
30-Jun-90	sodium isopropyl xanthate	20 kg	Reagent storage building	drums damaged	
11-Nov-89	ethylene glycol	1000 kg	Load out still bottom tank at weigh scale	valve left partially open	"steel bottoms" (50% ethylene glycol, 21 % tri-ethyl glycol-mono-ethyl ether). Valve left partially open and 205 gallons spilled near load out area. Flowed down loadout incline ramp and pooled on the snow/road surface. Some spread by vehicle traffic.
22-Aug-89	gasoline	200 litres	Bulk storage tank	overflow	contained in berm, left to evaporate
25-Apr-89	Hydrogen peroxide	300 kg	Reagent Compound	Barrels fell off pallets	contained, soil removed to tailings

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Table 6.6 Summary of Spills (1975 - 1996) cont.

Date	Substance	Amount	Location	Cause	Notes
07-Dec-88	sodium cyanide	1200 kg as NaCN	CN mix tank at mill	tank overflowed	20% solution (637 kg CN). Water supply line left on and tank overflowed inside mill. Material recovered and discharged to tailings.
01-Jan-87	motor oil/diesel oil	unknown	south of CIL plant	careless operations	over 86/87 winter operations around discharge water wells, 300 yards south of CIL plant. Near Rose Creek. Sheen observed in creek, old burned tires. Pictures on file at EC.
10-May-86	fuel oil	unknown	pipeline from above ground fuel oil storage near mill tanks adjacent to coal stockpile	leaking buried line	occurred many times since 1977. Observed fuel oil bubbling out of ground. Oil recoved in coal crusher sump.
01-Jan-81	diesel fuel	184,300 kg	Fuel storage tank	underground gravity feed line broke	
12-Dec-79	effluent	14,000,000 litres	tailings impoundment	overtopping dyke	
25-Nov-76	copper sulfate	52,200 kg	CIL plant	defective valve	drained through tailings
26-Aug-76	copper sulfate	10,900 litres (26%)	CIL plant	overflow of tank	contaminated water flowed into sump then into N. Fork Rose Creek.
13-Feb-76	sodium cyanide	45,000 litres (25%)	tailings impoundment	dumping of stock solution	mine shut down for strike
05-Nov-75	sulfuric acid	9000 litres (93%)	CIL plant (front of north door)	valve malfunction	acid drained on ground, diluted and unsuccessfully neutralized.
19-Mar-75	tailings effluent and fines	700 million litres	Rose Creek valley	failure of 2 tailings dykes	extensive deposits of tailings in flood plain.

7 Mine Site Contaminant Occurrence and Distribution

7.1 Regulatory Framework

The Phase 1 Environmental Site Assessment (ESA) of the Anvil Range Mining Complex in south-central Yukon Territory was undertaken to provide an initial inventory of environmental liabilities in support of the devolution of mineral resources in the Yukon from the Government of Canada to the Government of the Yukon Territory. Accordingly, for the assessment of environmental quality at the mine site, the Government of the Yukon Territory (YTG) is the ultimate jurisdictional authority.

The Yukon Territory Contaminated Sites Regulation (Order in Council 1996/192, December 16, 1996) issued under the Environment Act, ss. 145 is the governing legislation for the assessment and remediation of contaminated sites. The Contaminated Sites Regulation (CSR) provides standards for soil assessment as either a generic or matrix numerical standard for a given chemical parameter. Generic numerical soil standards are specified on the basis of current or proposed land use, including agricultural (AL), urban park (UL), residential (RL), industrial (IL) or commercial (CL). Matrix numerical soil standards consider both land use and site specific factors for the protection of human health and the environment.

For evaluation of chemical concentration data using the matrix soil standards, the site-specific factors of human intake of contaminated soil and toxicity to soil invertebrates and plants apply at all sites. In addition, the site-specific factor for groundwater flow to surface water used by aquatic life was also used to evaluate the soil quality data at the Faro mine site.

The Anvil Range Mining Complex is zoned for industrial land use. Therefore the generic and matrix numerical soil standards for industrial land use (IL) were used for the assessment of contamination.

7.2 Soil Quality Assessment

7.2.1 Methods

Fifty-eight soil samples were collected from various locations across the Faro/Vangorda/Grum mine site. Sampling was conducted in areas identified to be of potential environmental concern, where petroleum hydrocarbons, metals or other potential chemicals of concern (PCOC's) such as PCBs may have contaminated the subsurface environment. The sampling locations were previously described in sections 6.7 and 6.8. A limited number of soil samples were collected at each of the areas of environmental concern and submitted for chemical analysis to provide confirmation for contaminant observations during the site inspection. The results of soil testing were intended to identify the type of PCOC in the soil sample and provide a representative concentration of the PCOC in the area of concern.

Surficial soil samples were collected from the surface to approximately 0.1 meter depth using a stainless steel trowel. Samples collected to depths of up to 0.3 meters were obtained from the wall of soil pits dug using a shovel. The soil samples were placed into pre-cleaned, laboratory certified glass containers and stored in a cooler for shipment to the analytical laboratory. Each soil sample collected was labeled with a unique identification and recorded on standard chain-of-custody forms that were submitted to the laboratory concurrently with the samples. The sampling implements were rinsed with deionized water and wiped with clean paper towels to decontaminate between sampling locations.

7.2.2 Analytical Program

All soil samples collected during the limited sampling program were submitted to a CAEL accredited analytical laboratory, ASL Analytical Service Laboratories in Vancouver, B.C. Soil samples not submitted for analysis have been archived.

The soil sampling program targeted areas of the mine site where petroleum hydrocarbons were stored, used and disposed. Accordingly, the primary contaminants of concern were petroleum hydrocarbons including: gasoline, diesel, lubricating and hydraulic oils. Soil samples were also collected in areas of the mine site suspected to be contaminated with metals and chlorinated organics including polychlorinated biphenyls (PCBs). The majority of the soil samples were analyzed to determine concentrations of extractable petroleum hydrocarbons (EPHs) with selected soil samples analyzed to determine concentrations of non-halogenated volatiles (BTEX compounds and VPH), polycyclic aromatic hydrocarbons (PAHs), metals and PCBs. One soil sample, collected beneath an area of treated timber storage, was analyzed to determine the concentration of chlorinated phenols and PAHs.

A quality assurance and quality control program (QA/QC) was conducted concurrently with the chemical analysis of soil samples. The QA/QC program consisted of the analysis of blanks, duplicates, spike recovery, and where applicable, certified reference standards. The results of the QA/QC program for soil analysis are attached to the laboratory reports in Appendix B. Analytical detection limits consistent with the assessment standards for industrial land use specified in the Yukon Contaminated Sites Regulation were achieved for each chemical parameter analyzed. On the basis of known industrial activities that have occurred at the Faro mine site, the potential chemicals of concern and their sources include:

- *Petroleum Hydrocarbons:* diesel fuel, gasoline, hydraulic and lubricating oils from the storage, use and disposal of fuels and oils.
- *Mill and Laboratory Chemicals:* cyanide, xanthates, glycols and others
- *Heavy Metals:* mining, milling and processing of mineralized rock; naturally occurring concentrations due to natural geochemistry
- *Transformer and Capacitor Fluids:* potentially contributed from the former presence of PCB-containing electrical equipment;

The units of measure generally used to quantify concentrations of contaminants in soil are µg/g or equivalently, mg/kg, representing one part per million (ppm).

The results of chemical analysis of soil samples are summarized in Tables 7.1 through 7.3. The applicable regulatory standards are included with the analytical data in each table. The sampling locations are shown in Figure 7.1 through 7.3. The laboratory reports and quality assurance/quality control data are provided in Appendix B.

7.2.3 Petroleum Hydrocarbons and Chlorinated Organic Compounds

Source areas for recent and historic petroleum hydrocarbon storage, use and disposal at the mine site have been discussed previously in Section 6.7. Petroleum hydrocarbon analytical results from soil samples collected from various locations used for storage and dispensing of waste oil and fuels across the mine site are described below. The results for hydrocarbon and BTEX compounds are summarized in Table 7.1 and those for PAHs, PCBs and chlorinated phenols are summarized in Table 7.2.

- Faro mill site: Six soil samples at three locations were collected within the soil berm and near the pump at the fuelling installation across the road from the Guardhouse and Administration building (Sample Location 10). Four of the soil samples were analyzed to determine concentrations of BTEX compounds and extractable petroleum hydrocarbons (light and heavy: LEPH and HEPH). The analytical results (Table 7.1) indicate that one of the surface soil samples, collected within the berm, contained a concentration of volatile petroleum hydrocarbon (VPH) and xylene in excess of the Yukon CSR standards for industrial land use. The elevated concentrations of VPH and xylene are indicative of gasoline contamination. The analytical testing results therefore confirm the contaminant observations of staining and hydrocarbon odors within the berm, although the extent of contamination can not be determined on the basis of this limited sampling program.

- The Emergency Diesel Generator and Fuel Supply: Two surface soil samples were collected in this area and analyzed to determine the concentration of petroleum hydrocarbon parameters (Sample Location 5). One sample, collected from a location downslope of a historical fuel spill in this area, contained a concentration of LEPH in excess of the Yukon CSR industrial standard. EPH was not detectable in the soil sample collected near the generator building.

  Two surface soil samples were also collected near the pumphouse and fuelling nozzle for the primary fuel tank (Sample Location 4). The results of analysis are consistent with the contaminant observations indicating that LEPH concentrations in the soil sample collected between the tank and pumphouse, where evidence of small scale spills was noted, exceeded the Yukon CSR industrial land use standard.

- Faro Lube Shack: Four surface soil samples were collected in the vicinity of the lube facility (Sample Location 11) and analyzed for EPH, BTEX compounds and PAH. Table 7.1 shows that LEPH concentrations in the four samples and HEPH in one of the samples exceeded the Yukon CSR standard for industrial land use. The highest concentration of LEPH (1% LEPH) was detected in one sample (FLS 3), collected on the west side of the lube shack. This sample was also analyzed to determine concentrations of BTEX and PAH compounds, but the results shown in Table 7.1 and 7.2 indicate that these parameters are not present at elevated concentrations. The source of the petroleum hydrocarbon contamination in this area is likely diesel and heavy oils. The results of analysis for soil samples collected in the vicinity of the Faro Lube Shack confirm the contaminant observations during the site inspection (Section 6.7.2.3).

- Diesel Storage Tanks for Lube Shack Fuel Pump: Four soil samples were collected at the tank farm located uphill to the north of the Lube Shack (Sample Location 12). The analytical results confirm the observations recorded during the site inspection where staining and diesel odors were noted at the fill nozzle on the west side of the gravel berm and at the NE corner of the bermed area. LEPH concentrations exceeded the Yukon CSR standards for industrial land use in soils collected at these sampling locations (samples TF 1 and TF 4).

- Historic Fuel Storage Near the Core Shacks and at Scrap Area to NW of Faro Pit: Three surface soil samples were collected at the historic fuel storage area near the core shacks (Sample Location 13). LEPH concentrations exceeded the Yukon CSR industrial standard in two samples collected from locations directly adjacent to the tank pads and dispensing area. The sample collected from the area between the former tank locations (CA 1) contained an LEPH concentration of 1.2%. A soil sample collected approximately 3 m from the stained areas did not contain an elevated concentration of LEPH.

  Soil samples collected at a former tank pad located on the uppermost bench of the scrap area to the northwest of the Faro Pit did not contain concentrations of petroleum hydrocarbons that exceeded the CSR standards (Sample Location 14).

- Truck Laydown Area: Three surface soil samples were collected in this outdoor storage area (Sample Location 1). The results of analysis indicate that LEPH was not detectable in the soil samples and HEPH concentrations did not exceed Yukon CSR standards for industrial land use.

- Temporary Drum Storage: Three surface soil samples were collected in the vicinity of this bermed area currently used for the consolidation of waste oil collected from across the Faro and Grum mine sites (Sample Location 2). Soil within the berm was observed to contain evidence of hydrocarbon staining and odors. Soil samples were therefore collected outside the berm to determine the extent of the petroleum hydrocarbon contamination in this area. LEPH was not detected in the soil samples collected outside the bermed area, and only one sample contained a detectable concentration of HEPH, that was well below the Yukon CSR standard for industrial land use.

- Waste Oil Handling Area: Three surface soil samples were collected in the vicinity of another area used for waste oil consolidation at the Faro mine site (Sample Location 2a). The waste oil containing drums are stored within a soil bermed area and an open steel shipping container. The soil samples were collected both inside and outside the berm, and one sample was collected adjacent to the shipping container. The results of analysis (Table 7.1) show that the sample collected at the shipping container contained an LEPH and HEPH concentration that exceeded the Yukon CSR standard for industrial land use.

- Tank Cradle at Concentrate Shed: A glycol tank used to supply the truckbox spray-down area at the concentrate load-out had been located in this area (Sample Location 3). To confirm the absence of hydrocarbon contamination in this area, two samples were collected in the vicinity of the tank cradle. The results of analysis showed that the one soil sample analyzed did not contain elevated concentrations of petroleum hydrocarbons.

- Partially Buried Waste Oil Tank and Washbay Diesel Tank: Three surface soil samples were collected in the vicinity of these source areas for petroleum hydrocarbons and analyzed for EPH concentrations (Sample Location 7). The results of analysis (Table 7.1) show that the soil samples collected near the waste oil tank do not contain elevated concentrations of EPH (WOT 1 and 2). However, the sample taken at the front of the washbay contained an LEPH concentration that exceeds the Yukon CSR standards for industrial land use.

- Lube Building: Two surface soil samples were collected near the Faro maintenance area lube building (Sample Location 8). The results of analysis indicate that the samples contain elevated concentrations of HEPH, but the levels do not exceed the Yukon CSR standards for industrial land use.

- Reagent Mix Building: One soil sample (RMB 2) was collected on the west side of the Reagent Mix Building, in an area containing a strong, but unidentifiable chemical odor (Sample Location 6). A second soil sample (RMB 1) was taken in front of the loading doors for the building. The results of analysis show that the concentration of HEPH in sample RMB 1 slightly exceeded the Yukon CSR standard for industrial land use. EPH and BTEX concentrations in the sample collected in the odorous area (RMB 2) did not exceed the territorial standards.

- Grum Ore Haul Maintenance Shop: Four surface soil samples were collected in the vicinity of areas of potential environmental concern observed at the Grum Ore Haul Maintenance Shop (Sample Location 15). One of the samples (OMS 1), taken adjacent to an out-of-service transformer on the west side of the shop area, was analyzed for PCBs. The results (Table 7.2) show that the soil sample did not contain a measurable concentration of PCBs. Three samples were analyzed to determine the concentrations of EPH. The results (Table 7.1) indicate that a sample taken at the weigh scale (OMS 3) and a sample taken at the east exit of the area, in the direction of surface runoff (OMS 4), contained LEPH concentrations that exceeded the Yukon CSR standard for industrial land use.

- Grum Administration Area: Three surface soil samples were collected at the fuel storage and dispensing facility located at the Grum Administration area (Sample Location 16). The results of the analysis (Table 7.1) indicate that the samples did not contain elevated concentrations of EPH or BTEX compounds.

- Grum Lube Shop and Diesel Storage Tanks: Five surface soil samples were collected in the vicinity of the Grum lube shop and diesel storage tanks (Sample Location 17). The results of analysis show that two of the soil samples, one collected near a former aboveground fuel tank at the lube shop (GLS 3) and the other downslope of the lube shop area in the direction of surface runoff (GLS 5), contain LEPH concentrations that exceed the Yukon CSR standards for industrial land use.

- Grum Portal and Old Shop: Four surface soil samples were taken at the Old Shop and Grum Portal area (Sample Location 18). One of the samples (OS 3) was collected from beneath a pile of treated utility poles and was analyzed to determine concentrations of PAHs and chlorinated phenols. The results of analysis indicate that soil samples collected from this area do not contain elevated concentrations of petroleum hydrocarbons (Table 7.1) or chlorinated phenols (Table 7.2).

7.2.4 Metals (Lead and Zinc)

Lead and zinc concentrations were also determined in selected soil samples collected from areas used to store and dispense petroleum hydrocarbons. Lead was used as an additive in fuels for many years. The results of soil samples analysis are summarized in Table 7.3. Samples analyzed for metal concentrations were collected from the following areas:

- Truck laydown area – Location 1
- Temporary drum storage area – Location 2
- Emergency generator area – Location 5
- Reagent mix building – Location 6
- Waste oil and wash bay oil tank – Location 7
- Lube building – Location 8
- Gasoline tank near the guardhouse – Location 10
- Faro Pit lube shack – Location 11
- Diesel tank farm – Location 12
- Core shack area – Location 13
- Grum orehaul maintenance shop – Location 15
- Grum lube shop and diesel tanks – Location 17
- Old shop and Grum portal – Location 18

The results show that, in general, the concentrations of lead and zinc detected in the soil samples collected near source areas of petroleum hydrocarbons are indicative of metal contamination from mining and milling activities. Soil samples collected at the Faro mine site contain higher concentrations of lead and zinc than samples collected at the Grum mine site. The highest concentrations of lead and particularly zinc were found in soil samples collected near the Faro milling area, near the concentrate load-out. The highest concentration of zinc was detected in a soil sample collected along the west side of the Reagent Storage building, in the area noted to contain a strong chemical odor (RMB 2). The source of the chemical odor and zinc concentration has not been identified.

The major source of metal contamination in surface soils within the Faro mill area is therefore likely attributed to the presence of concentrate storage areas and vehicle tracking within the mine and mill site areas.

Metal concentrations in soil samples were also determined from two areas, outside the Rose Creek Tailings Facility, where tailings have been historically deposited:

- Emergency Tailings Disposal Area located just below the Concentrate Loadout (Figure 7.1)
- Old Tailings Spill Area downstream of the Rose Creek Tailings Facility.

The results of this analysis are also summarized in Table 7.3. In the old spill region, levels of arsenic, copper, lead and zinc were elevated compared to background soil concentrations (RCB 3). None of the levels were found to exceed the YCSR Industrial Standard. Although arsenic, copper, lead and zinc levels in the old tailings are above CCME industrial guideline. The presence of these elevated levels of metals in soil in this area may be a potential concern from an aquatic habitat point of view, providing a source of metals to the downstream receiving environment.

In the Emergency Tailings Disposal Area, samples taken adjacent to the tailings pipeline were found to have levels of arsenic, copper and zinc above the YCSR Industrial Standard. The other samples also contained elevated levels of lead, copper and zinc, although only TD 1 had zinc levels above the Yukon Industrial Standard.

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Table 7.1 Anvil Range Mining Complex - Faro - Phase 1 ESA - Limited Soil Sampling Program

Extractable Petroleum Hydrocarbons and BTEX Compounds in Soil (ug/g)

Sample Location	CCME[a]	YCSR[b]	Truck Laydown Area			Temporary Drum Storage			Waste Oil Handling Area		Tank Cradle	Tank & Pumphouse		Emergency Generator &	
Location Number			1			2			2a		3	4		5	
Sample ID			TLA 1	TLA 2	TLA 3	TDS 1A	TDS 2A	TDS 3A	WHA 2	WHA 3	TC 2	TP 1	TP 2	EG 1	EG 2
Sample Depth (m)			0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1
Extractable Hydrocarbons															
EPH (C10-19)	-	2000	<200	<200	<200	<200	<200	<200	569	***7940***	<200	***30500***	<200	<200	***5400***
EPH (C19-32)	-	5000	556	272	732	512	<200	<200	2810	***9340***	306	3480	<200	<200	1310

Sample Location	CCME[a]	YCSR[b]	Reagent Mix Bldg.		Waste Oil & Wash Bay Tanks			Lube Bldg.		Gasoline Tank Near Guardhouse			
Location Number			6		7			8		10			
Sample ID			RMB 1	RMB 2	WOT 1	WOT 2	WOT 3	LB 1	LB 2	GT 1A	GT 1B	GT 2A	GT 3A
Sample Depth (m)			0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1
Extractable Hydrocarbons													
EPH (C10-19)	-	2000	227	<200	<200	<200	***4640***	788	298	-	1340	-	-
EPH (C19-32)	-	5000	***5350***	1200	251	920	310	3990	4100	-	<200	-	-
Non-halogenated Volatiles													
Benzene	5	8	-	<0.04	-	-	-	-	-	0.08	-	0.14	0.97
Ethylbenzene	20	50	-	<0.05	-	-	-	-	-	4.89	-	0.09	0.89
Styrene	50	50	-	<0.05	-	-	-	-	-	<0.05	-	<0.05	<0.05
Toluene	0.8	30	-	0.06	-	-	-	-	-	*2.41*	-	0.66	*6.82*
Total Xylenes	20	50	-	0.09	-	-	-	-	-	***95.4***	-	0.51	7.84
VPH	-	200	-	-	-	-	-	-	-	***741***	-	<100	<100

Sample Location	CCME[a]	YCSR[b]	Faro Lube Shack				Tank Farm				Coreshack Area		Tank Pad	
Location Number			11				12				13		14	
Sample ID			FLS 1	FLS 2	FLS 3	FLS 4	TF 1	TF 2	TF 3	TF 4	CA 1	CA 3	TAP 1	TAP 2
Sample Depth (m)			0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1
Extractable Hydrocarbons														
EPH (C10-19)	-	2000	***2300***	***3690***	***10000***	***3480***	***9340***	<200	<200	***26200***	***12400***	***2540***	404	1870
EPH (C19-32)	-	5000	1070	1490	4670	***6790***	1420	463	<200	737	3570	2310	<200	254
Non-halogenated Volatiles														
Benzene	5	8	-	-	0.01	-	-	-	-	-	-	-	-	-
Ethylbenzene	20	50	-	-	<0.01	-	-	-	-	-	-	-	-	-
Styrene	50	50	-	-	<0.01	-	-	-	-	-	-	-	-	-
Toluene	0.8	30	-	-	0.04	-	-	-	-	-	-	-	-	-
Total Xylenes	20	50	-	-	0.09	-	-	-	-	-	-	-	-	-
VPH	-	200	-	-		-	-	-	-	-	-	-	-	-

Notes: *"<" = less than the analytical detection limit*

[a] CCME. 1999. Canadian Soil Quality Guidelines for Protection of Environmental Quality and Human Health

[b] Government of Yukon. 1997. Contaminated Sites Regulation. Generic and Matrix Numerical Soil Standards

Italic	*Exceeds CCME Industrial Guidelines*
Bold, Italic	*Exceeds the Yukon CSR standards for industrial land use*

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Table 7.1 Anvil Range Mining Complex - Faro - Phase 1 ESA - Limited Soil Sampling Program cont.

Extractable Petroleum Hydrocarbons and BTEX Compounds in Soil (ug/g)

Sample Location	CCME[a]	YCSR[b]	Grum Orehaul Maintenance Area			Grum Administration Area		Lube Shop & Diesel Tanks				Old Shop & Grum Portal	
			15			16		17				18	
Sample ID			OMS 2	OMS 3	OMS 4	GAA 2	GAA 3	GLS 1	GLS 2	GLS 3	GLS 5	OS 1	OS 4
Sample Depth (m)			0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1	0-0.1
Extractable Hydrocarbons													
EPH (C10-19)	-	2000	1980	***7980***	***4150***	-	<200	248	<200	***3550***	***9280***	<200	<200
EPH (C19-32)	-	5000	2870	4070	2250	-	<200	<200	<200	376	444	<200	<200
Non-halogenated Volatiles													
Benzene	5	8	-	-	-	<0.04	<0.04	-	-	-	-	-	-
Ethylbenzene	20	50	-	-	-	<0.05	<0.05	-	-	-	-	-	-
Styrene	50	50	-	-	-	<0.05	<0.05	-	-	-	-	-	-
Toluene	0.8	30	-	-	-	<0.05	<0.05	-	-	-	-	-	-
Total Xylenes	20	50	-	-	-	<0.05	<0.05	-	-	-	-	-	-
VPH	-	200	-	-	-	<100	<100	-	-	-	-	-	-

Notes:

"<" = less than the analytical detection limit

[a] CCME. 1999. Canadian Soil Quality Guidelines for Protection of Environmental Quality and Human Health

[b] Government of Yukon. 1997. Contaminated Sites Regulation. Generic and Matrix Numerical Soil Standards

Italic	*Exceeds CCME Industrial Guidelines*
Bold, Italic	*Exceeds the Yukon CSR standards for industrial land use*

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Table 7.2 Anvil Range Mining Complex - Faro
Phase 1 ESA - Limited Soil Sampling Program
PAHs, PCBs and Chlorinated Phenols in Soil (ug/g)

Sample Location	CCME[a] Industrial Guideline	YCSR[b] Industrial Standard	Old Shop & Grum Portal		Faro Lube Shack	Orehaul Maintenance Shop
Location Number			18		11	15
Sample ID			OS 3	OS 4	FLS 3	OMS 1
Physical Tests						
pH			7.94	7.87	-	-
Polycyclic Aromatic Hydrocarbons						
Acenaphthene	-	-	0.01	-	<0.8	-
Acenaphthylene	-	-	0.01	-	<0.2	-
Anthracene	-	-	0.03	-	0.3	-
Benz(a)anthracene	10	10	0.01	-	<0.1	-
Benzo(a)pyrene	0.7	10	<0.01	-	0.02	-
Benzo(b & k)fluoranthene	10	10	0.01	-	<0.01	-
Dibenz(a,h)anthracene	10	10	<0.01	-	<0.01	-
Benzo(g,h,i)perylene	-	-	<0.01	-	<0.01	-
Benzo(k)fluoranthene	-	10	0.12	-	<0.1	-
Chrysene	-	-	<0.01	-	<0.01	-
Fluoranthene	-	-	0.17	-	0.1	-
Fluorene	-	-	0.05	-	1.2	-
Indeno(12,3)pyrene	10	10	<0.01	-	<0.01	-
Naphthalene	22	50	<0.01	-	<0.8	-
Phenanthrene	50	50	1.15	-	2.2	-
Pyrene	100	100	0.55	-	0.8	-
Total Polychlorinated Biphenyls	33	15	-	-	-	<0.05
Chlorinated Phenolics						
2,3,4-Trichlorophenol	5	5	<0.02	-	-	-
2,3,5-Trichlorophenol	5	5	<0.02	-	-	-
2,4,5-Trichlorophenol	5	5	<0.02	-	-	-
2,4,6-Trichlorophenol	5	5	<0.02	-	-	-
2,3,4,5-Tetrachlorophenol	5	5	0.08	-	-	-
2,3,4,6-Tetrachlorophenol	5	5	0.2	-	-	-
2,3,5,6-Tetrachlorophenol	5	5	0.08	-	-	-
Pentachlorophenol	7.6	50	*24.5*	-	-	-

Notes: "<" = denotes less than the analytical detection limit

[a] *CCME. 1999. Canadian Soil Quality Guidelines for Protection of Environmental Quality and Human Health.*

[b] *Government of Yukon. 1997. Contaminated Sites Regulation. Generic and Matrix Numerical Soil Standards*

Italic	*Sample exceeds CCME Industrial Guideline*
Bold, Italic	*Sample exceeds Yukon CSR Industrial Standard*

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Table 7.3 Anvil Range Mining Complex - Faro - Phase 1 ESA - Limited Soil Sampling Program

Metal Concentrations in Soil (ug/g)

Sample Location	CCME[a] Industrial Guideline	YCSR[b] Industrial Standard	Rose Creek			Emergency Tailings Disposal Area			Truck Laydown Area		Temporary Drum Storage Area	Emergency Generator	Reagent Mix Bldg.	Lube Bldg.
Location Number						20			1		2	5	6	8
Sample ID Sample Depth (m)			RC#1	RC#2	RCB#3	TD#1	TD#2	TD#3	TLA 1	TLA 3	TDS 3A 0.1-0.2m	EG 2	RMB 2	LB 1
Physical Tests														
pH			3.06	3.67	5.52	8.09	2.16	3.21			6.23			
Total Metals														
Antimony	40	40	<20	<20	<20	<20	<40	<20			26			
Arsenic	12	60	*53*	*18*	*16*	*16*	***346***	*16*			*53*			
Barium	2000	2000	146	669	362	178	4	373			34			
Beryllium	8	8	1.2	0.8	0.8	0.7	<1	<0.5			0.6			
Cadmium	22	8-650[c]	<0.5	<0.5	1.2	1.9	2.1	0.9			14.1			
Chromium	87	60	55	36	56	40	8	12			23			
Cobalt	300	300	11	10	14	10	103	4			10			
Copper	91	250	*95*	36	38	52	***864***	64			*195*			
Lead	600	2000	*723*	98	60	*1240*	209	553	***3530***	***2110***	***9550***	164	492	***2210***
Mercury	50	10	0.553	0.094	0.052	0.95	8.23	0.252			5.87			
Molybdenum	40	40	<4	<4	4	<4	<8	<4			<4			
Nickel	50	500	35	25	50	29	<10	8			22			
Selenium	10	10	<2	<2	<2	<2	<2	<2			<2			
Silver	40	20	<2	<2	<2	<2	16	<2			12			
Tin	300	300	<10	<10	<10	<10	<20	<10			<10			
Vanadium	130	-	64	46	75	37	20	27			34			
Zinc	360	600	*433*	108	198	*1280*	***2670***	*568*	***4760***	***2730***	***10500***	***4590***	***16600***	***3250***

Notes: "<" = *denotes less than the analytical detection limit*

[a] *CCME. 1999. Canadian Soil Quality Guidelines for Protection of Environmental Quality and Human Health.*

[b] *Government of Yukon. 1997. Contaminated Sites Regulation. Generic and Matrix Numerical Soil Standards.*

[c] *Standard varies with soil pH*

italics	*Sample exceeds CCME Industrial Guideline*
bold, italics	*Sample exceeds Yukon CSR Industrial Standard*

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Table 7.3 Anvil Range Mining Complex - Faro - Phase 1 ESA - Limited Soil Sampling Program cont.

Metal Concentrations in Soil (ug/g)

Sample Location	CCME[a] Industrial Guideline	YCSR[b] Industrial Standard	Waste Oil & Wash Bay Tanks	Gasoline Tank Near Guardhouse	Faro Lube Shack		Oil Tank Farm	Coreshack Area	Orehaul Maintenance Shop	Grum Lube Shop & Diesel Tanks		Old Shop & Grum Portal
Location Number			7	10	11		12	13	15	17		18
Sample ID			WOT 2	GT 3B	FLS 1	FLS 4	TF 2	CA 3	OMS 4	GLS 1	GLS 2	OS 4
Sample Depth (m)				0.2-0.3								
Physical Tests												
pH												7.87
Total Metals												
Antimony	40	40										<20
Arsenic	12	60										*52*
Barium	2000	2000										224
Beryllium	8	8										0.5
Cadmium	22	8-650[c]										1.4
Chromium	87	60										44
Cobalt	300	300										16
Copper	91	250										47
Lead	600	2000	81	***4800***	*1140*	***2370***	*805*	*1220*	*636*	547	152	257
Mercury	50	10										0.264
Molybdenum	40	40										<4
Nickel	50	500										48
Selenium	10	10										<2
Silver	40	20										<2
Tin	300	300										<10
Vanadium	130	-										35
Zinc	360	600	223	***4150***	***1890***	***10100***	***2340***	***1150***	***1220***	***825***	174	*570*

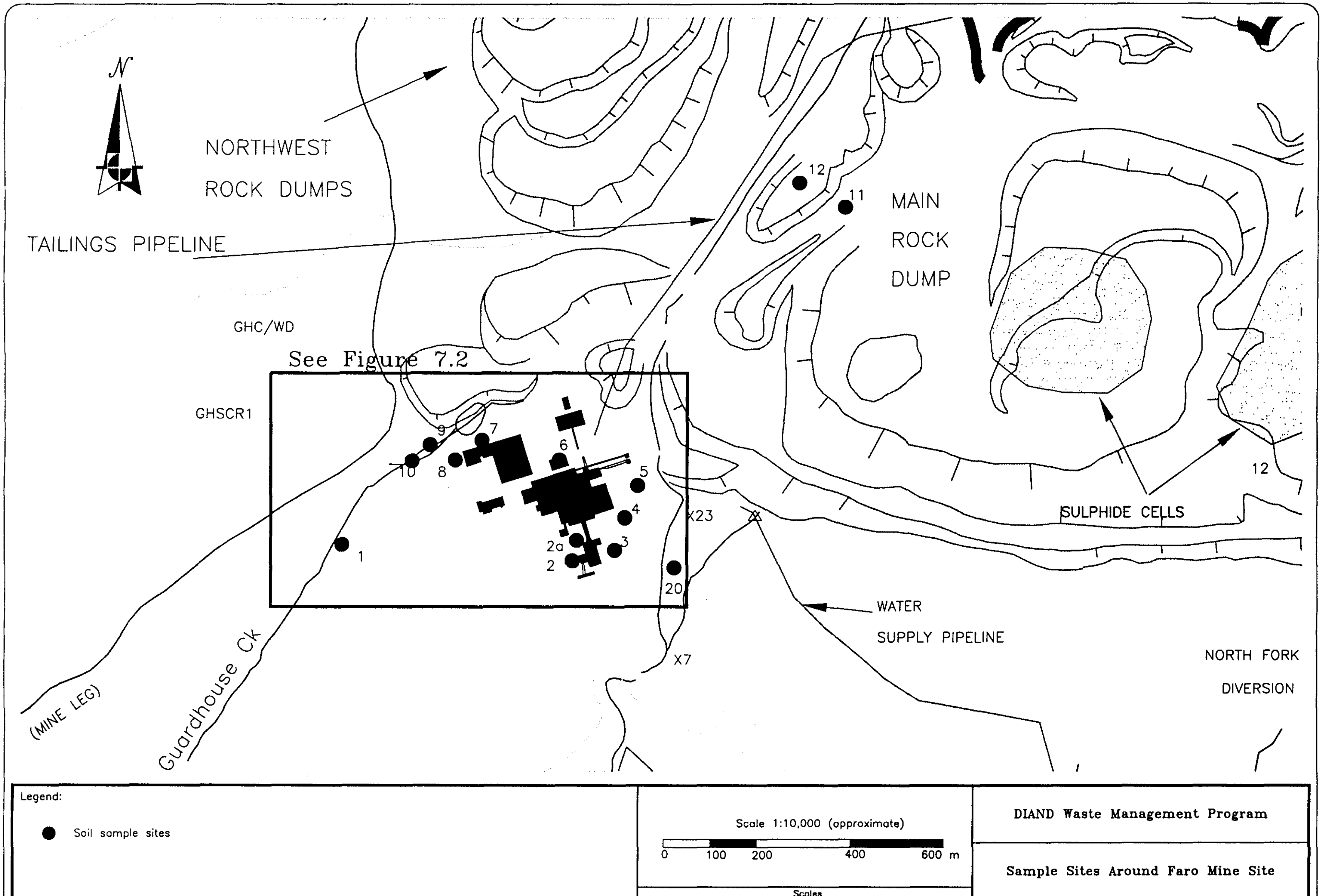
Notes: "<" = denotes less than the analytical detection limit

[a] CCME. 1999. Canadian Soil Quality Guidelines for Protection of Environmental Quality and Human Health.

[b] Government of Yukon. 1997. Contaminated Sites Regulation. Generic and Matrix Numerical Soil Standards.

[c] Standard varies with soil pH

italics	*Sample exceeds CCME Industrial Guideline*
bold, italics	*Sample exceeds Yukon CSR Industrial Standard*



Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Faro Mine	File Name:	FARO_10.DWG

DIAND Waste Management Program

Sample Sites Around Faro Mine Site

Gartner Lee Limited

Figure No. 7.1

Legend:

● Soil sample sites

Scale 1:500 (approximate)

0 5 10 20 30 m

Scales

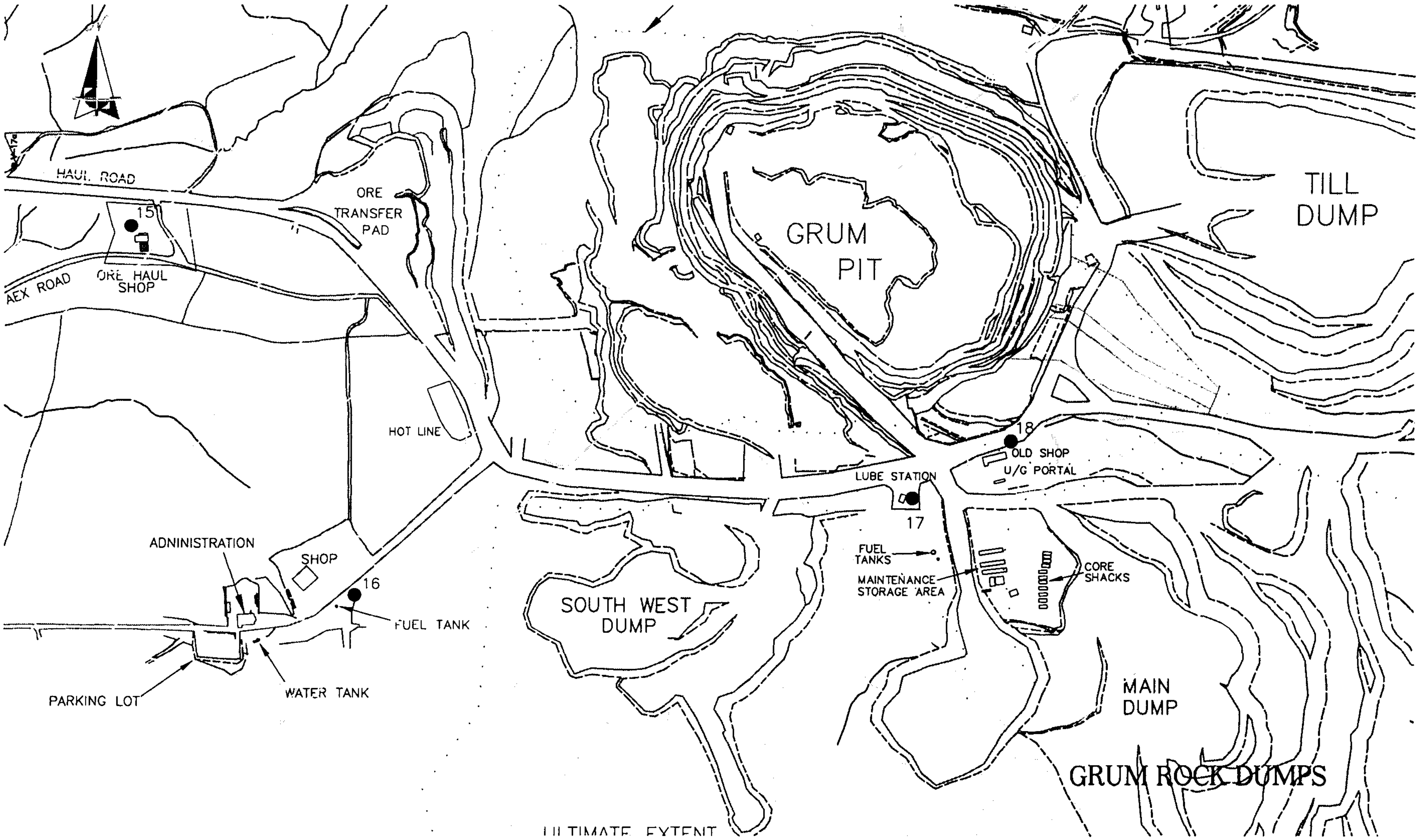
Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Location	File Name:	faro_air.dwg

DIAND Waste Management Program

Sample Sites Around Mill Area

Gartner Lee Limited

Drawing No. 7.2



Legend:

● Soil sampling sites

Scale 1:100,000 (approximate)

0 1000 2000 4000 6000 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Vangorda Plateau	File Name:	fig4_2.dwg

DIAND Waste Management Program

Sample Sites on Vangorda Plateau

Gartner Lee Limited

Figure No. 7.3

7.3 Water Quality Assessment

Surface and ground water quality sampling analysis has been carried out over the years of mine operation by both the mine operators and regulatory authorities. The licence specific water sampling stations for the Faro Mine Site are given in Table 7.4 and for the Vangorda Plateau are given in Table 7.5. The respective locations of these stations are shown in Figures 7.4 and 7.5. The licence sampling requirements for the present period of temporary cessation of operations differ from those for normal mine operations. The maximum allowable discharge limits are given in Table 7.6.

An overview of surface and groundwater quality for 1999 is given in the following sections and summarized in Tables 7.7 through 7.10 for the Faro Site and in Tables 7.11 through 7.13. A description of data for the most recent complete calendar year is considered appropriate for the mandate of this report. The following sections are based on the Anvil Range Mining Corporation 1999 Annual Environmental Reports for the Faro and Vangorda Plateau sites as filed with the Yukon Territory Water Board in March 2000.

7.3.1 Faro Pits And Rock Dumps

Near surface water chemistry in the Faro Main Pit (location X22B) is generally indicative of buffered acid rock drainage with elevated metals and sulphate at neutral pH (Table 7.7). This type of water chemistry is as expected for this location given the presence of mineralized rock dumps and pit walls in the drainage area and the inflow (to February 1998) of lime treated tailings slurry. It is possible that the elimination of the substantial inflow of high pH water via the tailings slurry in February 1998 could result in a long term deterioration of water quality. A total of 1.1 million m^3 of water was pumped from the Faro Main pit from May through August 1999 and was treated with lime and discharged as effluent via the Intermediate and Cross Valley ponds.

Water pH at location X22B was neutral in 1999 and ranged from 6.8 to 7.7 with an average of 7.3. The concentration of total ammonia was elevated above background (0.3 to 1.4 mg/L in 1999 with an average of 0.8 mg/L) due, likely, to leaching of residual blasting agents from surrounding rock dumps and tailings slurry. The 1999 concentrations of total zinc and sulphate in the Faro Main Pit Surface water ranged from 2.6 to 17.0 mg/L and from 190 to 692 mg/L, respectively, with average annual concentrations of 7.2 and 530 mg/L, respectively.

Depth profiling in the Faro Main pit was conducted on one occasion in 1999 by DIAND in July. These results indicated that the pit is not mixed below about 10 metres depth. The concentration of dissolved oxygen was near zero below 25 metres depth and was near saturation above approximately 6 metres depth. This correlated with the findings of previous depth profiles conducted since 1996.

Water chemistry in the backfilled Zone II Pit (location X26) showed elevated metals and sulphate at neutral pH in 1999 (Table 7.7) as was observed in the Main Pit. However, water quality was poorer in the Zone II Pit due, likely, to the absence of a substantial alkaline inflow into the Zone II Pit. The concentration of total zinc ranged from 50.1 to 95.4 mg/L and pH ranged from 5.8 to 6.8 during 1999 at location X26. The concentration of sulphate during 1999 ranged from 1751 to 2630 mg/L. The concentration of total ammonia was elevated (ranged from 1.7 to 2.3 mg/L in 1999) due, likely, to leaching of residual blasting agents from surrounding rock dumps. A total of 73,000 m^3 of water was pumped from the Zone II Pit into the Main Pit during 1999 where the water became part of the Main Pit pumping and treatment program.

Surface seepage from the toe of the main rock dump area is sampled at location X23 located in the old Faro Creek channel where a large portion of the seepage from the Main and Intermediate rock dumps collects (Table 7.8). This water is passed into the Intermediate Impoundment and receives treatment prior to discharge. Water quality is typical of buffered acid rock drainage with elevated metals and sulphate at neutral pH. The pH at location X23 ranged from 5.9 to 7.5 during 1999 with an average for the year of 6.7 and the concentration of total zinc in 1999 ranged from 32.6 to 363.4 mg/L with an average for the year of 97.3 mg/L. The concentration of sulphate in 1999 ranged from 3032 to 3757 mg/L with an average for the year of 3211 mg/L. The concentration of total ammonia was slightly elevated above background (0.2 to 1.5 mg/L in 1999) due, likely, to leaching of residual blasting agents from surrounding rock dumps. Concentrations of iron and copper at location X23 were relatively low in 1999 and the concentration of copper at X23 during 1999 was within the maximum allowable discharge limit of 0.20 mg/L (total). The concentrations of most metals and sulphate exceeded the CCME guidelines for protection of freshwater aquatic life as listed in Table 7.8.

7.3.2 Faro Intermediate (Tailings) Pond

The 1999 concentrations of total zinc at the outflow from the Intermediate Pond (location X4) ranged from 0.5 to 4.5 mg/L and the concentration of dissolved zinc ranged from 0.3 to 3.2 mg/L (Table 7.9). Water pH at location X4 was neutral to alkaline in 1999 (range from 6.5 to 8.5). The concentration of sulphate at location X4 ranged from 51 to 776 mg/L during 1999 with an average of 534 mg/L. The wide variations in pH and the concentrations of sulphate and zinc is related to the summer inflow of a relatively large volume of water from the Faro Main Pit that was pre-treated with lime.

The concentration of ammonia at location X4 in 1999 was similar to the concentration of ammonia in the Faro Main Pit. The range in concentrations of ammonia at location X4 during 1999 was from 0.1 to 1.4 mg/L with an average of 1.0 mg/L.

7.3.3 Faro Effluent Discharge

The two licenced surface effluent discharge locations for the Faro site are locations X5 and X13 (Table 7.9). A total of 1.76 million m^3 of effluent was discharged into Rose Creek via location X5 in 1999 at flow rates varying from 0 to 325 litres per second. A total of 1.71 million m^3 of water was discharged into Rose Creek via location X13 in 1999 at flow rates varying from 44 to 82 litres per second.

The first discharge of effluent via location X5 in 1999 was early in May following start up of the Faro Main Pit pumping system. The concentration of total zinc was indicated to be greater than the maximum allowable discharge limit of 0.5 mg/L by in-house analysis and discharge was immediately halted. Discharge was resumed on an intermittent basis on May 17. Continuous discharge related to pumping from the Faro Main Pit commenced on June 25 and continued through September 20 with only brief periods of no discharge. There was no discharge of effluent in 1999 after September 10.

The analytical results for samples at locations X5 and X13 show that these discharges were within the maximum allowable discharge limits in 1999 with only rare excursions as described below (Table 7.9). Numerous in-house analyses for zinc were also performed for location X5 during periods of discharge.

The concentration of total suspended solids (TSS) at location X5 on July 27 was 19 mg/L, which was greater than the maximum allowable discharge limit of 15 mg/L. The concentration of TSS had fallen to 7 mg/L on July 29. The cause of this brief exceedance is unknown. There were no other reported exceedances of the maximum allowable discharge limits at location X5 in 1999.

The pH at location X13 on December 14 was 6.3 which was less than the minimum allowable discharge limit of 6.5. Also, the concentration of ammonia (NH3) at location X13 on December 14 was 1.37, which is greater than the maximum allowable discharge limit of 1.3 mg/L. The cause of these isolated exceedances is unknown. There were no other reported exceedances of the maximum allowable discharge limits at location X13 in 1999.

All of the bioassay tests performed during 1999 for locations X5 and X13 were passed and all tests were non-lethal (no mortalities). There were three tests performed for location X5 (May, June and September) and four tests performed for location X13 (March, June, September and December). The bioassays were 96 hour LC_{50} tests using rainbow trout in which a pass is considered to be greater than 50% of the fish alive in 100% solution strength after 96 hours.

7.3.4 Rose Creek Background and Receiving Water

7.3.4.1 North Fork of Rose Creek

The potential for impacts on surface water in the North Fork of Rose Creek from the Faro Creek diversion, seepage from the Zone II Pit, and some rock dumps is monitored at locations R7 through R10 and location X2 in the North Fork of Rose Creek. Locations R7 and R8 are immediately upstream and downstream, respectively, of the confluence with the Faro Creek diversion. Location R9 is approximately adjacent to the area of the Zone II Pit. Location R10 is downstream of the Zone II Pit area and upstream of the rock drain in the Vangorda ore haul road. Location X2 is below the rock drain at the crossing of the mine access road. Analytical data for 1999 is listed in Table 7.10. The concentrations of some metals at all of these locations exceeded the CCME guidelines for protection of freshwater aquatic life.

A comparison of water quality at locations R7 and R8 suggests that, in 1999, a spring spike in the concentration of total zinc in the Faro Creek diversion caused a brief observable response at location R8. The concentrations of total zinc at locations R7, R8 and in the Faro Creek diversion on May 17, 1999 were 0.04, 0.04, and 0.09 mg/L, respectively. The data indicate that this was a brief event and that the concentrations of total zinc at locations R7 and R8 were at similar low levels (0.01 mg/L) in October 1999. There was no corresponding spring peak in the concentration of sulphate nor any corresponding spring dip in pH at location R8 as compared to location R7 in 1999.

A comparison of water quality at locations R8, R9 and R10 suggests that there was no significant impact on surface water in the North Fork of Rose Creek from the north east rock dumps or from the Zone II Pit area. The concentrations of total zinc, sulphate, pH and other parameters are relatively similar at these three locations, although a new trend of slightly higher concentrations at location R9 and lower concentrations at location R8 is appearing.

The North Fork of Rose Creek is monitored at location X2 prior to joining with the South Fork. The additional mine site influences at location X2 which may not be present at upstream location R10 are surface run off and seepage from the eastern portion of the main rock dump and the rock drain in the Vangorda ore haul road. The concentration of total zinc at location X2 during 1999 (Table 7.10) was generally within the range observed since 1988 (0.01 to 0.35 mg/L). The concentration of total zinc in 1999 at X2 ranged from <0.01 to 0.09 mg/L during 1999 with an average concentration of 0.03 mg/L. The range in concentration of dissolved zinc in 1999 at location X2 was lower, ranging between <0.01 to 0.03 mg/L.

7.3.4.2 Rose Creek Diversion Channel

Rose Creek is monitored at location X3, the outflow from the pumphouse pond immediately upstream of the diversion channel. The water monitored at location X3 includes all flow from the South Fork of Rose Creek via the freshwater reservoir and a large portion the flow from the North Fork of Rose Creek via location X2. A small portion of the flow from the North Fork of Rose Creek bypasses the pumphouse pond.

Water sampling at location X3 in 1999 (Table 7.10) indicated that the concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life. The concentrations of total and dissolved zinc at location X3 in 1999 ranged from <0.01 to 0.06 mg/L and from <0.01 to 0.03 mg/L, respectively, with averages for the year of 0.03 and 0.01 mg/L, respectively. The concentration of sulphate at location X3 in 1999 ranged from 4 to 27 mg/L with an average for the year of 17 mg/L.

Rose Creek was monitored near the downstream end of the diversion channel at location X10 in 1999. The potential influences on water quality between locations X3 and X10 are inflows from two side creeks and possible lateral seepage from the tailings impoundments. The water quality at location X10 in 1999 (Table 7.10) was similar to that at upstream location X3 although the concentrations of zinc and sulphate were very slightly greater at location X10 as was observed in previous recent years. The concentrations of total and dissolved zinc at location X10 in 1999 ranged from 0.04 to 0.08 mg/L and from <0.01 to 0.04 mg/L, respectively, with averages for the year of 0.06 and 0.02 mg/L, respectively. The concentration of sulphate at location X10 in 1999 ranged from 5 to 23 mg/L with an average for the year of 13 mg/L. The concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life.

7.3.4.3 Rose Creek Immediately Downstream of Mine Discharges

Rose Creek immediately downstream of the confluence with effluent discharges and downstream of the diversion channel is monitored at location X14. The analytical data for 1999 (Table 7.10) indicate that the concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life.

The concentrations of sulphate at location X14 in 1999 ranged from 23 to 326 mg/L with an average for the year of 142 mg/L. The concentrations of total and dissolved zinc at location X14 in 1999 ranged from 0.02 to 0.08 mg/L and from <0.01 to 0.03 mg/L, respectively, with averages for the year of 0.05 and 0.01mg/L, respectively. The peak concentration of total zinc in 1999 (0.08 mg/L) at location X14 occurred in December and corresponded to an elevated concentration at upstream location X10 (there was no effluent discharge at that time via location X5).

The average annual and peak concentrations of ammonia at location X14 were 0.16 and 0.35 mg/L, respectively, during 1999. These levels of total ammonia are well within the Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life. The Guidelines indicate that the lowest recommended limit for Rose Creek in the course of a typical year would be 0.93 mg/L for pH of 8 and temperature at 20° C. The guidelines take into consideration the effects of temperature and pH on the toxicity and proportion of un-ionized ammonia.

All of the 6 analyses for total cyanide in 1999 at location X14 were no greater than 0.02 mg/L and three were less than the method detection limit of 0.01 mg/L. All of the 6 analyses for WAD cyanide were less than the method detection limit of 0.01 mg/L.

7.3.4.4 Rose Creek at Anvil Creek

The mouth of Rose Creek at the confluence with Anvil Creek (location R4) was sampled in March 1999 (Table 7.10). This sample contained a moderate concentration of sulphate (149 mg/L) and a low concentration of ammonia (<0.05 mg/L). The concentrations of total and dissolved zinc were 0.05 and <0.01 mg/L, respectively. The source of the total zinc at location R4 is unknown. There was no discharge of effluent via location X5 at that time. The concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life as listed in Table 7.9.

7.3.5 Rose Creek Valley Groundwater Quality

Groundwater in the aquifer underlying and downstream of the Down Valley tailings impoundments was monitored during 1999 at piezometers X16 through X19, X21-96, X24-96, and X25-96. The "-96" label indicates that these piezometers were installed in 1996 as replacements for previously destroyed installations. Additional sampling of these and other piezometers was conducted in September 1999 by Environment Canada personnel. The analytical data for 1999 is listed in Table 6.1 and 6.4 and the concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life in most of these piezometers.

Piezometers X21-96 (three installations) are located at the toe of the Second tailings impoundment and provide an indication of groundwater chemistry within and immediately underlying the tailings mass. Piezometer X21A-96 is installed in the tailings mass and is used for static water level measurements and is not equipped with a sampler. Piezometers X21B-96 and X21C-96 are installed in the underlying aquifer with X21C-96 at the greatest depth.

The concentrations of dissolved zinc were very similar in piezometers X21B-96 and X21C-96 in 1999 and were low ranging from <0.01 mg/L in the spring to 0.04 mg/L in the fall. The concentrations of sulphate displayed a different trend wherein the concentrations were not similar in piezometers X21B-96 and X21C-96 in 1999. The spring/fall 1999 concentrations of sulphate were 405/504 mg/L and 10/942 mg/L in piezometers X21B-96 and X21C-96, respectively. The high concentration of sulphate in piezometer X21C-96 in fall 1999 (942 mg/L) is atypical for this location where concentrations of less than about 50 mg/L have been recorded in the past.

Piezometers X24-96 (four installations) and X25-96 (two installations) are located at the toe of the Intermediate dam and are installed at various depths up to 28 metres into the aquifer. Groundwater chemistry in these piezometers is generally characterized by neutral pH, moderately elevated sulphate concentration and low but occasionally measurable dissolved zinc concentration. A slight increasing trend with depth may exist for sulphate. Groundwater quality in the X24 piezometers appears to be slightly poorer than that in the X25 piezometers.

Piezometers X16 through X19 (two installations each) are located downstream of the Cross Valley Dam. Piezometers X16, X17 and X19 form a crude line along the valley bottom with X19 closest to the Cross Valley dam and X16 farthest. Piezometer X18 is located to the north of the valley bottom near and below the Cross Valley Dam.

The concentrations of sulphate in the X16 and X17 piezometers were all below 44 mg/L in 1999. The concentrations of sulphate in the X19 piezometers in 1999 ranged from 159 to 373 mg/L. The concentrations of dissolved zinc were all less than 0.01 mg/L in fall 1999 in the X16, X17 and X19 piezometers and in spring at the X16 piezometers. An unexplained event resulted in elevated concentrations of dissolved zinc in spring 1999 in the X17 and X19 piezometers when the concentrations of dissolved zinc ranged from 0.13 to 0.45 mg/L with the greatest concentration recorded at piezometer

X17A (shallow). These elevated spring 1999 concentrations of dissolved zinc correspond to the elevated concentrations observed at upstream piezometers X24-96 and X25-96.

Both the shallow (10m) and deep (20m) installations in piezometer X18 contained moderately elevated concentrations of sulphate in 1999. The concentrations of sulphate have generally increased from concentrations around 210 mg/L during the period from 1987 to 1992 to around 400 mg/L during the period from 1996 to 1999. The concentrations of dissolved zinc, however, were relatively low in the fall, ranging between <0.01 mg/L and 0.02 mg/L at both installations. As was observed in piezometers X17, X19, X24-96 and X25-96, an unexplained elevated concentration of dissolved zinc of 0.32 mg/L was recorded for piezometer X18A (shallow) in spring 1999.

7.3.6 Other Faro Groundwater Monitoring

Selected piezometers around the Faro site were monitored during 1999 as a continuation of the groundwater surveys performed in previous years. The analytical data for 1999 is listed in Table 6.1 and 6.4 and the concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life at the locations described below.

Shallow groundwater seepage between the Zone II Pit and the North Fork of Rose Creek was monitored on two occasions during 1999 at piezometers BH1 and BH2 and on one occasion in 1999 at piezometer BH4. Piezometer BH2 is closest to the Zone II Pit and BH4 is closest to the North Fork of Rose Creek. In July 1999, the concentrations of dissolved zinc in piezometers BH1 and BH2 were 25.9 mg/L and 9.8 mg/l, respectively, and the concentrations of sulphate were 399 mg/L and 259 mg/L, respectively. In October 1999, the concentrations of dissolved zinc in piezometers BH1, BH2 and BH4 were 3.5 mg/L, 4.2 mg/L and 1.3 mg/L, respectively, the concentrations of sulphate were 150 mg/L, 206 mg/L and 158 mg/L, respectively, and the pH's were 5.8, 5.8 and 6.0, respectively.

Groundwater seepage at the toe of the northeast rock dump above the North Fork of Rose Creek is monitored at piezometers BH12, BH13 and BH14 (two installations each with one installation at BH13 blocked/inaccessible). The concentrations of sulphate at these piezometers remained within or close to the range observed since 1994 with a range in 1999 from 259 to 1063 mg/L. The concentrations of dissolved zinc in these piezometers in 1999 remained within the range observed since 1994 at equal to or less than 0.07 mg/L in 1999 with the exception of installation BH12B where the concentration of dissolved zinc was 0.21 mg/L in October 1999. Groundwater pH remained slightly acidic in 1999 in a range from 5.4 to 6.8 with the lowest pH's recorded at locations BH14A and BH14B.

Lateral groundwater seepage from the main and intermediate rock dumps towards the North Fork of Rose Creek is monitored immediately above the Vangorda haul road at piezometer P96-6 (one installation). The ranges in concentrations of sulphate and dissolved zinc at this location in 1999 were from 341 to 428 mg/L and from 0.41 to 0.76 mg/L, respectively. The groundwater pH at this location remained slightly acidic in 1999 from 5.8 to 6.0.

Lateral groundwater seepage from the main and intermediate rock dumps towards the North Fork of Rose Creek is also monitored immediately below the Vangorda haul road at piezometers S1 (two installations), S2 (two installations) and S3 (one installation). The range in concentrations of sulphate and dissolved zinc at these locations in 1999 was from 345 to 2,533 mg/L and from <0.01 to 0.21 mg/L, respectively, with the exception of an unusually high spike in the concentration of dissolved zinc of 0.61 mg/L at installation S1A in July 1999. These concentrations are within or close to the ranges observed for these piezometers since 1996 with the exception of the unusual spike for dissolved zinc at installation S1A described above. The groundwater pH at these locations remained near neutral in 1999 in a range from 5.6 to 7.7.

Groundwater seepage from the central portion of the main and intermediate rock dumps is monitored close to the toe of the dumps at piezometer P96-7 (one installation). The concentrations of sulphate and dissolved zinc at this location in October 1999 were 1606 mg/L and <0.01 mg/L, respectively, and an increasing trend in the concentration of sulphate may be suggested. The groundwater pH at this location remained neutral in October 1999 at 6.8.

Groundwater seepage from the main and intermediate rock dumps and, possibly, other rock dumps, is monitored at piezometer P96-8 (two installations) located near the old Faro Creek channel and near surface monitoring location X23. Groundwater at this location is of poorer quality than at other seepage locations due likely, to the concentration of seepage flow in the old Faro Creek channel. The range in concentrations of sulphate and dissolved zinc in the P96-8 piezometers in 1999 was from 2290 to 3218 mg/L and from 2.2 to 11.2 mg/L, respectively. While the concentrations of dissolved zinc are within the range observed for these piezometers since 1996, an increasing trend in the concentration of sulphate may be suggested. The groundwater pH remained near neutral in 1999 in a range from 6.2 to 6.7.

7.3.7 Faro Surface Seep Survey

A surface seep sampling campaign was performed in 1999 at the Faro site as continuation of the seep surveys, which were performed in previous years. The sites included Faro Creek Diversion, North Fork of Rose Creek, old Faro Creek channel above the Main Pit, Upper Guardhouse Creek, Guardhouse Creek, North Wall Interceptor ditch, and seepage towards the North Fork of Rose Creek. Data are listed in Tables 7.7 through 7.10.

The following general observations may be made from the 1999 surface water chemistry data:

1. Water quality continues to show significant deterioration upon passage through the Faro Valley rock dump (locations FCO to A30) exhibiting substantial increases in the concentrations of total zinc and sulphate accompanied by lower pH (pH<4 at location A30).
2. The concentration of dissolved zinc increased along the length of the Faro Creek diversion in May 1999 from 0.06 mg/L at location FDU (above the Faro Valley rock dump) to 0.41 mg/L at location FCD (adjacent to the NE rock dumps). It then dropped to 0.08 mg/L at location FAROCR (above the confluence with the North Fork of Rose Creek). This increase was not consistent with the central location (FCD) showing the greatest concentration. There was also a corresponding slight increase in

the concentration of sulphate in May 1999 from 2 mg/L at location FDU to 34 mg/L at location FAROCR. The concentrations of total and dissolved zinc were all less than 0.01 mg/L at locations FDU and FAROCR in October 1999.

3. Water chemistry in lower Guardhouse Creek (GC) which reports to the Intermediate tailings impoundment was consistent in July 1999 with that observed since 1996; the concentrations of total and dissolved zinc in July 1999 were 1.7 and 4.0 mg/L, respectively.
4. Water chemistry at the south abutment of the Intermediate dam which reports to the Cross Valley pond (IDSEEP) was good in July 1999; the concentrations of dissolved zinc and sulphate were 0.02 and 278 mg/L, respectively.
5. Water quality at three small intermittent surface flows below the north east rock dumps (locations NE1, NE2 and NE3) showed one slightly elevated concentration of dissolved zinc in May 1999 of 0.24 mg/L at location NE3. The remaining concentrations of dissolved zinc in May 1999 were within the range observed at these locations since 1997 (less than 0.07 mg/L). The concentrations of dissolved zinc in July and October 1999 were all less than 0.01 mg/L where water was present. The concentrations of sulphate ranged from 69 to 560 mg/L during 1999 which were within the range observed at these locations since 1996.
6. Water chemistry upstream and downstream of the Vangorda haul road rock drain (locations NF1 and NF2) showed that the rock drain was not impacting on surface water chemistry. the concentrations of total suspended solids were 8 mg/L in July 1999 at both locations and decreased from 18 to 16 mg/L in October 1999. The concentrations of total and dissolved zinc at both locations were all less than or equal to 0.03 mg/L in 1999.
7. The concentrations of total and dissolved zinc at location NWINT in the North Wall Interceptor ditch in April 1999 were 0.04 and 0.02 mg/L, respectively; the concentration of sulphate in April 1999 was 19 mg/L although the concentration of total suspended solids was elevated at 71 mg/L.
8. Water chemistry at location SP5-6 (intermittent surface flow from the north east rock dumps which reports to the Main Pit) in May 1999 was slightly poorer than that observed in 1998. The concentrations of dissolved zinc and sulphate in April 1999 were 27.0 and 733 mg/L, respectively, with pH of 5.8.
9. Water chemistry for locations W10 and W8 in Upper Guardhouse Creek showed that water quality was not significantly affected by passage through a corner of the north west rock dump in July 1999. From location W10 to location W8, pH decreased slightly from 8.0 to 7.6, the concentration of total zinc increased slightly from 0.03 to 0.07 mg/L, and the concentration of sulphate increased very slightly from 3 to 5 mg/L.

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Table 7.4 Faro Mine Site Water Sampling Stations

Station #	Station Name
X2	North Fork Rose Creek at Road Bridge
X3	Rose Creek at Freshwater Pumphouse
X4	Intermediate Dam Decant
X5	Cross Valley Dam Decant
X10	Rose Creek Diversion Canal below Weirs
X11	Seepage from North Toe of the Cross Valley Dam
X12	Seepage from South Toe of the Cross Valley Dam
X13	Combined Seepage flows downstream from the Culvert and upstream of the Confluence with the Decant
X14	Rose Creek after mixing downstream of Diversion Channel Confluence
X16A	By Rose Creek downstream of Cross Valley Dam (5 m)
X16B	By Rose Creek downstream of Cross Valley Dam (30 m)
X17A	Downstream of Cross Valley Dam and upstream of X14 across Diversion (5 m)
X17B	Downstream of Cross Valley Dam and upstream of X14 across Diversion (20 m)
X18A	North of Cross Valley Dam and Right of Access Road to X14 (10 m)
X18B	North of Cross Valley Dam and Right of Access Road to X14 (20 m)
X19A	Downstream of Cross Valley Dam by X13 (12 m)
X19B	Downstream of Cross Valley Dam by X13 (27 m)
X21B-96	Toe of Second Impoundment (15.43 m). P96-5B
X21C-96	Toe of Second Impoundment (30.18 m). P96-5C
X22B	Main Pit Water
X23	Pit Drainage at Toe of Waste Dumps
X24A-96	North Abutment of Intermediate Dam (5.88 m), P96-4A
X24C-96	North Abutment of Intermediate Dam (15.87 m), P96-4C
X24D-96	North Abutment of Intermediate Dam (28.22 m), P96-4D
X25A-96	South Abutment of Intermediate Dam (9.65 m), P96-3A
X25B-96	South Abutment of Intermediate Dam (19.80 m), P96-3B
X26	Zone II Pit Water
R4	Rose Creek upstream of Anvil Creek
R7	North Fork Rose Creek above Faro Creek Diversion
R8	North Fork Rose Creek below Faro Creek Diversion
R9	North Fork Rose Creek adjacent to BH1 and BH2
R10	North Fork Rose Creek upstream of Rock Drain
NWINT	Noethwest Interceptor Ditch
FDU	Faro Creek Diversion upstream of Valley Dump
FCD	Faro Creek Diversion adjacent to NE Waste Rock Dumps
FAROCR	Faro Creek Diversion upstream of Confluence with North Fork Rose Creek
FCO	Old Faro Creek upstream of Valley Dump
W8	Upper Guardhouse Creek downstream of Noethwest Dump
W10	Northwest Waste Dump Toe
NF1	North Fork Rose Creek upstream of Haul Road
NF2	North Fork Rose Creek downstream of Haul Road
GC	Guardhouse Creek upstream of Intermediate Dam Impoundment
NE1	Flow to North Fork from Northeast Dumps (closer to R7)
NE2	Flow to North Fork from Northeast Dumps (mid NE1&3)
NE3	Flow to North Fork from Northeast Dumps (further from R7)
A30	Upper Pit Wall Zone MPA6 Sump
SP5-6	Ditch to Main Pit from Northeast Dumps
Weir3	Seepage near South Toe Area of Cross Valley Dam
IDSEEP	Intermediate Dam Seep near West Abutment
P96-6	Toe of Intermediate Dump above Rock Drain (20.85 m)
P96-7	Toe of Main Dump below Haul Road (9.90 m)
P96-8A	Old Faro Creek Channel by X23 (4.87 m)
P96-8B	Old Faro Creek Channel by X23 (9.30 m)
S1A	South of Sulphide Waste Dump (12.80 m)
S1B	South of Sulphide Waste Dump (5.37 m)
S2A	South of Sulphide Waste Dump (8.04 m)
S2B	South of Sulphide Waste Dump (10.60 m)
S3	South of Sulphide Waste Dump (6.56 m)
BH1	Southeast of Zone II by North Fork Rose Creek (5.18 m)
BH2	Southeast of Zone II by North Fork Rose Creek (5.55 m)
BH4	Southeast of Zone II by North Fork Rose Creek (3.20 m)
BH12A	Northeast of Zone II by North Fork Rose Creek (2.85 m)
BH12B	Northeast of Zone II by North Fork Rose Creek (8.05 m)
BH13B	Northeast of Zone II by North Fork Rose Creek (4.25 m)
BH14A	East of Zone II by North Fork Rose Creek (6.22 m)
BH14B	East of Zone II by North Fork Rose Creek (10.00 m)

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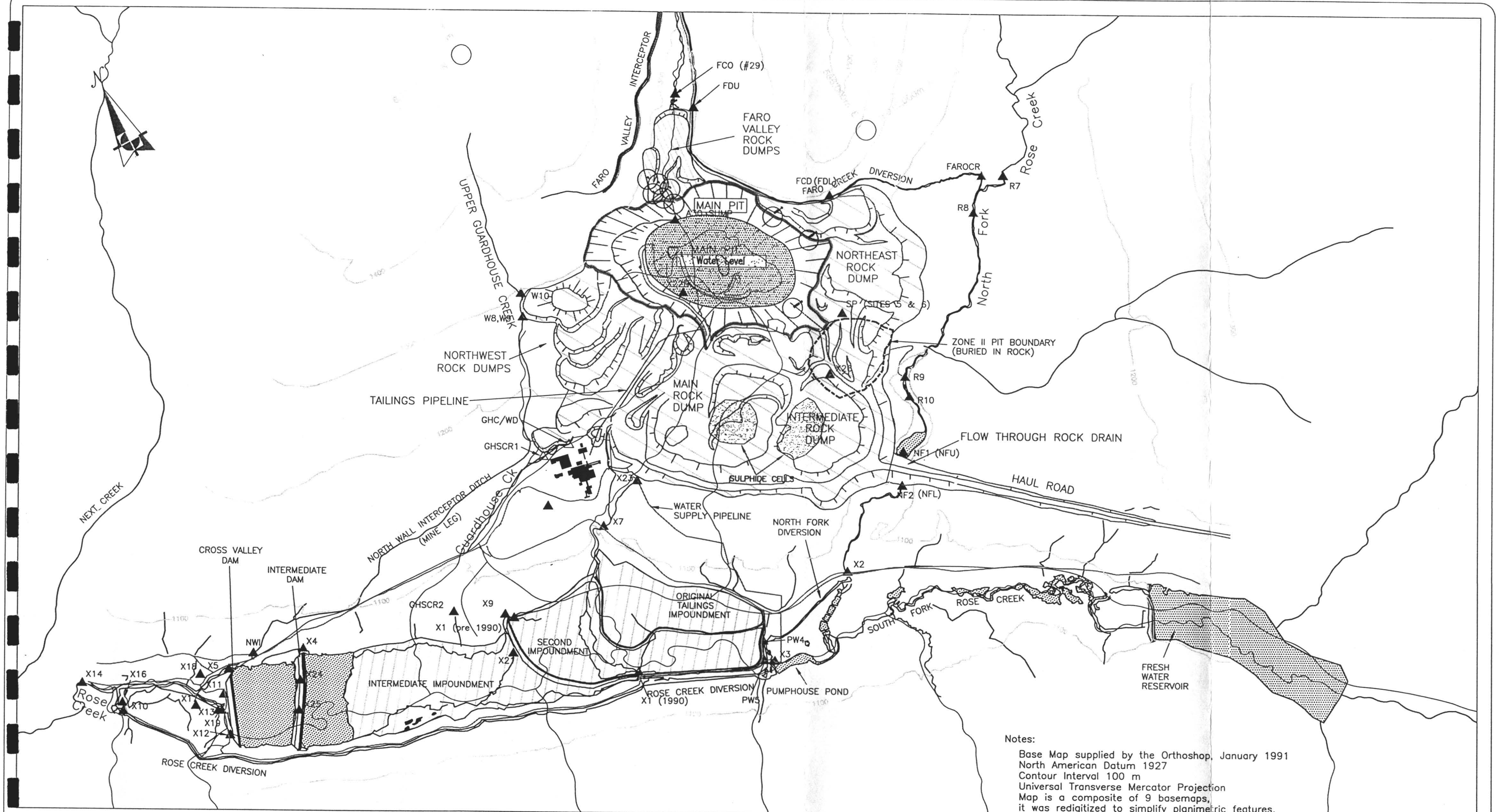
Table 7.5 Vangorda Plateau Water Sampling Stations

Station #	Station Name
V1	Vangorda Creek upstream from the Mine and Blind Creek Road
V2	Grum Creek upstream from the Mine and Blind Creek Road
V2A	Grum Creek Diversion to Moose Pond
V4	Shrimp Creek upstream from its Confluence with Vangorda Creek
V5	West Fork of Vangorda Creek upstream of Mine Access Road
V6A	A small Tributary (AEX Creek) to the West Fork of Vangorda Creek
V8	Vangorda Creek near Bridge to Faro Town Water Supply
V15	Sulphide Cell Sump, Grum Dump
V17A	Runoff from Ore Transfer Pad
V19	Vangorda Pit Northwest Interceptor Ditch
V19Culvert	Vangorda Creek below Haul Road Crossing
V21A	VG Dump Collector Ditch at LCD
V22	Vangorda Pit Water and Vangorda Lake at Closure
V23	Grum Pit Water
V25BSP	Below Sheep Pond at the Weir
V27	Vangorda Creek upstream of Shrimp Creek
V29	Vangorda Dump Drain #2
V30	Vangorda Dump Drain #3
V32	Vangorda Dump Drain #5
V33	Vangorda Dump Drain #6
VGMAIN	Main Fork Vangorda Creek
VGGR	Vangorda Creek at Grum Turn-off
V34	Groundwater Well GW94-01
V35	Groundwater Well GW94-02
V36	Groundwater Well GW94-03
V37	Groundwater Well GW94-04
96-9A	Groundwater at the Toe of Grum Dump
96-9B	Groundwater at the Toe of Grum Dump
GD1	Grum Dump Toe Seep just West of V15
GD2	Seep/Marsh near West End of Grum Dump Toe Road
LCD	Little Creek Dam Pond Water
VGSEEP	Vangorda Pit Ramp Ditch/Seepage



Notes:

Base Map supplied by the Orthoshop, January 1991
North American Datum 1927
Contour Interval 100 m
Universal Transverse Mercator Projection
Map is a composite of 9 basemaps,
it was redigitized to simplify planimetric features.

LEGEND

▲ SNP surface water sampling sites

Data Source: Robertson Geoconsultants Inc.

Scale 1:25,000

0 250 500 1000 1500 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	F.K.P.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Faro	File Name:	fig4_1.dwg

DIAND Waste Management Program

Faro Mine Surface Water Sampling Sites

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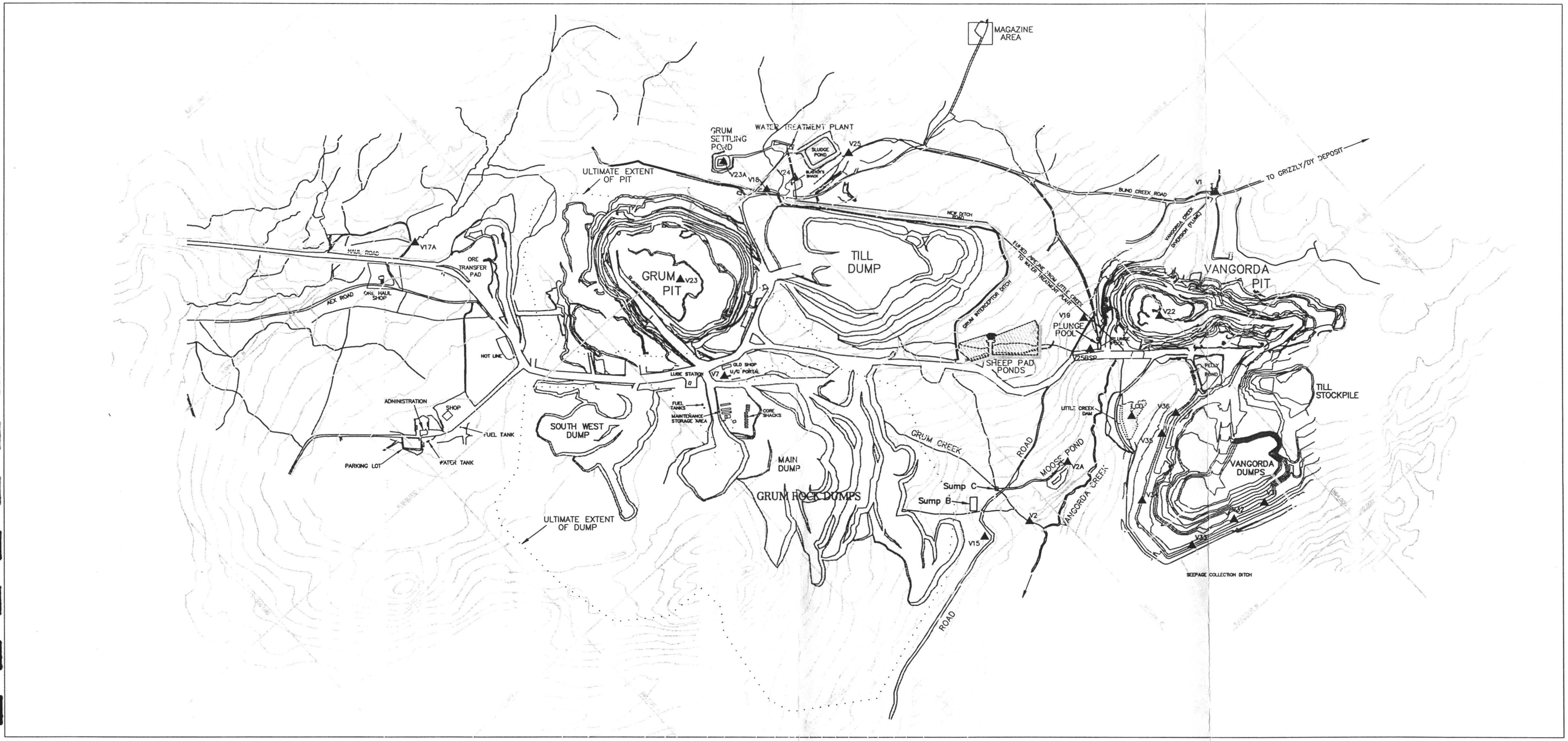
Figure No. 7.4



LEGEND

▲ SNP Sampling Stations

Scale 1:100,000

0 333 667 1000 m

Scales

Designed By:	D.L.	Drawn By:	D.L.
Checked By:	L.G.	Approved By:	L.G.
Date Issued:	03.16.01	Project No.	99-913
Site Name:	Vangorda Plateau	File Name:	fig7_1.dwg

DIAND Waste Management Program

Vangorda SNP Sample Location Map

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Figure No. 7.5

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Table 7.6 Yukon Territory Water Board Licence Limits for Faro and Vangorda

Faro - X5 and X13			
			Units
TSS		15	mg/L
pH		6.5	pH
Colour		20	Pt-Co
Turbidity		15	NTU
Ammonia (as N)	total	1.30	mg/L
Antimony	total	0.10	mg/L
Arsenic	total	0.05	mg/L
Barium	total	1.00	mg/L
Cadmium	total	0.02	mg/L
Copper	total	0.20	mg/L
Cyanide (as CN)	total	**0.05**	mg/L
Lead	total	0.20	mg/L
Mercury	total	0.005	mg/L
Molybdenum	total	0.50	mg/L
Nickel	total	0.50	mg/L
Selenium	total	0.05	mg/L
Silver	total	0.10	mg/L
Zinc	total	**0.50**	mg/L

Vangorda - V2 and V25BSP			
			Units
TSS		15	mg/L
pH		6.5	pH
Colour		20	Pt-Co
Turbidity		15	NTU
Ammonia (as N)	total	3.50	mg/L
Antimony	total	0.10	mg/L
Arsenic	dissolved	0.05	mg/L
Barium	total	1.00	mg/L
Cadmium	total	0.02	mg/L
Copper	total	0.20	mg/L
Cyanide (as CN)	total	**0.05**	mg/L
Lead	total	0.20	mg/L
Mercury	total	0.005	mg/L
Molybdenum	total	0.50	mg/L
Nickel	total	0.50	mg/L
Selenium	total	0.05	mg/L
Silver	total	0.10	mg/L
Zinc	total	**0.50**	mg/L

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Table 7.7. Faro Mine Site Pit Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X22B: Faro Pit Water while filling with Tailings									2BC-X26: Zone II Pit Water (from Well)		A30: Upper Pit Wall Zone MPA6 Sump
Date	CCME [a]	YCSR [b]	19-Jan-99	22-Feb-99	22-Mar-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99	10-Sep-99	30-Oct-99	17-May-99	27-Jul-99	17-May-99
Physical Tests														
pH	6.5-9..0		6.87	7.42	7.11	6.91	7.26	7.74	7.72	7.58	6.85	*5.79*	6.77	*3.06*
Conductivity			-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	98	-	-	-	-
Sulphate (mg/L)		1000	574	692	546	190	478	581	567	507	638	***2630***	***1751***	182
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	***0.53***	***1.35***	***0.74***	***0.33***	***0.94***	***1.15***	-	-	-	***2.29***	***1.72***	-
Total Metals														
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.13***	***0.41***	***0.3***	<0.05	***0.37***	***0.25***	<0.05	***0.2***	***0.12***	***0.27***	***0.2***	-
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	*0.005*	-
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.03***	***0.01***	***0.025***	<0.001	***0.009***	***0.005***	<0.001	***0.008***	<0.001	***0.073***	***0.011***	-
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.05***	***0.066***	***0.062***	***0.02***	***0.04***	***0.033***	*0.018*	***0.027***	*0.013*	***0.047***	*0.019*	-
Iron (mg/L)	0.3	3	0.08	0.024	0.17	0.03	*0.95*	0.24	0.11	0.13	0.29	***118.65***	***143.5***	-
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	***0.09***	***0.062***	***0.056***	*0.02*	***0.073***	***0.069***	***0.041***	***0.06***	*0.039*	***1.386***	***0.944***	-
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	*0.08*	<0.01	*0.04*	<0.01	<0.01	*0.05*	<0.01	<0.01	<0.01	***0.42***	<0.01	-
Silver (mg/L)	0.0001	0.001	<0.003	***0.014***	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	***0.005***	<0.003	-
Zinc (mg/L)	0.03	0.3	***16.95***	***3.92***	***14.98***	***2.56***	***8.5***	***5.56***	***4.19***	***4.11***	***4.31***	***95.45***	***50.11***	-
Dissolved Metals														
Aluminum (mg/L)			<0.05	0.11	0.1	<0.05	0.09	0.12	<0.05	0.08	<0.05	0.19	0.34	0.65
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.013	0.004	0.009	<0.001	0.001	0.003	0.003	<0.001	0.005	0.081	0.037	0.064
Copper (mg/L)			0.018	0.014	0.024	<0.002	0.015	0.008	0.01	0.014	0.01	0.083	0.029	0.188
Iron (mg/L)			<0.01	<0.01	<0.01	<0.01	0.23	0.01	0.04	<0.01	<0.01	2.92	41.75	1.16
Lead (mg/L)			0.079	0.028	0.047	<0.005	0.031	0.044	0.057	0.041	0.036	1.096	1.42	0.048
Nickel (mg/L)			0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.32	<0.01	0.12
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			9.79	0.65	8.35	0.52	5.67	2.28	1.03	0.54	2.26	68.48	64.42	23.04
Cyanide														
WAD Cyanide (mg/L)	0.005	0.05	-	-	<0.01	<0.01	<0.01	<0.01	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	0.01	<0.01	0.01	0.03	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.8. Faro Mine Site Waste Rock Dump Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X23: Pit Drainage at Toe of Waste Dumps										NE 1: Flow to North Fork from NE Dumps (closer to R7)
Date	CCME [a]	YCSR [b]	19-Jan-99	22-Feb-99	17-Mar-99	17-May-99	03-Jul-99	12-Aug-99	10-Sep-99	29-Oct-99	22-Nov-99	13-Dec-99	17-May-99
Physical Tests													
pH	6.5-9..0		7.15	6.87	7.52	5.88	6.61	-	6.34	6.61	6.32	6.98	7.21
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	98	-	-	-
Sulphate (mg/L)		1000	3132	3220	3074	3757	3179	3032	3150	3239	3272	3056	69
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	0.21	0.2	0.2	0.92	0.56	0.8	0.58	0.59	0.32	1.49	-
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	0.62	0.79	0.69	0.42	0.9	0.69	0.55	1.4	0.79	2.32	-
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	0.028	<0.005	0.169	<0.005	<0.005	-
Cadmium (mg/L)	0.000017	0.002-0.018[d]	0.03	0.032	0.042	0.755	0.07	0.01	0.058	0.01	0.049	<0.001	-
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	0.084	0.077	0.076	0.263	0.146	0.061	0.074	0.023	0.081	0.079	-
Iron (mg/L)	0.3	3	0.38	0.21	0.39	0.48	1.11	0.32	0.48	0.23	2.68	0.57	-
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	0.288	0.262	0.282	0.818	0.572	0.391	0.344	0.304	0.402	0.278	-
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	0.07	0.1	0.06	1.86	0.01	<0.01	0.28	0.21	0.44	<0.01	-
Silver (mg/L)	0.0001	0.001	0.018	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	-
Zinc (mg/L)	0.03	0.3	32.56	39.62	35.69	363.43	123.96	84.41	64.97	70.81	76.04	81.15	-
Dissolved Metals													
Aluminum (mg/L)			0.33	0.49	0.41	0.27	0.58	0.8	0.45	1.4	0.61	2.31	0.21
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	0.027	<0.005	0.044	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.018	0.006	0.012	0.458	<0.001	0.004	0.018	0.023	0.042	<0.001	<0.001
Copper (mg/L)			0.061	0.049	0.046	0.04	0.052	0.036	0.049	0.023	0.066	0.069	<0.002
Iron (mg/L)			0.15	0.1	0.05	0.11	0.39	0.24	0.3	0.93	1.26	0.42	0.1
Lead (mg/L)			0.263	0.204	0.163	0.574	0.082	0.326	0.23	0.281	0.34	0.273	0.017
Nickel (mg/L)			<0.01	0.01	<0.01	0.96	<0.01	<0.01	<0.01	<0.01	0.33	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			21.51	10.07	4.13	207.57	97.76	58.89	23.79	57.2	63.52	81.75	0.05
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	-	-	<0.01	0.01	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	0.02	0.03	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.8. Faro Mine Site Waste Rock Dump Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		NE 2: Flow to North Fork from North East Dumps (mid NE 1&3)			NE 3: Flow to North Fork from NE Dumps (further from R7)		FCO: Old Faro Creek Upstream of Valley Dump	A30: Upper Pit Wall Zone MPA6 Sump	SP5-6: Ditch to Main Pit from NE Dumps	W8: Upper Guard-house Creek d/s of NW Dumps	W10: Northwest Waste Dump Toe
Date	CCME [a]	YCSR [b]	17-May-99	04-Jul-99	30-Oct-99	17-May-99	04-Jul-99	17-May-99	17-May-99	17-May-99	03-Jul-99	03-Jul-99
Physical Tests												
pH	6.5-9..0		7.27	7.75	-	7.38	7.61	7.02	*3.06*	*5.75*	7.62	7.98
Conductivity			-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	79	108	262	158	560	15	182	733	5	3
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	-	-	-	-	-	-	-	-	<0.05	<0.05
Total Metals												
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	-	-	***4.14***	-	-	-	-	-	***0.22***	***0.31***
Arsenic (mg/L)	0.005	0.5	-	-	<0.005	-	-	-	-	-	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	-	-	<0.001	-	-	-	-	-	<0.001	***0.003***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	-	-	***0.03***	-	-	-	-	-	*0.013*	*0.008*
Iron (mg/L)	0.3	3	-	-	0.22	-	-	-	-	-	*0.88*	*0.86*
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	-	-	*0.009*	-	-	-	-	-	<0.005	<0.005
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	-	-	<0.01	-	-	-	-	-	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	-	-	<0.003	-	-	-	-	-	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	-	-	*0.06*	-	-	-	-	-	*0.07*	*0.03*
Dissolved Metals												
Aluminum (mg/L)			<0.05	<0.05	<0.05	0.26	0.23	0.09	0.65	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.064	0.067	<0.001	<0.001
Copper (mg/L)			<0.002	0.008	<0.002	0.07	0.021	0.044	0.188	0.032	0.003	<0.002
Iron (mg/L)			<0.01	0.31	<0.01	0.1	0.34	0.95	1.16	<0.01	0.26	0.26
Lead (mg/L)			0.007	<0.005	<0.005	0.016	<0.005	0.007	0.048	0.125	<0.005	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.06	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.01	<0.01	<0.01	0.24	<0.01	0.5	23.04	27	0.11	<0.01
Cyanide												
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.9. Faro Mine Site Tailings Containment Area Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X4: Intermediate Dam Decant									2BC-X5: Cross Valley Dam Decant	
Date	CCME [a]	YCSR [b]	18-Jan-99	21-Feb-99	06-May-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99	10-Sep-99	29-Oct-99	18-Jan-99	21-Feb-99
Physical Tests													
pH	6.5-9.0		6.51	7.47	-	7.86	7.52	8.05	8.49	7.15	7.79	6.97	7.62
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	673	776	509	51	487	563	545	552	647	611	629
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	***1.15***	***1.43***	***0.74***	0.1	***0.89***	***1.11***	***1.2***	***1.22***	***1.11***	***1.11***	***1.15***
Total Metals													
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.16***	***0.46***	***0.21***	<0.05	***0.49***	<0.05	<0.05	***0.23***	***0.24***	***0.17***	***0.38***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.007***	<0.001	***0.023***	*0.001*	<0.001	***0.004***	<0.001	<0.001	<0.001	***0.003***	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.041***	***0.776***	*0.009*	*0.011*	***0.048***	*0.015*	*0.011*	***0.025***	*0.018*	***0.044***	***0.035***
Iron (mg/L)	0.3	3	***3.83***	*0.75*	*0.89*	0.16	*1.02*	0.15	*0.51*	0.17	*0.35*	*0.39*	*0.38*
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	*0.015*	*0.038*	*0.018*	<0.005	<0.005	***0.04***	<0.005	*0.015*	*0.024*	*0.019*	*0.019*
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	0.02	*0.03*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	*0.03*	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	***0.018***	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	***0.015***
Zinc (mg/L)	0.03	0.3	***1.88***	***2.02***	***4.5***	***0.5***	***3.51***	***1.8***	***1.71***	***0.87***	***1.74***	***0.33***	***0.53***
Dissolved Metals													
Aluminum (mg/L)			<0.05	0.16	<0.05	<0.05	0.11	<0.05	<0.05	0.09	0.13	<0.05	0.14
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	0.009	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	<0.001
Copper (mg/L)			0.019	0.02	<0.002	<0.002	0.015	0.006	0.005	0.017	0.015	0.021	0.019
Iron (mg/L)			0.03	<0.01	0.18	<0.1	0.19	0.04	<0.01	<0.01	<0.01	0.12	0.09
Lead (mg/L)			0.006	0.01	0.015	<0.005	<0.005	0.018	<0.005	0.012	0.048	0.011	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.9	0.75	3.19	0.46	2.26	0.99	0.43	0.32	<0.01	0.16	0.18
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-	-	-
Total Cyanide (mg/L)			-	-	-	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.9. Faro Mine Site Tailings Containment Area Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X5: Cross Valley Dam Decant cont.										
Date	CCME [a]	YCSR [b]	21-Mar-99	20-Apr-99	06-May-99	17-May-99	27-May-99	03-Jul-99	27-Jul-99	29-Jul-99	12-Aug-99	10-Sep-99	29-Oct-99
Physical Tests													
pH	6.5-9..0		7.17	7.52	-	7.94	-	8.55	8.29	8.53	8.59	7.67	7.69
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	121	-
Sulphate (mg/L)		1000	538	442	377	181	228	430	541	480	493	536	627
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	***1.03***	***0.78***	***0.56***	***0.31***	0.27	***0.85***	***0.93***	***0.86***	***1.1***	***1.03***	***1.03***
Total Metals													
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.22***	***0.52***	***0.17***	***0.33***	***0.2***	***0.47***	***0.66***	***0.11***	<0.05	***0.27***	***0.46***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.004***	<0.001	***0.004***	<0.001	***0.012***	***0.002***	<0.001	<0.0002	***0.002***	*0.001*	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.041***	***0.028***	*0.011*	***0.042***	***0.043***	***0.03***	***0.032***	***0.029***	*0.008*	***0.028***	***0.033***
Iron (mg/L)	0.3	3	*0.76*	*0.76*	*0.3*	***3.61***	***3.12***	*0.89*	*0.72*	*0.43*	0.1	0.24	*0.36*
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	*0.014*	*0.006*	<0.005	<0.005	<0.005	<0.005	<0.005	*0.004*	<0.005	*0.015*	*0.022*
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.017	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	***0.31***	***0.3***	***0.41***	***0.39***	*0.25*	***0.37***	***0.38***	***0.342***	***0.3***	***0.31***	***0.6***
Dissolved Metals													
Aluminum (mg/L)			0.12	0.1	<0.05	<0.05	<0.05	0.12	0.17	0.05	<0.05	0.1	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.002	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.001	<0.001	<0.001
Copper (mg/L)			0.02	0.018	<0.002	0.008	0.008	0.014	0.011	0.015	0.01	0.018	0.003
Iron (mg/L)			<0.01	0.18	<0.01	0.01	0.02	0.19	0.06	0.03	<0.01	0.03	0.04
Lead (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	0.019	0.01	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.005	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.09	0.08	0.07	<0.01	0.13	0.09	0.1	0.1	0.07	0.06	0.04
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	<0.01	<0.01	-	<0.01	-	<0.01	<0.01	<0.01	<0.01	-	-
Total Cyanide (mg/L)			0.01	<0.01	-	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<" less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.9. Faro Mine Site Tailings Containment Area Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X11: Seepage from North Toe of the Cross Valley Dam						2BC-X12: Seepage from the South Toe of the Cross Valley Dam		
Date	CCME [a]	YCSR [b]	17-May-99	12-Aug-99	10-Sep-99	29-Oct-99	22-Nov-99	14-Dec-99	17-May-99	12-Aug-99	10-Sep-99
Physical Tests											
pH	6.5-9..0		6.98	7.14	6.92	*6.31*	7.05	6.73	6.94	7.34	6.89
Conductivity			-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	767	669	705	810	825	739	460	313	308
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	***1.1***	***0.94***	***0.9***	***0.94***	***0.47***	***1.73***	***0.86***	<0.05	<0.05
Total Metals											
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	<0.05	<0.05	***0.24***	***0.78***	***0.27***	***0.76***	***0.05***	<0.05	***0.17***
Arsenic (mg/L)	0.005	0.5	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	<0.001	***0.002***	<0.001	<0.001	<0.001	<0.001	<0.001	***0.018***	<0.001
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.037***	*0.017*	***0.031***	***0.026***	***0.055***	***0.032***	***0.027***	*0.006*	***0.02***
Iron (mg/L)	0.3	3	*2.97*	*1.84*	*2.21*	***3.01***	*2.77*	*2.3*	*1.7*	0.07	0.1
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.005	<0.005	*0.018*	***0.041***	*0.028*	*0.008*	<0.005	*0.017*	<0.005
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.01	<0.01	*0.03*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.05*	0.02	<0.01	<0.01	<0.01	*0.03*	*0.03*	0.01	<0.01
Dissolved Metals											
Aluminum (mg/L)			<0.05	<0.05	-	0.05	0.11	0.8	<0.05	<0.05	-
Arsenic (mg/L)			<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.05	-
Cadmium (mg/L)			<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	-
Copper (mg/L)			0.01	0.009	-	<0.002	0.032	0.03	0.005	0.004	-
Iron (mg/L)			<0.01	0.05	-	<0.01	0.05	0.14	<0.01	<0.01	-
Lead (mg/L)			<0.005	0.008	-	<0.005	<0.005	0.007	<0.005	<0.005	-
Nickel (mg/L)			<0.01	<0.01	-	<0.01	0.01	<0.01	<0.01	<0.01	-
Silver (mg/L)			<0.003	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	-
Zinc (mg/L)			0.03	0.01	-	<0.01	<0.01	0.02	0.02	<0.01	-
Cyanide											
WAD Cyanide (mg/L)	0.005	0.05	-	<0.01	-	-	-	-	-	<0.01	-
Total Cyanide (mg/L)			-	<0.01	<0.01	<0.01	<0.01	<0.01	-	0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"< "=less than detection limit

Italic — *results exceed CCME Aquatic Life Guidelines*

Bold, Italic — *results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.9. Faro Mine Site Tailings Containment Area Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X12: Seepage from the South Toe of the Cross Valley Dam cont.			2BC-X13: Combined Seepage Flows d/s from the Culvert and u/s of the Confluence with the Decant							
Date	CCME [a]	YCSR [b]	29-Oct-99	22-Nov-99	14-Dec-99	18-Jan-99	22-Feb-99	17-Mar-99	20-Apr-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99
Physical Tests													
pH	6.5-9..0		7.02	7.34	6.98	6.99	-	6.93	7.16	7.05	7.16	7.64	7.09
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	329	340	295	717	642	493	650	682	566	588	600
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	<0.05	0.25	***0.9***	***0.9***	***0.7***	***0.76***	***0.97***	***0.9***	***0.87***	***1.16***
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.13***	***0.2***	***0.25***	***0.18***	-	***0.38***	***16***	***0.05***	***0.53***	<0.05	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	*0.009*	-	<0.005	*0.011*	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	<0.001	***0.003***	-	<0.001	<0.001	<0.001	<0.001	***0.004***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	*0.011*	***0.035***	*0.016*	***0.041***	-	***0.039***	***0.034***	***0.033***	***0.035***	*0.011*	*0.012*
Iron (mg/L)	0.3	3	0.1	0.27	0.02	*2.77*	-	*1.54*	*2.69*	*2.7*	***3.07***	*2.46*	*2.16*
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	*0.017*	*0.007*	*0.018*	-	*0.005*	*0.008*	<0.005	<0.005	***0.051***	*0.016*
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	<0.01	<0.01	*0.03*	0.02	-	*0.04*	<0.01	*0.04*	*0.04*	0.02	0.02
Dissolved Metals													
Aluminum (mg/L)			<0.05	<0.05	0.24	<0.05	-	0.14	<0.05	<0.05	0.14	<0.05	<0.05
Arsenic (mg/L)			<0.005	0.015	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Copper (mg/L)			<0.002	0.018	0.008	0.022	-	0.021	0.023	0.01	0.017	0.012	0.005
Iron (mg/L)			<0.01	<0.01	<0.01	<0.01	-	<0.01	0.08	<0.01	0.21	0.68	0.02
Lead (mg/L)			<0.005	<0.005	<0.005	0.014	-	<0.005	<0.005	<0.005	<0.005	0.034	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	<0.01	0.03	-	<0.01	<0.01	0.03	<0.01	<0.01	0.05
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	<0.01	-	-	-	-	<0.01
Total Cyanide (mg/L)			<0.01	<0.01	<0.01	-	-	<0.01	-	-	-	-	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<" less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.9. Faro Mine Site Tailings Containment Area Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X13: Combined Seepage Flows d/s from the Culvert and u/s of the Confluence with the Decant cont.					2BC-X18: North of CV Dam & Right of Access Road to X14 (20m)	Weir 3: Seepage near South Toe Area of CV Dam	IDSEEP Int. Dam Seep near West Abutment
Date	CCME [a]	YCSR [b]	10-Sep-99	28-Sep-99	29-Oct-99	22-Nov-99	14-Dec-99	29-Jul-99	17-May-99	27-Jul-99
Physical Tests										
pH	6.5-9..0		6.91	-	*6.46*	7.18	*6.33*	8.03	7.39	7.92
Conductivity			-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	580	-	603	684	547	397	306	278
Hardness (CaCO3)			-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	***0.83***	-	***0.72***	***0.51***	***1.37***	***0.3***	0.05	0.06
Total Metals										
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.25***	-	***0.17***	***0.27***	***0.57***	-	***0.33***	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	-	<0.005	<0.005	<0.005	-	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	-	<0.001	<0.001	<0.001	-	<0.001	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	***0.026***	-	*0.003*	***0.049***	***0.029***	-	***0.029***	<0.002
Iron (mg/L)	0.3	3	*1.51*	-	*2.31*	*2.3*	*1.74*	-	*0.72*	0.13
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	*0.017*	-	<0.005	*0.034*	*0.015*	-	<0.005	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	-	<0.01	<0.01	<0.01	-	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	-	<0.003	<0.003	<0.003	-	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	<0.01	-	<0.01	<0.01	0.02	-	*0.04*	0.02
Dissolved Metals										
Aluminum (mg/L)			-	-	<0.05	0.09	0.52	0.17	<0.05	<0.05
Arsenic (mg/L)			-	-	<0.005	<0.005	<0.005	<0.001	<0.005	<0.005
Cadmium (mg/L)			-	-	<0.001	<0.001	<0.001	<0.0001	<0.001	0.003
Copper (mg/L)			-	-	<0.002	0.027	0.014	0.0183	<0.002	0.015
Iron (mg/L)			-	-	<0.01	0.02	0.11	0.014	<0.01	0.04
Lead (mg/L)			-	-	<0.005	<0.005	<0.005	0.001	<0.005	0.034
Nickel (mg/L)			-	-	<0.01	<0.01	<0.01	0.005	<0.01	<0.01
Silver (mg/L)			-	-	<0.003	<0.003	<0.003	<0.0001	<0.003	<0.003
Zinc (mg/L)			-	-	<0.01	<0.01	<0.01	<0.0004	0.01	0.02
Cyanide										
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			<0.01	-	<0.01	<0.01	<0.01	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X2: North Fork of Rose Creek at the Road Bridge											
Date	CCME [a]	YCSR [b]	18-Jan-99	22-Feb-99	17-Mar-99	20-Apr-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99	10-Sep-99	29-Oct-99	22-Nov-99	14-Dec-99
Physical Tests														
pH	6.5-9..0		6.73	6.61	6.93	7.06	7.35	7.71	7.89	7.68	7.58	6.99	6.65	7.21
Conductivity			-	-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	66	-	-
Sulphate (mg/L)		1000	31	32	26	24	4	8	7	11	10	19	23	21
Hardness (CaCO3)			-	-	-	-	21	43	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.5	<0.05	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Metals														
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.06***	***0.32***	***0.33***	***0.15***	<0.05	***0.29***	***0.38***	<0.05	***0.15***	<0.05	***0.08***	***0.14***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	*0.023*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	*0.009*	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	*0.001*	***0.002***	<0.001	<0.0001	<0.001	<0.001	***0.006***	***0.009***	<0.001	<0.001	<0.001	*0.001*
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	***0.034***	***0.027***	***0.049***	***0.026***	*0.016*	*0.018*	*0.009*	*0.014*	*0.014*	*0.007*	***0.037***	***0.021***
Iron (mg/L)	0.3	3	0.17	*1.77*	*1.58*	*2.12*	*0.51*	*1.38*	*1.16*	*0.34*	0.27	0.23	*1.18*	0.25
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	*0.005*	<0.005	<0.005	<0.005	<0.005	***0.05***	<0.005	<0.005	<0.005	<0.005	*0.023*
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	***0.03***	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.03*	*0.07*	0.02	0.02	*0.05*	*0.05*	<0.01	0.02	<0.01	0.02	<0.01	*0.09*
Dissolved Metals														
Aluminum (mg/L)			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001
Copper (mg/L)			0.003	<0.002	0.007	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.003	<0.002
Iron (mg/L)			<0.01	<0.01	<0.01	<0.01	0.12	0.22	0.13	0.06	0.03	0.02	0.02	<0.01
Lead (mg/L)			<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	0.029	<0.005	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	0.01	<0.01	0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cyanide														
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	<0.01	-	<0.01	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X3: Rose Creek at Freshwater Pumphouse										
Date	CCME [a]	YCSR [b]	18-Jan-99	22-Feb-99	17-Mar-99	20-Apr-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99	31-Oct-99	22-Nov-99	14-Dec-99
Physical Tests													
pH	6.5-9..0		6.91	6.62	7.41	8.27	6.99	7.95	7.97	7.7	7.18	7.05	7.62
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	121	-	-
Sulphate (mg/L)		1000	26	27	23	21	4	8	8	10	18	21	20
Hardness (CaCO3)			154	180	144	-	31	53	52	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	-
Total Metals													
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.08***	***0.31***	***0.28***	***0.13***	<0.05	***0.35***	<0.05	<0.05	***0.16***	<0.05	***0.08***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	***0.002***	*0.001*	<0.001	***0.002***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.03***	*0.019*	***0.027***	*0.018*	*0.014*	*0.017*	*0.004*	*0.004*	*0.011*	***0.023***	*0.018*
Iron (mg/L)	0.3	3	0.09	0.21	*0.5*	*0.62*	*0.46*	*1.11*	*0.35*	0.24	0.18	*0.42*	0.11
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.005	*0.005*	<0.005	<0.005	*0.008*	<0.005	<0.005	<0.005	*0.011*	*0.023*	*0.016*
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	***0.021***	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.02	*0.06*	*0.04*	0.02	*0.06*	*0.04*	<0.01	0.01	0.01	0.01	*0.05*
Dissolved Metals													
Aluminum (mg/L)			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)			0.005	0.003	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	0.011	0.003	0.01
Iron (mg/L)			<0.01	<0.01	<0.01	<0.01	0.11	0.23	0.07	0.03	<0.01	0.03	<0.01
Lead (mg/L)			<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	0.026	<0.005	0.009
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	-	-	<0.01	<0.01	-	<0.01	-	-	-	-	-
Total Cyanide (mg/L)			-	-	<0.01	<0.01	-	<0.01	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X10: Rose Creek Diversion Canal below Weirs			2BC-X14: Rose Creek after mixing d/s of the Diversion Canal Confluence							
Date	CCME [a]	YCSR [b]	17-May-99	27-Jul-99	14-Dec-99	18-Jan-99	22-Feb-99	17-Mar-99	20-Apr-99	17-May-99	03-Jul-99	27-Jul-99	12-Aug-99
Physical Tests													
pH	6.5-9.0		8.09	8.1	7.49	6.72	*5.94*	7.09	7.24	7.29	8.53	8.17	8.18
Conductivity			-	-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	5	11	23	265	326	268	201	23	38	32	135
Hardness (CaCO3)			35	61	-	387	413	398	-	51	86	89	199
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	<0.05	-	0.29	***0.35***	***0.3***	0.07	0.09	<0.05	0.08	-
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.1***	***0.39***	<0.05	***0.12***	***0.27***	***0.28***	***0.14***	***0.33***	***0.45***	***0.46***	<0.05
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	***0.005***	<0.001	***0.002***	<0.001	<0.001	<0.001	***0.003***	***0.003***	***0.005***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	***0.0222***	*0.007*	*0.014*	***0.035***	***0.022***	***0.033***	***0.02***	***0.022***	***0.023***	*0.005*	*0.005*
Iron (mg/L)	0.3	3	*0.64*	*1.19*	0.17	*0.46*	*0.53*	*0.51*	*0.48*	*1.06*	*1.19*	*1.05*	0.23
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	*0.009*	*0.012*	*0.007*	<0.005	*0.009*	<0.005	<0.005	<0.005	<0.005	*0.008*	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	***0.016***	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.06*	*0.04*	*0.08*	*0.06*	*0.03*	*0.04*	*0.03*	*0.07*	*0.05*	*0.04*	*0.08*
Dissolved Metals													
Aluminum (mg/L)			<0.05	<0.05	<0.05	<0.05	0.08	0.08	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	0.005
Copper (mg/L)			<0.002	0.002	0.014	0.011	0.012	0.014	0.011	0.057	<0.002	0.007	0.008
Iron (mg/L)			0.09	0.17	0.07	0.04	0.07	<0.01	0.19	0.08	0.3	0.18	0.1
Lead (mg/L)			<0.005	0.01	0.008	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	0.008	0.013
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.04	0.02	0.01	0.02	<0.01	<0.01	<0.01	0.03	<0.01	0.02	0.02
Cyanide													
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Total Cyanide (mg/L)			-	-	-	-	-	<0.01	0.02	<0.01	0.02	<0.01	0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		2BC-X14: Rose Creek after mixing d/s of the Diversion Canal Confluence cont.				2BC-X18B: North of CV Dam & Right of Access Road to X14 (20 m)	R-4: Rose Creek u/s of Anvil Creek	R-7: North Fork of Rose Creek above Faro Creek Diversion			
Date	CCME [a]	YCSR [b]	10-Sep-99	29-Oct-99	22-Nov-99	14-Dec-99	29-Jul-99	17-Mar-99	25-Feb-99	17-May-99	04-Jul-99	30-Oct-99
Physical Tests												
pH	6.5-9..0		7.95	8.06	7.49	7.81	8.03	-	7.19	7.46	7.17	7.82
Conductivity			-	-	-	-	-	565	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	119	76	104	114	397	149	13	6	5	10
Hardness (CaCO3)			177	-	156	243	-	262	153	21	54	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	-	-	<0.05	-	***0.3***	<0.05	0.09	<0.05	-	-
Total Metals												
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.15***	***0.06***	***0.13***	***0.33***	-	***0.23***	***0.16***	***0.25***	***0.35***	***0.08***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	***0.003***	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	***0.025***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	*0.015*	<0.002	***0.027***	***0.03***	-	***0.025***	***0.022***	*0.013*	*0.009*	*0.01*
Iron (mg/L)	0.3	3	0.24	*0.32*	*0.46*	*0.76*	-	0.06	0.11	*1.63*	*1.28*	0.09
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	<0.005	***0.103***	*0.025*	-	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.05*	0.02	*0.05*	*0.08*	-	*0.05*	*0.03*	*0.04*	*0.03*	<0.01
Dissolved Metals												
Aluminum (mg/L)			<0.05	<0.05	<0.05	0.06	0.17	0.07	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.001	<0.005	<0.005	0.011	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001
Copper (mg/L)			0.006	<0.002	0.008	0.009	0.0183	0.014	0.008	0.081	<0.002	0.006
Iron (mg/L)			0.05	0.09	0.07	0.13	0.014	<0.01	<0.01	0.1	0.3	<0.01
Lead (mg/L)			<0.005	<0.005	<0.005	0.008	0.001	<0.005	<0.005	0.022	<0.005	<0.005
Nickel (mg/L)			<0.01	<0.01	0.02	<0.01	0.005	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.0001	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	<0.01	0.01	<0.0004	<0.01	<0.01	0.02	<0.01	0.26
Cyanide												
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		R-8: North Fork of Rose Creek 900 m below Faro Creek Diversion				R-9: North Fork of Rose Creek Adjacent to BH1 AND BH2			R-10: North Fork of Rose Creek Upstream of Rock Drain		
Date	CCME [a]	YCSR [b]	25-Feb-99	17-May-99	04-Jul-99	30-Oct-99	17-May-99	04-Jul-99	30-Oct-99	17-May-99	04-Jul-99	30-Oct-99
Physical Tests												
pH	6.5-9..0		7.25	7.47	7.68	7.82	6.91	7.38	6.67	6.81	7.42	6.85
Conductivity			-	-	-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	12	2	5	9	6	8	15	3	7	15
Hardness (CaCO3)			124	-	-	-	-	-	-	-	55	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	<0.05	-	-	<0.05	-	-	<0.05	-	-
Total Metals												
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.18***	***0.28***	***0.37***	***0.07***	***0.76***	***0.41***	***0.14***	***0.43***	***0.3***	***0.15***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	*0.038*	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*0.001*	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	***0.021***	*0.014*	*0.011*	*0.005*	***0.024***	*0.01*	*0.008*	*0.017*	*0.008*	*0.012*
Iron (mg/L)	0.3	3	0.05	*1.06*	*0.93*	0.09	*1.89*	*1.32*	0.07	*1.17*	*0.94*	0.13
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	*0.008*	<0.005	*0.009*	*0.015*
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.01	*0.04*	*0.04*	0.01	*0.14*	*0.09*	0.01	*0.08*	*0.05*	*0.03*
Dissolved Metals												
Aluminum (mg/L)			<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Copper (mg/L)			0.004	<0.002	<0.002	<0.002	<0.002	0.003	0.007	0.078	<0.002	<0.002
Iron (mg/L)			<0.01	0.08	0.31	<0.01	0.34	0.35	<0.01	0.09	0.34	<0.01
Lead (mg/L)			<0.005	<0.005	<0.005	<0.005	0.013	<0.005	<0.005	0.009	<0.005	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	0.02	<0.01	0.02	0.04	<0.01	0.09	0.03	<0.01	0.03
Cyanide												
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		NWINT: Northwest Interceptor Ditch u/s of X5		FDU: Faro Creek Diversion u/s of Valley Dump		FCD: Faro Creek Diversion Adjacent to North East Waste Dumps	FAROCR: Faro Creek u/s of Confluence with North Fork of Rose Creek		
Date	CCME [a]	YCSR [b]	20-Apr-99	17-May-99	17-May-99	30-Oct-99	17-May-99	17-May-99	04-Jul-99	30-Oct-99
Physical Tests										
pH	6.5-9.0		8.02	7.94	7.21	6.93	6.56	7.32	7.34	-
Conductivity			-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	19	-	2	2	21	34	4	6
Hardness (CaCO3)			-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	-	-	-	-	-	-	-
Total Metals										
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***3.15***	-	***0.08***	***0.16***	***1.95***	***0.26***	***0.35***	***0.07***
Arsenic (mg/L)	0.005	0.5	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	-	*0.001*	<0.001	<0.001	<0.001	***0.005***	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	*0.019*	-	*0.013*	*0.011*	***0.05***	***0.032***	*0.011*	<0.002
Iron (mg/L)	0.3	3	***5.43***	-	0.23	0.05	***3.56***	*0.79*	*0.94*	0.07
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	-	<0.005	*0.006*	*0.008*	*0.009*	<0.005	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	-	<0.01	<0.01	*0.06*	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.04*	-	*0.09*	<0.01	***0.4***	*0.1*	*0.09*	<0.01
Dissolved Metals										
Aluminum (mg/L)			0.44	-	<0.05	<0.05	0.65	0.1	<0.05	<0.05
Arsenic (mg/L)			<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.002	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)			<0.002	-	<0.002	<0.002	0.025	0.017	0.004	<0.002
Iron (mg/L)			0.58	-	<0.01	<0.01	1.14	0.3	0.35	<0.01
Lead (mg/L)			<0.005	-	<0.005	<0.005	0.011	0.01	<0.005	<0.005
Nickel (mg/L)			<0.01	-	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.02	-	0.06	<0.01	0.41	0.08	<0.01	<0.01
Cyanide										
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic — *results exceed CCME Aquatic Life Guidelines*

Bold, Italic — *results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.10. Faro Mine Site Background and Receiving Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		FCO: Old Faro Creek u/s of Valley Dump	W 8: Upper Guardhouse Cr. d/s of Northwest Dump	W 10: Northwest Waste Dump Toe	NF 1: North Fork Rose Cr. Site 1 u/s of Haul Road		NF 2: North Fork Rose Cr. Site 2 d/s of Haul Road		GC: Guardhouse Cr. u/s of Intermediate Dam Impoundment
Date	CCME [a]	YCSR [b]	17-May-99	03-Jul-99	03-Jul-99	04-Jul-99	30-Oct-99	03-Jul-99	31-Oct-99	27-Jul-99
Physical Tests										
pH	6.5-9..0		7.02	7.62	7.98	7.23	6.65	7.64	6.65	8.23
Conductivity			-	-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	15	5	3	8	18	8	16	374
Hardness (CaCO3)			-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	-	<0.05	<0.05	0.05	-	0.05	-	<0.05
Total Metals										
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	-	***0.22***	***0.31***	***0.19***	<0.05	***0.32***	<0.05	***0.09***
Arsenic (mg/L)	0.005	0.5	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	-	<0.001	***0.003***	***0.003***	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	-	*0.013*	*0.008*	*0.005*	*0.01*	*0.011*	<0.002	<0.002
Iron (mg/L)	0.3	3	-	*0.88*	*0.86*	*0.92*	*0.81*	*1.03*	0.18	*1.36*
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Silver (mg/L)	0.0001	0.001	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	-	*0.07*	*0.03*	*0.03*	0.02	*0.03*	<0.01	***4.04***
Dissolved Metals										
Aluminum (mg/L)			0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.008
Copper (mg/L)			0.044	0.003	<0.002	<0.002	0.004	0.002	<0.002	0.02
Iron (mg/L)			0.95	0.26	0.26	0.38	0.49	0.4	<0.01	0.27
Lead (mg/L)			0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.05
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.5	0.11	<0.01	<0.01	<0.01	<0.01	0.02	1.66
Cyanide										
WAD Cyanide (mg/L)	0.005	0.05	-	-	-	-	-	-	-	-
Total Cyanide (mg/L)			-	-	-	-	-	-	-	-

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

7.3.8 Grum and Vangorda Pits

The water accumulating in the Grum pit (V23) was sampled twice during 1999. Water chemistry showed concentrations of ammonia, total zinc and sulphate which were generally within the ranges observed in recent years for Grum pit water (Table 7.11). The concentrations of ammonia and sulphate in September and October 1999 were 0.5 mg/L and 266/344 mg/L, respectively. The concentrations of total and dissolved zinc in September and October 1999 were 3.42/5.91 mg/L and 0.20/1.30 mg/L, respectively. The concentrations of most metals exceeded the CCME guidelines for protection of freshwater aquatic life.

Vangorda Pit water is monitored at location V22. Following the suspension of mining activities (and dewatering) in January 1998, water which has accumulated in the Vangorda open pit has included natural inflows, water pumped from Little Creek Dam, and, in 1999, water syphoned from the Sheep Pad pond. During 1999, three samples of Vangorda pit water were collected. The water chemistry data as listed in Table 7.11 showed an increase in the concentrations of zinc and sulphate through 1999 although not to the relatively high concentrations reported for September 1998. The concentrations of total and dissolved zinc in 1999 ranged from 11.2 mg/L to 37.4 mg/L and from 3.5 mg/L to 8.7 mg/L, respectively, and the concentration of sulphate in 1999 ranged from 247 mg/L to 635 mg/L. The concentrations of ammonia in 1999 ranged from 0.1 to 0.6 mg/L. The concentrations of most metals exceeded the CCME guidelines for protection of freshwater aquatic life.

The water level in the Vangorda open pit was monitored in 1999. The in-pit water elevation was estimated to have risen approximately 9 metres from April 1999 to February 2000 and was estimated to be approximately 1171.0 masl in February 2000.

7.3.9 Vangorda Rock Dump

Little Creek Dam is the collection point for local area run off and precipitation, surface run off from the Vangorda rock dump, and toe seepage from the Vangorda rock dump. Prior to the shut down of mining activities in January 1998, the Vangorda pit was dewatered directly into Little Creek Dam and all water was pumped from Little Creek Dam to the water treatment plant for treatment and discharge. During 1999, a total of 44,000 m^3 of water was pumped from Little Creek Dam into the Vangorda pit in order to maintain an acceptable water level in Little Creek Dam. One water sample was collected from Little Creek Dam in 1999 on June 18, which confirmed that the water was non-compliant with the water licence as expected. The sample pH was 7.5 with concentrations of sulphate, ammonia, total zinc and dissolved zinc of 299 mg/L, 0.5 mg/L, 7.2 mg/L and 4.8 mg/L, respectively.

Location V21A is the discharge end of the Vangorda Dump seepage collector ditch where the ditch empties into Little Creek Dam. One sample was collected at location V21A during 1999 on May 18 (Table 7.12). This sample likely includes a large portion of snowmelt and is not considered representative of this location. This is based on the relatively low concentrations of total and dissolved zinc, which were 0.14 and 0.10 mg/L, respectively. The concentration of sulphate was also relatively low for this location at 292 mg/L and the concentration of total suspended solids was low at only 9 mg/L.

The six transverse drains which pass toe seepage from the Vangorda rock dump (licence monitoring locations V28 through V33) were sampled as flow allowed during 1999. As usual, no flow was observed at drain #1. No flow was present in drains #2 and #4 even during freshet. Flow was present at drain #6 only during freshet. Flow was present at drains #3 and #5 until November or December. In general, water quality in the drains which were sampled continued to show high metal concentrations and sulphate at continued neutral pH with the exception of drain #5 where pH was in the acidic range (Table 7.12). Flows at the drains were extremely low in 1999 with a maximum observed flow rate of only 0.14 litres per second at drain #3 in May.

The poorest water quality in 1999 was observed in drain #5 with peak concentrations of dissolved zinc and sulphate of 4,004 mg/L and 17,010 mg/L, respectively, with a range in pH from 3.0 to 5.8. Flows from drain #5 were extremely low and ranged from only 0.01 Lps to only 0.03 Lps. Water quality for drain #3 may be more representative of general conditions within the dump because drain #3 most consistently has flow and because the collection area is thought to be the greatest. The peak and annual average concentrations of dissolved zinc in drain #3 during 1999 were 565 mg/L and 324 mg/L, respectively. The peak and annual average concentrations of sulphate in drain #3 in 1999 were 4,281 mg/L and 3,266 mg/L, respectively, and pH ranged from 5.1 to 6.5 in 1999. There may be an increasing trend in the concentrations of dissolved zinc and sulphate emerging at drain #5 which on-going monitoring may identify.

Standpipe piezometers labeled GW94-01 through GW94-04 (licence monitoring locations V34 through V37) were installed below the Vangorda rock dump seepage collector ditch in 1994 and allow monitoring of groundwater seeping below the collector ditch. Each of these piezometers was sampled twice during 1999 in June and October. Piezometer GW94-05 (licence monitoring location V38) was not monitored.

The water chemistry data for piezometers GW94-01 through GW94-04 showed no positive indications of the presence of acid generation products exiting the rock dump in 1999. The concentration of sulphate in piezometer GW94-02 was unusually elevated during winter 1998/99. The other concentrations of sulphate were generally within the ranges observed in previous years. The static water levels and pH for all four piezometers were generally stable with respect to previous years. The concentrations of most metals exceeded the CCME guidelines for protection of freshwater aquatic life as listed on Table 6.2.

A series of piezometers (P94-01 through P94-04, monitoring locations V39 to V47) are installed in the till berm which surrounds the base of the rock dump and through which the transverse drains are intended to pass seepage water. Static water levels in these piezometers were monitored for physical stability assessments in 1999 and not for water chemistry.

7.3.10 Grum Rock Dump and Grum Creek

The monitoring location for the Grum rock dump (V15) is located in a small draw which naturally collects some surface flow below the Grum rock dump including the area occupied by the sulphide cell. Water chemistry did not show a positive indication of the presence of acid generation products exiting the rock dump in 1999. Water chemistry at this location in 1999 showed neutral to slightly alkaline pH ranging from 7.6 to 8.5 (Table 7.12). The concentrations of total and dissolved zinc were relatively low through 1999 with peaks of only 0.04 mg/L and <0.01mg/L, respectively. The peak concentration of total suspended solids in 1999 was only 8 mg/L in July. The concentration of sulphate during 1999 ranged from 200 to 330 mg/L with the peak concentration occurring in December. The flow at location V15 was generally consistent in a range from 0.5 to 1.0 L/s. The water present at location V15 enters Grum Creek upstream of sampling location V2.

Groundwater wells P96-9A and P96-9B are nested in one drill hole in a bedrock valley at least 20 metres deep near surface monitoring location V15. The groundwater wells allow monitoring of groundwater seepage passing through the Grum Creek channel area, which drains a portion of the Grum rock dump including the sulphide cell. Each piezometer was sampled twice during 1999 and water chemistry did not show a positive indication of the presence of acid generation products exiting the dump. The deeper well (P96-9B) which is screened over the interval from 16.5 to 18.0 metres below surface flows during summer and fall (i.e. piezometric head higher than the ground elevation). The concentrations of dissolved zinc in the two piezometers during 1999 were all <0.01 mg/L and the concentrations of sulphate ranged from 167 mg/L to 190 mg/L with pH in a range from 7.0 to 7.7. The concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life as listed in Table 6.2 and 7.12.

Samples were analyzed for two small spring seepages from the Grum dump in 1999, which showed generally good water quality although the concentrations of some metals exceeded the CCME guidelines for protection of freshwater aquatic life.

Location V2 is in Grum Creek upstream of entry into Vangorda Creek. The changes to the water management system implemented during 1995 and 1996 allow for the diversion of a substantial portion of Grum Creek water towards the Moose pond where the water is observed to seep into the ground and enter the groundwater regime. This diversion was put into place as part of the mitigation plan for reducing suspended sediment loadings entering Vangorda Creek via Grum Creek. Diverted Grum Creek water is sampled at location V2A prior to entry into the Moose pond at times when the diversion is in place.

No freshet spike in the concentration of total suspended solids was observed in 1999 at location V2 and the peak concentration was within the discharge limit at only 11 mg/L. The flow at location V2 during 1999 ranged from 0.5 to 1.5 L/s. The concentration of total zinc during 1999 ranged from <0.01 to 0.24 mg/L with the peak concentration occurring in September (Table 7.13). The concentrations of dissolved zinc during 1999, however, were all <0.01 mg/L with the exception of one sample at 0.07 mg/L, which corresponded to the peak concentration of total zinc in September.

Flow at location V2A ranged from 0 to 2 L/s in 1999. Water chemistry was generally good with metals at or near detection limits (Table 7.13). The peak concentrations of total and dissolved zinc in 1999 were 0.08 mg/L and 0.05 mg/L, respectively, in September, which correspond to the peak concentrations recorded for location V2.

7.3.11 Grum Water Treatment Plant and Grum Interceptor Ditch

The water treatment plant located near the Grum pit is a conventional lime plant and the treatment process consists of pH modification using lime followed by enhanced settlement of metal hydroxides with the aid of flocculant. This process does not reduce ammonia concentrations except, possibly, via retention time in the clarification pond. During periods of past mining operations, the plant has been operated on an as-required basis to maintain acceptable water levels in in-pit sumps, Little Creek Dam and the Grum holding pond and the plant performed acceptable well.

The water treatment system was not operated during 1999. During 1999, run off water which accumulated in Little Creek Dam was pumped into the mined out Vangorda open pit as required to maintain an acceptable water level in the Little Creek Dam.

The outflow from the Sheep Pad pond (location V25BSP) is not currently included in the licence but is used to monitor flow into Vangorda Creek from the Grum Interceptor Ditch which was constructed during 1995 as part of the mitigative actions intended to minimize sediment loading into Vangorda Creek.

There was no flow at location V25BSP from January through mid-May 1999 and no flow again from mid-September through to year-end. Additionally, there was no flow for parts of May and June due to syphoning water from the Sheep Pad pond into the Vangorda pit. The syphoning was done to avoid the discharge of non-compliant concentrations of total suspended solids from the Sheep Pad pond during freshet as described below. An estimated 20,000 m^3 of water was syphoned from the Sheep Pad pond into the Vangorda open pit in May and June 1999. Flows at location V25BSP in 1999 ranged from 0 to 5 L/s.

The concentration of total suspended solids at location V25BSP was greater than the maximum allowable discharge limit of 15 mg/L on two occasions in 1999 (Table 7.13). The concentrations of total suspended solids were 129 mg/L and 148 mg/L on May 18 and May 27, respectively. The corresponding concentration of total suspended solids at the inflow to the Sheep Pad pond on May 18 was 299 mg/L which indicated that partial settlement was occurring in the Sheep Pad pond. The corresponding concentration of total suspended solids in Vangorda Creek immediately downstream of the plunge pool mixing zone (location V19 culvert) was 38 mg/L on May 18 which indicated that the inflow of water from location V25BSP was diluted in Vangorda Creek by a factor of approximately 3.5 times. The syphoning of water from the Sheep Pad pond into the Vangorda open pit as described above was implemented in May as a means of preventing the continued discharge of non-compliant concentrations of total suspended solids into Vangorda Creek.

The concentrations of total and dissolved zinc at location V25BSP which correspond to the elevated concentrations of total suspended solids on May 18 were compliant at 0.19 mg/L and 0.05 mg/L, respectively. The peak concentrations of total and dissolved zinc at location V25BSP in 1999 were 0.38 mg/L and 0.72 mg/L, respectively, in August although the concentration of dissolved zinc of 0.72 mg/L is considered unreliable given that it is nearly twice the corresponding concentration of total zinc.

Location V19 is the Vangorda north west interceptor ditch, which drains into Vangorda Creek at the plunge pool. A sump was built during April 1996 near the discharge end of the V19 ditch, which allows the low flows of ditch water to seep into the ground, thereby eliminating a flow of potentially high suspended sediment into Vangorda Creek.

One sample was collected at location V19 in 1999 in May (Table 7.13). No flow was observed exiting the V19 ditch at other times during 1999. The concentration of total suspended solids in May 1999 was slightly greater than the maximum allowable discharge limit of 15 mg/L at 25 mg/L. The concentrations of total and dissolved zinc in May 1999 were 0.19 mg/L and 0.09 mg/L, respectively.

7.3.12 AEX Creek

Location V17A is a small stream that contains natural run off from the slopes north of the Grum pit as well as surface run off from the north side of the Ore Transfer Pad. This stream then passes into AEX Creek that is sampled further downstream at location V6A.

Location V17A was sampled on two occasions in 1999 in July and September (Table 7.12). There was no flow during the winter season. In 1999, the concentrations of total and dissolved zinc ranged from 0.03 mg/L to 0.06 mg/L and from <0.01 mg/L to 0.02 mg/L and the concentration of sulphate ranged from 6 mg/L to 7 mg/L.

Location V6A is AEX Creek immediately prior to entry into the west fork of Vangorda Creek and was sampled on five occasions in 1999. The concentrations of total zinc in 1999 ranged from 0.01 mg/L to 0.08 mg/L and the concentrations of dissolved zinc in 1999 were all <0.01 mg/L (Table 7.13). The concentrations of sulphate in 1999 ranged from 10 mg/L to 46 mg/L.

7.3.13 Shrimp Creek and Upper Vangorda Creek Background and Receiving Water

Location V4 is Shrimp Creek upstream of the confluence with the main fork of Vangorda Creek. This location provides reference information regarding background water quality. There were four samples collected at location V4 during 1999. The water at location V4 continued to be harder than the other background water quality reference location in Vangorda Creek (V1) as has been observed in previous years (Table 7.13). Metal concentrations in Shrimp Creek were generally at or near detection limits in 1999 with the exception of total zinc, which was measured as high as 0.07 mg/L in June. The concentrations of dissolved zinc in 1999 were all <0.01 mg/L.

Location V1 is the main fork of Vangorda Creek immediately upstream of mine activities. This location provides information regarding background water quality upstream of the mine site. There were five samples collected at location V1 during 1999. During 1999, pH ranged from 6.8 to 8.1, sulphate concentrations ranged from 3 to 13 mg/L, and hardness ranged from 9 to 56 mg/L (Table 7.13). The concentrations of most total metals were at or near detection limits with the exceptions of total zinc that was unusually elevated at 0.24 mg/L in June and total iron, which ranged from 0.07 to 4.2 mg/L. The concentration of total suspended solids was low throughout the year at less than 3 mg/L.

Location V27 is the main fork of Vangorda Creek upstream of the confluence with Shrimp Creek and provides information regarding the impact on Vangorda Creek from mining activities on the Vangorda Plateau. All surface water from the Grum rock dump, the Grum interceptor ditch/Sheep Pad Pond, and the Vangorda north east interceptor ditch reports to location V27 via Grum Creek or the Vangorda Creek plunge pool. There were five samples collected at location V27 during 1999. The peak concentration of total zinc was 0.07 mg/L in March (Table 7.31). The peak concentration of dissolved zinc was 0.02 mg/L in July and October. The highest concentration of sulphate in 1999 was 46 mg/L in March and ammonia was measured at <0.05 mg/L for all samples.

7.3.14 Lower Vangorda Creek Receiving Water

Location V5 is the west fork of Vangorda Creek upstream of the confluence with the main fork. Location V5 receives drainage from AEX Creek and, thereby, potential influences from surface drainage from the north portion of the Ore Transfer Pad. Both AEX and West Fork Vangorda Creeks receive drainage from the Vangorda ore haul road and the mine access road. Road maintenance activities such as re-surfacing or application of dust suppression products or spills could potentially affect water quality at V5. There is a small portion of the Grum calcareous phyllite rock dump which drains into the west fork of Vangorda Creek between AEX Creek and location V5. This portion of the Grum rock dump does not include any part of the sulphide cell.

There were ten samples collected at location V5 during 1999. The concentration of total suspended solids was elevated from May through July 1999 at 100 mg/L to 731 mg/L (Table 7.13). The source of the suspended solids was not clearly identified except as being downstream of the mine developments and between the mine access road at the Grum turn off and the ski hill road. The concentration of total suspended solids at the mine access road crossing at the Grum turn off (and downstream of the mine developments) was 33 mg/L on June 20, 1999 when the concentration at downstream location V5 was 731 mg/L. The concentration of total suspended solids at location V5 during the remainder of 1999 was less than 29 mg/L. The concentrations of total iron and total aluminum at location V5 were also elevated from May through July 1999 in concert with the elevated concentrations of total suspended solids indicating that the source of these metals may have been clay-rich sediment in suspension. There were no corresponding elevated concentrations of total zinc from May to July 1999.

The concentrations of sulphate and hardness at location V5 continued to exhibit a general seasonal trend during 1999 in which these concentrations were greater during the winter season when surface run off was at a minimum. The ranges in concentrations of sulphate and hardness at location V5 in 1999 were from 34 to 532 mg/L and from 126 to 1161 mg/L, respectively.

Location VGMAIN is an informal (non licence) sampling location located in the main fork of Vangorda Creek immediately upstream of the confluence with the west fork. Water chemistry at this location provides important information regarding the relative impacts of the main and west forks on the fish rearing habitat in lower Vangorda Creek.

A total of five samples were collected at location VGMAIN in 1999 (Table 7.13). The concentration of total suspended solids at location VGMAIN followed the established trend for this location with generally low concentrations and a brief spring spike (125 mg/L on June 20). The concentration of ammonia was low with a peak concentration of only 0.07 mg/L. The peak and average concentrations of total zinc in 1999 were 0.12 mg/L and 0.06 mg/L, respectively. The peak concentration of total zinc occurred in June and corresponded to the peak concentration of total suspended solids. The peak concentration of dissolved zinc in 1999 also occurred on June 20 at 0.03 mg/L.

The concentrations of sulphate and hardness at location VGMAIN followed a seasonal trend in 1999 as observed for location V5 with higher concentrations observed in the winter season. The ranges in concentrations of sulphate and hardness in 1999 at location VGMAIN were from 7 to 126 mg/L and from 34 to 298 mg/L, respectively.

Location V8 is in the Vangorda Creek fish rearing area near the confluence with the Pelly River. There were ten samples collected at location V8 during 1999. The concentration of total suspended solids at location V8 was elevated from May through July 1999 in concert with elevated concentrations at upstream location V5 as described above (Table 7.13). The peak concentration of total suspended solids at location V8 in 1999 was 184 mg/L on June 20. The concentrations of total suspended solids during the remainder of 1999 (excluding May through July) were less than 12 mg/L.

The highest concentration of total zinc observed at location V8 during 1999 was 0.09 mg/L on June 20. This peak concentration corresponds to the peak concentration of total suspended solids as described above and also corresponds to the peak concentration of total zinc at upstream location VGMAIN. The peak concentration of dissolved zinc in 1999 also occurred on June 20 at 0.03 mg/L.

The peak concentration of total lead at location V8 in 1999 was 0.04 mg/L in December. Concentrations of ammonia were all less than the method detection limit of 0.05 mg/L in 1999. The concentrations of total aluminum and total iron were as high as 2.6 mg/L and 4.6 mg/L, respectively, in June, which corresponded to the peak concentration of total suspended solids.

The trend in the concentration of sulphate at location V8 closely followed that at location V5 during 1999 in a range from 12 mg/L to 238 mg/L. The hardness observed at location V8 in 1999 ranged from 37 mg/L to 462 mg/L and closely followed the trend described for locations V5 and VGMAIN with greater hardness recorded in the winter season when surface flows were at a minimum.

7.3.15 Longer Term Trends In Lower Vangorda Creek

The longer-term trends in water quality in lower Vangorda Creek from 1988 to 1999 indicate that mining activities on the Vangorda Plateau have had an influence on concentrations of total suspended solids, total zinc, total lead and ammonia in lower Vangorda Creek. It is also evident that water chemistry in the West Fork (V5) can have a significant effect on water chemistry in lower Vangorda Creek particularly for total suspended solids and sulphate and that the presence of these parameters in the West Fork is unrelated to current activities at the mine site. There are also likely sources of suspended sediments entering Vangorda Creek in the main fork below the mine site and in lower Vangorda Creek below the confluence of the main and west forks.

During the three-year period 1988 to 1990, there was a relatively small amount of work done in overburden stripping for the Grum Open Pit. Although few water samples were collected during this period, the water quality at location V8 during this period could be taken as representative of conditions largely unaffected by mine operations. This is evident through relatively low concentrations of total suspended solids, total zinc, ammonia, total lead and arsenic although the concentration of total zinc was recorded at or just greater than the recommended guideline for the protection of freshwater aquatic life (CCME) on two occasions. The average concentration of total suspended solids during this period was 12 mg/L with a peak value of 30 mg/L late in 1990. The average and peak concentrations of total zinc were 0.024 mg/L and 0.036 mg/L, respectively.

During 1991 and 1992, a substantial overburden stripping program was carried out on the Vangorda Plateau, mining was performed in the Vangorda Open Pit and the Vangorda ore haul road was constructed. The effect of this mining activity is reflected in the water quality in lower Vangorda Creek. The concentrations of total suspended solids, total zinc, total lead and ammonia all show an increase in average and peak values during this period. The average concentration of total suspended solids during this period was 62 mg/L with a peak value of 590 mg/L in spring 1991. Similarly, the average and peak concentrations of total zinc were 0.06 mg/L and 0.36 mg/L, respectively.

During 1993 and 1994, no mining operations were performed on the Vangorda Plateau. Although fewer water samples were collected during this period than during the previous operating period, reduced levels of total suspended solids and total zinc were observed in lower Vangorda Creek. The reduced levels were generally greater than those observed during the period preceding mine activities (1988 to 1990).

The average concentration of total suspended solids during 1993 and 1994 was 40 mg/L with a peak value of 112 mg/L in spring 1994. Similarly, the average and peak concentrations of total zinc were 0.03 mg/L and 0.11 mg/L, respectively.

During 1995, 1996 and 1997, mining activities on the Vangorda Plateau were resumed including operation of and discharge of treated effluent from the water treatment plant. Even in light of the resumption of mine operations, water chemistry in lower Vangorda Creek during this period did not show a return to the chemistry observed during the previous period of mine operations on the Vangorda Plateau (1991 and 1992). The concentrations of total suspended solids, total zinc, total lead, ammonia and arsenic observed from 1995 through 1997 remained similar to those observed during the shut down period of 1993 and 1994. During the period from 1995 to 1997, the average concentration of total suspended solids was 29 mg/L with a peak value of 271 mg/L. Similarly, the average and peak concentrations of total zinc were 0.04 mg/L and 0.12 mg/L, respectively.

In 1998 and 1999, mining activities were again suspended including cessation of discharge of treated effluent from the water treatment plant. The water chemistry observed in lower Vangorda Creek during 1998 and 1999 was generally similar to that observed during the preceding period of mine operation (1995 through 1997) with the exception of the elevated concentrations of total suspended solids during May, June and July 1999 which, as described above, did not appear to originate from the mine developments. During the period from 1998 to 1999, the average concentration of total suspended solids was 20 mg/L with a peak value of 184 mg/L. The average and peak concentrations of total zinc were 0.05 mg/L and 0.26 mg/L, respectively.

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Table 7.11. Vangorda Plateau Grum and Vangorda Pit Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-22: Vangorda Pit Water and Vangorda Lake @ Closure			V-23: Grum Pit Water	
Date	CCME [a]	YCSR [b]	18-Jun-99	10-Sep-99	12-Oct-99	10-Sep-99	12-Oct-99
Physical Tests							
pH	6.5-9..0		7.48	7.43	*6.48*	7.64	7.12
Conductivity			-	1120	1180	885	935
Alkalinity-Total			-	66	85	190	190
Sulphate (mg/L)		1000	247	513	635	266	344
Hardness (CaCO3)			-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	0.1	-	***0.55***	-	***0.54***
Total Metals							
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	***0.54***	***0.19***	***0.23***	***0.22***	***0.16***
Arsenic (mg/L)	0.005	0.5	<0.005	*0.065*	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	***0.017***	***0.058***	***0.061***	***0.01***	***0.019***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	***0.095***	***0.022***	***0.034***	*0.017*	***0.029***
Iron (mg/L)	0.3	3	*1.15*	0.28	*0.39*	0.18	0.14
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	***0.11***	***0.261***	***0.278***	***0.177***	***0.174***
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	*0.04*	*0.13*	*0.17*	<0.01	*0.04*
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	***11.21***	***22.59***	***37.36***	***3.42***	***5.91***
Dissolved Metals							
Aluminum (mg/L)			0.35	0.07	0.05	0.06	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.006	0.011	0.02	0.003	0.006
Copper (mg/L)			0.047	0.016	0.013	0.009	0.008
Iron (mg/L)			0.43	0.03	0.06	<0.01	0.06
Lead (mg/L)			0.062	0.142	0.175	0.052	0.112
Nickel (mg/L)			<0.01	<0.01	0.07	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			3.52	3.66	8.67	0.2	1.3

Notes:

[a] Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999

[b] Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997

[c] Guideline/Standard varies with water hardness

[d] Guideline/Standard varies with water pH

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.12. Vangorda Plateau Waste Rock Dump Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-15: Sulphide Cell Sump, Grum Dump					V-17A: Runoff from Ore Transfer Pad		V-21A: VG Dump Collector Ditch @ LCD
Date	CCME [a]	YCSR [b]	17-Mar-99	03-Jul-99	10-Sep-99	12-Oct-99	13-Dec-99	03-Jul-99	10-Sep-99	18-May-99
Physical Tests										
pH	6.5-9..0		8.48	8.02	7.58	7.69	7.67	7.89	7.64	7.31
Conductivity			935	-	1230	1240	1340	935	-	-
Alkalinity-Total			348	-	380	462	459	348	-	-
Sulphate (mg/L)		1000	200	215	240	320	330	6	7	292
Hardness (CaCO3)			-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05
Total Metals										
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	0.29	***0.51***	***0.21***	***0.21***	***0.64***	***0.33***	***0.1***	0.08
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.005	*0.007*	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	0.001	*0.001*	<0.001	***0.006***	***0.002***	<0.001	<0.001	0.002
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	0.032	***0.027***	***0.023***	***0.035***	***0.038***	*0.005*	*0.009*	0.026
Iron (mg/L)	0.3	3	0.06	*0.91*	0.05	0.13	0.14	*1.1*	0.28	0.17
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.005	<0.005	<0.005	*0.023*	*0.022*	<0.005	*0.007*	0.019
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.03	0.02	*0.04*	<0.01	*0.04*	*0.03*	*0.06*	0.14
Dissolved Metals										
Aluminum (mg/L)			0.07	0.14	0.11	0.08	0.52	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Copper (mg/L)			0.012	0.015	0.017	0.019	0.016	<0.002	0.003	0.002
Iron (mg/L)			<0.01	0.49	<0.01	0.05	<0.01	0.56	0.1	<0.01
Lead (mg/L)			<0.005	<0.005	0.009	0.016	<0.005	<0.005	<0.005	0.009
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.1

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.12. Vangorda Plateau Waste Rock Dump Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-30: Vangorda Dump Drain #3					V-32: Vangorda Dump Drain #5					V-33: Vangorda Dump Drain #6
Date	CCME [a]	YCSR [b]	18-May-99	18-Jun-99	12-Aug-99	12-Oct-99	13-Dec-99	18-May-99	18-Jun-99	12-Aug-99	12-Oct-99	13-Dec-99	18-May-99
Physical Tests													
pH	6.5-9..0		*5.52*	*5.85*	6.54	*5.14*	*6.31*	*5.82*	*4.61*	*4.81*	*3.04*	*3.98*	7.04
Conductivity			-	-	-	4550	-	-	-	-	15200	-	-
Alkalinity-Total			-	-	-	243	-	-	-	-	<5	-	-
Sulphate (mg/L)		1000	***2788***	***4281***	***3259***	***3367***	***2637***	***9365***	***9550***	***17010***	***16970***	***14646***	470
Hardness (CaCO3)			-	-	-	-	-	-	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	*5.46*	***6.55***	-	***7.24***	-	***1.36***	0.29	-	<0.05	-	0.12
Total Metals													
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	-	-	-	-	-	-	-	-	-	-	-
Arsenic (mg/L)	0.005	0.5	-	-	-	-	-	-	-	-	-	-	-
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	-	-	-	-	-	-	-	-	-	-	-
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	-	-	-	-	-	-	-	-	-	-	-
Iron (mg/L)	0.3	3	-	-	-	-	-	-	-	-	-	-	-
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	-	-	-	-	-	-	-	-	-	-	-
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	-	-	-	-	-	-	-	-	-	-	-
Silver (mg/L)	0.0001	0.001	-	-	-	-	-	-	-	-	-	-	-
Zinc (mg/L)	0.03	0.3	-	-	-	-	-	-	-	-	-	-	-
Dissolved Metals													
Aluminum (mg/L)			0.242	0.8	0.57	0.48	<0.05	1.38	2.22	0.94	6.03	6.2	<0.05
Arsenic (mg/L)			<0.005	<0.005	0.322	0.043	<0.005	0.048	<0.005	2.414	<0.005	0.419	<0.005
Cadmium (mg/L)			0.233	0.308	0.201	0.158	0.031	2.025	2.909	6.316	5.496	4.359	0.012
Copper (mg/L)			0.086	0.063	0.058	0.041	0.104	0.199	0.11	0.087	0.114	0.375	0.006
Iron (mg/L)			7.03	69.8	5.55	8.48	23.25	127.98	224.27	167.3	123.7	188.88	0.01
Lead (mg/L)			3.662	6.438	5.44	3.407	3.899	5.943	7.451	11.64	9.756	9.578	0.063
Nickel (mg/L)			1.17	2.14	1.37	0.92	<0.01	4.99	9.6	6.8	4.71	1.62	0.05
Silver (mg/L)			0.02	<0.003	<0.003	<0.003	<0.003	0.103	<0.003	0.517	<0.003	<0.003	<0.003
Zinc (mg/L)			229.88	565.17	370	228	226.75	1155.76	2243.28	4044	2886	3101.95	6.4

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic — *results exceed CCME Aquatic Life Guidelines*

Bold, Italic — *results exceed YCSR Generic Numerical Water Standards*

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Table 7.13. Vangorda Plateau Receiving and Background Water Quality

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-1: Vangorda Creek u/s from the Mine and Blind Creek Road					V-2: Grum Creek u/s from the Mine and Blind Creek Road				
Date	CCME [a]	YCSR [b]	17-Mar-99	18-Jun-99	29-Jul-99	31-Aug-99	12-Oct-99	17-Mar-99	18-Jun-99	10-Sep-99	12-Oct-99	13-Dec-99
Physical Tests												
pH	6.5-9..0		7.12	8.08	7.44	7.7	6.75	7.67	7.64	7.76	6.95	7.06
Conductivity			124	-	35.2	55.5	-	945	-	810	775	800
Alkalinity-Total			-	-	2	26	-	-	-	-	-	-
Sulphate (mg/L)		1000	13	3	6	7	10	202	180	169	191	146
Hardness (CaCO3)			56	10	9	22	17	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Metals												
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	0.24	***0.15***	*0.03*	*0.038*	***0.05***	0.57	***0.3***	*0.11*	*0.16*	*0.49*
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	<0.001	***0.002***	<0.0001	***0.0051***	*0.001*	<0.001	<0.001	<0.001	***0.005***	***0.003***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	0.025	*0.007*	*0.002*	*0.0113*	*0.013*	0.036	***0.032***	*0.017*	***0.027***	***0.036***
Iron (mg/L)	0.3	3	0.09	***4.18***	0.07	*0.421*	0.2	0.5	*1.61*	0.03	0.18	0.06
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.005	<0.005	<0.0002	0.0008	<0.005	<0.005	<0.005	<0.005	*0.007*	*0.018*
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	<0.01	*0.11*	<0.001	<0.001	<0.01	<0.01	0.02	<0.01	*0.03*	0.02
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.04	*0.24*	0.002	0.0015	0.01	0.07	*0.11*	*0.24*	<0.01	*0.05*
Dissolved Metals												
Aluminum (mg/L)			<0.05	<0.05	0.05	0.006	<0.05	0.11	<0.05	<0.05	<0.05	0.11
Arsenic (mg/L)			<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Copper (mg/L)			0.007	<0.002	0.0014	0.001	<0.002	0.017	0.013	0.007	0.012	0.009
Iron (mg/L)			<0.01	0.07	0.014	<0.001	<0.01	<0.01	0.04	<0.01	0.02	<0.01
Lead (mg/L)			<0.005	<0.005	0.002	<0.0002	<0.005	<0.005	<0.005	0.008	0.008	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.001	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	0.002	<0.0004	<0.01	<0.01	<0.01	0.07	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

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Table 7.13. Vangorda Plateau Receiving and Background Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-2A: Grum Creek Diversion to Moose Pond			V-4: Shrimp Creek u/s from its Confluence with Vangorda Creek				V-5: West Fork of Vangorda Creek u/s of Mine Access Road			
Date	CCME [a]	YCSR [b]	18-Jun-99	10-Sep-99	12-Oct-99	16-Mar-99	18-Jun-99	29-Jul-99	12-Oct-99	19-Jan-99	23-Feb-99	23-Mar-99	20-Apr-99
Physical Tests													
pH	6.5-9..0		7.81	7.58	7.58	8.17	8.06	8.42	8.09	8.37	7.75	7.47	8.14
Conductivity			-	-	-	800	-	442	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	379	370	269	134	40	43	66	435	532	235	208
Hardness (CaCO3)			-	-	-	458	259	255	322	810	1161	602	498
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	-	-	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	-
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	***0.52***	***0.2***	***0.15***	0.3	***1.23***	***0.24***	***0.16***	0.27	***0.47***	0.37	0.31
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	*0.007*	<0.005	<0.005	0.003	<0.005	0.028	<.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	*0.001*	***0.002***	0.001	<0.001	<0.0001	***0.002***	0.006	<.001	0.001	<0.001
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	***0.033***	***0.024***	***0.031***	0.03	*0.009*	***0.0273***	***0.025***	0.039	***0.036***	0.031	0.024
Iron (mg/L)	0.3	3	*0.81*	0.05	0.15	0.12	*2.56*	*0.342*	*0.46*	0.18	0.1	0.08	0.44
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	*0.007*	*0.006*	*0.009*	<0.005	<0.005	*0.002*	*0.008*	<0.005	<.005	<0.005	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	0.02	<0.01	<0.01	<0.01	0.005	<0.01	<0.01	<.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.0001	<0.003	<0.003	***0.007***	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	*0.05*	*0.08*	0.02	0.05	*0.07*	0.008	<0.01	0.02	*0.05*	0.06	0.01
Dissolved Metals													
Aluminum (mg/L)			0.15	0.11	<0.05	0.08	0.27	0.02	<0.05	-	-	0.1	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.005	<0.005	<0.005	<0.001	<0.005	-	-	<0.005	0.01
Cadmium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.001	-	-	<0.001	<0.001
Copper (mg/L)			0.016	0.017	0.012	0.015	0.01	0.0104	0.007	-	-	0.015	0.021
Iron (mg/L)			0.48	<0.01	0.03	<0.01	0.27	<0.001	0.09	-	-	<0.01	0.05
Lead (mg/L)			0.007	0.009	0.013	<0.005	<0.005	0.001	<0.005	-	-	<0.005	0.011
Nickel (mg/L)			<0.01	<0.01	<0.01	<0.01	<0.01	0.003	<0.01	-	-	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.003	<0.003	<0.003	<0.0001	<0.003	-	-	<0.003	0.01
Zinc (mg/L)			<0.01	0.05	<0.01	<0.01	<0.01	0.001	<0.01	-	-	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.13. Vangorda Plateau Receiving and Background Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-5: West Fork of Vangorda Creek u/s of Mine Access Road cont.						V-6A: A small Tributary (AEX Creek) to the West Fork of Vangorda Creek				
Date	CCME [a]	YCSR [b]	18-May-99	20-Jun-99	29-Jul-99	31-Aug-99	12-Oct-99	14-Dec-99	22-Mar-99	03-Jul-99	10-Sep-99	12-Oct-99	14-Dec-99
Physical Tests													
pH	6.5-9..0		8.04	7.97	8.53	8.6	7.09	7.68	7.93	8.45	7.69	7.23	7.45
Conductivity			-	-	328	431	-	-	-	-	159	178	250
Alkalinity-Total			-	-	22	187	-	-	-	-	-	-	-
Sulphate (mg/L)		1000	39	34	49	60	79	105	46	10	14	16	21
Hardness (CaCO3)			126	134	174	226	245	340	-	-	-	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	1.24	***13.82***	***4.67***	***0.082***	***0.2***	***0.26***	0.38	***0.46***	***0.12***	***0.08***	***0.22***
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	<0.0001	***0.0023***	<0.001	***0.002***	<0.001	<0.001	<0.001	*0.001*	***0.005***
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	0.016	***0.044***	***0.0204***	*0.0092*	***0.024***	***0.025***	0.027	*0.009*	*0.014*	*0.014*	***0.032***
Iron (mg/L)	0.3	3	2.15	***25.27***	***7.337***	0.242	*0.8*	0.06	0.11	*1*	*0.3*	*0.3*	0.29
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	0.009	*0.021*	*0.016*	<0.0002	<0.005	*0.02*	<0.005	<0.005	*0.008*	<0.005	*0.032*
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	*0.05*	0.018	<0.001	0.02	<0.01	0.02	<0.01	<0.01	<0.01	*0.06*
Silver (mg/L)	0.0001	0.001	<0.003	***0.003***	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.05	<0.01	*0.032*	<0.0004	<0.01	*0.03*	0.08	*0.03*	*0.04*	0.01	*0.06*
Dissolved Metals													
Aluminum (mg/L)			0.08	0.94	0.32	0.022	<0.05	<0.05	0.07	<0.05	<0.05	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			0.003	<0.001	<0.0001	0.0003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)			0.002	0.006	0.0101	0.0029	0.007	0.006	0.012	<0.002	0.003	<0.002	0.008
Iron (mg/L)			<0.01	0.94	0.01	0.004	0.01	<0.01	<0.01	0.54	0.04	0.03	0.09
Lead (mg/L)			<0.005	<0.005	0.001	<0.0002	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	0.009
Nickel (mg/L)			0.04	<0.01	0.002	<0.001	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.01	0.03	<0.0004	<0.0004	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:

[a] Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999

[b] Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997

[c] Guideline/Standard varies with water hardness

[d] Guideline/Standard varies with water pH

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.13. Vangorda Plateau Receiving and Background Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-8: Vangorda Creek near Bridge to Faro Town Water Supply									
Date	CCME [a]	YCSR [b]	19-Jan-99	23-Feb-99	23-Mar-99	20-Apr-99	18-May-99	20-Jun-99	29-Jul-99	30-Aug-99	12-Oct-99	14-Dec-99
Physical Tests												
pH	6.5-9..0		8.3	8.02	7.84	7.48	8.16	7.53	8.21	8.5	7.38	7.78
Conductivity			-	-	-	-	-	-	203	264	380	505
Alkalinity-Total			-	-	-	-	-	-	13	112	144	190
Sulphate (mg/L)		1000	190	136	238	174	39	12	31	36	61	85
Hardness (CaCO3)			451	462	458	404	116	37	107	135	164	271
Ammonia-N (mg/L)	1.37-2.2 [d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total Metals												
Aluminum (mg/L)	0.005-0.1 [d]	0.05-0.5 [d]	0.13	-	0.33	0.06	0.46	***2.57***	***1.09***	***0.065***	***0.12***	***0.26***
Arsenic (mg/L)	0.005	0.5	<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	*0.016*
Cadmium (mg/L)	0.000017	0.002-0.018 [d]	0.001	-	<0.001	0.002	<0.001	<0.001	<0.0001	*0.0007*	***0.002***	***0.005***
Copper (mg/L)	0.002-0.004 [c]	0.02-0.09 [c]	0.034	-	0.034	0.014	0.017	*0.005*	***0.0204***	*0.0081*	***0.02***	***0.034***
Iron (mg/L)	0.3	3	0.04	-	0.28	0.03	0.97	***4.55***	*1.745*	0.157	0.18	0.05
Lead (mg/L)	0.001-0.007 [c]	0.04-0.16 [c]	<0.005	-	<0.005	<0.005	0.01	<0.005	*0.004*	<0.0002	*0.008*	*0.034*
Nickel (mg/L)	0.025-0.150 [c]	0.25-1.5 [c]	0.03	-	<0.01	<0.01	<0.01	<0.01	0.007	<0.001	0.02	*0.04*
Silver (mg/L)	0.0001	0.001	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.02	-	0.08	0.02	0.05	*0.09*	0.021	0.0054	<0.01	*0.04*
Dissolved Metals												
Aluminum (mg/L)			-	-	0.1	<0.05	<0.05	0.07	0.15	<0.0001	<0.05	<0.05
Arsenic (mg/L)			-	-	<0.005	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005
Cadmium (mg/L)			-	-	0.003	<0.001	0.002	<0.001	<0.0001	0.0002	<0.001	<0.001
Copper (mg/L)			-	-	0.022	0.009	<0.002	<0.002	0.005	0.0011	0.006	0.011
Iron (mg/L)			-	-	<0.01	<0.01	<0.01	0.21	0.003	0.001	0.05	<0.01
Lead (mg/L)			-	-	<0.005	<0.005	0.008	<0.005	0.001	0.0002	0.009	0.007
Nickel (mg/L)			-	-	<0.01	<0.01	<0.01	<0.01	<0.001	<0.001	0.01	<0.01
Silver (mg/L)			-	-	<0.003	<0.003	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003
Zinc (mg/L)			-	-	<0.01	<0.01	0.02	0.03	<0.0004	<0.0004	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.13. Vangorda Plateau Receiving and Background Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-19: Vangorda Pit NW Interceptor Ditch	V-19 Culvert: Vangorda Creek below Haul Road Crossing	V-25BSP: Below Sheep Pad Pond at the Weir				
Date	CCME [a]	YCSR [b]	18-May-99	18-May-99	18-May-99	27-May-99	03-Jul-99	12-Aug-99	10-Sep-99
Physical Tests									
pH	6.5-9..0		8.02	-	7.95	-	8.21	-	7.83
Conductivity			-	-	-	-	-	-	-
Alkalinity-Total			-	-	-	-	-	-	-
Sulphate (mg/L)		1000	29	-	68	63	38	145	136
Hardness (CaCO3)			-	46	-	-	73	-	-
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	0.07	-	0.07	-	<0.05	<0.05	-
Total Metals									
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	0.51	-	5.26	6.93	***1.01***	<0.05	***0.2***
Arsenic (mg/L)	0.005	0.5	<0.005	-	<0.005	0.011	<0.005	<0.005	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	-	<0.001	0.009	***0.008***	<0.001	***0.002***
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	0.015	-	0.074	0.052	***0.023***	***0.026***	***0.044***
Iron (mg/L)	0.3	3	0.82	-	9.34	11.65	*1.79*	0.04	0.03
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	-	0.024	0.015	<0.005	<0.005	*0.011*
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	-	0.13	0.07	<0.01	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.19	-	0.19	0.1	*0.06*	***0.38***	*0.27*
Dissolved Metals									
Aluminum (mg/L)			0.19	-	0.27	3.49	0.42	<0.05	<0.05
Arsenic (mg/L)			<0.005	-	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium (mg/L)			<0.001	-	<0.001	0.008	0.004	0.007	<0.001
Copper (mg/L)			<0.002	-	0.065	0.034	0.011	0.013	0.012
Iron (mg/L)			<0.01	-	0.04	2.71	0.82	<0.01	<0.01
Lead (mg/L)			0.008	-	0.011	0.007	<0.005	0.007	0.011
Nickel (mg/L)			<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (mg/L)			<0.003	-	<0.003	<0.003	<0.003	<0.003	<0.003
Zinc (mg/L)			0.09	-	0.05	0.07	<0.01	0.72	0.16

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

Gartner Lee

Table 7.13. Vangorda Plateau Receiving and Background Water Quality cont.

Surface Water Analysis Results (mg/L)

Station	Water Quality Guidelines		V-27: Vangorda Creek u/s of Shrimp Creek					VGMAIN: Main Fork of Vangorda Creek					VCGR: Vangorda Creek at Grum Turn-off
Date	CCME [a]	YCSR [b]	16-Mar-99	18-Jun-99	29-Jul-99	31-Aug-99	12-Oct-99	20-Apr-99	18-May-99	20-Jun-99	29-Jul-99	12-Oct-99	20-Jun-99
Physical Tests													
pH	6.5-9..0		7.92	8.33	7.74	7.97	8.41	-	8.01	7.58	7.99	7.48	7.54
Conductivity			298	-	46.3	114	162	-	-	-	-	-	-
Alkalinity-Total			118	-	5	46	59	-	-	-	-	-	-
Sulphate (mg/L)		1000	46	5	14	16	27	126	33	7	20	46	6
Hardness (CaCO3)			149	18	36	49	69	298	100	34	74	134	20
Ammonia-N (mg/L)	1.37-2.2[d]	0.3-8.4 [d]	<0.05	<0.05	<0.05	<0.05	-	-	0.06	0.07	<0.05	<0.05	-
Total Metals													
Aluminum (mg/L)	0.005-0.1[d]	0.05-0.5 [d]	0.25	***0.19***	***0.08***	*0.048*	***0.08***	0.06	0.74	***0.11***	***0.11***	***0.1***	0.06
Arsenic (mg/L)	0.005	0.5	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.001	<0.001	*0.005*	<0.005
Cadmium (mg/L)	0.000017	0.002-0.018[d]	<0.001	<0.001	*0.0002*	*0.0009*	<0.001	0.002	<0.001	<0.0001	<0.0001	***0.002***	0.002
Copper (mg/L)	0.002-0.004[c]	0.02-0.09[c]	0.024	*0.015*	***0.0261***	*0.0076*	*0.018*	0.014	0.021	*0.0166*	*0.0166*	***0.022***	0.014
Iron (mg/L)	0.3	3	0.07	*0.5*	0.17	0.134	0.2	0.03	1.48	0.206	0.206	0.15	0.03
Lead (mg/L)	0.001-0.007[c]	0.04-0.16[c]	<0.005	<0.005	*0.004*	0.0009	<0.005	<0.005	0.007	*0.002*	*0.002*	*0.018*	<0.005
Nickel (mg/L)	0.025-0.150[c]	0.25-1.5[c]	<0.01	<0.01	<0.001	<0.001	<0.01	<0.01	<0.01	0.005	0.005	<0.01	<0.01
Silver (mg/L)	0.0001	0.001	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003
Zinc (mg/L)	0.03	0.3	0.07	*0.06*	*0.04*	0.0283	*0.07*	0.02	0.08	0.024	0.024	*0.03*	0.02
Dissolved Metals													
Aluminum (mg/L)			<0.05	<0.05	0.03	0.012	<0.05	<0.05	0.06	0.02	0.02	<0.05	<0.05
Arsenic (mg/L)			<0.005	<0.005	<0.001	<0.001	<0.005	<0.005	<0.005	<0.001	<0.001	<0.005	<0.005
Cadmium (mg/L)			<0.001	<0.001	<0.0001	0.0005	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.001	<0.001
Copper (mg/L)			0.01	<0.002	0.0008	0.0018	<0.002	0.009	0.003	0.0054	0.0054	<0.002	0.009
Iron (mg/L)			<0.01	0.08	0.015	<0.001	0.06	<0.01	<0.01	0.008	0.008	0.02	<0.01
Lead (mg/L)			<0.005	<0.005	0.001	0.0003	<0.005	<0.005	<0.005	0.001	0.001	<0.005	<0.005
Nickel (mg/L)			<0.01	<0.01	<0.001	<0.001	<0.01	<0.01	<0.01	0.001	0.001	<0.01	<0.01
Silver (mg/L)			<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003	<0.003	<0.0001	<0.0001	<0.003	<0.003
Zinc (mg/L)			<0.01	<0.01	0.02	<0.0004	0.02	<0.01	0.02	<0.0004	<0.0004	<0.01	<0.01

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Generic Numerical Water Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness*

[d] *Guideline/Standard varies with water pH*

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Generic Numerical Water Standards*

7.4 Acid Rock Drainage Assessment

7.4.1 Methods and Field Investigation

Limited sampling was undertaken with respect to ARD potential during the site visit, because of the extensive database previously reported for this site, and limited sampling budget. Sampling focused on areas that were thought to be under-represented in the existing databases.

Two rock samples were collected from the oxide fines stockpile and low-grade ore stockpile (Fuel Tank West) located near the Faro mill buildings. Samples were placed in a thick plastic bag, and submitted to Canadian Environmental and Metallurgical Inc., Vancouver BC for analyses of:

- Standard Sobek acid-base accounting, including rinse pH, paste pH, and inorganic carbon;
- Sulphur species, including total sulphur and sulphate sulphur;
- Inductive Coupled Plasma (ICP) Metals scan on the solids after aqua regia digestion;
- Atomic Absorption (AA) analyses for arsenic.

Samples were collected from pools of water associated with the two stockpile samples, and were submitted to a CAEL accredited analytical laboratory, ASL Analytical Service laboratories in Vancouver, B.C. Analyses were preformed for pH, hardness, total suspended solids, acidity/alkalinity, sulphate, and total and dissolved metals by ICP 33-metal scan. Results are provided in Appendix B.

Field pH measurements were taken using colorpHast7 paper, in pH ranges from 2.5 to 4.5, 4.0 to 7.0, and 6.5 to 10.0. Measurements were taken at the following sites:

Pools of water in tailings along the top of the Secondary Dam	pH 2.5 - 3.0
Orange coloured pools at toe of Secondary Dam	pH 6.1 - 6.5
X23 (Photo 67)	pH 6.5 - 7.0
Water behind Little Creek Dam	pH 6.5 - 7.0
Pools of water in ditch constructed in the top of the till dike around the phyllite portion of the Vangorda waste rock dump	pH about 5.8
Vangorda Drain #5 (water quality sample 2)	pH 3.6 - 3.9

The following additional water quality samples were taken during the site visit.

1. Sample 1: Seep at weir on south side of Vangorda Dump (Finger Drain #3). The sample was labeled Vangorda seep 1 (Photo 68). Dampness extends about 10 m on either side of the finger drain exit and flow measuring weir, suggesting that seepage was not being carried away in the collection ditch, but seeped into the ground. Flow, at the time of sampling, was only a dribble. Drain #2 was dry during the site visit, so that no sample was obtained.

2. Sample 2: Standing water behind Drain #5 (labeled Vangorda seep 3). Flow at the time of sampling was an occasional drip moving over weir.

3. Precipitate associated with Tailings below Cross-Valley Dam: The area below the Cross-Valley Dam was traversed on foot. Tailings were visible under a thin covering of shrubs. Water was ponded in eroded channels in areas that were likely the original Rose Creek bed. The base of these channels was seen to contain a fine, white amorphous precipitate. A sample of the precipitate, along with some of the bed material, was collected and submitted.

Table 7.14 ARD Water Quality Analysis

Water Analysis (mg/L)

Station	Water Quality Guidelines		Seep 1 Vangorda Drain #3	Seep 3 Vangorda Drain #5	Oxide Fines Seep	4-FTW Seep Faro	Rose Creek PPT
	CCME [a]	YCSR [b]					
Physical Tests							
Hardness ($CaCO_3$)			2460	8880	5690	822	194
pH	6.5-9		6.38	3.41	2.86	2.18	7.9
TSS			41	78	85	52	-
Dissolved Anions							
Acidity (to pH 8.3)			616	5390	13900	10800	6
Alkalinity -Total			218	<1	<1	<1	119
Bromide			-	-	-	-	-
Chloride			-	-	-	-	-
Fluoride		2-31 [c]	-	-	-	-	-
Sulphate		1000	3340	17600	23100	9510	-
Nutrients							
Nitrate Nitrogen		400	-	-	-	-	-
Nitrite Nitrogen	0.06	0.2-2 [c]	-	-	-	-	-
Total Metals							
Aluminum	0.005-0.1 [c]	0.05-0.5 [c]	<0.05	7	177	150	36.2
Antimony		0.3	<0.2	<4	<10	<2	<0.2
Arsenic	0.005	0.5	<0.2	<4	<10	4	<0.2
Barium		10	0.01	<0.2	<0.5	<0.1	0.1
Beryllium		0.053	<0.005	<0.1	<0.3	<0.05	<0.005
Boron			<0.1	<2	<5	<1	<0.1
Cadmium	0.000017	0.002-0.018 [c]	0.037	5.4	10.2	1.13	0.0009
Chromium	0.0089	0.02	<0.01	<0.2	<0.5	0.5	<0.01
Cobalt		0.5	2.37	17.9	8.6	1.4	<0.01
Copper	0.002-0.004 [c]	0.02-0.09 [c]	<0.01	<0.2	88.2	16	0.23
Iron	0.3	3	48.8	206	1810	3210	6.31
Lead	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	<1	4	1.51	1.21
Manganese		1	96.7	1380	885	33.9	0.09
Mercury	0.0001	0.001	<0.00005	-	-	0.00122	0.00021
Molybdenum	0.073	10	<0.03	<0.6	<2	<0.3	<0.03
Nickel	0.025-0.15 [c]	0.25-1.5 [c]	4.39	13	5	1	<0.05
Silver	0.0001	0.001	<0.001	<0.2	<0.5	0.003	<0.0001
Tin			-	<0.6	<2	-	-
Zinc	0.03	0.3	240	3740	7120	997	0.477
Dissolved Metals							
Aluminum	0.005-0.1 [c]	0.05-0.5 [c]	<0.05	6	174	159	36.2
Antimony		0.3	<0.2	<4	<10	<2	<0.2
Arsenic	0.005	0.5	<0.2	<4	<10	4	<0.2
Barium		10	0.01	<0.2	<0.5	<0.1	0.1
Beryllium		0.053	<0.005	<0.1	<0.3	<0.05	<0.005
Boron			<0.1	<2	<5	<1	<0.1
Cadmium	0.000017	0.002-0.018 [c]	0.036	5.5	10.2	1.2	0.0009
Chromium	0.0089	0.02	<0.01	<0.2	<0.5	0.5	<0.01
Cobalt		0.5	2.43	18	8.6	1.5	<0.01
Copper	0.002-0.004 [c]	0.02-0.09 [c]	<0.01	<0.2	86.1	16.2	0.23
Iron	0.3	3.0	48.3	206	1770	3230	6.31
Lead	0.001-0.007 [c]	0.04-0.16 [c]	<0.01	1	<3	0.42	1.21
Manganese		1	98.8	1380	869	34.1	0.09
Mercury	0.0001	0.001	<0.00005	-	-	0.00019	0.00021
Molybdenum	0.073	10	<0.03	<0.6	<2	<0.3	<0.03
Nickel	0.025-0.15 [c]	0.25-1.5 [c]	4.53	13	6	1.1	<0.05
Silver	0.0001	0.001	<0.001	<0.2	<0.5	0.002	<0.0001
Tin			-	<0.6	<2	-	-
Zinc	0.03	0.3	244	3750	6980	1010	0.477

Notes:

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 1999*

[b] *Yukon Contaminated Sites Regulations, Aquatic Life Standards, Government of Yukon, 1997*

[c] *Guideline/Standard varies with water hardness or pH*

"-"=not analyzed

"<"=less than detection limit

Italic	*results exceed CCME Aquatic Life Guidelines*
Bold, Italic	*results exceed YCSR Aquatic Life Standards*

Note: the detection limit for some of the metals in water have been increased due to analytical interferences

7.4.2 Faro Tailings Impoundment

ARD and metal leaching issues with respect to the tailings impoundment are related primarily to strong acid generating potential of the tailings mass. Currently, the concern relates to the continuing oxidation of the exposed tailings mass, the existence of a large store of soluble oxidation products in the tailings mass, and the rate at which the available buffering of the underlying tailings is utilized. Oxidation products will eventually overwhelm the buffering tailings and exit below of the Cross Valley Dam or to the sand and gravel aquifer underlying the tailings facility. Zinc and sulphate are likely to be the first expressions of ARD that will appear in the underlying aquifer and at the toe of the tailings facility. Delay in the implementation of remedial measures will allow continued reduction of the pH, increase the acidity, increase the store of soluble oxidation products that could be released, and allow these contaminants to increasingly threaten the quality of the underlying ground water aquifer and downstream surface waters.

The tailings impoundment is underlain by sand and gravel. Both Nicholson (1996) and Environment Canada (1995) have looked at the geochemistry of the porewater in the tailings and the groundwater under the tailings and their conclusions were inconsistent. At the downstream edge of the impoundment, groundwater wells show sulphate coming through at about 300 mg/L, but no trends are apparent for zinc. Sulphate and zinc are anticipated to be the earliest products of sulphide oxidation exiting the tailings impoundment, as they do not precipitate or attenuate as readily at neutral pH values as do other metals or ions.

Groundwater wells at the toe of the Cross Valley Dam indicate no groundwater problems as yet. Consideration has been given as to whether groundwater wells are placed in the correct locations, whether the unoxidized underlying tailings are buffering acidity generated in the near surface tailings, the developing geochemistry of the tailings mass, and the location and rate of movement of the dissolved zinc and sulphate fronts.

The release of metals and oxidation products from previously spilled tailings that lie on the valley bottom below the Cross Valley Dam is also a concern. This spill occurred in 1975, and while the majority of surface flows are directed around the spill area by the Rose Creek diversion channel, spilled tailings likely continue to provide a source of metals, sulphate and acidity. Sampling by Mehling Environmental Management Inc. (MEMI) of the salts emanating in the ground water to surface water channels below the dam suggest that aluminum is mobile in the subsurface tailings, and precipitates as aluminum hydroxide on exposure to more neutral pH water at the valley surface (Table 7.14).

7.4.2.1 Background

The Faro Mine tailings impoundment is located in the Rose Creek Valley and consists of three individual impoundments that were developed successively down the valley (Figure 4.1). The impoundments are known as the Original Impoundment, the Second Impoundment, and the Intermediate Impoundment.

The Cross Valley Dam is located immediately below the Intermediate Dam and serves as a polishing pond to control suspended solids. The Intermediate Dam and the Cross Valley Dam are collectively known as the Down Valley Scheme.

The deposition of tailings into the impoundment began in September 1969. The area covered by the Original Impoundment, the Second Impoundment, and the Intermediate Impoundment is approximately 42 hectares, 55 hectares, and 99 hectares respectively (Robertson Geoconsultants Inc., 1996a). The total amount of tailings contained in the impoundment is approximately 28.6 million m^3 (Robertson Geoconsultants Inc., 1996a).

During the period of 1986 to 1990 a series of programs were implemented to investigate the ARD and metal leaching potential of the tailings contained in the Faro Mine tailings impoundment. The programs were as follows:

- 1986 Test Pit Program completed by Golder Associates. The samples were stored and later analyzed by BC Research.
- 1987 Test Pit Program. The samples were analyzed in an Environment Canada laboratory.
- 1988 Drillhole Program. The samples were analyzed by BC Research.
- 1990 Surface Sample Program. The samples were analyzed by Analytical Services Laboratory.

Steffen, Robertson and Kirsten Inc. (1991) described the chemical characteristics of the in situ tailings as determined from the investigation of the tailings. The tailings characteristics are summarized in the following section for each impoundment.

7.4.2.2 Tailings Characteristics

The chemical and geochemical characteristics of the tailings are discussed for each impoundment and have been characterized as either "new" tailings, if deposited since 1986, and "old" tailings if deposited prior to the shutdown in 1982. Variability in ore, tailings, and processing will lead to heterogeneity within these classifications. However, the overall nature of each impoundment provides a clear indication of the long-term chemical stability and drainage water quality from each area. The data collected from the various programs are presented in Tables 7.15 to 7.18.

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Table 7.15 Summary of the Characteristics of Faro Original, Second and Intermediate Tailings

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	Golder															1987TP				
Test Sample	1	1	1	2	2	3	3	3	4	4	5	5	6	6	6	1	1	1	1	1
Sample No.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	11	12	13	14
Area of Impoundment	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original
Probable Age	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old
Depth (m)	0.3-0.4	1.15-1.2	1.45-1.5	0.2-0.3	1.65-1.8	0-0.4	1.5-1.6	2.4-2.5	0-0.3	1.3-1.4	0-0.3	0.75-0.95	0-0.3	1.5-1.6	2.7-2.8	0	0.5	1	1.5	2
Field Temp oC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	12	11	10
Moisture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	4.1	3.6	8	4
Paste pH Field	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.2	3.2	4.6	4.6	5
Paste pH Lab	3	3.8	5.8	3.1	4.7	2.9	5.8	4.8	2.3	5.9	2.6	4.4	3	4	5.8	3.2	3.1	4.2	3.6	4.1
Total % Sulphur	35.3	19.7	16.89	32.45	35.73	30.57	41.87	33.23	29.47	31.57	35.72	25.22	33.62	23.02	22.59	32.11	33.38	32.1	31.51	24.63
Sulphate Sulphur	0.7	0.4	0.99	0.55	0.33	0.67	0.37	0.23	1.17	0.17	0.82	0.52	0.32	0.32	0.49	1.17	1.23	1.82	1.71	1.59
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.94	32.15	30.28	29.8	23.04
AP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	967	1005	946	931	720
NP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-2.5	-2.2	15.3	6.2	22
NPP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-969.5	-1007.2	-930.7	-924.8	-698
Al (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	470	460	910	1630	890
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	270	160	450	140	460
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	400	1500	1700	1600	1400
Cd (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-3	19	9	27
Cu (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	639	810	1240	481	792
Fe (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	419000	414000	388000	346000	354000
Mg (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-200	-200	1100	1500	1600
Mn (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82	124	785	354	901
Ni (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8430	6840	11300	3670	7760
Zn (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14200	11400	16700	12900	23200

Test Program	1987TP cont.																		
Test Sample	1	2	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4
Sample No.	15	20	21	22	23	24	25	26	30	31	32	33	34	35	40	41	42	43	44
Area of Impoundment	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original
Probable Age	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old
Depth (m)	3	0	0.5	1	2	2	3	4	0	0.5	1	1.5	2	3	0	0.5	1	1.5	2
Field Temp oC	5.5	16	-	-	-	-	-	-	17	16	11	9	8	4	-	12	12	7	6
Moisture	19.9	3.6	4.3	6.9	3.6	3.6	8.2	10.9	11.5	6.9	4.4	8.4	5.8	13.2	13.7	4.6	4.6	25.5	26.3
Paste pH Field	4.8	2.9	3.1	4	5.1	5.1	5	6.6	2.1	2.1	3	4.4	4.1	5.9	2.6	4	4	-	-
Paste pH Lab	5.4	3	2.9	3.4	3.7	3.7	3.7	3.9	2.6	2.7	2.8	3.3	3.4	3.5	2.7	3.6	3.5	3.7	4.6
Total % Sulphur	14.36	31.98	36.07	32.75	34.7	33.69	33.69	39.64	44.67	33.09	34.53	37.31	42.31	40.18	47.05	27.7	21.23	21.9	15.7
Sulphate Sulphur	2.47	1.31	2.23	1.84	1.13	1.77	1.77	1.11	3.17	2.98	2.4	1.61	2.3	1.92	2.78	1.65	4.62	3.68	2.26
Pyritic Sulphur	11.89	30.67	33.84	30.91	33.57	31.92	31.92	38.53	41.5	30.11	32.13	35.7	40.01	38.26	44.27	26.05	16.61	18.22	13.44
AP	372	958	1058	966	1049	998	998	1204	1297	941	1004	1116	1250	1196	1383	814	519	596	420
NP	24.4	-1.7	-0.5	3.1	14.2	12.3	12.3	9.2	-12	-13.9	-8.8	0.5	6.5	12.7	-9.2	19.5	9.2	10.6	17.5
NPP	-347.6	-959.7	-1058.5	-962.9	-1034.8	-985.7	-985.7	-1194.8	-1309	-954.9	-1012.8	-1115.5	-1243.5	-1183.3	-1392.2	-794.5	-509.8	-585.4	-402.5
Al (mg/kg)	3260	460	580	1200	500	450	630	420	450	530	610	630	510	680	470	920	2500	4100	3300
As (mg/kg)	110	260	460	240	300	-90	110	200	-80	-80	120	-80	150	220	130	820	-90	-100	-80
Ca (mg/kg)	1700	500	1200	2300	2000	1400	1100	1500	600	700	1000	900	1200	1400	400	2100	500	1400	1900
Cd (mg/kg)	17	-3	-3	15	6	-3	7	-3	-3	-3	-3	47	-3	-3	-3	-3	8	10	5
Cu (mg/kg)	409	513	811	858	1240	891	992	1320	652	431	1270	1580	1930	1600	208	871	432	410	331
Fe (mg/kg)	140000	425000	417000	356000	420000	398000	378000	422000	409000	341000	421000	404000	433000	402000	422000	396000	212000	218000	165000
Mg (mg/kg)	2300	-200	-200	1000	1200	1000	1500	1000	-200	200	500	1200	1300	1400	-200	600	1300	3300	1900
Mn (mg/kg)	675	75	166	379	804	664	597	748	19	34	81	545	672	852	24	461	465	910	398
Ni (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pb (mg/kg)	3960	7290	10700	6030	14100	9600	7580	4860	6990	3730	4270	4150	4360	5810	8340	12600	6300	6470	4260
Zn (mg/kg)	12900	12300	9700	14000	12800	11100	8170	7280	876	663	3900	8260	1000	9260	442	11100	14300	17400	8540

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Table 7.15 Summary of the Characteristics of Faro Original, Second and Intermediate Tailings cont.

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1988DH																			
Test Sample	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI
Sample No.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Area of Impoundment	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original
Probable Age	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old
Depth (m)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	6.1	7.6	9.1	9.9	10.7	12.2	13.7	15.2	16.2	16.8
Field Temp oC	15	12	12	12	11	10	11	8	7.5	8	10	4	7.5	0	0	2	1	0	0	0
Moisture	-	2.6	-	-	2	-	-	-	-	-	-	-	13.9	-	-	-	14.2	-	-	-
Paste pH Field	2.3	4.5	3.9	4.7	5.1	5.4	5.5	5.5	5.5	5.5	6.5	8.4	8.4	7.5	7.7	6.5	6.4	7.5	7.1	5.9
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	23.1	49.9	-	-	41.9	41.7	-	41.6	-	-	40	-	38.9	-	-	-	32.6	-	-	-
Sulphate Sulphur	2.43	0.23	-	-	0.062	0.076	-	0.12	-	-	0.13	-	0.041	-	-	-	0.056	-	-	-
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	-	1521	-	-	1282	1276	-	1270	-	-	-	-	1190	-	-	-	997	-	-	-
NP	-	3.8	-	-	24	24.5	-	31.2	-	-	-	-	26.5	-	-	-	38.8	-	-	-
NPP	-	-1517.2	-	-	-1258	-1251.5	-	-1238.8	-	-	-	-	-1163.5	-	-	-	-958.2	-	-	-
Al (mg/kg)	-	119	-	-	882	597	-	314	-	-	-	-	476	-	-	-	748	-	-	-
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	-	10.2	-	-	14.7	17.1	-	15.2	-	-	-	-	9.4	-	-	-	17.9	-	-	-
Cu (mg/kg)	-	795	-	-	1239	1223	-	1086	-	-	-	-	1323	-	-	-	1198	-	-	-
Fe (mg/kg)	-	357143	-	-	252501	326407	-	280952	-	-	-	-	311284	-	-	-	299484	-	-	-
Mg (mg/kg)	-	120	-	-	1716	1399	-	1810	-	-	-	-	1616	-	-	-	1994	-	-	-
Mn (mg/kg)	-	-	-	-	1471	1305	-	1143	-	-	-	-	1446	-	-	-	1196	-	-	-
Ni (mg/kg)	-	<10	-	-	9.8	10.3	-	<10	-	-	-	-	10.2	-	-	-	16	-	-	-
Pb (mg/kg)	-	915	-	-	2763	589	-	3048	-	-	-	-	272	-	-	-	488	-	-	-
Zn (mg/kg)	-	8427	-	-	10958	15631	-	12381	-	-	-	-	8755	-	-	-	13822	-	-	-

Test Program	1988DH cont.																			
Test Sample	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.1 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI	2.2 HI
Sample No.	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
Area of Impoundment	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Second	Second	Second	Second	Second	Second	Second	Second	Second
Probable Age	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	?	?	?	?	?	?	?	?	?
Depth (m)	17.2	17.6	19.8	21.3	22.9	24.4	25.9	27.4	29	32	33.5	1	1.5	2	2.5	3	3.5	4	4.5	6.1
Field Temp oC	0	0	6.5	5	5.5	-	-	-	-	-	-	10	8	8	8	8	6	5	5	4
Moisture	-	-	-	-	-	-	-	-	-	-	-	-	22.6	-	17.1	-	-	-	-	-
Paste pH Field	-	7.8	8.2	8.1	7.4	-	-	-	-	-	-	5.4	5.5	-	5.3	5.8	7.1	7.2	7.6	7.8
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	-	-	-	-	-	-	1.69	-	-	0.08	-	18.6	24.8	21.5	25.5	-	-	-	-	-
Sulphate Sulphur	-	-	-	-	-	-	0.015	-	-	0.012	-	0.25	0.34	0.03	0.22	-	-	-	-	-
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	-	-	-	-	-	-	51	-	-	2.1	-	-	750	658	774	-	-	-	-	-
NP	-	-	-	-	-	-	12.8	-	-	40.5	-	-	28.5	26.5	25	-	-	-	-	-
NPP	-	-	-	-	-	-	-38.2	-	-	38.4	-	-	-721.5	-631.5	-749	-	-	-	-	-
Al (mg/kg)	-	-	-	-	-	-	8755	-	-	15353	-	-	-	-	-	-	-	-	-	-
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	-	-	-	-	-	-	<5.0	-	-	<5.0	-	-	15.1	11.9	15	-	-	-	-	-
Cu (mg/kg)	-	-	-	-	-	-	67.3	-	-	29.3	-	-	1001	749	791	-	-	-	-	-
Fe (mg/kg)	-	-	-	-	-	-	30136	-	-	24376	-	-	215552	217827	180198	-	-	-	-	-
Mg (mg/kg)	-	-	-	-	-	-	4932	-	-	8130	-	-	1604	1788	1581	-	-	-	-	-
Mn (mg/kg)	-	-	-	-	-	-	276	-	-	511	-	-	642	636	674	-	-	-	-	-
Ni (mg/kg)	-	-	-	-	-	-	17.6	-	-	29.3	-	-	21.7	18.9	22.5	-	-	-	-	-
Pb (mg/kg)	-	-	-	-	-	-	171	-	-	19.5	-	-	5206	1394	1902	-	-	-	-	-
Zn (mg/kg)	-	-	-	-	-	-	1507	-	-	176	-	-	12201	7841	12013	-	-	-	-	-

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Table 7.15 Summary of the Characteristics of Faro Original, Second and Intermediate Tailings cont.

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1988DH cont.														
Test Sample	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H1	2.2 H2	2.2 H2
Sample No.	62	63	64	65	66	67	68	69	70	71	72	73	74	74A	75
Area of Impoundment	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second	Second
Probable Age	?	?	?	?	?	?	?	?	?	?	?	Alluvium	Alluvium	Alluvium	Alluvium
Depth (m)	7.6	9.1	10.7	12.2	13.7	15.2	16.8	18.3	19.8	22.9	24.4	25	24.4	24.4	25.9
Field Temp oC	-	4	5	5	5	5	5	4	5	4	5	-	-	-	-
Moisture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paste pH Field	7.9	8.2	9.2	8.5	8.2	9.2	8.1	9.8	9.4	8.8	6.2	-	-	-	-
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	-	13.6	-	-	-	-	-	13.6	-	-	-	-	-	-	8.6
Sulphate Sulphur	-	0.097	-	-	-	-	-	0.37	-	-	-	-	-	-	0.13
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	-	413	-	-	-	-	-	404	-	-	-	-	-	-	260
NP	-	45.3	-	-	-	-	-	0	-	-	-	-	-	-	0
NPP	-	-367.7	-	-	-	-	-	-404	-	-	-	-	-	-	-260
Al (mg/kg)	-	3180	-	-	-	-	-	6478	-	-	-	-	-	-	4985
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	-	15.3	-	-	-	-	-	6.1	-	-	-	-	-	-	<5.0
Cu (mg/kg)	-	849	-	-	-	-	-	304	-	-	-	-	-	-	290
Fe (mg/kg)	-	168694	-	-	-	-	-	137457	-	-	-	-	-	-	87074
Mg (mg/kg)	-	2336	-	-	-	-	-	2438	-	-	-	-	-	-	2283
Mn (mg/kg)	-	1437	-	-	-	-	-	294	-	-	-	-	-	-	523
Ni (mg/kg)	-	26.1	-	-	-	-	-	16.5	-	-	-	-	-	-	12.4
Pb (mg/kg)	-	2761	-	-	-	-	-	569	-	-	-	-	-	-	164
Zn (mg/kg)	-	11246	-	-	-	-	-	4909	-	-	-	-	-	-	2032

Test Program	1988DH cont.														
Test Sample	2.2 H2	2.2 H2	2.2 H2	2.2 H2	2.2 H2	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1	2.3 H1
Sample No.	76	77	78	79	80	1	2	3	4	5	6	7	8	9	10
Area of Impoundment	Second	Second	Second	Second	Second	Second	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Probable Age	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium	"New"	"New"	"New"	"New"	"New"	"New"	"New"	"New"	"New"
Depth (m)	27.4	29	30.5	32	33.5	1	1.5	2	2.5	3	3.5	4	4.5	6	7.5
Field Temp oC	-	-	-	-	-	8	6.5	1.5	5.5	8	3	4.5	-	-	-
Moisture	-	-	-	-	-	-	18.5	-	-	7	-	-	-	-	10.2
Paste pH Field	-	-	-	-	-	7.8	8.3	8.6	8.6	8.6	7.7	7.1	-	-	-
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	-	-	1.74	-	-	24.1	34.4	-	-	35.1	39.2	-	-	-	0.67
Sulphate Sulphur	-	-	0.034	-	-	0.038	0.027	-	-	0.19	0.064	-	-	-	0.011
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	-	-	52	-	-	-	1053	-	-	1068	1200	-	-	-	-
NP	-	-	11.5	-	-	-	23	-	-	26.2	16.7	-	-	-	-
NPP	-	-	-40.5	-	-	-	-1030	0	0	-1041.8	-1183.3	-	-	-	-
Al (mg/kg)	-	-	7944	-	-	-	1211	-	-	1065	515	-	-	-	9786
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	-	-	<5.0	-	-	-	6.4	-	-	14	20.8	-	-	-	<5.0
Cu (mg/kg)	-	-	60.9	-	-	-	1137	-	-	1074	1043	-	-	-	25.2
Fe (mg/kg)	-	-	31212	-	-	-	300695	-	-	280899	302144	-	-	-	19765
Mg (mg/kg)	-	-	4781	-	-	-	1525	-	-	1477	1189	-	-	-	4619
Mn (mg/kg)	-	-	327	-	-	-	237	-	-	847	684	-	-	-	227
Ni (mg/kg)	-	-	18.4	-	-	-	16.1	-	-	16.3	14.9	-	-	-	19.7
Pb (mg/kg)	-	-	38	-	-	-	714	-	-	1232	3801	-	-	-	18
Zn (mg/kg)	-	-	434	-	-	-	6578	-	-	11827	16569	-	-	-	171

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Table 7.15 Summary of the Characteristics of Faro Original, Second and Intermediate Tailings cont.

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1988DH cont.														
Test Sample	2.3 H1	2.3 H2	2.3 H2	2.3 H2	2.3 H2	2.3 H2	2.3 H2	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1
Sample No.	14	16	17	18	19	20	21	81A	82	83	84	85	86	87	88
Area of Impoundment	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Original	Original	Original	Original	Original	Original	Original	Original
Probable Age	Alluvium	?	?	?	?	?	?	Old	Old	Old	Old	Old	Old	Old	Old
Depth (m)	14	1	1.5	2	2.5	3	3.5	0	0.5	1	1.5	2	2.5	3	3.5
Field Temp oC	-	5.5	3	1	6	5	2.5	7	10	8	8	9	7	7	6
Moisture	19.2	-	-	-	-	-	-	-	5.5	-	-	6.2	-	-	-
Paste pH Field	-	9.8	9.1	8	9	8.2	7.9	2.1	4	5	5.4	5.2	5.9	5.1	6.5
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	0.21	-	-	-	-	-	-	32.6	10.8	-	-	32.7	32.4	-	-
Sulphate Sulphur	0.006	-	-	-	-	-	-	1.56	0.72	-	-	0.42	0.26	-	-
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	6.4	-	-	-	-	-	-	-	309	-	-	988	-	-	-
NP	25.5	-	-	-	-	-	-	-	9.5	-	-	17.2	-	-	-
NPP	19.1	-	-	-	-	-	-	-	-299.5	-	-	-970.8	-	-	-
Al (mg/kg)	10735	-	-	-	-	-	-	-	2398	-	-	919	770	-	-
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	<5.0	-	-	-	-	-	-	-	17	-	-	10.2	9.8	-	-
Cu (mg/kg)	36.3	-	-	-	-	-	-	-	593	-	-	935	936	-	-
Fe (mg/kg)	23602	-	-	-	-	-	-	-	113592	-	-	292840	275726	-	-
Mg (mg/kg)	5214	-	-	-	-	-	-	-	345	-	-	1459	322	-	-
Mn (mg/kg)	282	-	-	-	-	-	-	-	168	-	-	919	966	-	-
Ni (mg/kg)	27	-	-	-	-	-	-	-	22.7	-	-	13.1	7	-	-
Pb (mg/kg)	9.1	-	-	-	-	-	-	-	2173	-	-	982	551	-	-
Zn (mg/kg)	209	-	-	-	-	-	-	-	12841	-	-	10863	10340	-	-

Test Program	1988DH cont.														
Test Sample	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.4 H1	2.5 H1	2.5 H1	2.5 H1
Sample No.	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Area of Impoundment	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Original	Intermediate	Intermediate	Intermediate
Probable Age	Old	Old	Old	Old	Old	Old	Old	Old	Old	Old	Till	Till	New?	New?	New?
Depth (m)	4	4.5	6.1	7.6	9.1	10.7	12.2	13.7	15.2	16.8	18.3	19.8	0	0.5	1
Field Temp oC	5	4	2	0	4	3	2	2	2	2	3	3	3	8	9
Moisture	-	-	-	35.3	-	-	15.7	-	-	-	-	-	-	7.6	-
Paste pH Field	7.9	7.4	8.5	8.8	7.4	6.9	7.9	9.4	8.6	8.6	8.3	7.9	2.5	3.5	5.1
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	38.7	-	-	38.4	-	-	-	25.7	-	-	-	0.38	18.4	13.1	-
Sulphate Sulphur	0.16	-	-	0.13	-	-	-	0.047	-	-	-	<0.01	1.2	0.89	-
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	1181	-	-	1172	-	-	-	786	-	-	-	11.6	-	373	-
NP	17.2	-	-	37.9	-	-	-	37.9	-	-	-	9	-	6	-
NPP	-1163.8	-	-	-1134.1	-	-	-	-748.1	-	-	-	-2.6	-	-367	-
Al (mg/kg)	859	-	-	888	-	-	-	805	-	-	-	6787	-	1805	-
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	14.3	-	-	16.2	-	-	-	24.5	-	-	-	<5.0	-	13.3	-
Cu (mg/kg)	1251	-	-	1574	-	-	-	1768	-	-	-	59.3	-	387	-
Fe (mg/kg)	277947	-	-	307467	-	-	-	228507	-	-	-	30593	-	127827	-
Mg (mg/kg)	1074	-	-	3715	-	-	-	3632	-	-	-	978	-	1238	-
Mn (mg/kg)	1163	-	-	1373	-	-	-	2454	-	-	-	320	-	145	-
Ni (mg/kg)	13.4	-	-	12.9	-	-	-	4.9	-	-	-	21.5	-	17.7	-
Pb (mg/kg)	730	-	-	1208	-	-	-	371	-	-	-	76.5	-	973	-
Zn (mg kg)	8686	-	-	13177	-	-	-	16815	-	-	-	956	-	10816	-

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Table 7.15 Summary of the Characteristics of Faro Original, Second and Intermediate Tailings cont.

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1988DH cont.													
Test Sample	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1	2.5 H1
Sample No.	104	105	106	107	108	109	110	111	112	113	114	115	116	117
Area of Impoundment	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Probable Age	New?	New?	New?	New?	New?	New?	New?	New?	Old?	Old?	Old?	Old?	Alluvium	Alluvium
Depth (m)	1.5	2	2.5	3	3.5	4	4.5	6.1	7.6	9.1	10.7	12.2	13.7	15.2
Field Temp oC	8	8	8	6	5	5	5	4	3	3	3	3	4	4
Moisture	5	-	-	-	-	-	-	14.6	-	-	10.5	-	-	-
Paste pH Field	5.4	5.3	7.1	7.2	7.9	7.5	7.6	7.5	7.9	6.9	8.7	8.5	6.8	6.9
Paste pH Lab	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total % Sulphur	15.1	16.6	17.9	-	-	-	-	34.2	-	-	40.8	-	-	0.83
Sulphate Sulphur	0.23	0.28	0.35	-	-	-	-	0.026	-	-	0.012	-	-	<0.01
Pyritic Sulphur	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AP	456	499	-	-	-	-	-	1047	-	-	1248	-	-	25
NP	27.2	24.3	-	-	-	-	-	22.9	-	-	20	-	-	13.3
NPP	-428.8	-474.7	0	0	0	0	0	-1024.1	0	0	-1228	0	0	-11.7
Al (mg/kg)	1806	1973	1176	-	-	-	-	456	-	-	-	-	-	6894
As (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca (mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cd (mg/kg)	15.7	14.5	20.1	-	-	-	-	19.9	-	-	-	-	-	<5.0
Cu (mg/kg)	419	432	480	-	-	-	-	960	-	-	-	-	-	97.6
Fe (mg/kg)	154660	147304	147656	-	-	-	-	277778	-	-	-	-	-	42572
Mg (mg/kg)	1276	2321	1339	-	-	-	-	3894	-	-	-	-	-	3959
Mn (mg/kg)	609	609	937	-	-	-	-	522	-	-	-	-	-	541
Ni (mg/kg)	32.4	33.8	30.6	-	-	-	-	19	-	-	-	-	-	19.3
Pb (mg/kg)	1297	1277	1938	-	-	-	-	5714	-	-	-	-	-	115
Zn (mg/kg)	16464	16695	16150	-	-	-	-	16667	-	-	-	-	-	1153

Test Program	SS1990							
Test Sample	1	2	3	4	5	6	7	8
Sample No.	S1	S2	S3	S4	S5	S6	S7	S8
Area of Impoundment	Original	Original	Original	Original	Second	Second	Second	Intermediate
Probable Age	Old?	Old?	Old?	Old?	New?	New?	New?	New?
Depth (m)	-	-	-	-	-	-	-	-
Field Temp oC	-	-	-	-	-	-	-	-
Moisture	16.6	7.33	15.4	4.95	20	15.6	9.69	23
Paste pH Field	-	-	-	-	-	-	-	-
Paste pH Lab	2.45	2.46	2.24	3.83	2.18	3.39	4.27	4.85
Total % Sulphur	19.6	31.5	31.4	31.1	29.9	31	34.2	33.3
Sulphate Sulphur	1.87	1.54	1.96	3.09	0.81	1.28	0.57	0.35
Pyritic Sulphur	-	-	-	-	-	-	-	-
AP	554.1	936.3	920	875.3	909.1	928.8	1050.9	1029.7
NP	-40.1	-26.2	-31.7	-6.4	-48.9	-1.3	2.1	12
NPP	-594.2	-962.5	-951.7	-881.7	-958	-930.1	-1048.8	-1017.7
Al (mg/kg)	140	80	90	140	90	120	50	100
As (mg/kg)	760	896	840	876	974	767	737	834
Ca (mg/kg)	180	130	260	140	290	190	140	160
Cd (mg/kg)	<0.5	<0.5	2.4	16.3	<0.5	0.78	4.6	8.6
Cu (mg/kg)	410	433	1220	687	583	911	1040	861
Fe (mg/kg)	18.18	29.34	33.44	29.66	27.58	29.2	32.94	29.04
Mg (mg/kg)	820	0	0	10	0	120	150	110
Mn (mg/kg)	36	52	130	214	22	54	85	652
Ni (mg/kg)	<1	<1	35	<1	<1	<1	7	<1
Pb (mg/kg)	5100	6490	5460	7410	>10000	9420	3280	3660
Zn (mg/kg)	2130	3000	1530	>10000	1840	3200	6080	9420

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Table 7.16 Pore Water Analysis Results

1988 Drillhole Program

(from Steffen, Robertson and Kirsten Inc., 1991)

Site	DH 88/1			DH 88/2					
Sample No.	32	34	38	55	56	56 Re-ext	57	63	63 Re-ext
Depth (m)	6	9	13.5	2	2.5	2.5	3	9.1	9.1
Volume Water Extracted (ml)	48	52	101	114	26	96	38	69	34
Volume Water Added (ml)	0	0	0	0	0	100	0	0	0
pH	7.5	7.3	5.9	4.8	4.9	4.3	3.8	8.6	7.5
Alk (mg CaCO3/L)	0	0	180	10	0	0	0	0	0
Sulphate (mg/L)	5640	1396	2264	8626	7790	3175	5308	591	265
Cu-D (mg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.05	0.05
Fe-D (mg/L)	0.1	0.1	40	3150	1830	524	209	0.01	0.01
Pb-D (mg/L)	0.2	0.2	1.1	0.1	3.6	4.6	1.4	0.1	0.1
Zn-D (mg/L)	4.08	5.5	7.7	90	700	380	75	0.35	2.3

Site	DH 88/3		DH 88/4				DH 88/5	
Sample No.	2	2 Re-ext	88	92	96	96 Re-ext	111	114
Depth (m)	1.5	1.5	3.5	6.1	12.2	12.2	6.1	10.7
Volume Water Extracted (ml)	58	83	71	137	73	79	88	30
Volume Water Added (ml)	0	100	0	0	0	100	0	0
pH	6.6	6.6	7.2	7.2	8.1	8.5	7.7	7.9
Alk (mg CaCO3/L)	60	60	0	0	0	0	0	0
Sulphate (mg/L)	1396	179	10616	680	460	281	3240	698
Cu-D (mg/L)	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Fe-D (mg/L)	4.92	19.7	0.12	0.22	0.14	0.4	0.1	0.46
Pb-D (mg/L)	0.3	0.2	0.1	0.1	0.3	0.3	0.1	0.2
Zn-D (mg/L)	6.5	2.33	2.01	3.18	1.47	0.23	1.7	6.2

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Table 7.17 Shake Flask Test Results

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1986Gtp1			1986Gtp2		1986Gtp3			1986Gtp4		1986Gtp5	
Sample No.	2	4	6	1	6	1	5	6	1	4	1	3
Depth	-	-	-	-	-	-	-	-	-	-	-	-
pH	3.02	3.82	5.84	3.13	4.66	2.85	5.8	4.81	2.34	5.86	2.58	4.39
SO4-2 (mg/L)	950	976	4850	700	1110	700	1110	776	2020	460	810	1510
SO4-2 (mg/kg)	4750	4880	24250	3500	5550	3500	5550	3880	10100	2300	4050	7550
Ca (mg/L)	221	191	530	233	163	272	15.3	192	251	132	83	264
Ca (mg/kg)	1105	955	2650	1165	815	1360	76.5	960	1255	660	415	1320
Cu (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cu (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe (mg/L)	41	16	<2	37	19	32	<2	<2	515	<2	122	12
Fe (mg/kg)	205	80	0	185	95	160	0	0	2575	0	610	60
Mg (mg/L)	8.5	52.6	336	5.5	65.7	2.4	61	46.1	3.8	23.8	3.6	74.5
Mg (mg/kg)	42.5	263	1680	27.5	328.5	12	305	230.5	19	119	18	372.5
Pb (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pb (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zn (mg/L)	195	190	1300	47	2305	35	455	51	64	51	94	240
Zn (mg/kg)	975	950	6500	235	11525	175	2275	255	320	255	470	1200

Test Program	1986Gtp6			1987TP*								
Sample No.	1	3	6	10	11	12	13	14	15	20	21	22
Depth	-	-	-	0	0.5	1	1.5	2	3	0	0.5	1
pH	2.96	4.04	5.76	3	3.1	4.2	4.3	4.6	5.9	3	3	3.7
SO4-2 (mg/L)	160	870	2180	110	210	200	380	290	430	130	290	310
SO4-2 (mg/kg)	800	4350	10900	2200	4200	4000	7600	5800	8600	2600	5800	6200
Ca (mg/L)	2.4	166	109	0.5	34.7	43.2	35.4	19	47	0.8	41.8	61.3
Ca (mg/kg)	12	830	545	10	694	864	708	380	940	16	836	1226
Cu (mg/L)	NA	NA	NA	0.915	1.8	0.071	0.277	0.033	0.005	0.977	2.34	0.348
Cu (mg/kg)	NA	NA	NA	18.3	36	1.42	5.54	0.66	0.1	19.54	46.8	6.96
Fe (mg/L)	22	20	<2	23.2	24.2	10.6	15.6	14.4	6.48	3.23	36	18.3
Fe (mg/kg)	110	100	0	464	484	212	312	288	129.6	64.6	720	366
Mg (mg/L)	0.66	49.4	231	0.4	3	13.6	30.7	20	41.9	0.6	2.6	17.3
Mg (mg/kg)	3.3	247	1155	8	60	272	614	400	838	12	52	346
Pb (mg/L)	NA	NA	NA	5.33	3.4	3.55	2.59	2.35	3.01	3.78	2.72	2.52
Pb (mg/kg)	NA	NA	NA	106.6	68	71	51.8	47	60.2	75.6	54.4	50.4
Zn (mg/L)	59	100	415	21.9	45.3	23	82.8	77	69.9	32.3	62.8	52.5
Zn (mg/kg)	295	500	2075	438	906	460	1656	1540	1398	646	1256	1050

** = Test procedures used to determine concentration differed from BC Research standard procedures - results converted to mg metal/kg of water for direct comparison*

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Table 7.17 Shake Flask Test Results cont.

(from Steffen, Robertson and Kirsten Inc., 1991)

Test Program	1987TP* cont.											
Sample No.	23	24	25	26	30	31	32	33	34	35	40	41
Depth	2	2	3	4	0	0.5	1	1.5	2	3	0	0.5
pH	4.5	4.4	4.5	4.8	2.5	2.5	2.8	4.1	4.3	4.5	2.6	4
SO4-2 (mg/L)	270	270	450	140	290	650	340	530	500	280	280	250
SO4-2 (mg/kg)	5400	5400	9000	2800	5800	13000	6800	10600	10000	5600	5600	5000
Ca (mg/L)	37.9	14.4	35.2	13.2	1.2	26.9	25.4	41.7	34.1	25.6	2.4	50.1
Ca (mg/kg)	758	288	704	264	24	538	508	834	682	512	48	1002
Cu (mg/L)	0.106	0.071	0.099	0.073	2.36	4.37	8.09	1.15	0.232	0.018	0.784	0.183
Cu (mg/kg)	2.12	1.42	1.98	1.46	47.2	87.4	161.8	23	4.64	0.36	15.68	3.66
Fe (mg/L)	17.2	20.6	22.3	5.37	92.3	204	66	29.5	29.1	40.8	101	16.8
Fe (mg/kg)	344	412	446	107.4	1846	4080	1320	590	582	816	2020	336
Mg (mg/L)	20.5	22	49.3	17.6	0.2	1.2	2.3	38.2	38.7	14.9	0.7	21.6
Mg (mg/kg)	410	440	986	352	4	24	46	764	774	298	14	432
Pb (mg/L)	3.16	3.2	2.47	5.06	0.61	1.48	1.91	1.99	2.56	3.55	2.51	4.71
Pb (mg/kg)	63.2	64	49.4	101.2	12.2	29.6	38.2	39.8	51.2	71	50.2	94.2
Zn (mg/L)	43.6	59.3	68.2	6.42	2.7	11.6	55.9	82.7	82.1	62.6	6.61	3.77
Zn (mg/kg)	872	1186	1364	128.4	54	232	1118	1654	1642	1252	132.2	75.4

Test Program	1987TP* cont.			1990ss*							
Sample No.	42	43	44	1	2	3	4	5	6	7	8
Depth	1	1.5	2	-	-	-	-	-	-	-	-
pH	5	5.1	5.4	2.42	2.99	2.54	2.93	2.55	4.02	4.54	6.31
SO4-2 (mg/L)	1000	1000	580	1180	500	1220	300	1200	760	370	15
SO4-2 (mg/kg)	20000	20000	11600	23600	10000	24400	6000	24000	15200	7400	300
Ca (mg/L)	97.7	95.9	134	44.1	34.7	65.5	3.33	32.1	80.3	56.3	11.1
Ca (mg/kg)	1954	1918	2680	882	694	1310	66.6	642	1606	1126	222
Cu (mg/L)	-0.005	0.006	-0.005	2.34	1.9	1.91	2.29	2.15	2.13	<.01	<.01
Cu (mg/kg)	0	0.12	0	46.8	38	38.2	45.8	43	42.6	0	0
Fe (mg/L)	94.6	51.5	5.82	369	139	418	40.6	444	11.3	2.74	<.2
Fe (mg/kg)	1892	1030	116.4	7380	2780	8360	812	8880	226	54.8	0
Mg (mg/L)	46.3	71.3	46.1	1.7	2.38	1.59	0.91	0.99	75.7	45.3	0.86
Mg (mg/kg)	926	1426	922	34	47.6	31.8	18.2	19.8	1514	906	17.2
Pb (mg/L)	2.95	3.53	4.45	0.65	3.1	2.45	4.04	2.64	3.53	3.7	0.06
Pb (mg/kg)	59	70.6	89	13	62	49	80.8	52.8	70.6	74	1.2
Zn (mg/L)	81.4	81.7	44.5	3.81	77.9	7.66	89.4	7.12	108	3.6	0.86
Zn (mg/kg)	1628	1634	890	76.2	1558	153.2	1788	142.4	2160	72	17.2

**=Test procedures used to determine concentration differed from BC Research standard procedures - results converted to mg metal/kg of water for direct comparison*

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Table 7.18 Humidity Cell Test Results - Summary

(from Steffen, Robertson and Kirsten Inc., 1991)

Impoundment	Original							
Sample No.	23	26	26-2	34	38	82	85	85-2
Depth	0.5	2	2	9	13.5	0.5	2	2
Initial pH	2.9	6.6	6	6.9	5.8	3	4.1	3.4
Final pH	3	4.1	4.2	4.2	4.3	3	3.6	3.2
$SO4^{-2}$ (mg/g)*	3005	1730	1419	3607	2271	8980	11395	17865
Cu (mg/g)*	45.8	<1	0.64	26.6	2.27	107	23.4	41.7
Fe (mg/g)*	693	9.4	6.5	37.8	21.7	280	116	317
Pb (mg/g)*	11.6	20	19.9	10.4	15.5	2.7	9.3	9.1
Zn (mg/g)*	532	440	350	1045	424	4155	3805	5730

Impoundment	Original cont.		Second					
Sample No.	92	96	54	54-2	56	102	104	104-2
Depth	6.1	12.2	1.5	1.5	2.5	0.5	1.5	1.5
Initial pH	7.1	6.6	5.8	6	5.6	2.9	4.9	4.9
Final pH	3.9	4.6	3.9	3.8	4	2.9	4.8	4.5
$SO4^{-2}$ (mg/g)*	6720	6015	6860	7800	5420	16235	8600	5280
Cu (mg/g)*	62.3	19.2	18.8	11.4	8.5	99.5	2.1	0.73
Fe (mg/g)*	84.2	43.6	52.7	53.8	33.3	723	12.8	12.8
Pb (mg/g)*	7.3	7.8	8	7.7	9.9	7.9	8.9	10.2
Zn (mg/g)*	2100	1917	2465	2560	1765	8010	4565	2872

Impoundment	Second cont.		Intermediate			Native Soils	
Sample No.	111	114	2	5	5-2	10	14
Depth	6.1	10.7	1.5	3	3	8	14
Initial pH	6.4	6.4	5.8	6	5.9	7	6.6
Final pH	4	3.9	4.2	4.1	4	7.3	6.9
$SO4^{-2}$ (mg/g)*	2800	1045	1700	1405	1015	351	417
Cu (mg/g)*	12.9	6.3	5.1	3.6	1.98	<1	<1
Fe (mg/g)*	39.1	14	33.9	17.7	14.2	<1	<1
Pb (mg/g)*	12.5	19.6	12.8	19.7	25.6	<1	<1
Zn (mg/g)*	770	232	305	231	142	35.2	<1

*=*Cummulative amount of analyte released - test results after 42 days*

7.4.2.3 Original Impoundment

Tailings deposited in the Original Impoundment are considered "old" tailings as they were deposited prior to 1982. These tailings have been sampled in each of the four programs described above.

The tailings in the Original Impoundment generally have a high sulphide content and a negative net neutralization potential (NNP) indicating that the tailing are potentially acid generating. Sulphide content averaged about 31 percent total sulphur with 1.2 percent sulphate sulphur, and NNP of -917 kg $CaCO_3$ equivalent/tonne. The sulphide content was variable, ranging from less than 0.1 to 49.9 percent sulphide sulphur.

Surface samples 1 through 4 showed acidic paste pH values and no neutralization potential, indicating oxidation and acid generation. Shake flask tests were conducted on these samples to provide an indication of the water soluble fraction on the solids, primarily stored oxidation products. The leachate solution for all samples was acidic, pH<3 and contained elevated metal concentrations, confirming that oxidation has occurred and there is a store of water soluble products within these tailings layers.

The 1987 test pit samples showed increasing neutralization potential (NP) with depth (from 0 at surface to 12.7 to 19.5 kg $CaCO_3$ equivalent/tonne in 3m) indicating consumption of alkali materials in the near surface layers from oxidation and acid generation reactions, and to a lesser degree, from rainwater infiltration. The development of oxidation fronts and migration of contaminants down from the surface of the tailings is evident from these results. Test pit 3, located in tailings deposited prior to 1976, indicated the lowest NP values to the greatest depth. The 1988 drilling program indicated similar results, with higher NP values of 38 kg $CaCO_3$ equivalent/tonne below 7.6 m depth.

Metal contents in the solids were also variable, and averaged 0.1 percent Cu and 1 percent Zn. Iron was more abundant (as the primary gangue minerals are iron sulphides) but less variable, averaging 31.4 percent. The 1987 test pit sampling program indicated variability in metal content both spatially within the impoundment and over depth in the test pits, reflecting the inherent variability of the tailings.

Analysis of pore waters extracted from drillhole samples 2.1 and 2.4 showed elevated sulphate and metal concentrations but generally near neutral pH values.

Humidity cell tests indicated all samples were readily acid generating with final solution values of less than pH 4.6. Samples at an initial pH of >6 decreased to a pH range of 3.9 to 4.6 within six weeks of testing. Elevated sulphate and metal release was evident from all samples, although sulphate, iron, copper, and zinc production was lower from drillhole 2.1 samples, coincident with less advanced acid generation.

Shake flask tests were also conducted on these samples. The results indicate a significant store of readily dissolved products in the Original Impoundment, particularly iron, lead, and zinc, with copper concentrations and loading being relatively low. With continued flushing of these tailings (but without additional acid generation), the maximum potential loading estimated from the results of the 1987 program could be 1011 g Zn, 16 g of Cu, 734 g of Fe, and 62 g of Pb per tonne of tailing. It is important to note, however, that shake flask testing will release virtually all soluble products contained with the sample; this complete release is highly improbable considering conditions of in situ percolation of natural water flows through the tailings.

7.4.2.4 Second Impoundment

Tailings were deposited in the Second Impoundment from 1975 until 1982, and subsequently for approximately 5 months in 1986. Thus, most of the tailings were considered to be "old". Tailings were deposited in 1986 in the western part of the impoundment and graded in thickness from about 1 m to 0 m in the east. An east/west section across the Second Impoundment would have shown the 1986 tailings pinching out towards the east.

The eastern half of the tailings impoundment was represented by 1988 drillhole 2.1 and 1990 surface samples 5 and 6. "Old" tailings were located in this area, with similar characteristics to those described in the original impoundment, and were not covered by the tailings deposited in 1986. These tailings were therefore exposed for approximately six years prior to the drilling and surface sampling programs. Acidic paste pH values were detected in the upper 2 m of the tailing. In the drillholes a zone of active oxidation, as indicated by paste pH was observed in the upper 1 m of tailings with low paste pH values of 2.5 to 3.5, elevated solid sulphate concentrations of 0.12 to 1.2 percent. The two surface solid samples (5 and 6) which were collected from the eastern section of the impoundment also showed an active oxidation zone. Acidic pH values of 2.2 and 3.4 were measured with no neutralization potential available and elevated solid sulphate levels at 8100 and 12,800 mg/kg respectively.

Humidity cell tests also indicated the acid generating nature of the drillhole samples. Sulphate and metal production was highest from previously oxidized samples due in part to the contained load of soluble oxidation product, and to more advanced acid generation. Over the 10.7 m depth, sulphate production varied from 16,235 mg/kg to 1,045 mg/kg, and zinc from 8,010 mg/kg to 232 mg/kg.

The water soluble fraction of the tailings, as indicated by shake flask extraction tests showed acidic extractant pH values and elevated metal concentrations. Soluble magnesium and calcium were higher in sample 6 at an extractant pH of 4.02, suggesting some residual alkalinity was present compared to sample 5 at pH 2.55. Sample 5 is clearly within the zone not covered by fresh tailings since closure. Shake flask extraction tests on the surface samples demonstrated that the solids samples from this impoundment contain significant levels of water soluble contaminants. Sample 5 released 24,000 mg/kg SO_4^{-2}, 43 mg/kg Cu, 8880 mg/kg Fe, and 142 mg/kg Zn. Higher zinc and lead loads were released from sample 6 that yielded concentrations of 2160 mg/kg Zn and 71 mg/kg Pb. Pore water samples extracted from the drillhole samples indicated elevated sulphate concentrations at 6.1 m depth, and slightly elevated iron and zinc concentrations (0.46 and 6.2 mg/L respectively) at 10.7 m depth. This may indicate migration of dissolved metals through the tailings, although more samples would be required to provide a profile over depth.

The western section of the impoundment contains "old" tailings covered by a thin layer of "new" tailings. These new tailings showed similar variability in metals and sulphur content as the older tailings. The median and mean total sulphur contents were 26.9 and 30.4 percent respectively. The sulphate content is lower in the newer tailings solids, probably due to the shorter exposure period of these tailings and less oxidation. These tailings are also probably acid generating with net neutralization potentials ranging from -367 to -1183 kg $CaCO_3$ equivalent/tonne. Average copper and zinc contents were 0.06 percent and 1.1 percent respectively.

The development of oxidation fronts is less extensive in the older tailings in this impoundment compared to the Original Impoundment. Paste pH and pore water pH values were approximately pH 5.5. The drillhole samples contained residual alkalinity with NP values of approximately 28 kg $CaCO_3$ equivalent/tonne. This area of the impoundment appeared to have been covered by water during a portion of the closure period, and paste pH values did not indicate an oxidation front at depth similar to the surface of the eastern section of the impoundment.

Sulphate, iron, and zinc concentrations were elevated in the upper 3 m of the tailings, corresponding to pore water pH values decreasing over depth from 4.8 to 3.8, with no dissolved alkalinity. Sulphate concentrations were greater than 3175 mg/L, iron up to 3150 mg/L, and zinc up to 700 mg/L. This would suggest oxidation has occurred, or is occurring within this area of the Second Impoundment. Shake flask tests again indicated acidic solution pH values and elevated dissolved metal concentrations.

Humidity cell tests on samples from drillhole 2.2 indicated acid production with final pH values of 3.9, sulphate production approximately 7,620 mg/kg (average), and 2,263 mg/kg Zn (average).

7.4.2.5 Intermediate Dam Impoundment

Portions of the tailings in the Intermediate Dam Impoundment are exposed on a tailings beach, but may be predominantly saturated. Tailings located adjacent to the Intermediate Dam are typically underwater. Thus oxidation of these tailings has not, and may never, proceed as far as those unsaturated tailings stored in the Original and Secondary Impoundments.

Tailings in the Intermediate Impoundment were characterized by the 1988 drillholes DH 2.3 #1 and #2, and the 1990 surface sample #8. These are "new" tailings with sulphide and metals contents as described above.

Paste pH values are neutral or slightly alkaline above pH 7.1 with NP values from 16.7 to 26.2 kg $CaCO_3$ equivalent/tonne. Pore water samples recovered from drillhole 2.3 showed that slightly elevated sulphate, iron, and zinc concentrations existed at pH 6.6. Shake flask tests did not indicate a high soluble fraction compared to other areas of the tailings with a near neutral leachate pH value. Humidity cell tests showed that the tailings are acid generating with final pH values of 4.1 Metal and sulphate production was lower than for other tailings samples (on average) at 1370 mg/kg SO_4^{-2} and 226 mg/kg Zinc. Lead production was higher, however, at 19.4 mg/kg (average). This may be due to relatively rapid lead release from solids in the early stages of oxidation.

7.4.2.6 Summary of Acid Generating Potential

In summary, the Valley Impoundment contains tailings with strong acid potential. Oxidation of the exposed tailings over the life of the mine has produced a store of soluble oxidation products, including sulphates, soluble metal salts and acidity. Most of these oxidation products appear to be still stored in the tailings, due to the buffering of underlying unoxidized tailings. Only the dissolved sulphate front appears to have moved through the tailings mass to effect underlying groundwater aquifer and the seepage at the toe of the Cross Valley Dam. The dissolved zinc front appears to be close to exiting into the underlying aquifer below the secondary tailings dam.

Continued exposure of these tailings will allow continued oxidation of remaining sulphides in the tailings mass, and continued transport of oxidation products down through the tailings, resulting in the eventual overwhelming of the available buffering capacity. Thus, delay of mitigation measures increases the potential for increasing loads of acidity and metals to be released to the receiving environment.

7.4.2.7 Management Alternatives

Given the acid generation and metal leaching potential of the tailing identified above, several management alternatives were reviewed by the company in order to reduce the potential leaching of heavy metals from the tailing impoundment and thereby protect the water quality of Rose Creek (Steffen, Robertson and Kirsten Inc., 1991). The five management alternatives considered by the company for the tailings were:

- Alternative 1 - no covers (base case);
- Alternative 2 - soil cover;
- Alternative 3 - water cover;
- Alternative 4 - water/composite soil cover; and
- Alternative 5 - water cover with reprocessing of some of the tailings.

After a thorough review of the various alternatives the following water quality predictions were made for each alternative (Steffen, Robertson and Kirsten Inc., 1991).

7.4.2.7.1 Alternative 1

High metal loads would be generated both in the in the groundwater below the tailings impoundments and in surface water discharging over the Intermediate Dam spillway. The predicted receiving water zinc concentrations would be high and probably unacceptable.

7.4.2.7.2 Alternative 2

The total soil cover alternative was predicted to provide good protection of receiving waters. Predicted incremental zinc concentrations downstream of the tailings impoundment were mostly lower than 0.003 mg/L with the peak monthly concentration only slightly exceeding this value. However, the predictions were tied to the assumption of soil cover performance and metal mobility. Variances in these assumptions would change the receiving water quality predictions.

7.4.2.7.3 Alternative 3

A total flooding of the entire Down Valley Tailings Impoundment would undoubtedly prevent the vast majority of potential acid generation, and was considered the best available technology (BAT) approach. However, the low concentration of zinc assigned to tailings seepage, when combined with the very high rates of seepage, did not produce an insignificant contaminant load. When translated into receiving water quality, this alternative appeared marginally worse compared with Alternative 2, the soil cover alternative.

7.4.2.7.4 Alternative 4

This alternative was a combination of Alternatives 2 and 3 with a soil cover on the Original and Second Impoundment, and a water cover over the Intermediate Dam Impoundment. The average zinc concentration in discharging groundwater was predicted to be marginally lower that Alternative 2, and marginally higher than Alternative 3. The seepage rates predicted for the water cover on the Intermediate Dam Impoundment were predicted to yield a zinc load marginally higher than either of the other two alternatives. Predicted water quality concentrations downstream of the impoundment were similar to Alternative 2 and 3, with an average zinc concentration of 0.003 mg/L. The peak monthly concentration was predicted to be an order of magnitude higher than the average concentration.

7.4.2.7.5 Alternative 5

Alternative 5 provided the lowest predicted contaminant load generated and best receiving water quality. This alternative combined low rates of acid generation and relatively low seepage rates. The predictions were based on a maximum tailings elevation in the Intermediate Dam Impoundment of 1044.3 m UTM. The predicted load would reduce progressively as the tailings elevation was reduced below this elevation. Receiving water zinc concentrations downstream were predicted to average 0.001 mg/L. In the low flow winter period, values were predicted to be roughly 0.006 mg/L.

A comparison of the predictions made for the alternatives showed that values for Alternatives 2, 3 and 4 were of the same order. The differences between values for these alternatives should not be considered particularly significant. Values predicted for Alternative 1 were high, while Alternative 5 values were the lowest.

Based on the above, except for Alternative 1, it was concluded that any of the alternatives have sufficient potential for protection of receiving water quality to warrant further investigation. Alternative 5 showed the highest promise based on long-term water quality. This alternative was contingent on the removal of a considerable volume of tailings.

7.4.2.8 Implementation of Management Alternatives

Although it is clear that implementation of one of the preferred management alternatives will be required in order to protect the water quality of Rose Creek (Alternative 1 is unacceptable), no significant action has been taken to date. Unless management of the tailings impoundment is undertaken, the water quality of Rose Creek could be significantly impacted in the long-term.

7.4.3 Waste Rock Piles

7.4.3.1 Faro Area

The ARD potential of the Faro area waste dumps was evaluated as part of the development of the site closure plan (Robertson Geoconsultants Inc., 1996a). The evaluation consisted of both a static and kinetic testing program.

Sample Selection

A sampling program was completed to collect representative samples of each of the four major rock types and various waste dumps. The samples were collected from the different dumps and pits in an attempt to address the variability in:

- rock types (units);
- "ages" of material (i.e., time since mining or deposition);
- geochemical composition within the rock unit;
- weathering over time within each rock type; and
- weathering over time compared for different rock units.

While the sampling focused on the waste rock dumps, much of the testing was also applicable to the ARD potential of the pit walls.

7.4.3.2 Dump Composition and Description

The geology of the waste rock in the Faro Area was summarized in a review of the Faro waste dump composition by Pigage (1988). The five main rock units identified were as follows:

1. Non-Calcareous Schists (Unit 1): Includes schist and altered schist from Faro, phyllite from Vangorda Plateau, and carbonaceous phyllite and schist;
2. Sulphides (Unit 2): Includes massive and disseminated sulphides and also ribbon banded graphic quartzite from Faro;

3. Calc-Silicate (Unit 3): Includes calc-silicate found primarily at Faro but elsewhere in the district and calcareous phyllite from Vangorda Plateau but also elsewhere in the district.
4. Intrusives (Unit 4): Includes both intrusives from Faro and meta-intrusives which can be massive or foliated; and
5. Overburden (Unit 5).

The overall dump composition at the Faro Site comprises:

- Non-calcareous biotite-muscovite-garnet-staurolite schists (Unit 1);
- Intrusives - hornblende diorite, quartz feldspar porphyry, granite (Unit 4);
- Meta - intrusives – basaltic greenstone from Grum (Unit 4);
- Disseminated sulphides, quartzites w/ varying sulphide content (Unit 2); and
- Calc-silicate (Unit 3).

The Faro Main and Intermediate Dumps are primarily schists to the north, with schists and calc-silicates to the south. These dumps also contain two "sulphide cells" where the massive and disseminated sulphides were deliberately deposited, and then covered on top and on the sides with calc-silicates and schist.

The Northeast Dumps are reported to be primary schists and calc-silicates with some diorites. The western portion of the dump fills the Zone II pit. There are also overburden piles on these dumps. Sulphides are not a major component of these dumps, however minor sulphides are evident in localized piles.

The Northwest Dumps are the oldest dumps, and comprise primarily intrusives (i.e., diorite) and calc-silicates with free dumped sulphides evident on the surface in one area.

The waste rock deposited in the Faro Valley Dump was reported to be primarily diorites, with some schists, calc-silicates and sulphides. The sulphides were dumped in three main areas. The Faro Valley Dump is know to be potentially acid generating, and drains to the Faro Main Pit.

The distribution of samples, by rock type, for each of the dumps is summarized in Table 7.18.

Table 7-19. Summary of Faro Area Waste Dump Rock Samples.

Waste Dump	Rock Unit			
	Schist Unit 1	Sulphide Unit 2	Calc-Silicate Unit 3	Intrusives Unit 4
Main & Intermediate	11	25	8	-
Northeast	3	5	5	3
Zone II Dump	4	2	2	2
Northwest	-	4	-	2
Faro Valley Dump	8	6	1	7

7.4.3.3 Static Testing Results

The static testing program for the rock samples presented in Table 7.18 included solids analysis for metals, acid base accounting, extraction testing, mineralogy, and particle size determinations. At the time of the preparation as this report the detailed results of the static testing program were unavailable (missing from Robertson Geoconsultants Inc., 1996a). As a result, only a summary of the key findings of the static testing program is presented below.

7.4.3.3.1 Schists

The schists, which were estimated to comprise approximately 51% of the Faro Area waste dumps, had zinc concentrations ranging from 100 to 8900 ppm. The highest concentrations were in the samples collected from the Main Dump. These samples were also the samples with the highest total sulphide sulphur. However, the next highest sulphide samples from the main dump had relatively low zinc content, ranging from 368 to 720 ppm. The range in lead and copper concentrations was also high with lead ranging from 32 to 3751 ppm and copper ranging from 3 to 2029 ppm.

The acid base account testing on the schist samples indicated that the schists would typically be considered net acid generating, although the paste pH values generally ranged from 6 to 8.4. Total sulphur contents range from 0.05% to 3.5%, with sulphate sulphur representing up to 40% of the total sulphur. Neutralization potential was generally low, with an average of 11 kg $CaCO_3$ equivalent/tonne, and a median value of 5.7 $CaCO_3$ equivalent/tonne for the 20 samples tested. Thus, the ratio of neutralization potential to acid potential (NP:AP) was less than 2:1 for all but one of the samples tested. The schist samples did not contain any significant carbonate minerals.

In the extraction tests, a few of the samples showed acidic solution pH values. These samples also displayed acidic paste pH values in the ABA testing. Calculations based on the Ca and Mg concentrations in solution indicated that all of the residual NP in the solids was available, however the available NP was insufficient to neutralize all of the acidity in solution. Samples from the main dump and sulphide cell showed comparatively high soluble zinc content in the extraction tests with concentrations up 314 mg/L in solution. In addition these samples all displayed high levels of sulphur, sulphate, and dissolved acidity. Zinc dissolution appeared to be more strongly related to sulphur content and extent of oxidation than to either the pH or zinc content of the solids. With decreasing pH there was increasing acidity as well as increasing dissolution of sulphate, calcium, and zinc into the extraction water. In addition, the data showed that these samples were also associated with higher levels of dissolved magnesium, copper, cobalt, and iron.

7.4.3.3.2 ***Sulphides***

The sulphides, which are estimated to comprise approximately 11% of the Faro Area waste dumps, had metal contents typical of the sulphide material with economic levels of zinc, lead, and iron content (i.e., ore). Arsenic, cobalt and nickel were also present in elevated levels in the sulphide samples.

The results of the acid base accounting on the sulphide samples showed that the sulphide samples are strongly acid generating having essentially no neutralization potential. The total sulphur contents ranged from 0.8% to 42%. Sample pH values tended to be acidic ranging from pH 7.7 to a low of 1.8. Typically the lower pH samples corresponded with higher sulphate contents and lower sulphide contents.

Like the schist samples, the sulphide samples also displayed elevated levels of sulphate, calcium, and zinc into the extraction water. Other elements such as magnesium, copper, cobalt, and iron were also elevated in these samples.

7.4.3.3.3 Calc-Silicates

The calc-silicates, which were estimated to comprise approximately 33% of the Faro Area waste dumps, showed relatively low metal contents for elements of potential environmental concern such as zinc, lead, arsenic, cobalt, and nickel. ICP analysis on the solid samples indicated that, for this rock type, the calcium and magnesium content was higher and the iron content lower when compared to the other rock types.

All of the samples collected from the Faro Area waste dumps had neutral to alkaline pH values ranging from 7.1 to 8.8. The calc-silicate material was generally acid consuming with NP values ranging from 12 to 136 kg $CaCO_3$ equivalent/tonne. The sulphide content of the calc-silicate samples varied from 0.2 to 0.6% sulphur, with sulphate contents of 0% in all but a few of the samples. The acid consuming nature of the rock was further supported by the paste pH values that were neutral to alkaline. The calcium concentrations in the samples correlated well with the measured NP values and with the geologic description of these calcareous materials. Alkalinity in these samples was determined to be derived from calcium and magnesium carbonate minerals. In general the calc-silicate samples were strongly acid consuming with NP:AP ratios of 5:1 and higher.

Extraction testing completed on calc-silicates samples resulted in alkaline test solutions with pH values ranging from greater than 8 to about pH 7.5 over the 24 hour test period. The conductivity values increased slightly over the test period, but in general remained relatively low reflecting the low concentration of sulphate (65 mg/L) in the test solution. The extraction solutions showed very little soluble metal associated with these samples. The highest zinc and sulphate concentrations in solution were 0.021 mg/L and 65 mg/L respectively.

7.4.3.3.4 Intrusives

The intrusives are estimated to comprise approximately 7% of the Faro Area waste dumps. The two metals of specific concern with respect to leaching from the intrusives were initially believed to be nickel and cobalt. Nickel values were generally higher in these samples than in other rock types, however the cobalt values were not. Overall the analysis of the metals in the solids showed a range of metal contents typical of the waste rock on site. Metal contents ranged between 3.4 and 6% for iron, 35 and 2382 ppm for lead, and 70 to 3400 ppm for zinc. The samples from the Northwest Dump, which were weathered diorites mixed with some sulphides, showed the influence of the sulphides as a much higher zinc concentration in the solids than the "pure" diorite samples from other sites. In addition, there is a higher percentage of the sulphur occurring as sulphate than in the other diorite samples.

The intrusive samples from the Faro Area were primarily diorites, however, they also included quartz feldspar porphyry rocks (QFP). The acid generation potential of the QFP samples was determined to be very low, with sulphur levels less than 0.13%, no sulphate, and low metals in the solids. There was effectively no NP in the QFP samples.

Extraction testing on the QFP sample with the highest metal contents confirmed that the leaching potential of the QFP was very low. The extraction solution had a neutral pH, low conductivity, sulphate concentrations of less than 10 mg/L, and very low metal concentrations.

7.4.3.4 Kinetic Testing Results

The majority of the kinetic cell testwork for the Faro Area waste dumps focused on the Unit 2 rock types (i.e., sulphide and pyritic quartzite). The results of the kinetic cell testing for the sulphide and pyritic quartzite samples confirmed the results of the static testing program. In general, all of the Unit 2 samples were relatively strong acidic producers with essentially no buffering capacity (i.e., minimal NP). In addition, the samples displayed elevated levels of sulphate, copper, iron, lead, manganese, and zinc.

The kinetic cell testing on the Unit 1 rock type (i.e., non-calcareous schists) also supported the results of the static testing program. The schists were determined to be relatively weak acid producers as indicated by the relatively low sulphate production for this sample. During the testing period, approximately 11 weeks, the schist sample did not release any significant amounts of metals into solution. It appears that there was still sufficient alkalinity in the sample to prevent any significant drop in the pH of the solution, as thus, prevent the mobilization of metals into solution.

The Unit 3 (i.e., calc-silicate) kinetic cell also performed as predicted by the static testing program. The cell essentially produced no significant acidity and had relatively elevated alkalinity levels compared to kinetic cells containing other rock types. The solution from the calc-silicate kinetic cell did contain a small amount of zinc.

7.4.3.5 *Summary*

Based upon the results of the static and kinetic cell testing programs the following was concluded:

- The Unit 1 rock type (i.e., non-calcareous schists) could be initially classified as a potentially weak acid generator. However, based on the results of the static and kinetic testing programs it is unclear if this rock type will become significantly acidic in the future. Further kinetic cell testing is required to determine the long-term pH drainage characteristics of this rock type. The testing also indicated that long-term metal leaching, primarily zinc, would occur from this material.

- The Unit 2 rock type (i.e., sulphide and pyritic quartzite) could be characterized as a relatively strong acid generator with significant levels of associated metal production. Production of acid and various metals from this rock type was considered likely to be rapid due to the high levels of contained sulphur and the lack of any significant levels of neutralizing capacity.

- The Unit 3 rock type (i.e., calc-silicate) could be classified as a relatively strong acid consumer with the potential for the long-term release of low levels of soluble zinc.

- The Unit 4 rock type (i.e., intrusives) could be classified as generally inert. No significant levels of acid producing or acid consuming minerals were present in the intrusives. In addition, no significant levels of leachable metals were present in this rock type.

In summary, strong acid generation is only anticipated from approximately 10% to the total waste rock in the Faro Area (i.e., sulphides). The potential for weak acid generation from the schists is a possibility and could potentially increase the acid drainage problem at the site if it were to occur. The schists account for approximately 50% of the total waste rock in the Faro area. Metal leaching, primarily zinc, is anticipated to occur at various rates from greater than 90% of the waste rock in the Faro Area.

The acid consuming properties of the calc-silicates may provide an opportunity to control the acid generation from the site through blending with/capping of acid generating waste. However, this strategy may not significantly improve the leaching of metals from the various rock types.

From an ARD point of view the intrusives appear to be the best material available for construction at the site due to their minimal acid generating and metal leaching characteristics.

7.4.3.6 *Management Strategies*

Based upon the information available, the only apparent management strategy implemented for the Faro Area waste dumps has been to deposit sulphide material into cells located in the waste dumps. The cells were then capped with calc-silicates and schist. The overall effectiveness of this management strategy is likely to be limited given the characteristics and quantities of the various rock types. Long-term metal leaching (primarily zinc) and overall weak acid drainage is likely to occur in the Faro Area. A comprehensive management plan that controls both acid generation and metal leaching as well as addresses runoff/seepage from the area is required to protect water quality in the long-term.

7.4.3.7 Vangorda and Grum

Detailed static and kinetic ARD data for the Vangorda and Grum Area waste dumps was limited. As a result, the following is a general summary of the ARD and metal leaching potential of the waste dumps.

The majority of the waste rock at the Vangorda and Grum Area is composed of sulphides and phyllite. Based on the previous experience with the Faro waste dumps, and geochemical testing completed on the Vangorda/Grum samples, the following was concluded:

- The sulphide and phyllite waste rock have the potential to generate acid and leach metals, specifically zinc and lead; and
- The sulphide waste rock has a greater potential to generate acid than the phyllite rock.

These conclusions are consistent with the results of the static and kinetic testing programs conducted on the Faro Area waste dumps for the schist (Unit 1) and sulphide (Unit 2) rock types.

The phyllites from the Grum Pit are reported to contain substantially fewer sulphides, as compared to the Vangorda Pit, and are considered relatively inert (ARMC, 1999).

During the September 1999 site visit, water samples were taken from Drain # 3, at the south side of the Vangorda dump, and at Drain #5, located just above the collection pond at the Little Creek Dam. Results (Table 7.14) indicated that the pooled seepage from Drain #3 was relatively neutral (pH 6.4), but contained high levels of sulphate (3340 mg/L) and dissolved metals. Dissolved metals included iron at 48.3 mg/L, zinc at 244 mg/L, nickel at 4.53 mg/L and cobalt at 2.43 mg/L.

Drain #5 demonstrated higher sulphate and metal levels, perhaps due to increased influence from the sulphide portion of the dump, as compared to the predominantly phyllite material near Drain #3. The Drain # 5 water was pH 3.4, with sulphate levels at 17600 mg/L, and dissolved iron, zinc, nickel and cobalt at 206, 3750, 13 and 18 mg/L respectively.

No samples were taken below the Grum Dump, as possible sites were well removed from the toe of the dump.

7.4.3.7.1 Management Strategies

Vangorda

Given the ARD and metal leaching potential of the waste, a management plan was developed to ensure that drainage from the Vangorda waste rock facility did not adversely affect the water quality of the receiving environment (Steffen, Robertson and Kirsten, 1989). The management plan specified that all of the waste materials from the overburden stripping and pit development at the Vangorda orebody were to be deposited into the Vangorda waste rock facility. The two waste rock types were to be separated into two different cells in the facility in order to provide better waste management. The rock containing a higher portion of sulphides was placed closest to the Vangorda Pit. A till berm was to be constructed around the toe of the facility including finger drains which were to direct seepage out of the facility and into a seepage collection ditch in a controlled manner. Seepage collected in the ditch was then to be directed to a collection pond prior to being pumped to the water treatment plant. In addition, all of the waste was to eventually be covered by a 3-metre thick layer of till. The purpose of the till cover was to:

- Limit oxygen entry into the waste rock facility; and
- Control contaminant migration by restricting infiltration.

In general the facility appears to have been built and operated according to the conceptual management plan outlined above. There are some exceptions. Modifications to the seepage collection ditch and finger drains were required in order to improve the efficiency and reliability of the seepage collection system. However, while some seepage was visible in the drains in the phyllite portion of the dump during the September 1999 site visit, it appeared that little seepage was being transported in the ditches to the collection pond.

In 1994 groundwater monitoring wells were installed in order to monitor the quality of the groundwater below the toe of the facility. Also in 1994, a small section of the facility was resloped and approximately 50% of the resloped area was covered with 2 metres of compacted till. Only a small portion of the facility was reclaimed at that time due to limited funding. Thus, the current effectiveness of the cover in preventing/controlling acid generation and metal leaching from the facility is minimal.

The lack of seepage from the phyllite portion of the dump may be due to the water capacity of the waste rock not yet being exceeded, or may be due to the escape of seepage into the ground below the dump, or may be due to evaporation of water that is temporarily stored in the dump.

Exposure of the waste rock since the cessation of mining, without the cover to act as an oxygen barrier, has likely allowed substantial oxidation to occur. In order to improve the long-term protection of water quality resources in the area of the Vangorda waste rock facility, the till cover should be placed over the entire facility to reduce infiltration and the outward transport of the available oxidation products. A research program that would define the current water balance for the facility and that would identify the reasons for the absence of significant volume of toe seepage would be beneficial. The seepage collection and treatment systems must also be functional. Long-term collection and treatment of seepage containing acid drainage and soluble metals will likely be required at the Vangorda waste rock facility.

Grum

Waste materials from the stripping of the Grum orebody were stockpiled on either side of the haul road. The main overburden stockpile drains to settling ponds. No acid-base accounting information was available for the overburden materials, but the majority is expected to be till. However, the overburden may contain amounts of waste sulphide or phyllite rock, such that some low levels of metals may be present in the drainage. It is considered that continued control of the drainage will be required to prevent degradation of water quality in the area.

While no specific data was found, waste rock in the main Grum dump is reported to consist predominantly of non-potentially acid generating waste rock. A cell of sulphide waste was reportedly placed on the outside center portion of the dump, so that it was bracketed on either side by more benign waste rock (ARMC, 1999). The closure plan proposes to place a till cover over the sulphide cell. Delay in placing the cover has diminished the cover's potential benefit as an oxygen barrier to reduce sulphide oxidation. The placement of a cover would now act to reduce infiltration and transport of the existing oxidation products stored in the dump.

The collection ditch at the toe of the Grum Waste Rock Dump is unlikely to be effective. During the September site visit, it was noted that the ditch is poorly graded, and eroded and breached in several areas.

7.4.4 Pit Walls

7.4.4.1 Faro Area

No specific acid-base account information was available for the Faro area pit walls. However it is anticipated that, in general terms, the ARD and metal leaching characteristics of the pit walls will be similar to the characteristic of the various rock types described in the waste rock dump section of the report. It is not believed that any measures had been taken to prevent/mitigate ARD and metal leaching from the pit walls.

7.4.4.1.1 Main Faro (Zone I) Pit and Zone III Pit

Tailings deposition into the mined out Main (Zone I) and Zone III Pits began in August 1992 and continued until closure in 1997. The Main Pit filled to the elevation that had been determined to represent an acceptable safety freeboard (elevation 3909.6 feet mine datum or approximately 50 feet below the elevation of overflow into the backfilled Zone II pit) in 1997. Since that time, the pit has required pumping to maintain the water elevation within the acceptable range and therefore reduce the potential for water to overflow to the Zone II pit and escape to the North Fork of Rose Creek. Thus water from various sources collects or is pumped to the Main Pit. Pit water quality is typical of buffered ARD, with elevated zinc (2-3 mg/L) and sulphate at near neutral pH. The pit water is pumped to the mill during the summer months, where lime is added and the treated water discharged to the Valley Tailings Impoundment.

Partial flooding of the pit is likely to have reduced oxidation of the lower pit walls. However, acidic drainage continues to enter the Main Pit from the Faro Valley Waste Dump, and water containing elevated concentrations of metals is also pumped to the Main Pit from the Zone II pit. Poor quality drainage is also likely to be derived from the exposed pit walls, and from other waste rock dumps that drain to the pit area. The fluctuating exposure of the pit walls from pumping likely enhances oxidation and metal release.

Management of the poor water quality from the Main Pit will require continued monitoring of the pond elevation, pumping, and lime treatment. Also, adequate capacity will be required in the Valley Impoundment to provide contingency storage and treatment.

7.4.4.1.2 Zone II Pit

The Zone II Pit contains elevated concentrations of zinc (approximately 50 mg/L in 1999), and is expected to continue to collect poor quality water draining off the pit walls and waste rock piles in the immediate area. Water is pumped to the Main Pit, which will continue to be required in order to prevent overflow to the North Fork of Rose Creek.

7.4.4.2 Vangorda and Grum

No specific information was available for the Vangorda and Grum pit walls. However it is anticipated that, like the Faro pit walls, the ARD and metal leaching characteristics of the Vangorda and Grum walls will be similar to the characteristic of the various rock types described in the waste rock dump section of the report. It is not believed that any measures had been taken to prevent/mitigate ARD and metal leaching from the pit walls, other than to divert clean runoff around the pit areas.

The closure plan for the Vangorda pit calls for the pit to be reclaimed as a clean water pit, with the creek flowing through it (i.e. Vangorda Creek Diversion to be removed). However, it is not clear that adequate water quality can be achieved to support this closure plan. During operations, pit water quality ranged from 40 to 50 mg/L total zinc. In the later part of 1999, the pit water quality was reported at less than 10 mg/L. However, the walls are visibly friable, and mineralized. Thus continued erosion and spalling will continue to expose fresh sulphide surface for oxidation.

7.4.5 Miscellaneous Areas

7.4.5.1 Ore and Low Grade Ore Stockpiles

Curragh deposited low grade ore (3-5% lead and zinc) into two stockpiles (A and C) beside the main haul road from the Main Zone I Pit. Curragh processed oxidized ore stockpiled by Cyprus Anvil after screening out the fine fraction of the ore. The oxidized fines are still present near the mill.

During the September 1999 site visit, water quality samples were collected from a pool of water at the oxidized fines stockpile (Oxide Fines Seep) (Photo 69), and from a pool of bright orange water on top of a low grade ore stockpile at Fuel Tank West (4-FTW Seep Faro). Results are provided in Table 7.14. The results indicate both samples were highly acidic (pH 2.9 and 2.2, and acidity to pH 8.3 of 13,900 and 10,800 mg/L $CaCO_3$ respectively, and very oxidized (sulphate levels of 23,100 and 9,510 mg/L respectively). The water contained elevated dissolved metal levels, including aluminum (174 and 169 mg/L), cadmium (10.2 and 1.20 mg/L), copper (86.1 and 16.2 mg/L), and zinc (6980 and 1010 mg/L respectively).

Samples of the solids were also collected from these sites in September 1999 and submitted for acid-base accounting analyses and metal scans. The results are provided in Appendix C, and confirmed the acidic pH of the samples. The samples were highly weathered, with sulphate - sulphur content of 1.18% and 2.04, and negligible neutralization potential, with values of - 6.4 and -19.0 kg $CaCO_3$ equivalents/tonne based on titration of the samples. Residual sulphide-sulphur content (21.5% and 9.0%) and metal content (Zn at 2.71% and 5024 ppm) were still very high indicating that acid generating and metal leaching could continue for some time.

All existing stockpiles may not have been identified in the closure plan, or previously sampled (ARMC, 1999). A stockpile of oxidized fines is reported located on the Vangorda waste rock dump (the coarse fraction was milled) (ARMC, 1999). Other ore and low grade ore stockpiles were not sampled, but may also be sources of highly concentrated acid and metal solutions.

7.4.5.2 Emergency Tailings Discharge Area and Concentrate Storage Sites

The emergency tailings discharge area below the mill contains residual tailings that are likely to be similar to the tailings in the Valley Impoundment (Photo 70 and 71). Thus they must be considered a minor but likely continuing source of acidity and dissolved zinc. Elevated levels of lead, zinc, arsenic, copper and lead were found in soil samples taken from this area (Section 7.2.4). Soil pH in two of the samples from this region were extremely acidic with pH between 2.2 and 3.2.

Any areas where concentrate was stored in bulk, or areas where concentrate was loaded into pots and concentrate bags are considered to be likely sources of acidic drainage with elevated metal levels. As discussed in Section 7.2.4, elevated levels of metals, specifically lead and zinc were detected near the concentrate load-out area.

7.4.5.3 *Ore Transfer Area*

Eight types of ore from the Grum and Vangorda Pits were stockpiled for blending at the Grum-Vangorda end of the haul road. Stockpiles still exist at the transfer site, and are suspected of being low grade ore stockpiles. The residual ore stockpiles are likely to have strong acid generating and metal leaching potential. The soils below and adjacent to existing or historic stockpiles potentially contain elevated levels of metal salts. Sampling was not conducted at these locations during the September 1999 site visit.

8 Conclusions

This section provides an overall summary of the environmental issues identified in the Phase 1 Environmental Site Assessment conducted at the Faro mine complex located near the town of Faro in the Yukon Territory.

The Phase 1 ESA was conducted in Fall 1999. The first phase of the environmental site investigation process consisted of a review of available information relating to historic and current mine site operations, interviews with Ross River Dena, and a preliminary site inspection to identify issues and areas of potential environmental concern.

A summary of the traditional land use/ heritage resources, health and safety, environmental, geotechnical, and hydrogeological issues that were identified as part of this Phase 1 ESA are summarized as follows:

8.1 Traditional Land Use and Heritage/Archeological Resources

1. Impacts on traditional use and heritage resources of the Faro and Anvil Range areas were not taken into consideration prior to mine development.

2. The Ross River First Nation community experienced, and continues to experience, major socio-economic impacts due to the establishment and operation of the Faro Mine.

3. Through extensive interviews and questionnaires it has been shown that, prior to mine development, the Anvil Range study area was one of two "core" areas traditionally important to the subsistence economy of the Ross River First Nation community.

4. Key resources for the Ross River First Nation people in the Anvil Range study area were salmon, sheep, caribou, moose and fur-bearers.

5. Changes to the use of the Anvil Range area by the Ross River First Nation included abandonment of traditional foods, now perceived as contaminated due to mining activities, the change in resource abundance and conflicts with other users.

6. The traditional land use data suggests that the Anvil Range study area has or had heritage site potential.

7. A post-development heritage impact assessment in recommended, to document what remains of sites, and learn something from these places before they are further damaged.

8.2 Human Health and Safety

1. The Faro and Vangorda Plateau mine sites are secured with locked gates on all of the vehicle access roads with the exceptions of the Faro fresh water supply dam and reservoir, the Faro bulk explosives and copper sulphate plants, the Faro fresh water pumphouse and the Faro surface tailings impoundments. The used oil, reagent, PCB, gasoline and diesel storage areas are within the locked gates as are the three open pits. A security attendant was posted at the Faro access gate on a 10 hour/day, 7 day/week basis at the time of the site inspection in September 1999. No security presence was maintained at the site during evenings.

2. The buildings located in the public access portions of the mine complex were all locked at the time of the inspection.

3. The public access areas of the mine site are heavily used by the public for hunting, fishing, recreation, and sight seeing.

4. A hazard to human safety in the public access areas of the mine sites existed at an old garage that was constructed in a soil bank below the fresh water supply dam. It is understood that this structure was removed during March 2000, that safety signage was installed, and that the safety hazard no longer exists.

5. All areas of the mine complex are accessible by ATV, snow machine or dirt bike via numerous trails through the bush and via a public access ramp which allows such small vehicles access to cross the Vangorda haul road above the fresh water supply dam. Once on the mine site, the public may be exposed to numerous safety hazards such as extreme drop offs around the open pits and rock dumps, hazardous materials around the mill, and within the mill and associated buildings. Snow fencing marks the top of the ramps into the Grum and Vangorda open pits.

8.3 Environmental Issues

The following is a summary of the specific environmental concerns at the Faro Mining.

8.3.1 Soils Quality

A limited soil sampling and analysis program was conducted by GLL in September 1999 to confirm contaminant observations during the site inspection, identify the type and representative concentrations of chemicals of concern in potential source areas. The soil quality data has shown that:

1. Observations during site inspection and the results of soil testing suggest that petroleum hydrocarbon contamination appears to be localized within the source areas for storage and dispensing of fuel and oil products.

2. The concentrations of the regulated petroleum hydrocarbon parameter, light extractable petroleum hydrocarbons (LEPH), exceed the Yukon *Contaminated Sites Regulation* (YCSR) standard for industrial land use at several fuel and oil storage and dispensing areas at the Faro and Vangorda Plateau mine sites. Other petroleum hydrocarbon parameters including polycyclic aromatic hydrocarbons (PAHs), and BTEX compounds were not present at elevated concentrations.

3. Levels of petroleum hydrocarbon contamination in soils are higher at the fuel/oil facilities located at the Faro mine site than those at the Vangorda Plateau likely due to the longer history of mine operations.

4. The high concentrations of residual oils in surface soils at the Faro Pit Lube Shop and Grum Lube Shop may be migrating from the source area via surface runoff.

5. The ongoing fuel and oil consolidation program is providing effective management of the residual petroleum hydrocarbons by removing the contaminant source at the various storage and dispensing locations across the mine site.

6. A soil sample was collected adjacent to an out-of-service transformer observed at the Grum Ore Haul Maintenance Shop; the results of analysis showed that the sample did not contain a detectible concentration of PCBs.

7. The concentrate load-out area represents an area of concern with respect to the presence of residual concentrate and the associated elevated metal concentrations in surficial soils.

8.3.2 Water Management

1. The Faro Main Pit currently collects water from the local catchment below the Faro Creek diversion channel. The performance of the diversion channel is critical to the success of the seasonal pumping program that is currently in place because a failure of the diversion channel would result in a significant inflow of additional water into the pit that would require pumping and treatment. Further, if treatment and pumping and repairs to the diversion channel were not implemented on a timely basis, then an overflow of contaminated water out of the main pit might occur. The management plan under implementation (seasonal pumping and treatment) is based on maintaining a freeboard in the pit below the overflow elevation of approximately 15 metres. This is based on calculations that provide for short term storage of flood flows into the Main Pit while an emergency response plan is being implemented. Nonetheless, the Faro Creek diversion represents a considerable risk factor and a significant environmental concern. As does the current pump and treatment water management scheme.

2. The Faro Zone II pit collects water of poor quality from its local catchment area. The management plan currently being implemented for the Zone II pit is to pump this water into the Main Pit where it

becomes integrated into the seasonal pumping and treatment program. This plan appears to be adequate as long as attention to monitoring and subsequent pump response is maintained. The installed pumping rate greatly exceeds the inflow rate such that sufficient time exists to implement repairs should the pumping system fail. The Zone II pit represents an environmental concern that is currently being adequately managed.

3. The Vangorda pit is anticipated to fill to a maximum acceptable water elevation by 2002 and, by that time, a management program will need to be implemented. An unexpected high precipitation event or a failure of the Vangorda Creek diversion flume could shorten this anticipated timeframe. The risk of failure of the Vangorda Creek diversion flume represents a significant risk factor at this time because of the management plan that will be implemented when the pit fills to the acceptable elevation is under development and not finalized. It is understood that several studies are being undertaken in 2000 that will work towards developing a management plan for the Vangorda pit.

4. The near absence of seepage from the toe of the Vangorda rock dump is favourable regarding surface water quality and a reduced requirement for water treatment, but the uncertainty regarding the mechanisms controlling the dump water balance is an issue of significant concern. Given that one possible explanation for the fate of the "missing" water is undetected deep groundwater seepage, a study of the water balance for the rock dump would be beneficial in assessing the possibility that contaminated water is escaping collection undetected. This issue also applies to a lesser degree to some of the Faro rock dumps.

5. Overall, the current water management relies on continued monitoring of water levels, and appropriate response regarding pumping and treatment. While currently being adequately managed, this plan relies on continued attention and effort to avoid unacceptable discharges.

6. The Rose Creek Diversion is a water management concern (see Section 8.4).

8.3.3 Surface Water Quality

8.3.3.1 Faro Site

1. The mine effluent was largely in compliance with the Faro water licence (QZ95-003) in 1999. The excursions above the maximum allowable discharge limits were infrequent and did not appear to result in a significant impact on the receiving water. The manner of treating water pumped from the Faro Main pit is adequate for removal of zinc and other contaminants to below the maximum allowable discharge limit. Although the application of lime treatment in the Intermediate Dam spillway represents a considerable risk factor since there is no backup system downstream of the Cross Valley Pond.

2. The Faro Main pit is stratified into two regimes with an oxygen depleted and low temperature lower zone that occupies approximately 2/3 of the pit underlying an upper zone that behaves as a natural

freshwater system. The stratification is likely directly related to the past inflow of large volumes of high pH tailings slurry that would have contained significant quantities of calcium, sulphate, and thiosulphates. The stratification appears to be stable over recent years although the information is insufficient to assess the long term stability of the stratification. If the stratification were found to be stable over the long term, this would be an important component of evaluating long term management strategies for the Faro site.

3. Surface run off through the Rose Creek tailings impoundments that accumulates in the Intermediate pond is contaminated with metals and needs to be managed and treated prior to release into Rose Creek in order to prevent an impact on local fisheries. This water includes poor quality inflows from the Faro rock dumps, the emergency tailings discharge area and the beached tailings in the surface impoundments. The management plan being implemented effectively addresses this concern by providing lime treatment at the spillway from the Intermediate pond and by co-treating this water with water pumped from the Faro Main pit.

4. The North Fork of Rose Creek near the confluence with the South Fork has displayed some significantly elevated concentrations of some contaminants (especially zinc) that appears to be related to shallow groundwater flow from some of the Faro rock dumps. This situation has been monitored for a number of years and no clear increasing trend is evident. Nonetheless, this is an issue of concern since it is possible that shallow groundwater seepage from these rock dumps may deteriorate further over time resulting in an increased impact on surface receiving water.

5. Elevated concentrations of metals (esp. zinc) in the Faro Creek diversion channel is an issue of concern regarding surface water quality in the North Fork of Rose Creek. Minor spring peaks in the concentration of zinc in the North Fork of Rose Creek appear to be related to inflows from the Faro Creek diversion channel.

6. Overall the water quality is managed adequately but requires continued attention, effort and response.

8.3.3.2 Vangorda Plateau Site

1. The quality of water entering Vangorda Creek was largely in compliance with the Vangorda Plateau water licence (IN89-002) in 1999 although total suspended solids was a problem below the Sheep Pad pond and significant non-compliance was avoided by diverting this water into the Vangorda pit during freshet. Water chemistry in the fish habitat area in lower Vangorda Creek was reasonably good in 1999 as compared to previous recent years although the concentrations of many parameters were elevated above background.

2. The quality of the extremely low volumes of seepage from the Vangorda rock dump is very poor and is acidic at one location. This is a significant environmental concern because of the uncertainty regarding the water balance for the rock dump. Given the possibilities that the dump has not yet

reached its water capacity such that significant seepage volumes may emerge in the future, or that a significant volume of water is escaping undetected via deep groundwater flow, a study of the water balance for the rock dump would be beneficial.

3. Seepage from the Grum rock dump appears to be of good quality where sampled near Grum Creek. The current information suggests that there are no identifiable seeps from the dump toe other than the one routinely monitored location. There is not an effective seepage collector ditch in place and this would be of concern if contaminated seepage were detected.

4. The concentration of total suspended solids entering Vangorda Creek from the Grum Interceptor Ditch/Sheep Pad Pond during freshet is an issue which needs active management to prevent an impact on important downstream fisheries habitat. The management plan being implemented is preventing serious non-compliance by diverting this water into the Vangorda pit during freshet.

5. Monitoring of benthic invertebrates in Vangorda Creek in 1999 suggested that the health of the creek is good and that pollution sensitive species are present in reasonable populations.

8.3.4 Ground Water Quality

8.3.4.1 Faro Site

1. Groundwater chemistry in the Rose Creek valley below and downstream of the tailings impoundments is generally better than expected given the acid generation characteristics of the tailings and the length of time that the impoundments have been exposed to the atmosphere. Migration of metals (especially zinc) out of the tailings into the underlying aquifer has not been detected. However, a significant environmental concern exists regarding the expectation that a breakthrough will take place in the near future and that the groundwater regime will become contaminated. This risk is heightened by the fact that there is no contingency or reclamation plan in place for the surface impoundments. A plan was developed by Steffen, Robertson and Kirsten Inc. (1991) but was not approved and therefore not implemented. Research into the hydrogeology and geochemical interactions taking place within, below and downstream of the tailings would be beneficial in assessing the risks of significant contamination of the groundwater regime in the near future. The key is to implement reclamation plans to reduce continued oxidation of sulphides and release of existing oxidation products.

2. Shallow groundwater reporting to the North Fork of Rose Creek from the Main and Intermediate rock dump areas appears to confirm quantities of contaminants sufficient to cause elevated concentrations (esp. zinc) in the North Fork of Rose Creek near the confluence with the South Fork. Additional research into the nature of and the impacts from this shallow groundwater would be beneficial in assessing the current and future risks to freshwater aquatic life from this source.

8.3.4.2 Vangorda Plateau Site

1. Groundwater below the Vangorda rock dump shows inconsistent chemistry and this is an issue of environmental concern because of the inconclusive interpretation of the data. This data does suggest that significant contaminated groundwater is not being detected.

8.3.5 Acid Rock Drainage

With respect to ARD and metal leaching potential, the following conclusions are made:

8.3.5.1 Faro Site

1. The Rose Creek tailings impoundments contain tailings with strong acid generating. Oxidation of the exposed tailings over the life of the mine has produced a store of soluble oxidation products, including sulphates, soluble metal salts and acidity. Most of these oxidation products appear to be still stored in the tailings, due to the buffering of underlying unoxidized tailings. Only the dissolved sulphate front appears to have moved through the entire tailings mass to effect underlying groundwater aquifer, and the seepage at the toe of the Cross Valley Dam. The dissolved zinc front appears to be close to exiting into the underlying aquifer below the secondary tailings dam.

2. Continued exposure of the tailings will allow continued oxidation of remaining sulphides in the tailings mass, and continued transport of oxidation products down through the tailings, resulting in the eventual overwhelming of the available buffering capacity. Delay in the implementation of remedial measures will allow these contaminants to increasingly threaten the quality of the underlying ground water aquifer and downstream surface waters.

3. In the waste rock stored in the Faro Mine area, 11% is considered to have a strong acid generating potential, 51% is considered to have a weak acid generating potential, and 90% is considered able to release zinc in significant quantities. The intrusives, compromising about 7% of the waste rock in the Faro area, appear to be the best material available for construction at the site due to their minimal acid generating and metal leaching characteristics.

4. The only apparent management strategy implemented for the Faro Area waste dumps has been to deposit sulphide material into cells located in the waste dumps. The cells were then capped with calc-silicates and schist. The overall effectiveness of this management strategy is likely to be limited given the characteristics and quantities of the various rock types. Long-term metal leaching (primarily zinc) and overall weak acid drainage is likely to occur in the Faro Area. Active management in the form of collection and treatment of runoff and seepage, will be required to prevent impacts on surface receiving waters.

5. Seepage from the Faro Main Pit walls and adjacent waste rock dumps provide an on-going source of acidity and metals to the Faro Main Pit. The Faro Zone II pit will also continue to collect poor quality water from the local waste rock dumps and pit walls. Water in these pits will require active

management, including continued monitoring of the pond elevation, pumping, and lime treatment, to avoid impacts on surface receiving waters. Also, adequate capacity will be required in the Valley Impoundment to provide contingency storage and treatment for these waters.

6. Some of the low grade ore stockpiles on the Faro mine site are an on-going source of highly concentrated acid and metal solutions. Not all of the existing stockpiles have been identified in the closure plan, or previously sampled. Other areas with the potential for acid rock drainage and/or metal leaching are: the Faro emergency tailings discharge area (consider a small but likely continuing source of acidity and dissolved zinc), concentrate storage sites, and the previously spilled tailings lying on the valley bottom below the Cross Valley Dam.

8.3.5.2 Vangorda Plateau Site

1. There is limited data available for the Gram and Vangorda rock dumps, but based on the previous experience with the Faro waste dumps, and geochemical testing completed on the Vangorda/Grum samples, the following general conclusions have previously been made:

   - The majority of the waste rock at the Vangorda and Grum Area is composed of sulphides and phyllite.
   - The sulphide and phyllite waste rock have the potential to generate acid and leach metals, specifically zinc and lead; and
   - The sulphide waste rock has a greater potential to generate acid than the phyllite rock.
   - The phyllites from the Grum Pit are reported to contain substantially fewer sulphides, as compared to the phyllites in the Vangorda Pit, and are considered relatively inert.

2. The waste rock in the main Grum dumps is reported to consist predominantly of non-potentially acid generating waste rock. The exception is a cell of sulphide waste placed on the outside center portion of the dump, so that it was bracketed on either side by more benign waste rock. The closure plan proposed to place a till cover over the sulphide cell. Delay in placing the cover has diminished the cover's potential benefit as an oxygen barrier to reduce sulphide oxidation. The placement of a cover would not act to reduce infiltration and transport of the existing oxidation products stored in the dump.

3. The seepage collection ditch at the toe of the Grum waste rock dump is unlikely to be effective in either collecting or allowing monitoring of seepage from the dump.

4. Limited information was available for the Grum Pit walls, such that the potential for poor water quality could not be evaluated. The upper pit walls consist primarily of till overburden.

5. The main overburden stockpile from the Grum Pit may include small amounts of waste sulphide or phyllite rock, such that some low levels of metals may be present in the drainage. The overburden

stockpile currently drains to settling ponds. Continued control of the drainage will be required to address suspended solids, and will allow monitoring for potential metal leaching.

6. The Vangorda waste rock dump is considered to consist predominantly of acid generating material, with material with the strongest potential (highest portion of sulphides) placed closest to the pit. Seepage and runoff from the waste rock dump is directed either to the Vangorda Pit, or the Little Creek Dam via a series of collection ditches. However, the fate of infiltrating water is unclear, as the majority of the collection ditches have not actually transported seepage flows. Definition of the current water balance for the facility, and identification of the reasons for the absence of significant volumes of toe seepage would be beneficial.

7. The closure plan for the Vangorda waste rock dump proposed placement of a till. Exposure of the waste rock since the cessation for mining has likely allowed substantial oxidation to occur. Thus, long term collection and treatment of seepage containing acidity and soluble metals will likely continue to be required at the Vangorda waste rock facility.

8. The Vangorda Pit is anticipated to fill to the maximum acceptable elevation by 2002, assuming continued operation of the Vangorda Pit diversion. The release of oxidation products from the existing pit walls, as well as runoff from a portion of the Vangorda waste rock dump are likely to result in poor quality water in the filled pit. A portion of the acid generating wall rocks in the pit will remain above the water level. It is expected that erosion and spalling of the walls will continue to expose fresh sulphide surfaces for oxidation on an on-going basis. The closure plan calls for reclamation of the pit as a clean water flow through system, with Vangorda Creek flow returned to the pit. It is not clear whether this closure plan is attainable, such that continued treatment of the pit water overflow is likely to continue to be required.

Other sites with the potential for acid rock drainage and/or metal leaching in the Vangorda Plateau area are the residual ore and low grade stockpiles at the Grum Ore Transfer Pad.

8.4 Geotechnical Issues

8.4.1 Faro Mine Site

1. The overall geotechnical stability of tailings dams and clarification pond dams at the Anvil Range Mining Complex is presently acceptable. However, ongoing monitoring and maintenance will be required to ensure that water levels are safely maintained and spillways remain operational. Until seepage from the waste dumps is no longer directed into the tailings facility, water will have to flow through the tailings system and be treated. The hydrologic system will require continuous maintenance and inspection.

2. The waste dumps are geotechnically stable although the stability may be marginal. The dumps are at their angle of repose and cannot be revegetated at that angle. Dump flattening will be required if revegetation is to occur.

3. The diversion ditch on the north side of the Faro Pit is in disrepair. The diversion ditch is likely leaking water into the pit. Slope instability on the channel walls could lead to blockage of the ditch with subsequent flow into the Main Pit. Water in the pit is presently pumped and treated and any excess water that reports to the pit will increase treatment costs. The pit walls below the Faro Creek diversion ditch have a documented history of instability and may fail, in the future, to the degree where the diversion ditch is breached into the pit. Monitoring for movement of the pit walls should be implemented.

4. The Rose Creek Diversion Channel is still required to divert fresh water flows around the tailing facility. The ditch will have to be monitored for the duration of its use. The stability of the ditch is not presently an issue as permafrost thaw appears to be almost complete and the side slopes are relatively stable. However, a large flood could trigger erosion that could potentially lead to partial blockage of the ditch. Flow would then be diverted through the tailings system jeopardizing the chemical and physical balance at the site.

5. The Water Supply Dam is no longer required and should be decommissioned at the earliest possible time.

6. The access road between Faro and the Vangorda Plateau is stable. Minor sediment erosion appears to be occurring, but the volumes are small. The overall stability of the road and the flow through rock drain are considered to be good.

8.4.2 Vangorda Plateau

1. The overall water diversion schemes used at Vangorda and Grum Pits will require continued scrutiny and maintenance for the duration of their use. The Vangorda Pit diversion flume is in need of maintenance. Loss of the flume would mean that Vangorda Creek would re-enter the pit, leading to filling and an over top of the Vangorda Pit if active intervention were not applied. Water quality may not be acceptable for release.

2. The Grum Diversion Channel consists of an open ditch that eventually passes through the sheep pad sediment ponds and into Vangorda Creek. The ditch and ponds will require continued monitoring and maintenance to ensure uninterrupted operation. The spillway on the Little Creek Dam consists of a new culvert and exit channel that does not appear to have been tested. Continued observation will be required, particularly during spring when the culvert could be blocked by ice, to ensure safer operation. The dam itself appears stable and shows no signs of distress.

3. Overall dump stability at the Grum site is marginal. Sediment is escaping due to erosion problems and the factor of safety of the overall dump appears to be marginal in some of the outer higher dump faces. Sediment loading could be reduced by resurfacing and revegetation. The dump may continue to creep with time, but a catastrophic failure is not anticipated.

4. Seepage out of the Vangorda rock dump does not presently appear to be causing a problem, but the lack of seepage reporting to the toe ditches is a concern. Seepage could be passing around the collection ditches along deeper flow paths. Covering the dumps with till and grading the surfaces to divert water away from the dump centres will assist in limiting the amount of water that can infiltrate to become seepage. A research project to define the water balance for the rock dump would be beneficial.

8.5 Hydrogeological Concerns

8.5.1 Faro Site

1. Seepage of water from the Zone II Pit to the North Fork of Rose Creek has occurred in the past. However, dewatering of the pit has prevented a recurrence of this seepage.

2. There is the possibility of groundwater seepage along fracture zones associated with north-south trending faults from to Zone II Pit to the North Fork of Rose Creek is a possibility which could be further investigated given the wide range in water quality encountered in monitoring wells located in this area.

3. Several monitoring wells have been constructed to evaluate groundwater quality at the toe of the Faro Rock Dumps. Many of these are no longer serviceable and should be replaced.

4. Monitoring wells should be placed at varying distances from the toe of the dumps to monitor the progression of any ARD.

5. A geophysical survey with a ground conductivity meter would be useful in identifying areas that may act as groundwater flowpaths for acid rock drainage in the vicinity of the Faro Waste Rock Dumps.

8.5.2 Vangorda Plateau

1. A thick soil layer occurs along the north wall of the Grum Pit. It should be determined if this deposit extends southward into the discharge area located in the valley below, as this could be a major conduit for seepage from the Grum Pit.

2. A geophysical survey around the perimeter of the Grum Pit may be useful in identifying zones that may act as groundwater flow paths for acid rock drainage.

3. Only one monitoring well has been constructed to monitor ARD from the Grum Rock Dumps. Several more monitoring wells should be installed to determine the quality of groundwater seeping from this area.

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