Draft for Discussion

Description of Environmental Conditions

Assessment of the Closure and Remediation Plan for the Faro Mine Complex

Prepared for

Faro Project Management Team

Submitted by

Gartner Lee Limited

March 2008

Gartner Lee

Draft for Discussion

Description of Environmental Conditions

Assessment of the Closure and Remediation Plan for the Faro Mine Complex

Prepared for

Faro Project Management Team

In association with

Aurora Wildlife Research
Laberge Environmental Services
Kestrel Research Incorporated

March 2008

Reference: **GLL 70-384**

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March 31, 2008

Stephen Mead
Faro Project Management Team
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Energy Mines and Resources
Whitehorse, Yukon Y1A 5W1

draft for discussion

Dear Stephen:

Re: GLL 70-384 – Description of Environmental Conditions, Assessment of the Closure and Remediation Plan for the Faro Mine Complex

Please find enclosed our draft report titled *Description of Environmental Conditions, Assessment of the Closure and Remediation Plan for the Faro Mine Complex*. This report will remain in draft format to allow for inclusion of updated information as it becomes available as the project progresses towards the selection of a final closure alternative.

We thank you for the opportunity to conduct this work. Please contact the undersigned if you have any questions regarding the information included in this report.

Yours very truly,
GARTNER LEE LIMTED

Heather Badry, B.Sc.
Senior Environmental Scientist

HB:gc

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Gartner Lee Limited

March 31, 2008

Stephen Mead
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Assessment and Abandoned Mines Branch
Energy Mines and Resources
Whitehorse, Yukon Y1A 5W1

draft for discussion

Dear Stephen:

Re: GLL 70-384 – Issuance of Draft Reports

A DRAFT is a rough copy of a report. The intent in issuing it is to allow other knowledgeable people associated with the project an opportunity to review the style and content prior to final issuance.

Since the FINAL report may differ from the draft, we think it is only prudent to collect all of the DRAFT reports prior to issuance of the FINAL report.

We would appreciate it if you would see that all copies of the DRAFT are returned to us and then we will issue our FINAL report.

We thank you in advance for your cooperation.

Yours very truly,
GARTNER LEE LIMITED

E. Grant Anderson, P.Eng.
President

EGA:
Attach.

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A. Hydrology
B. Hydrogeology
C. Surface Water Quality
D. Aquatic Resources
E. Vegetation

1. Introduction

1.1 Report Objectives

This report includes a summary of environmental baseline information, as of 2007, regarding the Faro Mine Complex. This information is a necessary foundation for the preparation of a "Proposal for a Project" for submission to the Yukon Environmental and Socio-economic Assessment Act (YESAA) process at the Executive Committee level, specifically to support the assessment of environmental effects of the Closure and Remediation Plan (FCMP) for the Faro Mine Complex (defined as the "Project"). It is anticipated that the YESAA submission will be made in the first quarter of 2009.

Of note is that this report is to be considered an evolving draft, in effect a "work in progress", and it will be updated as new information becomes available. At this time, the final option for closure has yet to be determined. Therefore, it is not possible to finalize either the temporal or physical scope of the project. It will be important to revisit the information base following final determination of the preferred alternative. Areas requiring review at a later date include:

- the incorporation of Traditional Knowledge from affected First Nations (Ross River Dena Council, Liard First Nation, Kaska Dena Council and Selkirk First Nation are identified as "affected First Nations" in the Devolution Transfer Agreement);
- finalization of the Local Study Areas and Regional Study Areas which differ between disciplines and require additional information before final definition can be given; and
- assessment of environmental impacts.

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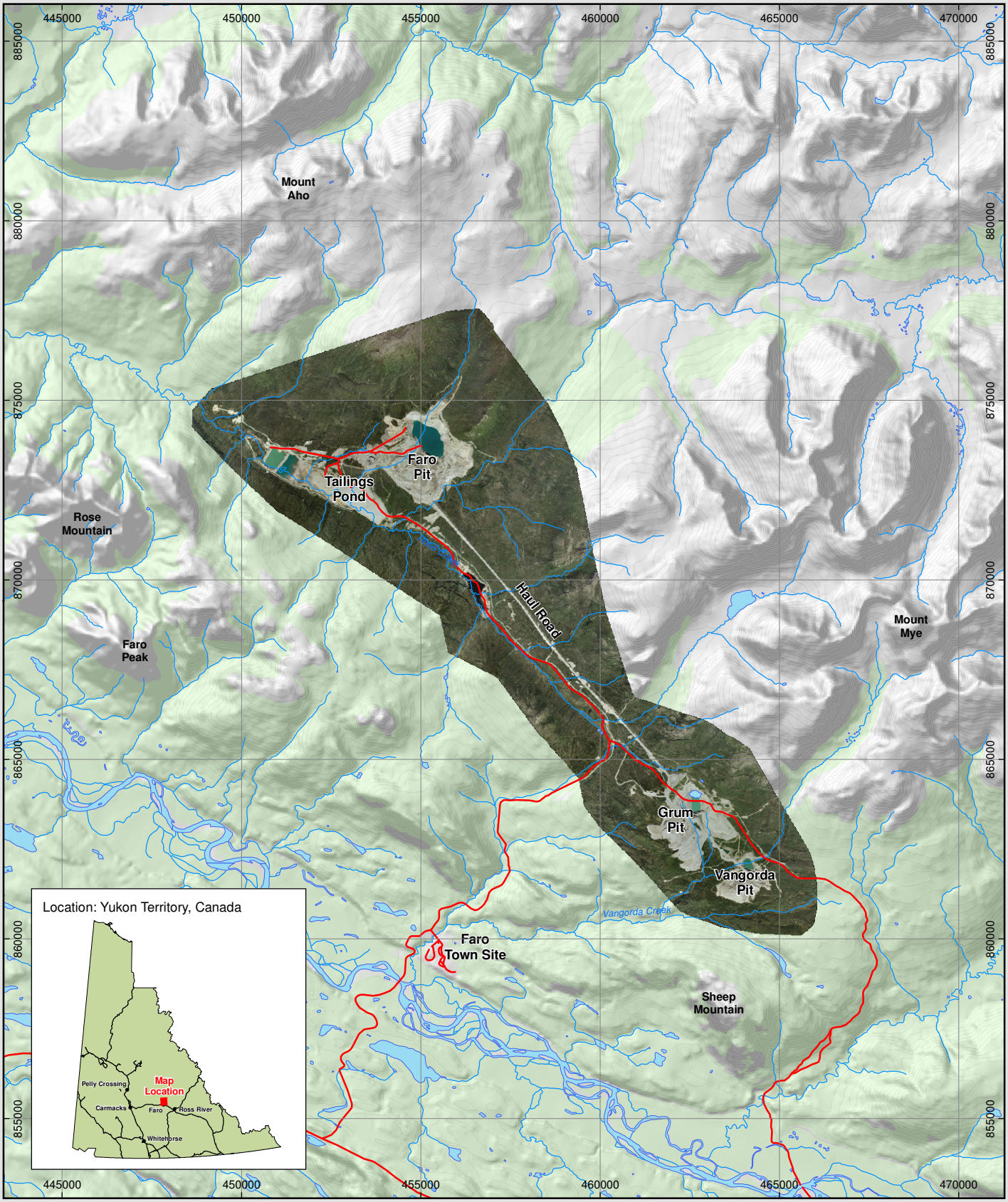
Project Number: 70384 Date Issued: March 20, 2008
Prepared By: GS Reviewed By: GS/HB

Environmental Assessment of the Closure and Remediation Plan for the Faro Mine Complex

Project Location

Gartner Lee

Figure 1.1-1



Map Sources/Notes:
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Hillshade imagery obtained from the Yukon Department of Environment, Information Management & Technology Department.
Orthophoto produced from 1:40,000 aerial photography (Aug. 9, 2003)

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NAD 27, Zone 08

Legend

Existing Features
- Community
- Road

Elevation Contours
- Contour interval (100m)

Hydrological Features
- Watercourse
- Waterbody

Boundaries
- Vegetation

Environmental Assessment of the Faro Closure and Remediation Plan

Site Overview

19 February 2008

Figure 1.1-2
Version 1

Gartner Lee

File: 70384 C1 Fig 1.3-1 ProjectLocation 19Feb08.mxd

1.2 Report Characteristics and Acknowledgements

Anticipating the need for incorporation of this baseline information into the YESAA Proposal for a Project, the report has been organized along lines consistent with the guidelines recommended by the Yukon Environmental and Socio-economic Assessment Board (YESAB).

This report includes a summary of baseline information, as of 2007, regarding the Faro Mine Complex. This report provides a brief description and history of the Faro Mine Complex, and environmental information (water resources, terrestrial and aquatic resources, climate and atmospheric, and geology and terrain) representing the current conditions at the mine site. The primary references for this compilation of information were:

1. Annual Environmental Reports for the Years 2004 through 2007 for the Faro and Vangorda Plateau Mine Sites as prepared by Gartner Lee Limited (GLL) for submission to the Yukon Territory Water Board by Deloitte & Touche Inc. (in their capacity as Interim Receiver for Anvil Range Mining Corporation (ARMC)) (GLL 2005, GLL 2006 and GLL 2007).
2. The Anvil Range Mine Complex 2002 Baseline Environmental Information Report (GLL 2002a) and the 2004 to 2008 Water Licence Renewal of Environmental Assessment Report, Volume II of III, Existing Environment (GLL 2003a).
3. Ecological Impact Assessment (Minnow 2007).
4. Pelly River Aquatics Effects Assessment – 2004 to 2006 (Access *et al.* 2004,2005, 2006).
5. Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils (GLL 2006a)
6. Phase 1 Environmental Site Assessment completed in 1999 by GLL for the Ross River Dena Council and DIAND Contaminants/Waste Program (GLL 2001), and following up work conducted 2004 for the purposes of delineating hydrocarbon contamination for closure planning.

1.3 Historical and Physical Overview

1.3.1 Introduction

The Faro Mine 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. Lead, zinc, silver and gold were the minerals of economic importance and were produced in lead and zinc concentrates. The Faro Mine Complex is located approximately 200 km north-northeast of Whitehorse, the capital of the Yukon Territory. The Faro Mine site, which includes a mill and tailings facilities, is located approximately 15 km north of the town of Faro. The Vangorda Plateau Mine site, which includes two open pits and associated mine facilities, is located approximately 9 km northeast of the town of Faro and can be reached by a heavy haul road (approximately 13 km) in length from the Faro Mine site.

1.3.2 Faro Site Operational History

The Faro Mine began production in 1969 at a milling rate of 5,000 tonnes of ore per day. In 1970, production was 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 Zone 2 reserves was initiated soon after and was completed in 1981. Cyprus Anvil ceased production in 1982 although waste stripping was carried out between June 1983 and October 1984.

The Faro Mine 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. An underground mining program to access deep ore from near the pit bottom was undertaken late in the life of the open pit. The deposit was depleted of economic ore reserves in 1992.

1.3.3 Vangorda Plateau Site Operational History

The Vangorda Deposit was discovered in 1953. Two smaller occurrences, Champ and Firth, were also discovered at that time. In 1973, the Grum Deposit was discovered between these two occurrences. During the years 1975 to 1977, extensive work programs, including an underground exploration program, were carried out at Grum to delineate the ore deposit.

The current Vangorda Plateau Mine facilities were first developed in 1988, when de-watering of the overburden of the Vangorda and Grum Deposits began. Mining of the Vangorda Deposit began in 1990.

Stripping was carried out intermittently at the Grum Deposit from 1990 to 1992, resulting in the excavation of approximately 22 million tonnes of glacial overburden and rock. Only a small amount of ore was mined from the Grum Pit by Curragh Resources prior to a temporary mine shut down in 1993.

ARMC assumed ownership of the mine site in November 1994 and resumed pre-production stripping at the Grum Pit and mining in the Vangorda open pit temporarily.

1.3.4 Recent Activities

Milling and mining operations permanently ceased in early 1998, shortly after the owner, Anvil Range Mining Corporation, filed for creditor protection under the Companies' Creditor Arrangement Act. Deloitte & Touche Inc. was appointed Interim Receiver of Anvil Range Mining Corporation in April 1998. Since mine shut down in 1998, the Interim Receiver has overseen the management of the property under the terms and conditions of the Water Licence including ongoing care,

maintenance and environmental protection activities, and will continue in this role until February 2009. At which time, the Government of Yukon will take over responsibility for the ongoing site care and maintenance activities.

Since 1998, site activities have focussed on a seasonal pumping and water treatment program for the Faro Main pit annually and the Vangorda Pit as required. Other environmental protection activities that are conducted on an ongoing basis include:

1. Inspections and maintenance of water retention and water diversion structures.
2. Monitoring of surface and groundwater quality.
3. Ongoing Implementation of an Adaptive Management Plan, providing a response framework that will be implemented if issue-specific triggers are activated.
4. Submission of monthly and annual environmental reports to the Yukon Water Board.

In addition there have been numerous studies conducted in various disciplines to provide a more substantive picture of site characteristics that will be useful for the development of the closure plan. Relevant information from these studies has been used in subject-specific sections of this report.

1.4 Setting Context for Environmental Assessment

1.4.1 Overview

The context that envelops all activities relating to ongoing care and maintenance and subsequent closure planning is the fact that the Faro Mine Complex exists as a property resulting from former mining and milling activities. This property has recognized environmental liabilities. The care and maintenance activities and the associated Water Licensing timeframe were selected to allow the property to be maintained while allowing sufficient time for a Final Closure and Reclamation Plan (FCRP) to be developed. Significant progress has been made toward a preferred FCRP option, and it is anticipated that a preferred closure option will be reached in May 2008, followed by preparation and submission of a Proposal for a Project to the YESAA process.

1.4.2 Temporal Scope of Baseline Compilation

A key consideration in defining baseline data needs, as a backdrop to moving to assessment, is determination of the temporal scope used in describing the existing baseline conditions. It is assumed for the purposes of the baseline work herein, that the scope largely begins in the present. The mining activity is now historic, and therefore “closure” needs to be considered in this light, focusing on the existing environmental attributes. To further clarify, the assessment will be based on the existing environmental conditions under the care and maintenance program, not based on the historic pre-mining operations conditions.

1.4.3 Influence of Past Mining Activities on Current Environmental Conditions

While respecting the interest in focussing on the present, there is no doubt from the amassed environmental information, as described both in the 2002 Baseline Report and the 2003 "2004-2008 Water Licence Renewal – Environmental Assessment Report" (2003 EAR), that past (i.e., pre-1998) mining activities have had a demonstrable impact on the aquatic and terrestrial receiving environments. Furthermore, in some cases, the environmental information demonstrates that some of the mine facilities that were operated or created prior to 1998 (such as the Rose Creek Tailings Facility, for example) continue to have an ongoing impact on the receiving environments.

These historical (i.e., pre-1998) environmental impacts can be summarized as follows:

Air Quality: There is no scientific baseline data on historical air quality, but traditional knowledge, experience at similar projects and indirect evidence from other studies indicate that effects would have occurred due to mine operating activities.
Stream-flow in the Receiving Environment: Construction and operation of mine facilities, diversion and interception of surface water and discharge of water from treatment systems substantially altered stream-flow in the receiving environment.
Surface Water Quality in the Receiving Environment: Runoff from rock dumps, the mill area, roads and other developed areas, groundwater discharge to surface in some areas, discharge of (generally compliant) water from water treatment systems and spills and other unforeseen events have resulted in degraded water quality in Rose and Vangorda Creeks as compared to upstream reference locations and general guidelines.
Groundwater Flow in the Receiving Environment: Interception of subsurface flow in pits and ditches, changes to groundwater recharge and discharge areas (either increasing or decreasing rates) and active pumping to surface for water supply altered groundwater flow patterns substantially within the immediate mine area
Groundwater Quality in the Receiving Environment: Seepage to ground from mine facilities such as rock dumps and tailings impoundments has had a negative impact on groundwater quality in the immediate mine area.
Fish Habitat Integrity: Construction of mine facilities such as the Fresh Water Supply Dam (although now removed), the Rose Creek Diversion Canal and the North Fork Rock Drain substantially altered the fish habitat in Rose Creek. Fish habitat in Vangorda Creek has not been similarly altered because the habitat is restricted to the lower reaches downstream of mine facilities.
Fish Population Health: There are no scientific baseline data on historical fish health or quality, however, traditional knowledge, experience at similar projects and indirect evidence from other studies indicate that effects would have occurred due to mine operating activities.
Wildlife Habitat Integrity: Construction of mine facilities altered or removed wildlife habitat from use by occupying the land.
Wildlife Population Health: There are no scientific baseline data on historical wildlife health, however, traditional knowledge, experience at similar projects and indirect evidence from other studies indicate that effects may have occurred due to mine operating activities. Nonetheless, the

information indicates that the local population of Fannin Sheep remained healthy throughout the mine operating period.

Future monitoring and mitigation of environmental effects related to past mining activities will be the focus of the FCRP that is to be developed by the closure Faro Project Management Team.

1.4.4 Integration of Traditional Knowledge

1.4.4.1 Overview

A cursory Traditional Knowledge (TK) study was been conducted in this area, with RRDC, as part of the 2003 environmental assessment process for the Water Licence Renewal. RRDC and SFN have developed processes for the collection and treatment of TK for their respective Traditional Territories and this work is currently underway. Once available, this information will be integrated to subsequent drafts of this baseline report.

1.4.4.2 YESAA Requirements Regarding First Nations Considerations and Traditional Knowledge

Although Traditional Knowledge is not captured in this report, it is useful to understand the context within which TK will be required in preparing for submission to the YESAA process.

The purposes of the YESAA assessment process include a guarantee that opportunities will be granted for the participation of Yukon Indian persons and that it will make use of their knowledge and experience in the assessment process.

YESAA s. 50 (3) notes that "Before submitting a proposal to the executive committee, the proponent of a project shall consult any first nation in whose territory, or the residents of any community in which, the project will be located or might have significant environmental or socio-economic effects."

In the Rules relating to the YESAA process, Part 7 speaks to "Integrating Scientific Information, Traditional Knowledge and other Information". Specifically the following direction is provided:

> **"Part 7**
> **Integrating Scientific Information,**
> **Traditional Knowledge and other Information**
>
> **Strict rules of evidence do not apply**
> In conducting a screening of a project, the Executive Committee may take into account information, including traditional knowledge, which may not be admissible as evidence in a court of law.
>
> **Full and fair consideration of scientific information and traditional knowledge**

The Executive Committee shall, in accordance with section 39 of the Act, give full and fair consideration to scientific information, traditional knowledge and other information provided to it or obtained by it in the course of conducting a screening of a project.

Relevance and weight of information
The Executive Committee shall determine the relevance and weight to be given to any information provided to it or obtained by it in the course of conducting a screening of a project, and there shall be no presumption that scientific information or traditional knowledge, as the case may be, should be accorded greater weight based solely on the fact that the information is, respectively, scientific information or traditional knowledge."

1.4.5 Valued Ecosystem Components (VECs)

Valued ecosystem components (VECs) are environmental attributes or components that are perceived as important for ecological, social, cultural and/or economic reasons. In addition, these components are identified as a result of their importance to community members, as well as being components that could potentially be influenced by the Project. VECs are selected, to represent the issues identified during consultation and scoping processes, and represent key components of each discipline that could be affected by the Project activities.

To focus the compilation of environmental baseline conditions, some disciplines have provided a preliminary identification of VECs. The final selection of VECs to be carried forward through the assessment process will be finalized as the preferred alternative is selected and the project proceeds to the next phase: preparation of the environmental assessment documentation.

1.4.6 Local and Regional Study Areas

The spatial boundaries of this study follow standard environmental assessment methodology. There are two spatial scales: a local scale, the local study area (LSA); and a regional scale, the regional study area (RSA). For some of the environmental disciplines, the LSA and RSA have been defined to focus the compilation of existing baseline information. These will be revisited and potentially adjustments made to these areas when the preferred closure option is finally determined and when TK is made available.

The local study areas (LSA) are areas that are directly affected by Project activities, (e.g. disturbed areas) and are used to assess direct and some indirect impacts of the Project on VECs. The regional study areas (RSA) are used to assess indirect impacts of the Project on VECs that may extend beyond the LSA.

2. Meteorology

2.1 Meteorological Data

In consideration of new meteorology stations installed at the Faro Mine complex, baseline meteorology data will be updated as information from these stations is obtained from recent monitoring periods.

2.2 Air Quality

2.2.1 Historical Air Quality

There are no historical monitoring data available to characterize either background air quality or air quality during mining operations.

Mining, milling and all of the associated activities were a source of air emissions throughout the operating period from 1969 to 1998. In general these sources can be characterized as follows:

Source	Characteristics
Mobile sources including mining machinery and transport vehicles	■ Source of NOx, CO_2/CO and particulate emissions from internal combustion engines ■ Fugitive dust emissions from site preparation and construction activities (overburden stripping, road and impoundment construction) ■ Fugitive dust emissions from roadways during transport of ore and concentrate ■ Fugitive dust associated with ore and concentrate handling and transport
Open pit and rock dumps	■ Source of wind-blown particulate emissions with characteristics similar to waste minerals (parent rock)
Milling operations	■ Fugitive dust emissions from ore crushing operations – characteristics similar to ore body ■ Fugitive dust emissions from concentrate drying and handling operations – high Pb and Zn concentration ■ Stationary sources of combustion gases (NOx, CO_2/CO and particulate) associated primarily with boilers
Tailings impoundments	■ Source of wind-blown particulate – characteristics generally similar to ore body and enriched in Pb and Zn relative to natural conditions

There were no licences for atmospheric emissions from the mine and there is no historical data available on the magnitude of these sources. Source controls were employed to minimize dust emissions from significant sources. For example, a baghouse was employed to control dust emissions from the ore crushing operation and a wet scrubber was used on the discharge from the concentrate dryer. Although these controls would have reduced emission levels, there are no performance data available and no record of stack surveys being conducted. The main stationary combustion source (mill boilers) were initially fired with coal and later converted to oil. Waste oil

generated on the mine site was used to supplement fuel requirement and processed in the boilers. There were no emission controls employed on the boiler stacks.

Occupational health and safety sampling was conducted, generally inside mill buildings. However, there are no data available on ambient contaminant levels.

Changes in the source of emissions would have occurred throughout the life of the mine. These would generally be associated with changes in mining activities and the excavation of the various pits over time. In addition, the location of tailings disposal also changed. For example, open pit mining shifted from the Faro open pit to the Grum and Vangorda open pits in 1992. The tailings disposal location was also changed at this time from the Rose Creek Tailings Facility to the Faro Main Pit. The Rose Creek Tailings Facility would likely become a more significant source of fugitive (wind-blown) emissions following the cessation of active tailings deposition in each of the three impoundments. In recent years, fugitive (wind-blown) emissions are visible primarily from the Intermediate Impoundment and this would likely have become more significant after the cessation of active tailings deposition in 1992.

When active mining was terminated in 1998, operational atmospheric emission sources would have been eliminated. This would include all mill sources (crushing and concentrate production and boiler operation) and mine sources (ore removal). Activities on the site are currently restricted to care and maintenance of the tailings impoundments and transfer and treatment of water. These activities do not have the potential to generate significant atmospheric emissions.

2.2.2 Existing Air Quality

Activities on the site are currently restricted to care and maintenance including the transfer and treatment of water. These activities do not have the potential to generate significant atmospheric emissions. However, the open pits, rock dumps, mill area and tailings impoundments are currently potential source of fugitive dust through wind erosion.

2.2.2.1 Ambient Air Quality Monitoring

In 2005, RWDI was contracted by Gartner Lee to conduct an ambient air quality monitoring program (RWDI 2005). The program consisted of a an intensive program which was designed to sample continuously for 24 hours, for a two week duration, and a consolidated program which sampled for 24 hours every six days, according to the National Air Pollution Surveillance (NAPS) cycle.

Eight locations were selected for both the intensive and the consolidated monitoring programs. Locations were concentrated near likely point sources of contamination for the intensive monitoring, and were distributed more widely for the consolidated monitoring program. Sites for the intensive monitoring program included the tailings impoundments, emergency tailings pond area, the heavy haul road/mill area, and the rock dumps. The sampling sites for the consolidated

locations included: tailings impoundments, rock dumps, the Faro town site, a harvesting and hunting area, and a reference background site.

Due to very wet weather conditions during the sampling period, negligible amounts of fugitive emissions were detected from the mine site during both sampling programs (RWDI 2005). Additional work is proposed for the summer of 2008 to characterize ambient air quality at the Faro Mine Complex. The baseline report will be updated as information becomes available and local and regional study areas defined at that time.

2.2.3 Terrestrial Effects Study

Between 2003 and 2005 Gartner Lee conducted a Terrestrial Effects Study at the Faro Mine Complex for the purpose of delineating distribution and movement of elemental concentrations in the terrestrial environment (GLL 2006a). As part of a this program, moss bags were deployed in the area of the Faro Mine Complex in order to examine the amounts and distribution of airborne contaminants in the area of the mine. The results were used to determine if there is ongoing aerial deposition of mine related contaminants, rather than historical deposition that may be associated with past mine operations. Although not a true air quality monitoring program, the moss bags were used to capture wind-blown dust from the mine site, and to delineate the area surrounding the mine site that is affected by wind-blown deposition. Moss bag sampling locations are illustrated in Figure 2.2-1.

Thirty-four sites for moss bag deployment were selected with the objective of sampling areas that were:

- Closest to potential dust sources (Faro tailings impoundment / mill complex, Vangorda / Grum pits, the haul road and the connector road between the Town of Faro);
- At the three Swim Lake reference locations;
- On a transect from the immediate vicinity of potential sources (i.e., northwest to north of the tailings impoundments and mill complex); and
- Near the Town of Faro.

To capture seasonal variability in dust deposition, three bags were deployed at each sampling location in August 2004 and one bag was collected from each site at 10, 20 and 30 week intervals:

- Week 10: The first moss bag collection was in early November and sampled a period that represented fall (August 18, 2004 – November 1, 2004);
- Week 20: The second collection was in mid-January and sampled a period that represented fall and early winter (August 18, 2004 – January 26, 2005); and
- Week 30: The third collection was in early April and sampled a period that represented fall to late winter (August 18, 2004 – April 5, 2005).

Because 10-week samples from August 18 to November 1, 2004 had measurable elemental concentrations, sampling was conducted over two additional 10 week periods in 2005: (1) April 5 to

June 14 and (2) June 14 to August 16, which represented the spring and summer seasons, respectively. These two sampling periods were added to allow the identification of periods throughout the year during which deposition occurred.

The analyses of moss bags indicated that significant accumulations of lead occurred at a number of sampling sites over the 10-week August to November 2004 exposure period. All elevated concentrations were significantly higher than pre-exposure levels. Moderately elevated zinc concentrations in comparison to reference sites was detected in moss bags sampled immediately adjacent to the Faro Mill Complex and emergency tailings area.

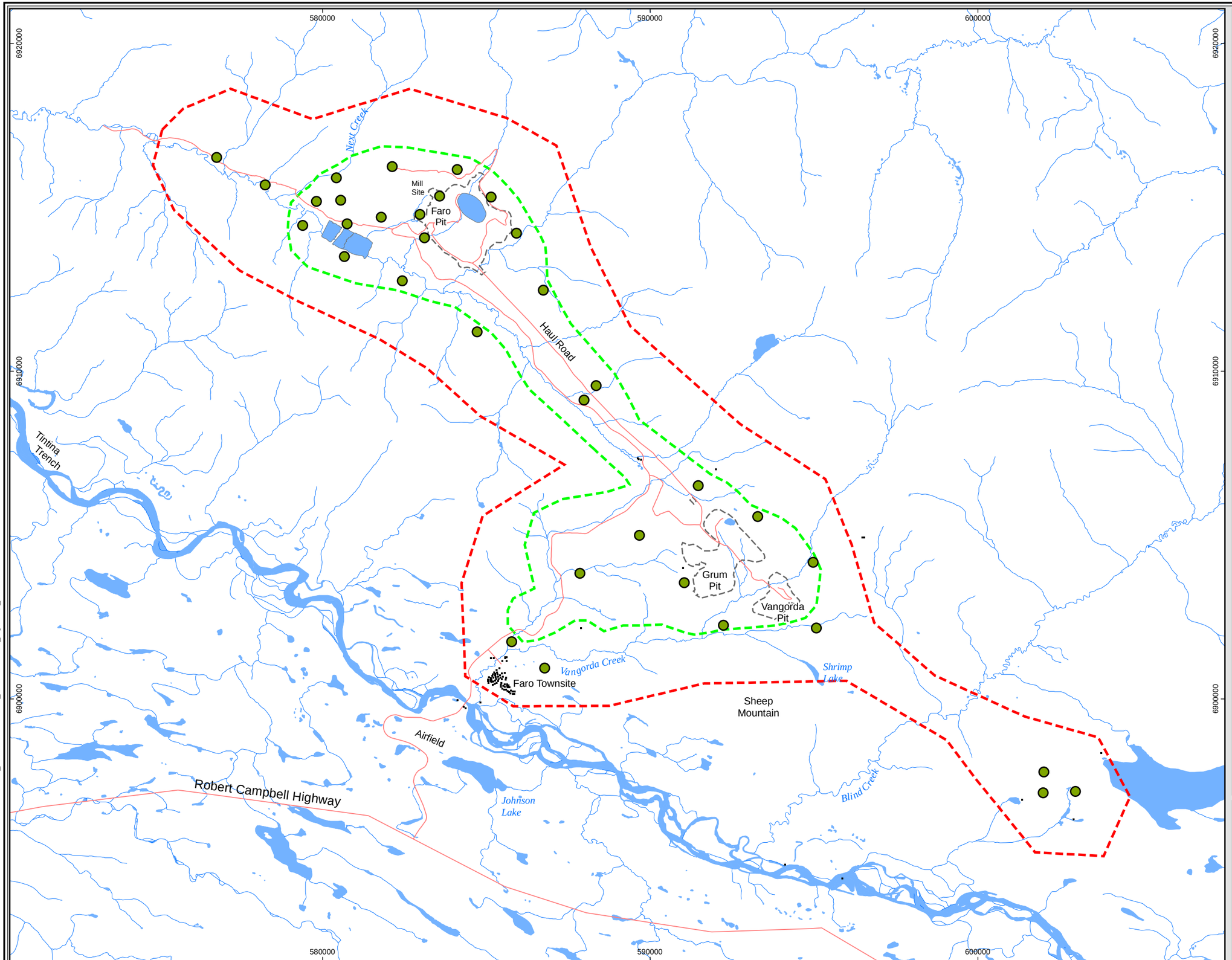
The exposure of moss bags for different time periods from August 2004 to August 2005 indicated that mine-generated deposition for a number of elements is ongoing. Lead had the highest amount of deposition and the pattern was generally similar to that for accumulated lead levels in lichens (i.e., elevated levels are concentrated in the vicinity of the Faro tailings impoundment / mill complex and northwest down the Rose Creek valley). The results of the moss bag monitoring program suggest that lead is deposited in fall (August to November) and again from January to August. In contrast, very little appears to be deposited during the early winter period. It therefore appears that lead is deposited in the study area during most of year but that deposition either does not occur or is greatly reduced when snow covers the ground.

Concentration patterns of elements other than lead in moss bags are somewhat different from the observed cumulative patterns recorded for lichens. For example, arsenic has the second highest cumulative elemental concentration in lichens relative to reference levels but there appears to be little current deposition. In contrast, barium and nickel accumulations in lichens are low but these elements were among those with high levels of deposition in moss bags. Furthermore, aluminum, manganese, silicon, and uranium levels were elevated in moss bags but there was no evidence of mine-generated accumulations in lichens. Disparities between observed cumulative elemental elevation and current elemental deposition suggest that:

- the contribution of current mine-site elemental dust sources is different than historical contributions, due to different operational and care and maintenance practices; and / or
- the period monitored by moss bag exposure does not reflect the entire range of conditions that have contributed to cumulative elemental elevation in the study area.

Moss bags are useful indicators of current airborne deposition and can also provide a general indication of where sources of deposition are located. Moss bags, however, do not provide an indication of specific sources nor do they represent empirical measurements of ambient elemental concentrations in the air.

The ambient air quality monitoring proposed for the summer of 2008 will be used to further characterize ambient air quality at the Faro Mine Complex. Information from this program will be used to assess the effects of the closure plan on air quality



Legend

- Moss Bag Sampling Locations
- Roads
- Regional Study Area
- Local Study Area
- Surface Water

Study Area

N
W E
S

0 1 2 3 4 5
Kilometres

1:110,000
UTM Zone 8N, NAD 83

Project Number: 70384
Prepared By: RH
Date Issued: March 25, 2008
Reviewed By:
File Name: 70384_Figure2-4_Mar19.mxd

Environmental Assessment of
the Closure and Remediation Plan
for the Faro Mine Complex

Air Quality
Study Area

Gartner Lee

Figure 2.2-1

Date Revised: March 24, 2008
Date Plotted: March 24, 2008
Revision: 0
File Location: S:\GIS_Pdata\Faro\70384-1_EA\MXD\70384_Figure2-4_Mar19.mxd

3. Terrain

3.1 Physiography

The physical geography of the Faro area can be broadly divide into three main areas (Bond 2001) which are illustrated in Figure 3.2-1.

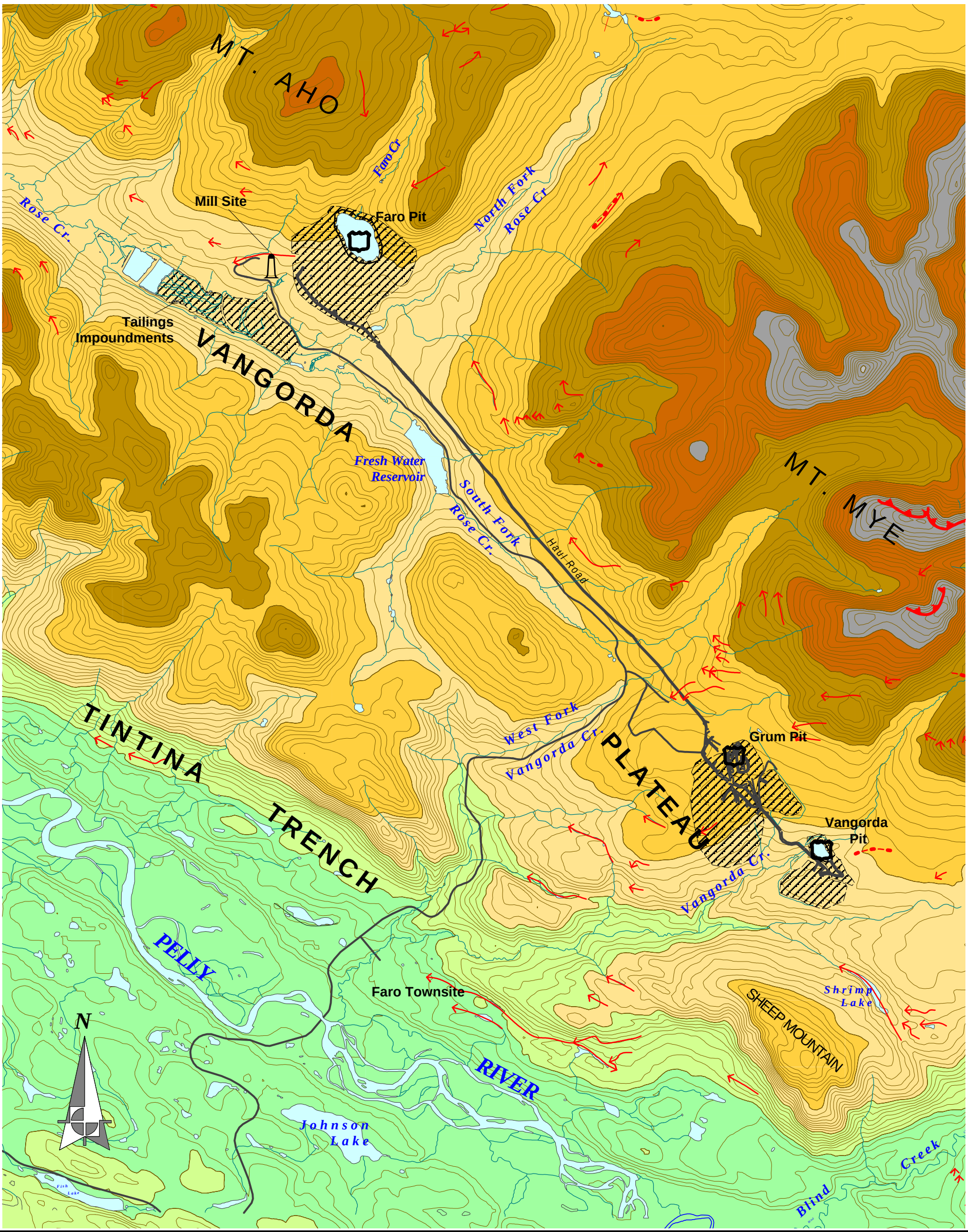
1. The broad, linear southeast-northwest trending **Tintina Trench**. The Trench is the dominant structural feature of the area and is occupied by the northward flowing Pelly River. The Pelly River floodplain has an elevation of approximately 600 m ASL.

2. The upland areas of the Swim Basin (not shown) and the **Vangorda Plateau**. The bulk of the mine facilities are located on the Plateau. The Plateau generally parallels the Tintina Trench and is drained by the Vangorda Creek watershed to the south and Rose Creek to the northwest. The Plateau ranges in elevation from 1,000 to 1,400 mASL. A ridge of hills and mountains divide the Plateau from the Tintina Trench, most significant of these is Sheep Mountain to the southeast and Faro Peak to the northwest.

3. The third physiographic region is the **Anvil Range** Mountains. The Anvil Range is located to the northeast of the Vangorda Plateau and rises to a series of peaks over 2,000 mASL. The Range is characterized by steep, U-shaped alpine valleys terminating in cirques, and shattered rock and felsenmeer above 1,770 m. Major summits in the Anvil range include Mount Mye, east of the Grum and Vangorda open pits, and Mount Aho, north of the Faro Main Pit.

3.2 Surficial Geology

The landforms and surficial deposits of the Vangorda Plateau have been shaped and are attributable to the last ice age, which is estimated to have existed in the Yukon between 35,000 and 10,000 years ago. The southern Yukon was covered by at least four Cordilleran (i.e., mountain) ice sheets. These glaciations, from oldest to the youngest, are named the Nansen, the Kalza, the Reid and the McConnell (Bond 2001). The landforms of the Faro area are for the most part attributed to the youngest of the Yukon glaciations, the McConnell.



LEGEND

ELEVATION RANGES
(metres ASL)

- below 800 m
- 800-1,000 m
- 1,000-1,200 m
- 1,200-1,400 m
- 1,400-1,600 m
- 1,600-1,800 m
- above 1,800 m

SYMBOLS

- Cirque
- Glacial meltwater channel
- Moraine ridge

1 0 1 2 3
Kilometers

Scale: 1:75,000

SOURCE: Surficial Geology from "Quaternary geology and till geochemistry of the Anvil District, central Yukon Territory (Bulletin 11)" Bond, J.D., 2001.

Faro Mine Complex

Physiographic Setting

Drawn By: F.K.P.	Reviewed By: E.J.D.
Revision No.: 0	Project No: 22-307
Date Issued: APR. 2003	Projection: UTM Z8, NAD83
Site Name: FARO	File Name:22307-D6-V2-FIG10.PDF

Gartner Lee Limited

6.2-6

Figure 3.2-1

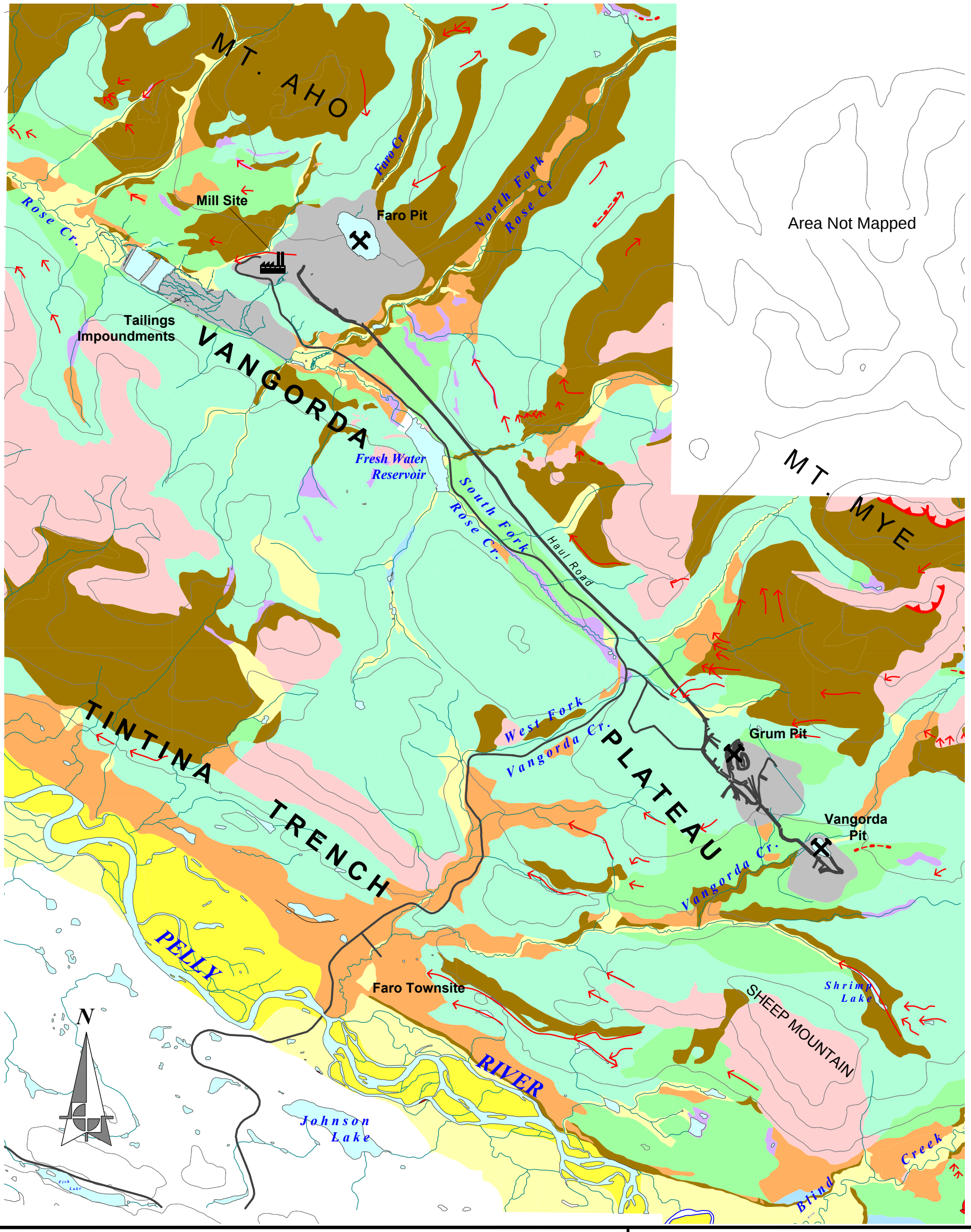
Significant surficial material in the study area consists of bedrock and associated colluvium, glacial till, and glaciofluvial outwash sands and gravels (Figure 3.2-2). Glaciolacustarine, modern alluvial and organic deposits, are found sporadically but are not discussed in detail herein. The following discussion of surficial materials is derived from the *Quaternary geology and till geochemistry of the Anvil district, central Yukon Territory* (Bond 2001):

Bedrock – bedrock and/or frost shattered bedrock (felsenmeer) is frequently found at surface in the alpine areas of the Anvil Range. Elsewhere, mountain slopes are covered in thin veneer of colluvium (materials derived from slope movement processes) derived from the local bedrock. Glacial deposits are relatively absent above 1,500 m, although meltwater channels were identified as high as 1,700 m. Solifluction is common above the tree line.

Morainal Deposits (Till) – glacial till is poorly sorted deposits of clay, silt, sand, gravel and angular boulders which is deposited directly from glacial ice. A thick blanket of till is found covering the Vangorda Plateau. In some locations where pre-glacial valley existed, the till deposits can be over 100 m thick (e.g., Grum valley). Generally till deposits thin to a veneer (<1 m) along the valley walls and are generally absent above 1,500 m. Till also commonly underlies glaciofluvial deposits in areas of former meltwater drainage. The area surrounding the Grum and Vangorda Deposits is characterized by a thick till blanket overlying bedrock.

Glaciofluvial Deposits – during the retreat of the glaciers, melting water derived from the decaying ice transported and deposited sand and gravel in the valley bottoms and associated lateral meltwater channels. These deposits are typically stratified to crudely stratified deposits varying from sand with some silt to cobble gravels. These materials are found as significant valley fills as in the Rose Creek valley, as kame terraces at the mouth of alpine valleys or as glacial terraces and complexes associated with the Vangorda Creek valley and the Tintina Trench. Glaciofluvial deposits host the Rose Creek aquifer that underlies the Faro Mine tailings facility. The Faro townsite is located on a major glaciofluvial (and glaciolacustarine) terrace with a well developed stagnant ice (i.e., hummocky terrain) glacial fluvial complex to the northwest of the townsite. The valley bottom glaciofluvial deposits are frequently covered by silts, sands and gravel derived from contemporary stream.

The majority of the natural soil located in the Faro Mine Complex consist of granular soils (i.e., locally derived tills, glacial outwash deposits and fluvial deposits). The region is within an area of discontinuous permafrost.



LEGEND

SURFICIAL MATERIALS

- Anthropogenic
- Colluvium
- Fluvial (Active)
- Glaciofluvial
- Fluvial
- Glaciolacustrine
- Morainal Veneer (Till)
- Morainal Blanket (Till)
- Organic
- Bedrock

SYMBOLS

- Cirque
- Glacial meltwater channel
- Moraine ridge

1 0 1 2 3

Kilometers

Scale: 1:75,000

SOURCE: Surficial Geology from "Quaternary geology and till geochemistry of the Anvil District, central Yukon Territory (Bulletin 11)" Bond, J.D., 2001.

Faro Mine Complex

Surficial Geology and Landforms

Drawn By: F.K.P.	Reviewed By: E.J.D.
Revision No.: 0	Project No: 22-307
Date Issued: APR. 2003	Projection: UTM Z8, NAD83
Site Name: FARO	File Name:22307-D6-V2-FIG9.PDF

Gartner Lee Limited

Figure No. 3.2-2

3.3 Soils

3.3.1 Soil Quality

1.1.2.1 Petroleum Hydrocarbons

A Phase 1 Environmental Site Assessment was conducted in the fall of 1999 (GLL 2001) that included the collection and analyses of 58 surface grab samples from various locations on the Faro and Vangorda Plateau Mine sites (noted on Figure 3.3-1 and Figure 3.3-2). On the basis of known industrial activities that had occurred at the site, petroleum hydrocarbons are of concern from diesel fuel, gasoline, hydraulic and lubricating oils from the storage, use, and disposal of fuels and oils.

As indicated on Table 3.3-1 and Table 3.3-2, elevated concentrations of petroleum hydrocarbons were noted in soil samples collected at the following locations:

1. *Faro mill site*: volatile petroleum hydrocarbon (VPH) and xylene from one sample of the berm, which are indicative of gasoline contamination;
2. *The Emergency Diesel Generator and Fuel Supply:* LEPH from one surface soil sample collected downslope of a historical fuel spill and two surface soil samples collected near the pumphouse and fuelling nozzle for the primary fuel tank, also evidence of small scale spills;
3. *Faro Lube Building*: LEPH concentrations in all of four samples and HEPH in one sample, with the source likely being diesel and heavy oils;
4. *Diesel Storage Tanks for Lube Shack Fuel Pump*: Samples LEPH in samples collected from the west side of the gravel berm and at the NE corner of the bermed area;
5. *Historic Fuel Storage Near the Core Shacks and at Scrap Area to NW of Faro Pit*: LEPH in samples collected directly adjacent to the tank pads and dispensing area;
6. *Waste Oil Handling Area*: LEPH and HEPH in the sample collected at the shipping container;
7. *Partially Buried Waste Oil Tank and Washbay Diesel Tank*: LEPH in the sample taken at the front of the washbay;
8. *Reagent Mix Building*: HEPH in one sample taken in front of the loading doors for the building;
9. *Grum Ore Haul Maintenance Shop*: LEPH in samples from the weigh scale and the east exit of the area; and
10. *Grum Lube Shop and Diesel Storage Tanks*: LEPH in two of the soil samples collected in the near a former aboveground fuel tank location at the lube shop and downslope of the lube shop area in the direction of surface runoff.

N

WATER TREATMENT PIPELINE

ORIGINAL FARO CREEK CHANNEL

MAIN ROCK DUMP

INTERMEDIATE ROCK DUMP

MILL

NORTH WALL INTERCEPTOR DITCH

GUARDHOUSE CK

EMERGENCY TAILINGS AREA

WATER SUPPLY PIPELINE (UNUSED)

ORIGINAL GUARDHOUSE CREEK CHANNEL

INTERMEDIATE DAM

EFFLUENT PIPELINE

SECOND IMPOUNDMENT

ORIGINAL TAILINGS IMPOUNDMENT

NORTH FORK DIVERSION

SOUTH FORK ROSE CREEK

INTERMEDIATE IMPOUNDMENT

1100

1 2 2a 3 4 5 6 7 8 9 10 11 12

LEGEND:

- ROADS
- EXISTING SURFACE DRAINAGE
- PRE-MINE DRAINAGE
- E — E — EFFLUENT PIPELINE
- PIPELINE
- WATER TREATMENT PIPELINE
- SURFACE WATER
- WASTE DUMPS
- TAILINGS IMPOUNDMENT
- 3 SOIL SAMPLE SITES

SOURCES OF INFORMATION:

1. DIGITAL COPY OF 1:50,000 TOPOGRAPHIC MAP SUPPLIED BY SRK CONSULTING.
2. MAP COORDINATES ARE UTM NAD83 ZONE 8; CONTOUR INTERVAL 100 FT.
3. FARO MINE DETAILS ADAPTED FROM DRAWINGS BY ROBERTSON GEOCONSULTANTS INC.

0 50 100 200 300 400 500 Metres

SCALE 1:10,000

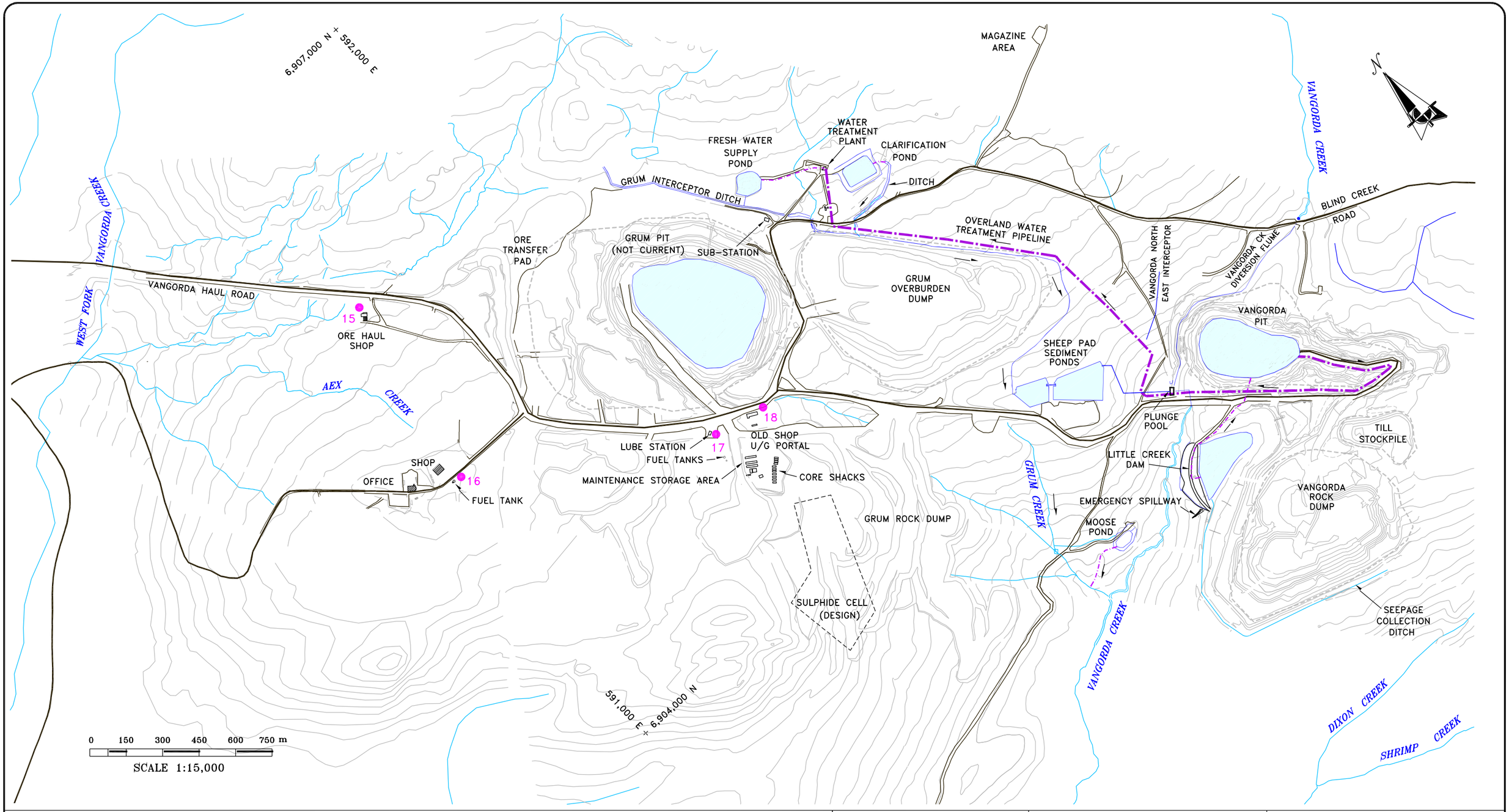
DRAWING INFORMATION:	
REVIEWED BY:	LH/ED
DRAWN BY:	CPW
DATE ISSUED:	APRIL, 2003
PROJECT NUMBER:	22-307
FILE NAME:	22307-D6-V2-19.DWG
REVISION:	0

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

SOIL SAMPLING SITES AROUND FARO MINE SITE

Gartner Lee

FIGURE 3.3-1



LEGEND:

- ROADS
- EXISTING SURFACE DRAINAGE
- PRE-MINE DRAINAGE
- E — EFFLUENT PIPELINE
- PIPELINE
- WATER TREATMENT PIPELINE
- SURFACE WATER
- SOIL SAMPLING SITES

SOURCES OF INFORMATION:

1. DIGITAL COPY OF 1:50,000 TOPOGRAPHIC MAP SUPPLIED BY SRK CONSULTING.
2. FARO MINE DETAILS ADAPTED FROM DRAWINGS BY ROBERTSON GEOCONSULTANTS INC.

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ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

SOIL SAMPLING SITES AROUND VANGORDA PLATEAU MINE SITE

Gartner Lee

FIGURE 3.3-2
6.2-6

Table 3.3-1. 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
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

Bold *Exceeds the Yukon CSR standards for industrial land use*

Table 3.3-1. 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*

Bold *Exceeds the Yukon Excceds CCME Industrial Guidelines*

Table 3.3-2. 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

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

The following summary regarding petroleum hydrocarbon contaminated soil is repeated from GLL 2001:

1. Petroleum hydrocarbon contamination appears to be localized within the source areas for storage and dispensing of fuel and oil products;
2. Concentrations of LEPH were greatest at several fuel and oil storage and dispensing areas at the Faro and Vangorda Plateau Mine sites. PAHs and BTEX compounds were not present at elevated concentrations;
3. Levels of petroleum hydrocarbon contamination in soils are higher at the Faro Mine site than at the Vangorda Plateau, likely due to the longer history of mine operations.

In 2004, with the acknowledgment of petroleum hydrocarbon contaminated soil on the site in 2001, and the 2003 Water Licence renewal process, a larger, multi-year ESA program was developed and implemented. The 2004 investigation identified areas of potential concern for petroleum hydrocarbon-contaminated soils, provided a preliminary investigation of those areas through a test-pitting program, and provided a general verification and preliminary information regarding the areas of concern.

In 2005, Gartner Lee continued with this work to further investigate areas identified during the 2004 field program. Eight areas were identified for follow up investigation using a vibrasonic drilling technique to determine the depth of contamination and to improve the first-order estimates of petroleum hydrocarbon contaminated soil volumes.

The eight areas that were targeted for further investigation in 2005 are as follows:

1. Faro Emergency Generator Yard – if deemed safe by site management;
2. Faro Mill Diesel Tank – if deemed safe by site management;
3. Faro Waste Oil Tank;
4. Faro Maintenance Bays Area;
5. Faro Lube Shack;
6. Faro Tank Farm;
7. Vangorda Plateau Lube Shack; and
8. Vangorda Plateau Tank Farm.

For petroleum hydrocarbons in soil, the CCME 2001 Canada Wide Standards for Petroleum Hydrocarbons in Soil (“CWS”) had been used and includes consideration of fine grained versus coarse-grained soils as well as depth below ground in the determination of guideline values. The soils that have been encountered at the Anvil Range site generally fall within the CWS definition of “coarse-grained” soil. Samples with petroleum hydrocarbon concentrations that fell between the two standards were dried and sieved with a 75 um screen to confirm that greater than 50% of the material was sand size (coarse grained). The *Yukon Contaminated Sites Regulations’* Generic and Matrix Numerical Soil Standards [Industrial Land Use (IL) criteria] were also used for comparison purposes.

The site investigation involved the drilling of 21 boreholes, to a maximum depth of 10.7 m below ground surface, in areas where soil contamination had previously been found. Soil samples were collected at all of the borehole locations. Selected soil samples were analyzed for some or all of the following parameters:

- Benzene, Toluene, Ethylbenzene, Xylene, (BTEX) compounds;
- CCME Hydrocarbon Fractions F1 (C_6 to C_{10}), F2 (C_{10} to C_{16}), F3 (C_{16} to C_{34}), F4 (C_{34} to C_{50});
- Polycyclic Aromatic Hydrocarbons (PAHs); and
- Metals.

The following table lists the areas of concern that were investigated in 2005, a summary of the type of hydrocarbon contaminant found, the estimated area of extent and the estimated contaminated soil volume. This summary is based on the combined results of the 2004 and 2005 investigations.

Table 3.3-3. Hydrocarbon Contaminated Soil Volume Estimate Summary

Location	Contaminant	Estimated Area (m^2)	Estimated Depth (m)	Estimated Volume (m^3)	Total with 50% Contingency (m^3)
Faro Lube Shack (>IL)	HC – F1, F2, F3	>2700	6.0	>16,200	>24,300
Faro Tank Farm (>IL)	HC – F2, F3	≥ 900	4	≥ 3,600	≥ 5,400
Faro Waste Oil Tank (>IL)	HC – Toluene, F2, F3, VPH	≥1,550	6	≥9,300	≥ 14,000
Faro Maintenance Bays (>IL)	HC – xylenes, F1, F2, F3	8,200	3.5	28,700	43,000
Vangorda Lube Shack (>IL)	HC – F1, F2, F3, VPH	>1350	3.0	>4,050	> 6,100
Vangorda Tank Farm (>IL)	HC – toluene, xylenes, F1, F2, F3, napth.	≥ 2100	3.5	≥ 7,350	≥ 11,000

It should be recognized that not all areas of the mine site were accessible or safe to investigate. The Mill Diesel Tank and Emergency Generator Yard at Faro are also likely to have associated petroleum hydrocarbon contamination; however, these two areas were not safe to investigate due to the presence of underground utilities. In addition, others identified diesel odour in drill cuttings during a separate drill program in the Emergency Tailings Area, located south of the mill building (SRK Consulting, pers. comm.). The drill hole(s) referenced passed through tailings and into the underlying native soil. This area is downgradient of the mill in a flowpath to the Rose Creek Tailings Facility where, historically, it is known that tailings and other contaminants were discharged. Therefore, it is reasonable that there may be hydrocarbon-contamination within and, possibly, underlying the tailings, and this area is considered to be an additional area of concern. In

consultation with Deloitte & Touche Inc., this area was not investigated in 2005 pending a decision regarding possible removal of the tailings as part of closure activities (and likely some of the upper native soils) from this area, which would then allow for a detailed test pit investigation of the native soils. This would provide for a more efficient and effective examination of the area than drill holes though the overlying tailings (up to 8 m thick).

The nature of hydrocarbon products present in the soil tested range from light volatiles (i.e., F1 fraction) to thicker oils and greases (i.e., F3 fraction). The information suggests that the dominant products lie within the F2 fraction, generally representative of gasoline and diesel constituents.

A first-order minimum estimate of the volume of hydrocarbon-contaminated soil outlined through these investigations was determined as approximately 100,000 m^3. In comparison, a preliminary ballpark volume of 15,000 to 25,000 m^3 had been suggested for discussion purposes in the 2003 Water Licence Renewal process prior to any investigations (i.e., without the benefit of any field studies). The updated volume estimate and spatial characterization of hydrocarbon contaminated soils at the Faro and Vangorda mine sites will guide remedial planning activities associated with closure of the Faro Mine Complex.

3.3.1.1 Heavy Metals in Soil

The Phase 1 Environmental Site Assessment conducted in the fall of 1999 (GLL 2001) also identified the potential concerns and sources of heavy metals from mining, milling, and processing of mineralized rock as well as naturally occurring concentrations due to natural geochemistry. Lead and zinc concentrations were determined in selected soil samples collected from various areas. Metal concentrations in soil samples were determined from the old tailings spill area downstream of the Rose Creek tailing facility. Generally, the concentrations of lead and zinc detected in the soil samples were indicative of metal contamination from historical mining and milling activities.

The 1999 field investigation demonstrated that soil samples collected at the Faro Mine site contained higher concentrations of lead and zinc than samples collected at the Grum mine site due, likely to the presence of milling operations and the longer operating history (Table 3.3-4). The highest concentrations of lead and particularly zinc were found in soil samples collected near the concentrate load-out on the Faro Mine site. The major source of metal contamination in surface soils within the Faro mill area was attributed to the presence of concentrate storage areas and vehicle tracking within the mine and mill site areas.

Table 3.3-4. Metal Concentrations in Soil (ug/g)

Sample Location	CCME[a] Industrial Guideline	YCSR[b] Industrial Standard	Historical Rose Creek Tailings Facility Spill Area			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			RC#1	RC#2	RCB#3	TD#1	TD#2	TD#3	TLA 1	TLA 3	TDS 3A	EG 2	RMB 2	LB 1
Sample Depth (m)											0.1-0.2m			
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

Bold *Sample exceeds CCME Industrial Guideline*

Bold *Sample exceeds Yukon CSR Industrial Standard*

Table 3.3-4. 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

Bold *Sample exceeds CCME Industrial Guideline*

Bold *Sample exceeds Yukon CSR Industrial Standard*

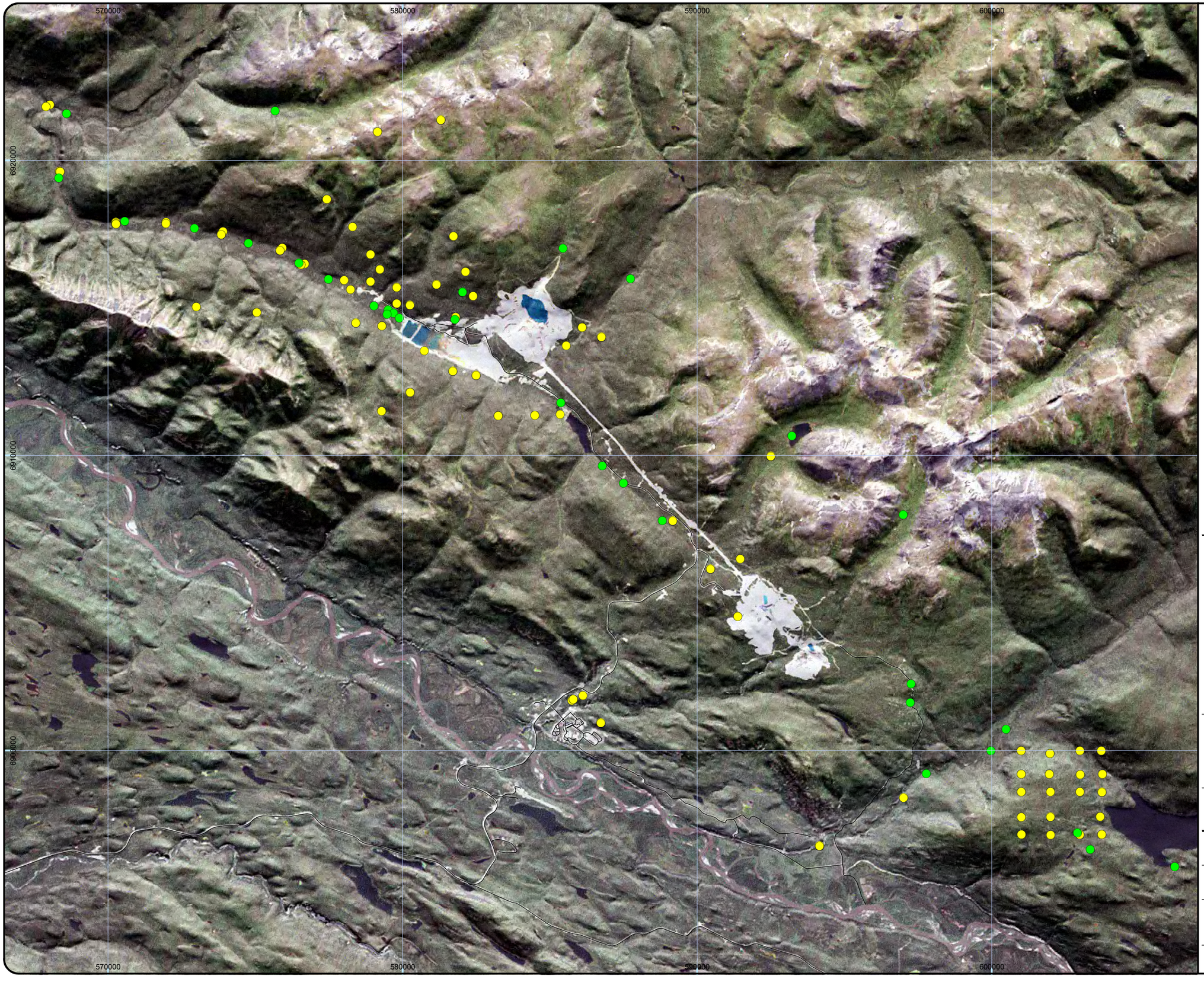
Additional monitoring for metals in soils at the Faro Mine Complex was conducted in 2002 by C.E. Jones and Associates (C.E. Jones and Associates Ltd. 2003). This study determined that elevated metals concentrations from potential airborne deposition occurs in a zone that extends a minimum of 2 to 3 km in all directions from the potential mine-site elemental dust sources, with the highest concentrations extended north/northwest of the tailings impoundments. In 2004 and 2005, field investigations were conducted to further characterize the spatial distribution of elevated elemental concentrations and determine if deposition is ongoing (Gartner Lee Limited 2005). Sampling of lichen was performed to delineate the effects of airborne deposition from mineralization on metal concentrations in the area, as lichens depend entirely on airborne material and precipitation for nutrients, and therefore are unaffected by underlying mineralization. Metal concentrations in lichens and sample vegetations species are discussed in further detail in Section 8.1 of this report. Soil sampling was conducted to confirm the results of lichen sampling.

Soils are also perennial accumulators and therefore provide an additional record of cumulative airborne deposition; however, elemental concentrations in mineral soils can also be influenced by natural mineralization and glacial transport. To detect naturally elevated elemental concentrations (i.e., unrelated to the mine) in local surficial materials, Swim Lake basin was used as a reference sampling location. The Swim Lake basin is the most distant of the similar deposits that occurred off-site of the Anvil Range Mine Complex and is situated in an upwind direction with respect to prevailing summer winds (when elemental dust sources on the mine site are not frozen or snow-covered).

In the first year of the study (2002), sampling sites were determined subjectively by establishing transects that radiated from the centre of the Rose Creek tailings impoundment in cardinal/ordinal directions. In 2004 and 2005, however, the identification of sampling sites was based on the geostatistical analysis and Kriging of data from previous years. Soil was sampled by the depth and the type of material at a number of locations in the study area (Figure 3.3-3) because such sampling provides some interpretative power. Soil samples were collected at the surface organic, subsurface organic and subsurface mineral layers as follows:

- surface organic (0-2 cm of F horizon) – obtained directly under live vegetation and its associated litter layer;
- subsurface organic (lower F / H horizon) – obtained directly over the organic/mineral interface, at a minimum depth of 5 cm from the soil surface; and
- subsurface mineral sample (B horizon).

All soil samples were collected from August to November 2004 and from August to September 2005. A total of 168 samples was analyzed for 29 elements by depth and parent material (Table 3.3-1).



LEGEND

- 2004 Soil Sample Sites
- 2005 Soil Sample Sites
- Road

DATA SOURCES AND DISCLAIMERS:

Sample Site Locations determined by field Global Positioning System (GPS). Locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. and C.E. Jones & Associates Ltd.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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File Name: S:\GIS_Proj\Y2005\P50712\report_mar06\50712_distribution_sampling_soils_fig4_11x17_fig3.mxd

Revision: 1.1

Projection: UTM Zone 8 NAD83

0 0.5 1 2 3 4 5 6

Kilometers

Scale 1: 120 000

6.2-6

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

Distribution of Soil Samples Collected and Analyzed in 2004 and 2005

Gartner Lee | C.E. JONES & ASSOCIATES LTD.

Figure 3.3-3

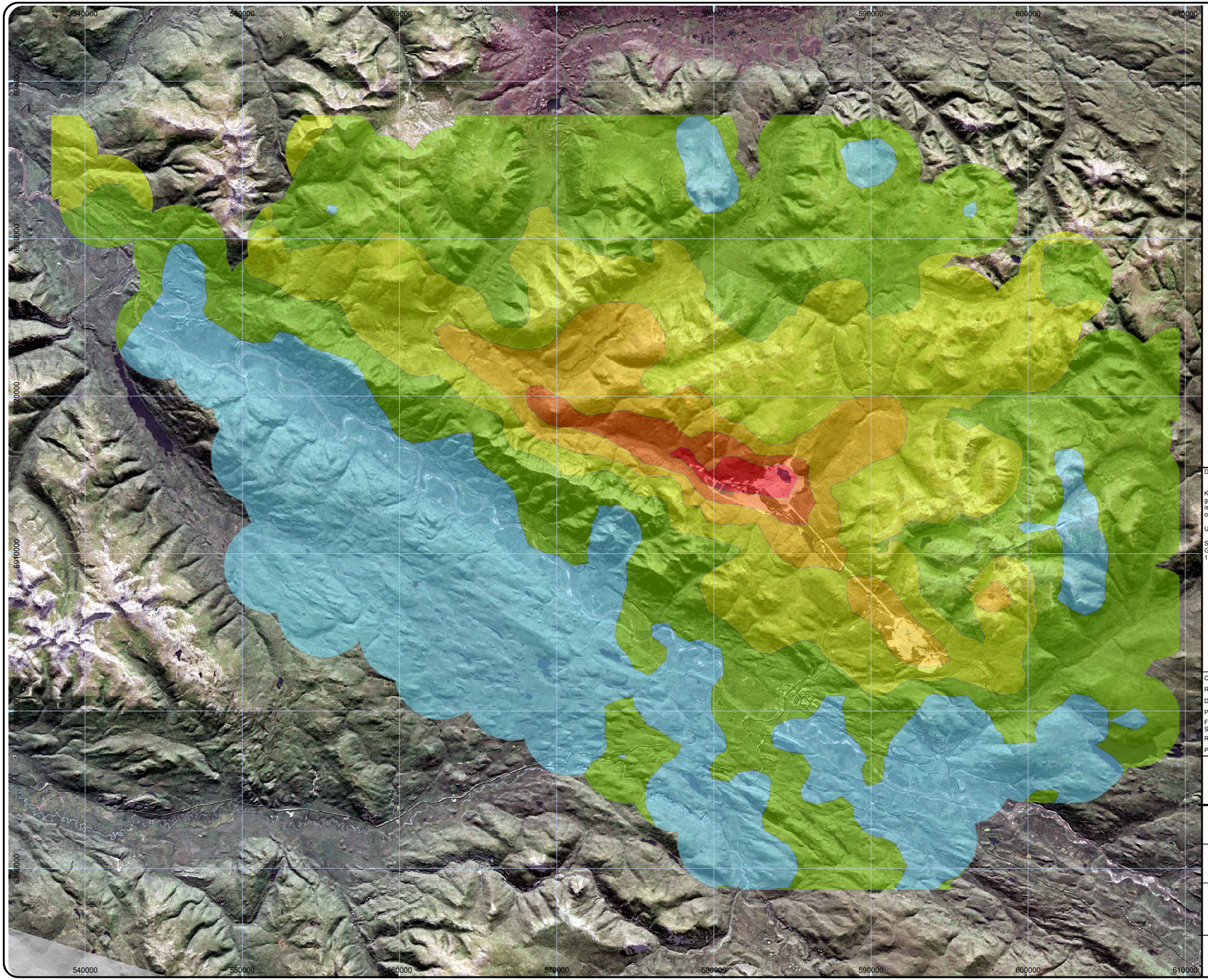
Table 3.3-5. Summary of all Soil Samples Collected and Analyzed for 29 elements and pH in 2004 / 2005 by Depth / Parent Material

Depth / Parent Material	Number of Soil Samples Analyzed
Surface organic	72
Subsurface organic	42
Subsurface mineral	44
Surface mineral	6
Tailings	2
Ash	2
Total	**168**

Also in 2004 and 2005, five soil samples were analyzed for cyanide, and thirty-seven soil samples were analyzed for mobility using sequential extraction.

The following is a summary of the results of element concentrations in soil:

- **Surface Organic Soils.** The zone with the highest lead levels in surface soils was centered on the Faro tailings impoundment / mill complex, and extends northwest down the Rose Creek valley and northeast up the North Fork of Rose Creek valley (Figure 3.3-4). Maximum lead concentrations in surface soils on the Anvil Range Mine were found to be approximately 350 times the Swim Lake maximum. Maximum zinc concentrations in soils near the mine were approximately five times the Swim Lake maximum (Figure 3.3-5).
- **Subsurface Soils.** Lead levels in mineral soils were found to be elevated at the Swim Lake reference area and at a sampling site on fluvial material directly below the Faro waste rock dump. The highest zinc levels were in mineral soil samples from the Swim Lake reference area. Other areas with relatively high zinc concentrations in mineral soils were along Blind Creek, near the Faro town site, on Rose Mountain and at two sampling sites near the mine (Figure 3.3-6 and Figure 3.3-7).
- **Comparison of Surface Organic and Subsurface Soils.** There is no correlation between lead and zinc concentrations in subsurface and surface organic soils, which again indicates that the underlying organic material has little influence on surface soils. This comparison therefore supports the conclusion that the Anvil Range Mine is the source of elevated lead and zinc concentrations.
- **Rose Creek Soils- Organic Horizons.** Lead concentrations in surface organic soil samples from the Rose / Anvil Creek valleys were generally comparable to each other (Figure 3.3-8). Lead concentrations on the side slope were higher than those on the floodplain location at one site, lower at two sites and similar at two sites. Sampling sites at the confluence of Anvil and Rose Creeks had lead concentrations of 224 and 245 ppm, 12 to 14 times the Swim Lake maximum.



LEGEND

Lead Concentration (ppm)

0.2 - 1.6	Zone 1
1.6 - 4.6	Zone 2
4.6 - 17	Zone 3
17 - 61	Zone 4
61 - 210	Zone 5
210 - 748	Zone 6
Road	

DATA SOURCES AND DISCLAIMERS:

Kriging surfaces compiled by Gartner Lee Ltd. Kriging is an interpolation technique based upon a generalized least-squares algorithm using distance-variance relationships as weighting functions. It is used to produce unbiased estimates of concentrations in unsampled areas. The prediction is constrained to one-third of the total prediction standard error.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

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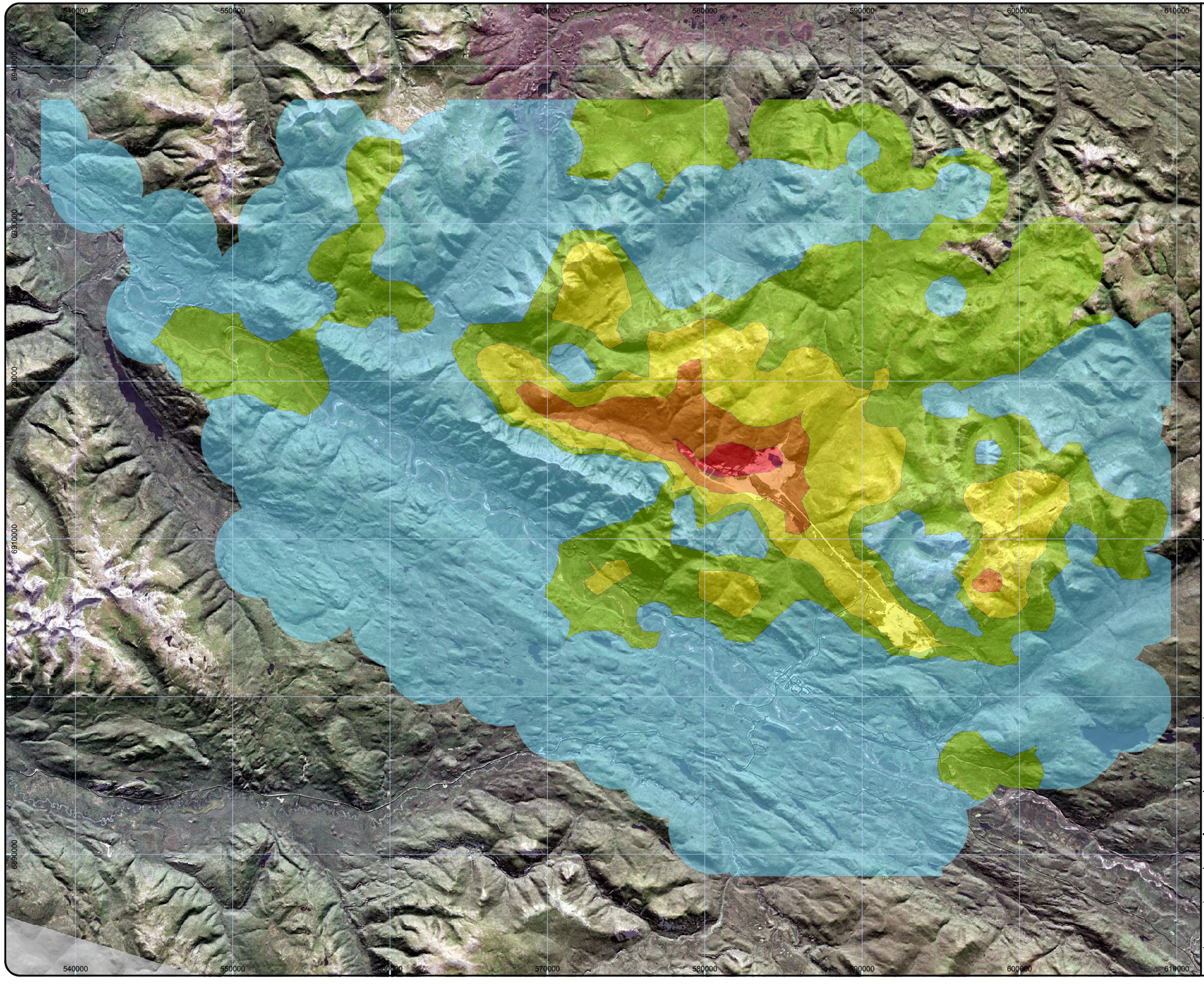
Projection: UTM Zone 8 NAD83

0 2.5 5 10 15

Kilometers

Standard Geostatistical Kriging of Lead in Surface Organic Soil

Gartner Lee | JONES | Figure 3.3-4



LEGEND

Zinc Concentration (ppm)

- 10.7 - 29.7
- 29.7 - 39.7
- 39.7 - 89.8
- 89.8 - 284.7
- 284.7 - 1043.4
- Road

DATA SOURCES AND DISCLAIMERS:

Kriging surfaces compiled by Gartner Lee Ltd. Kriging is an interpolation technique based upon a generalized least-squares algorithm using distance-variance relationships as weighting functions. It is used to produce unbiased estimates of concentrations in unsampled areas. The prediction is constrained to one-third of the total prediction standard error.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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File Name:
S:\GIS_Proj\Y2005\P50712\report_mar06\50712_zinc_surface_organic_soils_krig_11x17_fig32.mxd

Revision: 1

Projection: UTM Zone 8 NAD83

0 2.5 5 10 15

Kilometers

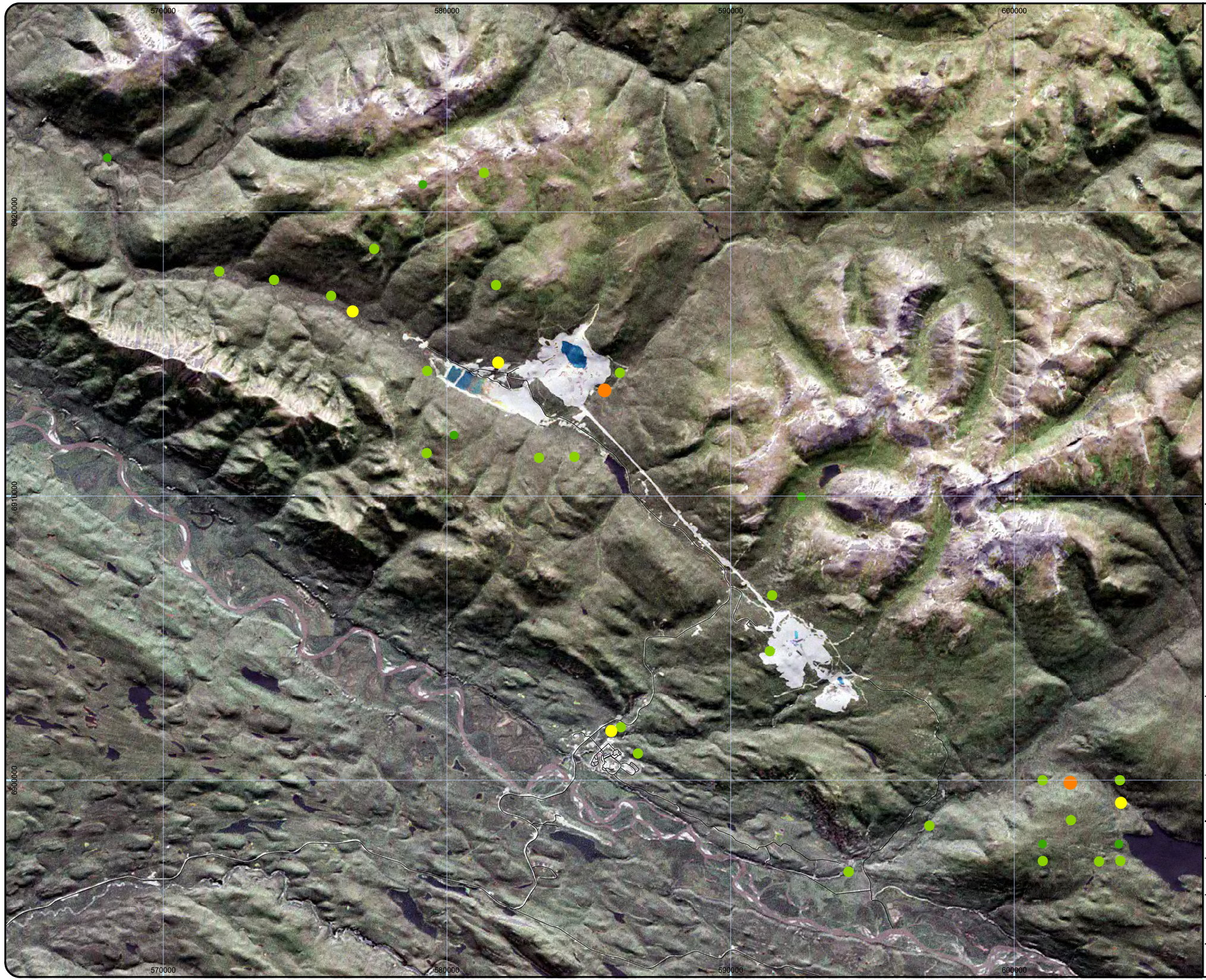
Scale 1: 225 000

ENVIRONMENTAL ASSESSMENT OF THE
CLOSURE AND REMEDIATION PLAN FOR
THE FARO MINE COMPLEX

Standard Geostatistical Kriging of Zinc in Surface Organic Soil

Gartner Lee | JONES

Figure **3.3-5**



LEGEND

Lead Concentration (ppm)

- < 7
- 8 - 22
- 23 - 60
- 61 - 175
- 176 - 1330
- Road

DATA SOURCES AND DISCLAIMERS:

Sample site locations determined by field Global Positioning System (GPS) locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. And C.E. Jones and Associates Ltd.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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Revision: 1

Projection: UTM Zone 8 NAD83

1 0.5 0 1 2 3

Kilometres

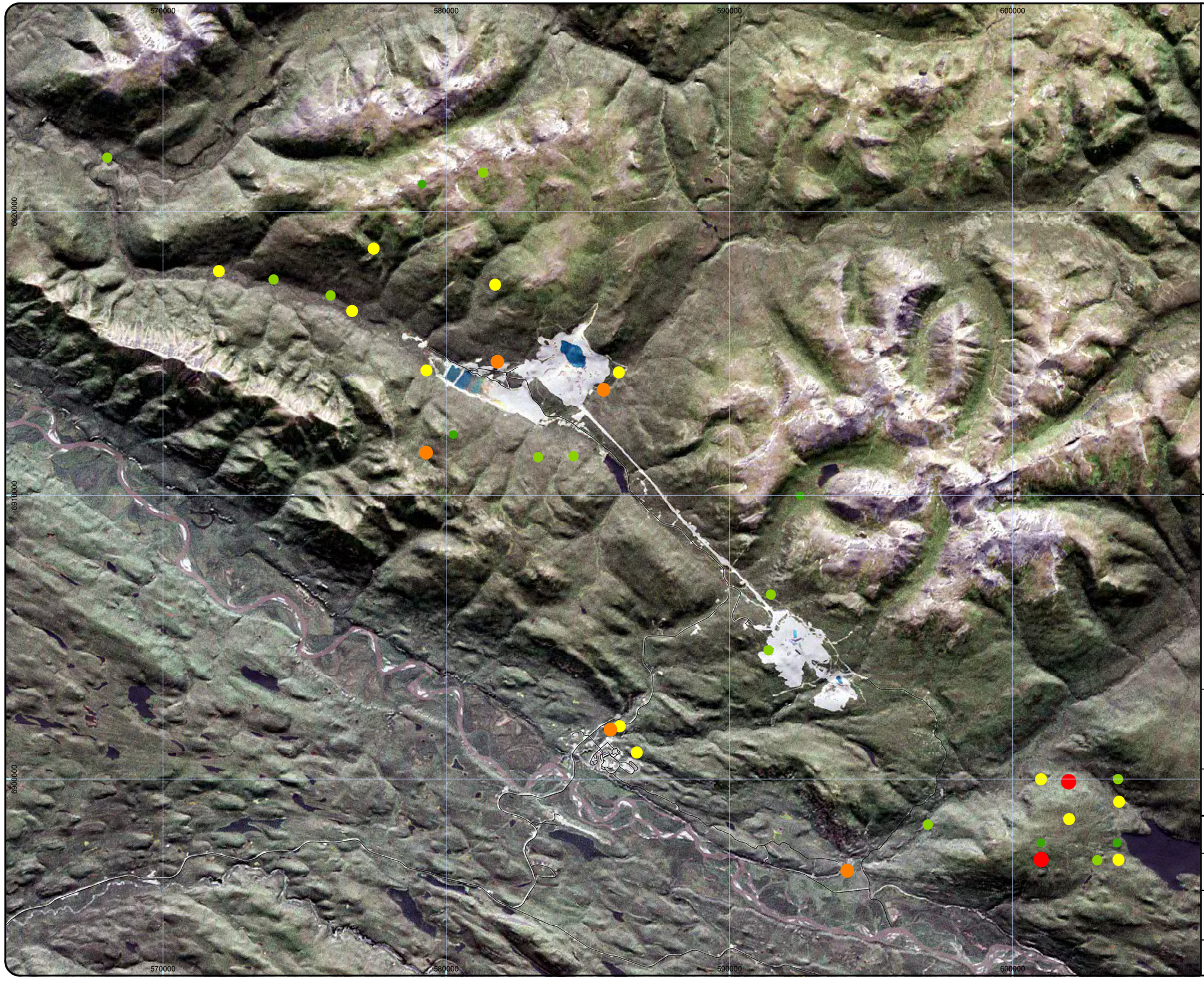
Scale 1: 125 000

ENVIRONMENTAL ASSESSEMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

Lead Levels in Subsurface Mineral Soil

Gartner Lee | C.E. Jones & Associates Ltd.

Figure **3.3-6**



LEGEND

Zinc Concentration (ppm)

- < 17
- 17 - 65
- 65 - 97
- 97 - 134
- 134 - 309
- Road

DATA SOURCES AND DISCLAIMERS:

Sample site locations determined by field Global Positioning System (GPS) locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. And C.E. Jones and Associates Ltd.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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File Name: S:\GIS_Proj\Y2005\P50712\report_mar06\50712_zinc_mineral_soil_no_rc_11x17_fig36.mxd

Revision: 1

Projection: UTM Zone 8 NAD83

1 0.5 0 1 2 3 4

Kilometres

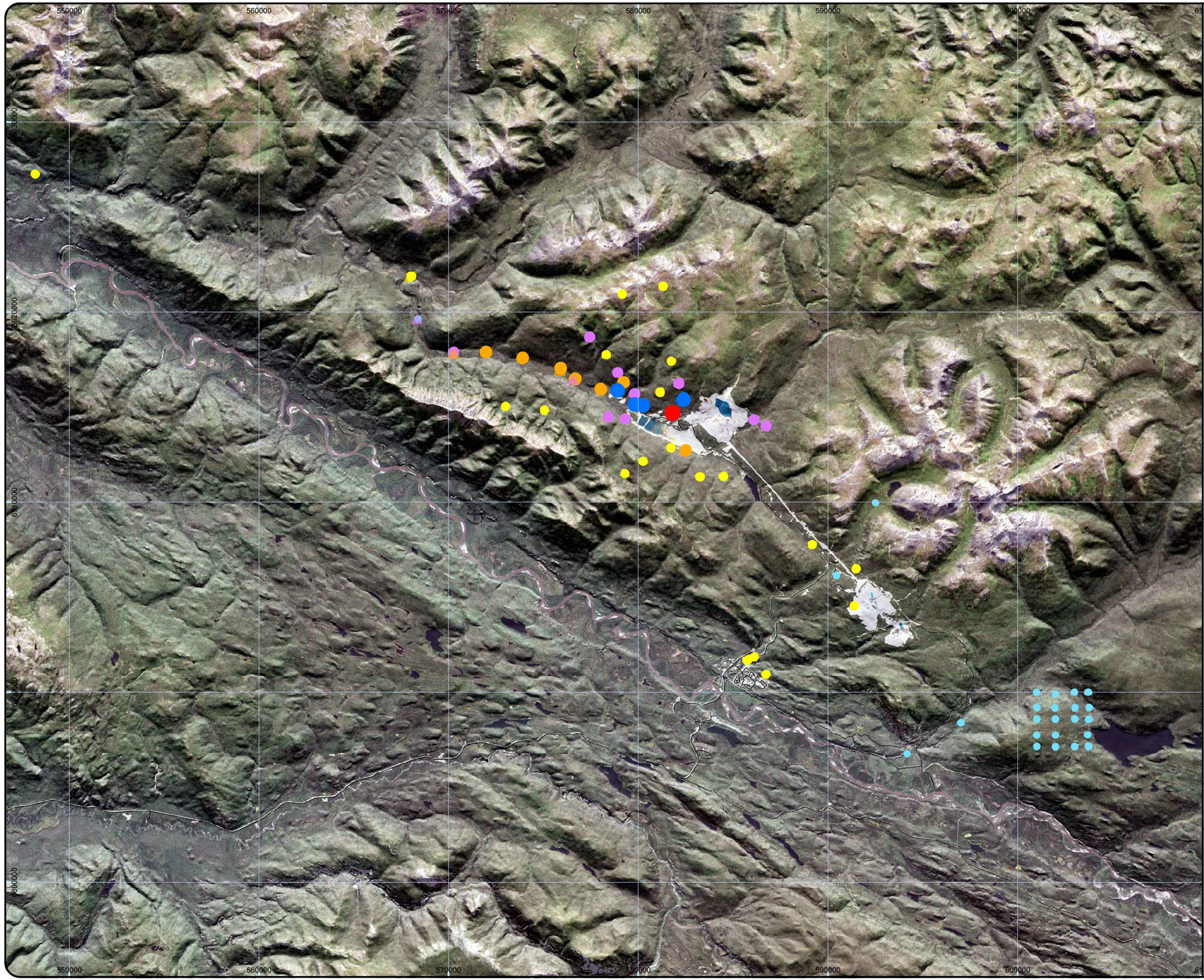
Scale 1: 125 000

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

Zinc Levels in Subsurface Mineral Soil

Gartner Lee | C.E. JONES & Associates Ltd.

Figure **3.3-7**



LEGEND

Lead Concentration (ppm)

Rose Creek Floodplain Sites

- < 18
- 19 - 274
- 275 - 705
- 706 - 1310
- 1311 - 2450
- 2451 - 5930

Side Slope Sites

- < 18
- 19 - 274
- 275 - 705
- 706 - 1310
- 1311 - 2450
- 2451 - 5930
- Road

DATA SOURCES AND DISCLAIMERS:

Sample Site Locations determined by field Global Positioning System (GPS). Locations recorded in UTM Zone 8, NAD83. All sample locations recorded by Gartner Lee Ltd. and C.E. Jones & Associates Ltd.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

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Project Number:

File Name: S:\GIS_Proj\Y2005\P50712\report_mar06\50712_lead_surface_orgainic_soils_11x17_fig41.mxd

Revision: 1

Projection: UTM Zone 8 NAD83

1 0.5 0 1 2 3 4 5 6

Kilometres

Scale 1: 125 000

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

Lead Levels in Surface Organic Soil in Rose Creek

Gartner Lee | C.E. JONES & Associates Ltd.

Figure **3.3-8**

- **Rose Creek Soils- Mineral Horizons.** Direct, large-scale tailings deposition from the 1975 impoundment breach has affected the downstream active floodplain and were noted as an additional source of elevated off-site elemental concentrations. Although the remaining large tailings deposits were discontinuous, smaller-scale transport and deposition appears to have been ubiquitous and resulted in elevated lead levels in active fluvial sediments throughout the Rose Creek drainage downstream of the tailings impoundments. The effects of the 1975 breach were not confined to historical impacts. Lead levels in fugitive tailings deposits were found to be greatly elevated. It is likely that the downstream transport of fugitive tailings in the Rose Creek drainage contributed to the large distance over which effects can be measured in a northwest direction.
- **White River Ash.** Metal content were not elevated in the two ash samples submitted for analysis; lead concentrations in both samples were below the 5 ppm detection limit.

Sequential analysis demonstrated that a greater portion and much greater absolute amount of lead in surface soil from mine-affected areas are in a weakly complexed or more mobile form than in the reference area. The implications are that lead deposited from the mine site is not environmentally inert. Instead, it can be expected to have some mobility through plant uptake and leaching through to lower soil horizons, where it will likely become more permanently fixed.

Results for total cyanide analysis in soils show that Rose Creek floodplain samples (<0.4 ppm in surface and subsurface mineral soil samples) were below CCME soil-quality guidelines for free cyanide (0.8 ppm for agricultural and residential / parkland soils). Cyanide levels in all of these samples were below the 0.8 ppm CCME soil quality guideline for free cyanide in soil. Free cyanide and total cyanide were less than 0.6 ppm at one site and total cyanide was less than 0.3 ppm at the other two sites.

3.3.1.2 Transformer and Capacitor Fluids

During the Phase 1 Environmental Site Assessment, surface grab samples were also analysed for transformer and capacitor fluids due to the presence of PCB-containing electrical equipment during operational periods of the mine. Polycylic Aromatic Hydrocarbons (PAH's), total Polychrorinated Biphenyls (PCB's) and chlorinated phenolics were analysed for samples collected at the old shop, portal area, and the ore haul maintenance shop (Figure 3.3-1). Analytical results were compared to the Canadian Soil Guidelines for the Protection of Environmental Quality and Human Health (CCME 1999) and the Yukon Contaminated Sites Regulations, Generic and Matrix Numerical Soil Standards (Industrial Standard (Government of Yukon 1997).

All samples were within the CCME and Yukon CSR guidelines, with the exception of one sample collected at the old shop and grum portal area (sample OS 3), which had pentachlorophenol concentrations of 24.5 μg/g), exceeding the CCME guideline of 7.6 μg/L (Table 3.3-2)

4. Geology

4.1 Regional Setting

The area surrounding the Faro Mine Complex is underlain by metamorphic and volcanic bedrock. The Proterozoic and Paleozoic schists and phyllites were intruded by the Anvil Batholith, which consists of granite, granodiorite and quartz monzonite. The crystalline nature of these rocks typically creates a very low primary porosity (0-10%), therefore and groundwater flow through the bedrock likely occurs along planes of weakness or deformation, such as fractures, faults or shear zones. Predicting the occurrence of groundwater and its flow direction in this type of rock is difficult at best, and there is little information available for the Anvil District.

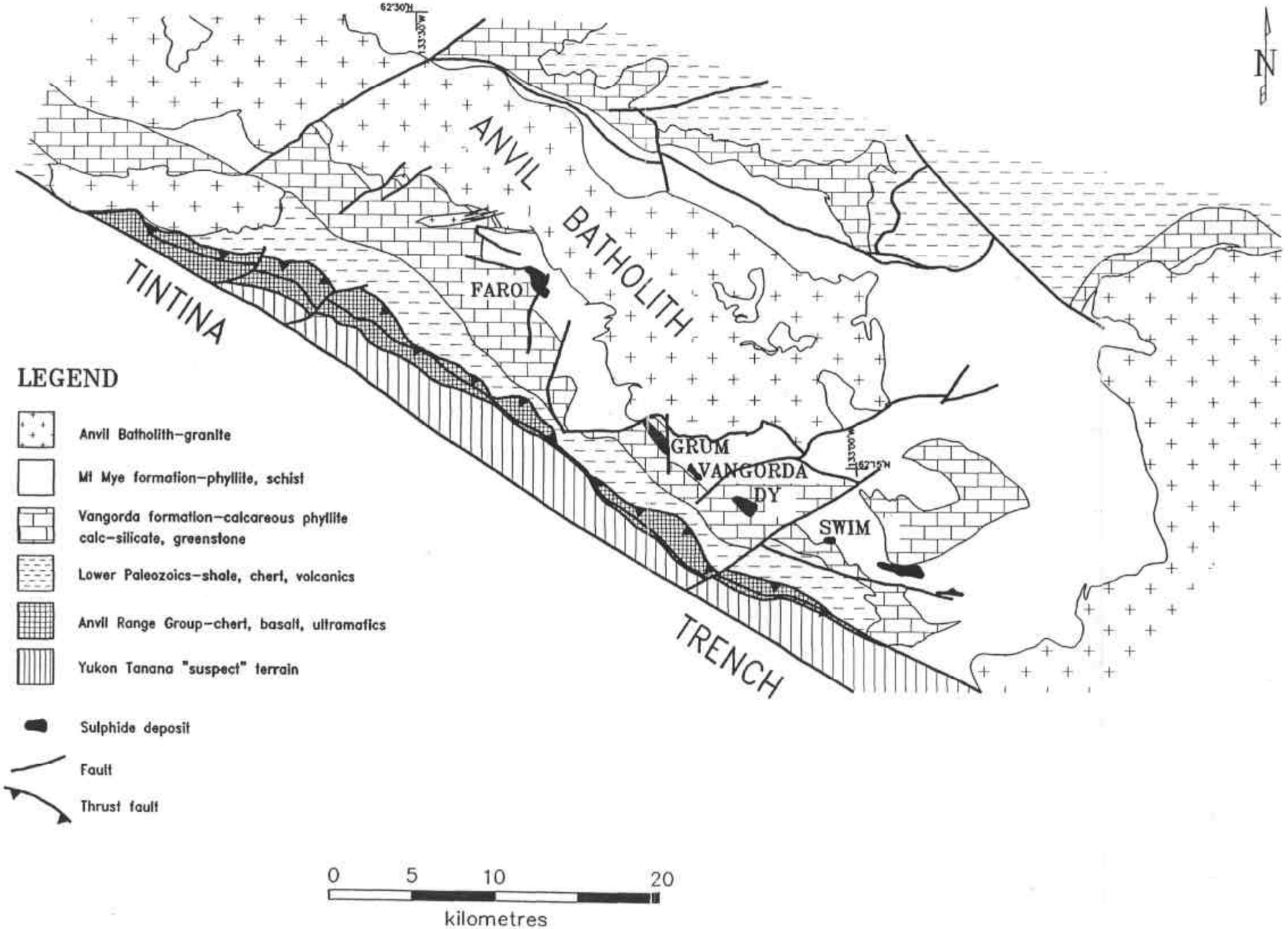
Bedrock is overlain by various types of surficial deposits (or overburden) consisting primarily of glacial till, glaciofluvial sediments and alluvium. In topographically elevated areas, these surficial deposits are thin and irregularly distributed. Surficial deposits are generally thickest in the valley bottoms, although significant thicknesses of till have been documented in the uplands of the Vangorda Plateau.

The presence, characteristics and thickness of surficial deposits (natural, waste rock and tailings) are the primary control on flow of groundwater in the study area. Groundwater flow occurs primarily in the overburden, or through the upper most weathered surface of the bedrock. Flow direction is controlled mainly by surficial and bedrock topography. Recharge occurs via infiltration of precipitation to the water table and mostly horizontal flow, generally following topography to discharge zones into local creeks or shallow depressions. The bedrock valley sides act as recharge sites and groundwater flow progresses to the valley bottom as a discharge zone. Recharge to valley aquifers may also occur locally through the beds of losing streams occupying the valley.

Large glaciated valleys, including the Pelly River, Rose Creek, and Blind Creek valleys, have been filled with significant thickness of glacial sediments. Where these deposits are primarily glaciofluvial sands and gravel, they represent relatively high yield aquifers. Valley aquifers are usually unconfined, with shallow depths to water and significant groundwater yields. However, if confining layers, such as glacial till or other fine-grained deposits such as tailings extend across the valley floor and partially up the valley sides, confined aquifers, with significant hydraulic heads may be encountered.

4.1.1 Bedrock Geology

The geology of the Anvil District has been described in detail in RGC 1996. A regional geology map, repeated from RGC 1996, is provided in Figure 4.1-1.



SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY ROBERTSON GEOCONSULTANTS INC.
REPORT NO. 033001/3 DATED NOVEMBER 1996
"ANVIL RANGE MINING COMPLEX – INTEGRATED COMPREHENSIVE ABANDONMENT PLAN"
DRAWING TAKEN FROM ACCESS MINING, 1996

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Anvil Range Mining Corporation

Anvil Complex Closure Plan

Geological Map of the Anvil Range

PROJECT NO. 033001 | DATE Nov. 1996 | APPROVED | PAGE 3-2

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REVISION:	0

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

REGIONAL GEOLOGY

Gartner Lee

FIGURE 4.1-1

The stratigraphy of the Anvil District consists of regionally metamorphosed sedimentary bedrock, ranging in age from late Precambrian to Permian (approximately 900 to 250 million years ago). The degree of metamorphism ranges from moderate (schist) to low (phyllite). The lower part of the sequence, Silurian aged and earlier, as represented primarily by the Mt. Mye and Vangorda Formations, is the most important with respect to the Anvil Range ore bodies. During the Cretaceous, the meta-sediments were intruded by the Anvil Batholith, a granitic pluton that varies in composition from granite to granodiorite to quartz monzonite. A higher degree of metamorphism is generally observed near the Anvil Batholith contact. The meta-sediment rocks dip northeast and southwest, away from the Batholith.

The Mt. Mye Formation is represented by schists, with the dominant rock type being grey, non-calcareous, weakly carbonaceous phyllite with lesser interlayered black carbonaceous phyllite and schists. Mafic meta-igneous rocks, now amphibolites, are present locally but are volumetrically minor. A white, calc-silicate and marble marker horizon occurs about 500 to 700 m below the top of the Mt. Mye Formation, which has a structural thickness of at least 2,000 m (the base is not exposed).

The Vangorda Formation is represented by light to medium grey to greenish-grey calcareous phyllites. At higher metamorphic grade (amphibolite facies), the calcareous phyllite is transformed to calc-silicate rocks. Major interbanded units in the Vangorda Formation include meta–igneous greenstone, which is more common near the top of the Formation, and carbonaceous pelite. The Vangorda Formation varies from 0.5 to 2 km in apparent thickness.

Five ore deposits have been identified in the Anvil Range area: Faro, Grum, Vangorda, Grizzly (previously DY) and Swim. Mining is complete (depletion of known economic reserves) in Faro and Vangorda deposits, partially complete in Grum and has not occurred in Grizzly or Swim. The three deposits at which mining has taken place are described below.

4.1.2 Faro Ore body

Rocks of the Faro Mine site were metamorphosed in the amphibolite facies of regional metamorphism. The result is that schists are more important at Faro than elsewhere, and the calc-silicate gneiss, a rock type not seen at other sites, is widespread as the major rock of the Vangorda Formation. The increased metamorphism generally tended to coarsen mineral grain sizes, including sulphide minerals.

Deformation is so complex and flattening into the metamorphic foliation is so pronounced at the Faro site that the geology appears to be a simple layer cake of stratigraphy. The ore-body is concordant to formational boundaries and is stratigraphically approximately 75 m below the top of the Mt. Mye Formation. It consists of a gently dipping, stratiform zinc-lead-silver massive sulphide deposit, offset by faults. The main deposit (Zones 1 and 3) was approximately 1.5 km long, 500 m wide and averaged 46 m thick. The satellite Zone 2 deposit was approximately 300 m long, 180 m wide and average 24 m thick.

The main ore body was composed of two zones (Zones 1 and 3) vertically offset by a normal fault as illustrated on Figure 4.1-2. This northeast trending fault, the Faro fault, is sub-vertical and bisects the main ore-body. The east block is down dropped approximately 50 m. A diorite dyke is intruded along the fault zone. The satellite Zone 2 ore body was geologically part of the same sulphide lens but was separated by normal fault offset. The Big-Indian – North Fork fault system separates Zone 2 from Zone 3. This fault set consists of several strands with a throw of roughly 75 m, west block down.

The Zone 2 Pit was one of the few areas where the Faro deposit was exposed on surface. Thus, a weathered mantle was present over part of the deposit. The Zone 2 ore body was at the edge of the overall Faro deposit and was rich in ribbon banded quartzite ore. Massive sulphide was limited and the ore grade was low compared to Zone 1 and 3 in the Main Pit. Anvil Batholith instrusives were found along the northeast side of the Zone 2 ore body.

4.1.3 Vangorda Ore body

The Vangorda deposit was a small deposit for this area and had a number of characteristics that made it unusual. These included:

- shallow depth and a greater degree of weathering;
- abundance of foot wall sulphides; and
- 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 thickest part of the ore body occurred below a ridge of highly compacted till east of Vangorda Creek.

The Vangorda deposit consisted of one major sulphide 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. A number of thin horizons occurred above the sulphide 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 ratios). The deposit itself contains the same sulphide rock types as the other deposits in the Anvil District.

A major fault is found at the northwest end of the Vangorda Pit as illustrated in Figure 4.1-3. This fault truncated the ore body and juxtaposed the black graphitic phyllite of the basal member of the Vangorda Formation against the ore body.

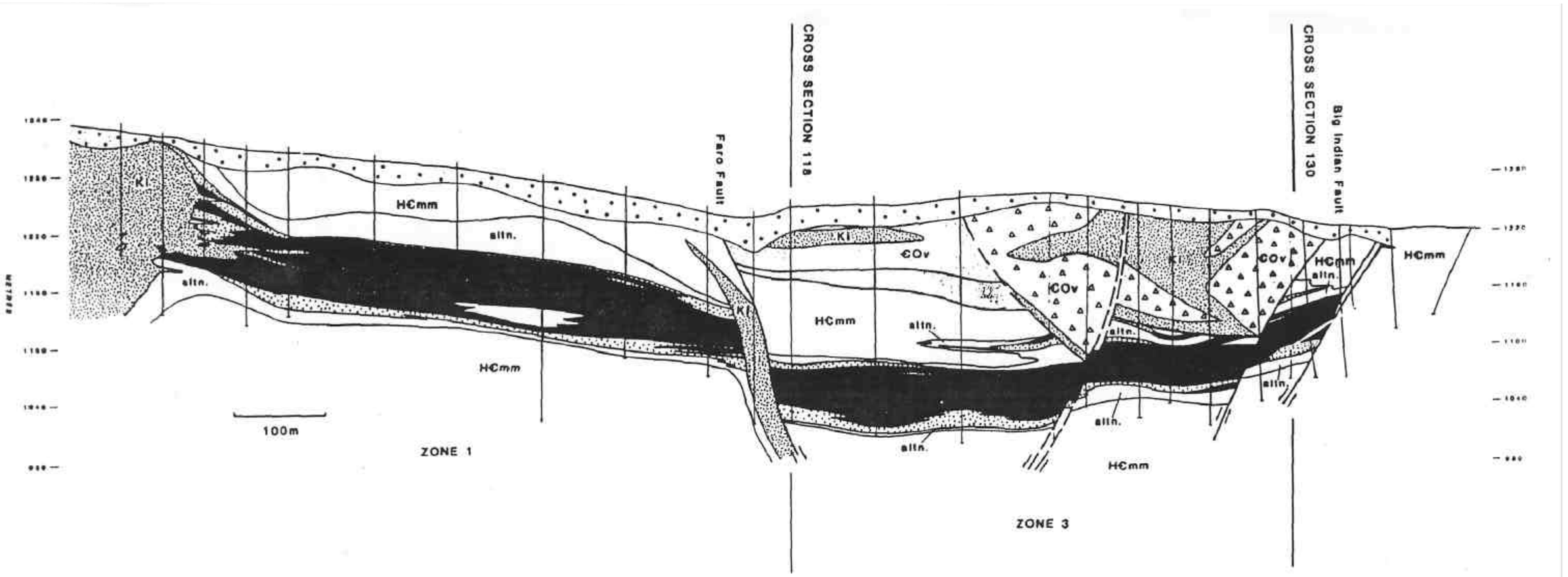

FIGURE Vertical longitudinal section 22 of the Faro deposit, looking northeast, no vertical exaggeration. Units are same as Figure 4-3 Zones 1 and 3 are indicated, the largely eroded northeast extension of zone 2 is just beneath the overburden southeast of the Big Indian Fault. Within about 150 m of the diorite dyke at the northwest end of the section, the massive sulphides are altered to pyrrhotite rich assemblages containing local large magnetite octahedra and partly reverted to pyrite. Adjacent to the diorite dyke along the Faro Fault massive magnetite is developed in the sulphides.

SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY ROBERTSON GEOCONSULTANTS INC.
REPORT NO. 033001/3 DATED NOVEMBER 1996
"ANVIL RANGE MINING COMPLEX – INTEGRATED COMPREHENSIVE ABANDONMENT PLAN"

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Anvil Range Mining Corporation

Anvil Complex Closure Plan

FARO DEPOSIT
VERTICAL LONGITUDINAL SECTION 22

PROJECT No. 033001 | DATE Nov. 1996 | APPROVED | FILE 4-4

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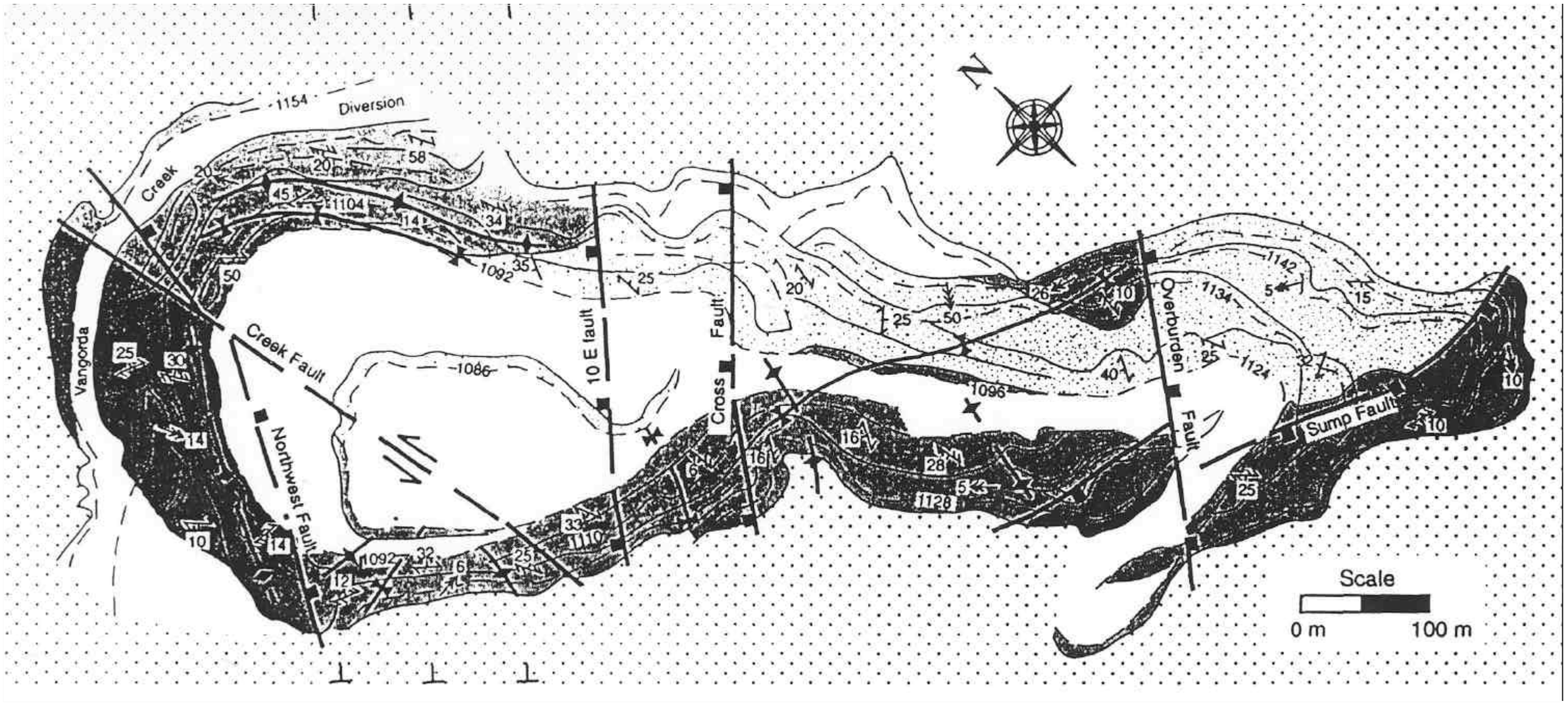
ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

FARO OREBODY

Gartner Lee

FIGURE 4.1-2



SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY STEFFEN, ROBERTSON KIRSTEN (CANADA) INC.
REPORT NO. 60647
DATED MAY 1992
"CONSTRUCTION REPORT VANGORDA CREEK DIVERSION REALIGNMENT VANGORDA PLATEAU DEVELOPMENT"

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ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

VANGORDA OREBODY

Gartner Lee

FIGURE 4.1-3

4.1.4 Grum Ore body

The Grum Deposit, with mineable reserves of approximately 25 million tonnes, has a number of characteristics that make it unique. These include:

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

The deposit was covered by up to 100 m of till and glaciofluvial silt, sand and gravel. The material fills a buried channel trending north-south through the southeast pit area. No notable weathering features are present at Grum as were observed at Vangorda.

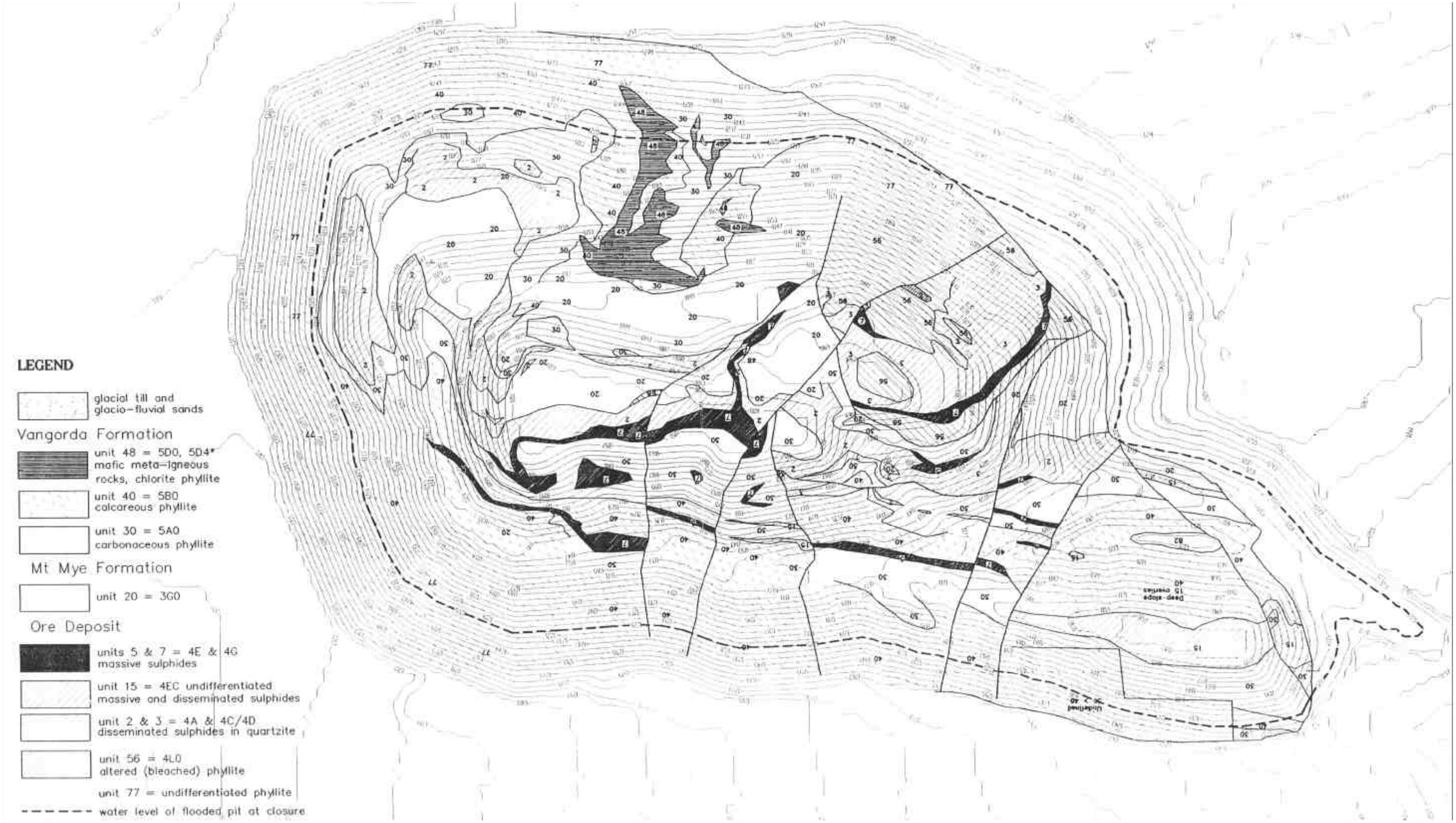
The Grum deposit consists of three to five highly contorted layers of massive and disseminated sulphide mineralization within a 150 m thick section of phyllite. The most important mineralized horizon occurs just beneath the basal carbonaceous member of the Vangorda Formation. There are thin low-grade horizons with the Vangorda Formation and more important horizons in the upper part of the Mt. Mye Formation. A unique feature of the geology of the Grum ore body is the presence of quartoze ore types, which formed up to 50% of the reserves. The other ore types are similar to the other deposits.

The Vangorda Formation at the Grum Deposit consists primarily of soft calcareous phyllites. They are not as strongly altered as at the Vangorda Deposit and are strongly calcareous. The Mt. Mye Formation at the Grum Deposit also consists of phyllites, which are non-calcareous and less distinctly banded than those of the Vangorda Formation.

There are several important faults at the Grum Deposit. The largest displacements occur on moderately dipping structures that truncate the deposit at both its northwest and southeast ends but do not crop out in the pit. A steeply north-west dipping fault set down drops the deposit about 60 m on the north-west. A myriad of smaller steeply dipping faults has also been mapped both underground and in the pit. Figure 4.1-4 illustrates geology for the ultimate design Grum Pit, which is larger than the existing excavation.

4.1.5 Rose Valley Geology

The mine area is situated within an area of discontinuous permafrost. At the mine site, north facing slopes and areas with older forest cover are more likely to contain permafrost. Permafrost ground, with varying degrees of ground ice content, was encountered during the construction of the Cross Valley Dam and the Rose Creek Diversion Channel. Felsenmeer is formed near the top of high hills due to frost action effects on exposed bedrock.



SOURCE OF FIGURE:
DRAWING SHOWN BELOW DRAWN FROM REPORT BY STEFFEN, ROBERTSON KIRSTEN (CANADA) INC.
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"CONSTRUCTION REPORT VANGORDA CREEK DIVERSION REALIGNMENT VANGORDA PLATEAU DEVELOPMENT"

ROBERTSON GEOCONSULTANTS INC.
Consulting Geotechnical and Environmental Engineers

Anvil Range Mining Corporation

Anvil Complex Closure Plan

GRUM OPEN PIT GEOLOGY

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ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

GRUM OREBODY

Gartner Lee

FIGURE 4.1-4

The surficial geology of the Rose Creek valley generally consists of colluvial, fluvial and morainal deposits forming a discontinuous cover over the bedrock. On the valley sides, bedrock is discontinuously covered with a veneer of morainal and colluvial deposits that increases in thickness towards Rose Creek. A complex assemblage of fan and outwash sand and gravels, dissected by stream channel and lacustrine materials fill Rose Creek Valley. Terraces and fans are prominent on the north side of the valley, where they, in part, underlie the existing tailings area.

Bedrock underlying the Rose Creek valley consists primarily of the Cambrian to Ordovician rocks of the Vangorda Formation. This formation is described as a “soft silvery grey calcareous phyllite with interbands of medium crystalline grey marble” (RGC 1996). This formation has been locally intruded by granodiorites and quartz monzonites of the Anvil Batholith. Foliation in the bedrock underlying the Rose Creek valley is mapped as generally parallel with the valley axis (west northwest to east southeast and dipping shallowly to the southwest (15 to 30 degrees) (Pigage 2001). The competence of the bedrock varies but in most cases is poor. Exposures were found to be easily eroded by freeze –thaw and stream flow processes. In places, the schist is reported as being weathered up to 2 m depth (Golder 1980).

A 2003 Rose Creek aquifer and tailings investigation and monitoring well drilling investigation by Gartner Lee (2003d) and a hydrogeological assessment for groundwater capture scenarios completed by RGC (2006) provided information about the depth and type of overburden sediments at several locations throughout the tailings area and downgradient from the Cross-Valley dam. Several monitoring wells and boreholes were advanced down to bedrock surface.

5. Geological Hazards and Seismicity

5.1.1 Geological Hazards Overview

Geological hazards resulting from natural conditions have the potential to significantly impact facilities and infrastructure at a mine site. An assessment of hazards at the Faro Mine Complex was described by BGC based on a review of surficial and bedrock geological information coupled with an assessment of climatic and topographic conditions related to mine infrastructure locations. The assessment utilized information provided in BGC 2001, which was a qualitative risk assessment for structures situated in the Rose Creek valley.

Some potential geological hazards that may exist at the site consist of the following:

1. Landslides, in either soil or rock.
2. Falls.
3. Debris torrents.
4. Fault movements.

The three types of slope movements, landslides, falls and debris torrents, have essentially similar consequences. Failure debris that travels into the mine complex area may impact either a pond of water, a water channel, the access roads or some other component of the mine infrastructure such as a pipeline, dam or treatment facility. If the debris falls into a pre-existing body of water, a wave could be generated that would overtop the water retention structure (a dam or dike). If the debris falls into a channel, then the channel could be blocked, or if the volume of debris is small, the hydraulic capacity of the channel will be changed. If the debris falls on the road, then access could be blocked. Other component specific consequences (e.g., complete damage to a water treatment pipeline) are possible as well.

Fault movements, a hazard related to the seismic risk assessment for a site, consists of the rapid movement of the ground beneath one of the site structures or channels.

5.1.2 Slope Movement and Falls

As outlined previously, the majority of the natural soil located in the Faro Mine Complex consist of granular soils; *i.e.,* locally derived tills, glacial outwash deposits and fluvial deposits. These soils are not particularly prone to slope stability hazards, except for the mechanism of river erosion and within active fluvial fans. Even in these two cases, slope stability issues will likely be confined to local failures due to oversteepening and eroding water.

The colluvial deposits that have been mapped at the Faro Mine Complex are either soils that are actively moving or soils that have moved downslope into their current position. The colluvial soils should be considered to be quasi-stable or in an active state of movement. These materials are typically located on the steeper sections of the surrounding Rose Creek or Vangorda Creek valleys and could provide erratic rockfalls into the valley or local small slides.

Unless in very weak rock masses, rockslides are controlled by the discontinuities within the rock mass. Most rock slopes failures can be classified as either: planar failures, wedge failures, toppling failures or circular failures. The initiation of failures would be dependent upon site-specific geological controls (foliation planes, joints, etc.) and the orientation and height of exposed surfaces.

For rock falls to occur, there needs to be exposed rock faces, steep slopes on the exposed faces and adverse geological controls. The areas of the Faro Mine site that are the most likely candidates for exposure to rock fall hazards are the exposures located above the former FWS Dam reservoir area and the Rose Creek Diversion Canal. The steepness of the overall slopes in the area of the Faro Mine Complex range up to 30 degrees (based on Figure 4.9). Some local oversteepening in the area surrounding the creeks and rivers is likely. In addition, the exposed rock slopes are likely locally steeper than the general overall slope angles.

Earthquake loading should also be considered as part of any slope stability assessment. Earthquakes can have two main effects on the stability of the slopes; increased horizontal force in the slope that decreases the stability and liquefaction of soil within the slope or at the foundation. As noted for soil slides, the addition of earthquake loading will adversely affect the stability of rock slopes.

5.1.3 Debris Flows

Debris flows consist of a spatially continuous movement where the soil/rock moves as a viscous liquid. This type of failure may occur in the upper reaches of the surrounding mountains and feed soil and rock into the Faro Mine Complex. This type of failure would require steep slopes and debris within the steep area. It is envisioned that only in the high altitudes along some headwaters of the creeks that this type of failure could occur.

5.1.4 Fault Movements

Faults occur throughout the Faro Mine Complex site area. A major regional fault is the Tintina Trench, located close to the study area. The major geological hazard related to faults is related to fault movements that induce earthquakes. If the fault is located in the immediate vicinity, then the direct movements of the fault can impact structures and slopes. The secondary geological hazard related to faults is in the local control of slides within the rock mass. The rockmass, located at a fault zone, can generally be recognized by a zone of intense shearing, fracturing and brittleness of the rock. These factors combine to potentially form the boundaries of rock slides or falls.

Known faults within the Faro Mine Complex include the Rose Creek Fault, Vangorda Fault, Blind Creek Fault, and the Tie Fault.

5.1.5 Seismicity

Earthquakes can produce both ground ruptures and seismic shaking of the ground, depending upon the magnitude (M) of the earthquake, the distance from the epicenter and the local site-specific conditions. Both of these resultant occurrences have potential impacts on engineered

structures, such as dams and other water diversion structures. Before any impact analyses can be undertaken on the various engineered structures, it is necessary to estimate the level of seismic shaking that a structure may undergo. This task is generally referred to as a seismic hazard assessment. Peak ground acceleration (PGA) values resulting from seismic events are stated as a percentage of gravity (g).

Vick 1983 noted that there are three main approaches to seismic risk assessment that will likely result in different estimates of potential site acceleration values:

1. Historical seismicity approach – examination and summary of historic earthquake record proximal to the site in question.
2. Probabilistic approach – refinement of the historical approach where the historical record is the basis of a probabilistic analyses to determine a unique probability of occurrence for each possible level of seismic acceleration.
3. Deterministic approach – where an estimate of the maximum seismic acceleration is based on an assessment of available geological data without regards for past historic events. The geological data is used to determine the nearest fault and then to estimate the magnitude of the earthquake that would result on this fault. This approach is commonly applied in areas where active earthquake-generating faults exist. Generally, the acceleration estimated by this method is termed as “maximum” or “maximum credible”.

A range of PGA’s have been used for designing various facilities at the Faro Mine Complex.

In the “Abandonment Plan for Faro Mine Tailings” report, dated September 1981, Klohn Leonoff (Klohn) estimated PGA values based on two different approaches as follows:

1. 0.07 g for a 475 year return period.
2. 0.10 g for a 900 year return period.
3. 0.32 g for a 10,000 year return period.
4. 0.40 g for Maximum Credible Earthquake (MCE).

Klohn noted that the closure design criteria would be much different than the values used for an operating mine. Therefore, Klohn recommended that the MCE be used for the design criteria. The data available at that time was very limited and a conservative approach was taken.

Based on the historical movement rates within the Tintina Trench, Klohn estimated that an earthquake with a magnitude of M6.5 could occur. Using an empirical formula that included the distance from the site to the location of the earthquake, a peak ground acceleration of 0.40 g was estimated. Using the same methodology and an estimated M6.0 earthquake within the local faults of the Rose Creek Valley, a peak ground acceleration of 0.36 g was estimated for the site facilities.

Statistical analysis was also performed by Klohn, based on earthquake analysis provided by GSC Pacific Geoscience Centre (PGC). The 10,000-year event resulted in a peak ground acceleration of 0.32 g. The analysis was also performed to estimate the 475-year return period earthquake, which was determined to be 0.07 g. The report noted that one method used to estimate the MCE

(maximum considered earthquake) was by doubling the magnitude of the 475 year event and that this would result in an MCE of 0.14 g.

In a Dome Petroleum memo dated September 1984, based on information supplied by the PGC, the seismic risk for the Faro area was calculated to be 0.063g for a 475-year return period and 0.08 g for the 1,000-year return period event.

In a report dated March 1986, "Report on design and proposed construction, Rose Creek Water Reservoir Dam Raising" Kilborn Engineering performed pseudo-static analysis on the proposed dam raise. It was noted that the analysis was performed using a "conservative design earthquake" value of 0.15 g. No quantification of the method used to determine this earthquake loading was made, nor was the return period for this earthquake mentioned.

In a report dated February 1989, Appendix I of the report entitled "1988 Performance Monitoring and Additional work on the Down Valley Tailings project: Faro Mine", Golder Associates Ltd. used a PGA value of 0.08 g (475-year return period) as part of an analysis of the geotechnical stability of the FWS Dam. It was noted that the earthquake parameters used for this analysis of the FWS Dam were based on the values employed in the 1980 design of the Down Valley Tailings containment project. The design earthquakes for that project were a PGA of 0.052 g (100-year return period) and 0.097 g (200-year return period). The determination of these design earthquakes were based on a statistical analysis of historical earthquakes, based on data provided from the Pacific Geoscience Centre.

In a report dated November 1996, Appendix A of the report "Anvil Range Mining Complex – Integrated Comprehensive Abandonment Plan (ICAP)" Robertson Geoconsultants had an assessment of the seismic ground motions for the Faro area performed. This was based on historical data and the assumption that earthquake loading would be transmitted through rock. The PGA was estimated as follows:

1. 0.05 g for a 475 year return period and
2. 0.13 g for a 10,000 year return period event.

The Robertson report noted that "there is no evidence of more recent displacement along the Tintina Fault and the fault is not included as an earthquake source zone in either the H or R zonations given in the GSC report, i.e., the fault is not considered active and no maximum magnitude has been defined for the fault. Thus, it is unrealistic to consider a deterministic estimate of seismic ground motions at Faro in which an earthquake is assumed to occur on the Tintina."

In a report dated November 2001, entitled "Physical Stability Assessment of the Fresh Water Supply Dam" undertaken by BGC, the seismic loading values were as follows:

1. 0.063 g for 475 year return period.
2. 0.080 g for 1,000 year return period.

This estimate was based on information provided by the Pacific Geoscience Center, which estimated these parameters on the basis of historical earthquake loading and the 1990 NBCC seismic zoning maps.

Table 4.1-1. Summary of Earthquake Loading

	Return Period Event				
Study	**475**	**1,000**	**10,000**	**Estimated MCE (based on twice the 475 Year Event)**	**MCE**
Klohn Leonoff (1981)	0.07g	0.10g	0.32g (probabilistic)	0.14g	0.40g (deterministic)
Dome/PGC (1984)	0.063g	0.08g		0.126g	
Golder (1989)	0.08g			0.16g	
Robertson (1996)	0.05g		0.13g	0.10g	
BGC/PGC (2001)	0.063g	0.080g		0.126g	

The above information indicates that the seismic loading design criteria have been quite variable in the 20 years that have been reviewed for the Faro area. It should be noted that the design horizontal acceleration determined for the 475-year return period has been relatively consistent in this period from 0.05 g to 0.08 g. Using the suggestion provided in Klohn 1981 that the maximum credible earthquake (MCE) is twice the magnitude of the 475 year event, relatively consistent values emerge for the magnitude of this event, from 0.10 g to 0.16 g even though the single deterministic analysis resulted in a larger magnitude.

In 2004, a seismic hazard assessment was performed for the Faro Mine Complex site, which considered the regional seismicity and regional geological features, including the Tintina Trench. (Atkinson 2004). Findings of this assessment concluded that for an annual probability of 0.0001, corresponding to a 10,000 year return period ground motion, the mean peak ground acceleration (PGA) is 546 cm/s^2 for NEHHRD D soil conditions (soil conditions believed to apply to the Faro site, and a median PGA of 343 cm/s^2 (Atkinson 2004). These ground motions correspond to an earthquake of approximately M7, at a distance of 10 to 20 km from the Faro site.

In the report titled “Seismic Stability of Cross Valley Dam – 1 in 500 Year Earthquake”, Klohn Crippen Berger concluded that the Cross Valley Dam will not fail under a 500 year return period earthquake, but would fail if shaken by a MCE (Klohn 2007). This work predicted that the 1 in 500 year earthquake, a M5.8 producing 0.11 g at the Cross Valley Dam, would not liquefy the foundation soils. The report noted that structures such as the Cross Valley Dam are regulated to survive the 1 in 500 year motions during temporary closure design and construction, however, the of the dam must be improved for long term closure.

6. Water Resources

Water resources include hydrology, hydrogeology, and water quality environmental components. For each component, a temporal scope has been defined based on relevant information required to characterize existing environmental conditions. Historical data has also been evaluated and presented for the purpose of providing context of the effects of previous mining activities on the current water resource on and down gradient of the Faro Mine Complex.

Local and regional study areas have been defined for each discipline based the anticipated Project footprint and watershed boundaries, as well as availability of information. During the assessment of the FCRP, cumulative effects of the project will be assessed in conjunction with other relevant projects and activities that may impact water resources with the RSA

6.1 Hydrology

Hydrology baseline characterization will be updated with recent site climate and hydrology information in the near future: spring 2008.

6.1.1.1 Watershed Description

Anvil Creek (including Rose Creek drainage) and Vangorda Creek are both tributaries to the Pelly River. The Rose Creek watershed is approximately 340 km^2 and flows to the 980 km^2 Anvil Creek watershed, which drains the southeast slopes of the Anvil Range Mountains to the Pelly River. The Faro Mine site facilities are within the Rose Creek watershed.

Vangorda Creek drains an area of approximately 90 km^2 via an east (mainstem) and west fork. Drainage from the south slope of Mount Mye flows into the main stem and drainage from the northwest slope flows into the west fork. The two forks join together just above the Town of Faro. The Vangorda Plateau Mine site is located within the Vangorda Creek watershed.

6.1.1.2 Historical Hydrological Changes

Development of the complex resulted in significant changes to surface hydrology both during the initial development stages and on an ongoing basis as additional surface water management structures were constructed or existing structures were modified. These changes relate primarily to the interception and rerouting of surface flows in constructed diversion channels or the construction of surface water barriers that altered the downstream flow.

Initial construction of the Faro Mine Site (1968/1969) and subsequent activities involved construction of the facilities (listed in Table 6.1-1) that changed the surface hydrology.

Table 6.1-1. Hydrological Changes Resulting from Construction at the Faro Mine Site

Timeframe	Facility	Change to Hydrology
Initial Construction	Fresh Water Supply Dam South Fork of Rose Creek	Introduction of manual control over winter flow rate in Rose Creek; delay in the release of freshet flows to Rose Creek
	Pumphouse Pond	Removal of water from Rose Creek to the mill
	Faro Creek Diversion	Rerouting of most flow from tributary to Rose Creek to tributary to North Fork of Rose Creek
	Original Tailings Impoundment	Addition of tailings supernatant into Rose Creek at an artificial (i.e., not natural) flow schedule
	Faro Main Pit	Interception of surface runoff and rerouting to various outflow pumping locations
	Mine Access Road	Consolidation of possible surface sheet flow and ground infiltration into discreet streams at culvert crossings
Mine Life	Rerouting of Faro Creek Diversion	Change of entry into North Fork of Rose Creek to current location
	North Fork of Rose Creek Diversion	Change of location of confluence with the South Fork and possible change to groundwater recharge characteristics
	Groundwater recharge ponds in North Fork of Rose Creek	Possible increase of surface water losses to ground
	Upper leg of Rose Creek Diversion Canal	Rerouting of Rose Creek through a constructed channel
	Second Tailings Impoundment	Change of location of entry of tailings supernatant into Rose Creek
	North Wall Interceptor Ditch	Rerouting of water from Guardhouse Creek drainage into a constructed channel and change of entry location into Rose Creek
	Intermediate and Cross Valley Dams	Change of entry of tailings supernatant into Rose Creek and change of flow schedule to accommodate water treatment processes; local changes to surface water/groundwater interactions
	Lower leg of Rose Creek Diversion Canal	Rerouting of an additional length of Rose Creek through a constructed channel
	Rock Dumps	Changes to surface infiltration/runoff characteristics and routing of surface runoff flows
	Zone II Pit	Interception of surface runoff and rerouting to various outflow pumping locations
	Faro Main Pit as tailings disposal facility	Decrease in water (tailings supernatant) entering Rose Creek taken up as storage in Main Pit
	Faro Main Pit pumping/ recycle system	Periodic releases of high flows into Rose Creek via Cross Valley Pond

Initial construction of the Vangorda Plateau mine site (1989/1990) and subsequent activities involved construction of the facilities that changed the surface hydrology as listed in Table 6.1-2.

Table 6.1-2. Hydrological Changes Resulting from Construction at the Vangorda Plateau Mine Site

Timeframe	Facility	Change to Hydrology
Initial Construction	Rock Drain in North Fork Rose Creek	Delay of passage of high flow events (i.e., freshet) to Rose Creek and possible changes to local surface water/groundwater interactions
	Haul Road	Consolidation of possible surface sheet flow and infiltration to ground into discreet streams at culvert crossings
	Mine Access Road ("Grum turnoff")	Consolidation of possible surface sheet flow and infiltration to ground into discreet streams at culvert crossings
	Grum Interceptor Ditch	Rerouting of surface flows to Grum Creek around the Grum pit
	Vangorda Creek Diversion Flume	Rerouting of Vangorda Creek into a constructed channel
	Grum and Vangorda Pits	Interception of surface runoff for storage or rerouting to water treatment plant
	Vangorda Pit interceptor ditches	Rerouting of surface flows and consolidation of possible surface sheet flow into discreet streams
	Water Treatment Plant	Periodic releases of high flows into Grum Creek (pre-1995) and Vangorda Creek via the Grum Interceptor Ditch (post 1995)
Mine Life	Overburden dump, rock dumps and ore transfer pad	Changes to surface infiltration/runoff characteristics and routing of surface runoff flows
	Vangorda Rock Dump collector ditch/Little Creek Dam	Interception of surface runoff for storage or rerouting to water treatment plant
	Rerouting of Grum Interceptor Ditch to Sheep Pad Pond	Rerouting of surface flows from tributary to Grum Creek to tributary to Vangorda Creek
	Moose Pond	Rerouting of partial surface flow from Grum Creek to ground

6.2 Hydrogeology

6.2.1 Introduction

The Faro Mine Complex is within a discontinuous permafrost region of Central Yukon. Within discontinuous permafrost regions, groundwater flow occurs in un-frozen overburden sediments and active zones within bedrock. Shallow bedrock geology, topography and the thickness and distribution of surficial overburden sediments play a critical role in defining the shallow groundwater flow system. A summary is provided of bedrock geology, overburden geology and the Rose Creek aquifer, and permafrost conditions in the Faro Mine Complex Area. Baseline groundwater quality is summarized for the shallow overburden aquifers. Pre mine-closure hydraulic heads and groundwater flow have been measured and calculated and are presented herein.

The most relevant supporting documents relating to the hydrogeology of the site are:

- Anvil Range Mine Complex Annual Environmental Reports Water Licence QZ03-059 (GLL). Prepared for Deloitte and Touche (2004-2007).
- Anvil Range Mine Annual Groundwater Monitoring Reports (GLL). Prepared for Deloitte and Touche (2003 – 2007).
- Robertson GeoConsultants Inc., 2005. Water and Load Balance Study for Rose Creek Tailings
- SRK 2005/2006 Seepage Investigations:
    - SRK Consulting (Canada) Inc., 2006. 2005 Seepage Investigation at the S-cluster Area Below the Fan, Waste Rock Dump – 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.
    - SRK Consulting (Canada) Inc., 2006. 2005 Seepage Investigation at the Emergency Tailings Area, - 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.
    - SRK Consulting (Canada) Inc., 2006. Task 20e, 2005/06 Preliminary Seepage Collection Options, Faro and Grum Waste Rock Dumps – 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., November 2006.
    - SRK Consulting (Canada) Inc., 2007. Continued Seepage Investigation, Zone 2 Pit.
        - Outwash Area, - 2005/06 Task 20e, Report prepared for Deloitte & Touche Inc., January 2007.
    - SRK Consulting (Canada) Inc., 2007. Anvil Range Mining Complex, 2005 Seepage Investigation at the Grum Dump Area – 2005/06 Task 20e. Report prepared for Deloitte & Touche Inc., January 2007.
- Roberston GeoConsultants Inc Consulting Inc., 2007. Groundwater Review, Anvil Range Mining Complex, Yukon Territory – 2007. Draft Report 118012/1 Submitted to Deloitte and Touche Inc., December 2007.

6.2.1.1 Historical Hydrogeological Changes

Mining activities and on-going reclamation and care and maintenance activities have affected the local groundwater flow in several ways, including the following:

- interception of groundwater in open pits.
- increased permeability in the rock mass through blasting of open pit walls.
- interception of groundwater in diversion ditches.
- alterations to the Rose Valley aquifer from development and operation of the Rose Creek Tailings Impoundments.
- increased infiltration through unvegetated and poorly drained areas (e.g., free dumps) as well as leakage from diversions.

The Faro Main Pit was developed on the north side of the Rose Creek valley. Much of the area was covered by a thin layer of compacted till over bedrock. The pit was excavated to a depth of approximately 365 metres below the original ground surface at its deepest point and now intercepts

both shallow groundwater flow at the soil/bedrock interface and deeper groundwater flow in faults and fractures. Leakage from the Faro Creek Diversion Ditch into the pit via the northeast pit wall is known to contribute to groundwater inflows. Groundwater inflow rates are not specifically monitored and separated from surface inflows. However, mine dewatering pumping records indicate pumping rates between 40 and 55 L/s were required to keep the pit drained from 1986 to 1990 (RGC 1996).

The Faro Zone II Pit similarly intercepts both shallow and deeper groundwater flow, although at a smaller scale than the Faro Main Pit. The presence of substantial faulting in the southern area of the Main pit creates the possibility for subsurface flow of water from the Main Pit into the Zone II Pit. Annual monitoring of volumes dewatered for the Zone II Pit, as reported in annual environmental reports, indicates that seepage from the Main Pit did not increase substantially with an increase in the water level in the Main Pit. The groundwater inflows into the Zone II Pit were estimated at 13 L/s during mine operations (RGC 1996).

The Vangorda Pit is located on the south side of Vangorda Creek. The overburden encountered consisted primarily of compacted glacial till up to approximately 30 metres in thickness. Groundwater flow into the Vangorda Pit was estimated at 0.14 L/s during mine operations (RGC 1996). A net inflow of groundwater into the Vangorda Pit was also suggested by a geochemical study conducted in 2000 (SRK 2000b) that indicated an unidentified source of alkalinity that could be attributed to groundwater influx.

The Grum Pit is located on the north side of Vangorda Creek and was developed in a small depression in the hillside. A small lake (Doal Lake) was present prior to the development of the pit. The surficial deposits at the Grum Pit were thicker than at the other pits. A north-south trending bedrock valley was intersected in the southeast corner of the pit. It was filled with approximately 100 m of glacial till over a basal layer of sand and gravel. This aquifer was dewatered by pumping wells during mine operations prior to 1997 and has subsequently flowed directly into the Grum Pit since pumping operations ceased. The effect of the interception of this flow is also observed in changes observed in the degree of saturation of surface soils downgradient of the Grum Pit in the Grum Creek area. Prior to development of the Grum Pit, this area was observed to be largely saturated near surface with some test pits reported as filling with water during excavation whereas the area is currently observed to be drier near surface (Anvil Range, pers. comm.).

Other effects of open pits may relate to the increased permeability (compared to natural bedrock) of blasted rock walls due to fracturing which may enhance or modify active groundwater pathways.

Diversion ditches that are seated in bedrock, or that intersect other shallow groundwater zones, will alter the pre-existing flow regime. For example, the Rose Creek Diversion Canal is interpreted to largely intercept and re-direct shallow groundwater flow from the south side of the Rose Creek Valley that previously flowed into the valley aquifer (GLL 2002c).

Alternately, diversion ditches may result in groundwater recharge (through ditch leakage). For example, the Faro Creek diversion ditch is known to leak water into the shallow aquifer above the Faro Main Pit.

Prior to development of the tailings impoundments, the local Rose Creek Valley hosted an unconfined aquifer that produced an estimated 3,000 to 4,000 m^3 of groundwater per day (GLL 2002c). Development of the tailings impoundments introduced a confining surface layer (tailings), additional groundwater recharge (tailings slurry water) and surface ponds that have had a substantial effect on local groundwater flow. An interpretation and numerical model of the existing groundwater flow regime are described in GLL 2002c. This water balance and load study was revised and updated by Robertson Geoconsultants Inc in 2005 (RGC 2005).

Some rock dumps may promote increased infiltration (groundwater recharge) compared to the original ground conditions where free dump piles or other lose materials are present. Alternately, hard packed and compacted surfaces of rock dumps may restrict groundwater recharge and promote increased surface runoff compared to the original ground conditions.

6.2.1.2 Issue Focused Approach

An issues-based approach was used to establish baseline conditions and VEC selection for hydrogeology. Issues identified include impacts to groundwater quality and groundwater quantity as a result of the proposed Project. Issues were identified based on consultation with communities, regulators and project scientists. Groundwater contamination as a result of historical activities has occurred within the mine site and is an ongoing issue of concern.

6.2.2 Valued Ecosystem Components

VECs are groundwater quality and groundwater quantity. Groundwater quality was identified in consultation with communities / Elders, who expressed concern about groundwater contamination. The project scientists identified groundwater quantity is also an issue, as changes in groundwater levels and dewatering associated with mine closure activities are expected components of the Project. Potential issues will be confirmed as the project progresses through on-going consultation based on current options. Table 6.2-1 identifies VECs and the reason for VEC selection.

Table 6.2-1. Hydrogeology VECs

Issue	Reason for Selection of VEC	VEC
Changes in groundwater quality	Groundwater contamination identified by project scientists and in consultation with communities/ Elders	Groundwater quality
Changes in groundwater quantity	Project scientist identified quantity issues	Groundwater quantity

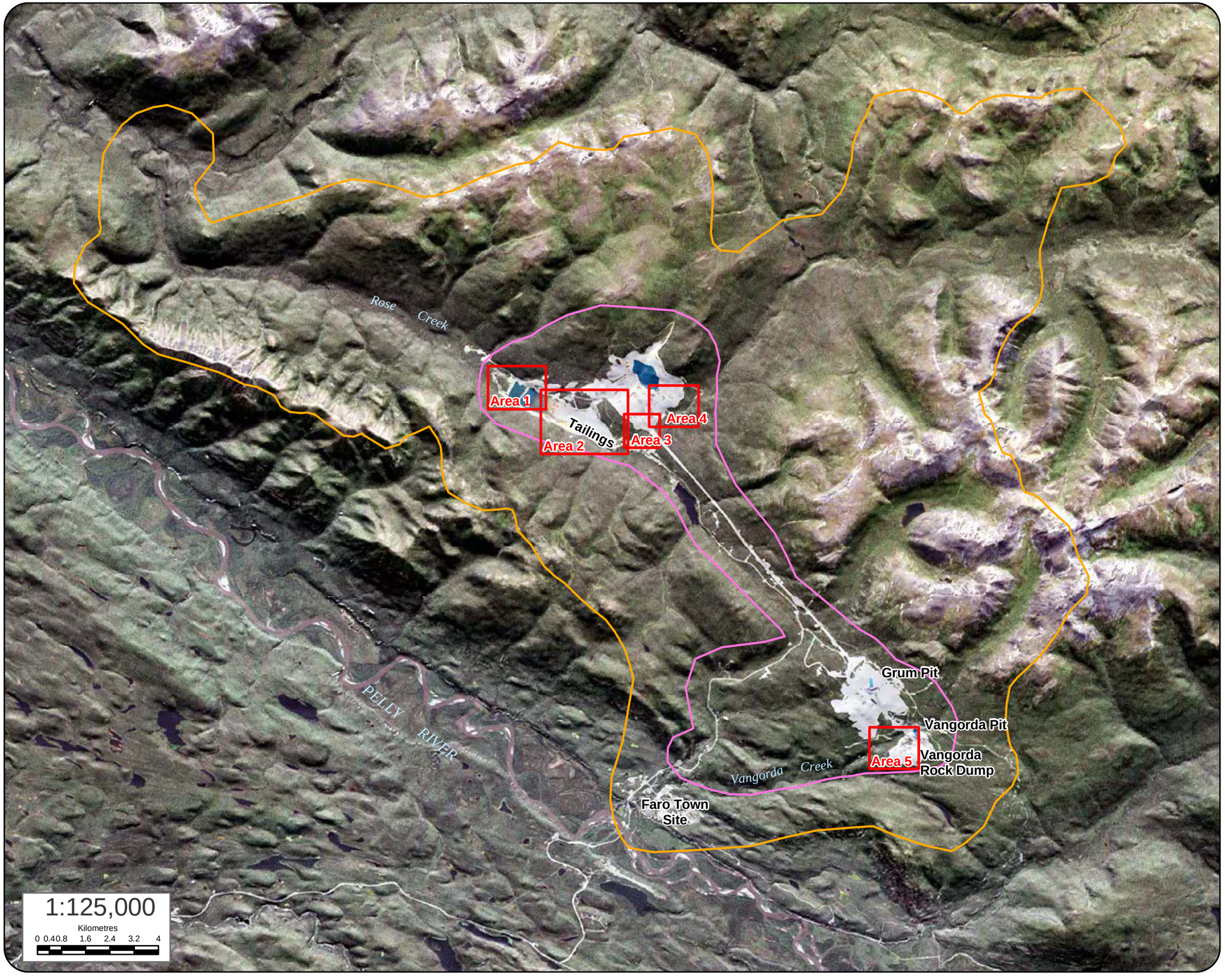
6.2.3 Study Area

The local study area (LSA) is based on the physical and hydrogeologic footprint of both mine sites, including the Haul Road as this is the area of immediate influence on the environment. The LSA

extends from the recharge zones upgradient of each mine site where little to no data on groundwater quality currently exists to the first groundwater monitoring point downgradient of each site where downstream / downgradient groundwater quality is monitored in wells specified in the existing water licence (Figure 6.2-1).

The LSA comprises the surficial overburden aquifers located mostly along valley bottoms and include on surface upper Vangorda Creek, Faro Creek and the North and South Forks of Rose Creek. The aerial extent of the groundwater LSA is similar to the hydrology LSA because of the nature of the interaction between both systems. The downgradient boundary is delimited by areas where groundwater is not suspected to be influenced by mining operations. In the case of the Faro Mine, the aquifer downgradient of the Cross-Valley dam near the confluence of the Rose Creek diversion channel and Rose Creek and the aquifer in the Vangorda Creek Valley downgradient of the Grum and Vangorda waste rock piles are the two main areas where groundwater exits the project area. In terms of surficial features, the LSA extends from Vangorda Creek upstream of the Vangorda mine site, to the main stem of Vangorda Creek downstream of the mine, just upstream of the confluence with the West Fork (Figure 6.2-1).

The depth of the LSA has been defined as roughly the thickness of overburden sediments and is limited to the uppermost few meters of underlying bedrock where there is known active groundwater flow. This is the limit of available groundwater quality information for the area based on the current monitoring network. The depth of the LSA can be refined should more information become available about the deeper bedrock aquifer system as the project gets more defined.



Legend

- Local Study Area
- Regional Study Area

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

Projection: UTM Zone 8 NAD27

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FARO MINE COMPLEX

Hydrogeology Study Area

Gartner Lee

Figure No.

6.2-1

A regional study area ("RSA") is defined to incorporate data outside of the project footprint that may be important to the determination of direct effects on an environmental component and to allow for examination of potential cumulative effects where project effects extend beyond the study area boundary. The boundaries of a RSA (Figure 6.2-1) for hydrogeology are established based on the "zone of influence" beyond which the effects of care and maintenance activity and historical mining activities have diminished to an acceptable or trivial state.

The regional study area for the Faro Mine site is defined by all upgradient recharge areas for aquifers within the project area, mainly the Rose Creek aquifer. This allows assessment of any effects of mining activity on these aquifers to be assessed for impacts to groundwater aquifers in the vicinity of Anvil Creek. It also allows consideration of any effects at this point in the watershed in a cumulative effects assessment for activities in the Anvil Creek watershed and, ultimately, in the Pelly River.

The Vangorda Mine site RSA is defined by all catchment areas upgradient of the confluence of Vangorda Creek with the Pelly River. This boundary allows the assessment of any mine effects on fish and fish habitat in lower Vangorda Creek and also for effects on the town of Faro water supply wells located at the confluence of Vangorda Creek and the Pelly River. Any detectable aquatic effects at this point would need to be included in a cumulative effects assessment for activities in the Pelly River.

6.2.4 Data Sources

Data sources for the LSA include field data, engineering and scientific reports, technical memos and scholarly literature sources. Specifically, the reports listed in Section 6.2.1 were primary sources of data for the baseline compilation of the site hydrogeology.

6.2.5 Baseline Description

The purpose of this section is to describe the existing hydrogeological regime at the Faro Mine Complex within the LSA in order to provide enough baseline information from which to determine whether there are hydrogeological impacts occurring in the Project area as a result of the undertaking. The existing baseline conditions prior to mine closure activities are defined as those that exist presently, recognizing that there has already been significant impacts to groundwater quality and quantity as a result of historical mine operations and on-going maintenance activities.

Statistical analyses were performed on groundwater quality data for the baseline temporal range (2005-2007) and the historical temporal range (2000-2007). Method detection limits (MDLs) were set to one-half the method detection limit for statistical calculations. All calculations and data can be found in Appendix B2.

6.2.5.1 Data Collection Methods

Valuable data has been collected at the site since the 1980s when the mine was operating. Some of this data along with more recent water quality data collected in recent years is valuable to establish baseline conditions. Most of this data has been documented in reports along with the methodology used for data collection. The relevant references are summarized below, along with some rationale for collecting different types of information.

- Ground temperature information can be used to determine the zones of permafrost and unfrozen ground in the LSA. No ground temperature information was found in the documents reviewed for the hydrogeology component of this project. However, should this information be found in other reports, this report should be updated to reflect the information. There is anecdotal evidence that discontinuous permafrost occurs within the tailings sediments. This was noted during several well drilling investigations (GLL 2003d).
- Hydraulic conductivity testing was completed during several monitoring well installation studies and also during recent characterization work and seepage interception studies. Hydraulic conductivity and physical properties of geological units are summarized in Table 6.2-2 and discussed in Section 6.2.5.2.
- Hydraulic head within the LSA has been monitored throughout the years in a network of groundwater wells. Water level data in the existing monitoring wells was summarized and interpreted by GLL (2002b) as part of a preliminary assessment and subsequently revised and updated by RGC (2004). Water level information is summarized in yearly groundwater monitoring reports and contained in the site water quality database currently managed by Gartner Lee. This data is presented in Appendix B3.
- Groundwater quality in the valley bottom aquifer beneath the Rose Creek Tailings Facility has been monitored in conventional monitoring wells and multi-level wells with sampling points extending throughout the entire aquifer and tailings profile.
- Groundwater quality throughout the site has been monitored using a network of monitoring wells. Some of these wells were designed and located for acquiring information about localized groundwater impacts, which are internal to the site and specific to certain areas. Consequently, these are not relevant for establishing baseline conditions and have not been included in this assessment. Furthermore, throughout the years, there have been operational issues identified with some of the wells which bring into question the validity of groundwater quality results. These have also not been included in this baseline compilation.

Confidence in the baseline data is high as it has undergone rigorous QA/QC. Furthermore, most of the sampling stations have an extended period of record with many sampling events. Data confidence, limitations and assumptions include the following:

- Confidence in the water quality down-gradient of the cross valley dam (Figure 6.2-2) is high because there is a long record of data for these monitoring locations and all data has undergone rigorous review and QA/QC. There are also several monitoring locations with sampling points extending the depth of the overburden aquifer.
- Confidence in horizontal hydraulic head estimates is moderate to high because of the accuracy and large datasets associated with water levels in groundwater wells.

Legend

Wells

- Conventional Wells
- Multilevel Wells

Contours

- Index Contours (10m)
- Intermediate

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

Projection: UTM Zone 8 NAD27
Created By: RH
Reviewed By: MG
Date Issued: March 2008
Project Number: 70549
File Name: Fig6.2-2_70549_rpt_Mar_2008.mxd
Revision: 0

FARO MINE COMPLEX

Area 1 - Tailings Down Valley Area
Faro Mine, Yukon

Gartner Lee

Figure No.

6.2-2

- Confidence in vertical hydraulic head estimates within the tailings and near the Cross valley dam is high because of the large dataset associated with multi-level water levels from different depths.
- Confidence in the shallow bedrock hydraulic conductivity in the vicinity of the intermediate and cross-valley dams is low. References to 1980 and 1981 investigations only were found in the reviewed documents (Independent Peer Review Panel, 2007).
- Confidence in bedrock hydrogeology of the Rose Creek Valley (Figure 6.2-3) beneath the tailings impoundment is low. As stated by the Independent review panel (2007), deep bedrock structural features have not been investigated and therefore migration of groundwater within deeper bedrock in the valley has not been determined.

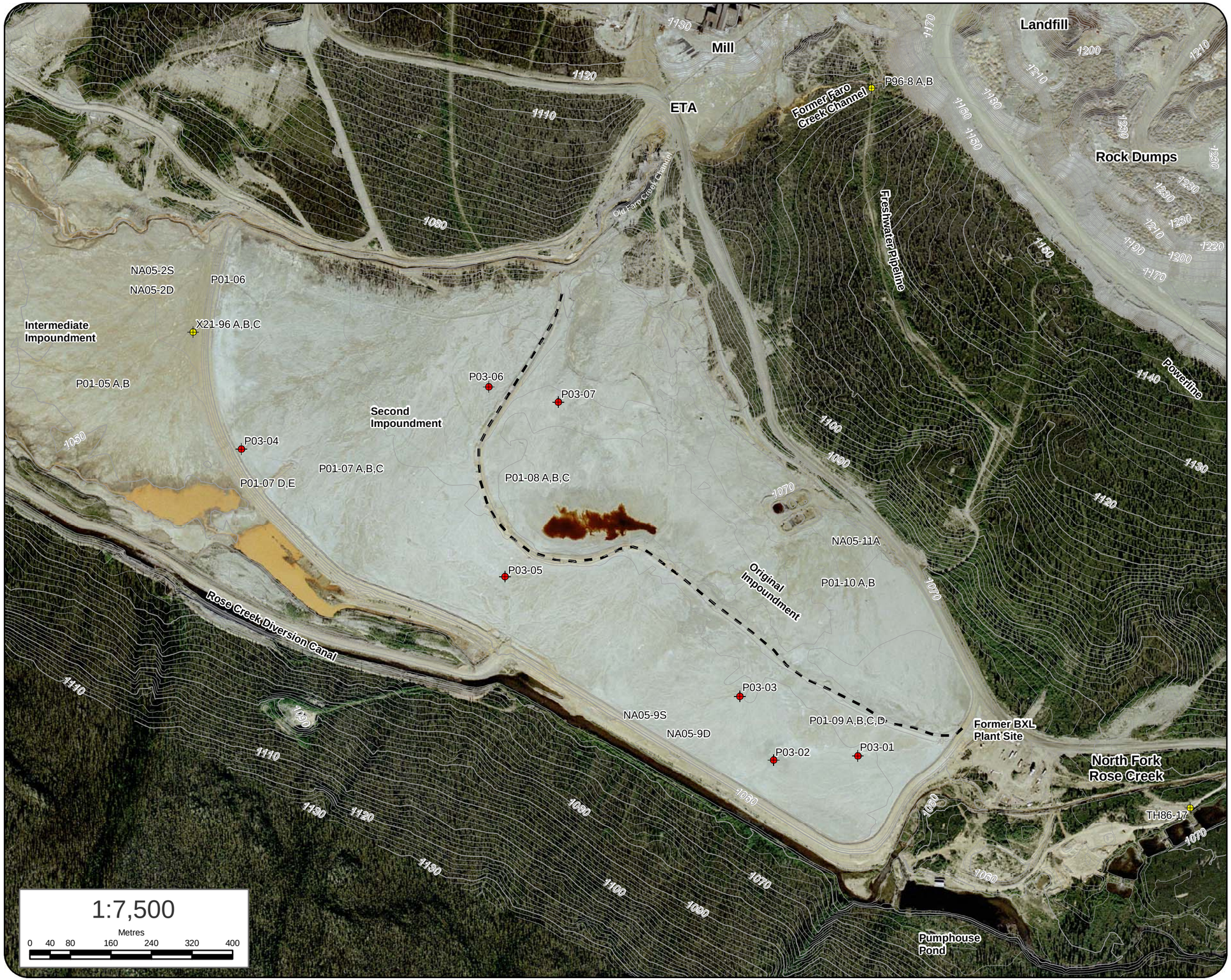
6.2.5.2 Aquifer Hydraulic Conductivity

Aquifer hydraulic conductivity in combination with hydraulic gradients (i.e., water levels) provides essential information for calculating rates of groundwater movement in the subsurface and consequently travel times and mass flux of contaminants to critical receptors. In 2005, hydraulic conductivity testing was completed by SRK at a few areas of the Faro Mine Complex including the S-Cluster wells (Figure 6.2-4), the Emergency Tailings Area (Figure 6.2-3), and the Grum Dump Area (Figure 6.2-5).

A summary of the available hydraulic conductivity results for the defined units found in each area are summarized in Table 6.2-2 below. These values are included herein to provide baseline information about the physical characteristics of overburden sediments throughout the site.

Table 6.2-2. Summary of Hydraulic Conductivity Values

Location	Hydraulic Conductivity (m/s)
S-Cluster Wells (SRK 2006a)	
Shallow Aquifer Unit	$3x10^{-5}$
Low Conductivity Unit	$2x10^{-7}$ to $3x10^{-7}$
Deep Aquifer Unit	$1x10^{-4}$ to $9x10^{-6}$
Bedrock	unknown; anticipated to be orders of magnitude lower than overlying aquifer units 1 and 3
Emergency Tailings Area (SRK 2006b)	
Tailings	unknown; lower than primary aquifer unit
Primary Aquifer	$2x10^{-4}$
Bedrock	$1.1x10^{-7}$ to $4.3x10^{-8}$
Grum Dump Area (SRK 2007b)	
Surficial Aquifer Till Deep Aquifer Unit Bedrock	unknown; insufficient hydrogeological information to provide adequate hydraulic conductivity estimates



Legend

Wells

- Conventional Wells
- Multilevel Wells

Contours

- Index Contours (10m)
- Intermediate
- Impoundment (original)

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

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Project Number: 70549	
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Revision: 0	

FARO MINE COMPLEX

Area 2 - Rose Creek Tailings Impoundment and ETA Area
Faro Mine, Yukon

Gartner Lee

Figure No.

6.2-3

Legend

Wells

- Drive Points
- Conventional Wells
- Multilevel Wells

Contours

- Index Contours (10m)
- Intermediate

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

Projection: UTM Zone 8 NAD27

Created By: RH

Reviewed By: MG

Date Issued: March 2008

Project Number: 70549

File Name: Fig6.2-4_70549_rpt_Mar_2008.mxd

Revision: 0

FARO MINE COMPLEX

Area 3 - Faro Rock Dumps
Faro Mine, Yukon

Gartner Lee

Figure No.

6.2-4

Legend

Wells

- Conventional Wells
- Multilevel Wells

Contours

- Index Contours (10m)
- Intermediate

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

Projection: UTM Zone 8 NAD27
Created By: RH
Reviewed By: MG
Date Issued: March 2008
Project Number: 70549
File Name: Fig6.2-5_70549_rpt_Mar_2008.mxd
Revision: 0

FARO MINE COMPLEX

Area 4 - Grum and Vangorda Area
Faro Mine, Yukon

Gartner Lee

Figure No.

6.2-5

S-Cluster Wells

Hydraulic testing was completed in all 2005 monitoring wells with the exception of SRK05-06, which was dry. The original S-cluster wells were also tested. Tests were completed as standard slug tests or as "mini-pumping" tests. Results varied from approximately 1 x 10-^{4} to 4 x 10^{-7} m/s.

Based on the geology and results of hydraulic testing, four hydrostratigraphic units are defined for the S-cluster area (Figure 6.2-4):

Shallow aquifer unit: Characterized by sand and gravel. Hydraulic conductivity is approximately 3 x 10^{-5} m/s. Higher water levels in this zone suggest that this shallow aquifer is perched.

Low conductivity unit: Predominantly fine-grained materials. It represents a confining layer for the shallow (perched) aquifer and the underlying, confined aquifer. The unit appears to be laterally continuous, though likely inter-fingers with coarser grain materials. Grain size analyses completed on samples from surface exposures of these materials, taken from a test pitting program in 2004, suggest maximum hydraulic conductivity values in the range of 2 x10^{-7} to 3x10^{-7} m/s.

Unit 3: The deep aquifer unit includes sand and gravel materials found at depth and/or overlying bedrock, as well as the weathered bedrock profile. Thickness varies across the site from <1 metre to approximately 10 metres. In some areas, such as SRK05-SP5 and –SP6, the deep aquifer unit may consist predominantly of weathered bedrock with only a minor component of unconsolidated material. Hydraulic conductivity ranges from 1 x 10^{-4} to 9 x 10^{-6} m/s.

Unit 4: The bedrock in the S-cluster area consists of schist of the Mt. Mye Formation. Bedrock is defined as a calcareous schist to calc-silicate. In the area of the S-cluster, bedrock has a phyllitic texture and has been called phyllite in the drill logs. No significant fractures or structures have been identified, but drilling generally did not continue far into bedrock and the drilling method precludes recovery of continuous core. Hydraulic testing was not carried out in this unit; however, the hydraulic conductivity of the bedrock is expected to be orders of magnitude lower than the overlying aquifer units 1 and 3.

Groundwater flow directions are suggested to be affected by shallow, hyporheic flow system near the North Fork Rose Creek (NFRC). Discharge measurements suggest that the NFRC loses water to the shallow groundwater system in reaches immediately upgradient of the S-cluster wells, and gains water from the shallow groundwater system along reaches at the S-cluster wells and downgradient.

Emergency Tailings Area (ETA)

The ETA area (Figure 6.2-3) is internal to the site and therefore may not be relevant for the baseline evaluation once the project gets more defined.

Hydraulic testing during the 2005 ETA field program consisted of packer injection tests completed in wells during drilling and, after completion of all monitoring wells, a 24-hour pumping test. Based on geologic data, hydraulic testing results and hydrology data, the ETA is interpreted to have three hydrostratigraphic units and a limited, but in certain areas direct, connection of groundwater with surface flow in the former Faro Creek channel. A summary of ETA hydrostratigraphy is as follows:

Unit 1 – Tailings: silt to gravel size tailings up to 6.5 meters thick, thinning up-valley and towards the valley sides, with coarser, gravel-size, waste rock interbeds. Tailings may represent a partially confining layer to the primary aquifer, which may desaturate during pumping. Coarse waste rock interbeds may represent preferential pathways within the tailings. Hydraulic conductivity unknown, but interpreted to be lower than primary aquifer unit.

Unit 2 – Primary Aquifer: sand to gravel size alluvium interpreted to be deposits of historic Faro Creek, with sandy or gravelly-silt till in up-valley sections of the ETA and along valley walls. Includes weathered bedrock where present. Alluvium thickness varies between 2-6 meters near the mine access road, but is uncertain up-valley. Average transmissivity = 67 m^2/day (conductivity = $2x10^{-4}$ m/s); average storativity = 0.014.

Unit 3 – Bedrock: phyllitic bedrock is relatively minor aquifer unit only. Intermittent discrete fracturing present but with no known preferred orientation. Average hydraulic conductivity = $4.3x10^{-8}$ m/s with higher zones (up to $1.1x10^{-7}$ m/s).

Review of available hydraulic gradient and stream flow data suggests that the Faro Creek channel gains significant flow from groundwater along its length. While the exact location of gaining or losing reaches is unknown, data suggests this occurs in the upper reaches, but below surface sampling point X23. Below the mine access road, Faro Creek does not appear to gain significantly from upwelling groundwater emanating from bedrock.

Grum Dump Area

Based on geology from available drillholes, four hydrostratigraphic units are defined for the Grum area (Figure 6.2-5):

Unit 1 – Surficial aquifer: gravelly fine to coarse sand with variable organics. Present at ground surface in vicinity of SRK05-5C and Grum Creek. Thickness varies from two to six meters.

Unit 2 – Till: clayey to sandy silt with trace gravel. Present in all drillholes, ranging in thickness from 2.5 to over 8 meters and in depth from just below ground surface to a maximum of approximately 15 meters. Acts as confining unit for deeper aquifer. This unit is likely the confining unit where the deep aquifer is present.

Unit 3 – Deep Aquifer: fine to coarse sand with gravel and underlying weathered bedrock. This deep aquifer was encountered at SRK04-5 and P96-9. Thickness in range of six to seven meters.

Unit 4 – Bedrock: chlorite schist to phyllite. Depths range from approximately 2 meters to approximately 20 meters below ground surface. Assumed to have a relatively low hydraulic conductivity.

Available information suggests that the majority of groundwater flow occurs within the area of the bedrock depression. The exact extents of this bedrock low to the east of SRK04-5 are unknown, but the presence of isolated bedrock outcrops indicates that bedrock likely becomes closer to ground surface.

6.2.6 Groundwater Quality

The groundwater quality baseline summary presently contains a summary of available information extracted mainly from the 2007 Groundwater Quality Review (Draft) prepared by Robertson GeoConsultants (RGC). These data and interpretation are currently being updated to capture sampling done up to and including November 2007. Although much of this information will remain the same, some of it will be re-worked into a more "baseline" focused discussion.

Supplemental information to be added to this section include summary tables of existing baseline groundwater quality for the different mine areas, based on statistics including in Appendix B2. In the long term, data form the on-going geochemistry work presently being carried out by RGC will also be incorporated.

6.2.6.1 Available Data

Groundwater quality for the 2000-2007 period includes data from regularly monitored locations on the Faro and Vangorda Plateau Mine sites. These include locations designed to monitor subsurface seepage from the Vangorda Rock Dump, the Grum Rock Dump, the Faro Rock Dumps along the North Fork of Rose Creek, the Old Faro Creek channel below the Faro Rock Dumps and the Rose Creek Tailings Facility. Most of these wells were installed for the purpose of investigating potential or existing impacts to groundwater at several key locations throughout the site, where mitigation measures likely will affect groundwater quality. Consequently, only a portion of the overall monitoring points are deemed to be located in areas relevant for establishing baseline groundwater quality conditions for the purposes of mine closure activities.

There have been a number of discrete well installation programs over the mine life and, therefore, the monitoring wells discussed here have varying periods of record. As mentioned previously, the period of record ranging between 2000 and present (2007) was selected for statistical analysis as this period of record is deemed to represent the most reliable and consistent dataset. In some cases, more recent data will be used for establishing present day current conditions to carry forward into the environmental assessment, recognizing that groundwater quality is changing and evolving as a result of on-going processes within impacted areas.

The major monitoring well installation programs are summarized below:

1996 Groundwater Monitoring Well Installation – RGC

A series of groundwater monitoring wells were installed in 1996 by RGC, primarily intended to replace some of the 1981 wells that had become inoperable or destroyed but that were referenced in the Water Licence. These wells include X21-96 A/B/C, X24-96 A/B/C/D and X25-96 A/B. Stations X24 and X25 are located at the toe of the Intermediate Dam and station X21 is located near the north toe of the Second Impoundment Dam.

2001 Groundwater Monitoring Well Installation – Gartner Lee Limited

In 2001, a comprehensive hydrogeological and geochemical investigation of the Rose Creek Tailings Facility was conducted by Gartner Lee Limited. The purpose of the study was to update the characterization of the hydrogeological system and geochemical state of the tailings. As part of the investigation, twenty two groundwater monitoring wells at eleven locations (P01-01 through P01-11) were installed within each of the impoundments, at the toe of the Intermediated Dam and downgradient of the Cross Valley Dam. These wells were installed to enhance the monitoring of groundwater quality beyond that being undertaken through an existing network of wells. Issues suspected with the integrity of some of these wells led to the decommissioning of several of these wells in 2005 (RGC, 2005).

2003 Rose Creek Tailings Impoundment Area Multilevel Well Installation – Gartner Lee Limited

In 2003, Gartner Lee Limited installed a series of groundwater monitoring wells as part of a follow up to the 2001 hydrogeological investigation. Sonic drilling technology was used to obtain detailed stratigraphic information through the complete soil horizon through the tailings and down to the bedrock interface at many locations. As part of this program, 76 additional groundwater monitoring points were installed at nine locations (P03-01 through P03-09) within each of the impoundments and downgradient of the Cross Valley Dam. The monitoring points are completed both within the tailings and in the underlying native soils.

2004 and 2005 Monitoring Well Installation – SRK Consulting

SRK was retained by Deloitte and Touche to carry out additional field investigations to better characterize local groundwater conditions and to assess options to intercept any ARD impacted seepage for collection and treatment. The groundwater investigation and seepage collection assessment was targeted for 3 specific areas: (i) Emergency Tailings Area (old Faro Creek valley), (ii) North Fork Rose Creek, and (iii) the Grum Creek areas. These areas were identified during initial review and planning stages as the areas with highest priority for seepage interception; lower priority areas were not completed as part of the program.

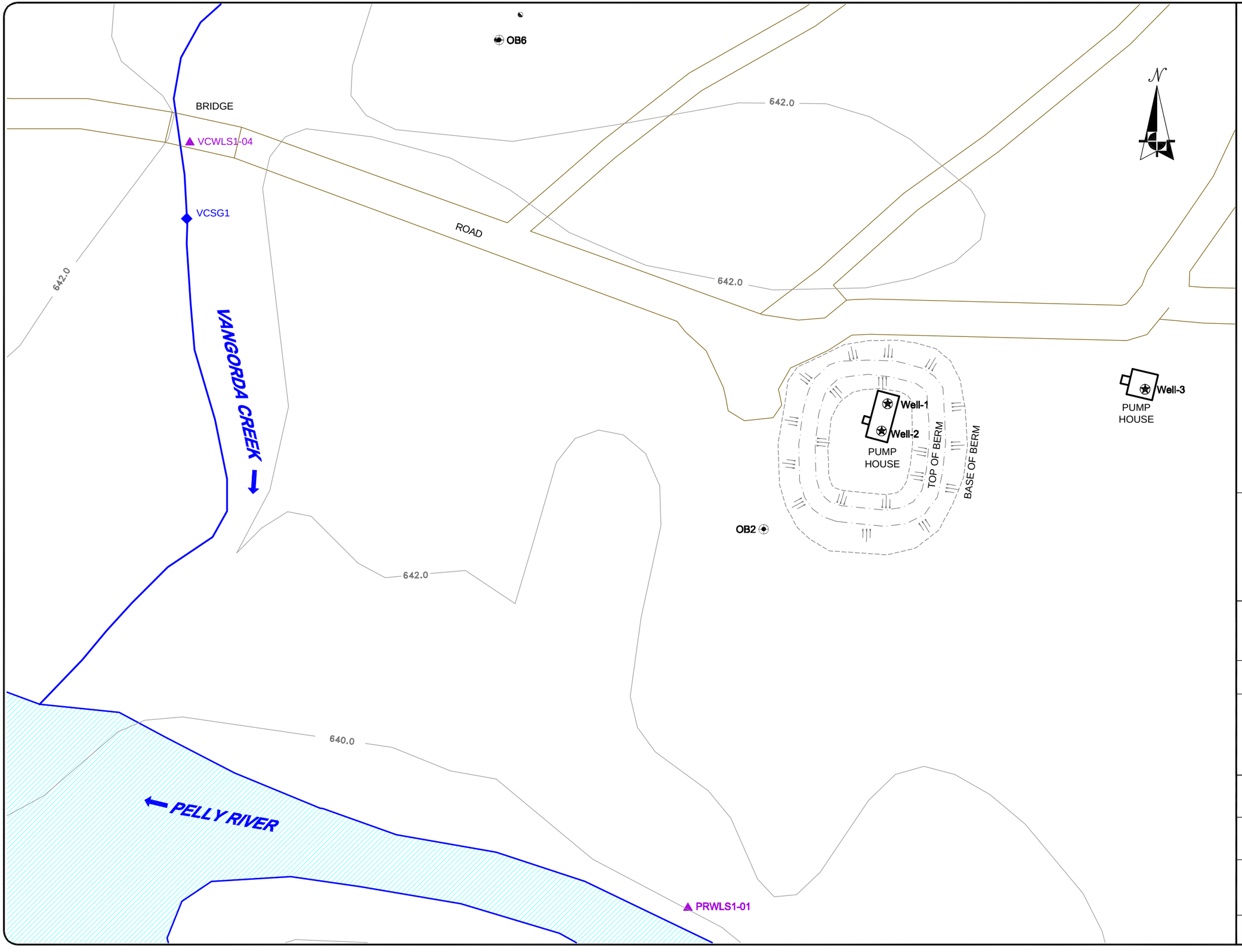
2005 Pumping/Monitoring Well Installation and Pumping Test Analysis – RGC

RGC installed one 6-inch diameter pumping well (PW3) and two conventional monitoring wells (BH05-01 and P05-04) within the Zone 2 outwash area to use for hydraulic testing of shallow overburden sediments. Two additional 6-inch pumping wells (PW1 and PW2) and two conventional

monitoring wells (MW1 and MW2) were installed at the base of the Cross Valley Pond and used to assess seepage interception capacity and efficiency.

2007 Town of Faro Water Wells Investigation - GLL

A focussed sampling and analysis program was conducted for Vangorda Creek to evaluate the interaction between the Town of Faro water supply wells and the adjacent surface water in Vangorda Creek (GLL, 2007b). Although this was not a well installation program, the study utilized several observation wells and the pumping wells located at the mouth of Vangorda Creek where it meets the Pelly River (Figure 6.2-6).



Legend:

- Building
- Stream, River
- Road
- VCSG1 — Location of Stream Gauge
- PRWLS1-04 — Water Level Sensor
- OB6 — Observation Well 2" or 6" diameter
- Well-2 — Town of Faro Water Supply Well
- Abandoned Well

Data Sources:

1. Digital copy of 1:50,000 topographic map and orthophoto supplied by SRK Consulting.
2. Survey conducted in summer 2004 by Yukon Engineering Services

0 5 10 20 Metres

SCALE 1:500

Projection : UTM NAD 27 Zone 8
Contour Interval : 2 m (ASL)

Reviewed By : DMcC/JK
Prepared By : PW
Date Issued : February 3, 2006
Project No. : 50-564
File Name : 50564_B2_06bFeb03_Fig2.DWG
Revision : 0

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN

Gartner Lee

Figure 6.2-6

6.2.6.2 Overview and Approach

Some of the groundwater monitoring wells associated with recent studies provide information useful for detailed monitoring for the pathways of contaminants released from the tailings but do not provide information that is useful for environmental assessment (i.e., they are internal to the facility). Therefore, a smaller number of sites were selected to describe the existing (baseline) environmental conditions for the Faro Mine Complex. The most important groundwater quality requirement is to document the existing (defined as 2005 to 2007) groundwater quality. Groundwater quality data and groundwater statistics from 2000 to 2007 for the Faro and Vangorda Mine sites are provided in Appendix B2.

A summary of groundwater quality for the Faro Mine Complex for data up to and including May 2007 was completed by RGC (2007). Time series concentration plots were updated for this assessment to include data up to November 2007. Plotted data can be found in Appendix B1. RGC (2007) provided a summary and interpretation of all available groundwater quality data, including data from highly impacted areas (e.g., tailings porewater, shallow groundwater underlying the tailings, base of rock dumps with seepage impact, Zone II area historically impacted, etc.). It is important to note that groundwater movement is extremely slow relative to surface water (i.e., on the order of a few cm per year to a few meters per year). Consequently, groundwater impacts observed presently at the site are indicators of potential impacts many years in the future at receptors downgradient as impacted groundwater plumes move along flowpaths within the aquifers. The RGC (2007) report was aimed at evaluating both current conditions and historical time trends at all monitoring locations. This baseline compilation focuses on many of the same impacted areas, however, it attempts to focus more on groundwater wells thought to best represent local groundwater conditions as established by RGC (2007). Groundwater quality within these areas provides useful information regarding the potential for future impacts on groundwater quality receptors downgradient or surface water receptors in the vicinity.

The major areas of concern targeted as part of this baseline study and the supporting rationale are included in Table 6.2-3.

The following summaries of groundwater quality (6.2.6.3 to Section 6.2.6.6) at these different areas are adapted from and are in some cases, excerpts from RGC 2007 identified using *italics*. The following assessments of baseline conditions currently include detail or data that may be refined once project alternatives are identified. The scope of the data assessment is large and therefore a large amount of data has been included herein and is considered relevant at this point in time to properly characterize existing baseline conditions. This data will likely have to become more focused as the project evolves.

Table 6.2-3. Summary of Relevant Areas for Baseline Groundwater Quality Data

Area	Rationale
Downgradient / Downstream of the Cross Valley Dam (External)	The Rose Creek Valley sides act as boundaries for groundwater flow which generally flows along the length of the Valley. Groundwater at this location is downgradient of all currently proposed closure activities and represents baseline conditions for groundwater from the Faro Mine area leaving the local study area.
Faro Town Site Water Wells (External)	This location is at the confluence of Vangorda Creek and the Pelly River. Vangorda Creek is recharged by and/or recharges groundwater along it's reach. Contaminated surface water and/or groundwater from the Grum and Vangorda sites are drained to this area.
Rose Creek Tailings Impoundment (Internal)	Wells in this area have monitoring points in the aquifer underlying the tailings.
Faro Rock Dumps – North (Internal)	Shallow groundwater at this location may impact North Fork or Rose Creek.
Zone II Outwash Area (Internal)	Shallow groundwater at this location may impact North Fork or Rose Creek.
S-Cluster Area (Internal)	Shallow groundwater at this location may impact North Fork or Rose Creek.
Grum and Vangorda Rock Dump Area (External)	Wells located at the toe of the rock dumps represent current baseline conditions downgradient of the source zones (i.e., the rock dumps). Groundwater in the area could impact Vangorda Creek.

6.2.6.3 Faro Mine Site

The Faro Mine site area comprises the Faro Pit, the surrounding Faro waste rock dumps, the mill area and the Emergency Tailings Area (ETA). Groundwater monitoring is generally concentrated in areas where impacts from mining activities have been observed historically. These include the Emergency Tailings Area (ETA) (Figure 6.2-3); S-cluster area (Figure 6.2-4); and Zone 2 Outwash area (Figure 6.2-7).

There are currently mitigation measures being implemented at the ETA area. Extensive groundwater monitoring has been performed in the last few years to delineate local groundwater contamination from rock dump seepage and this area presently has mitigation measures implemented. A discussion of current groundwater conditions is included in RGC (2007) and is not discussed herein.

In addition, several monitoring wells are located along the downgradient toe of the waste rock dumps, between the rock piles and the North Fork of Rose Creek (NFRC) and the main Rose Creek valley (Figure 6.2-4 and Figure 6.2-7). In general, groundwater quality in these geographic areas can be summarized as follows:

S-Cluster Area

This area is located at the downgradient toe of the Faro waste rock dumps, south of the haul road and immediately adjacent to the North Fork of Rose Creek. Wells in this area were installed to monitor seepage impacts to groundwater from the upgradient rock dumps and to evaluate the potential for impact to nearby Rose Creek. Table 6.2-4 lists information relevant for groundwater quality interpretation (i.e., mainly depth of screen and lithology) for all groundwater monitoring wells located in the area. Groundwater monitoring in this area started in 1989 with the installation of three nested standpipe piezometers ("S" wells), followed by (P96-7) installed in 1996 (RGC 1996) and 6 nested piezometers ("SRK05-SP" series) and several drive points ("DPs") installed in 2005.

Table 6.2-4. Monitoring Wells in the S-Cluster Area

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
S-cluster Area							
S1A	6912942	584539	1.34	9.2	12.2	1989	BR (phyllite)
S1B	6912942	584539	1.16	1.3	4.3	1989	Till
S2A	6912944	584577	1.44	9.2	12.2	1989	BR (phyllite)
S2B	6912944	584577	1.77	3.7	6.7	1989	Till
S3	6912918	584585	1.12	2.6	5.6	1989	Till
P96-7	6913105	584225	0.68	6.26	9.24	1996	Overburden / BR
SRK05-SP-1A	6912901	584727	0.54	13.7	19.2	2005	Overburden / BR
SRK05-SP-1B	6912901	584726	0.66	9.0	12.3	2005	Overburden
SRK05-SP-2	6912861	584791	0.44	7.9	11.0	2005	Alluvium / BR
SRK05-SP-3A	6912924	584651	0.85	17.4	21.9	2005	Overburden
SRK05-SP-3B	6912924	584652	0.66	8.3	11.4	2005	Overburden
SRK05-SP-4A	6912939	584612	0.69	16.5	21.0	2005	Overburden / BR
SRK05-SP-4B	6912939	584611	0.76	0.6	3.5	2005	Overburden
SRK05-SP-5	6912956	584576	0.91	9.4	12.5	2005	Overburden / BR
SRK05-SP-6	6912975	584492	-	3.1	11.0	2005	BR / Schist
DP1	6912887	584630	-	1.14	1.14	2005	NFRC Sediments
DP2	6912904	584554	-	0.53	0.53	2005	NFRC Sediments
DP3	6912901	584514	-	0.75	0.75	2005	NFRC Sediments
DP4	6912911	584535	-	0.94	0.94	2005	NFRC Sediments

A review of groundwater quality time trends in the S-cluster area was completed in 2004 (RGC 2004). These findings were updated with initial water quality results (September 2005) from the newly installed monitoring wells in the area in 2006 (SRK 2006a). Groundwater quality in this area shows significant spatial variation, both in space and with depth, indicating very heterogeneous

subsurface conditions. Furthermore, groundwater quality in this area has deteriorated dramatically over the last five years.

In general, the groundwater quality in the S-cluster area can be grouped into three broad categories (RGC, 2007): Highly impacted groundwater (S1A, S1B, S2A, S3, SRK05-SP4B and -SP5); Moderately impacted groundwater (SRK05-SP1A, -SP3A, SP3B and -SP4A); Slightly impacted groundwater (S1B, SRK05-SP1B and SRK05-SP2).

> *The highly impacted groundwater has a slightly acidic pH (field pH 5.5 to 6.5), moderate alkalinity (~200 mg/L) and elevated SO_4 (~5,000 mg/L) and magnesium (~800 mg/L). The key metals of concern are also significantly elevated, with Zn currently around 200-300 mg/L and Mn ranging from 75-100 mg/L. Fe concentrations in this highly impacted groundwater were generally low (<1 mg/L) except in monitoring well S2B (~100 mg/L). (RGC, 2007).*

Concentrations of contaminants, particularly dissolved zinc, in the groundwater in this area have been increasing in recent years, as much as 100 mg/L between September 2005 and June 2007. Based on a comparison of contaminant "breakthrough" in the S-cluster well area and that observed at the toe of the Faro Main Dump, dissolve zinc concentrations in impacted groundwater in the S-cluster area can be expected to reach maximum concentrations as high as 1,000 mg/L (or more) within a few years (RGC, 2007).

The moderately impacted groundwater also has a slightly acidic pH (field pH 5.5 to 6.5) and moderate alkalinity (~200-300 mg/L), but much lower sulphate (~300-500 mg/L) and magnesium (~50-60 mg/L) concentrations than the highly impacted groundwater. The key metals of concern are also significantly lower, with zinc and manganese concentrations around 1-2 mg/L. Iron concentrations are typically higher (10-50 mg/L) than most of the highly impacted groundwater.

Moderately impacted groundwater is observed mostly in deeper monitoring wells (SRK05-SP1A, SP3A and -SP4A) suggesting that this groundwater is a mixture of (highly impacted) seepage from the Intermediate Dump and less impacted groundwater moving in the Rose Creek valley sediments.

The "slightly impacted" groundwater in the area can be characterized by very low metal concentrations, including zinc and iron concentrations of <0.5 mg/L. Groundwater quality in monitoring well SRK-05-SP2 is generally very dilute (with sulphate and magnesium around 40 and 15 mg/L, respectively), suggesting very little, if any, impact from mine waste seepage.

Monitoring wells S1B and SRK05-SP1B show moderately elevated sulfate and magnesium concentrations, similar to those observed in the "moderately impacted" wells in the S-cluster area. The lower metal concentrations in those wells may still increase in time (RGC, 2007).

Monitoring well P96-7 is located at the toe of the main Faro waste rock dump and further to the northwest of the S-cluster area. Groundwater in this well shows high sulphate and magnesium concentrations (~1,500-2,000 mg/L sulfate and 100-130 mg/L magnesium, respectively) but very low zinc and other metal concentrations. It is anticipated that this well location will exhibit a contaminant "breakthrough" as is currently being observed at the S-cluster area. Increasing sulphate and magnesium concentrations during many years of monitoring suggest that dissolved metals concentrations in groundwater have not reached steady-state conditions.

Zone 2 Outwash Area

Figure 6.2-7 shows the layout of the Faro waste rock dumps draining towards the North Fork of Rose Creek (upgradient of the rock drain) and the most relevant monitoring wells in the area. The majority of groundwater monitoring wells is located in the Zone 2 outwash area. Additional monitoring wells are located along the toe of the Northeast Dumps and the Intermediate Dump. Table 6.2-5 lists information of groundwater monitoring wells relevant to baseline assessment, which are located in the Zone 2 Outwash area. Wells BH1 to BH4 were installed in 1991 in the outwash area. In 1994, additional nested piezometers were installed ("BH5" to "BH10") closer to the Zone 2 pit (SRK 1994). An additional monitoring well (P05-04) and two drive points (DP5 and DP6) were installed in 2005, as part of the recent seepage investigation in this area (SRK 2007b).

Table 6.2-5. Monitoring Wells in the Zone II Outwash Area

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Zone 2 Outwash Area						
BH1	6913532	585267	0.07	-	-	N/A
BH2	6913523	585206	0.63	-	-	N/A
BH4	6913467	585247	0.7	-	-	N/A
BH5	6913377	585194	0.49	6.01	7.62	Alluvium
BH6	6913466	585198	0.75	4.72	6.25	Alluvium
BH8	6913599	585253	*0.79*	19.05	20.57	BR (phyllite?)
BH9	6913638	585211	*0.13*	53.34	54.86	BR (biotite/schist)
BH10A	6913533	585190	angled	35.05	36.58	BR (biotite/schist)
BH10B	6913533	585190	angled	53.34	54.84	BR (phyllite/schist)
P05-04	6913475	585224	0.66	2.19	6.34	Alluvium
DP5	6913450	585260	1.55	-	-	NFRC Sediments
DP6	6913355	585214	1.49	-	-	NFRC Sediments

Legend

Wells

- Conventional Wells
- Drive Points
- Multilevel Wells

Contours

- Index Contours (10m)
- Intermediate

DATA SOURCES AND DISCLAIMERS:

Basemap: Orthoshop, Calgary, AB, November 2003. Prepared for SRK Consulting. Based on August 2003 aerial photography.

Projection: UTM Zone 8 NAD27
Created By: RH
Reviewed By: MG
Date Issued: March 2008
Project Number: 70549
File Name: Fig6.2-7_70549_rpt_Mar_2008.mxd
Revision: 0

FARO MINE COMPLEX

Area 5 - Faro Rock Dumps, Zone II Pit Area
Faro Mine, Yukon

Gartner Lee

Figure No.

6.2-7

A review of groundwater quality time trends in the Zone 2 outwash area was completed in 2004 (RGC 2004) and updated with initial water quality results (September 2005) from a pumping test in the area (SRK 2007a).

The Zone 2 outwash area is located immediately downgradient of the Zone 2 pit which is backfilled with waste rock. RGC (2007) provides a discussion about current and historical groundwater quality in this area. The following summary has been adapted from this report.

Groundwater in the sediments of the Zone 2 outwash area currently has a slightly acidic pH (~6.0), with moderate alkalinity (100-160 mg/L) and slightly elevated sulphate and magnesium (50-100 mg/L sulphate and ~20 mg/L magnesium, respectively). Metal concentrations are also very low, with iron and manganese concentrations typically less than 1 mg/L and 0.1 mg/L, respectively. Zinc concentrations are elevated, typically ranging from 1-10 mg/L. The shallow wells (BH1, 2 and 4), at least those partially screened in the outwash sediments, show very similar general water quality to that observed in the deeper wells screened in the alluvial sediments (BH5, BH6, P05-04).

In recent years, the highest zinc concentrations have been recorded consistently in BH2 located closer to the toe of the waste rock dumps and is screened in the top 5m of the sediments. Zinc concentrations in this shallow well have shown significant variations, ranging from 10-45 mg/L over the last five years. Elevated zinc concentrations in this well could be a result of less dilution compared to other wells located further downgradient of the source zones (Zone 2 pit and associated waste rock dumps). Note, however, that this well goes routinely dry during purging and may not representative of groundwater moving in the more permeable alluvial sediments of the NFRC valley. Oxidation and/or leaching of zinc from the overlying mineralized outwash sediments in this area may be a secondary source of zinc contamination.

Northeast and Intermediate Dumps Towards NFRC

Figure 6.2-7 shows the monitoring wells located along the toe of the Northeast Dumps and the Intermediate Dump, upgradient of the North Fork of Rose Creek. Table 6.2-6 lists information of all groundwater monitoring wells in the area. Wells in the area were installed in 1994 (SRK 1994) and 1996 (RGC 1996).

Table 6.2-6. Monitoring Wells at the toe of Northeast Dumps and Intermediate Dump (NFRC)

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Date Installed	Formation
Toe of Northeast Dumps(NFRC)							
BH12A	6914068	585871	2.38	1.53	3.05	1994	BR (weathered)
BH12B	6914068	585871	2.43	6.1	8.23	1994	BR (phyllite/schist)
BH13A	6914339	585844	0.75	2.29	3.81	1994	Aquifer
BH13B	6914339	585844	0.54	6.71	8.23	1994	BR (phyllite/schist)
BH14A	6913826	585676	0.12	4.72	6.25	1994	BR (weathered)
BH14B	6913826	585676	0.78	7.77	9.3	1994	BR (quartz/diorite)
Toe of Intermediate Dump (NFRC)							
P96-6	6913133	584999	0.7	18.07	20.12	1996	Alluvium

A brief review of historical groundwater quality time trends in these areas was completed in 2004 (RGC 2004). An updated review of groundwater quality in the general area of the NFRC was provided in the Zone 2 seepage assessment report (SRK 2007a). The following summary of water quality is adapted from (RGC 2007).

BH14A/B has shown the greatest impact of waste rock dump seepage in this area. Groundwater is well buffered with circum-neutral (field pH ~7.0) and high alkalinity (~400 mg/L). Sulphate and magnesium concentrations have increased significantly since start of monitoring in 1994, and currently are at 1,750 mg/L sulphate and 200 mg/L magnesium. Zinc concentrations have also increased to approximately 0.4 to 0.5 mg/L in recent years. Iron and manganese concentrations have generally remained very low (<0.1 and <0.5 mg/L, respectively). The recent increase in zinc at BH14A/B, while still at relatively low concentrations, is of concern. The observed increases in zinc concentrations were preceded by a systematic and substantial increase in sulphate, magnesium and alkalinity.

BH12A/B, located to the north of BH14A/B, shows moderate impact of waste rock dump seepage. Groundwater in these wells generally shows lower concentrations of all major constituents, including alkalinity (~200 mg/L), sulphate (500-1,000 mg/L) and magnesium (~50-150 mg/L) than observed in BH14A/B. Zinc concentrations have routinely been above the detection limit. Iron and manganese concentrations have generally remained at or below the detection limit. Groundwater quality in well BH12B, shows no consistent increase over time. Sulphate and magnesium concentrations have decreased over the last three years.

BH13A/B has shown the least impact of waste rock dump seepage in this area to date. Groundwater in both wells is slightly alkaline (field pH ~7.0-8.0) and all major ions, including alkalinity (~100-200 mg/L), sulphate (250-500 mg/L) and magnesium (~50 mg/L), are significantly lower than observed in BH14A/B. Zinc concentrations are also low (<0.1 mg/L). Iron and manganese concentrations have generally remained at or below the detection limit.

Groundwater quality at P96-6 is characteristic of "moderately impacted" groundwater, as described for some wells in the S-cluster area (e.g., SRK05-SP1A, -SP3A, SP3B and -SP4A). The groundwater is slightly acidic (field pH ~5.5 to 6.5) but has significant alkalinity (300-350 mg/L). Sulphate and magnesium concentrations are moderately elevated (~300 mg/L SO4 and ~50 mg/L Mg) and have not increased since start of monitoring. Zinc concentrations have fluctuated between 0.5 and 1.5 mg/L. Iron concentrations have varied from non-detect to as high as 10 mg/L. Manganese has been <0.2 mg/L in the last five years.

> *The similarity in groundwater quality in P96-6 and several of the monitoring wells in the S–cluster area is not surprising considering both areas are drained by the Intermediate Dump. As observed in most of the "moderately impacted" wells in the S-cluster area, P96-6 is screened at greater depth in very permeable alluvial sediments. [The] 1996 installation report specifically mentioned the presence of alluvial sediments (sand and gravel) at greater depth with an estimated hydraulic conductivity of ~1x10-2 m/s (RGC 1996). Hence, the groundwater in P96-6 is likely a mixture of (highly impacted) seepage from the Intermediate Dump (and associated sulphide cells) and relatively unimpacted groundwater moving in the sediments of the North Fork of Rose Creek.*

The sediments encountered at depth in P96-6 are similar to those observed in the Zone 2 outwash area. It is possible that they form part of a contiguous "alluvial aquifer" along the NFRC and it is possible that impacted groundwater from the Zone 2 outwash area is influencing water quality at P96-6.

6.2.6.4 Rose Creek Valley (Tailings Facility)

Figure 6.2-2 and Figure 6.2-3 show the Rose Creek tailings facility and the location of groundwater monitoring wells most relevant to this baseline assessment. The Rose Creek tailings facility is located within the Rose Creek Valley. Tailings deposition in this area has caused significant changes in water levels within the underlying aquifer by changing recharge conditions and providing a confining layer over the aquifer. The tailings represent a major source of contamination to the underlying aquifer and therefore, many monitoring locations within that aquifer represent important data points for establishing and monitoring baseline conditions.

The groundwater monitoring network in and around the Rose Creek tailings facility is extensive and covers all impoundments including the Original Impoundment, Second Impoundment, Intermediate

Impoundment (with Intermediate Dam) and also includes wells downgradient of the polishing pond (with Cross Valley Dam). The main well installation programs are:

- "X" series of wells installed in 1981 (Klohn Crippen, 1981);
- "X" series of wells installed in 1996 (RGC 1996);
- "P01" series of wells installed in 2001 (GLL 2001);
- "P03" series of wells installed in 2003 (GLL 2003d); and
- "P05" series of wells installed in 2005 (RGC 2006).

Groundwater quality time trends for the Rose Creek Tailings Facility area was completed in 2004 (RGC 2006a) and updated with results of initial sampling of new wells at the toe of Cross Valley Dam (September 2005) (RGC 2006c). A most recent review of groundwater quality was completed in 2007 (RGC, 2007). The following discussion about water quality is adapted from RGC (2007). Groundwater quality is discussed according to the following geographic areas:

- Upstream of Rose Creek Tailings Facility;
- Original Impoundment;
- Second Impoundment;
- Intermediate Impoundment;
- Toe of Intermediate Dam;
- Toe of Cross Valley Dam; and
- Downstream of Cross Valley Dam.

Upstream of Rose Creek Tailings Facility

Groundwater well TH86-17 is the only well immediately upgradient of the Rose Creek tailings facility which has been routinely monitored since 2002. The well is located about 450m upgradient of the Original Impoundment and is a test well originally drilled for a water supply project (International Water Supply, 1987). It is suspected to be screened within 15m of ground surface and therefore is representative of updgradient baseline conditions for relatively shallow groundwater. The well is located close to Rose Creek and may be influenced by groundwater recharge from the Creek.

Groundwater quality at TH86-17 has calcium (~25 mg/L) and bicarbonate (70-80 mg/L $CaCO_3$eq) the dominant major ions. Concentrations of all contaminants of concern are very low (~15 mg/L sulphate, ~6 mg/L magnesium, ~0.01 mg/L zinc, <1.0 mg/L iron and <0.02 mg/L manganese).

Original Impoundment

Table 6.2-7 lists pertinent information for groundwater monitoring wells located in the Original Impoundment and relevant to baseline assessment.

Table 6.2-7. Monitoring Wells upgradient and in the Original Impoundment

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Original Impoundment						
TH86-17	6912478	583957	1.04	-	-	N/A
P03-07-01	6913279	582710	*0.776*	38.10	38.40	Alluvium
P03-07-02	6913279	582710	*0.776*	33.53	33.83	Alluvium
P03-07-03	6913279	582710	*0.776*	28.65	28.96	Alluvium
P03-07-04	6913279	582710	*0.776*	21.34	21.64	Alluvium
P03-07-05	6913279	582710	*0.776*	19.81	20.12	Alluvium
P03-07-06	6913279	582710	*0.776*	17.98	18.29	Tailings
P03-07-07	6913279	582710	*0.776*	16.46	16.76	Tailings
P03-07-08	6913279	582710	*0.776*	13.41	13.72	Tailings
NA05-11A	6912978	583299	*0.82*	12.8	14.3	Alluvium

Groundwater monitoring in the foot print area of the Original Impoundment commenced in 2001 with the installation of two nested piezometers (P01-08A/B and P01-10A/B). However, these wells were decommissioned (sealed with bentonite) in October 2005 due to concerns about the integrity of these wells (RGC 2006b). Consequently, water quality data from wells P01-08 and P01-10 has not been used for this baseline assessment. Groundwater quality is presently monitored in some points in multi-level well P03-07 within the foot print of the original Impoundment. The following observations are summarized from RGC (2007).

> *P03-07 is affected by permafrost (at depth of ~12m bgs) causing problems with sampling of all monitoring points except P03-07-05 (Gartner Lee Limited, 2007); these problems severely limit the use of this monitoring well in establishing reliable water quality time trends (in depth and time). The limited sampling of groundwater in the alluvial aquifer shows significantly elevated sulphate (500-1,900 mg/L), magnesium (30-120mg/L) and zinc (0.01-1.4mg/L). The (limited) sampling at this location suggest an "inverse" profile with higher concentrations at depth within the aquifer; this pattern would suggest a source located further upgradient, i.e., either the coarse and well-drained tailings located further east in the Original Impoundment and/or seepage from the Faro Creek channel / diversion channel.*

Well NA05-11A, is located in the northeastern section of the Original Impoundment and screened about 3-5 m beneath the tailings in sand and gravel was sampled once in September 2006 as a single sampling event. RGC (2007) provides a discussion of water quality results from this well.

In general, groundwater quality in the aquifer beneath the Original Impoundment shows elevated sulfate, magnesium, zinc, iron and manganese suggesting impact from tailings porewater seepage.

Second Impoundment

Table 6.2-8 lists pertinent information of groundwater monitoring wells used in establishing baseline conditions in the Second Impoundment.

Table 6.2-8. Monitoring Wells in the Second Impoundment

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Second Impoundment						
P03-01-01	6912580	583301	*0.526*	46.48	46.79	Alluvium
P03-01-02	6912580	583301	*0.526*	38.56	38.86	Alluvium
P03-01-03	6912580	583301	*0.526*	30.33	30.63	Alluvium
P03-01-04	6912580	583301	*0.526*	24.23	24.54	Alluvium
P03-01-05	6912580	583301	*0.526*	18.14	18.44	Alluvium
P03-01-06	6912580	583301	*0.526*	12.95	13.26	Alluvium
P03-01-07	6912580	583301	*0.526*	10.52	10.82	Alluvium
P03-01-08	6912580	583301	*0.526*	8.99	9.30	Tailings
P03-01-09	6912580	583301	*0.526*	7.47	7.77	Tailings
P03-02-01	6912572	583135	*0.692*	33.53	33.83	Alluvium
P03-02-02	6912572	583135	*0.692*	30.18	30.48	Alluvium
P03-02-03	6912572	583135	*0.692*	22.56	22.86	Alluvium
P03-02-04	6912572	583135	*0.692*	16.46	16.76	Alluvium
P03-02-05	6912572	583135	*0.692*	13.41	13.72	Alluvium
P03-02-06	6912572	583135	*0.692*	12.5	12.80	Alluvium
P03-02-07	6912572	583135	*0.692*	11.58	11.89	Tailings
P03-02-08	6912572	583135	*0.692*	8.53	8.84	Tailings
P03-02-09	6912572	583135	*0.692*	7.32	7.62	Tailings
P03-03-01	6912698	583068	*0.817*	42.67	42.98	Alluvium
P03-03-02	6912698	583068	*0.817*	32.92	33.22	Alluvium
P03-03-03	6912698	583068	*0.817*	26.82	27.13	Alluvium
P03-03-04	6912698	583068	*0.817*	21.95	22.25	Alluvium
P03-03-05	6912698	583068	*0.817*	18.29	18.59	Alluvium
P03-03-06	6912698	583068	*0.817*	16.76	17.07	Alluvium
P03-03-07	6912698	583068	*0.817*	14.94	15.24	Tailings
P03-03-08	6912698	583068	*0.817*	11.89	12.19	Tailings
P03-03-09	6912698	583068	*0.817*	18.84	9.14	Tailings

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
P03-04-01	6913186	582085	*0.777*	57.91	58.22	Alluvium
P03-04-02	6913186	582085	*0.777*	47.24	47.55	Alluvium
P03-04-03	6913186	582085	*0.777*	41.15	41.45	Alluvium
P03-04-04	6913186	582085	*0.777*	34.75	35.05	Alluvium
P03-04-05	6913186	582085	*0.777*	25.76	26.06	Alluvium
P03-04-06	6913186	582085	*0.777*	17.07	17.37	Alluvium
P03-04-07	6913186	582085	*0.777*	15.24	15.54	Alluvium
P03-04-08	6913186	582085	*0.777*	13.41	13.72	Tailings
P03-04-09	6913186	582085	*0.777*	12.50	12.80	Tailings
P03-05-01	6912934	582605	*0.843*	44.20	44.50	Alluvium
P03-05-02	6912934	582605	*0.843*	36.58	36.88	Alluvium
P03-05-03	6912934	582605	*0.843*	27.43	27.74	Alluvium
P03-05-04	6912934	582605	*0.843*	23.16	23.47	Alluvium
P03-05-05	6912934	582605	*0.843*	21.34	21.64	Tailings
P03-05-06	6912934	582605	*0.843*	18.29	18.59	Tailings
P03-05-07	6912934	582605	*0.843*	13.72	14.02	Tailings
P03-05-08	6912934	582605	*0.843*	10.67	10.97	Tailings
P03-06-01	6913309	582573	*0.867*	25.60	25.91	Alluvium
P03-06-02	6913309	582573	*0.867*	22.56	22.86	Alluvium
P03-06-03	6913309	582573	*0.867*	19.51	19.81	Alluvium
P03-06-04	6913309	582573	*0.867*	16.15	16.46	Alluvium
P03-06-05	6913309	582573	*0.867*	14.02	14.33	Alluvium
P03-06-06	6913309	582573	*0.867*	12.19	12.50	Tailings
P03-06-07	6913309	582573	*0.867*	10.67	10.97	Tailings
NA05-9D	6912641	582921	0.75	7.9	10.9	Alluvium
NA05-9S	6912642	582918	0.66	1.4	4.4	Tailings

Groundwater monitoring in the Second Impoundment commenced in 2001 with the installation of two nested piezometers (P01-07A/B/C/D/E and P01-9A/B/C/D). These wells were decommissioned in 2005 due to concerns about well integrity (RGC 2006b). In 2003, six multilevel monitoring wells were installed in the footprint of the Second impoundment to complement the P01 series of wells. The aquifer monitoring points in following wells are deemed useful for establishing baseline conditions: P03-01, P03-03, P03-04, P03-05 and P03-06. RGC (2007) provides a more detailed review of all available groundwater data for the intermediate impoundment. The following is a summary of key findings from that report relevant to the baseline assessment.

Groundwater quality in the aquifer at locations P03-01, P03-02 and P03-03 varies significantly despite the relatively close proximity of the sites.

- At P03-01 and P03-02 concentrations of sulphate, magnesium, and various metals (zinc, iron and manganese) initially showed a decreasing trend with depth in the alluvial sediments as would be expected with seepage from the overlying tailings deposit being the source of contamination; however, zinc and manganese concentrations at deeper monitoring points (in particular at P03-01-4 and P03-02-4) have shown significant increases over the last 3 years of monitoring.

- At P03-03 contaminant concentrations showed an inverse depth profile with significantly higher concentrations of sulphate, zinc and iron to much greater depth (e.g., 1860 mg/L sulphate and 148 mg/L zinc about 18 m below the base of tailings); previous analyses had suggested that leakage from P01-09 (in particular from P01-09E) is the most likely cause for the highly elevated sulphate and zinc at depth at this location (RGC 2006b); the observed decline in contaminant concentrations in the deeper monitoring points of P03-03 since decommissioning of the "leaky wells' in late 2005 supports this contention.

- Concentrations of zinc and manganese deep in the Rose Creek aquifer (at P03-01 and P03-02) are cause for concern and should be further monitored. Note that both wells are located upgradient (or cross-gradient) of the P01-09 wells, hence leakage effects can be ruled out as a source for the recent increases. The most likely source for the observed increases in contaminants (in particular zinc) at greater depth is seepage from tailings located further upgradient (i.e., in the Second Impoundment). However, this would indicate a very high degree of vertical dispersion (i.e., up to 15 m over a horizontal distance of only ~120m). Alternatively, an upstream source (other than tailings seepage) may be contributing zinc load to the Rose Creek aquifer. Additional monitoring upstream of the Rose Creek tailings facility would be required to clarify the source of contamination at greater depth in the Rose Creek aquifer at P03-01.

Groundwater quality at P03-05 in the aquifer has remained very constant since 2003 when it was installed. This well shows a strong dilution profile with elevated sulphate (~1,000 mg/L), magnesium (~60 mg/L) and sodium (~45 mg/L) confined to 4 m below the base of the tailings; the deeper aquifer profile shows 3-4 times lower concentrations of all major constituents, supporting the conceptual model that tailings seepage is generally confined to a narrow zone at the top of the aquifer (in the southern portion of the Rose creek aquifer) (RGC, 2007).

Groundwater quality in the aquifer at P03-06 has deteriorated since the start of monitoring in 2003. This multi-level well shows a general "dilution profile", with the highest contaminant concentrations (sulphate, magnesium, zinc etc) in the shallow monitoring point immediately below the tailings but also shows elevated contaminant concentrations deeper into the aquifer.

> *P03-06-05 (~2m beneath the base of the tailings) has shown a significant increase in sulphate from 331 mg/L in June 2004 to 2740 mg/L in May 2007; zinc*

> *concentrations have also increased from ~0.1 mg/L in June 2004 to 63.3 mg/L [ ]in May 2007; The deeper portion of the aquifer (at P03-06-02 and P03-06-03) has also shown a significant increase in all contaminants, including Sulphate, magnesium, zinc, iron and manganese; for example, sulphate concentrations have increased from ~800 mg/L to ~2,000 mg/L over the past three years and zinc has increased from ~0.2 to ~2.6 mg/L; the most dramatic increases were observed for iron which reached ~100 mg/L in May 2007. [The] alkalinity has significantly decreased in the shallow as well as in the two deeper monitoring points suggesting that the buffering capacity of the aquifer is gradually being depleted; this raises concerns about the potential for further increases in metal concentrations in the near future;*

The presence of oxidation products and metal concentrations in the aquifer at P03-06 (in particular at depth) suggest that groundwater is impacted by tailings porewater seepage or from a source located further upgradient (i.e., either the coarse and well-drained tailings located in the Original Impoundment and/or seepage from the Faro Creek channel/diversion channel) (RGC, 2007).

Groundwater quality in the aquifer at location P03-04 shows a narrow zone of high TDS water beneath the tailings. The deeper part of the aquifer also has elevated sulphate (400-880 mg/L) (RGC, 2007).

The groundwater quality in the aquifer beneath the Secondary Impoundment is summarized below by RGC (2007):

> *[There is] incremental loading [of contaminants] from east (upstream) to west (downstream) with SO4, Mg, Zn and Na generally increasing in a downstream direction. At most locations, concentrated ARD seepage is observed in a narrow zone beneath the tailings. However, ARD products are also observed at significant depth, in particular in recent years at P03-06. Potential reasons for this occurrence include (i) leakage from deep piezometers (P01 series), (ii) vertical dispersion along the flow path and/or (iii) seepage of WRD from the Faro site (in particular the Faro Creek canyon and diversion channel) along the north side.*
>
> *The recent increases in ARD products, and in particular zinc, in the Rose Creek aquifer underlying the Second Impoundment indicate that the assimilative capacity along the flow path (i.e., tailings and/or aquifer) is slowly being depleted. Further increases in metal concentrations in the groundwater flowing in the Rose Creek aquifer beneath the Second Impoundment can therefore be expected and should be monitored.*

Intermediate Impoundment

Table 6.2-9 lists information for groundwater monitoring wells located in the Intermediate Impoundment and relevant for establishing baseline conditions.

Table 6.2-9. Monitoring Wells in the Intermediate Impoundment

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Intermediate Impoundment						
X21A-96	6913417	581989	0.69	2.43	8.53	Tailings
X21B-96	6913417	581989	0.74	11.64	14.69	Alluvium
X21C-96	6913417	581989	0.81	27.86	29.37	Alluvium
P03-08-01	6913514	580980	*0.878*	32.31	32.61	Alluvium
P03-08-02	6913514	580980	*0.878*	28.04	28.35	Alluvium
P03-08-03	6913514	580980	*0.878*	24.38	24.69	Alluvium
P03-08-04	6913514	580980	*0.878*	22.86	23.16	Alluvium
P03-08-05	6913514	580980	*0.878*	21.34	21.64	Alluvium
P03-08-06	6913514	580980	*0.878*	19.81	20.12	Tailings
P03-08-07	6913514	580980	*0.878*	16.76	17.07	Tailings
P03-08-08	6913514	580980	*0.878*	13.72	14.02	Tailings

Wells X21A/B/C were first installed in the Intermediate Impoundment in 1981. These wells were destroyed and replaced with wells at a similar location in 1996 (RGC 1996). In 2001, additional piezometers (P01-05A/B and P01-06) were installed (Gartner Lee Limited, 2002) and subsequently decommissioned in October 2005 due to concerns about the integrity of these wells (RGC 2006b). In 2003, one multilevel monitoring well was installed with monitoring points in the aquifer within the foot print of the Intermediate Impoundment. A summary of groundwater conditions adapted from RGC (2007) is provided below.

The upper aquifer (X21B) has shown an increase in ARD products, with sulphate concentrations reaching ~1,100 mg/L and zinc concentrations reaching ~6 mg/L; the groundwater quality time trends observed at X21B suggest incremental loading from the Secondary Impoundment. There have been seasonal variations in groundwater quality observed at X21B and P03-06 located further upgradient showing higher contaminant levels in the fall. This suggests higher seepage and contaminant loading from the overlying tailings during the summer/fall period (RGC 2007). Deeper groundwater at X21C has consistently shown very low sulphate, magnesium, sodium and zinc characteristic of background concentrations. Downward contaminant migration may be controlled by a thick silt layer separating the upper and lower portion of the aquifer.

Deep groundwater at P03-08 (located in the southwestern section) shows very little influence of tailings seepage, with sulphate, zinc, sodium and magnesium all approaching background values. There is a narrow zone with elevated TDS (<5m) observed at shallower depths near the tailings aquifer interface (as observed at P03-04).

[In summary], there are only a few wells completed in the aquifer beneath the Intermediate Impoundment, most of which are located either relatively close to the upstream end of the impoundment (e.g., X21, P01-06) and/or near the perimeter of the valley (P03-08), thus limiting an interpretation of groundwater quality in this reach. Thus far, only one monitoring well (X21B) has shown a significant increase in contaminant concentrations (SO4, Zn, Fe and Mn). The recent increases at X21B may be related to the observed deterioration in groundwater quality at P03-06, located further upgradient in the (much older) Second Impoundment.

The only multi-level piezometer installed in the Intermediate Impoundment (P03-08) shows a relatively narrow zone of groundwater influenced by tailings seepage (as opposed to much deeper influence observed further upgradient). This observation might, however, be a result of the general proximity of this well to the side of the valley where inflow from the hillside and seepage from the Rose Creek Diversion could provide significant dilution.

Toe of Intermediate Dam

Table 6.2-10 lists information of groundwater monitoring wells located in the Intermediate Impoundment which are relevant to establishing baseline conditions.

Table 6.2-10. Monitoring Wells at the toe of the Intermediate Dam

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Intermediate Dam						
X24A-96	6914124	580655	0.8	6.46	6.48	Alluvium
X24B-96	6914124	580655	0.75	9.8	11.3	Alluvium
X24C-96	6914124	580655	0.7	14.97	16.47	Alluvium
X24D-96	6914124	580655	0.7	26.84	28.34	Alluvium
X25A-96	6913945	580519	0.68	7.44	8.97	Alluvium
X25B-96	6913945	580519	0.63	17.7	19.17	Alluvium
P01-03	6914056	580617	0.3	7.78	9.3	Alluvium
P01-04A	6913893	580496	0.31	31.7	33.22	Alluvium
P01-04B	6913893	580496	0.3	51.0	52.5	Till

Wells X24A/B and X25A/B were first installed in the area in 1987. These wells had to be replaced in 1996 when the dam was raised (RGC 1996). In 2001, additional wells P01-03 and P01- 04A/B

were installed to complement the existing monitoring wells at X24 and X25, respectively (Gartner Lee Limited, 2002). Wells X24B/C have not been sampled in recent years because of problems with sand heaving. Main observations for groundwater quality in this area are provided below and are summarized from RGC (2007).

Groundwater wells located along the northern portion of the Intermediate Dam have provided groundwater samples from the aquifer which show a greater impact than along the southern portion. Groundwater in this area down to a depth of approximately 30m below ground surface (b.g.s.) is characterized by elevated sulfate, magnesium and alkalinity but generally low metal concentrations. Concentrations of sulphate and magnesium have increased significantly since 2001 in all (still functional) wells screened in the aquifer along the north side of the Intermediate Dam (RGC, 2007). In May 2007, sulphate and magnesium concentrations in the deep well X24D had reached 1,700 mg/L and 120 mg/L, respectively. Increases in sulphate and magnesium the shallow well P01-03 suggest "breakthrough" of a TDS front across the entire depth of the aquifer. In May 2007, manganese and zinc concentrations in the deep well X24D had reached 50 mg/L and 0.1 mg/L, respectively. The shallow well P01-03 showed very similar increases in manganese but zinc has remained below the detection limit of 0.01 mg/L at shallow depth.

The groundwater quality in wells (X25A/B, P01-04A/B) screened in the aquifer beneath the southern portion of the Intermediate Dam shows concentrations of sulphate and magnesium 3-4 times lower than along the northern section. Zinc concentrations are typically <0.1 mg/L. No apparent increasing trend in dissolved metals concentrations is observed in this area.

> *In summary, groundwater in the northern portion of the aquifer shows significantly higher influence of ARD products (SO4, Mg, Zn, Mn) than on the southern side at the Intermediate Dam. Such a distinct difference has not been observed further up-gradient. Potential reasons for the higher TDS along the north side of the aquifer include (i) higher ARD loading on the northern side (e.g., from the coarse tailings beaches and/or seepage from the Faro Creek canyon and/or (ii) dilution from the Rose Creek Diversion along the south side.*

Toe of Cross Valley Dam

Table 6.2-11 lists the wells located along the toe of the Cross Valley Dam which are useful for establishing baseline conditions downgradient of the Cross Valley Dam and consequently downgradient of all major sources of contamination from mining activities. .

Table 6.2-11. Monitoring Wells at the toe of the Cross Valley Dam

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Toe of Cross Valley Dam						
P01-02A	6914044	580081	0.59	12.37	13.89	Alluvium
P01-02B	6914044	580081	1.57	26.21	27.7	Till
P01-11	6914306	580214	0.55	9.15	10.67	Alluvium
P03-09-01	6914229	580065	*0.689*	34.75	35.05	Alluvium
P03-09-02	6914229	580065	*0.689*	32.00	32.31	Alluvium
P03-09-03	6914229	580065	*0.689*	26.82	27.13	Alluvium
P03-09-04	6914229	580065	*0.689*	23.47	23.77	Alluvium
P03-09-05	6914229	580065	*0.689*	21.64	21.95	Alluvium
P03-09-06	6914229	580065	*0.689*	18.59	18.90	Alluvium
P03-09-07	6914229	580065	*0.689*	13.11	18.41	Alluvium
P03-09-08	6914229	580065	*0.689*	9.14	9.45	Alluvium
P03-09-09	6914229	580065	*0.689*	7.32	7.62	Alluvium
P05-01-01	6914335	580165	*0.671*	25.15	25.45	Till / BR
P05-01-02	6914335	580165	*0.671*	19.67	19.82	Alluvium
P05-01-03	6914335	580165	*0.671*	16.62	16.77	Alluvium
P05-01-04	6914335	580165	*0.671*	11.13	11.28	Alluvium
P05-01-05	6914335	580165	*0.671*	5.33	5.48	Alluvium
P05-01-06	6914335	580165	*0.671*	3.20	3.35	Alluvium
P05-02	6914265	580143	0.98	1.83	4.88	Alluvium
P05-03	6914171	580088	0.84	3.44	7.62	Alluvium

Groundwater monitoring started in 2001 along the toe of the Cross Valley Dam at wells P01-02A/B and P01-11. Multilevel wells P03-09 and P05-01 were installed in the center of the valley in 2003 and 2005 respectively. Two single piezometers (P05-02 and P05-03) were installed as part of a study to design a seepage interception system in this area (RGC 2006).

The groundwater quality in vicinity of the Cross Valley Dam shows significant transverse variations (from north to south) suggesting greater impact from mine waste seepage along the northern portion of the valley aquifer (RGC 2007).

Groundwater on the North side of the Cross Valley Dam (P01-11, P05-01 and P05-02) generally shows elevated sulphate (~1,000 mg/L), magnesium (~75 mg/L), and alkalinity (~300 mg/L as $CaCO_3$); selected metal concentrations are also above background, including iron (10-20 mg/L), manganese (10-15 mg/L) and zinc (~0.03 mg/L). Sampling at P05-01 shows that groundwater quality is fairly uniform from the water table down to bedrock. Only the deepest monitoring point

(P05-01-01) screened in highly cemented basal till shows a different composition, including lower sulphate (~400 mg/L) but higher sodium (120-140 mg/L) and higher alkalinity (400-500 mg/L); metal concentrations are also significantly lower at P05-01-01.

- *Time trends at P01-11 indicate a gradual increase in SO4 and Mg over time; current SO_4 and Mg concentrations are ~1,100 mg/L and ~80 mg/L (May 2007); alkalinity has also shown an increase over time (currently at ~300 mg/L $CaCO_3$ eq); manganese and iron concentrations have also shown a moderate increase at P01-11 since start of monitoring in 2001 (currently at 27 mg/L Fe and 17 mg/L Mn, respectively);*
- *Despite this significant increase in oxidation products, zinc concentrations at P01-11 have remained at comparatively low concentrations, ranging from 0.01 to 0.1 mg/L; note that the method of detection limit (MDL) for zinc analysis have been very high in recent years (e.g., 0.025 mg/L for the May 2007 survey) making it difficult to assess zinc time trends in this portion of the aquifer (see section 3.6.4 below);*
- *The initial (limited) monitoring at P05-01 and P05-02 carried out since 2006 suggest that the increases in ARD products (SO4, Mg etc) observed at P01-11 are representative of the entire northern portion of the Rose Creek aquifer; future monitoring at P05-01 and P05-02 will be required to confirm this contention;*

Central Portion of Cross Valley Dam (P03-09, P05-03);

- *The groundwater in the central portion of the aquifer at the Cross Valley Dam (at P03-09 and P05-03) shows significantly lower concentrations of all ARD products: SO_4 and Mg concentrations range from 300-500 mg/L SO_4 and 30-40 mg/L Mg, respectively and all metals (including iron, manganese and zinc) show significantly lower concentrations (note that zinc was generally non-detect but the MDL for zinc was as high as 0.025 mg/L so the actual zinc concentrations in the middle portion of the aquifer are uncertain);*
- *Detailed depth monitoring at P03-09 indicates fairly uniform groundwater quality throughout the central portion of the sand & gravel aquifer with only slightly higher SO_4 and Mg concentrations in the upper portion of the aquifer; only the two deepest ports (screened in very compact basal TILL) show slightly higher sulphate, magnesium, and iron but lower manganese concentrations; zinc was also non-detect in the basal TILL unit;*
- *The initial (limited) time trend monitoring carried out at P05-03 since 2006 suggests that sulphate and magnesium concentrations are also increasing in the central portion of the aquifer. Note, however that such an increase is not readily apparent at P03-09, possibly due to the*

seasonal variations in groundwater quality observed at this location (more dilution in the spring sampling); additional monitoring will be required to confirm whether this portion of the aquifer is also showing a gradual deterioration in groundwater quality;

South Side of Cross Valley Dam (P01-2A/B);

- *Groundwater in the southern portion of the aquifer is much more dilute than the northern, or even the central portion of the aquifer: SO_4 and Mg concentrations range from 100-150 mg/L SO_4 and ~25 mg/L Mg, respectively; zinc concentrations are usually below detection and iron and manganese are 1-2 orders of magnitude lower than in the central portion of the aquifer; note that sodium concentrations are also significantly lower (~15 mg/L) than observed elsewhere in the Rose Creek aquifer along this reach suggesting dilution by seepage from the Rose Creek Diversion Canal;*
- *The groundwater quality in the upper well (P01-02A screened in alluvium) and the lower well (P01-02B screened in basal Till) is generally very similar, except for slightly higher manganese in the upper S&G aquifer (~1 mg/L) and higher iron concentrations (0.8 mg/L) in the deeper till; groundwater quality in both wells has remained very stable over the last six years except for some initial changes in metal concentrations (possibly due to re-equilibration after drilling);*

  The recent increases in oxidation products and metal concentrations in the northern, and to a lesser extent, in the central portion of the Rose Creek aquifer at the Cross Valley Dam are significant. Note that the SO_4 and Mg concentrations observed recently in the aquifer are significantly higher than observed in the Polishing Pond (SO_4 <700mg/L and Mg <40 mg/L), hence seepage from the Polishing Pond can be ruled out as the main source of contamination. Instead, the source for this seepage must be located further upgradient. Note that the chemical composition of the impacted groundwater on the northern side of Cross Valley Dam (P01-11, P05-01 and P05-02) is very similar to that observed on the north side further upgradient at the toe of the Intermediate Dam (at X24C/D) around 2002 is therefore likely that the breakthrough of ARD products observed at the Cross Valley Dam represents the "leading edge" of the breakthrough observed further upgradient at the Intermediate Dam.

Downstream of Cross Valley Dam

Table 6.2-11 lists groundwater monitoring wells located downgradient of the Cross Valley Dam which are relevant to establishing baseline conditions.

Table 6.2-12. Monitoring Wells Downgradient of the Cross Valley Dam

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Downgradient of Cross Valley Dam						
X16A	6914672	579538	0.5	3.0	6.0	Alluvium
X16B	6914672	579538	0.1	20.0	34.0	Alluvium
X17A	6914475	579874	0.62	4.5	6.2	Alluvium
X17B	6914475	579874	1.16	17.0	25.0	Alluvium
X18A	6914539	580105	0.63	8.8	10.6	Alluvium
X18B	6914539	580105	0.59	16.6	22.8	Alluvium
P01-01A	6914675	579819	0.74	19.8	21.36	Alluvium
P01-01B	6914675	579819	0.65	33.35	34.9	Alluvium

Wells X16A/B, X17A/B and X18A/B were installed downstream of the Cross Valley Dam in 1981 (Klohn Crippen, 1981). In 2001, another set of nested monitoring wells (P01-01A/B) was installed along the north side of the valley. The recent time trends can be summarized as follows:

North Side of Rose Creek Aquifer (P01-01A/B and X18A/B):

- *Monitoring wells X18A/B and P01-01A show very similar time trends in groundwater quality, with a gradual increase in sulphate, magnesium and alkalinity; the highest concentrations were observed in the most recent survey (May 2007) with ~600 mg/L SO4, ~60 mg/L Mg, and ~260 mg/L $CaCO_3$eq; metal concentrations have generally remained low and show no clear increasing trend except for manganese in P01-01A (~4.5 mg/L in May '07); time trends in zinc concentrations have been fairly erratic, at least in part due to problems with the high detection limits for zinc in recent years;*
- *Monitoring well P01-01B (screened in deep alluvium) has not shown the same recent increases (since 2001) in sulphate and magnesium as observed elsewhere on the north side; note also that manganese concentrations have also remained very low (~0.1 mg/L) in P01- 01B;*

Central Portion of Rose Creek aquifer (X16A/B and X17A/B):

- *The monitoring wells screened in the central portion of the Rose Creek aquifer (at X16A/B and X17A/B) generally show significantly less impact than on the north side, with all ARD products (SO4, Mg, Na and metals) at significantly lower concentrations; however the water quality time*

trends in those two sets of piezometers show some important differences:

- *Monitoring well X17B, screened in the deeper portion of the alluvial aquifer, has recently shown an increase in most major ions, including SO4, Mg, Na and alkalinity; in addition, iron and manganese concentrations have also shown a slight increase (again, zinc time trends could not be evaluated due to problems with the high MDL); note that the recent time trends also show a distinct seasonal trend, with higher concentrations typically observed during the spring/early summer;*

  Monitoring wells X17A and X16A, both screened in the upper portion of the alluvial aquifer, and X16B (screened in the deeper portion of the aquifer) have not shown the same recent increases in major ions or metals, as observed at X17B;

  In summary, the groundwater quality time trends observed in the Rose Creek aquifer further downgradient of the Cross Valley Dam mimic the trends observed along the toe of the Dam, with higher impacts observed on the northern side of the aquifer. The sulphate and magnesium concentrations currently observed further downgradient (at X18A/B and P01-01A) are similar to those observed several years earlier at the toe of the Cross Valley Dam (around 2002 in P01-11). This would suggest that the recent increases in sulphate and magnesium represent the "leading edge" of the contaminant plume observed in the northern portion of the aquifer (at the Cross Valley Dam and Intermediate Dam).

  The recent increases in major ion and selected metal concentrations at X17B differ from that observed elsewhere in that (i) increases in sulphate and magnesium are also accompanied by significant increases in sodium and alkalinity, and (ii) the increases show significant seasonal variations. Elevated sodium and alkalinity levels have also been observed in the deep monitoring points at P03-09 and P05-01, which are screened in compact, basal till. It is therefore possible that the observed seasonal increases in major ions at X17B reflect increased contributions of deep groundwater upwelling from underlying bedrock and/or basal till, in particular during the spring runoff season.

  The chemical composition and low ionic strength of the groundwater observed in the other wells (at X17A and X16A/B) is similar to that observed along the southern abutment of the Cross Valley Dam (P01-02A/B). As discussed earlier, leakage of very dilute surface water from the Rose Creek Diversion likely provides significant dilution to the groundwater in the Rose Creek aquifer in those areas.

6.2.6.5 Grum and Vangorda Mine Site

Figure 6.2-5 shows the general layout of the Grum/Vangorda mine site and the groundwater monitoring wells used for this baseline assessment. The Grum site comprises the Grum Pit, Grum rock dump (with suphide cell) and the Overburden stockpile. The Vangorda site comprises the Vangorda Pit (with in-pit rock dumps) and the Vangorda rock dump. The area is drained by Vangorda Creek, which runs between both mine sites and flows out towards the Pelly river. Groundwater monitoring wells are located along the toe of both the Grum and Vangorda rock dumps.

6.2.6.6 Downstream of Grum Rock Dump

Table 6.2-13 lists information for the monitoring wells used in the baseline assessment.

Table 6.2-13. Monitoring Wells downgradient of Grum Rock Dump

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Grum WRD Area						
P96-9A	6903165	592753	0.84	4.96	9.45	Overburden
SRK04-5A	6903205	592871	0.76	22.7	23.7	BR (weathered)
SRK04-5B	6903205	592871	0.78	13.7	14.7	Overburden
BH05-9B-R	6903172	592747	1.06	15.50	18.60	Overburden/BR
SRK05-05C	6903200	592882	0.93	1.5	3.0	Overburden
SRK05-06	6902991	593032	0.73	0.7	2.7	Overburden
SRK05-07	6903011	592477	0.75	0.75	5.8	Overburden / BR
SRK05-08	6903063	592690	0.5	2.1	7.6	Overburden
SRK05-09	6902986	593058	0.94	0.5	3.5	Overburden

The most recent review of groundwater quality time trends in the Grum area was completed in 2004, i.e., prior to installation of the recent monitoring wells (RGC 2004). The 2005 seepage investigation report also provided initial water quality results from the 2004 and selected 2005 monitoring wells (up to November 2005) (SRK 2007a).

The following observations are summarized from the latest groundwater quality review (RGC, 2007).

Monitoring well SRK05-05C located near Grum Creek suggest that shallow groundwater is impacted by waste rock seepage from the Grum dump. Groundwater from one sample collected in

2006 showed that in shallow alluvial sediments, concentrations of sulphate (~400 mg/L), magnesium (57 mg/L), and alkalinity (240 mg/L $CaCO_3$eq) were elevated. Metal concentrations were also slightly elevated (iron ~1.2 mg/L, manganese ~4.0mg/L and zinc ~0.02 mg/L). Artesian conditions were encountered in wells (SRK04-5A/B), screened deeper in coarse sediments and weathered bedrock, respectively. Water quality from these wells does not suggest deep groundwater impact from waste rock seepage. Groundwater from this deeper confined zone has an alkaline pH (~8.0) and comparatively low concentrations of sulphate (~100 mg/L), magnesium (16 mg/L), and alkalinity (~140 mg/L); zinc concentrations are detectable but generally very low (<0.01 mg/L) (RGC, 2007).

- *Monitoring wells SRK05-06 (Moose Well 1) and SRK05-09 (Moose Well 2) are both screened in shallow colluvium, between "Moose Pond" and Vangorda Creek; groundwater in those shallow soils shows significant seasonal variation, for example, sulphate concentrations range from ~200-400 mg/L in the winter months to ~800 mg/L in the summer/fall; similar seasonal variations are observed for magnesium and alkalinity; in contrast, metal concentrations have remained low throughout the year (Zn <0.01 mg/L; Fe <0.1 mg/L and Mn <0.01 mg/L) and do not show similar seasonal fluctuations.*

  The seasonal increases in ARD products (SO_4, Mg, alkalinity) in SRK05-09 ("Moose Well 2") are likely a result of seepage from the Moose Pond which collects seepage from the Grum Rock Dump. The Grum Creek seepage entering the Moose Pond shows similar seasonal variations to those observed in the Moose Well 2, with sulphate values ranging from ~400 mg/L in the spring to 800-900 mg/L in the summer/fall. Note that the Grum Creek seepage shows elevated zinc concentrations (up to 1 mg/L). The lack of elevated zinc concentrations in SRK05-09 suggests that zinc is still being attenuated in these shallow sediments.

The time trends in those wells located west of Grum Creek can be summarized as follows:

- *Monitoring well P96-9A, screened in shallow, alluvial sediments in a narrow side drainage, has shown a significant increase in ARD products (sulphate, magnesium, alkalinity) since about year 2000; at present, sulphate concentrations are around 1,600 mg/L, magnesium concentrations are ~300 mg/L and alkalinity is around 450-500 mg/L $CaCO_3$eq; the observed increases are clear evidence of seepage from the Grum waste rock dump; note that metal concentrations have remained near or below the detection limit (Fe ~0.1 mg/L, Mn ~0.1 mg/L and Zn <0.1 mg/L) throughout the observation period indicating natural attenuation of these metals along the flow path;*
- *Monitoring well P96-9B (and more recently BH05-9B-R), screened in deeper till-like sediments and weathered bedrock, show very little, if any*

impact from waste rock seepage: groundwater in these deeper wells has virtually the same composition as observed in the deeper wells located further west at Grum Creek (see SRK04-05A/B discussed above);

The two monitoring wells (SRK05-07 and SRK05-08), screened in shallow phyllite bedrock show elevated concentrations of ARD products (sulfate, magnesium and alkalinity) and trace concentrations of metals as observed further west at P96-09A and indicative of neutralized waste rock dump seepage.

Vangorda WRD Area

Figure 6.2-5 shows the monitoring wells located downgradient of the Vangorda Rock Dump and Table 6.2-14 lists those monitoring wells relevant to the baseline assessment.

Table 6.2-14. Monitoring Wells downgradient of Vangorda Rock Dump

Well ID	Northing	Easting	Field Stickup (m) *	Top of Screen (mbgs)	Bottom of Screen (mbgs)	Formation
Vangorda WRD Area						
V34	6902295	593553	0.55	-	-	BR
V35	6902371	593293	0.44	-	-	Alluvium
V36	6902733	593243	0.5	-	-	Alluvium
V37	6902913	593420	0.47	-	-	Alluvium
P2001-02A	6902677	593252	0.34	25.8	27.3	Till
P2001-02B	6902677	593252	0.34	12.3	13.9	Clay and Gravel
P2001-03	6902700	593214	0.68	58.5	61.6	Till / BR

Monitoring of groundwater quality at the Vangorda Rock Dump commenced in 1994 with the installation of four “GW-94” wells along the toe of the Vangorda Rock Dump (SRK 1994). In 2001, three additional piezometers were installed further downgradient towards Vangorda Creek (“P2001” wells). A recent evaluation of groundwater quality for the site was completed by RGC (2007) and values are provided below:

Most monitoring wells located downgradient of the Vangorda Rock Dump show some increase in ARD products (primarily sulphate and magnesium). The extent of impact varies between the locations.

- *Monitoring well V35 shows the highest impact with sulphate and magnesium concentrations recently (May 2007) reaching 1,700 mg/L SO4 and 300 mg/L Mg, respectively. alkalinity concentrations have also increased markedly in 2006/07 (600- 700 mg/L$CaCO_3$eq); zinc concentrations have also increased in recent years reaching a high of 0.113 mg/L in September 2006; (note, however, that zinc was below the detection limit in May 2007). Groundwater at V36 has also shown a significant increase in sulphate, magnesium and zinc but peak concentrations are still well below those observed at V35 (SO_4~ 700 mg/L; Mg ~160 mg/L, Zn ~0.05 mg/L). Monitoring well V34 and the "P01" wells all show a similar trend of only slightly increasing concentrations of sulphate and magnesium (reaching ~100-300 mg/L SO_4 and ~85-100 mg/L Mg); however, metal concentrations (including zinc) have remained very low (e.g., Zn <0.01 mg/L, Mn <0.1 mg/L). Monitoring well V37 has not shown any increase in ARD products (SO_4, Mg, metals) since start of monitoring in 1994;*

In general, water quality in the area show ARD impacts to groundwater along the toe of the dumps at the Vangorda site. RGC (2007) provides the following interpretation of physical flow conditions at the Grum and Vangorda sites:

- *[M]ost of the monitoring wells, in particular those clearly impacted, are located in close proximity of the toe of the waste rock dump. Hence, while contaminant concentrations in some Vangorda wells are now of similar magnitude than those observed at the Grum rock dump, travel times are inferred to be significantly slower than at Grum. This observation is consistent with the presence of thick deposits of low permeability tills at Vangorda compared to more permeable alluvial sediments, at least in some drainage channels, at Grum.*

<u>*Vangorda Creek / Town of Faro Area*</u>

Figure 6.2-6 shows the location of the Town of Faro drinking water supply wells and nearby observation wells. These wells provide baseline information for groundwater within the Vangorda Creek and Pelly River alluvial sediments. This location is significant as the Town water supply wells receive a portion of their water from Vangorda Creek (GLL, 2007).

(This section to be expanded in next version of the baseline compilation report)

6.2.6.7 Summary of Baseline Groundwater Quality

The groundwater quality within the Faro Mine Complex was recently reviewed and summarized by RGC (2007):

The following are *excerpts* from the report:

Faro Mine Area

The main conclusions of the groundwater quality review at the Faro Mine Area are as follows:

- *The groundwater quality in the S-cluster area has deteriorated dramatically over the last five years [with] rapid increase in dissolved zinc concentrations which have increased by as much as 100 mg/L in the last 20 months (Sep 2005 to June 2007) in selected wells (e.g., S1A, S2B, S3). Note that the affected monitoring wells are all in close proximity of the North Fork of Rose Creek and, hence there is a potential for significant increase in zinc concentrations in NFRC along this reach of NFRC.*
- *Recent seepage investigations in the Zone 2 Outwash Area (completed in 2005) indicate the presence of moderately impacted groundwater (primarily elevated zinc concentrations) in the permeable alluvial sediments of the NFRC valley.*
- *Groundwater quality downgradient of the Northeastern Dump (at BH14A/B) has shown recent increases in zinc concentrations, with peak concentrations around 0.4 to 0.5 mg/L zinc (observed in 2006). The observed increases in zinc concentrations were preceded by a systematic and substantial increase in sulphate, magnesium and alkalinity. Geochemical characterization work has identified sulphide-rich waste rock in this portion of the Northeast Dumps and it is possible that groundwater quality will continue to deteriorate in this area with sulphate and eventually zinc concentrations reaching similar concentrations as currently observed in the Faro Creek and S-cluster areas.*

Rose Creek Tailings Facility

The main conclusions of the groundwater quality review at the Rose Creek Tailings facility are as follows:

- *Groundwater quality in the underlying Rose Creek aquifer has significantly deteriorated in the last three years in all reaches of the Rose Creek Tailings Facility, i.e., not only within the foot print area of the tailings impoundments but also further downstream at the Intermediate Dam and the Cross Valley Dam. Of particular concern are the significant*

increases in sulphate, magnesium and metal concentrations (including iron, zinc and manganese) at greater depth in the aquifer, in particular in the northern portion of the aquifer (see for example P03-06, X21B, X24D). These recent time trends clearly indicate that the entire depth of the aquifer is affected by seepage from the tailings (and possibly the ETA area).

- *Additional wells screened at shallow depth in the aquifer sediments underlying shallow tailings deposits (NA wells) show significantly elevated zinc concentrations (e.g., 22 mg/L at NA11) suggesting that the attenuation capacity of the tailings and/or organic soils underlying the tailings profile is slowly being exhausted; this process may explain the recent increases in zinc concentrations in many parts of the Rose Creek aquifer;*

Grum/Vangorda Area

The main conclusions of the groundwater quality review at the Grum/Vangorda mine site are as follows:

- *Recent groundwater quality time trends observed in wells located downgradient of the Grum Rock Dump confirm earlier interpretations which had suggested that seepage from the Grum rock dump is responsible for the gradual increase in ARD products (SO4, Mg, and to a lesser extent Zn) in shallow groundwater draining towards Vangorda Creek. The more recent monitoring data also support earlier conclusions that metal concentrations (in particular zinc) are (still) attenuated along the flow path.*
- *The new deeper monitoring wells drilled in 2004 near Grum Creek and in 2005 at P96-9B also confirmed that seepage from the Grum rock dump appears to be limited to fairly shallow depth.*
- *Groundwater quality impacts are generally more delayed at Vangorda, compared to anywhere else at the Anvil Range Mining Complex, due to the low permeability of the local till deposits. Nevertheless, one monitoring well (V35) has shown a recent increase in some contaminants of concern (SO4, Mg, Zn)*

Town of Faro / Vangorda Creek Area

(To come)

6.3 Surface Water Quality

6.3.1 Introduction

Surface water quality has been extensively monitored at the Faro Mine Complex for regulatory compliance and environmental monitoring purposes since cessation of mining activities in 1998. Selected water quality data collected though these programs have been used to determine existing baseline surface water quality conditions at the Faro Mine Complex within the Rose Creek and Vangorda Creek drainages, as well as a portion of the Pelly River to which these tributaries drain. It is these current day water quality conditions (2005 to 2007), rather than historical pre-mining or operational water quality characteristics, that will be used to assess potential effects associated with implementation of the Faro Mine Closure Plan.

6.3.1.1 Regional Setting

The Faro Mine Complex footprint is located within two watersheds: the Anvil Creek watershed (includes Rose Creek drainage) and the Vangorda Creek watershed. Anvil Creek and Vangorda Creek are tributaries of the Pelly River (Figure 6.3-1). The two watersheds receive drainage from the mine sites by means of surface run-off, treated effluent discharge, natural and diverted surface water inflows and groundwater interactions.

6.3.1.2 Issue Focused Approach

An issues-based approach was used to focus the environmental assessment and assist in the identification of valued ecosystem components (VEC's). Potential surface water related issues identified by communities, First Nations, regulators, and project scientists include changes to the aquatic environment, including potential impacts to downstream surface water quality.

Based on the proposed project and closure objectives and the issued focused approach, baseline water quality characterization focuses predominately on background/reference, effluent and receiving water quality, rather than intermediate stations that are monitored for optimization of care and maintenance activities and may not be applicable upon selection of a final closure alternative.

6.3.2 Valued Ecosystem Components

Surface water quality has been defined as a valued ecosystem component (VEC) for the Environmental Assessment of the Closure and Remediation Plan for the Faro Mine Complex based on issues raised by communities, First Nations, regulators and project scientists, as well as previous environmental assessments, including the 2003 environmental assessment conducted for care and maintenance activities for the Faro Mine Complex (GLL 2003a).

6.3.3 Study Area

6.3.3.1 Local Study Area

The local study area (LSA) for surface water quality is based on the physical and hydrological footprint of the Faro and Vangorda mine sites and includes drainages that are directly influenced by site infrastructure associated with closure activities including the haul roads, waste rock piles and pits. The LSA extends from reference stations, which are located upstream from the Faro and Vangorda mine sites, to the first monitoring point downstream of treated effluent discharge points and site influence drainage inflows. At the Faro Mine Site, water quality in the lower boundary of the LSA is monitored at stations X14 and R2, and at station V5 at the Vangorda site. The water quality LSA and regional study areas (RSA) for the environmental assessment of the Closure and Remediation Plan of the Faro Mine Complex are illustrated in Figure 6.3-1. Both the LSA and RSA will be finalized upon selection of a preferred closure alternative.

6.3.3.2 Regional Study Area

The surface water quality regional study area (RSA) encompasses data outside of the project footprint that may be important to determine direct effects on downstream surface water quality and to allow for the determination of cumulative impacts where project effects extend beyond the study area boundary. The boundary of the surface water quality RSA is typically based on watershed boundaries as well as the zone of influence of the mine on downstream receiving environments. A previous environmental assessment conducted on the Faro Mine site for care and maintenance activities in 2003 defined the downstream RSA boundary to sampling locations within Rose and Vangorda Creeks (GLL 2003a). Due to recently available water quality data within the ultimate receiving environment to which both these watersheds drain, the Pelly River, the surface water quality RSA boundary has been extended to the portion of the Pelly River which receives drainage influenced by the mine sites. The surface water quality RSA is illustrated in Figure 6.3-1.

6.3.4 Temporal Scope of Baseline Compilation

For the purposes of the assessment of the closure plan, a temporal range spanning from 2005 to 2007 has been selected for characterization of *current* baseline water quality conditions in background, mine impacted and receiving waters draining from the Faro Mine site. This three year (inclusive) temporal range allows for characterization of seasonal trends and represents a time frame of consistent sampling and laboratory analysis techniques. For stations and parameters that demonstrate long-term historical changes, water quality over a larger temporal range (1998-2007) is discussed for the purposes of historical trend analysis. Data collected prior to 1998 will not be included in the historical trend analysis due to inconsistent laboratory methodology, including variable detection limits.

6.3.5 Data Sources

Surface water quality data for the baseline characterization was obtained from several sources including the following:

- Surface water quality monitored for Water Licence reporting and compliance purposes. Sampling frequency under this program includes monthly, quarterly and biannual sampling requirements, and weekly sampling requirement during periods of active discharge. Water quality data from this program is currently housed within a water quality database managed by Gartner Lee Limited.
- *Ecological Impact Assessment* (Minnow 2007). This assessment included statistical analysis of existing surface water quality data and development of preliminary background water quality benchmarks.
- *Pelly River Aquatics Effects Assessment* – 2004 to 2006 (Access *et al. 2004,2005, 2006).* This study included annual water quality monitored of selected historic stations, as well as new stations within the Pelly River and associated tributaries. The program was enhanced in 2007 to facilitate water quality analyses with method detection limits below water quality current guideline concentrations (CCME 1999).
- The *Anvil Range Mine Complex 2002 Baseline Environmental Information* Report (GLL 2002) and the *2004 to 2008 Water Licence Renewal of Environmental Assessment Report, Volume II of III, Existing Environment* (GLL 2003a). The environmental assessment documents were used to establish and confirm long-term historical trends observed in surface water quality at the Faro and Vangorda sites.

6.3.6 Monitoring Sites

Water quality is regularly monitored throughout the Faro Mine complex for water licence reporting purposes and environmental monitoring investigations. Based on the proposed project and closure objectives, baseline water quality characterization focuses predominately on background/reference, effluent and receiving water quality, rather than intermediate or internal stations that are monitored for optimization of care and maintenance activities and may not be applicable upon selection of a final closure alternative and therefore are not appropriate for assessment of potential impacts.

A total of 16 stations at the Faro Mine site and 9 stations at the Vangorda Mine site have been selected for baseline characterization and assessment. Surface water quality sampling locations are illustrated in Figure 6.3-1, Figure 6.3-2, and Figure 6.3-3. Water quality monitoring stations descriptions are provided in Table 6.3-1.

All stations are sampled as part of the routine monitoring program as part of care and maintenance activities with the exception of FC and VR. Station FC is a historic sampling station that after a period of inactivity was sampled in 2007. Station VR is a station that has been recently established for the purpose of characterizing reference water quality. Both FC and VR were sampled under a non-routine monitoring program, the Interim Aquatic Ecosystem Monitoring Program (IAEMP). Lower detection limits were employed under this programs to facilitate comparison of trace metals to water quality guideline benchmarks.

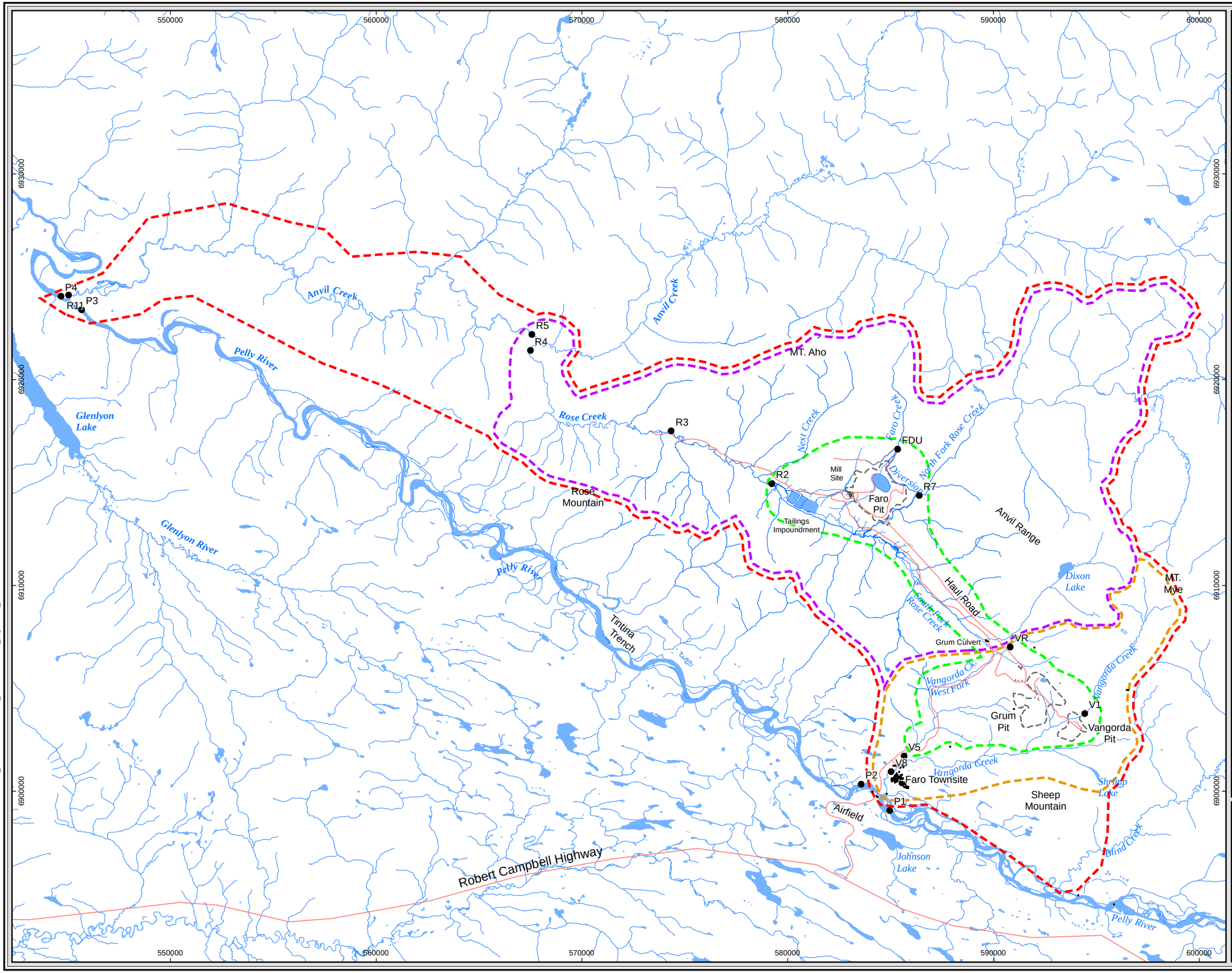
Monitoring sites within the Pelly River were also sampled under the IAEMP. Water quality at these sites, as well as additional locations within the River sampled as part of multi-year Pelly River Aquatic Effects Monitoring Program (PRAEMP) conducted by Access Consulting Group in conjunction with Selkirk First Nation, were used to characterize water quality within the RSA receiving environment.

Table 6.3-1. Water Quality Station Descriptions

Station Function	Station ID	Station Description
Faro Site		
Reference – LSA	FDU	Faro Creek, upstream of diversion
	FC	Faro Creek, upstream of FDU
	R7	North Fork Rose Creek – upstream of Mine
	W10	Upper Guardhouse Creek
Reference – RSA	R6	Anvil Creek – upstream of confluence with Rose Creek
Mine Runoff, Effluent and Internal Receiving Water Body	X5	Cross Valley Pond Outflow
	X13	Cross Valley Dam Seepage
	NE1	Surface seep below the Northeast Dump
	NE2	Surface seep below the Northeast Dump
	X2	North Fork Rose Creek, 100 m upstream of rock drain
	X10	Rose Creek Diversion Channel upstream of X13
Receiver – LSA	X14	Rose Creek, downstream of diversion channel
	R2	Rose Creek, downstream of diversion channel
Receiver – RSA	R3	Rose Creek – mid-way to Anvil Creek confluence
	R4	Rose Creek at Anvil Creek
	R5	Anvil Creek, downstream of confluence with Rose Creek
	R11	Anvil Creek, upstream of confluence with Pelly River
Vangorda Site		
Reference – LSA and RSA	V1	Vangorda Creek above mine
	VR	West Fork Vangorda Creek, above haul road
Mine Effluent and Runoff	V6A	AEX Creek
	V25BSP	Vangorda Creek, below Sheep Pad Pond
	V2	Grum Creek
Receiver - Local Study Area	V27	Vangorda Creek, Main Stem, downstream of mine flow
	VGMAIN	Vangorda Creek, above confluence with West Stem
	V5	West Stem Vangorda Creek
Receiver – Regional Study Area	V8	Vangorda Creek, upstream of the confluence with the Pelly River.
Pelly River		
Reference – RSA	PB	Pelly River, upstream of Blind Creek
Receiver – RSA (Pelly River Aquatic Effects Assessment)	P1[a]	Pelly River, between Vangorda and Anvil Creeks
	P1A	Pelly River, downstream of Anvil Creek
Reference –RSA (Interim Aquatic Ecosystem Monitoring Program)	P1[b]	Pelly River, Upstream of Vangorda Creek
Receiver – Regional Study Area	P2	Pelly River, downstream of Vangorda Creek
	P3	Pelly River, Upstream of Anvil Creek
	P4	Pelly River, downstream of Anvil Creek

[A] *Sampled under the Pelly River Aquatic Effects Assessment Program.*

[b] *Sampled under the Interim Aquatic Ecosystem Monitoring Program.*



Legend

- Water Quality Sampling Locations
- Roads
- Pits
- Regional Study Area
- Rose Creek Watershed
- Local Study Area
- Vangorda Watershed
- Surface Water
- Buildings

Study Area

0 1.25 2.5 5 7.5 10

Kilometres

1:175,000
UTM Zone 8N, NAD 83

Project Number: 70384
Prepared By: RH
Date Issued: March 25, 2008
Reviewed By:
File Name: 70384_Figure2-3_Mar18.mxd

Environmental Assessment of
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for the Faro Mine Complex

Surface Water Quality Study Area

Gartner Lee

Figure 6.3-1

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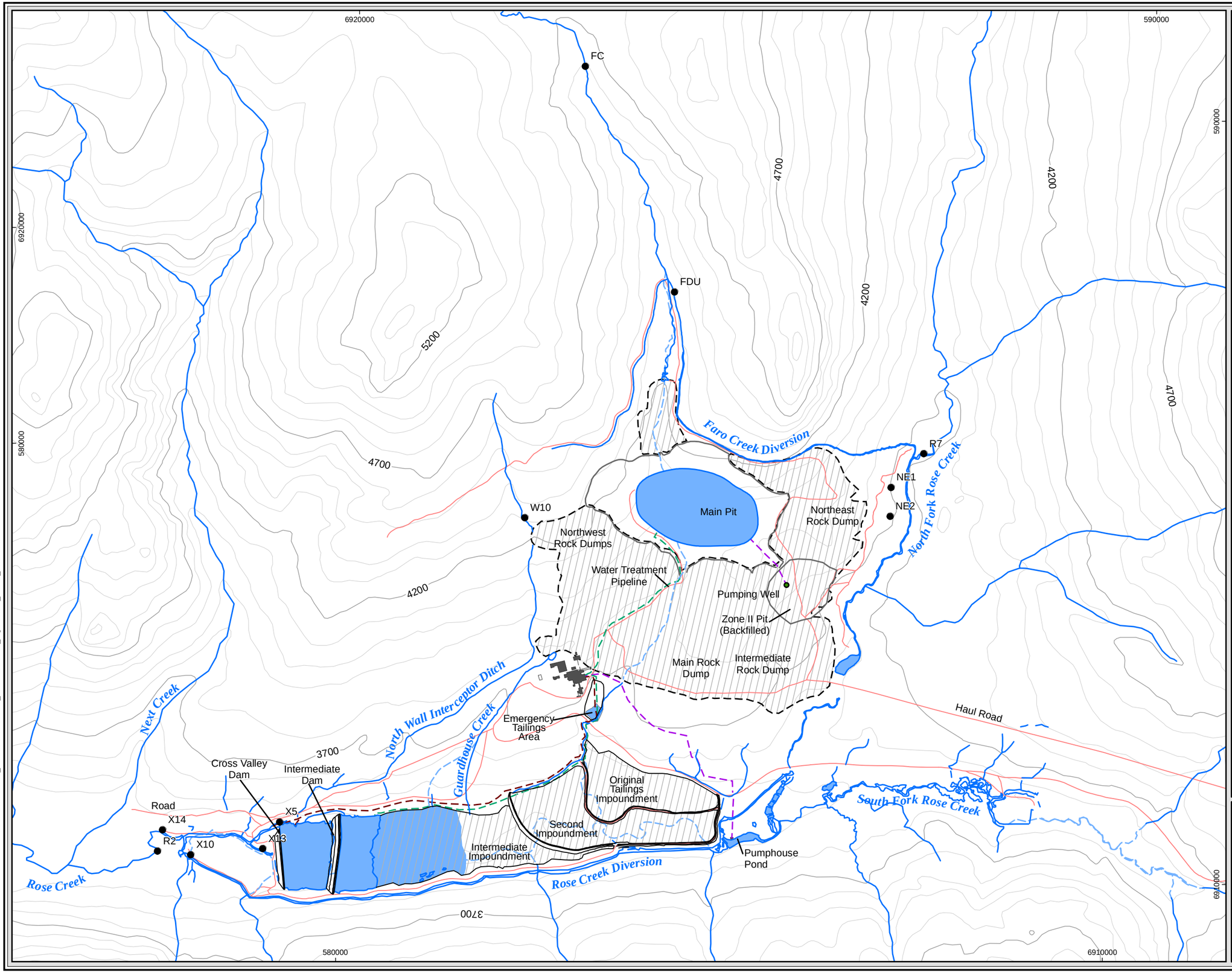
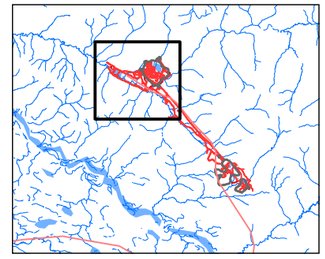
Date Revised: March 24, 2008
Date Plotted: March 24, 2008



Legend

- Surface Water Sampling Locations
- Existing Surface Drainage
- Pre-Mine Drainage
- Effluent Pipeline
- Water Treatment Pipeline
- Pipeline
- Roads
- Buildings
- Tailings Impoundment
- Rock Dump
- Surface Water

Study Area



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UTM Zone 8N, NAD 83

Project Number: 70384
Prepared By: RH
Date Issued: March 25, 2008
Reviewed By:
File Name: 70505_Figure6.5-2_Mar11_ver2.mxd

Environmental Assessment of
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for the Faro Mine Complex

Faro Mine Site
Surface Water Quality
Sampling Locations

Figure 6.3-2

Gartner Lee

Revision: 0
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Date Revised: March 24, 2008
Date Plotted: March 24, 2008

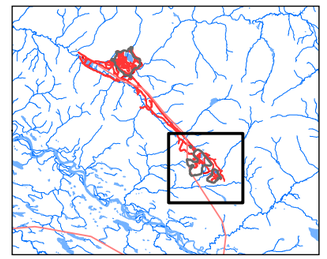
West Fork Vangorda Creek
Vangorda Creek
Magazine Area
Water Treatment Plant
Clarification Pond
Fresh Water Supply Pond
Ditch
Grum Interceptor Ditch
Overland Water Treatment Pipeline
VR
Ore Transfer Pad
Grum Pit (Not Current)
Sub-Station
Grum Overburden Dump
V1
Blind Creek Road
Vangorda North West Interceptor
Vangorda Ck Diversion Flume
Vangorda NE Interceptor Ditch
Vangorda Haul Road
Vangorda Pit
Waste Rock Piles
Former Ore Haul Shop
V6A
Aex Creek
Sheep Pad Sediment Ponds
V25BSP
Plunge Pool
Till Stockpile
590000
Former Old Shop U/G Portal
Former Lube Station
Fuel Tanks
Former Core Shacks
Former Maintenance Storage Area
Shop
Office
Fuel Tank
Little Creek Dam
Emergency Spillway
Moose Pond
Vangorda Rock Dump
Grum Rock Dump (Not Current)
Grum Creek
V2
Seepage Collection Ditch
Sulphide Cell (Design)
Dixon Creek
Shrimp Creek
Vangorda Creek
590000

Date Revised: March 24, 2008
Date Plotted: March 24, 2008
Revision: 0
File Location: S:\GIS_Pdata\Faro\70384-1_EA\MXD\70505_Figure1-3_Mar11.mxd

Legend

- Surface Water Sampling Locations
- Pipelines
- Water Treatment Pipelines
- Roads
- Existing Surface Drainage
- Buildings

Study Area



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Kilometres

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UTM Zone 8N, NAD 83

Project Number: 70384
Prepared By: RH
Date Issued: March 25, 2008
Reviewed By:
File Name: 70505_Figure1-3_Mar11.mxd

Environmental Assessment of
the Closure and Remediation Plan
for the Faro Mine Complex

Vangorda Plateau Mine Site Surface Water Quality Sampling Locations

Gartner Lee

Figure 6.3-3

6.3.7 Baseline Description

For discussion purposes, baseline surface water quality is discussed according to the two watersheds occurring within the mine footprint: the Rose Creek drainage and the Vangorda Creek drainage. Surface water quality within the ultimate downstream receiving environment, the Pelly River, is discussed for the portion of the river that captures inflows potentially influenced by the mine site within the regional study area.

Surface water quality data is presented in Appendix C2 and C3. Statistical analysis was performed on water quality data for the baseline temporal range (2005-2007). A larger temporal range (1998-2007) was evaluated to enable historical trend analysis. Method detection limits (MDLs) were set to one-half the method detection limit for statistical calculations.

To facilitate the interpretation of current influence of the mine site on surface water quality, baseline water quality was evaluated through:

- comparison of water quality to reference stations;
- comparison of water quality between sites; and
- comparison of water quality to draft benchmark guidelines.

Draft water quality benchmarks have been developed for water quality comparison purposes. These benchmarks have been derived from the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 1999), or where no CCME guideline exists, the most conservative provincial water quality criterion from the British Columbia, Saskatchewan, or Ontario was selected. For parameters for which no water quality criteria guideline exists, alternative benchmarks were identified that represent a low- or no- observed effect concentration reported in the scientific literature for a sensitive aquatic species. A total hardness of 100 mg/L was used for those metals where the CCME guidelines are hardness dependent. Selected benchmarks are provided in Table 6.3-2. Guideline sources for each selected benchmarks are provided in Appendix C1.

Background water quality benchmarks are currently being developed for the Faro Mine Complex by Minnow Environmental Inc. on behalf of the Faro Project Management Team. These benchmarks will characterize reference (background) water quality in the Rose Creek and Vangorda Creek watersheds and will facilitate application of a standardized approach for comparing mine exposed stations to natural reference conditions. Preliminary background benchmarks have been developed for the site (Minnow 2007) using routine monitoring water quality data; however, additional water quality data collected from recent sampling events in 2007 will be used to update these benchmarks. The inclusion of the additional water quality data collected in 2007 will provide recent data for background stations not monitored in the last several years (Station FC), as well as lower detection limits for selected parameters below selected benchmark guidelines. Once updated benchmarks are made available, direct comparison of mine influenced waters to background benchmarks will be made as part of the environmental assessment.

Table 6.3-2. Selected benchmarks for evaluation of water quality at Faro Mine, Y

Parameters	Units	Selected Benchmark
Micellaneous Parameters		
alkalinity	mg/L	12.6[a]
ammonia - N, total	"	0.25
chloride	"	250
conductivity	uS	
cyanide, WAD	mg/L	0.005 (free)
dissolved solids, total (TDS)	"	500
fluoride	"	0.12
hardness	"	
nitrate - N	mg/L	13
nitrite - N	"	0.06
organic carbon, dissolved (DOC)	"	
organic carbon, total (TOC)	"	
pH	pH units	6.5-9.0
phosphorus, total	mg/L	0.03
sulphate	"	50
suspended solids, total (TSS)	"	29[b]
Metals		
aluminum	mg/L	0.1
antimony	"	0.020
arsenic	"	0.005
barium	"	1.0
beryllium	"	1.1[c]
bismuth		0.260
boron	"	
cadmium	"	0.00003[c]
calcium	"	
chromium	"	0.001
cobalt	"	
copper	"	0.002[c]
iron	"	0.3
lead	"	0.002[c]
magnesium	"	82.000
manganese	"	1.0[c]
mercury, total	ug/L	0.026
molybdenum	mg/L	0.073
nickel	"	0.065[c]
potassium	"	53
selenium	"	0.001
silver	"	0.0001
sodium	"	200
strontium	"	9.3
thallium	"	0.0008
tin	"	0.35
titanium	"	1.83
uranium	"	0.005
vanadium	"	0.006
zinc	"	0.030
zirconium	"	0.004

[a] Represents a 25% decrease below background level of 16.8 mg/L reported by Minnow (2007)

[b] Based on an increase of 25 mg/L above background level of 4 mg/L reported by Minnow (2007)

[c] Based on water hardness of 100 mg/L as $CaCO_3$

Table 6.3-3. Background Water Quality Benchmarks

Will be updated as information becomes available.

Total metals have been selected for direct comparison to benchmarks based on the following rationale:

- guidelines (and therefore selected benchmarks) for the protection of aquatic life are predominately based on total metals;
- significant correlation between dissolved and total metals species demonstrated through previous investigations (Minnow 2007); and
- delay of filtering for some historic sampling sites until samples are received by the laboratory.

Dissolved metal concentrations for sampling sites within the LSA and RSA have been evaluated for baseline characterization in the context of determining the dominant source of analysed concentrations (i.e., dissolved versus solid phase).

6.3.8 Rose Creek Watershed Surface Water Quality

6.3.8.1 Reference Water Quality

Reference or background water quality in the Rose Creek watershed is regularly monitored at stations FDU, R6, R7, and W10 (Figure 6.3-1). These sites receive surface runoff that have no direct contact with mining activities or site infrastructure. Reference water quality in the Rose Creek drainage collected through routine monitoring programs is compiled in Appendix C2. A summary of reference water quality for selected parameters monitored under this program is provided in Table 6.3-4 and Table 6.3-5.

Additional reference water quality sites were sampled in 2007 under the PRAEMP and IAEMP. These data are compiled separately in Appendix C4. Additional sampling locations monitored under these non-regulated monitoring programs are illustrated in Figure 6.3-17.

Background water quality in Faro Creek in monitored at Station FDU. This station is located immediately upstream of the Faro Creek diversion interception point. Water quality observed between 2005 and 2007 at location FDU is neutral to slightly alkaline, with low hardness (7 mg/L to 14 mg/L) and low alkalinity. Low total zinc and sulphate concentrations were observed over the study period, with median concentrations of 0.025 and 1.79 mg/L, respectively. No historical temporal trends for the above noted parameters are apparent at this location. Total copper at location FDU exceeded the selected water quality benchmark (CCME) for one sampling event in October 2007. Total zinc concentrations exceeded the selected benchmark once between 2005 and 2007. Analytical method detection limits used during routine sampling unfortunately precluded the comparison of silver and cadmium at reference stations to CCME derived selected benchmarks.

In 2007, station FC was sampled outside of the regular routine monitoring program for the purpose of establishing a larger dataset for characterization of reference water quality conditions, with analyses conducted using lower detection limits. Station FC is located upstream of the Faro Creek Diversion Channel. Water quality at this location was sampled monthly from September to

December 2007. Water chemistry at this location is slightly acidic to slightly alkaline, with low alkalinity and low hardness suggesting sensitivity to acidic inputs. Sulphate and total zinc concentrations are low, ranging from 1.2 mg/L to 2.9 mg/L, and 0.0015 mg/L to 0.0061 mg/L, respectively. These concentrations are comparable to the downstream monitoring location FDU. Lower analytical detection limits employed for these analyses allowed comparison of cadmium and silver to selected benchmark values. Neither cadmium or silver concentrations exceeded the selected benchmarks during these sampling events (Appendix C4); however, further monitoring with ultra-low detection limits will be required to evaluate seasonal variability as these samples represent low flow conditions only. No other guideline benchmarks were exceeded during this sampling program at location FC. Water quality at location FDU was also monitored under this sampling program in March 2007. Water quality was comparable to routine sampling events, with low metal and sulphate concentrations and circumneutral pH.

Station R6, located on Anvil Creek just upstream of the confluence with Rose Creek, is sampled biannually. Waters at this station can be characterized as neutral to alkaline, with pH concentrations ranging from 7.4 to 8.4. Waters in Anvil Creek appear to have higher hardness and alkalinity concentrations in comparison to other reference stations, ranging from 7 mg/L to 14 mg/L $CaCO_3$ and 122 mg/L to 135 mg/L $CaCO_3$, respectively. Higher calcium, magnesium, sulphate and hardness concentrations observed at this location in comparison to other reference stations suggests different geochemistry in the upper Anvil Creek watershed than in watersheds upstream of the other reference stations (Minnow 2007). Total zinc concentrations average 0.0047 mg/L, ranging from less than MDL (<0.005 mg/L) to 0.011 mg/L. Additional monitoring conducted in 2007 at this location using lower detection limits determined that cadmium and silver concentrations were below the selected benchmark for these sampling events (Appendix C4).

Reference water quality in North Fork Rose Creek is measured at location R7. The pH at this location ranged from 7.5 to 8.3 and hardness concentrations ranged from 28 mg/L $CaCO_3$ to 147 mg/L $CaCO_3$. Total zinc concentrations range from below MDL (<0.005 mg/L to 0.035 mg/L).

Water quality at station W10 represents reference water quality in Upper Guardhouse Creek, upstream of the northwest rock dump. Field pH ranged from 7.2 to 7.9 and sulphate concentrations are low, averaging 3.5 mg/L. Total zinc concentrations ranged from less than MDL (<0.005 mg/L) to 0.023 mg/L, and dissolved zinc concentrations were below MDL (<0.005 mg/L) over the study period.

Between 2005 and 2007, water quality at routinely monitored reference stations (FDU, R6. R7, and W10) were typically below selected benchmarks. Although concentrations above the selected benchmark were infrequently observed at the four reference stations from 2005 to 2007 with the majority of concentrations elevated above the benchmark were observed at location R7. Total aluminium and iron concentrations recorded above the selected benchmarks at location R7 were associated with spring sampling events, suggesting that elevated concentrations of these parameters are attributed to suspended solids. It should be noted that elevated suspended solids and significantly higher total iron and aluminium concentrations compared to dissolved concentrations were observed during these sampling events.

Total chromium, copper and selenium also exceeded the selected benchmarks during a limited number of sampling events (less than three) at reference stations; however, concentrations were only slightly elevated above the benchmarks on these occasions. Total zinc exceeded the selected benchmark at location R7 during the January 2005 sampling event.

In summary, trace metal concentrations at reference stations exceeded the selected benchmarks for aluminium, copper, chromium, iron and zinc during a limited number of sampling events (less than 20% of the total sampling events for each parameter).

Table 6.3-4. Water Quality at Rose Creek Reference Sites (2005-2007)

Parameter		Alkalinity mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
FDU	N		6	5	6	6	6	6
	Median		30	11	0.0075	7.45	1.785	0.75
	Mean		28.2	11	0.009167	7.5	1.6	0.8
	Minimum		19	7	< 0.01	7.1	1.04	< 1
	Maximum		36	14	0.02	7.9	2.1	1
R6	N	6	6	6	6	6	6	6
	Median	137.5	289	162	0.005	8.05	20.1	0.5
	Mean	138.5	296.7	171.8	0.008	8	29.9	0.8
	Minimum	122	240	132	< 0.01	7.5	19.3	< 1
	Maximum	159	382	261	0.02	8.3	80.1	2
R7	N		35	35	34	35	34	35
	Median		192	103	0.0075	7.8	8.535	0.5
	Mean		191.3	98.9	0.013	7.8	8.4	2.4
	Minimum		53	28	< 0.01	7.3	1.7	< 1
	Maximum		289	147	0.07	8.2	16.9	21
W10	N		6	5	6	6	6	6
	Median		102	49	0.005	7.75	3.44	0.5
	Mean		91.8	47.6	0	7.7	3.5	1
	Minimum		55	27	< 0.01	7.2	2.5	< 1
	Maximum		123	60	0.04	7.9	4.2	3

Table 6.3-5. Trace Metal Concentrations at Rose Creek Reference Sites (2005– 2007)

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00003**		**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.03**
FDU	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.073	0.0005	3.32	0.0001	0.0005	0.0005	0.00075	0.06	0.002	0.0005	0.0005	0.0025
	Mean	0.000125	0.088	0.0005	3.11	0.0001	0.0005	0.0005	0.001083	0.065	0.002	0.0005	0.0005	0.004667
	Minimum	< 0.00025	0.047	< 0.001	2.07	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.001	< 0.001	< 0.001	< 0.005
	Maximum	< 0.00025	0.18	< 0.001	4.11	< 0.0002	< 0.001	< 0.001	0.003	0.14	0.004	< 0.001	< 0.001	0.011
R6	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.018	0.0005	46.2	0.0001	0.0005	0.0005	0.0005	0.115	0.013	0.0005	0.0005	0.0025
	Mean	0.000388	0.0385	0.0005	49.2	0.0001	0.0005	0.000917	0.000917	0.114167	0.0132	0.0008	0.0005	0.003667
	Minimum	< 0.00025	0.013	< 0.001	35.3	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.01	< 0.001	< 0.001	< 0.005
	Maximum	0.0017	0.14	< 0.001	77.8	< 0.0002	< 0.001	0.003	0.003	0.18	0.018	0.002	< 0.001	0.006
R7	N	35	35	35	35	35	35	35	35	35	35	35	35	35
	Median	0.000125	0.018	0.0005	30.6	0.0001	0.0005	0.0005	0.0005	0.12	0.014	0.0005	0.0005	0.0025
	Mean	0.000133	0.0526	0.0006	29.5	0.0001	0.0005	0.0005	0.0008	0.2043	0.0253	0.0006	0.0005	0.0062
	Minimum	< 0.00025	< 0.005	< 0.001	8.41	< 0.0002	0.001	< 0.001	< 0.001	0.05	0.005	< 0.001	< 0.001	< 0.005
	Maximum	0.0004	0.35	0.002	43.9	0.0004	0.001	0.002	0.003	1.41	0.15	0.001	< 0.001	0.035
W10	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.0315	0.0005	15.6	0.0001	0.0005	0.0005	0.001	0.025	0.0005	0.0005	0.0005	0.00375
	Mean	0.000125	0.0432	0.0005	14.4	0.0001	0.0005	0.0005	0.0013	0.0442	0.002	0.0005	0.0005	0.00725
	Minimum	< 0.00025	0.011	< 0.001	7.67	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	< 0.001	< 0.001	< 0.001	< 0.005
	Maximum	< 0.00025	0.13	< 0.001	20	< 0.0002	< 0.001	< 0.001	0.003	0.14	0.007	< 0.001	< 0.001	0.023

6.3.8.2 Mine Runoff, Effluent and Internal Receiving Water Bodies

Water that has had contact with mining activities is treated and discharged from the site via outflow from the Cross Valley Pond (Station X5) or through seepage from the Cross Valley Dam (X13). These two water streams mix with water from the Rose Creek Diversion Channel (which contains diverted clean water and water that may have interacted with mine infrastructure/components).

The discharge of water from the Faro site occurs as seasonal discharge over the Cross Valley Dam (Site X5) or as seepage through the dam (Site X13). The discharge consists of treated pit water and overland runoff from the mine site, and until 2006 water treated in the Down Valley Treatment System. Following decommissioning of the Down Valley Treatment system in 2007, water collected from site runoff, including the ERA, is collected and discharged in the Intermediate Pond. Water from the Intermediate Pond is then pumped for treatment in the Mill Water Treatment System, with treated effluent discharge into the Cross Valley Pond prior to release via X5.

Water quality at these sites was sampled on a regular basis starting in 1986. Prior to 1992, water quality in the Cross Valley Pond was controlled primarily by the characteristics of the settled tailings supernatant from upstream deposition of mill tailings. Zinc and sulphate concentrations averaged 0.24 and 436 mg/L, respectively, and pH ranged from 6.7 to 9.6. Seepage from the pond had lower pH levels (6.1 – 7.8), and zinc concentrations ranged from 0.01 to 0167 mg/L. Iron levels in the seepage (X13) averaged 2.0 mg/L.

Discharge water quality conditions from 1998 to 2007 showed moderate to high levels of calcium (12.8 mg/L to 361 mg/L) as a result of lime treatment upstream. Sulphate concentrations generally remain stable from 1998 to 2002; however, a slight increasing trend is apparent between 2002 and 2007 (Figure 6.3-4). Sulphate concentrations in effluent discharged from the Cross Valley pond between 2005 and 2007 ranged from 74.2 mg/L to 1180 mg/L and pH ranged from neutral to alkaline (7.1 to 8.8). The pond is effective in settling solids, as total suspended solids ranged from <1 mg/L to 5 mg/L, below the selected benchmark of 29 mg/L.

Zinc concentrations increased (average of 0.334 mg/L) in the dam discharge from 1998 to 2002, compared to 0.24 mg/L during operations, likely related to the periodic introduction of a relatively large volume of water pumped from the Faro Main pit beginning in 1998, which was ultimately released to Rose Creek as treated and compliant effluent via location X5.

The implementation of the Mill Treatment system in 2001 resulted in lower zinc concentrations in effluent discharge via X5 than those observed in previous years (Figure 6.3-5). Total zinc concentrations in effluent discharged from 2005 to 2007 via location X5 ranged from 0.018 mg/L to 0.47 mg/L (2005 to 2007), with a median concentration of 0.15 mg/L. Approximately 98% of zinc concentrations at X5 exceeded the selected water quality benchmark of 0.05 mg/L. Total zinc concentrations at X5 are approximately one order of magnitude higher in comparison to those of reference (background) stations.

Figure 6.3-4 Sulphate at X5

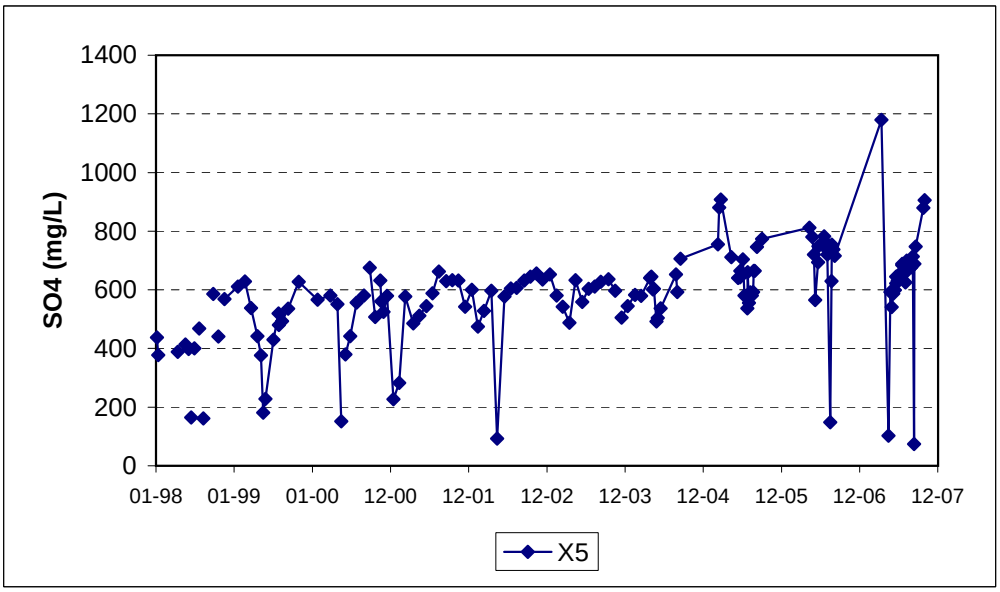
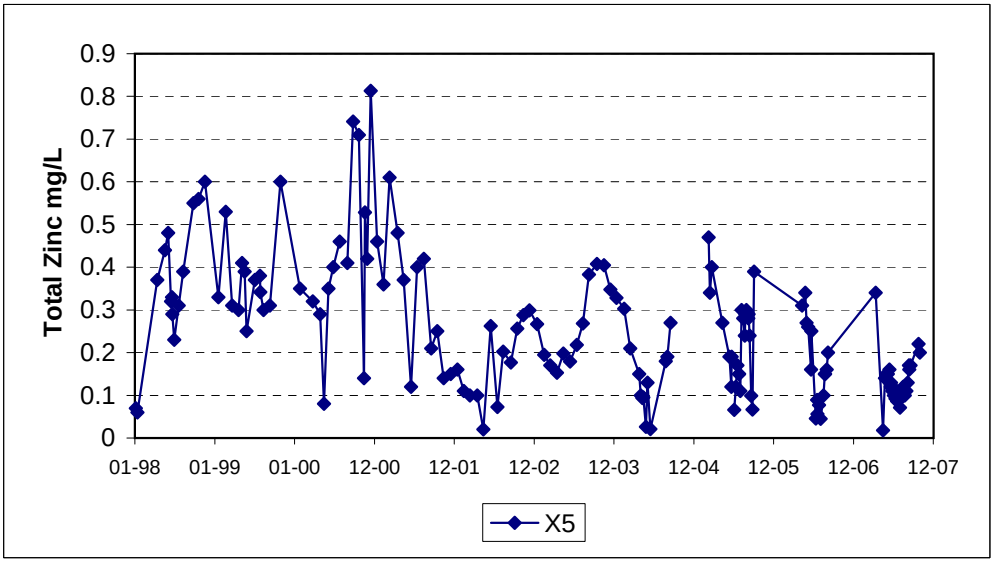


Figure 6.3-5 Zinc at X5



Other trace metal concentrations at location X5 remained low throughout the study period (2005 to 2007). The majority of trace metals are below the selected benchmarks, with the exception of manganese, which exceeded the benchmark concentration of 1 mg/L during most sampling events (98%). Manganese concentrations at X5 range from 0.86 mg/L to 26.5 mg/L, approximately two to four orders of magnitude higher than concentrations (<0.001 mg/L to 0.15 mg/L) observed at reference stations FDU, R6, R7 and W10.

Cyanide exceeded the respective benchmark for all sampling events between 2005 and 2007, while ammonia (NH_3-N) exceeded the selected benchmark of 0.25 mg/L during 98% of the total number of sampling events for the same period.

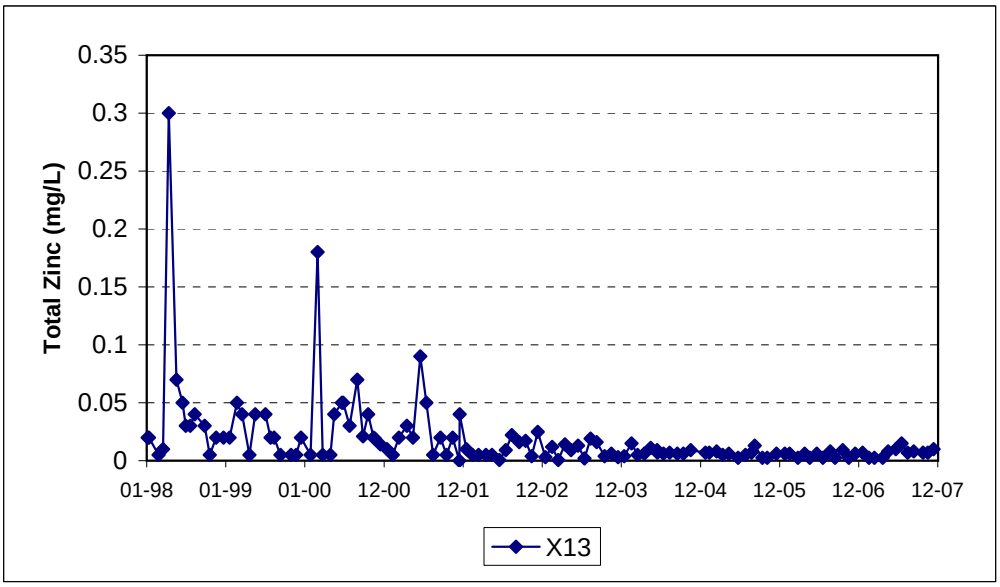
Zinc concentrations in the Cross Valley Pond seepage (location X13) were reduced following mine closure. They averaged 0.039 mg/L between 1998 and 2002, approximately 15% of the concentrations recorded during mine operations. Zinc concentrations increased (average of 0.334 mg/L) in the dam discharge during the care and maintenance phase, compared to 0.24 mg/L during operations, likely related to the periodic introduction of a relatively large volume of water pumped from the Faro Main pit beginning in 1998, which was ultimately released to Rose Creek as treated and compliant effluent via location X5. Zinc concentrations in the seepage at X13 are generally less than those observed at X5 and are comparable to reference water quality, ranging from below MDL (<0.005 mg/L) to 0.015 mg/L between 2005 and 2007 (Figure 6.3-6). Sulphate and pH averaged 756 mg/L and 7.2, respectively, for the same time period.

At location X13, manganese and iron concentrations averaged 10.35 mg/L and 2.02 mg/L, respectively, with concentrations exceeding the selected benchmarks for all sampling events recorded between 2005 and 2007. Manganese and iron concentrations at X13 are typically one to three orders of magnitude greater than concentrations observed at reference stations.

Surface water and groundwater that do not report directly to the tailings impoundment area or that are not collected for treatment have the potential to influence water quality within the downstream receiving environment. Key groundwater loadings to the receiving environment are discussed in Section 6.2.

Surface seepage from the Northeast Waste Rock Dumps is monitored at location NE1 and NE2. Water quality from these locations enters the North Fork of Rose Creek, therefore seepage from these locations contribute to the downstream water quality observed at location X10. Total zinc concentrations at NE1 and NE2 range from less than MDL (<0.005 mg/L) to 0.011 mg/L and 0.071 mg/L, respectively. Field pH at both seep locations are comparable, from neutral to slightly alkaline; however, sulphate concentrations at NE2 are typically higher than those observed at NE1. Sulphate concentrations at both locations have exceeded the selected benchmark of 50 mg/L since 1998, with concentrations ranging from 100 mg/L to 927 mg/L, up to 10 times above reference concentrations. Water chemistry within these seeps suggests that buffered acid rock drainage from the adjacent waste rock piles is impacting water quality at these sites.

Figure 6.3-6 Zinc at X13



Previous studies have noted that sulphate and zinc concentrations undergo a general increase along the North Fork from upstream reference station R7 to stations X2, located at the crossing of the mine access road downstream of the rock drain and rock dumps (GLL 2008). This trend is typically observed during winter months, during low flow conditions. It is suggested that during winter baseflow conditions, groundwater entering the creek is influencing surface water quality; however, in summer months the signature of groundwater contributions are masked by dilution due to higher flow volumes. Water quality at location X2 is circumneutral, with hardness concentrations ranging from 33 mg/L $CaCO_3$ to 187 mg/L $CaCO_3$. Zinc concentrations are typically an order of magnitude higher at this location in comparison to upstream reference station R7. Sulphate concentrations are approximately three to four times higher at X2 compared to R7. Comparison of zinc concentrations over a larger temporal range (1998 to 2007) indicates an increasing trend over the last several years at location X2 (Figure 6.3-8).

Recent investigations suggest that groundwater impacted by seepage from the adjacent waste rock piles is entering the channel via groundwater inflows between locations R7 and X2. Potential groundwater contributions to surface water within this portion of the north fork of Rose Creek are discussed further detail in Section 6.2 of this report.

The increasing trend along the length of the north fork of Rose Creek is not apparent for other trace metals.

The Rose Creek diversion channel receives runoff and seepage from the northeast and intermediate waste rock dumps and other disturbed areas at the Faro Mine Site, including possible lateral seepage from the tailings impoundment. Water quality at X10 is also influence by two tributaries draining from the south side of the Rose Creek Valley. Water quality of the downstream end of the Rose Creek Diversion Channel is monitored at X10, just upstream of the confluence with the discharges at X13 and X5. Between 2005 and 2007 total zinc concentrations at X10 ranged from 0.011 mg/L to 0.10 mg/L, comparable water quality observed at this location since the cessation of mining activities in 1998. Total zinc concentrations at location X10 exceeded the selected benchmark guideline of 0.03 mg/L for half of the sampling events conducted between 2005 and 2007. Minimum total zinc concentrations at this location are comparable to reference water quality, while the upper concentration range is approximately one order of magnitude higher than reference station concentrations.

Sulphate concentrations and pH averaged 12.6 mg/L and 7.6, respectively, between 2005 and 2007 at location X10 with no apparent historical trends observed over a larger temporal range. Trace metal concentrations at this location have remained low since 1998; however, iron concentrations infrequently exceeded (less than 15% of the total sampling events) the selected water quality benchmark of 0.3 mg/L. Iron concentrations ranged from less than MDL (<0.05 mg/L) to 0.81 mg/L for the selected baseline temporal range (2005 to 2007). Lead concentrations slightly exceeded the selected benchmark during four sampling events.

Figure 6.3-7 Sulphate at X2

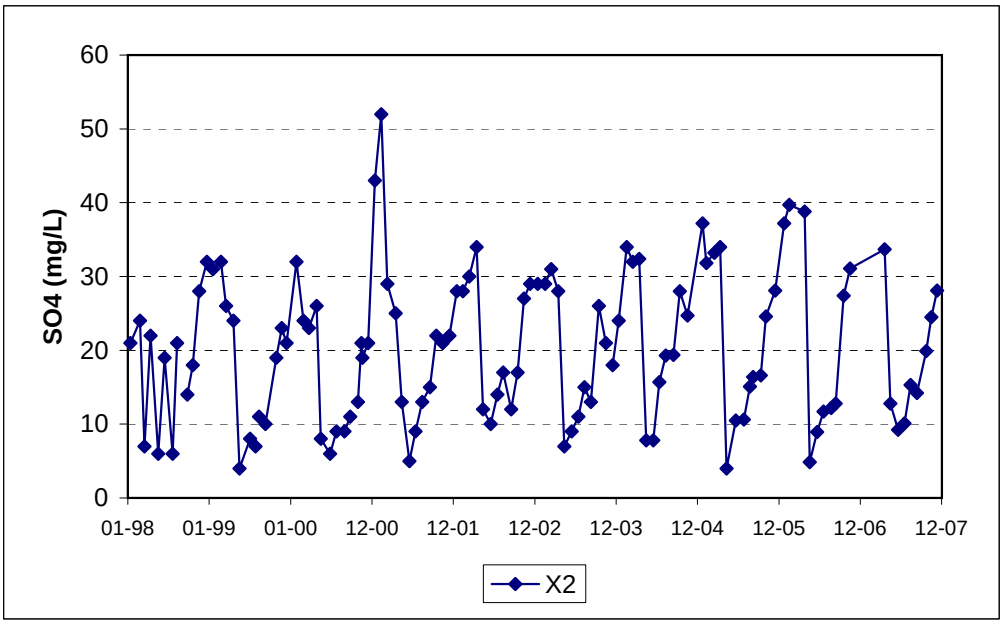


Figure 6.3-8 Zinc at X2

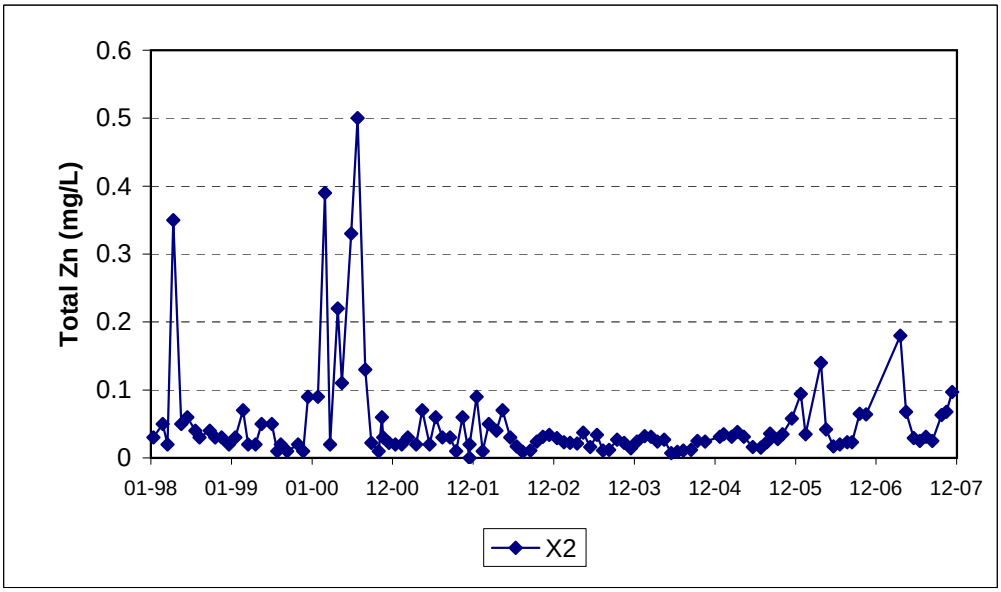


Table 6.3-6. Water Quality at Rose Creek, Mine Effluent/Runoff Sites (2005-2007)

Parameter		Alk-T mg/L	Cond. µs/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
NE1	N		6	5	6	5	6	6
	Median		498.5	286	0.005	7.7	157	0.5
	Mean		571	269	0.008	7.7	171.8	0.5
	Minimum		352	158	< 0.01	7.5	100	< 1
	Maximum		1060	332	0.02	8	266	1
NE2	N		6	5	6	5	6	6
	Median		1075	595	0.005	7.8	454.5	1.25
	Mean		1276.2	685.2	0.012	7.8	553	14.6
	Minimum		867	584	< 0.01	7.4	391	< 1
	Maximum		1980	1020	0.04	8.2	927	51
X5	N	43	66	66	66	62	62	66
	Median	113	1295	690.5	0.89	7.8	680.5	0.5
	Mean	176.5	1336	714.1	0.8	7.9	667.9	0.9
	Minimum	29.8	297	266	0.08	7.1	74.2	< 1
	Maximum	791	2260	1230	1.67	8.8	1180	5
X13	N	30	36	36	36	52	36	36
	Median	279.5	1645	830.5	0.62	7.2	756	4
	Mean	272.9	1638.4	840.6	0.6	7.2	730.3	4.1
	Minimum	231	852	578	0.35	7	422	1
	Maximum	302	2700	1120	0.77	7.7	939	6
X2	N		31	31	31	31	31	31
	Median		191	108	0.005	7.5	16.6	0.5
	Mean		211.9	110.8	0.014	7.5	21.1	1.8
	Minimum		61	33	< 0.01	7.1	4	< 1
	Maximum		344	187	0.06	8	39.7	9
X10	N	30	36	36		36	36	36
	Median	104.5	242.5	126.5		7.8	24.05	0.5
	Mean	114.6	239.3	126.9		7.8	24.1	1.4
	Minimum	34.2	79	40		5	5.4	< 1
	Maximum	242	421	212		8.5	45.8	14

Table 6.3-7. Trace Metal Concentrations at Rose Creek, Mine Effluent/Runoff Sites (2005– 2007)

Parameter		Ag mg/L	Al mg/L	As mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Ni mg/L	Pb mg/L	Zn mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00003**		**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.03**
NE1	N	6	6	6	6	6	6	6	14	6	6	6	6	6
	Median	0.000125	0.00425	0.0005	71.15	0.0001	0.0005	0.0005	0.0035	0.0475	0.0005	0.001	0.0005	0.00425
	Mean	0.00013	0.007	0.001	66.57	0.0001	0.0005	0.0005	0.0166	0.05	0.0012	0.001	0.0006	0.0059
	Minimum	< 0.00025	< 0.005	< 0.001	41.5	0.0002	< 0.001	< 0.001	0.001	< 0.05	< 0.001	< 0.001	< 0.001	< 0.005
	Maximum	< 0.00025	0.019	< 0.001	88.1	0.0002	< 0.001	< 0.001	0.114	0.09	0.004	0.002	0.001	0.011
NE2	N	6	6	6	6	6	6	6	13	6	6	6	6	6
	Median	0.000125	0.0895	0.0005	108	0.0001	0.0005	0.0005	0.003	0.14	0.0025	0.005	0.0005	0.078
	Mean	0.00013	0.136	0.001	118.67	0.0001	0.0005	0.0005	0.0144	0.21	0.0051	0	0.0005	0.0622
	Minimum	< 0.00025	< 0.005	< 0.001	103	< 0.0002	< 0.001	< 0.001	0.002	0.06	< 0.001	0.002	< 0.001	< 0.005
	Maximum	< 0.00025	0.39	< 0.001	155	< 0.0002	< 0.001	< 0.001	0.049	0.52	0.012	0.006	< 0.001	0.12
X5	N	66	66	66	66	66	66	66	154	66	66	66	66	66
	Median	0.000125	0.0085	0.0005	213.5	0.0001	0.006	0.0005	0.002	0.19	4.79	0.012	0.0005	0.15
	Mean	0.00016	0.01	0.001	215.9	0.0001	0.007	0.001	0.0115	0.238	6.029	0.014	0.001	0.176
	Minimum	< 0.00025	< 0.005	< 0.001	90.6	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.86	0.002	< 0.001	0.018
	Maximum	0.001	0.039	0.001	361	0.0005	0.026	< 0.001	0.137	1.02	26.5	0.051	0.005	0.47
X2	N	36	36	36	36	36	36	36	124	36	36	36	36	36
	Median	0.000125	0.005	0.002	246	0.0001	0.006	0.0005	0.008	2.02	10.35	0.0145	0.0005	0.006
	Mean	0.00013	0.008	0.002	251.4	0	0.006	0.001	0.0193	2.053	10.352	0.015	0.001	0.006
	Minimum	< 0.00025	< 0.005	< 0.001	173	< 0.0002	0.002	< 0.001	< 0.001	0.55	6.01	0.011	< 0.001	< 0.005
	Maximum	< 0.00025	0.031	0.003	328	0.0006	0.012	< 0.001	0.666	3.26	14.5	0.019	< 0.001	0.015
X13	N	36	36	36	36	36	36	36	124	36	36	36	36	36
	Median	0.000125	0.005	0.002	246	0.0001	0.006	0.0005	0.008	2.02	10.35	0.0145	0.0005	0.006
	Mean	0.00013	0.008	0.002	251.4	0	0.006	0.001	0.0193	2.053	10.352	0.015	0.001	0.006
	Minimum	< 0.00025	< 0.005	< 0.001	173	< 0.0002	0.002	< 0.001	< 0.001	0.55	6.01	0.011	< 0.001	< 0.005
	Maximum	< 0.00025	0.031	0.003	328	0.0006	0.012	< 0.001	0.666	3.26	14.5	0.019	< 0.001	0.015
X2	N	31	31	31	31	31	31	31	115	31	31	31	31	31
	Median	0.000125	0.021	0.0005	31.1	0.0001	0.0005	0.0005	0.007	0.19	0.068	0.001	0.0005	0.035
	Mean	0.000125	0.046	0.0005	31.785	0	0.0005	0.0005	0.0154	0.23	0.076	0.0009	0.0012	0.048
	Minimum	< 0.00025	< 0.005	< 0.001	9.71	< 0.0002	< 0.001	< 0.001	< 0.001	0.05	0.019	< 0.001	< 0.001	0.015
	Maximum	< 0.00025	0.27	0.001	53.4	0.0002	< 0.001	0.001	0.253	0.66	0.21	0.002	0.007	0.18
X10	N	36	36	36	36	36	36	36	36	36	36	36	36	36
	Median	0.000125	0.012	0.0005	36.25	0.0001	0.0005	0.0005	0.0005	0.225	0.042	0.0005	0.0005	0.0355
	Mean	0.000185	0.031	0.0005	36.41	0.0001	0.0005	0.0005	0.0008	0.244	0.046	0.0008	0.0009	0.040278
	Minimum	< 0.00025	< 0.005	< 0.001	11.7	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.009	< 0.001	< 0.001	0.011
	Maximum	0.0023	0.25	0.001	62.6	< 0.0002	< 0.001	< 0.001	0.003	0.81	0.089	0.003	0.005	0.1

6.3.8.3 Receiving Water Quality

Water quality downstream of the mine site is influenced by the discharge of compliant effluent from the Cross Valley Pond, seepage from the dam, groundwater inflows from the Rose Creek Aquifer and inflows from in the Rose Creek Diversion Channel, which contain source loadings from surface runoff and groundwater inputs from mine areas and waste rock dumps via the North Fork of Rose Creek. Receiving water quality within the local study area is regularly monitored at locations X14 and R2. Local study area receiving water quality is summarized in Table 6.3-8 and Table 6.3-9.

Sampling station X14 is located immediately downstream of the confluence of effluent discharges (locations X5 and X13) and Rose Creek. Water quality observed at location X14 is significantly influenced during periods of active discharge of treated effluent from the Cross Valley Pond. Sulphate and zinc concentrations typically increase during periods of active discharge (summer months), with peak annual concentrations observed in concert with initiation of active discharge in the spring. Total zinc concentrations averaged 0.045 mg/L between 2005 and 2007, slightly elevated in comparison to reference stations. Sulphate concentrations at this location are approximately 5 to 10 times higher than reference concentrations, ranging from 16.8 mg/L to 704 mg/L (Table 6.3-9). Waters are neutral to slightly alkaline, with hardness concentrations ranging from 54 mg/L $CaCO_3$ to 812 mg/L $CaCO_3$ (Table 6.3-8). Aluminium, copper, and lead exceeded the selected benchmarks during 12 to 13% of all sampling events between 2005 and 2007. Manganese concentrations exceeded the selected benchmark of 1.0 mg/L on several occasions (33%), and total zinc exceeded the selected benchmark during 55% of the sampling events. Total iron concentrations exceeded the selected benchmark of 0.3 mg/L for during half of the sampling events between 2005 and 2007. Maximum iron and lead concentrations are typically observed in concert with peak total suspended solids in the spring.

Station R2 is located approximately 100 m downstream of location X14 in Rose Creek below the effluent-mixing zone. Water chemistry at this location is comparable to X14, which is expected based on the close proximity of the two stations and the lack of significant surface inflows within this portion of the creek. R2 has been historically sampled twice a year; therefore, seasonal and temporal trends are not as apparent at this station in comparison to X14. Total zinc concentrations at this location ranged from 0.022 mg/L to 0.052 mg/L (Figure 6.3-9).

Table 6.3-8. Receiving Water Quality, Local Study Area, Rose Creek Drainage (2005 - 2007)

Parameter		Alk-T mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		12.6			0.25	6.5-9.0	50	29
R2	N	6	6	6	6	6	6	6
	Median	133.5	524.5	277.5	0.125	7.65	152	2
	Mean	137.8	537.2	284.3	0.13	7.6	166	1.8
	Minimum	91.9	341	158	0.08	7.2	88.2	< 1
	Maximum	203	815	425	0.19	8	288	3
X14	N	62	89	89	89	84	85	89
	Median	102	332	174	0.09	7.8	99.3	1
	Mean	109.6	424.9	215.1	0.107	7.8	131.2	3.7
	Minimum	32.5	112	54	< 0.01	7.2	16.8	< 1
	Maximum	240	1630	812	0.56	8.4	704	46

6.3.8.4 Regional Study Area Water Quality, Rose Creek Drainage

Water quality within the regional study area of the Rose Creek drainage is monitored at downstream sampling sites R3, R4, R5 and R11. Regional water quality within the Rose Creek drainage is summarized in Table 6.3-10 and Table 6.3-11.

Figure 6.3-9 Zinc at X14/R2

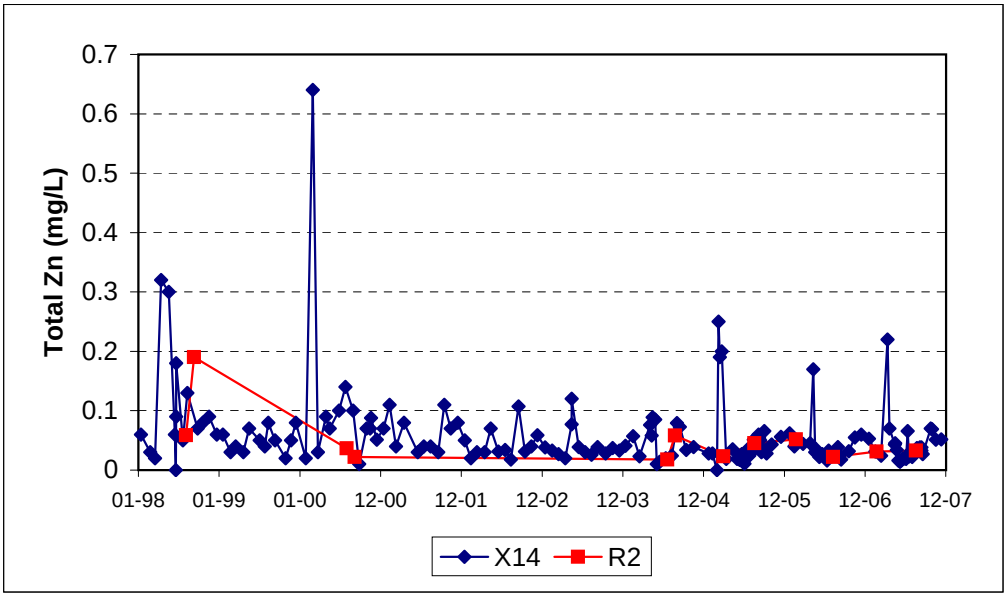


Figure 6.3-10 Sulphate at X14/R2

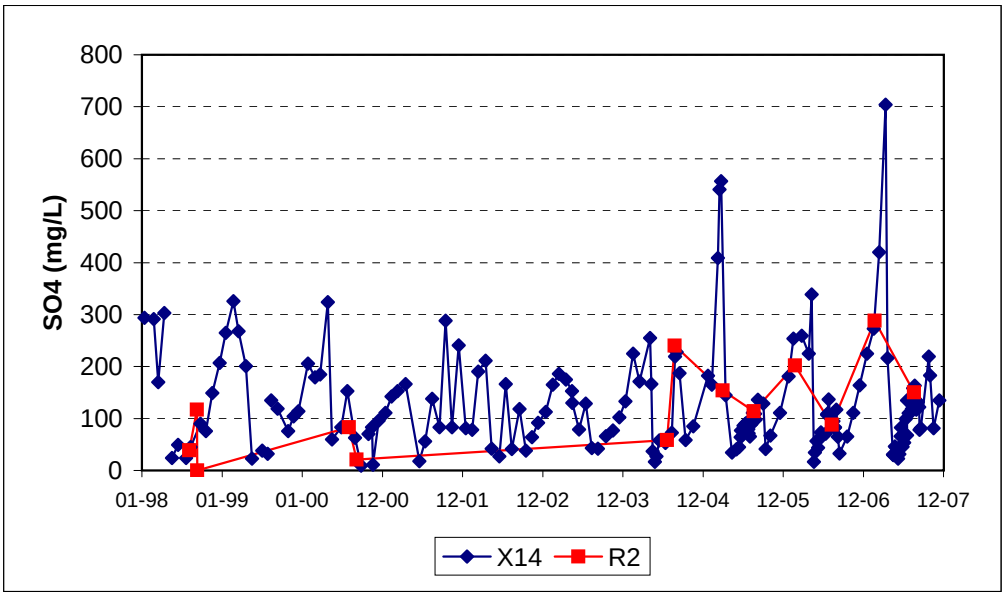


Table 6.3-9. Trace Metal Concentrations in Rose Creek Local Study Area Receiving Waters (2005-2007)

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00003**		**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.03**
R2	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.015	0.0005	80.4	0.0001	0.001	0.0005	0.0005	0.32	1.465	0.0025	0.0005	0.032
	Mean	0.000171	0.0168	0.0007	83.6	0.0001	0.0012	0.0005	0.0008	0.32	1.56	0.0032	0.0005	0.034
	Minimum	< 0.00025	0.009	< 0.001	47.4	< 0.0002	< 0.001	< 0.001	< 0.001	0.24	0.51	0.002	< 0.001	0.022
	Maximum	0.0004	0.026	0.001	126	< 0.0002	0.002	< 0.001	0.002	0.45	3.02	0.006	< 0.001	0.052
X14	N	89	89	89	89	89	89	89	89	89	89	89	89	89
	Median	0.000125	0.024	0.0005	50.6	0.0001	0.0005	0.0005	0.001	0.3	0.75	0.002	0.0005	0.032
	Mean	0.00017	0.068	0.0005	63.23	0.0001	0.0013	0.0005	0.0012	0.3838	1.4363	0.0035	0.0012	0.0446
	Minimum	< 0.00025	< 0.005	< 0.001	16.1	< 0.0002	< 0.001	< 0.001	< 0.001	0.12	0.19	< 0.001	< 0.001	0.011
	Maximum	0.0023	0.58	0.002	243	0.0003	0.015	0.001	0.012	1.59	16	0.03	0.008	0.25

Table 6.3-10. Water Quality in Rose Creek, Regional Study Area

Parameter		Alk-T mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		12.6			0.25	6.5-9.0	50	29
R3	N	6	6	6	6	6	6	6
	Median	131	472.5	230.5	0.07	7.9	132	0.5
	Mean	131.6	467.7	245	0.059	7.85	127.8	1
	Minimum	93.6	333	160	< 0.01	7.4	81.3	< 1
	Maximum	180	619	334	0.08	8.2	187	2
R4	N	6	6	6	6	6	6	6
	Median	123	383	217	0.02	7.95	97.3	0.5
	Mean	125.5	400.2	214	0.019	7.9	100	1
	Minimum	99	302	150	< 0.01	7.6	74.9	< 1
	Maximum	163	514	262	0.04	8.4	127	3
R5	N	4	4	4	4	4	4	4
	Median	133.5	274.5	150	0.005	8.1	26.55	0.5
	Mean	130.3	296	176.8	0.005	8	38.8	1.1
	Minimum	117	252	135	< 0.01	7.5	21.7	< 1
	Maximum	137	383	272	< 0.01	8.3	80.3	3
R11	N	6	6	6	6	6	6	6
	Median	124.5	311	164.5	0.0125	7.95	48.3	0.5
	Mean	124.5	314.7	179.3	0.014	7.8	51.4	1.3
	Minimum	101	245	135	< 0.01	7.4	38.6	< 1
	Maximum	151	383	290	0.03	8.2	81.9	4

R3 is located in Rose Creek approximately mid-point between station R2 and the confluence with Anvil Creek. Location R4 is located within Rose Creek, upstream of the confluence with Anvil Creek. Water chemistry at R3 and R4 is characterized by neutral to alkaline conditions with hardness ranging from 160 mg/L $CaCO_3$ to 619 mg/L $CaCO_3$. Zinc concentrations at R3 and R4 are elevated in comparison to reference water quality and concentrations frequently exceed the selected benchmark of 0.03 mg/L. Sulphate, calcium, and manganese also remain elevated above reference concentrations within this reach of Rose Creek; however, the low toxicity of these parameters suggest minimal impact to aquatic life.

Further downstream, below the confluence of Anvil and Rose Creek, water quality at station R5 is comparable with reference water quality, with the exception of calcium and magnesium concentrations, which are slightly elevated over reference sites. Iron and copper frequently exceed the selected CCME derived selected benchmark during the majority of sampling events; however,

Table 6.3-11. Total Metals in Rose Creek, Regional Study Area

Parameter		Ag	Al	As	Ca	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00003**		**0.001**	**0.002**	**0.3**	**1**	**0.065**	**0.002**	**0.03**
R3	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.007	0.0005	67.6	0.0001	0.0005	0.0005	0.0005	0.115	0.57	0.0015	0.0005	0.018
	Mean	0.00025	0.0084	0.0006	72.2	0.0001	0.0005	0.0005	0.0005	0.1	0.588	0.0016	0.0005	0.02
	Minimum	< 0.00025	< 0.005	< 0.001	48.2	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.076	< 0.001	< 0.001	0.01
	Maximum	0.0006	0.016	0.001	99	< 0.0002	< 0.001	< 0.001	< 0.001	0.17	1.16	0.003	< 0.001	0.034
R4	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.013	0.0005	63.6	0.0001	0.0005	0.0005	0.0005	0.105	0.1	0.001	0.0005	0.008
	Mean	0.000204	0.012	0.0006	63.3	0.0001	0.0005	0.0005	0.0005	0.09	0.19	0.001	0.0005	0.01
	Minimum	< 0.00025	< 0.005	< 0.001	45.2	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.017	< 0.001	< 0.001	< 0.005
	Maximum	0.0006	0.019	0.001	77.6	< 0.0002	< 0.001	< 0.001	< 0.001	0.17	0.47	0.002	< 0.001	0.025
R5	N	4	4	4	4	4	4	4	4	4	4	4	4	4
	Median	0.000125	0.018	0.0005	41.9	0.0001	0.0005	0.0005	0.0005	0.11	0.028	0.0005	0.0005	0.0025
	Mean	0.000244	0.02075	0.0005	50.4	0.0001	0.0005	0.0005	0.0006	0.104	0.0373	0.0005	0.0005	0.0036
	Minimum	< 0.00025	0.017	< 0.001	36.3	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.016	< 0.001	< 0.001	< 0.005
	Maximum	0.0006	0.03	< 0.001	81.5	< 0.0002	< 0.001	< 0.001	0.001	0.17	0.077	< 0.001	< 0.001	0.007
R11	N	6	6	6	6	6	6	6	6	6	6	6	6	6
	Median	0.000125	0.021	0.0005	48.15	0.0001	0.0005	0.0005	0.0005	0.08	0.0195	0.0005	0.0005	0.0025
	Mean	0.000254	0.026	0.0007	52.55	0.0001	0.0005	0.0005	0.0005	0.075	0.024	0.0005	0.0005	0.004
	Minimum	< 0.00025	0.007	< 0.001	38.3	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.005	< 0.001	< 0.001	< 0.005
	Maximum	0.0009	0.061	0.001	85.9	< 0.0002	< 0.001	< 0.001	< 0.001	0.12	0.059	< 0.001	< 0.001	0.008

reference background water quality also exceeds these benchmarks.

Site R11 represents the most downstream water quality monitoring station within Anvil Creek, immediately upstream of the confluence with the Pelly River. Water quality at this location is comparable to reference water quality conditions. Total zinc concentrations at this location ranged from below MDL (<0.005 mg/L) to 0.008 mg/L, comparable to reference locations. Manganese, sulphate, calcium and conductively are elevated in comparison to reference stations. Minnow Environmental Inc. noted similar historical trends at downstream locations during previous investigations (Minnow 2007). Aluminium, iron, copper, chromium, iron, nickel lead and zinc concentrations at R11 are within ranges typically observed at reference stations. Inadequate detections limits in the analyses of silver and cadmium preclude comparison to benchmark concentrations.

Comparison of spatial water quality trends from R3 to R11 suggests that dilution of mine site related discharge is the dominant influence of water quality along the length of these tributaries. Typically, median metal concentrations decrease as distance from the mine site increases (Table 6.3-11).

6.3.8.5 Rose Creek Watershed Surface Water Quality Summary

In summary, baseline water quality conditions in the Rose Creek Watershed are characterized by:

- circumneutral to alkaline conditions, low total suspended solids, low sulphate concentrations with trace metals of aluminium, cooper, chromium, iron, selenium and zinc exceeding selected benchmark (CCME guideline) concentrations in reference water quality;
- elevated concentrations of calcium, manganese, and sulphate in effluent released from the Cross Valley Pond several orders of magnitude above reference water quality, and elevated concentrations of ammonia, iron, nickel and zinc above reference concentrations;
- water quality immediately downstream of the mine site reflects the signature of mine discharge, with elevated concentrations of trace metals above benchmark guidelines including aluminium, copper, iron, manganese, and zinc; and
- dilution of all mining related influences at downstream monitoring locations within Anvil Creek with the exception of sulphate, calcium and manganese.

6.3.9 Vangorda Watershed Surface Water Quality

6.3.9.1 Reference Water Quality

Location V1 is in the Main Fork of Vangorda Creek, immediately upstream of mine activities. This location provides background reference stream water quality for Vangorda Creek upstream of the mine site. Location V1 was sampled eleven times between 2005 and 2007. Reference site water quality data are provided in Table 6.3-12. An additional reference station, site VR, was monitored as part of the Pelly River Aquatics Effects Assessment in the fall of 2007. Site VR is located in the west fork of Vangorda Creek, upstream of the haul road (Figure 6.3-1). Water quality data from

monitoring programs other than routine monitoring for water licence compliance purposes are provided in Appendix C4.

Table 6.3-12. Water Quality at Vangorda Creek Reference Site (V1), 2005 – 2007

	Parameter	Alk-T mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
V1	N	9	11	11	11	10	11	11
	Median	26.2	73	29	0.005	8.05	9.75	0.5
	Mean	28.3	75.9	33.5	0.007	7.8	8.8	0.8
	Minimum	14.8	35	13	< 0.01	7	3.62	< 1
	Maximum	45.4	121	59	0.03	8.3	11.3	3

Other water quality stations, including V4 and V20 were used to characterize reference water quality during the 2003 environmental assessment for care and maintenance activities (GLL 2003a). Although these locations do not directly receive mine discharge inflows, these location are not physically located upstream of mine infrastructure including waste rock piles, and therefore have not been included in the characterization of reference water quality.

Between 2005 and 2007, sulphate concentrations ranged from 3.62 mg/L to 11.3 mg/L, with a neutral to slightly alkaline pH ranging from 7 to 8.3. The stream waters were clear, with total suspended solids levels of less than 1 mg/L to 3 mg/L. Ammonia concentrations were less than detection limit (0.01mg/L) for all sampling events between 2005 and 2007 with the exception of the June 2005 sampling event (0.03 mg/L). Sulphate concentrations during this period were also similar to historical concentrations, including a seasonal sulphate trend, with slightly higher concentrations observed during winter months (Figure 6.3-11). Reference stream water quality for 2005 to 2007 were found to have low to moderate hardness ranging from 13 to 59 mg/L $CaCO_3$.

Trace metal concentrations in reference waters indicate mineralized geology, with detectable concentrations of most trace metals (Table 6.3-13). Trace metal levels in upper Vangorda Creek for aluminium, arsenic, chromium, copper, iron, nickel, lead and zinc generally did not exceed the selected benchmarks between 2005 and 2007, while total metal concentrations for silver, arsenic, cadmium, chromium, copper, nickel, lead, selenium, antimony and thallium were generally less than the detection limit.

Table 6.3-13. Trace Metal Concentrations at Vangorda Creek Reference Site (V1), 2005 – 2007

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	ZN-T mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00004**	_	**0.001**	**0.002**	**0.26**	**1**	**0.065**	**0.0005**	**0.0168**
V1	N	11	11	11	11	11	11	11	11	11	11	11	11	11
	Median	0.00013	0.024	0.0005	9.48	0.0001	0.0005	0.0005	0.0005	0.025	0.001	0.0005	0.0005	0.0025
	Mean	0.00013	0.11473	0.00068	10.7	0.0001	0.0005	0.00055	0.00064	0.0505	0.0026	0.0005	0.0005	0.00714
	Minimum	< 0.00025	0.006	< 0.001	4.31	< 0.0002	< 0.001	< 0.001	< 0.001	0.05	< 0.001	< 0.001	< 0.001	< 0.005
	Maximum	< 0.00025	0.99	0.002	18.7	< 0.0002	< 0.001	0.001	0.002	0.14	0.014	< 0.001	< 0.001	0.038

Figure 6.3-11 Sulphate at V1

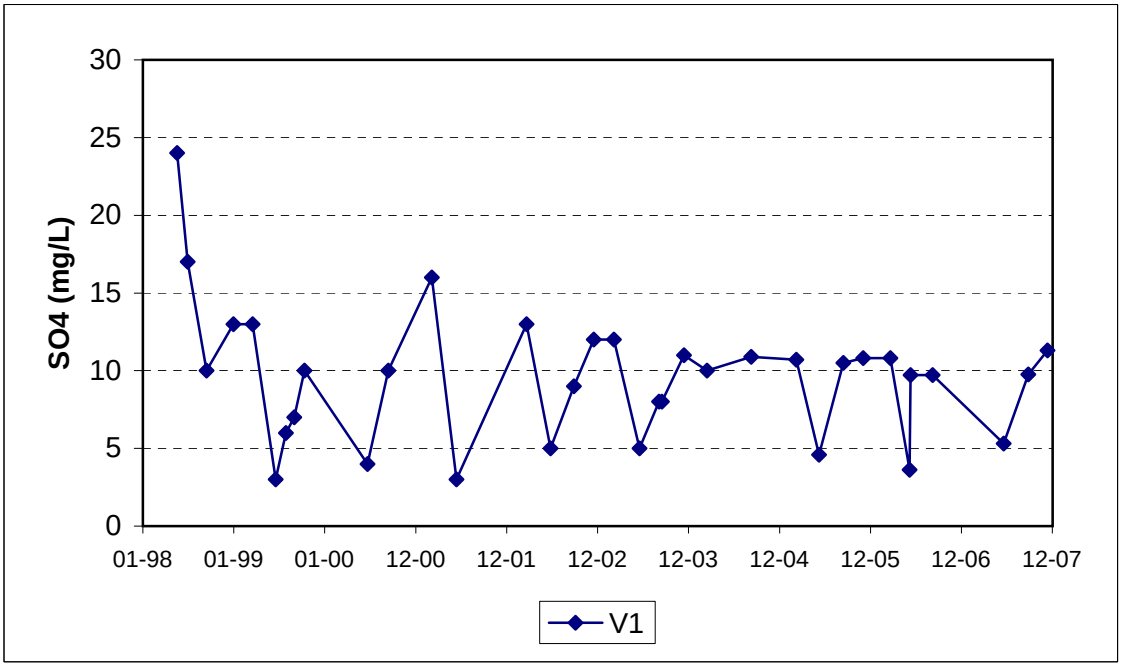
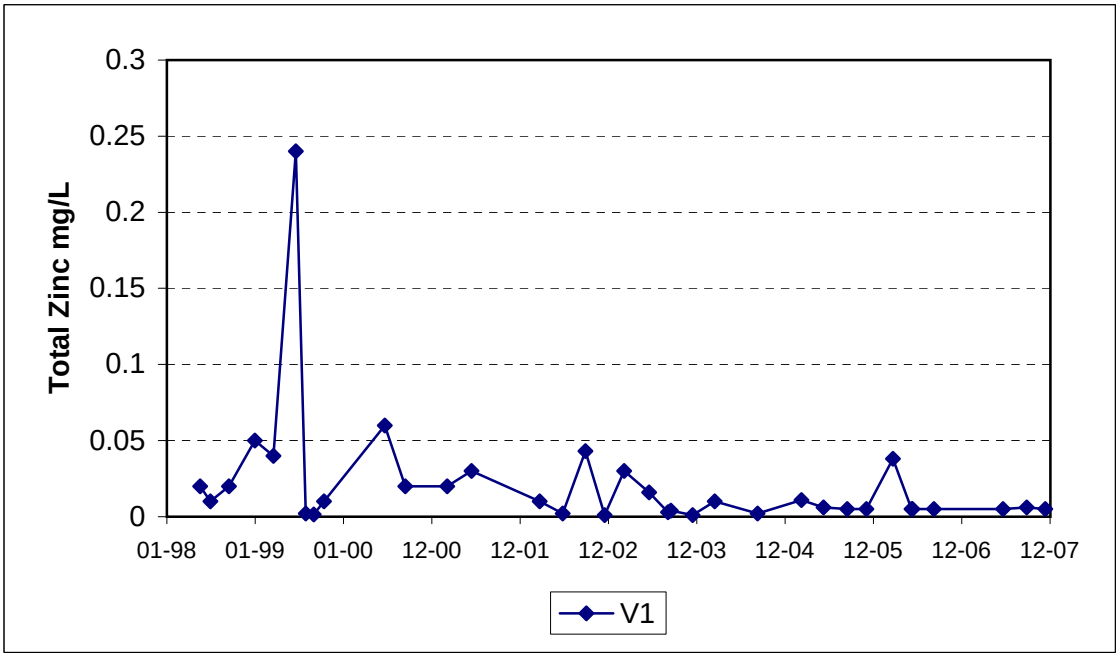


Figure 6.3-12 Zinc at V1



Total zinc concentrations ranged from <0.005 mg/L to 0.038 mg/L. Zinc concentrations in 2007 are similar those previously recorded between 1998 and 2007 at this site (Figure 6.3-12). Total iron concentrations ranged from 0.05 to 0.14 mg/L and were below the selected guideline benchmark of 0.30 mg/L for all sampling events between 2005 and 2007. Lower detection limits used for samples collected at V1 through additional monitoring programs indicate that cadmium concentrations exceeded the benchmark concentration of 0.00003 mg/L on only one occasion, in October 2007 (Appendix C3). Silver concentrations remain below the detection limit during this monitoring program. Higher detection limits reported during routine monitoring programs prevent to comparison of cadmium and silver concentrations to selected benchmarks for this dataset.

Water quality at station VR during the fall of 2007 is comparable to V1, with neutral pH, low hardness, alkalinity, and sulphate concentrations. Total zinc concentrations range from 0.009 mg/L to 0.0049 mg/L, with all recorded concentrations below the benchmark value of 0.03 mg/L. Low detection limits employed during analyses of samples collected from this location facilitates comparison of cadmium and silver to benchmark concentrations, as detection limits are below benchmarks for these analyses. One recorded cadmium concentration was slightly elevated above the CCME derived benchmark of 0.00003 mg/L in October 2007, whereas silver concentrations remained below the selected benchmark. Other parameters were generally below benchmark concentrations. Limited data prevents the analyses of seasonal trends at this site.

6.3.9.2 Mine Runoff and Effluent

Mine runoff water and effluent from the Vangorda Plateau enter the receiving water, Vangorda Creek, at three locations as follows.

1. Location V25BSP is the outlet of the Sheep Pad Pond, which includes periodic or seasonal release of effluent from the Grum/Vangorda water treatment plant. There is typically no flow at this location in the winter season.
2. Location V2 is the outlet of Grum Creek that includes runoff from the Grum rock dump.
3. Location V6A is the outlet of AEX Creek that includes runoff from the ore transfer pad.

Water quality at V25BSP, V2, V6A were sampled on a regular basis starting in 1996, 1988 and 1989, respectively. Data for these three sites for the 2005 to 2007 timeframe is summarized on Table 6.3-14 and Table 6.3-15.

Sheep Pad Pond

Location V25BSP was created in 1995 as part of the sediment mitigation activities that rerouted the Grum Interceptor Ditch into the Sheep Pad Pond. Location V25BSP consists of all water that enters Vangorda Creek via the Sheep Pad Pond, including water discharged from the water treatment plant/clarification pond and natural runoff. Location V25BSP is a licence discharge location and is a point of compliance for water entering Vangorda Creek from the Sheep Pad Pond. Sampling is undertaken weekly during periods of discharge from the water treatment plant and monthly at other times.

Table 6.3-14. Water Quality at Vangorda Mine Site Runoff and Effluent Discharge Sites, 2005-2007

Parameter		Alk-T mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
V25BSP	N	28	34	34	34	35	33	34
	Median	63.4	735	419.5	0.02	7.9	387	0.5
	Mean	63.1	1002.4	628.7	0.1	7.8	614.4	1.9
	Minimum	35.1	119	63	< 0.01	7	27.8	< 1
	Maximum	85.2	2190	1300	0.46	8.3	1340	34
V2	N	47	49	49	31	50	48	49
	Median	318	1900	1210	0.005	8	940	0.5
	Mean	318.7	1889	1138	0.013	8	892.1	1.7
	Minimum	257	1270	719	< 0.01	7.5	554	< 1
	Maximum	364	2410	1460	0.04	8.3	1160	18
V6A	N	8	10	10	10	9	10	10
	Median	64.3	168	79.3	0.01	8.1	24.3	1
	Mean	65	186.3	97.7	0.05	7.97	29.9	2.7
	Minimum	33.8	99	47	< 0.01	7.4	13.6	< 1
	Maximum	98.2	315	182	0.32	8.3	53.5	11

The concentrations of total suspended solids at location V25BSP were below the maximum allowable discharge limit of 15 mg/L and the selected benchmark of 29 mg/L, with the exception of the May 2005 sample (34 mg/L). Hardness was elevated between 2005 and 2007 in comparison to reference station V1, ranging from 63 to 1,300 mg/L $CaCO_3$.

The concentrations of sulphate ranged from 27.8 mg/L to 1340 mg/L with peak concentration occurring during August 2005. The peak concentration observed in August 2005 is well above the maximum concentration seen in 2006 and 2007(Figure 6.3-13). The pH ranged from 7.0 to 8.3 being neutral to slightly alkaline. Ammonia levels were elevated (0.12-0.46 mg/L) during the summer of 2005 consistently exceeding the selected benchmark (0.25 mg/L). In 2006 and 2007 ammonia concentrations were detectable, but low (<0.01 to 0.04 mg/L) and well below the selected benchmark (0.25mg/L).

The concentrations of total and dissolved zinc ranged from 0.026 mg/L to 0.26 mg/L and from <0.005 mg/L to 0.27 mg/L, respectively, between 2005 and 2007. The concentration of total zinc was moderately elevated at 0.076 mg/L in comparison to the reference location V1 (0.025 mg/L). All total zinc concentrations were greater than the selected benchmark of 0.03 mg/L, with the exception of the July 2007 sampling event (0.026mg/L). The 5th percentile total zinc concentration, 0.038 mg/L, was above the selected benchmark of 0.03 mg/L. The highest zinc concentration (0.26 mg/L) occurred in April 2005.

The total cadmium, copper, iron, and lead concentrations ranged from 0.0002 mg/L to 0.0048 mg/L, 0.001 mg/L to 0.018 mg/L, <0.05 mg/L to 2.12 mg/L and <0.001mg/L to 0.008 mg/L, respectively. Maximum iron and lead concentrations correspond with maximum total suspended solid concentrations observed during spring sampling events. The median concentration for copper (0.004 mg/L), and the maximum concentration for iron (2.12 mg/L) and lead (0.008 mg/L) exceed the selected benchmarks of 0.002 mg/L, 0.3 mg/L and 0.002 mg/L, respectively.

The signature of treated effluent is apparent in existing water quality at V25BSP, particularly throughout 2005, through comparison to water quality at the reference location (V1). The concentration of calcium and hardness is higher during periods of lime treated effluent discharge. Figure 6.3-14 illustrates the elevated calcium signature at V25BSP during active treatment prior to 2006. No treatment was required in 2006 and 2007 due to substantial drawdown and treatment of pit water in 2005. Ammonia is slightly elevated above reference water quality and sulphate is elevated by one order of magnitude. Concentrations of cadmium, manganese and zinc were elevated by an order of magnitude over concentrations in the reference stream. Concentrations of silver, arsenic and iron were below concentrations observed at the reference locations. Concentrations of copper and lead are similar to reference locations.

Existing water quality conditions at location V25BSP reflect a source of ongoing metals loadings to the receiving environment. Of most concern is zinc because of a combination of elevated loadings and relatively high toxicity. Relatively high concentrations of sulphate are also discharged. Sulphate concentrations serve as a good indicator of mine influence on receiving waters, but are relatively non-toxic to aquatic life in comparison to other contaminants of concern. Elevated concentrations of manganese are also discharged in comparison to reference water quality.

Grum Creek

Location V2 is in Grum Creek upstream of entry into Vangorda Creek. The changes to the water management system implemented during 1995 and 1996 diverted a large portion of the Grum Creek catchment area into the Sheep Pad Pond and this, in combination with the interception of shallow ground water by the Grum open pit, reduced the flow in Grum Creek substantially from its original (i.e., pre-mine) levels.

Location V2 was sampled monthly or bimonthly for the period of 2005 to 2007. The concentration of total suspended solids at location V2 continued to be greatly improved over previous years prior to about 1996. The concentrations of total suspended solids ranged from less than 1 mg/L to 18 mg/L between 2005 and 2007 and were below the maximum allowable discharge limit of 15 mg/L with the exception of the January 2005 sampling event (18 mg/L). The pH, being neutral to slightly alkaline, ranged from 7.5 to 8.3.

Table 6.3-15. Trace Metal Concentrations at Vangorda Mine Site Runoff and Effluent Sites, 2005-2007

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD-T mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	ZN-T mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00004**	_	**0.001**	**0.002**	**0.26**	**1**	**0.065**	**0.0005**	**0.03**
V25BSP	N	34	34	34	34	34	34	34	34	34	34	34	34	34
	Median	0.000125	0.0265	0.0005	126	0.00055	0.004	0.0005	0.004	0.08	0.1015	0.002	0.0005	0.0755
	Mean	0.00014	0.0932	0.0006	183.7	0.0012	0.0053	0.0006	0.0046	0.18	3.19	0.003	0.001	0.0994
	Min	< 0.00025	< 0.005	< 0.001	18.6	0.0002	< 0.001	< 0.001	0.001	< 0.05	< 0.001	< 0.001	< 0.001	0.026
	Max	0.0005	1.55	0.002	384	0.0048	0.035	0.002	0.018	2.12	13.1	0.006	0.008	0.26
V2	N	49	49	49	49	49	49	49	49	49	49	49	49	49
	Median	0.000125	0.019	0.001	245	0.0001	0.0005	0.0005	0.001	0.09	0.002	0.003	0.0005	0.018
	Mean	0.0009	0.0327	0.0031	243.47	0.0009	0.0021	0.0012	0.0028	0.13	0.0056	0.0043	0.0033	0.0209
	Min	< 0.00005	0.004	0.0008	170	0.00008	< 0.0002	0.0002	0.001	< 0.01	0.0006	< 0.001	0.0003	< 0.005
	Max	< 0.01	0.13	< 0.03	311	< 0.01	< 0.02	< 0.01	0.02	0.63	0.036	< 0.02	< 0.03	0.074
V6A	N	10	10	10	10	10	10	10	10	10	10	10	10	10
	Median	0.000125	0.044	0.001	23.75	0.0001	0.0005	0.0005	0.0005	0.15	0.0075	0.0005	0.00075	0.0235
	Mean	0.00013	0.1317	0.00115	28.93	0.0001	0.0005	0.00055	0.00095	0.204	0.0117	0.00055	0.00085	0.0216
	Min	< 0.00025	0.021	< 0.001	14	< 0.0002	< 0.001	< 0.001	< 0.001	0.08	0.004	0.001	< 0.001	0.013
	Max	< 0.00025	0.76	0.003	54.4	< 0.0002	< 0.001	0.001	1.42	0.61	6.67	0.001	0.107	86.5

Figure 6.3-13 Sulphate at V25BSP

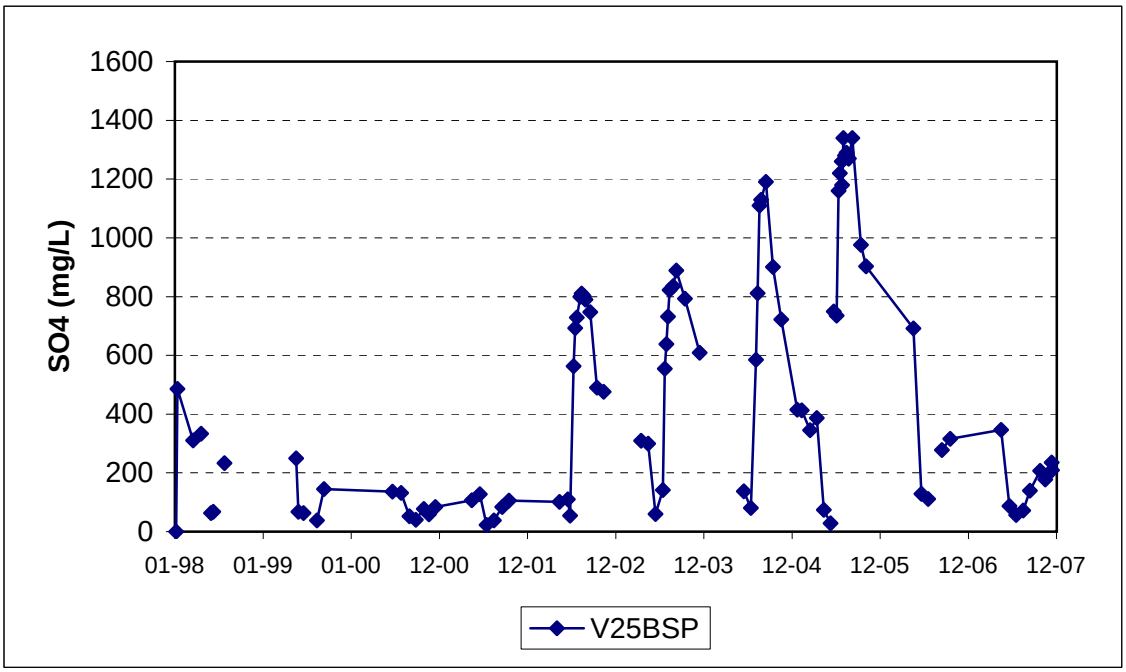
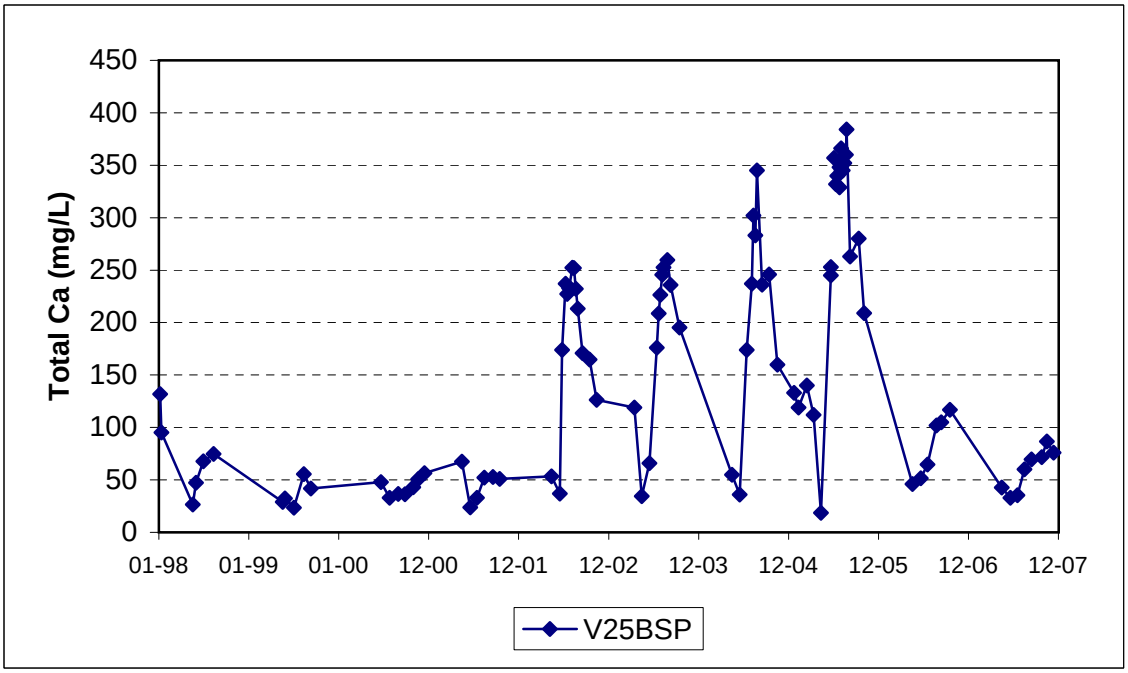


Figure 6.3-14 Calcium at V25BSP



The concentrations of sulphate at location V2 between 2005 and 2007 ranged from 554 mg/L to 1,160 mg/L (Figure 6.3-15). An increasing trend in the concentration of sulphate at V2 is evident from 1989 (beginning of sample record) through 2005, with a sharp increase observed between 2000 and 2005. Sulphate concentrations appear to have stabilized over the last two years. There has not been a corresponding increase in the concentrations of total or dissolved zinc. This trend in sulphate is consistent with upstream location V15. The sulphate concentrations are higher at location V15, which is reasonable given that it is a smaller flow closer to the suspected source, the Grum rock dump.

The hardness at V2 was elevated between 2005 and 2007 in comparison to reference concentrations, <0.01 mg/L to 0.04 mg/L, between 2005 and 2007.

The concentrations of total and dissolved zinc at location V2 between 2005 and 2007 ranged from less than 0.005 mg/L to 0.074 mg/L and from <0.001 mg/L to 0.11 mg/L, respectively (Figure 6.3-16). Total copper and iron concentrations ranged from 0.01 mg/L to 0.02 mg/L and <0.01 mg/L to 0.63 mg/L, respectively. Total lead concentrations were 76% less than detection limit for samples between 2005 and 2007 with a median of 0.0005 mg/L, which is below the selected benchmark of 0.002 mg/L. The median concentration of total zinc was slightly elevated above reference water quality at 0.018 mg/L.

The signature of runoff and seepage from the Grum Rock Dump is apparent in existing water quality at location V2 as compared to water quality at the reference locations. The concentrations of calcium and hardness are elevated by one order of magnitude. Ammonia is slightly elevated above reference concentrations and sulphate concentrations are higher than reference by one order of magnitude. Concentrations of arsenic, copper, iron, manganese, nickel, lead and zinc are elevated from the reference location V1. Total aluminium concentrations are within ranges typically observed within reference water quality.

AEX Creek

Location V6A is in AEX Creek immediately upstream of its entry into the West Fork of Vangorda Creek. AEX Creek at this location includes the tributary sampled at upstream location V17A which receives runoff from the slopes north of Grum Pit and the Ore Transfer Pad. Location V6A was sampled ten times between 2005 and 2007. The concentrations of total zinc ranged from 0.013 mg/L and 0.021 mg/L and dissolved zinc were 0.011 mg/L and 0.029 mg/L. The total zinc concentrations for V6A are below the selected benchmark (0.03 mg/L) with the exception of the maximum total zinc concentration seen in December 2005 (0.031 mg/L). Total lead concentrations range from less than 0.001 to 0.002 mg/L, and none exceed the selected benchmark of 0.002 mg/L. Total iron and copper concentrations range from 0.09 mg/L to 0.61 mg/L and less than 0.001 mg/L to 0.003, respectively. The maximum observed concentration between 2005 and 2007 for V6A exceeded the selected benchmarks for iron (0.3 mg/L) and copper (0.002 mg/L).

Figure 6.3-15 Sulphate at V2

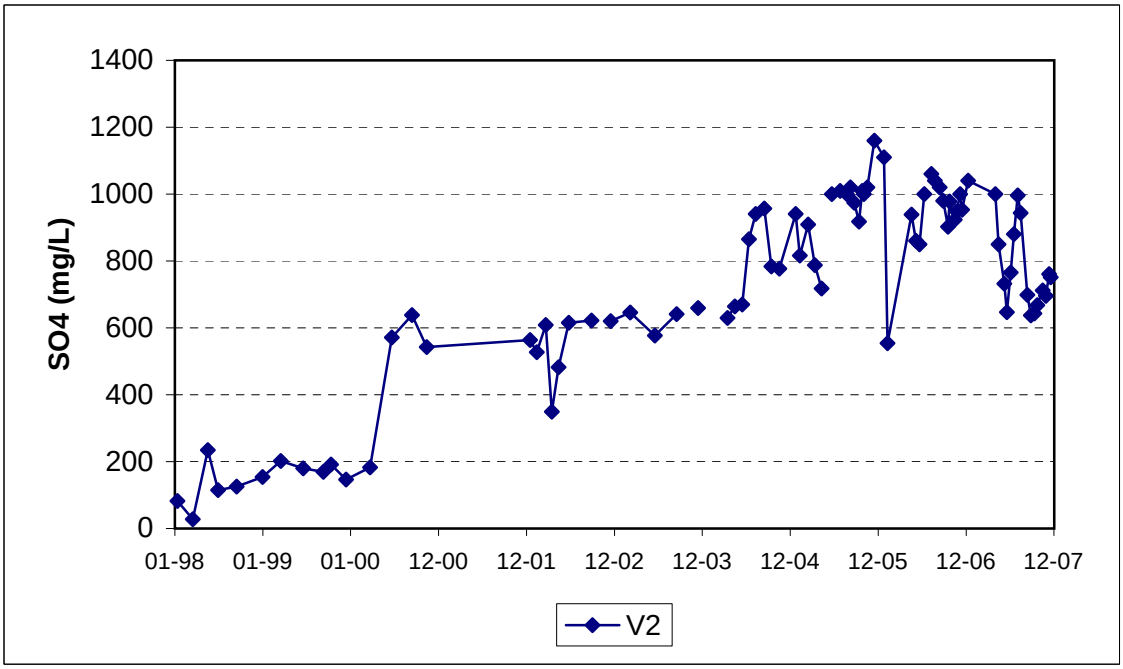
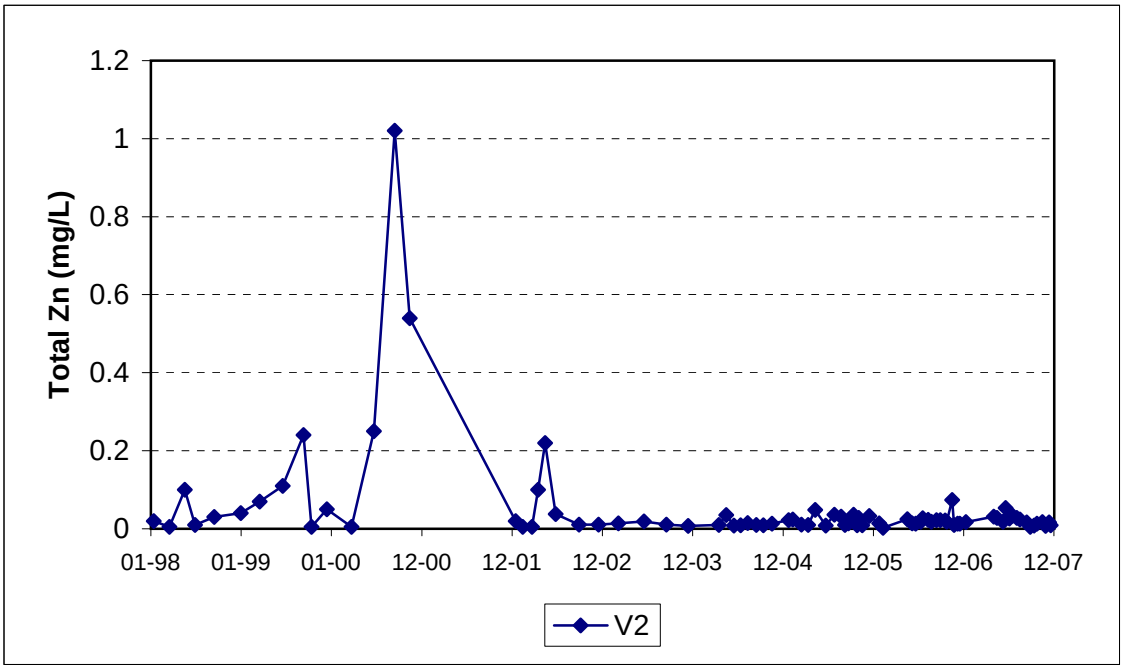


Figure 6.3-16 Zinc at V2



The concentrations of sulphate between 2005 and 2007 ranged from 13.6 mg/L and 53.5 mg/L. These concentrations are consistent with those observed since mine shut down in 1998. The pH between 2005 and 2007 was neutral to slightly alkaline ranging from 7.4 to 8.3. Ammonia levels were detectable, but low, with the exception of the September 2007 sampling event (0.32 mg/L) exceeding the selected benchmark of 0.25 mg/L.

Water quality at location V6A in AEX Creek is very similar to that at the reference locations. This indicates that runoff from the ore transfer pad and haul road (in the AEX Creek drainage area) are not having an observable effect in AEX Creek and therefore indicate the absence of mine-related metals loadings to the receiving environment.

6.3.9.3 Receiving Water Quality

Location V27 is in the Main Stem of Vangorda Creek, immediately below the mine site and upstream of the confluence with Shrimp Creek. All surface water from the Grum rock dump, the Grum Interceptor Ditch/Sheep Pad Pond, and the Vangorda Northeast Interceptor Ditch reports to location V27 via Grum Creek or the Vangorda Creek plunge pool. This location is internal to the local study area but is influenced by the discharge of treated and compliant effluent and other runoff waters and by mixing with water from the Vangorda Creek Diversion Flume.

Between 2005 and 2007, sulphate ranged from 8.46 to 64.1 mg/L, pH from 7.5 to 8.2 and total zinc from 0.016 to 0.031 mg/L. Historical trends of zinc indicated a peak in concentration in 2003 to 0.175 mg/L, followed by a decline and subsequent stabilization to concentrations observed during recent years (2005 to 2002), averaging 0.023 mg/L. Zinc concentrations are elevated at location V27 in comparison to reference water quality. Zinc and aluminium concentrations infrequently exceeded the selected benchmarks of 0.003 mg/L and 0.1 mg/L, respectively. The total iron concentrations between 2005 and 2007 were all below the selected benchmark of 0.3 mg/L and comparable to reference stations, with the exception of the June 2007 sampling event. The June 2007 sampling had the maximum observed total suspended solids concentrations between 2005 and 2007. Total copper and lead concentrations were low, but detectable ranging from less than 0.001 to 0.002 mg/L. Although analytical detection limits for cadmium used during the routine monitoring program are too high to compare to benchmarks. Lower detection limits employed during additional monitoring programs indicate cadmium concentrations are elevated above the selected benchmark of 0.00003mg/L, ranging from 0.00039 to 0.00081 mg/L.

Location VGMAIN is at the extent of the local study area on the Main Stem of Vangorda Creek immediately upstream of the confluence with the West Fork. VGMAIN includes water from the Main Stem via location V27, plus water from Shrimp Creek via reference location V4, plus natural runoff into the creek below Shrimp Creek. Routine sampling was introduced here in 1997. Historic sulphate seasonal trends continued throughout the baseline study period, with higher sulphate concentrations typically observed during the winter season. Waters at this location are neutral to alkaline, with low to moderate alkalinity. Total zinc ranged from 0.010 to 0.086 mg/L (averaging 0.0208 mg/L), with concentrations elevated in comparison to reference locations. Total cadmium and lead were generally less than the detection limit 0.0002 mg/L and 0.001mg/L, respectively, for

routine monitoring. Total iron concentrations at VGMAIN ranged from <0.05 mg/L to 0.95 mg/L. The selected benchmark of 0.3 mg/L for total iron was not exceeded at VGMAIN between 2005 and 2007, with the exception of the May 2005 sampling event. The May 2005 sampling event had the maximum observed total suspended solids concentrations (23mg/L) between 2005 and 2007. The median total copper concentration between 2005 and 2007 was 0.0005 mg/L and is below the selected benchmark of 0.002 mg/L.

The receiving waters at both locations V27 and VGMAIN (Table 6.3-16 and Table 6.3-17) continued to show elevated levels of some metals as compared to the selected benchmarks and to the reference locations throughout the baseline study period. Comparison of water quality in Vangorda Creek with that in the mine runoff water showed substantial dilution and assimilation of mine water in the receiving environment. Spatial comparison of water quality at locations V27 and VGMAIN shows that most metals were reduced in concentration along the length of the main stem of Vangorda Creek. However, elevated concentrations of cadmium, copper, iron, and zinc at both locations suggests impairment to receiving water quality from mining related drainage.

Table 6.3-16. Water Quality in Vangorda Creek Local Study Area, 2005-2007

	Parameter	Alk-T mg/L	Cond. □s/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
V27	N	1	8	8	8	6	8	8
	Median	48.50	194.50	89.00	0.01	7.85	48.00	1.25
	Mean	48.5	176.5	78.1	0.01	7.8	41.3	2
	Minimum	48.5	47	17	< 0.01	7.5	8.46	< 1
	Maximum	48.5	239	110	0.03	8.2	64.1	6
VGMAIN	N	35	35	35	35	35	34	35
	Median	137.00	451.71	251.37	0.01	8.05	131.17	1.63
	Mean	137	451.7	251.4	0.014	8	131.2	1.6
	Minimum	62.2	170	86	< 0.01	7.5	32.9	< 1
	Maximum	205	804	526	0.11	8.5	399	23
V5	N	28	28	28	28	28	27	28
	Median	185.50	440.50	264.50	0.01	8.10	78.00	8.50
	Mean	185.1	469.4	273.5	0.014	8.1	90.3	40.1
	Minimum	0.5	172	126	< 0.01	7.4	28	2
	Maximum	285	793	436	0.11	8.4	174	249

Table 6.3-17. Trace Metal Concentrations in Vangorda Creek Local Study Area, 2005-2007

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD-T mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	ZN-T mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00004**	_	**0.001**	**0.002**	**0.26**	**1**	**0.065**	**0.0005**	**0.03**
V27	N	8	8	8	8	8	8	8	8	8	8	8	8	8
	Median	0.000125	0.022	0.0005	23.25	0.0001	0.0005	0.0005	0.001	0.08	0.006	0.0005	0.0005	0.0225
	Mean	0.000125	0.0561	0.0005	20.46	0.0001	0.0005	0.0005	0.0012	0.1225	0.0115	0.0006	0.0011	0.023
	Min	< 0.00025	< 0.005	< 0.001	4.68	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.003	< 0.001	< 0.001	0.016
	Max	< 0.00025	0.16	< 0.001	28.6	< 0.0002	< 0.001	< 0.001	0.002	0.36	0.039	0.001	0.002	0.031
VGMAIN	N	35	35	35	35	35	35	35	35	35	35	35	35	35
	Median	0.000125	0.012	0.0005	60.6	0.0001	0.0005	0.0005	0.0005	0.07	0.007	0.002	0.0005	0.019
	Mean	0.00013	0.0345	0.0006	61.3	0.00012	0.0005	0.0005	0.0024	0.111	0.045	0.002	0.0008	0.0208
	Min	< 0.00025	< 0.00025	< 0.001	21.2	< 0.0002	< 0.001	< 0.001	< 0.001	< 0.05	0.002	< 0.001	0.001	0.01
	Max	0.0003	0.49	0.002	145	0.0004	0.001	0.001	0.052	0.95	0.61	0.011	< 0.001	0.086
V5	N	28	28	28	28	28	28	28	28	28	28	28	28	28
	Median	0.000125	0.15	0.0005	62.55	0.0001	0.0005	0.0005	0.001	0.365	0.026	0.002	0.0005	0.009
	Mean	0.00013	0.86	0.0012	64.29	0.0001	0.0009	0.0024	0.003	1.439	0.045	0.0042	0.0018	0.013
	Min	< 0.00025	0.024	< 0.001	30.8	< 0.0002	< 0.001	< 0.001	< 0.001	0.09	0.007	0.001	< 0.001	< 0.005
	Max	0.0004	6.95	0.005	101	0.0003	0.005	0.016	0.018	11	0.19	0.02	0.01	0.046

Concentrations of arsenic, cobalt and lead were the same as, or less than, concentrations at the reference water quality sites at one or both of the receiving water locations V27 and VGMAIN. Concentrations of aluminium, copper, iron, manganese, nickel, and zinc were greater than the upstream reference sites at one or both of receiving water locations V27 and VGMAIN.

In summary, receiving water quality in the main stem of Vangorda Creek contained elevated concentrations of aluminium, iron, copper, manganese, nickel, zinc and sulphate when compared to reference water quality and selected benchmarks. Most exceedances have occurred during discharge periods (2005) and were therefore short-term events.

Location V5 is at the downstream boundary of the local study area in the West Fork of Vangorda Creek, immediately upstream of the confluence with the Main Stem. V5 includes runoff water from AEX Creek, plus a portion of the Grum Rock Dump (excluding the sulphide cell), plus natural runoff into the creek below the mine access road. Routine sampling was introduced here in 1991. From 2005 to 2007, water quality at this site was slightly alkaline, circumneutral (pH 7.4 to 8.4), with sulphate concentrations (20 to 174 mg/L) typically above reference sites. Total zinc concentrations ranged from <0.005 mg/L to 0.046 mg/L, comparable to reference water quality. Sulphate and hardness concentrations typically follow pre-established seasonal trends, with higher concentrations associated with winter conditions, when surface is minimal (GLL 2008). On occasion sediment loading was also very high at location V5 (range from 2 mg/L to 249 mg/L total suspended solids), which is attributed primarily to sediment flushed into the creek during freshet originating from “non-mine” areas such as the landslide area and the old ski hill area.

During 2005 to 2007, the receiving waters at location V5 (Table 6.3-16 and Table 6.3-17) continued to show elevated levels of some metals as compared to the selected benchmarks and to the reference locations. Receiving water quality was impaired when compared with the selected benchmarks for sulphate, aluminium, chromium, copper, and iron. Concentrations of silver, cadmium and were similar, or less than concentrations at the reference water quality site (V1). Concentrations of aluminium, arsenic, copper, iron, manganese, nickel, lead and zinc were slightly greater than the reference sites.

In summary, during the baseline study period (2005 to 2007), receiving water quality in the West Fork of Vangorda Creek contained elevated concentrations of aluminium, copper, iron, zinc, sulphate and total suspended solids when compared to reference water quality and selected benchmarks.

6.3.9.4 Regional Study Area Water Quality, Vangorda Creek Drainage

The regional study area (RSA) downstream of the immediate receiving waters for the Vangorda Plateau site is described by water quality at location V8, immediately upstream of entry into the Pelly River. This includes flow from the Main Stem via location VGMAIN, plus flow from the West Fork via location V5, plus natural runoff into the creek below the confluence of the Main Stem and West Fork along the north perimeter of the Town of Faro. The Town of Faro water supply is taken from groundwater wells located at the entry of Vangorda Creek into the Pelly River.

From 2005 to 2007, water quality at this site was variable with sulphate ranging from 33.3 mg/L to 312 mg/L, pH from 7.3 to 8.5 and zinc from 0.007 mg/L to 0.064 mg/L (averaging 0.019 mg/L). Seasonal trends in sulphate mirror those observed upstream, with elevated concentration typically observed during winter months. Similar to upstream at V5, on occasion sediment loading was also high at location V8 (ranging from less than 1 to 67 mg/L total suspended solids), which is attributed primarily to natural sources.

From 2005 to 2007, the receiving waters at location V8 (Table 6.3-18 and Table 6.3-19) continued to show elevated levels of some metals as compared to the selected benchmarks and to the reference locations. Aluminium, chromium, copper and iron are elevated compared to selected guideline benchmarks. Concentrations of arsenic, cobalt and lead were the same as, or less than concentrations at the reference water quality site. Concentrations of cobalt, manganese, nickel, and zinc were slightly greater than the reference sites. Sediment loading continued to be elevated during freshet at location V8 (range up to 67 mg/L total suspended solids), which is attributed primarily to the influence of natural debris.

Table 6.3-18. Water Quality Concentrations in Vangorda Creek Regional Study Area, 2005-2007

	Parameter	Alk-T mg/L	Cond. µs/cm	Hardness mg/L	NH3-N mg/L	pH	SO4 mg/L	TSS mg/L
Benchmark		**12.6**			**0.25**	**6.5-9.0**	**50**	**29**
V8	N	36	36	36	36	36	35	36
	Median	172.35	502.17	281.03	0.02	8.06	128.46	7.71
	Mean	172.4	502.2	281	0.0155	8.1	128.5	7.7
	Minimum	76.6	174	112	< 0.01	7.3	33.3	< 1
	Maximum	255	781	449	0.13	8.5	312	67

In summary, receiving water quality contained elevated concentrations of aluminium, copper, iron, sulphate and total suspended solids when compared to reference water quality and selected guideline benchmarks.

Table 6.3-19. Trace Metal Concentrations in Vangorda Creek Regional Study Area, 2005-2007

Parameter		AG-T mg/L	AL-T mg/L	AS-T mg/L	CA-T mg/L	CD mg/L	CO-T mg/L	CR-T mg/L	CU-T mg/L	FE-T mg/L	MN-T mg/L	NI-T mg/L	PB-T mg/L	ZN-T mg/L
Benchmark		**0.0001**	**0.1**	**0.005**		**0.00004**	**-**	**0.001**	**0.002**	**0.26**	**1**	**0.065**	**0.0005**	**0.0168**
V8	N	36	36	36	36	36	36	36	36	36	36	36	36	36
	Median	0.000125	0.033	0.0005	68.75	0.0001	0.0005	0.0005	0.00075	0.14	0.028	0.002	0.0005	0.016
	Mean	0.000125	0.1679	0.0013	66.63	0.00013	0.0007	0.0009	0.00275	0.341	0.046	0.0025	0.0022	0.019
	Minimum	< 0.00025	< 0.005	< 0.001	26.9	< 0.0002	< 0.001	< 0.001	< 0.001	0.049	0.006	< 0.001	< 0.001	0.007
	Maximum	< 0.00025	1.37	0.05	120	< 0.002	0.007	0.005	0.045	2.13	0.38	0.02	0.04	0.064

6.3.9.5 Vangorda Watershed Surface Water Quality Summary

The existing water quality for the Vangorda Plateau Mine Site is described by the following:

- Alkaline conditions, low solids and concentrations of some metals, which exceeded benchmarks in reference waters isolated from mine influence;
- Entry into Vangorda Creek of mine runoff and effluent waters from the Sheep Pad Pond and Grum Creek, which contained calcium, hardness, cadmium, zinc, sulphate and manganese at concentrations that were an order of magnitude above reference levels, and other trace metals that exceeded reference levels by a factor of two;
- Water quality in the main stem of Vangorda Creek downstream of the mine facilities, which reflected the influence of the mine facilities as elevated levels of cadmium, copper, iron, zinc and sulphate;
- Water quality in the West Fork of Vangorda Creek downstream of the mine facilities, which reflected the influence of the mine facilities as elevated levels of aluminium, arsenic, copper, iron, manganese, nickel, lead and zinc; total suspended solids was also elevated between 2005-2007 and this was attributed to a natural debris flow; and
- Assimilation of all mine influences with the exception of cadmium and iron in Vangorda Creek upstream of the Pelly River.

6.3.10 Regional Study Area Water Quality, Pelly River

Water quality within the Pelly River has recently been monitored through the Pelly River Aquatics Effects Assessment (PEAEA) from 2004 to 2006 (Access *et al.*, 2005, 2006, 2007) and through the Interim Aquatic Ecosystem Monitoring Program (IAEMP) in 2007. The Pelly River Aquatics Effects Assessment program was conducted in conjunction with Selkirk First Nation (SFN). The Pelly River flows through Selkirk First Nation traditional territory, downstream of the Faro Mine Complex. Sample sites are illustrated in Figure 6.3-17 (map provided by Access Consulting Group).

The IAEMP was implemented in 2007 to delineate water quality for assessment purposes and development of site-specific water quality objectives using improved detection limits. Sites sampled under the Pelly River locations are illustrated in Figure 6.3-1. It should be noted that although there is duplication in station nomenclature between the programs, sample locations are not consistent. Analytical detection limits used for this program were improved over previous programs, allowing comparison to low level water quality benchmarks, including cadmium and silver.

Water quality sampling sites used to characterize regional water quality within the Pelly River are listed in Table 6.3-20. Water quality data from these programs are compiled in Appendix C4.

Table 6.3-20. Pelly River Sampling Sites

Sampling Site	Site Description
Pelly Aquatic Effects Monitoring Program[1]	
PB	Pelly River, upstream of Blind Creek
P1	Pelly River, upstream of Anvil Creek
P1A	Pelly River, downstream of Anvil Creek
Interim Aquatic Ecosystem Monitoring Program[2]	
P1	Pelly River upstream of Vangorda Site
P2	Pelly River downstream of Vangorda Site
P3	Pelly River upstream of Anvil Creek
P4	Pelly River downstream of Anvil Creek

[1] Sample sites illustrated in Figure 6.3-17

[2] Sample sites illustrated in Figure 6.3-1.

Water quality data obtained from these two programs for the main stem of the Pelly River have been evaluated at sampling points located upstream (reference) and downstream of inflowing tributaries draining the mine site.

6.3.10.1 Interim Aquatic Ecosystem Monitoring Program (IAEMP)

Water quality upstream of the confluence of all mine drainages was monitored at location P1 in the fall of 2007 (four sampling events) and at station PB in 2004 and 2005 (two sampling events). Station P1 is located within the main stem of the Pelly River immediately upstream of the confluence with Vangorda Creek. Water quality at this location is circumneutral with hardness ranging from 154 mg/L to 216 mg/L. The majority of trace metals are detectable, with total zinc concentrations ranging from 0.0142 mg/L to 0.0234 mg/L (Appendix C4). Sulphate concentrations remained low, ranging from 56 mg/L to 69 mg/L. Cadmium and iron concentrations exceeded the CCME derived benchmarks of 0.0003mg/L and 0.3 mg/L during all sampling events.

Water quality immediately downstream Vangorda Creek was monitored through the IEAMP at location P2 during the fall of 2007. Total aluminium, cooper, lead and zinc concentrations at this sight are slightly elevated in comparison to upstream (P1), with the highest concentrations typically observed in early fall (September). Cadmium exceeded the CCME derived benchmark of 0.00003 mg/L during the four consecutive months of samples, whereas aluminium, chromium and zinc slightly or infrequently exceeded the respective benchmarks. Sulphate concentrations between the sites were comparable. Metal concentrations were typically higher during the September sampling event in comparison to subsequent months.

Comparison of water chemistry between stations P2 and P3 suggests that dilution of iron, nickel and zinc is occurring along the length of this portion of the Pelly River: however, concentrations of other trace metals at site P3 are comparable or slightly elevated in comparison to P2, suggesting natural metal loading from inflowing tributaries is the dominant influence on trace metal concentrations. Copper and cadmium concentrations are slightly elevated at P3 in comparison to

P2. Annual or seasonal temporal trends cannot be determined for this program due to limited data. Cadmium concentrations exceeded the CCME derived benchmark of 0.00003 mg/L for the four fall samples.

Location P4 is located immediately downstream of Anvil Creek. Water at this station represents mixing of drainage from the Anvil Creek and the Pelly River, and therefore is potentially influenced by mine related discharges from the Faro Mine site. Total zinc and cadmium concentrations were slightly elevated at P4 in comparison to upstream location P3 in the fall of 2007; however, no apparent increasing trends were detected in other trace metals. Cadmium concentrations exceeded the selected benchmark for all samples, ranging from 0.000099 mg/L and 0.000177 mg/L.

6.3.10.2 Pelly River Aquatic Effects Assessment (PEAEA)

Water quality of the Pelly River upstream of inflowing tributaries draining the Faro and Vangorda mine sites was monitored at location PB which is immediately upstream of Blind Creek. Water quality at this site was similar to that observed at upstream locations under the IAEMP, with detectable trace metal concentrations, neutral to alkaline pH, and low sulphate. This station reported total and dissolved zinc concentrations of 0.005 mg/L and 0.035 mg/L, and 0.003 mg/L and 0.012 mg/L for the July 2004 and August 2005 sampling events, respectively (Access *et al.*, 2005, 2006), indicating that the majority of the total zinc is associated with the solid phase (particulate matter). Total cadmium and iron concentrations upstream of mine drainage exceeded the selected water quality benchmarks during both sampling events. Zinc, aluminium and selenium were slightly elevated above benchmark concentrations during two separate sampling events. Total suspended solids range from 292 mg/L to 400 mg/L, well above the selected benchmark of 29 mg/L.

During the program, water quality was monitored in the Pelly River approximately mid-point between Vangorda Creek and Anvil Creek, at location P1 (PREAE). Water quality was also measured downstream of the confluence of Anvil Creek, at station P1A. During the 2004 program, Access Consulting Group noted that total zinc concentrations within the Pelly River slightly increased along the length of the river between stations PB, P1 and P1A with concentrations of 0.005 mg/L, 0.007 mg/L and 0.01 mg/L (Access *et al.* 2005). An opposite trend was noted in 2005, with decreasing concentrations observed between PB and P1A, suggesting natural zinc loading, presumably from inflowing tributaries, is occurring within this portion of the study area in 2005. No data is available for station PB in 2006; therefore, a similar comparison cannot be made for this sampling year. It should be noted that total zinc was below the CCME guideline of 0.03 mg/L throughout the sampling program. Cadmium concentrations exceeded the selected benchmark of 0.00003 mg/L at stations P1 and P1A from 2004 to 2006. Total aluminium and selenium concentrations exceeded the CCME derived benchmarks during 75% and 50% of the sampling events, respectively.

Of interest is the lack discernable trend in sulphate concentrations between the upstream reference station, PB, and station P1A, the station located on the downstream boundary of the RSA. Although sulphate does not pose the same toxicology risk as other contaminant of concern, it does serve as an indicator of mining related activities on the receiving environment.

6.3.10.3 Pelly River Water Quality Summary

Evaluation of water quality collected from the Pelly River monitoring programs indicates that although waters draining from the Faro and Vangorda mine sites may influence water chemistry within the Pelly River, the signature of drainage is not readily apparent or consistent between sampling dates and programs. Although some spatial trends in total zinc, copper, and lead concentrations were occasionally evident, natural contributions to the watershed combined with significant dilution (and limited data) suggest that the mine-related influences on the Pelly are not readily detectable.

Monitoring locations upstream of all mine-related drainages indicate elevated concentrations of cadmium and iron above selected benchmarks (CCME), while total zinc, aluminium, selenium, and total suspended solids also were slightly elevated above benchmark concentrations.

Water quality at the lower boundary of the Pelly River RSA is characterized by neutral to slightly alkaline pH and low sulphate concentrations. Cadmium concentrations were consistently above the CCME derived benchmark of 0.00003 mg/L.

Selkirk First Nation

Pelly River Aquatic Effects Assessment 2004-2006

Monitoring Station Locations

P2
Tay
Tay River
GR
P1A
A2
A3
A1
Glenlyon River
Anvil Creek
A4
R5
R6
R4
R3
Rose Creek
R2
R7
P1
R1
Faro Mine
Pelly River
Blind Creek
B1
PB
Campbell Highway

3

Legend

- Selkirk First Nation Monitoring Station
- Aquatic Effects Monitoring Station
- Faro Mine Licence Monitoring Station
- 100ft Topographical Contour
- Watercourses
- Cut line
- Limited-used road
- Road
- Waterbodies

1:300,000

0 2.5 5 10 15 20 km

Figure 6.3-17

ACCESS CONSULTING GROUP

Date: March 2007

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7. Aquatic Resources

7.1 Aquatic Study Area

Aquatic resources discussed here include sediment quality, benthic invertebrates (communities and metal concentrations), fish (species distribution and metal concentrations) and fish habitat. The study area is watershed based and includes both the Rose Creek and Vangorda Creek watersheds as shown in Figure 7.1-1. The above studies are discussed per watershed. The features of the Rose and Vangorda watersheds have distinct characteristics and these are briefly summarized in Table 7.1-1. Due to the geology, habitat characteristics and the stream morphology of each watershed, differences in the geochemistry of the substrates and in the biotic communities (abundance and composition) are reflected. Consequently, each watershed is discussed separately.

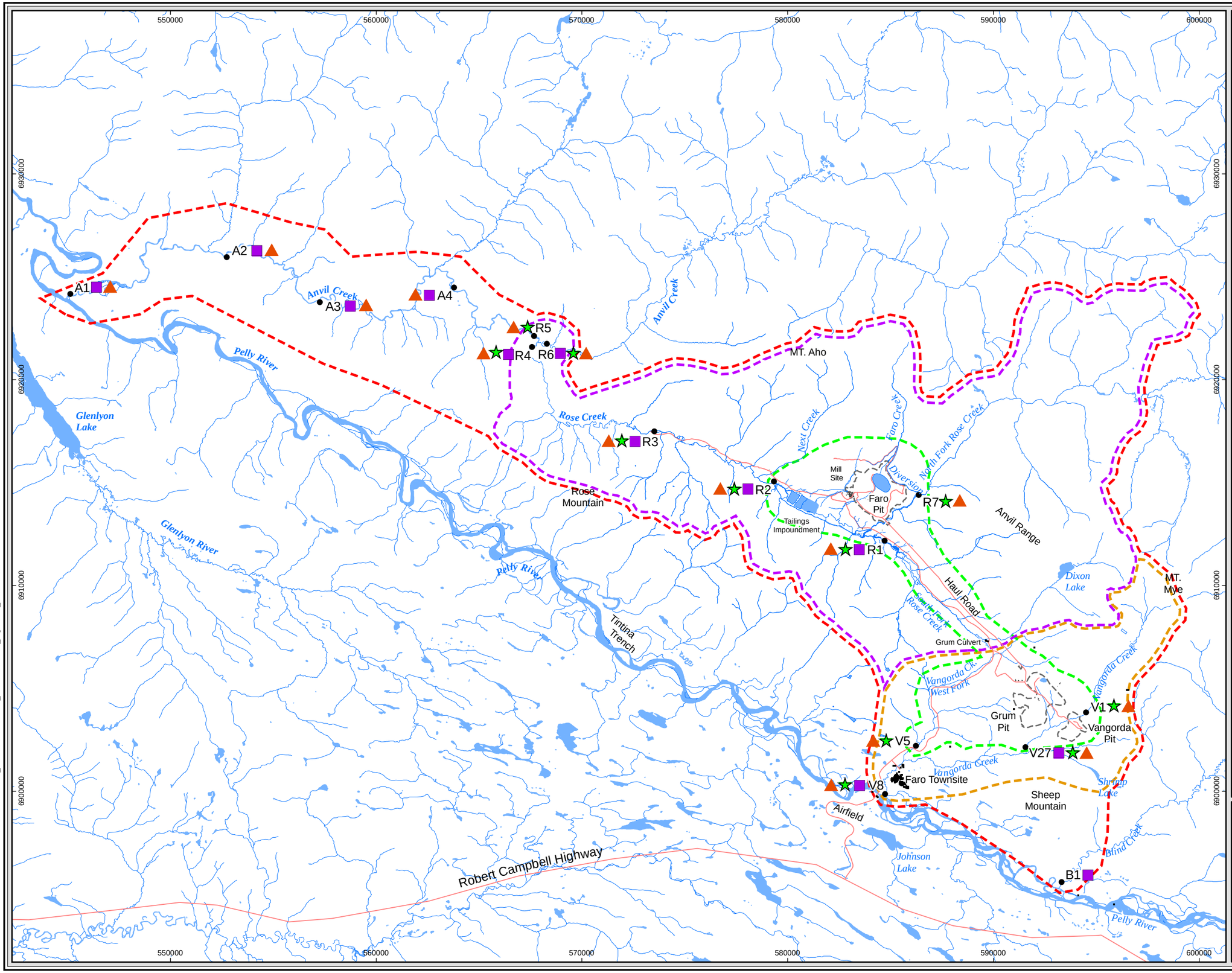
Table 7.1-1. Characteristics for Vangorda and Rose Creek Watersheds

Characteristic	Vangorda Watershed	Rose Watershed
Drainage Area (km^2)	90	340
Change in Elevation (m)	1000	750
Stream Order	3	3
Area drained	South slope of Mount Mye	Southeast slopes of Anvil Range Mountains
Empties into	Pelly River	Anvil Creek

The local and regional study areas for aquatic resources are the same as those for surface water quality and described in Section 6.3.3 and illustrated on Figure 7.1-1. The regional study area includes Anvil Creek from the confluence of Rose Creek to the confluence with the Pelly River. The drainage area of Anvil Creek, which includes Rose Creek drainage, is 980 km^2. Several studies have been completed on the receiving waters of this area. Some fish data from Blind Creek is also presented.

Aquatic resource studies in the local and regional study areas have been completed over time as both routine sampling required under the water licenses and on a less routine basis for additional purposes. Sample site locations are illustrated on Figure 7.1-1. Metals in stream sediment data and benthic invertebrate community data exists from 1973 to 2007, while fish presence and metals in fish tissue data exists from 1974 to 2007. Metals in benthic invertebrate tissue data were collected in 2002 and 2006.

Table 7.1-2 outlines the aquatic resource studies that have been completed within the study areas. In addition, studies have been carried out in the Pelly Rivers through the Pelly River Aquatics Effects Assessment and through the Interim Aquatic Ecosystem Monitoring Program in 2007. For the purposes of the following table, Anvil Creek sampling is included within the Rose Creek watershed.



Legend

- Benthic Invertebrate
- Fish Sampling
- Stream Sediment
- Sampling Locations
- Roads
- Pits
- Regional Study Area
- Rose Creek Watershed
- Local Study Area
- Vangorda Watershed
- Surface Water
- Buildings

Study Area

0 1.25 2.5 5 7.5 10

Kilometres

1:175,000
UTM Zone 8N, NAD 83

Project Number: 70384
Prepared By: RH
Date Issued: March 25, 2008
Reviewed By:
File Name: 70384_Figure2-3_Mar18.mxd

Environmental Assessment of
the Closure and Remediation Plan
for the Faro Mine Complex

Aquatic Resources Study Area

Gartner Lee

Figure 7.1-1

Revision: 0
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Date Revised: March 24, 2008
Date Plotted: March 24, 2008

Table 7.1-2. Aquatic Resource Studies Completed

Study Topic	Watershed	Study Date	Reference
Metals in stream sediment	Rose	1973	Hoos & Holman (Env. Can), 1973
Metals in stream sediment	Rose	1985	Godin & Osler (Env. Can), 1985
Metals in stream sediment	Vangorda	1993	Laberge, 1993
Metals in stream sediment	Vangorda	1996	Davidge (Env. Can.), 1996
Metals in stream sediment	Vangorda	1996	Laberge, 1996
Metals in stream sediment	Vangorda	1997	Laberge, 1997
Metals in stream sediment	Vangorda	1999	Laberge, 1999
Metals in stream sediment	Rose	1999	Env. Can. Unpublished
Metals in stream sediment	Vangorda	2001	Laberge, 2001
Metals in stream sediment	Rose, Vangorda	2002	Gartner Lee, 2003
Metals in stream sediment	Vangorda	2003	Laberge, 2003
Metals in stream sediment	Rose	2004	Laberge, 2004
Metals in stream sediment	Vangorda	2005	Laberge, 2005
Metals in stream sediment	Rose	2006	Laberge, 2006
Metals in stream sediment	Vangorda	2007	Laberge, 2007
Metals in stream sediment	Rose (Anvil)	2006	Laberge and Access, 2007
Metals in stream sediment	Vangorda	2007	Laberge, 2007
Benthic invertebrate studies are outlined in Table 7.3-1.			
Fish presence, metal in fish tissue	Rose	1974	S.A. Baker, 1979
Fish presence, metal in fish tissue	Rose	1975	S.A. Baker, 1979
Fish presence, metal in fish tissue	Rose, Vangorda	1975	Mtl. Engineering Co., 1976
Fish presence, metal in fish tissue	Rose	1976	S.A. Baker, 1979
Fish presence, metal in fish tissue	Vangorda	1976	Mtl. Engineering Co., 1977
Fish presence, metal in fish tissue	Vangorda	1977	Mtl. Engineering Co., 1978
Fisheries impact of Rose diversion	Rose	1981	K. Weagle, 1981a
Arctic grayling survey	Rose	1981	K. Weagle, 1981b
Fisheries	Rose	1986	Leverton & Associates, 1986
Fish presence and habitat	Vangorda	1987	P.A. Harder & Associates, 1987
Fish spawning survey	Rose	1988	P.A. Harder & Associates, 1988
Fish production and overwintering	Vangorda	1989	P.A. Harder & Associates, 1989
Fish habitat, production and feeding	Rose	1989 / 1990	P.A. Harder & Associates, 1991
Fish feeding, growth and population	Vangorda	1990	P.A. Harder & Associates, 1992
Fish habitat, metal in fish tissue	Rose	1992	P.A. Harder & Associates, 1993
Fish habitat use	Vangorda	1996	P.A. Harder & Associates, 1996
Metal in fish tissue		1997	Yukon Territorial Government
Fish habitat associated with FWSD	Rose	2000	Gartner Lee Ltd., 2000
Fish habitat, some fish presence and metals in fish tissue	Rose, Vangorda	2002	Gartner Lee Ltd., 2003c
Fish habitat and presence	South Fork Rose	2004	White Mountain
Fish habitat, presence, metal in tissue	Rose	2004	White Mountain
Fish habitat and presence	South Fork Rose	2005	White Mountain
Fish habitat, presence, metal in tissue	Rose	2005	White Mountain
Fish habitat and presence	South Fork Rose	2006	White Mountain
Fish habitat, presence, metal in tissue	Rose	2006	White Mountain
Fish habitat and presence	South Fork Rose	2007	Laberge, 2008
Fish habitat, presence, metal in tissue	Rose	2007	White Mountain

7.2 Stream Sediment Quality

Stream sediment samples have been collected from various sites in and near the Faro Mine Complex for several decades. Chemical analysis was performed on the portion of the sediment that passed through a 100 mesh screen, particle size 0.15 mm. All data examined are the means of triplicates (except for the 1983 data which are means for six samples).

7.2.1 Vangorda Watershed

7.2.1.1 Historic Sediment Quality

Sediment sampling and analyses for metals have been conducted every two years at four sites on Vangorda Creek since 1993 as required by the Water Licence. The concentrations of copper, lead and zinc have been examined and discussed in annual and compilation reports. These three metals are found in the ore deposits, can be toxic to aquatic organisms at high concentrations and have sediment quality guidelines available for comparison. These data have been summarized and graphed along with the recent data in Table 7.2-1 and Figure 7.2-1.

The sites have been arranged in the tables and graphs as they occur geographically. V1 is the uppermost site and represents the reference site. V27 is located below all mine inputs and represents the near field site. Both V5 and V8 are far field sites.

The 1993, 1995, 1997 and 1999 (historical data) results for Vangorda Creek sediments indicate that the highest arsenic, copper, lead and zinc concentrations are in sediments from the impacted site V27. Metal concentrations at site V5 on the West Fork are the lowest and comparable to reference site V1 results, while concentrations at the creek mouth (V8) are between the results of sites V27 and V5. All samples exceeded the Interim Sediment Quality Guidelines (ISQG) for arsenic and most also exceeded the Probable Effects Level (PEL). Copper levels exceeded the 35.7 µg/g ISQG for some sample results at all of the sites. Lead levels exceeded the 91.3 µg/g PEL in the V27 and V8 sediments, while zinc levels exceeded the 315 µg/g PEL in all V27 and some V8 samples. Increasing levels of the metals at site V27 over time is an evident data trend.

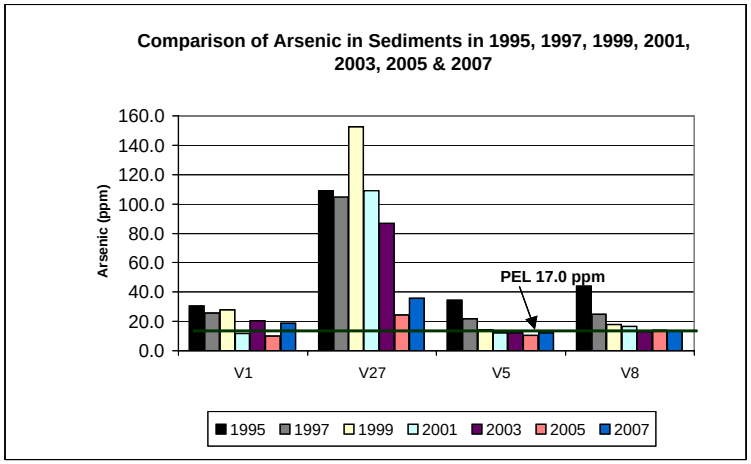
7.2.1.2 Recent and Current Sediment Quality

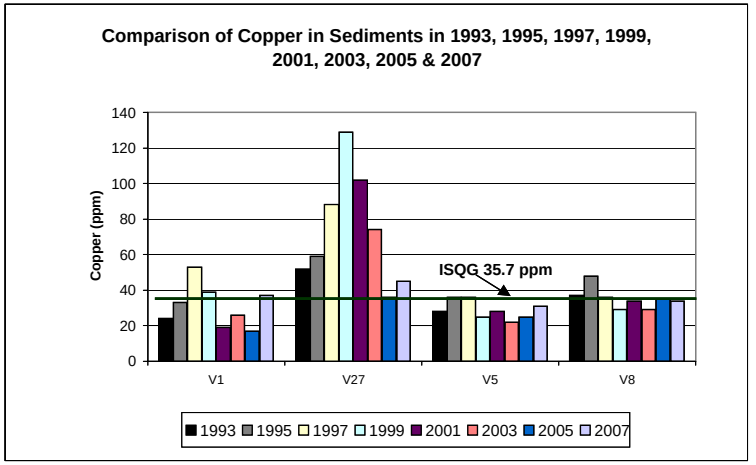
Minnow Environmental Inc (2007) examined all the data collected from the Vangorda Watershed from 1993 to 2005. Statistical evaluation of the data spatially and temporally, identified that the key indicators of mine influence on sediment chemistry were arsenic, lead and zinc. More recent stream sediment samples were collected in July 2007. The concentrations of these metals, as well as copper, are included in Table 7.2-1 and Figure 7.2-1.

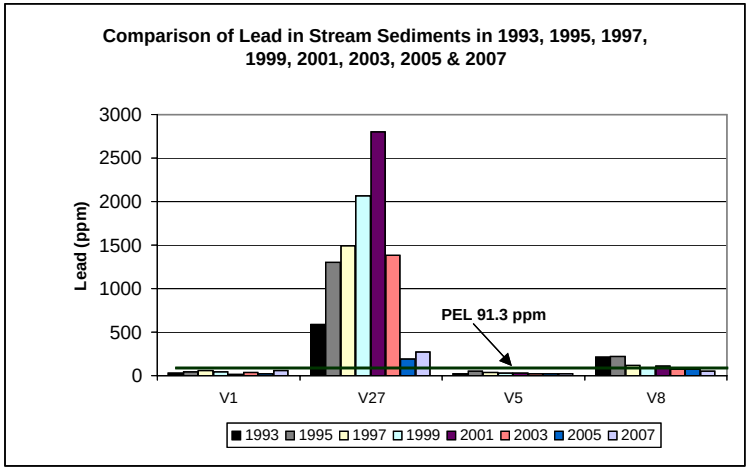
Table 7.2-1 Selected Metal Concentrations in the Stream Sediments of the Vangorda Creek Watershed

Station	Year	Metal (mg/kg)			
		Arsenic	Copper	Lead	Zinc
V1	1993	not done	24	30	120
	1995	**30**	33	**43**	**177**
	1997	**26**	**53**	**58**	**132**
	1999	**28**	**39**	**45**	**141**
	2001	**12**	19	18	88
	2003	**21**	26	**37**	**132**
	2005	**10**	17	19	60
	2007	**19**	**37**	**62**	**131**
V27	1993	not done	**52**	**587**	**436**
	1995	**109**	**59**	**1305**	**519**
	1997	**105**	**88**	**1492**	**652**
	1999	**152**	**129**	**2069**	**921**
	2001	**109**	**102**	**2802**	**868**
	2003	**87**	**74**	**1383**	**951**
	2005	**24**	**36**	**188**	**288**
	2007	**36**	**36**	**269**	**564**
V5	1993	not done	28	23	98
	1995	**34**	**36**	**52**	**129**
	1997	**22**	**36**	35	100
	1999	**15**	25	30	81
	2001	**12**	28	32	116
	2003	**12**	22	25	80
	2005	**10**	25	21	86
	2007	**12**	31	25	113
V8	1993	not done	**37**	**214**	**251**
	1995	**44**	**48**	**218**	**391**
	1997	**25**	**36**	**114**	**221**
	1999	**18**	29	**89**	**148**
	2001	**17**	34	**110**	**248**
	2003	**13**	29	**74**	**243**
	2005	**14**	35	**75**	**192**
	2007	**13**	34	**51**	**187**
ISQG		5.9	35.7	35.0	123
PEL		17.0	197.0	91.3	315

Note: ISQG = Interim freshwater Sediment Quality Guidelines, in **bold** where exceeded
PEL = Probable Effects Level in **bold** and shaded where exceeded







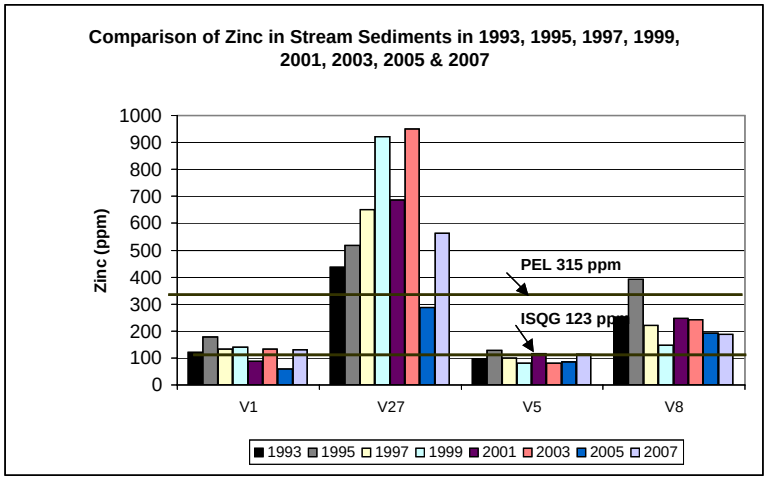


Figure 7.2-1: Temporal comparison of average sediment metal concentrations at Vangorda Creek monitoring stations, 1993 to 2007

Current metal concentrations (2001 to 2007) in the stream sediments have been relatively stable at V1, V5 and V8 with a gradual reduction in lead and zinc concentrations at V8. Although metal concentrations have been significantly greater at V27 than at the other sites, the concentrations of the metals have been decreasing steadily since peaking in 2001, with some fluctuation of zinc.

All samples exceeded the ISQG for arsenic, with the PEL also exceeded in all V27 samples and some of the V1 samples (Table 7.2-1). Concentrations of arsenic in the stream sediments at the far field sites are similar to the reference site and appear to be a natural element found in the Vangorda watershed.

Copper concentrations in the stream sediments at V27 have been decreasing in recent years and are approaching background levels.

Lead concentrations in the stream sediments at V5 have typically been lower than the reference site V1. Significantly higher levels of lead have been documented at V27, peaking in 2001. Concentrations have decreased drastically since then, although they are greater than concentrations in the sediments at V1, V5 and V8. Lead concentrations at V8 continue to exceed the ISQG.

Zinc concentrations in the stream sediments have frequently exceeded the ISQG at V1 and V8, and have exceeded the PEL at V27. Levels appear relatively stable over time at V1, V5 and V8, and appear to display a decreasing trend at V27.

There have been no mine related inputs to the Vangorda system since 2005. Analysis is completed on the fine grained and easily transported sediment, and it would appear that this material has been gradually mobilized through the system. The documented high concentrations of metals at V27 during the 1990s have either not yet mobilized to V8, or have mobilized to the Pelly River.

7.2.2 Rose Creek

7.2.2.1 Historical Data

Stream sediment samples have been collected sporadically and inconsistently in the Rose Creek watershed with the first collection occurring in 1973. It was not until 2004 that monitoring the quality of stream sediments became a licensed requirement. Samples have been collected from a total of eleven sites within the Rose/Anvil Creek drainage, ranging from upstream on the North Fork of Rose Creek to Anvil Creek at the mouth near the confluence with the Pelly River. The sites have been arranged in the tables and graphs with the reference sites (R6, R7, and R1) at the beginning followed by the near and far field sites as they occur downstream.

The 1973, 1983, 1996 and 1999 (historical data) results for Rose Creek sediments indicate that copper concentrations exceed the 35.7 ug/g ISQG in most impacted areas and some reference area samples (Table 7.2-2, Figure 7.2-2). Lead concentrations in sediment exceed the 91.3 µg/g PEL in most impact and reference area samples. Some zinc concentrations exceed the 123 µg/g

ISQG while the remainder exceed the 315 µg/g PEL at impact and reference area samples. Spatial trends in the data set are not apparent and temporal trends indicate highest values for the three metals in 1983 samples from the impacted area (following a 1975 tailings spill into Rose Creek) as compared to 1973 and 1996 values. However, very high concentrations of arsenic, lead, mercury and zinc were also documented in 1983 at R6, a reference site for Anvil Creek, leading to speculation on the accuracy of these analyses. Concentrations of these metals in the sediments at R6 since 1983 have been constantly much lower.

The stream sediments at R2, the near field site, consistently had the highest concentrations of the metals examined with all samples exceeding the ISQG for all metals, and the PEL for arsenic, lead and zinc.

7.2.2.2 Recent Data

Minnow Environmental Inc (2007) examined all the data collected from the Rose Creek Watershed from 1973 to 2006. Statistical evaluation of the data spatially and temporally, identified that the key indicators of mine influence on sediment chemistry of this watershed were arsenic, lead, manganese and zinc. Summarized data for cadmium and mercury have also been included in Table 7.2-2 and Figure 7.2-2. There are no guidelines for manganese but since this metal exceeded background concentration by the greatest magnitude, it has been identified as a parameter to monitor (Minnow 2007).

The recent data (2002, 2004, 2005 and 2006) for arsenic are generally stable at the sites with the stream sediments at R2, R3 and R4 having the greatest concentration (except for an outlier in 2005 at R5). Arsenic levels appear to be decreasing and levelling off at R2, R3 and R4 approaching background levels.

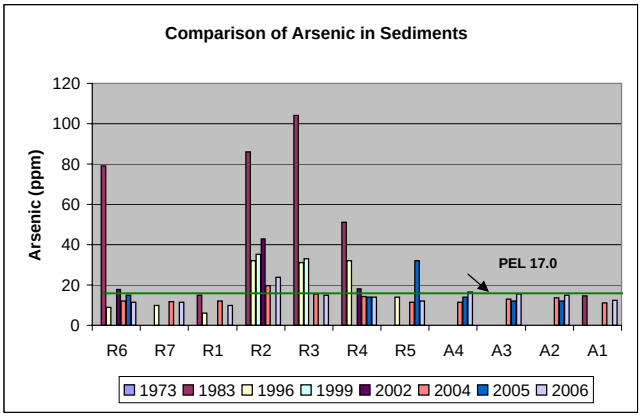
The recent data (2002, 2004, 2005 and 2006) indicates that lead and zinc levels continue to be greatest at the near field site, R2, and gradually decrease progressively downstream. Lead and zinc have been relatively low at the reference sites R6 and R7, however the ISQG has occasionally been exceeded at R1. Lead and zinc levels appear to be decreasing over time at the impacted sites R2, R3 and R4.

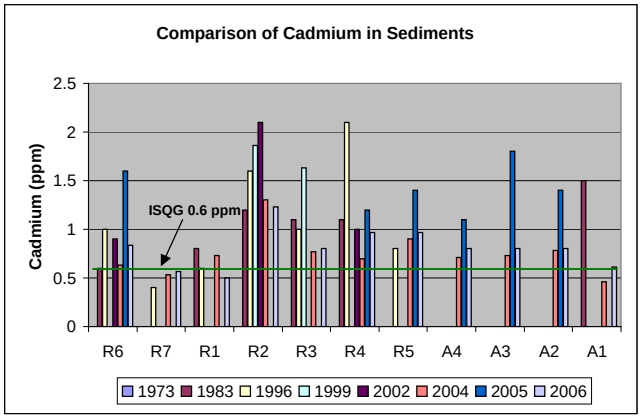
Cadmium, mercury and manganese concentrations are greater than the reference sites, however cadmium levels at R6 are quite similar to the other sites.

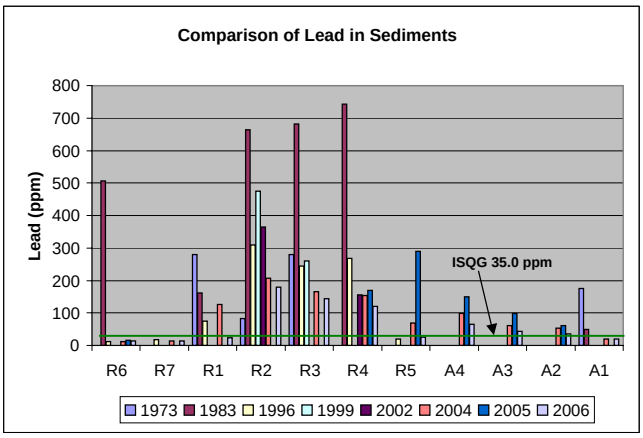
Table 7.2-2 Selected Metal Concentrations in the Stream Sediments of the Rose Creek Watershed

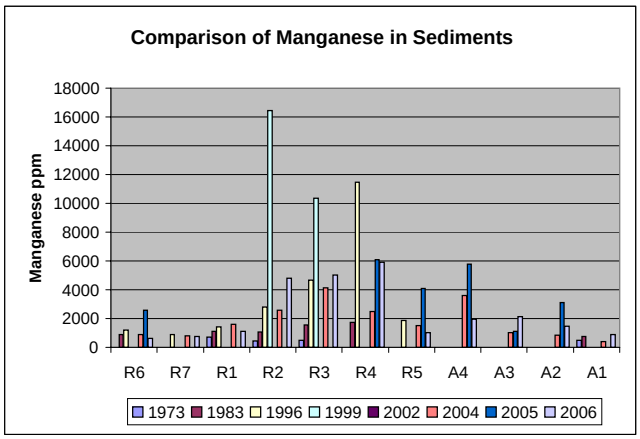
Station	Year	Metal (mg/kg)						
		Arsenic	Cadmium	Copper	Lead	Manganese	Mercury	Zinc
R6	1973							
	1983	**79.0**	**0.6**	**116.0**	**83.0**	901	**1.0**	877
	1996	**9.0**	**1.0**	34.0	11.0	1222	0.02	**125**
	1999							
	2002	**17.7**	**0.9**	29.3	30.0		0.03	**155**
	2004	**12.2**	**0.6**	20.0	11.0	890	0.01	66
	2005	**15.0**	**1.6**	31.0	16.0	2600	0.05	**140**
	2006	**11.3**	**0.8**	33.0	14.7	634	0.02	109
R7	1973							
	1983							
	1996	**10.0**	0.4	14.0	18.0	887	0.05	82
	1999							
	2002							
	2004	**11.9**	0.5	17.3	14.7	809	0.02	78
	2005							
	2006	**11.3**	0.6	17.3	14.7	745	0.02	81
R1	1973			**64.0**	**280.0**	700		**270**
	1983	**15.0**	**0.8**	25.6	**161.0**	1122	**0.23**	**260**
	1996	**6.0**	0.6	21.0	**74.0**	1419	0.05	**221**
	1999							
	2002							
	2004	**12.1**	**0.7**	18.3	**125.3**	1590	0.09	**203**
	2005							
	2006	**10.0**	0.5	10.0	22.7	1123	0.01	**131**
R2	1973			24.0	**83.0**	460		**180**
	1983	**86.0**	**1.2**	**116.0**	**665.0**	1053	**1.10**	**918**
	1996	**32.0**	**1.6**	**60.0**	**310.0**	2808	**0.28**	**617**
	1999	**35.1**	**1.9**	**122.6**	**475.7**	16430	**0.37**	**1060**
	2002	**42.7**	**2.1**	**82.7**	**364.0**		**0.27**	**1583**
	2004	**19.6**	**1.3**	**58.3**	**207.3**	2577	0.18	**482**
	2005							
	2006	**23.7**	**1.2**	**60.7**	**178.7**	4797	0.18	**694**
R3	1973			**44.0**	**280.0**	490		**440**
	1983	**104.0**	**1.1**	**117.0**	**682.0**	1550	**1.10**	**996**
	1996	**31.0**	**1.0**	**59.0**	**244.0**	4665	0.17	**581**
	1999	**33.0**	**1.6**	**85.5**	**261.0**	10340	**0.23**	**890**
	2002							
	2004	**15.6**	**0.8**	**46.7**	**165.3**	4151	0.12	**376**
	2005							
	2006	**15.0**	**0.8**	**46.3**	**143.0**	5040	0.10	**464**
R4	1973							
	1983	**51.0**	**1.1**	**172.0**	**742.0**	1723	**1.00**	**885**
	1996	**32.0**	**2.1**	**78.0**	**267.0**	11466	0.11	**908**
	1999							
	2002	**18.0**	**1.0**	**44.3**	**156.0**		0.16	**171**
	2004	**14.2**	**0.7**	**38.7**	**153.7**	2483	0.11	**294**
	2005	**14.0**	**1.2**	**48.0**	**170.0**	6100	0.18	**560**
	2006	**14.0**	**1.0**	**47.0**	**120.0**	5927	0.09	**470**
R5	1973							
	1983							
	1996	**14.0**	**0.8**	35.0	20.0	1855	0.11	**161**
	1999							
	2002							
	2004	**11.4**	**0.9**	**42.3**	**69.3**	1518	0.03	**212**
	2005	**32.0**	**1.4**	**78.0**	**290.0**	4100	**0.34**	**470**
	2006	**12.0**	**1.0**	**38.3**	24.7	1014	0.04	**149**
A4	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**11.5**	**0.7**	24.0	**98.0**	3580	0.05	**274**
	2005	**14.0**	**1.1**	**42.0**	**150.0**	5800	0.14	**430**
	2006	**16.4**	**0.8**	**42.6**	**65.6**	1937	0.08	**313**
A3	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**13.0**	**0.7**	26.8	**62.0**	1020	0.06	**184**
	2005	**12.0**	**1.8**	**58.0**	**99.0**	1100	0.13	**400**
	2006	**15.7**	**0.8**	**122.7**	**44.3**	2140	0.07	**221**
A2	1973							
	1983							
	1996							
	1999							
	2002							
	2004	**13.6**	**0.8**	27.5	**52.9**	862	0.06	**167**
	2005	**12.0**	**1.4**	**44.0**	**61.0**	3100	0.04	**300**
	2006	**14.8**	**0.8**	**92.4**	34.8	1455	0.07	**195**
A1	1973			**100.0**	**175.0**	500		**275**
	1983	**14.7**	**1.5**	30.0	**50.0**	745	0.13	**145**
	1996							
	1999							
	2002							
	2004	**11.0**	0.5	18.0	19.4	381	0.04	90
	2005							
	2006	**12.3**	**0.6**	**82.7**	20.1	872	0.05	**133**
ISQG		5.9	0.6	35.7	35.0		0.2	123
PEL		17.0	3.5	197.0	91.3		0.486	315

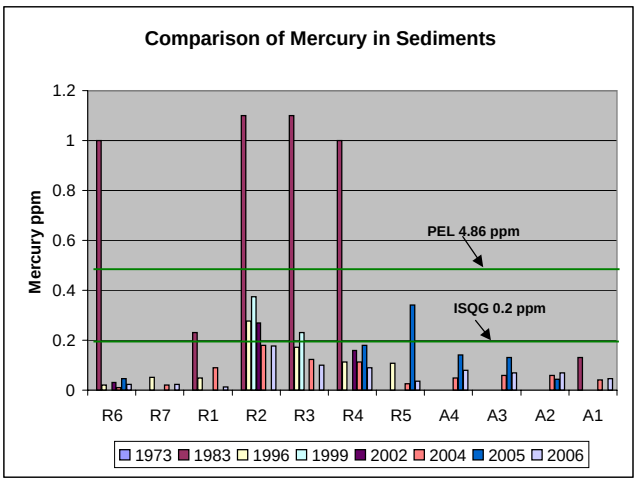
Note: ISQG = Interim freshwater Sediment Quality Guidelines, in **bold** where exceeded
PEL = Probable Effects Level in **bold** and shaded where exceeded











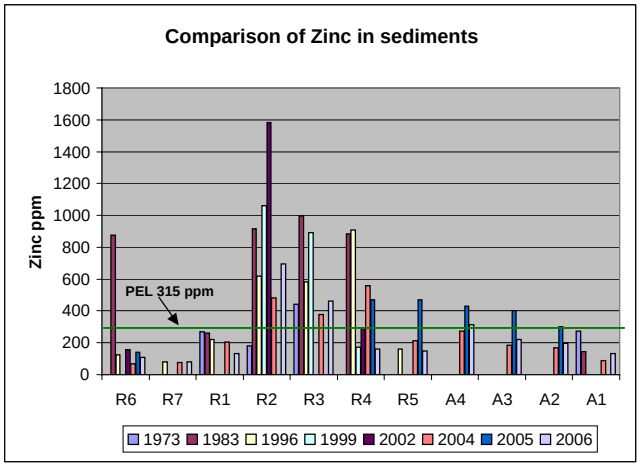


Figure 7.2-2: Temporal comparison of average sediment metal concentrations at Rose and Anvil Creek monitoring stations, 1973 to 2006

7.3 Benthic Invertebrates

Benthic invertebrates include insects, crustaceans, aquatic worms and mollusks that reside in and on stream bottoms. Benthic invertebrate community structures are often used as measure of ecosystem health. Impacts to watercourses such as substrate composition, water flows and, in particular, water and sediment quality can affect benthic organisms. Sampling has been conducted at the following stations in the Rose and Vangorda watersheds:

1. R1 - Rose Creek south fork d/s of FWSD Reservoir, a reference site
2. R2 - Rose Creek at confluence of diversion channel and tailings outlet
3. R3 - Rose Creek between tailings and Anvil Creek
4. R4 - Rose Creek at confluence with Anvil Creek
5. R5 - Anvil Creek d/s of Rose Creek
6. R6 - Anvil Creek u/s of Rose Creek, a reference site
7. R7 - North Fork of Rose Creek, a reference site
8. V1 - Vangorda Creek upstream of diversion, a reference site
9. V5 - Vangorda Creek west fork downstream of mine activity
10. V27 - Vangorda Creek downstream of mine activity
11. V8 - Vangorda Creek at mouth

Sampling was initiated at some of these sites in 1973 within the Anvil/Rose watershed and in 1975 within the Vangorda watershed. From 1988 (Rose Creek) and 1991 (Vangorda Creek) benthic invertebrate population monitoring has been conducted at each of the applicable sites every second year as per the requirements of the water licences. Artificial substrates were used for the majority of the sampling events, allowing consistency across much of the data set. Triplicate samples were collected at each site during each sampling event and the results pooled to report community structure. A summary of the benthic invertebrate projects and the methods used are provided in Table7.3-1.

Sampling results have been summarized in terms of abundance (total number of organisms) and richness (number of taxa), as a means of comparing the benthic invertebrate community health over time and throughout the watersheds.

7.3.1 Vangorda Watershed

Similar to the sediment data, sites have been arranged in the tables and graphs as they occur geographically.

Table 7.3-1 Summary of Studies and Methods used in Benthic Invertebrate Community Assessments and Tissue Analysis

Reference	Year Sampled	Stations	Sampler	Replicates/station	Incubation or collection dates	mesh size	Taxonomy
Hoos and Holman 1973	1973	R1-R3, R5, R11	1 square foot circular sampler	3	Sept 17-21, 1973	not specified	genus
Baker 1979	1974-1976	R1-R4, R6, R11 and Pelly River	chrome-plated baskets with rocks	3	1974, 1975, and 1976 (dates not given)	100 microns (surber)	genus
Montreal Engineering 1976	1975	West Fork Vangorda, South Fork Rose (u/s R1), Blind Creek	Surber and plankton tow	3 (surber)	August 1975	not specified	Partially to family
Weagle 1981a	1977	R1-R4, R6, R11 and Pelly River	chrome-plated baskets with rocks	3	August 18 to Oct 5, 1977	100 microns (surber)	genus
Weagle 1981a	1978	R1-R4, R6, R11 and Pelly River	Surber	3	August 18 to Oct 5, 1977	100 microns (surber)	genus
Weagle 1980	1980	R1-R5, V1, V27, VGMAIN, Blind Creek, Swim Creek	cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	Aug 14-15 to Sept 17-18, 1980	100 microns (surber)	genus/species
Weagle 1981b	1981	R1-R6, V1, V27, Blind Creek, Swim Creek	chrome-plated cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	Aug 27/28 to Sept 30/Oct 2, 1981	100 um (surber)	genus/species
Weagle 1982	1982	R1-R5	chrome-plated cylindrical BBQ baskets, 17cm dia, 24cm long. Filled with rocks to up to 5 cm	2	September 7-October 8, 1982	100 um (surber)	genus/species
Godin and Osler 1985	1983	R1-R6, R11, and Pelly River	Baskets with rocks 1-8 cm diameter	3	July 26 to Sept 15, 1983	0.76mm	genus
Weagle 1983	1983	R1-R5	BBQ baskets, 40 x 40 x 15 cm. Filled with rocks to up to 2.5 cm	2	Aug 19/20 to Oct 13/14, 1983	100 um (drift net)	genus/species
Leverton and Associates 1987	1986	R2-R5 (see comment re: R1)	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	July 14 to August 27, 1986	not specified	genus/species
Burns 1989	1988	R1-R5	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 5 to Sept 21-22, 1988	sieved through 300 micron mesh bucket	genus/species
Burns 1989	1988	R6, V8 and Blind Creek	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 5 to Sept 21-22, 1988	sieved through 300 micron mesh bucket	genus/species
Burns 1991	1990	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Aug 22/24 to	sieved through 300 micron mesh bucket	genus
Harder and Associates 1991c	1990	V8 and Blind Creek	baskets with clean substrata; no details provided	3	July 29 to Sept. 5, 1990	sieved through 300 micron mesh bucket	family/genus
Harder and Associates 1992	1990	V1, V5, V27, V8, Blind and Buttle Creeks	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	installed July 18-19, 1990, for five weeks	sieved through 300 micron mesh bucket	not specified
Harder and Associates 1993a,b	1992	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	July 8/10 to Aug 16/17, 1992	sieved through 300 micron mesh bucket	family/genus
Burns 1994	1994	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Burns 1993 1996, 1998, 2000, 2001, 2002b, 2003, 2005, 2007	1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007	V1, V5, V27, V8	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Burns 1997, 1999, 2001, 2002b, 2004, 2006	1996, 1998, 2000, 2002, 2004, 2006	R1-R7	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia)	3	Installed late July and retrieved after about five weeks	sieved through 300 micron mesh bucket	genus/species
Access, Laberge and White Mountain	2004	A1 - A4	Surber and Kick net	3		300 microns	genus/species
Access, Laberge and White Mountain	2005	A1 - A4	Surber and Kick net	3		300 microns	genus/species
Access, Laberge and White Mountain	2006	A1 - A4, R5, R6	Galvanized wire mesh cylinder 26cm long, 17cm dia. Filled with gravel (2-15cm dia), kick net	3	Installed late July and retrieved after about five weeks		genus/species

7.3.1.1 Historical Data

The historical data encompasses the years 1976, 1980, 1990, 1991, 1993, 1995, 1997 and 1999. Community populations were very low in 1976, 1980, 1991 and 1999 at all sites (Table 7.3-2 and Table 7.3-1). Populations were considerably greater in 1993, 1995 and 1999, with V27 seeing a significant increase in abundance. Although the metal concentrations in the stream sediments at V27 during these years exceeded the PEL, which should create adverse effects to the biotic community, there is no evidence of detrimental effects in terms of numbers of organisms. The reference site V1 generally had the lowest population per sampling period.

The diversity of the communities did not range as much during the years and there was not a great deal of difference between each site (Figure 7.3-2).

7.3.1.2 Recent and Current Data

The current and recent data include samples collected in 2001, 2003, 2005 and 2007. These data have been included in Table 7.3-2 and Figure 7.3-1 and Figure 7.3-2. Community populations have continued to fluctuate in recent years with V5 showing a significant increase in abundance. Population numbers continue to be lowest at the reference site V1. The low productivity at V1 is probably a function of the habitat here rather than the quality of the water or substrate.

The diversity of the benthic communities at all of the sites is increasing over time in the Vangorda watershed. The communities at the near field site, V27, have similar or greater population numbers and diversity than at the reference site V1, indicating that mine-related effects have had little or no effect on the biota here.

The community structure is an important indication on the health of the population at a site. In recent years one or more of the pollution sensitive insect orders Ephemeroptera, Plecoptera or Trichoptera have dominated the community at V27 (Burns, 2007). Minnow (2007) performed various statistics on the benthic data collected from Vangorda Creek. It was found that the percent EPT (pollution intolerant Ephemeroptera, Plecoptera and Trichoptera) was significantly greater at the near field site V27 than at any other station. The other sites did have representatives of these organisms but not to the degree as V27. The high proportion of EPT at V27 would also indicate that any mining-related activities have had little or no impact on the biological productivity of Vangorda Creek.

Table 7.3-2 Community Abundance and Diversity at the Vangorda Sites Over Time

Year	V1		V27		V5		V8	
	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity
1976	136	15						
1980	350	24	216	21			133	26
1990	300	7	1,299	7	2,985	15	3,162	16
1991	763	17	953	24	1,298	29	594	22
1993	3,090	19	5,952	17	2,193	21	3,024	19
1995	1,758	26	4,929	28	1,550	28	8,340	35
1997	1,663	29	11,751	29	9,291	38	904	25
1999	1,025	20	1,061	23	1,284	32	1,061	28
2001	707	21	3,698	24	17,232	40	5,867	28
2003	1,025	30	1,301	27	3,377	42	3,989	31
2005	5,534	32	6,329	28	13,570	35	6,687	36
2007	2,918	37	2,338	36	7,279	49	3,385	48

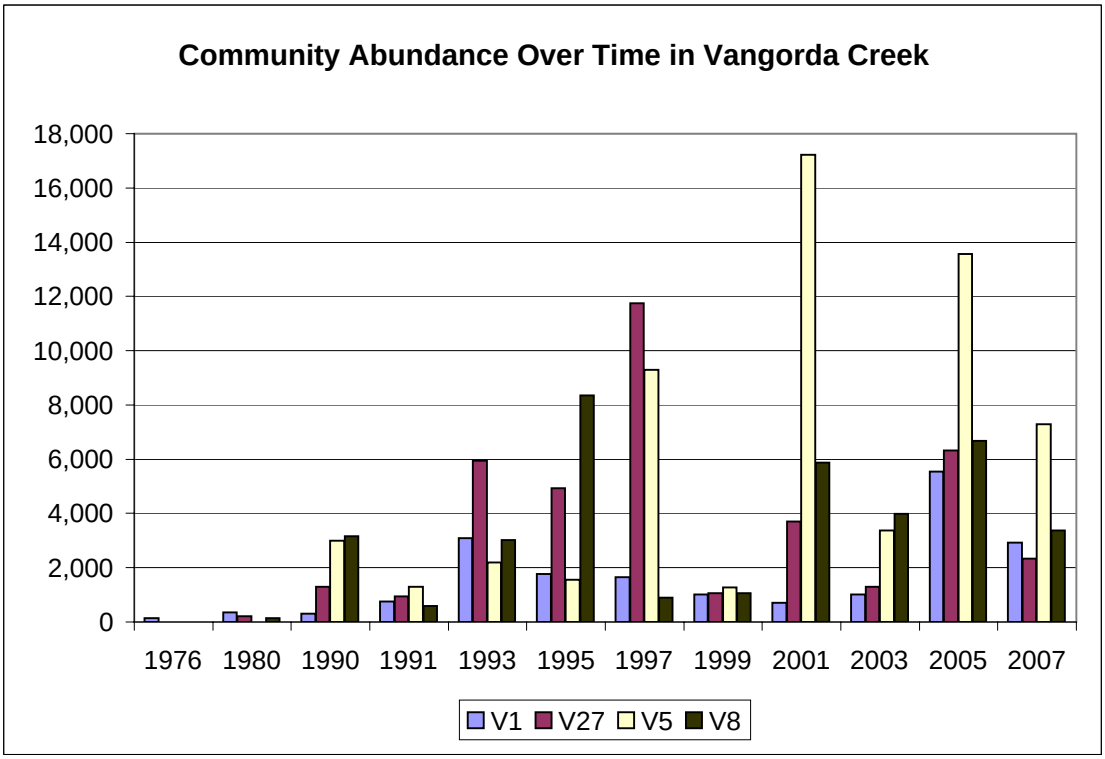


Figure 7.3-1: Community Abundance Over Time in Vangorda Creek

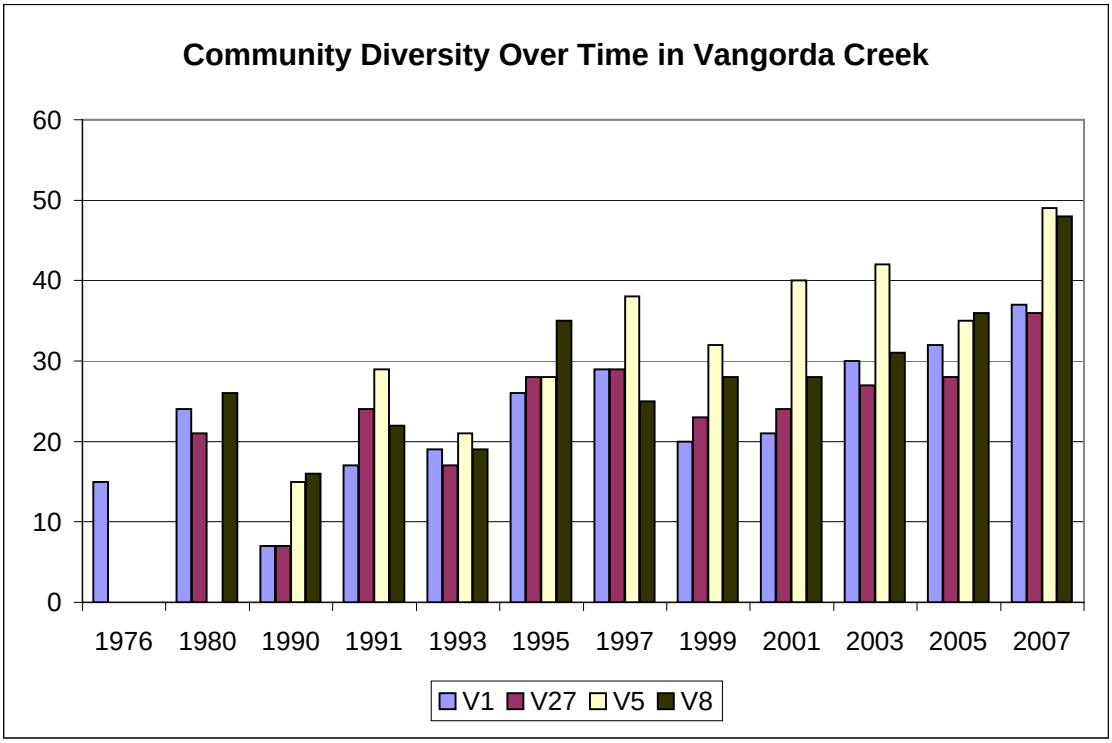


Figure 7.3-2: Community Diversity Over Time in Vangorda Creek

7.3.2 Rose Creek Watershed

7.3.2.1 Historical Data

The historical data covers the period from 1974 to 1998. Populations were very low in the early years, 1974 to 1980. Not all sites have been sampled consistently and it was not until 1980 that R4 was sampled for the first time. Within this limited data set populations ranged from 3 at R3 in 1974 to 547 at R6 in 1975. Abundance increased from 1981 to 1992 with a range of 32 individuals at R3 in 1988 (all sites had low populations in 1998) to 5,903 organisms at R4 in 1986. There were some population explosions during the period 1994 to 1998. The highest population occurred at R3 in 1994 with a total of 54,875 individuals and the lowest was also at R3 in 1996 with 144 individuals. R1 also saw a population boom in 1998 with a total of 50,808 individuals collected (Table 7.3-3).

In general terms the historic data shows that populations were very depressed from 1974 to 1980, gradually recovered from 1981 to 1992, and exhibited very high populations in 1994 and 1998 at some of the sites, including the impacted site of R3 (Figure 7.3-3).

The diversity of the benthic communities generally followed the same trend as the abundance data. Populations became more diverse during the early to mid 1980s, then diversity decreased at all sites from 1988 to 1992. Diversity increased at all sites in 1994 and remained high up to 2000 (Table 7.3-4, Figure 7.3-4). Generally per sample period, the community at R1 had the greatest diversity.

Table 7.3-3 Community Abundance at the Rose Creek Sites Over Time

Year	R1	R2	R3	R4	R5	R6	R7
1974	25	33	3		24	247	
1975	182	213	65		466	547	
1976	137	32	45		190	328	
1976	215						
1977	398	99	47		226		
1978	74	5	8		375		
1980	333	191	6	37	434		
1981	2,457	634	166	274	4,126		
1982	784	2,193		1,856	777		
1983	2,906	5,187	5,436	2,336	2,401		
1983	1,226	1,709	517	907			
1984	1,736	320	101	4,780	161		
1986	469	2,736	3,250	5,903	4,702		
1986	156	911	1,083	1,973	1,605		
1987	374	93	1,619	1,106	2,226		
1988	128	115	32	116	425		
1990	1,373	4,564	2,455	2,175	3,470	3,477	2,467
1992	1,141	400	321	312	1,263	3,911	1,053
1994	5,489	920	54,875	2,366	4,115	15,431	14,756
1996	1,629	991	144	666	2,726	2,741	7,029
1998	50,808	1,945	13,491	8,148	7,974	26,944	39,292
2000	5,368	6,611	18,929		66,975	39,344	4,574
2002	9,988	6,611	13,491	4,430	15,088	1,232	10,965
2004	55,191	11,639	18,929	4,964	2,206	8,759	32,380
2006	16,685	38,042	1,808	4,252	1,768	8,934	838

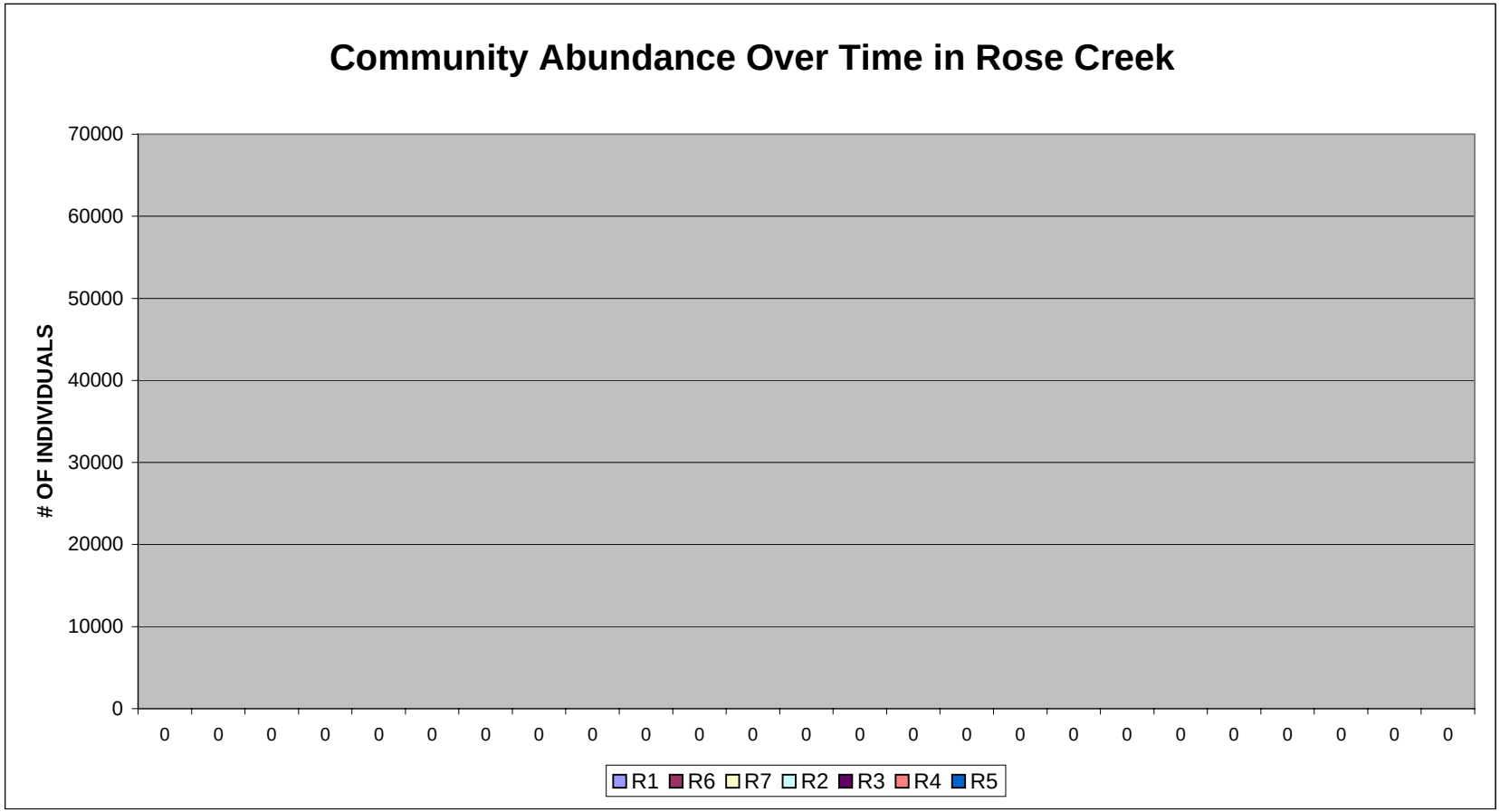


Figure 7.3-3 Community Abundance at the Rose Creek Sites Over Time

Table 7.3-4 Community Diversity at the Rose Creek Sites Over Time

Year	R1	R2	R3	R4	R5	R6	R7
1974	7	7	4		7	9	
1975	9	6	7		10	15	
1976	16	6	11		17	23	
1976	30						
1977	23	10	13		17		
1978	10	3	4		17		
1980	34	13	3	10	24		
1981	35	21	19	20	33		
1982	40	30		28	26		
1983	56	41	47	38	39		
1983	40	29	28	31			
1986	29	58	48	50	51		
1988	24	24	8	15	22		
1990	21	20	20	20	25	25	26
1992	27	14	12	14	25	31	22
1994	60	47	49	53	55	46	44
1996	57	37	25	35	43	45	45
1998	57	47	39	48	44	43	44
2000	57	48	42	na	54	56	40
2002	60	54	40	52	45	36	37
2004	49	43	41	44	44	46	44
2006	57	53	48	51	38	45	38

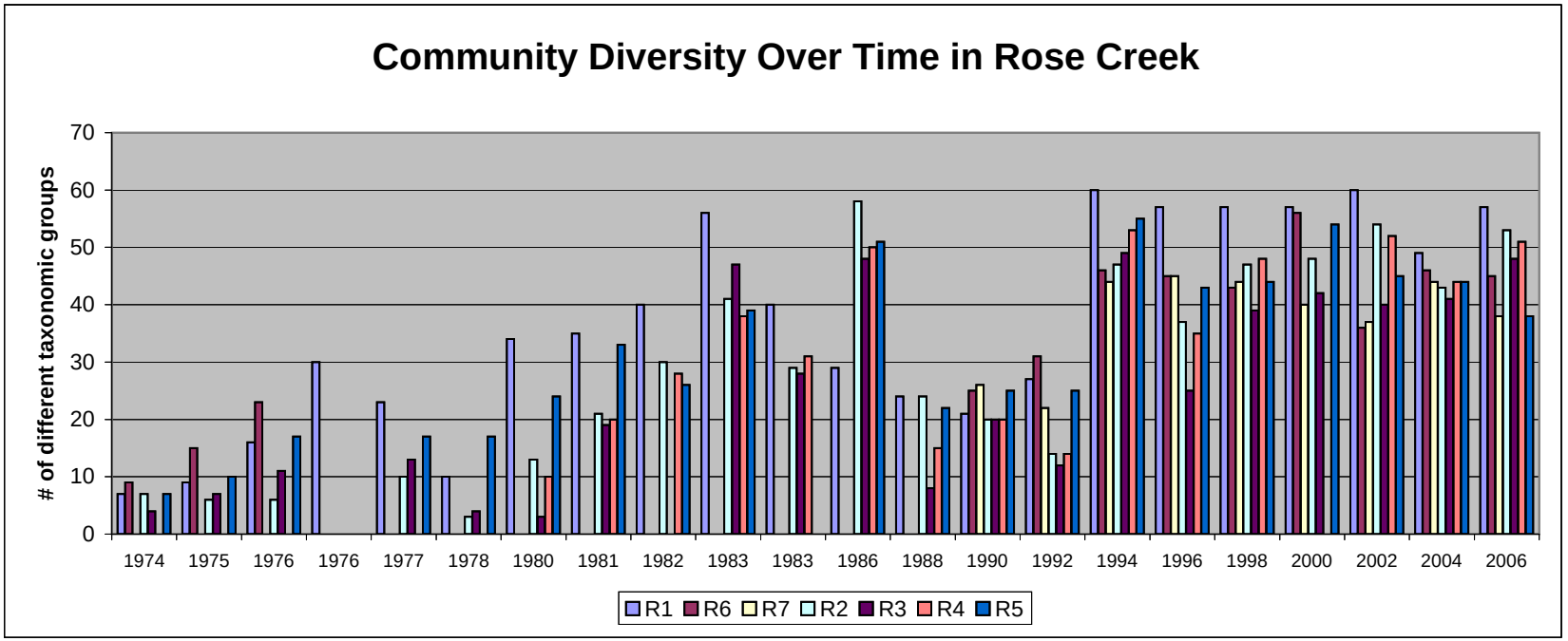


Figure 7.3-4: Community Diversity at the Rose Creek Sites Over Time

Table 7.3-5. Percentage of Pollution Sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) at Rose Creek Sites

Site	2000	2002	2004	2006	Average
R6	20.6	18.3	40.5	23.0	25.6
R7	15.5	11.1	14.4	24.3	16.3
R1	14.4	19.8	22.6	17.2	18.5
R2	38.1	26.3	21.1	49.2	33.7
R3	81.9	11.6	39.8	23.3	39.2
R4		25.1	22.8	50.1	32.7
R5	30.6	15.5	14.3	42.5	25.7

Note: Due to high water the samplers at R4 could not be retrieved from R4 in 2000.

7.3.2.2 Recent and Current Data

To reflect current conditions at the Rose Creek site, the data for the years 2000, 2002, 2004 and 2006 were examined. Population numbers increased significantly during this period at several of the sites although numbers did fluctuate between year and site (Table 7.3-3 and Figure 7.3-3). The community at R5 had the highest population in 2000 and 2002. The greatest abundance was documented at R1 in 2004 and at R2 in 2006. Several other sites also had high populations during each of these years. Populations in the tens of thousand did not occur at any of the sites until 1994 but became fairly frequent from 1998 on.

The benthic communities at all of the sites have become much more diverse in recent years (Table 7.3-4, Figure 7.3-4). Diversity ranged from 36 taxa to 60 during the studies conducted from 2000 to 2006. The community at R1 continued to be the most diverse of the sites during this time period. The community at the reference site, R7, was typically the least diverse in recent years.

To further characterize the recent Rose Creek data, the percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT), insects that are typically sensitive to chemical pollution, were calculated (Table 7.3-5). The proportion of EPT did fluctuate somewhat, although overall the %EPT in the exposure areas (R2, R3 and R4) was greater than in the reference areas (R1, R6 and R7). Although R1 had the highest diversity, it usually had a lower proportion of sensitive organisms than the mine exposed sites R2, R3 and R4.

The above data shows that the benthic communities at all the sites are healthy and robust and suggests that there are minimal, if any, mine influenced impacts to the stream biota in Rose Creek downstream of the tailings facility from 2000 to 2006.

7.3.3 Metals in Benthic Invertebrates

Benthic invertebrates were collected for the analysis of metals in tissue around the Faro Mine Complex for the first time in 2002. The analysis was initiated to determine the extent to which metals were accumulating in the benthic invertebrates (benthos) and thus the pathway for bioaccumulation in

aquatic vertebrates (slimy sculpin and Arctic grayling). While most metals do not biomagnify between trophic levels, small invertebrates tend to accumulate greater concentrations of metals than large invertebrates, and therefore, early-life stage fish (which eat smaller invertebrates) may be exposed to a larger dose of metals than adults (which eat larger invertebrates; Fareg *et al* 1998). Benthos were collected at the regular benthic monitoring sites R2, R4, R6 and V8.

Table 7.3-6 outlines the results of selected metals (arsenic, cadmium, copper, mercury, lead and zinc) in benthic invertebrate tissue.

Table 7.3-6. Summary of Metal Concentrations in Benthic Invertebrate Tissue (wet weight µg/g), 2002

Creek	Site	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
Rose Creek	R2	0.35	0.075	12.8	0.011	6.42	50.6
Rose Creek	R4	0.25	0.055	4.7	0.006	3.14	34.2
Anvil Creek	R6	1.32	0.141	4.7	0.007	1.35	39.4
Vangorda Creek	V8	0.30	0.117	4.8	0.009	1.86	50.8

Concentrations of copper, mercury and lead are highest in benthos collected from site R2, while concentrations of arsenic and cadmium are the highest in benthos collected from the reference site R6. This correlates with the 2002 stream sediment results where sediment collected from R2 also contained the highest concentrations of copper, mercury and lead. Zinc concentrations are similar in benthos collected from R2 and V8. This does not correlate with the 2002 sediment sample results where the zinc concentration in V8 sediment is lower than R2 sediment.

During aquatic studies conducted on tributaries to the Pelly River by the Selkirk First Nation, benthic invertebrates were collected for metal analysis at sites A1, A2, A3 and A4 in 2004, 2005 and 2006. As there was no analysis on benthic tissues from any Rose Creek sites in 2004 and 2005, no correlation of this data can be accomplished. In 2006, benthic invertebrates were collected for metal analysis from R4, R5 and R6. Only benthos from R6 had been analyzed for metals previously. However, the tissues in 2002 were analyzed as wet weight, whereas in 2006, the data was reported as dry weight. The lab did not report the percent moisture, so these two data sets cannot be compared. The 2006 data is presented in Table 7.3-7. Details of the studies can be found in the individual reports prepared by ACG, LES and WMEC (2004, 2005, 2006).

Table 7.3-7. Summary of Metal Concentrations in Benthic Invertebrate Tissue (dry weight µg/g), 2006

Creek	Site	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
Anvil Creek	R6	1.3	8.9	48.3	0.6	3.4	299
Rose Creek	R4	<1	1.0	52.2		5.9	681
Anvil Creek	R5	4.8	1.0	57.5	0.9	12.0	374
Anvil Creek	A4	2.0	2.0	51.6	0.8	7.7	671
Anvil Creek	A3	1.9	2.7	64.5	0.4	7.3	552
Anvil Creek	A2	2.5	3.2	47.1	0.4	4.0	509
Anvil Creek	A1	2.0	6.0	56.0	0.5	6.1	614

The highest cadmium concentrations were again found in the benthos from the reference site R6. Concentrations were considerably lower in the main stem of Anvil Creek but increased progressively downstream. The lowest concentrations of lead and zinc were documented in the benthos from the reference site R6. Zinc concentrations were approximately double in the main stem of Anvil Creek and were similar in the benthos at the other sites. The highest arsenic and lead concentrations were reported in the benthos collected from R5. Copper and mercury concentrations did not range much in the benthos tissues at the sites.

7.4 Fish

7.4.1 Vangorda Creek

7.4.1.1 Fish Habitat

Activities associated with the Vangorda Plateau mining project occurred within the Vangorda watershed. Vangorda Creek contains two upper branches that meet to form the main stem plus a major tributary called the West Fork. The mainstem has been diverted around the various pits and dumps, and the mine haul road crosses this branch. The mine access road crosses the West Fork in three locations and a culvert under the Town of Faro access road crosses the main stem. Lower Vangorda Creek, upstream of the confluence with the Pelly River, is low gradient (1.5% to 2.7%) with large gravels, cobbles and boulders. Some spawning habitat is available in this section and rearing and the pools and in-stream cover offer summer habitat. This habitat provides excellent rearing habitat for Chinook salmon and moderate rearing for grayling and sculpin. Moderate over wintering habitat is provided for Chinook and sculpin (see Table 7.4-4 in Section 7.4.2.1).

The culvert under the Town of Faro access road and waterfalls just upstream are barriers to upstream fish movement. The channel gradient becomes progressively steeper upstream (4% in the mid-section and 6% in the headwaters) with larger substrate and log debris from adjacent burn areas (Harder 1987).

7.4.1.2 Fish Presence

The absence of fish in the West Fork and upper Vangorda Creek is likely due to the presence of impassable barriers located near the Town of Faro (Minnow 2007): perched culvert preventing fish passage and a steep natural cataract/waterfall. The reach near the licensed site V8, on lower Vangorda Creek has typically been investigated for fish assessments over the years. Slimy sculpin (*Cottus cognatus)*, Arctic grayling (*Thymallus arcticus*), Chinook salmon (*Oncorhynohus tshawytscha*), burbot (*Lota lota*), round whitefish (*Prosopium cylindraceum*) and longnose sucker (*Catostomus catostomus*) have been documented here.

Chinook salmon fry are present in large numbers in lower Vangorda Creek each year from the spring or early summer where they rear until outmigration in the fall. These fish are migrating from spawning grounds, including Blind Creek.

The reach at V8 has been assessed annually since 2004 as a licensed requirement, namely the *Aquatic Life Sampling and Testing Program*. Fish habitat and presence are documented and fish are collected for the analysis of metals in their tissues. The summaries of the electro-fishing and minnow trapping results conducted each August are provided in Table 7.4-1 and Table 7.4-2 respectively. Catches in Table 7.4-1 have been expressed by unit of effort as the number of fish recorded per 100 seconds shocking time. Catches in Table 7.4-2 have been expressed by capture/trap/24 hours. Minnow traps were also set at Blind Creek as a reference. Electro-fishing has not been conducted at Blind Creek as the assessment coincides with Chinook spawning activity during August.

Table 7.4-1. Comparison of electro-fishing results from August sampling of V8 on Vangorda Creek, 2004 to 2007.

Site	Year	Grayling sub ad. & adult	Grayling juvenile	Sculpin adult	Sculpin fry	Burbot	Chinook Salmon juvenile	Round Whitefish
V8	2004	1.08	0.59	0.69	0	0	16.60	0
	2005	0.30	0	0.49	0	0	18.62	0
	2006	1.02	0	0.26	0	0.13	4.99	0
	2007	2.58	2.57	0.22	0	0.11	15.45	0.11

Table 7.4-2. Comparison of Minnow trap results from August sampling V8 on Vangorda Creek, 2004 to 2007.

Site	Year	Arctic Grayling	Slimy Sculpin	Burbot	Juvenile Chinook Salmon 0+	Juvenile Chinook Salmon 1+
V8	2004	0.00	0.00	0.00	79.28	0.00
	2005	0.00	0.00	0.00	17.89	0.00
	2006	0.00	0.00	0.00	11.78	0.00
	2007	0.00	0.00	0.00	34.59	0.00
B1	2004	0.00	0.13	0.00	75.76	0.53
	2005	0.11	0.32	0.00	55.90	0.32
	2006	0.00	0.00	0.21	9.36	0.34
	2007	0.00	0.00	0.00	13.92	4.80

Of all species captured, Chinook salmon juveniles form the greatest densities. Densities were lower in 2006 and this corresponds with escapement numbers for adult Chinook salmon from the year proceeding the year of capture (WMEC, 2007). For the first time, numerous two and three year old (age estimated by weight) juvenile Chinook salmon were recorded in Blind Creek during the 2007 assessment (WMEC, 2007).

Sub-adult and adult Arctic grayling densities appear to be increasing over time (Table 7.4-1), and are a common presence in lower Vangorda Creek, whereas slimy sculpin appear to be slightly decreasing. Both sculpin and burbot are uncommon in this reach.

Relatively high fish species diversity and density in lower Vangorda Creek, compared to reference areas (Blind Creek), suggests negligible mine-related influence on local fish populations (Minnow, 2007).

7.4.2 Rose Creek

7.4.2.1 Historical Fish Habitat

Most of the Faro Mine Complex is located within the Rose Creek watershed, and construction and operations have altered the creek to result in the following:

- diversion of Faro Creek around the Faro Pit to enter the north fork of Rose Creek, rather than flowing directly into the main stem of Rose Creek;
- diversion of the main stem (reach 3) around the tailings impoundment facilities;
- creation of the pumphouse pond at the junction of the north and south forks;
- two alternative routes for the lower 500 m of the North Fork – one is the original channel with a series of excavated ponds, with a culvert at the upstream end preventing upstream fish migration and the other is a boulder-lined channel;

- construction of the Fresh Water Supply Dam (FWSD) converting approximately 1,500 m length of stream habitat into lake habitat;
- creation of a barrier on the south fork of Rose Creek through the installation of hanging culverts just downstream of the FWSD spillway; and
- a fish migration barrier on the North Fork at the haul road crossing; and
- fish migration barriers on the South Fork at the haul road and mine road crossings.

7.4.2.2 Existing Fish Habitat

Descriptions of the various established reaches on the Rose Creek watershed are detailed in Volume 2 of the Environmental Assessment Report prepared by Gartner Lee Ltd (2003). The only recent alteration to fish habitat has been the dewatering of the freshwater reservoir in November/December 2003. The South Fork of Rose Creek has more or less resumed its flow in its original channel since dewatering. Fish habitat assessments have been conducted annually since the summer of 2004. Three reaches (1 to 3) are within the dewatered reservoir, one reach (4) includes the area of the breach and just downstream, another reach (5) extends below the construction zone into the wetland complex and a final reach was assessed below the diversion canal to the water quality and flow site, X14. This final reach is assessed annually as it is the location where all fish removed from the freshwater reservoir prior to breaching of the dam were released. The descriptions of each reach are provided in Table 7.4-3.

Minnow (2007) examined all the fish studies completed at the Faro Mine Complex and summarized the habitat requirements and habitat availability of Arctic grayling, Chinook salmon and slimy sculpin in Rose and Vangorda watersheds (Table 7.4-4). The North Fork of Rose Creek (R7) and the South Fork of Rose Creek (R1) were found to have excellent rearing habitat for Arctic grayling. The South Fork of Rose Creek (R1) provided excellent spawning, rearing and overwintering habitat for slimy sculpin.

Table 7.4-3. Channel, cover and morphology characteristics from stream reaches of Rose Creek associated with the former reservoir, dam breach section and downstream from the breach construction area, (August 2007).

	Parameter	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	X-14
Site	Survey Date (dd/mm/yr)	14/08/2007	15/08/2007	15/08/2007	15/08/2007	15/08/2007	15/08/2007
	Reach Length (m)	370	690	950	265	335	360
	Survey Location (UTM)	08V 05 86 359 E 69 10 168 N	08V 05 86 190 E 69 104 00 N	08V 05 85 908 E 69 110 90 N	08V 05 85 523 E 69 113 22 N	08V 05 85 300 E 69 114 22 N	08V 05 79 349 E 69 150 78 N
Channel	Ave. Channel Width (m)	6.0	8.1	8.7	8.7	4.9	13.1
	Ave. Wetted Width (m)	4.7	7.2	6.3	6.9	4.2	10.9
	Ave. Residual Pool Depth (m)	0.3	0.6	0.9	0.4	0.4	1.1
	Bankfull Channel Depth (m)	0.3	0.3	0.8	0.5	0.6	0.3
	Discharge (m^3/sec)	0.432	0.664	--	0.613	0.554	2.039
	Gradient (%)	2.5	0.2	0.1	1.2	0.6	0.2
Cover	**Cover Abundance (%)**	**moderate (~15)**	**moderate (~15)**	**abundant (~25)**	**moderate (~15)**	**moderate (~15)**	**abundant (~20)**
	Dominant Cover Type	boulders and scour pools	deep pools	deep pools	Boulders	boulders	deep pools
	Subdominant Cover Type	undercut banks	undercut banks	undercut banks	deep pools	undercut banks and overhanging vegetation	large and small woody debris
	Other Cover Types Present	overhanging vegetation, small and large woody debris	boulders, overhanging vegetation, small and large woody debris	overhanging and instream vegetation, and small woody debris	Overhanging and instream vegetation, and small woody debris	instream vegetation, small woody debris, and scour pools	overhanging and instream vegetation
	LWD Frequency	Few	Few	none	None	none	few

Parameter		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	X-14
	% Crown Closure	0	0	0	0	0	0
Bank Characteristics	Left Bank Shape	vertical (>45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)	sloping (<45°)
	Bank Texture	fines	fines	fines	cobbles and boulders	fines	gravels
	Riparian Vegetation	grasses	grasses	grasses	grasses and shrubs	shrubs	shrubs
	Riparian Stage	Initial	Initial	initial	Initial	shrub/herb	shrub/herb
	Right Bank Shape	vertical (>45°)	vertical (>45°)	sloping (<45°)	vertical (>45°)	vertical (>45°)	vertical (>45°)
	Texture	fines	fines	fines	cobbles and boulders	fines	fines
	Riparian Vegetation	grasses	grasses	grasses	grasses and shrubs	shrubs	shrubs
	Riparian Stage	initial	Initial	initial	Initial	shrub/herb stage	shrub/herb stage
Morphology	Dominant Bed Material (cm)	boulder (> 25.6)	gravel (0.2 – 6.4)	fines (<0.2)	Fines (<0.2)	cobble (6.4 – 25.6)	fines (<0.2)
	Subdominant Bed Material (cm)	cobble (6.4 – 25.6)	fines (<0.2)	gravel (0.2 – 6.4)	cobble (6.4 – 25.6)	fines (<0.2)	gravel (0.2 – 6.4)
	D95 (cm)	60	30	5	35	40	8
	D (cm)	20	10	5	18	15	5
	Morphology	riffle-pool	riffle-pool	riffle-pool	step-pool	riffle-pool	riffle-pool
	Pattern	sinuous	tortuous meanders	tortuous meanders	regular meanders	sinuous	irregular meanders
	Islands	none	none	occasional	none	none	none
	Bars	side	side	mid-channel and span	side	side	side
	Confinement	unconfined	unconfined	unconfined	confined	unconfined	occasionally confined
Water Quality	Temperature (ºC)	8.5	12.5	13.5	12.0	-	9.0
	pH	8.9	9.0	8.8	8.8	-	8.6
	Conductivity (μS/cm)	120	160	170	170	-	440
	Turbidity	clear	clear	clear	clear	clear	clear

Table 7.4-4 Summary of Arctic grayling, Chinook salmon and slimy sculpin habitat requirements and habitat availability within the Rose-Anvil Creek system and lower Vangorda Creek

Species	Habitat Requirements			Habitat Availability Rating					
	Spawning (S)	Rearing (R)	Overwintering (OW)	Upper Anvil Creek (R6 Reference)	North Fork Rose Creek (R7 Reference)	South Fork Rose Creek (Station R1)	Lower Rose Creek (Station R2, R3, R4)	Lower Anvil Creek (Stations R5, A1 to A4)	Lower Vangorda Creek (Station V8)
Arctic grayling (*Thymallus arcticus*)	Small gravel- or rock-bottomed stream-runs at 0.3 m to 0.8 m depth, often near inlet/outlet of ponds and lakes; males territorial	Fry occupy shallow, quiter waters of stream edges and side channels; older fry and/or juveniles may migrate from hatching grounds to deeper pools and ponds with suitable cover, therefore both rocky-bottomed streams and silt-covered ponds important habitats	Deepwater habitats including lakes & ponds mainly [adults], but also deep pools with ample instream cover (e.g., vegetative debris, undercut banks, large cobble and boulder substrate) in streams and/or rivers [adults and juveniles]; adults relatively tolerant of low oxygen (i.e., winter hypoxia) conditions	Poor S, R & OW (lack of side channels and deep water)	Moderate S, OW habitat; Excellent R	Moderate S, Excellent R, Poor OW	Moderate S, OW Poor R	Moderate S, R, OW	Poor S, OW Moderate R
Chinook salmon (*Oncorhynchus tshawytscha*)	Larger tributaries with relatively large substrate (25 to 305 mm diameter) and deep water (0.3 m to 9.5 m deep) near riffles (water velocity from 0.25 m/s to 2.25 m/s); large redds constructed	Young fry are found primarily along the sides of pools and near the cover of over-hanging banks. Older fry increase their distance from cover and tend to occupy greater water depths and velocities which are sheltered from current.	In small streams, deeper pools with ample instream cover (e.g., vegetative debris, undercut banks, large cobble and boulder substrate) required; fry often migrate out of smaller tributaries in the fall	Poor S, R & OW (? based on low numbers observed)	NA (no access)	Poor S, R & OW (? based on low densities observed)	Poor S, R & OW (? based on low numbers observed)	Poor S Moderate R, OW	Poor S Excellent R Moderate OW
Slimy Sculpin (*Cottus cognatus*)	Rock-bottomed run-habitat of streams, or rocky areas of lakes	Gravel and rock-bottomed areas of streams and lakes; juveniles may occupy areas with smaller substrate and water velocities (e.g., stream edge and side channels) relative to adults	Same as rearing habitat, but often in proportionately deeper waters; species exhibits limited seasonal migration	Unknown S, OW Poor R	Moderate S, R, OW	Excellent S, R, OW	Moderate S,R & OW at R2; Poor S, R and OW at R3 and R4	Moderate S, R, OW	Moderate S, R, OW

(Taken from Minnow (2007))

7.4.2.3 Fish Presence

As at lower Vangorda Creek, slimy sculpin, Arctic grayling, Chinook salmon, burbot, round whitefish and longnose sucker have been captured in the Rose-Anvil watershed. Slimy sculpin were generally the most commonly encountered species, found at most of the sites on most of the occasions, and frequently occurred in the highest densities. Arctic grayling also are common throughout the watershed and is the only species that has been fished for sport. Fishing had been popular in the freshwater reservoir and in the pumphouse pond. Chinook salmon have been documented in the lower reaches of Anvil Creek over time, and in recent years as far upstream as R1 (juveniles only).

Minnow (2007) examined fish studies from 1989 to 2005 and concluded that the relatively high fish species diversity and density at areas immediately below the tailings facility discharge (Station R2) in Rose Creek relative to reference areas and to areas in lower Anvil Creek during the recent biological studies, suggest that mine-related activities were not adversely affecting Rose-Anvil system fish populations.

Electro-fishing, minnow trapping and angling have been the primary methods for collecting fish. Sites on Rose Creek, as well as one on Anvil Creek, have been assessed annually since 2004 as a licensed requirement, namely the *Aquatic Life Sampling and Testing Program*. Fish habitat and presence are documented and fish are collected for the analysis of metals in their tissues each year. Fish capture data as it relates to electro-fishing and minnow trapping results for 2004 to 2007 have been summarized in Table 7.4-5 and Table 7.4-6 respectively, for these long established sites on the Rose Creek system. Adult grayling have been caught at all sites by angling (Table 7.4-7).

All life stages of Arctic grayling occur at the Rose Creek sites. Only adults have been captured at Anvil Creek, R6. Habitat is limited for adults at R1, however juveniles are found here more frequently than at the other Rose Creek sites. R2 had the highest numbers for adults obtained by electro-fishing. R4 and R6 had the highest numbers of adult grayling collected by angling.

Burbot occur at all the sites although have only been caught in minnow traps at R2.

Juvenile Chinook salmon were captured by electro-fishing and minnow trapping at the Rose Creek sites (none at R6, Anvil Creek) in 2004 and 2005, but have been absent since. No salmon aged one year or more have been documented in the Rose Creek drainage during these assessments.

Table 7.4-5. Comparison of electro-fishing results from August sampling of the regular stream reaches of Rose Creek, 2004 to 2007.

Site	Year	Grayling Sub ad. & Adult	Grayling Juvenile	Sculpin Adult	Sculpin Fry	Burbot	Chinook Salmon Juvenile	Round Whitefish
R1	2004	0.36	1.80	3.47	0	0.24	0.36	0.12
	2005	0	1.53	4.83	0	0.24	0	0
	2006	0	0	1.75	0	0	0	0
	2007	0	0.34	3.09	0.11	0	0	0
R2	2004	0.27	0	15.65	1.10	0.27	0	0
	2005	1.81	0.11	8.60	0.79	0.79	0.23	0
	2006	0	0	4.22	0.55	0.08	0	0
	2007	0	0.18	5.12	0.18	0	0	0
R4	2004	0.11	0	2.86	0	0	0	0
	2005	0.57	0	4.31	0.58	0	0	0
	2006	0	0.10	8.37	5.10	0	0	0
	2007	0.11	0.68	11.12	0	0.11	0	0
R6	2004	0.11	0	2.86	0.11	0	0	0
	2005	0	0	4.21	0.10	0	0	0
	2006	0	0	6.29	1.28	0.26	0	0
	2007	0	0	5.02	0	0.18	0	0

Note: The site at R6 was moved 800 m upstream in 2006.

Catches have been expressed by unit of effort as the number of fish recorded per 100 seconds shocking time

Table 7.4-6. Comparison of Minnow trap results from August sampling of the regular stream reaches of Rose Creek, 2004 to 2007.

Site	Year	Arctic Grayling	Slimy Sculpin	Burbot	Juvenile Chinook Salmon 0+	Juvenile Chinook Salmon 1+
R1	2004	0.16	0.49	0.00	0.16	0.00
	2005	0.28	0.28	0.00	0.00	0.00
	2006	0.16	0.16	0.00	0.00	0.00
	2007	0.00	0.00	0.00	0.00	0.00
R2	2004	0.00	0.15	0.15	0.84	0.00
	2005	0.00	0.34	0.67	0.84	0.00
	2006	0.15	0.15	0.00	0.00	0.00
	2007	0.00	0.39	0.19	0.00	0.00
R3	2004	0.00	0.00	0.00	0.51	0.00
	2005	0.00	0.31	0.00	0.00	0.00
	2006	0.00	0.28	0.00	0.00	0.00
	2007	0.11	1.37	0.00	0.00	0.00
R4	2004	0.00	0.00	0.00	0.51	0.00
	2005	0.00	0.31	0.00	0.00	0.00
	2006	0.00	0.28	0.00	0.00	0.00
	2007	0.11	1.37	0.00	0.00	0.00
R6	2004	0.00	0.00	0.00	0.00	0.00
	2005	0.00	0.21	0.00	0.00	0.00
	2006	0.00	0.20	0.00	0.00	0.00
	2007	0.00	0.25	0.00	0.00	0.00

Note: 0+ = young of the year, 1+ = juveniles one year and older

The site at R6 was moved 800 m upstream in 2006.

Catches have been expressed by capture/trap/24 hrs.

Table 7.4-7. Comparison of angling efforts and catches from August investigations of the regular stream reaches of Rose Creek, 2004 to 2007

Sample Site	Year	Effort	Catch	Comment
R1	2004	30 minutes	2 Arctic grayling	
	2005	45 minutes	4 Arctic grayling	
	2006	190 minutes	9 Arctic grayling	Ag mostly sub. ad
	2007	90 minutes	9 Arctic grayling	
R2	2004	30 minutes	7 Arctic grayling	caught u/s and d/s of discharge
	2005	105 minutes	0	observe 0 Ag
	2006	180 minutes	5 Arctic grayling	well dispersed
	2007	110 minutes	5 Arctic grayling	
R4	2004	10 minutes	0	
	2005	30 minutes	5 Arctic grayling	
	2006	50 minutes	6 Arctic grayling	u/s of site
	2007	40 minutes	12 Arctic grayling	
R6	2004	30 minutes	2 Arctic grayling	
	2005	50 minutes	1 Arctic grayling	
	2006	50 minutes	3 Arctic grayling	
	2007	40 minutes	12 Arctic grayling	

Note: The site at R6 was moved 800 m upstream in 2006.

Arctic grayling and burbot densities have decreased at R1 since 2004 (Table 7.4-5 and Table 7.4-6). Large numbers of grayling and burbot were removed from the freshwater reservoir prior to breaching of the dam in late 2003, and it is likely that remnant populations remained in the creek after dewatering and have slowly reduced in numbers since (WMEC, 2007).

Fish utilization in the reaches within the dewatered reservoir and downstream have been assessed annually since 2004 as part of the adaptive management strategy for the breach project. Table 7.4-8 and Table 7.4-9 summarize the electro-fishing and minnow trapping data respectively, for these reaches of the South Fork of Rose Creek for 2004 to 2007.

Densities of Arctic grayling tend to be lower in the reaches in the dewatered reservoir compared to downstream in the physically unaltered reach. The wide distribution and low catch numbers of burbot, as was the case in all assessments, suggest continued stability in use as rearing habitat of juvenile populations in the assessment area. The wide distribution of slimy sculpin throughout the reaches and similar catch statistics suggest some stability of populations within this area. These three species have historically been documented in the freshwater reservoir prior to dewatering and in the South Fork of Rose Creek (Gartner Lee 2003a). Their continued presence since dewatering indicates success in the re-establishment of the channel and habitat in this section of the South Fork of Rose Creek.

Table 7.4-8. Comparison of electro-fishing results from August sampling of stream reaches of Rose Creek associated with the former reservoir, dam breach section, and downstream from the breach construction area, 2004 to 2007.

Site	Reach	Species	Density (capture/100 sec)			
			2004[1]	2005[1]	2006[1]	2007[2]
Former reservoir	1	Arctic grayling	1.00	1.84	0.30	0.14
		burbot	0.36	0.12	0.10	0
		slimy sculpin	0.68	0.86	0.64	0.98
	2	Arctic grayling	0.23	0.24	0	0.14
		burbot	0	0	0	0
		slimy sculpin	4.28	3.30	7.11	3.59
	3	Arctic grayling	0.26	0.07	0	1.34
		burbot	0.58	0.21	0.03	0
		slimy sculpin	2.02	5.50	4.22	2.28
Dam breach section	4	Arctic grayling	1.28	0.28	0.06	0.75
		burbot	0.37	0.14	0.06	0.13
		slimy sculpin	0.64	0.14	0.49	0.40
Downstream of breach construction area	5[2]	Arctic grayling	2.96	5.13	2.00	1.12
		burbot	0.23	0	0	0
		slimy sculpin	0.56	1.84	3.41	0.70
		round whitefish	0	0.17	0.41	0

[1] based on 2 pass block net electrofishing technique.

[2] based on 1 pass electro-fishing technique.

Table 7.4-9. Comparison of minnow trapping results from combined June and August sampling of stream reaches of Rose Creek associated with the former reservoir, dam breach section, and downstream from the breach construction area, 2004 to 2007.

Site	Reach	Species	Density (capture/trap/24 hr)			
			2004	2005	2006	2007
Former reservoir	1	Arctic grayling	0	0.62	0	0.08
		burbot	0.12	0.07	0.09	0.08
		slimy sculpin	0.12	0.21	0	0.25
	2	Arctic grayling	0.12	0.08	0	0
		burbot	0.06	0.17	0.42	0.18
		slimy sculpin	0	0.08	0	0.53
	3	Arctic grayling	0	0.19	0	0
		burbot	0	0.09	0	0.08
		slimy sculpin	0.06	0	0	0.08
Dam breach section	4	Arctic grayling	1.04	0.65	0	0
		burbot	0	0.20	0	0.15
		slimy sculpin	0	0	0.10	0.15
Downstream of breach construction area	5	Arctic grayling	0.15	0.17	0	0.33
		burbot	0.14	0.17	0.20	0.16
		slimy sculpin	0	0	0	0
	X-14	Arctic grayling	0	0.08	0	0
		burbot	0.14	0	0	0
		slimy sculpin	0.14	0	0	0.07

7.4.3 Metals in Fish Tissue

Fish tissues have been analyzed over the years from the Rose and Vangorda watersheds to assess whether the Faro Mine Complex has influenced fish tissue quality. The analysis of metals in fish tissue has been carried out in 1975, 1976, 1977, 1989, 1992, 1997, 2002, 2004, 2005, 2006 and 2007 within the regional aquatic study area and reference sites in Anvil and Blind Creeks. These data have been summarized for slimy sculpin whole body tissue (Table 7.4-10), Arctic grayling muscle tissue (Table 7.4-11) and Arctic grayling liver tissue (Table 7.4-12). In each table the data have been compared with the wildlife consumption benchmark, and also the with the human consumption benchmark in Table 7.4-11 (Arctic grayling muscle).

Overall the tissue data suggests that mining activities have had only minor influences on the quality of fish tissue in the Rose-Anvil and Vangorda Creek systems (Minnow, 2007).

Table 7.4-10 Summary of Arctic grayling muscle tissue metal concentrations (mg/kg ww), Rose-Anvil and Vangorda Creek systems, 1975 to 2007

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		0.300	0.515						0.581	0.540
	2002		0.028	0.045						0.038	0.038
	2004						< 0.1	< 0.1			
	2005	< 0.3	< 0.3		< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
	2006										
	2007	<0.6	<0.1	<0.1	<0.1					<0.1	<0.1
Cadmium	1992		< 0.1								
	1997		0.013	0.013						0.038	0.093
	2002		< 0.005	0.010						0.011	0.351
	2004	<0.005	0.015	0.097	<0.005		0.019	0.006		0.032	0.033
	2005	< 0.05	0.050		0.830	0.062	0.068	0.062	0.075	0.090	0.167
	2006	< 0.02	< 0.02	< 0.02	< 0.02					< 0.02	0.030
	2007	<0.02	<0.02	<0.02	<0.02					0.020	<0.02
Copper	1975								0.40	0.76	0.75
	1976										0.96
	1977										0.86
	1992		2.45								
	1997		0.32	1.38						0.39	0.83
	2002		0.62	0.73						0.30	1.15
	2004	0.77	0.68	0.74	0.96		0.84	0.65		0.50	0.53
	2005	0.71	0.76		0.80	0.58	0.45	0.57	0.52	0.59	0.67
	2006	0.27	0.35	0.5	0.37					0.25	0.29
	2007	0.55	0.48	0.43	0.48					0.31	0.25
Lead	1975								0.2	1.0	1.1
	1976										0.9
	1977										< 1.0
	1992		< 2								
	1997		0.479	0.684						0.917	0.940
	2002		0.076	0.075						< 0.02	0.045
	2004	< 0.05	< 0.05	<0.05	< 0.05		0.09	< 0.05		< 0.05	< 0.05
	2005	< 0.5	< 0.5		< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	2006	< 0.1	< 0.1	< 0.1	< 0.1					< 0.1	< 0.1
	2007	<0.1	<0.1	<0.01	<0.1					<0.1	<0.01
Manganese	1975									0.60	1.5
	1976										2.9
	1977										< 0.50
	1997		4.98	7.97						3.48	3.60
	2004	< 2.0	< 2.0	< 2.0	< 2.0		2.7	< 2.0		< 2.0	< 2.0
	2005	2.76	8.30		10.4	7.85	4.99	4.46	3.75	1.88	2.76
	2006	0.52	0.83	1.38	0.8					0.30	0.26
	2007	0.33	0.47	0.34	0.48					0.36	0.29
Mercury	1975									0.13	0.08
	1976	0.11	0.07						0.10		0.01
	1977										< 0.062
	1992		0.066								
	1997		0.058	0.052						0.030	0.020
	2002		0.053	0.023						0.022	0.040
	2004	0.042	0.042	0.030	0.041		0.070	0.059		0.046	0.051
	2006										
	2007										
Zinc	1975								4.0	9.2	11.8
	1976										14.6
	1977										8.5
	1992		23.7								
	1997		17.9	18.3						17.1	27.3
	2002		11.0	14.6						11.1	24.3
	2004	8.29	9.37	7.74	9.44		8.30	7.48		6.49	8.09
	2005	17.7	13.1		12.6	14.8	10.5	12.8	18.5	10.6	17.7
	2006	5.1	6.2	6.7	6.4					6.1	6.8
	2007	4.4	4.1	5.1	4.8					4.7	4.5

Value exceeds respective either human or wildlife consumption benchmark (Arsenic - 0.20 mg/kg, 0.56 mg/kg, 0.28 mg/kg for human toddler, human child and wildlife, respectively; Mercury - 0.07 mg/kg for human toddler)

Table 7.4-11 Summary of Arctic grayling liver tissue metal concentrations (mg/kg ww), Rose-Anvil and Vangorda Creek systems, 1975 to 2005

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		1.17	0.72						2.97	6.74
	2002		0.04	0.05						0.04	0.03
Cadmium	1997		0.244	0.689						1.220	1.296
	2002		0.149	1.25						1.35	0.8
Copper	1975								1.8	3.9	
	1992		8.3								
	1997		2.82	2.76						3.53	3.01
	2002		2.14	5.32						2.81	1.85
Lead	1975								0.20	2.0	
	1992		2.35								
	1997		0.740	0.639						3.81	7.28
	2002		0.138	0.18						< 0.02	< 0.02
Manganese	1975									3.2	
	1997		9.21	5.75						4.97	4.41
Mercury	1975									0.54	
	1976	0.26	0.20						0.11		
	1997		0.161	0.072						0.077	0.056
	2002		0.090	0.054						0.051	0.047
Zinc	1975								20.0	22.2	
	1992		89.8								
	1997		31.1	26.6						29.7	45.9
	2002		22.8	28.8						25.0	19.9

Value exceeds respective wildlife consumption benchmark (0.28 mg/kg for Arsenic; 4.9 mg/kg for lead; 0.45 mg/kg for mercury)

Table 7.4-12 Summary of slimy sculpin whole body tissue metal concentrations (mg/kg ww), Rose-Anvil and Vangorda Creek systems, 1975 to 2007

Metal	Year	Rose-Anvil System								Vangorda System	
		Reference	Exposure							Reference	Exposure
		R6	R1	R2	R4	A4	A3	A2	A1	B1	V8
Arsenic	1997		1.33	3.83						3.27	7.69
	2002		0.23							0.14	0.11
	2004					0.14	0.16	0.22	0.12		
	2005	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
	2006										
	2007	0.1	0.1	0.1	<0.1					0.15	0.1
Cadmium	1997		0.077	0.227						0.133	0.349
	2002		0.030							0.117	0.453
	2004	0.072	0.011	0.051	0.062	0.045	0.086	0.073	0.199	0.108	0.184
	2005	0.076	0.050	< 0.05	<0.05	0.066	0.064	0.096	0.260	0.085	0.180
	2006	0.058	0.040	0.03	0.04					0.06	
	2007	0.04	0.020	<0.02	0.03					0.07	0.180
Copper	1975									0.63	0.73
	1976										1.90
	1977										2.93
	1989										1.26
	1992	3.8							3.7	3.1	4.9
	1997		1.14	0.96						0.24	0.32
	2002		1.18							1.00	0.73
	2004	0.93	0.57	1.2	0.88	0.92	1.1	1.4	1.2	0.87	0.79
	2005	0.98	1.12	1.25	0.96	0.89	0.79	0.99	1.19	1.12	0.95
	2006	0.56	0.72	0.56	0.41					0.61	
	2007	0.78	0.85	0.68	0.66					0.78	0.92
Lead	1975									1.1	1.9
	1976										2.8
	1977										< 1.0
	1989										0.4
	1992	2.0							< 2	< 2	23.0
	1997		3.70	3.04						2.79	3.77
	2002		0.62							0.04	0.27
	2004	0.13	0.41	0.24	0.22	0.16	0.21	0.19	0.35	0.08	0.16
	2005	< 0.50	0.57	1.02	0.56	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
	2006	<0.1	<0.1	<0.1	<0.1					<0.1	
	2007	<0.1	<0.1	0.2	0.2					<0.1	0.1
Manganese	1975									9.8	5.1
	1976										7.0
	1977										5.5
	1989										4.7
	1997		13.7	30.0						12.7	13.6
	2004	30.8	28.1	31.7	30.8	36.6	18.5	35.2	11.0	9.17	6.7
	2005	26.4	25.0	38.8	47.7	42.7	16.3	17.4	35.2	8.67	7.37
	2006	8.2	16.7	19.7	37.0					11.1	
	2007	18.2	22.4	84.5	61.7					14.3	7.81
Mercury	1975									0.40	0.190
	1976										0.017
	1977										< 0.050
	1989										0.019
	1997		0.020	0.013						0.027	0.031
	2002		0.032							0.035	0.046
	2004	0.032	0.023	0.029	0.022	0.020	0.021	0.018	0.032	0.036	0.043
	2006										
	2007										
Zinc	1975									19.6	26.8
	1976										39.3
	1977										32.0
	1989										27.4
	1992	127							138		184.0
	1997		28.4	44.5						23.2	52.4
	2002		37.4							23.3	71.4
	2004	41.0	53.1	39.3	57.6	47.5	38.3	45.7	48.6	31.3	55.1
	2005	39.1	30.1	51.8	49.9	49.0	33.4	40.1	43.4	26.1	45.7
	2006	27.2	33.0	49.6	44.5					23.7	
	2007	32.7	28.3	48.5	54.4					28.1	0.2

Value exceeds respective wildlife consumption benchmark (0.28 mg/kg for Arsenic; 4.9 mg/kg for lead)

8. Terrestrial Resources

8.1 Vegetation

8.1.1 Introduction

The diversity, distribution and health of vegetation in natural ecosystems play an important role in ecosystem function. Vegetation patterns on the land are influenced by climate, substrate, terrain and water availability. Characteristic groupings of vegetation occur on the landscape, influenced by substrate, moisture and nutrient regimes. Different vegetation associations provide a variety of habitats used by wildlife. Wildlife and people can influence vegetation abundance and diversity and industrial development in particular has the potential to affect vegetation ecosystem health.

The objectives of the vegetation baseline assessment for the Closure and Remediation Plan for the Faro Mine Complex (the Project) are to identify the current condition of vegetation components of the ecosystem, including:

- composition and cover of vegetation associations at a local scale; and
- levels of contaminants from the Faro Mine Complex in vegetation in the region.

The environmental assessment of the effects of the Project will then:

- identify effects of the Project on the baseline condition of vegetation components of the ecosystem;
- identify mitigation;
- evaluate the predicted residual effects and their significance; and
- identify vegetation monitoring requirements.

8.1.1.1 Regional Setting – Vegetation

The Faro Mine Complex is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone of the Yukon (Environment Canada, 2005). The region consists of rolling uplands, small mountain groups, and nearly level tablelands dissected by U-shaped valleys. A prominent valley called the Tintina Trench traverses the ecoregion from southeast to northwest. The mine complex lies within the zone of discontinuous, widespread permafrost, wherein Turbic Cryosolic and Eutric Brunisolic soils predominate and occasional pockets of Dystric Brunisols occur on coarse-textured morainal and fluvioglacial materials. Vegetation is predominantly white spruce with willow, dwarf birch, ericaceous shrubs, and occasionally, lodgepole pine. Poorly drained lowland sites consist of black spruce, scrub willow, birch, and mosses. Subalpine areas are vegetated with alpine fir, lodgepole pine mountain avens, dwarf willow, birch, ericaceous shrubs, graminoid species, and mosses (Environment Canada, 2005).

8.1.2 Impact Assessment

8.1.2.1 Issue Focused Approach

Although a preferred option for closure has yet to be selected for the Project, an issue-based approach was used to focus the baseline information collection and Valued Ecosystem Component (VEC) selection for vegetation. The primary issues for vegetation are whether Project activities will result in changes to:

- Health of vegetation on the landscape and the potential for transfer of contaminants to wildlife and humans through plant uptake and ingestion; and
- Sustainable cover of vegetation on the landscape, consistent with native vegetation communities in the region.

* (This is a preliminary list and public consultation to confirm or expand this list is necessary.)

8.1.3 Valued Ecosystem Components

The VECs selected for the vegetation impact assessment related to the issue of health of vegetation on the landscape, is:

- Vegetation Health.
- Sustainable native vegetation cover
- Vegetation diversity

Maintaining vegetation health an important component of maintaining ecosystem health. Vegetation is a receptor for pollutants through uptake from soil, water, from air through gas exchange or through deposition on vegetation surfaces. Absorption by vegetation is one mechanism by which pollutants enter living components of an ecosystem and the food chain. Pollutants can accumulate in vegetation tissues. At higher concentrations pollutants can affect plant health and the composition and abundance of vegetation communities.

The VECs selected for the vegetation impact assessment related to the issue of diversity of vegetation on the landscape include:

- Rare and threatened plant species
    - Vascular plants ranked as S1 or S2 in the Yukon Status Ranks document;
    - Vascular plant species ranked as “at risk” or “may be at risk” in the document “Wild Species 2005: The General Status of Species in Canada” (CESCC 2006); and
    - Vascular plants and bryophytes listed under Schedule 1 (or pending Schedule 1) of the Species at Risk Act (SARA) (Government of Canada 2007).

These vegetation species or species associations are important to the diversity, health and/or function of the ecosystem. Indicators and thresholds for effects to these ecosystem components are identified in Table 8.1-1. Indicators are chosen to evaluate potential Project effects on the abundance, diversity and health of each of the VECs selected. Thresholds are measurable parameters of the indicator that demonstrate the level of unacceptable change.

Table 8.1-1. Vegetation VECs, Indicators and Thresholds

Issue	VEC	Indicator	Threshold
Vegetation health	**Vegetation health –** annual atmospheric concentrations or accumulations of pollutants resulting in changes in phenology and community composition	Accumulation of TSP Cumulative deposition of Zn and Pb	Annual deposition of TSP >4.6 g/m^2/yr Cumulative deposition of Zn >15 g/m^2 Cumulative deposition of Pb > x
Vegetation health	**Sustainable Native Vegetation Cover**	Persistent, weed free surface cover of native vegetation on disturbed, erosive surfaces.	X % cover on erosive substrates < x% cover of weeds or non-native species
Vegetation diversity	**Rare or Threatened plant species**	Presence of rare or threatened plant species	>20% loss of a population of rare (S1, S2) or "may be at risk" plant species

Notes: Total Suspended Particulates (TSP), zinc (Zn) and lead (Pb).

8.1.4 Study Areas

8.1.4.1 Local Study Area

A vegetation Local Study Area (LSA) is designed to represent the diversity of vegetation in the immediate Project area and to encompass the area within which all-direct effects and some indirect effects of Project activities on vegetation are likely to occur. A vegetation map of the area is developed at a scale of 1:20,000, using aerial photography and field data (completed in 2007).

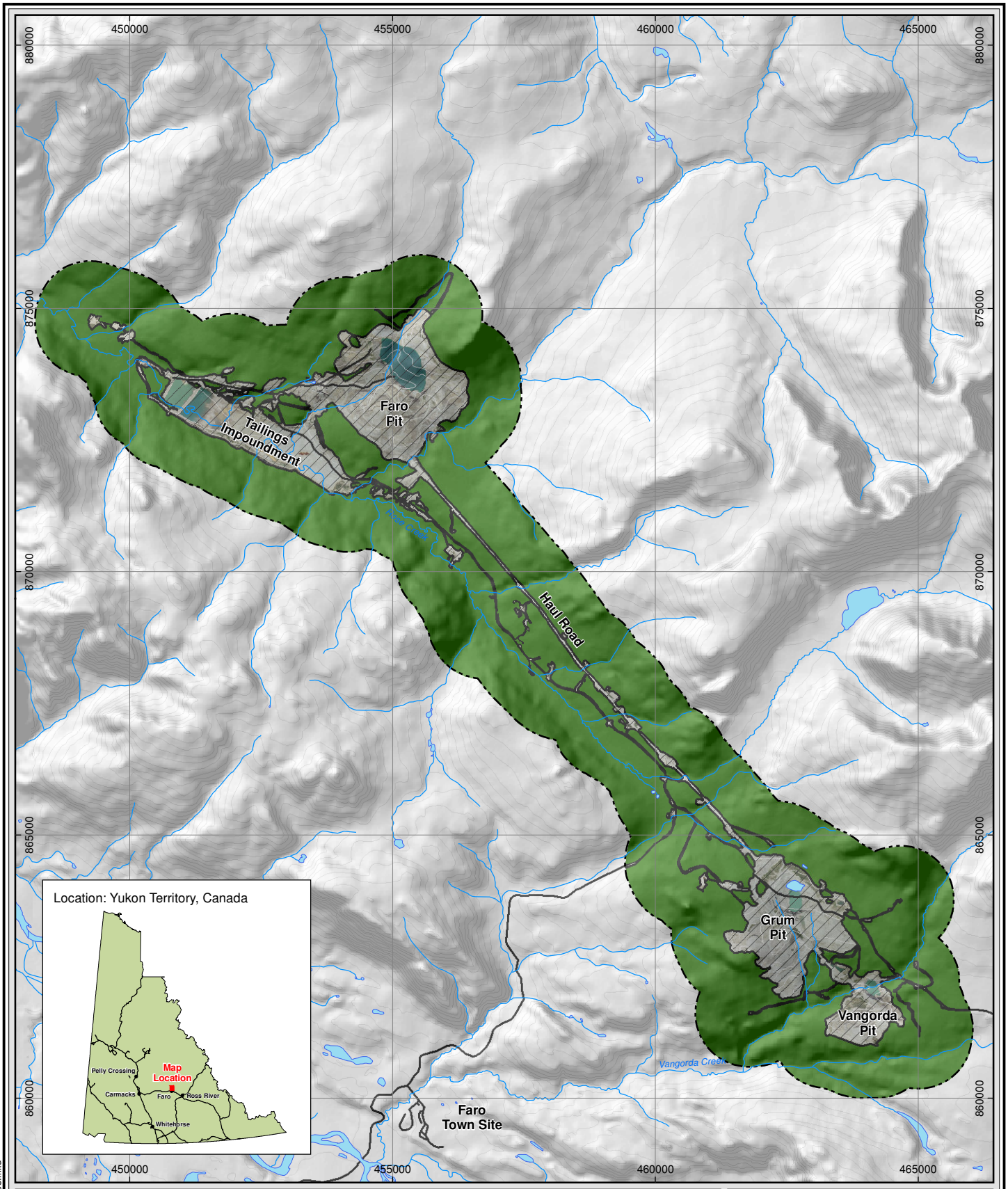
For the purposes of this project, the LSA includes the area within a 1 km wide buffer around mine facilities, infrastructure and road corridors, and covers an area of approximately 81.2 km^2. The location and extent of the LSA is represented in Figure 8.1-1.

8.1.4.2 Regional Study Area

The Regional Study Area (RSA) encompasses the area within which any regional effects of Project activities on vegetation are predicted to occur. The RSA includes the area within which accumulations of contaminants above background levels have been recorded.

8.1.4.3 Baseline Project Footprint

The baseline Project footprint includes the total current disturbance area of the proposed Project, including the Faro Mine Area, Vangorda /Grum mine area and associated infrastructure including pits, tailings impoundment, quarries, ponds and roads. The area of the baseline Project footprint is 16.1 km^2. The location and extent of the Project footprint is represented in Figure 8.1-1.



Map Sources/Notes:
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Hillshade imagery obtained from the Yukon Department of Environment, Information Management & Technology Department.
Orthophoto produced from 1:40,000 aerial photography (Aug. 9, 2003)
Local study area delineated by Gartner Lee Limited.

N
W
E
S

0.5 0 0.5 1 1.5 2 2.5 Km

1:100,000

Yukon Albers

Legend

Existing Features
- Community
- Road

Elevation Contours
- Contour interval (100m)

Boundaries
- Project Footprint
- Local Study Area

Hydrological Features
- Watercourse
- Waterbody

Closure and Remediation Plan
For The Faro Mine Complex

Local Study Area and Project Footprint

06 February 2008

Gartner Lee

Figure 8.1-1
Version 1

File: 70384 C1 Fig 1.4-1 LSAProjectFootprint 06Feb08.mxd

8.1.5 Data Sources

Data sources for the LSA are primarily Project field data collection, 1:10,000 scale black and white aerial photos and a 1:20,000 colour ortho photo of the area. Data sources for contaminant accumulation in vegetation in the RSA are primarily the results of the Anvil Range Mine Complex – Terrestrial Effects Study: Investigation into Metal Concentrations in Vegetation, Wildlife and Soils, prepared for Deloitte & Touche Inc. on behalf of the Faro Mine Closure Planning Office by Gartner Lee Limited September 2006.

References for plant species identification and nomenclature include: Flora of the Yukon Territory (Cody, 2000), Plants of Northern British Columbia (Mackinnon et. al, 1999) and Plants of the Western Boreal Forest and Aspen Parkland (Johnson et. al, 1995).

The 2007 draft revegetation program conducted by EDI was consulted for additional information regarding natural communities within the Project (EDI, 2008).

8.1.6 Baseline Description

8.1.6.1 Local Study Area

Local Study Area Baseline Data Collection Methods

During the summer of 2007, representative vegetation associations were surveyed in order to describe their composition and develop vegetation map units. The characteristic composition and cover of species in each association was determined through standardized plot sampling in representative areas. A preliminary vegetation map of the area was then developed at a scale of 1:20,000, using aerial photography flown in July 2003. Map units for the LSA vegetation associations map were designed to link to the existing Sheep Mountain studies (Staniforth, 1998), taking into consideration that modifications of the Sheep Mountain associations were undertaken to better represent the vegetation in the project LSA. Many potential associations are not identified for this project as they were too small to map or there was a lack of clarity in their delineations.

The vegetation sampling density for LSA mapping was guided by the British Columbia Terrestrial Ecosystem Mapping (TEM) inventory standards for 1:20,000 scale mapping (Resource Inventory Committee 1998). These guidelines provide a previously evaluated sampling strategy that is scientifically accurate and efficient, particularly for collecting data in remote locations with limited access. Data collection identified in these guidelines includes 5% detailed vegetation plots, 20% ground plots and 75% visual calls to confirm map polygon identifications.

During the 2007 vegetation field survey of the Faro LSA, 17 ground plots and 59 visual calls were inventoried (see Figure 8.1-2). A list of the sites surveyed in 2007 and their corresponding vegetation associations are presented in Appendix E1.

Baseline descriptions are developed for each mapped vegetation association, including plant species composition, terrain and general soils characteristics, e.g., site moisture and nutrient regime, based on field data. No specific soil characterizations were undertaken during this investigation.

Local Study Area Baseline Conditions

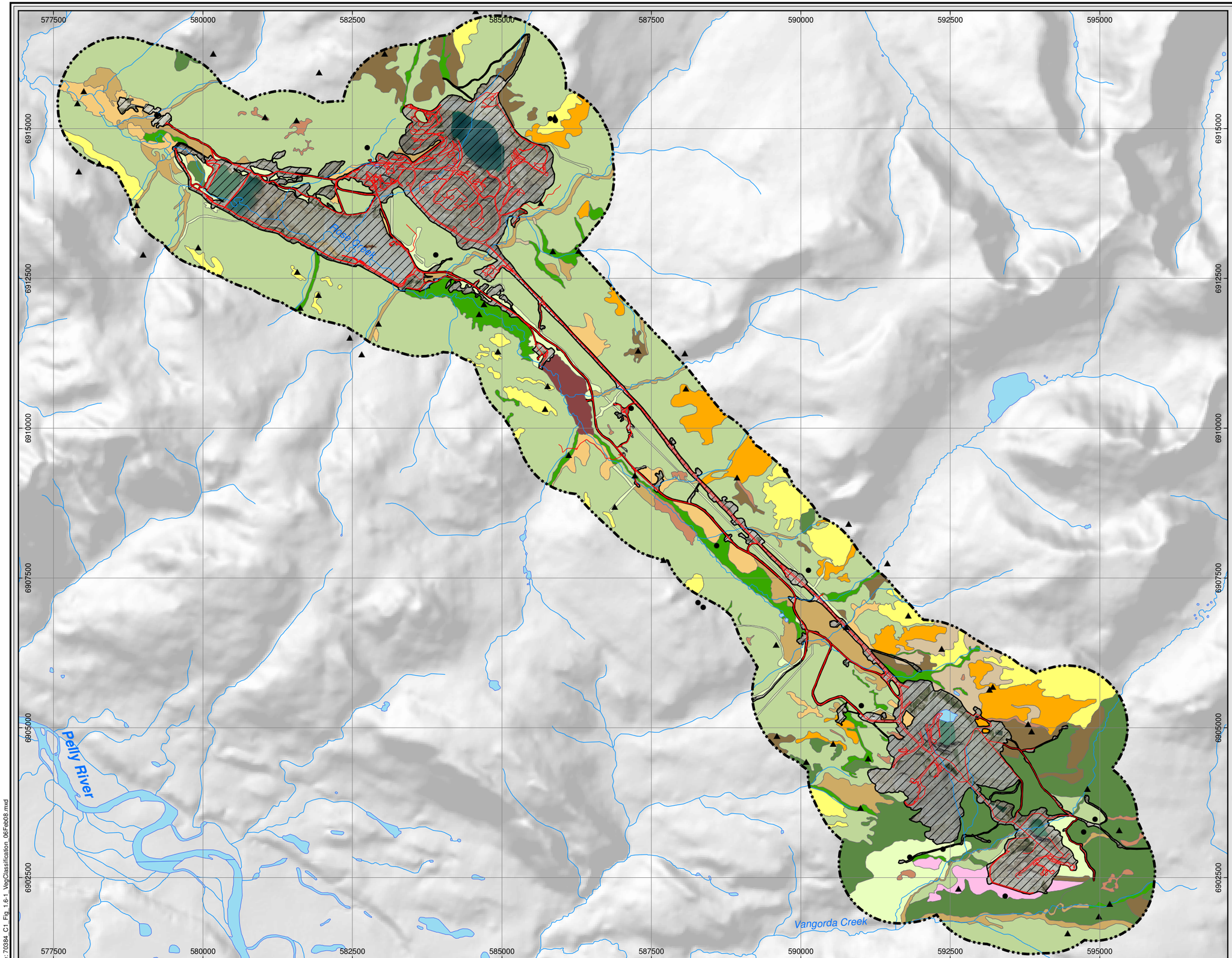
The LSA baseline conditions are generally described in relation to each issue (vegetation abundance and diversity and vegetation health), and more specifically for the VECs associated with those issues.

Vegetation Association Descriptions

Thirteen vegetation associations and the project footprint have been identified and mapped within the LSA of the project. Their distributions are shown in Figure 8.1-2. The abundance of each vegetation association and the abiotic features in the LSA are presented in Table 8.1-2. The white spruce/willow vegetation association covers the largest area at 3657.4 ha (45%) of the LSA. Detailed descriptions of the vegetation associations including their component vegetation species and a representative photo are presented in Appendix E2. A list of vegetation species observed during the 2007 field survey is presented in Appendix E1.

Table 8.1-2. Faro Mine Closure Project LSA Vegetation Associations Baseline Area

Vegetation Association	LSA Map Code	LSA Baseline Area	
		Area (ha)	% of LSA
Sedge/Willow	S/W	54.6	0.7
Willow/Sedge	W/S	254.7	3.1
Willow/White Spruce	W/Sw	326.0	4.0
Willow/Dwarf Birch	W/B	182.2	2.2
Dwarf Birch/Willow	B/W	232.2	2.9
Dwarf Birch/Lichen/Subalpine Fir	B/L/Fa	357.8	4.4
Dwarf Birch/Subalpine Fir	B/Fa	279.9	3.4
White Spruce/Willow	Sw/W	3657.4	45.0
White Spruce/Feathermoss	Sw/Fm	105.1	1.3
Pine	Pl	52.4	0.6
Mixed Coniferous-Deciduous	Mx	682.0	8.4
Deciduous	Dd	276.6	3.4
Graminoid	Gr	49.3	0.6
Project Footprint	PF	1612.7	19.9
LSA Total Area		**8122.8**	**100.0**



Legend

Existing Features
- Road
- Local Study Area

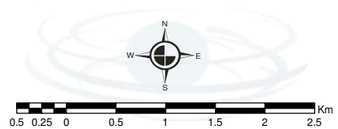
Hydrological Features
- Watercourse
- Waterbody

Survey Sites (2007)
- Visual Calls
- Ground Plots

Vegetation Classification
- B/Fa
- B/L/Fa
- B/W
- Dd
- Gr
- Mx
- Pl
- S/W
- Sw/Fm
- Sw/W
- W/B
- W/S
- W/Sw
- Project Footprint

Location: Yukon Territory, Canada

Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Branch.
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Survey sites provided by Gartner Lee Limited.
Vegetation classification conducted by Gartner Lee Limited from aerial photography at 1:10,000 scale.
Local study area delineated by Gartner Lee Limited.



1:60,000
UTM Zone 8N, NAD 27

Closure and Remediation Plan
For The Faro Mine Complex

Vegetation Associations and 2007 Survey Sites

06 February 2008

Gartner Lee

Figure 8.1-2
Version 1

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Ecozones

Vegetation associations throughout the mapped LSA vary according to elevation, soil drainage, aspect and disturbance (Oswald *et al.*, 1983). Due to the mountainous nature of the LSA, elevation is a prominent element in determining vegetation associations. The LSA can be divided into two zones; the boreal zone and the subalpine zone.

Boreal Zone

The boreal zone contains forested, low elevation valley bottoms and low-lying terrain (GLL 2003a). Most waterbodies and wetlands are associated with this zone, which dominates the majority of the study area below 1200 m. This area was extensively glaciated, leaving morainal and glacial-fluvial deposits (Staniforth, 1998), and contains a large number of associations linked to terrain variation and fire.

Subalpine Zone

In the 2004 to 2008 Water License Renewal Environmental Assessment Report (GLL 2003a), it is stated that; “the subalpine zone refers to the one between the relatively closed-canopy forests in the boreal zone and the dwarf shrub, herb and non-vegetated rock areas in the alpine zone. The subalpine zone represents a broad gradient between low and high elevation conditions. It is dominated by tall shrub vegetation with scattered spruce and fir forests at its lower limits, grading into lower stature shrub and herb communities at upper elevations.” This zone begins at roughly 1200 m and is noted as being higher on southern aspects than on northern ones (Oswald *et. al,* 1983).

Rare or Threatened Plant Species

The current regulatory lists for rare and threatened species; “Wild Species 2005: The General Status of Species in Canada” (CESCC 2006) identifies and ranks threats to plant populations on consideration for the following factors: population size, number of occurrences, geographic distribution, trend in population, trend in distribution, threats to population and threats to habitat. Rare and threatened plants include species ranked as “may be at risk” and “at risk”. A third risk category, “sensitive”, includes species not currently at risk or rare, but species that may be vulnerable to impacts to populations. Status rank categories are presented in Table 8.1-3. There are currently 227 “Sensitive” vascular plant species in the Yukon, 249 “may be at risk” and none are “at risk” (see Appendix E4).

Table 8.1-3. General Status Rankings for Vascular Plants

General Status Categories*	
At Risk	Species for which a formal detailed risk assessment (COSEWIC assessment or territorial equivalent) had been completed and that have been determined to be at risk of extirpation or extinction (i.e., endangered or threatened).
May be at Risk	Species that may be at risk of extinction or extirpation, and are therefore candidates for detailed risk assessment. These species are ranked with the highest priority for COSEWIC or jurisdictional consideration.
Sensitive	Species which are not at risk of extinction or extirpation but may require special attention or protection to prevent them from becoming at risk. These species are ranked with a medium priority for further consideration.
Secure	Species which are not at risk or sensitive. These species have the lowest priority for further consideration.
Undetermined	Species for which insufficient information, knowledge, or data is available to reliably evaluate their general status.
Not Assessed	Species which are known or believed to be present, but which have not been examined.
Exotic	Species that have been moved beyond their natural range as a result of human activity.
Accidental	Species occurring infrequently and unpredictably, outside their usual range.

** Canadian Endangered Species Conservation Council (CESCC) 2006. Wild Species 2005: The General Status of Species in Canada.*

The Yukon Conservation Data Centre under NatureServe Canada documents ranks and tracks populations of rare plant species, but does not assign a "threat or risk" status. Status rank categories are presented in Table 8.1-4. There are currently 185 "S1" vascular plant species in the Yukon, 147 "S2" species and 59 "S3" species (see Appendix E3).

Table 8.1-4. NatureServe Yukon's Status Ranks for Rare Species

Status Categories *	
S1	≤5 occurrences or only a few remaining individuals
S2	6-20 occurrences or with many individuals in fewer occurrences
S3	21-100 occurrences may be rare and local throughout its range, or in a restricted range (may be abundant in some locations or may be vulnerable to extirpation because of some factor of its biology)
S4	Apparently secure under present conditions, typically > 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally
S5	Demonstrably secure under present conditions, > 100 occurrences but may be rare in parts of its range, especially peripherally.
SU	Status uncertain often because of low search effort or cryptic nature of the element; possibly in peril, unrankable, more information needed.

** Yukon Department of the Environment, Fish and Wildlife Branch 2005. Yukon NatureServe.*

At the federal level, species determined to be at risk (endangered, threatened or of special concern) by COSEWIC undergo a regulatory review process administered under the *Species at Risk Act* (*SARA*) (Government of Canada, 2003; CWS, 2005) for listing in Schedule 1 of the Act. There is currently one SARA-listed plant in the Yukon, *Carex sabulosa*, however it is restricted to sand dunes in south/ southwest Yukon.

No surveys for rare, threatened and sensitive vascular plants were undertaken in 2007, however they will be conducted during the 2008 growing season for all areas where new disturbance to natural vegetation is planned.

8.1.6.2 Regional Study Area Baseline Vegetation Health

Vegetation Health Background

As a result of concern with respect to the potential for elevated metal concentrations to occur in vegetation, soils and wildlife near the Faro Mine Complex, a Terrestrial Effects Study was completed by Gartner Lee Ltd (GLL) and associates in 2006. The overall objective of the Terrestrial Effects Study was to gather data that could be used to better understand the distribution and movements of elevated elemental concentrations in the terrestrial environment. Such information could then be used for a future human and ecological risk assessment (HHERA). The specific objectives of this study were to:

- characterize the spatial distribution of elevated elemental concentrations,
- determine if deposition is ongoing,
- improve characterization of elemental concentrations in reference materials,
- investigate elemental concentrations in vegetation and mineral licks,
- investigate elemental concentrations in wildlife tissues,
- determine specific sources of elemental lead, and
- determine elemental concentrations in ambient air.

The findings of this study with respect to vegetation health are presented in the following sections. Although the Terrestrial Effects Study was designed to provide an understanding of the spatial extent, timing and concentrations of elements in the terrestrial environment near the Faro Mine Complex, it does not deal with the significance of these findings in terms of human health and ecological risk.

Vegetation Health Baseline Data Collection

Several interrelated environmental parameters were examined to obtain the data needed for the terrestrial effects assessment. The study design applicable to vegetation health is summarized below. Further detail on study design and methods is contained in the GLL 2006a report.

Characterization of the Spatial Distribution of Elevated Elemental Concentrations

To isolate the effects of airborne deposition from mineralization, the spatial distribution of elevated elemental concentrations was determined, primarily by sampling lichens. Lichens (*Cladina spp*.) were selected as the indicator species because they are long-lived, non-deciduous and depend entirely on airborne material and precipitation for nutrients and are therefore unaffected by the mineralization of underlying soils. Soils are also perennial accumulators and provide an additional record of cumulative airborne deposition; however, elemental concentrations in mineral soils can also be influenced by natural mineralization and glacial transport. Soil sampling was therefore conducted to:

- confirm the results of lichen sampling, and
- detect naturally elevated elemental concentrations (i.e., unrelated to the mine) in local surficial materials.

Timing of Deposition of Mine-Related Dust

Initial studies conducted in 2002 (C.E. Jones & Associates Ltd. 2003) indicated that elemental deposition occurs in the study area from operations at the mine but did not provide information about its timing. Studies were conducted in 2004 and 2005 to determine if deposition is ongoing. This study component was designed to determine if measured elemental concentrations are at their maxima or will continue to increase into the future. Moss bags were used to determine if airborne deposition is ongoing and its timing.

Elemental Concentrations in Vegetation and Mineral Licks

Selected plant species were collected in the study area to determine the uptake of various elements by vegetation used by wildlife (e.g., forage species) or humans (e.g., medicinal use or ingestion). However, elemental concentrations in vascular (i.e., rooting) vegetation can be influenced by both pre-existing mineralization (elemental uptake via root systems) and by airborne elemental deposition (through deposition on plant surfaces and uptake through surface soil). To distinguish between these sources and ensure that elevated concentrations were not erroneously attributed to mine operations, soils were collected, subsampled and analyzed where plants important to wildlife or humans were collected. Soil was also collected at mineral licks because wildlife using licks may consume soils either directly or indirectly through the ingestion of soils while foraging, providing a potential secondary source of elemental uptake. These study components provide information about elevated metal concentrations in the human and wildlife food chains and will assist in predicting potential impacts on local land-users from elevated metal concentrations resulting from care and maintenance operations at the mine.

Sources of Elevated Lead Concentrations

Potential mechanisms for the dispersal of elements in the Faro Mine Complex study area include windblown dusts and a historic spill of tailings into Rose and Anvil Creeks, which drain portions of the Faro Mine Complex. The potential for lead from naturally occurring and outside sources to affect the study area required that local “background” levels were distinguishable from those

resulting from the Faro Mine Complex. Lead (Pb) isotope tracing was used to determine the origin of lead in samples of dust, soils and moss bags from the study area. The analysis was conducted to:

- Identify and quantify ore deposit leads in dusts and soils from the Faro Mine Complex,
- Distinguish and quantify lead from mine ores and from long-range lead sources in airborne dust at locations on and off of the mine site, and
- Determine whether tailings from a historic spill are present in the floodplains of Rose and Anvil Creek below the mine.

Vegetation Health Baseline Conditions

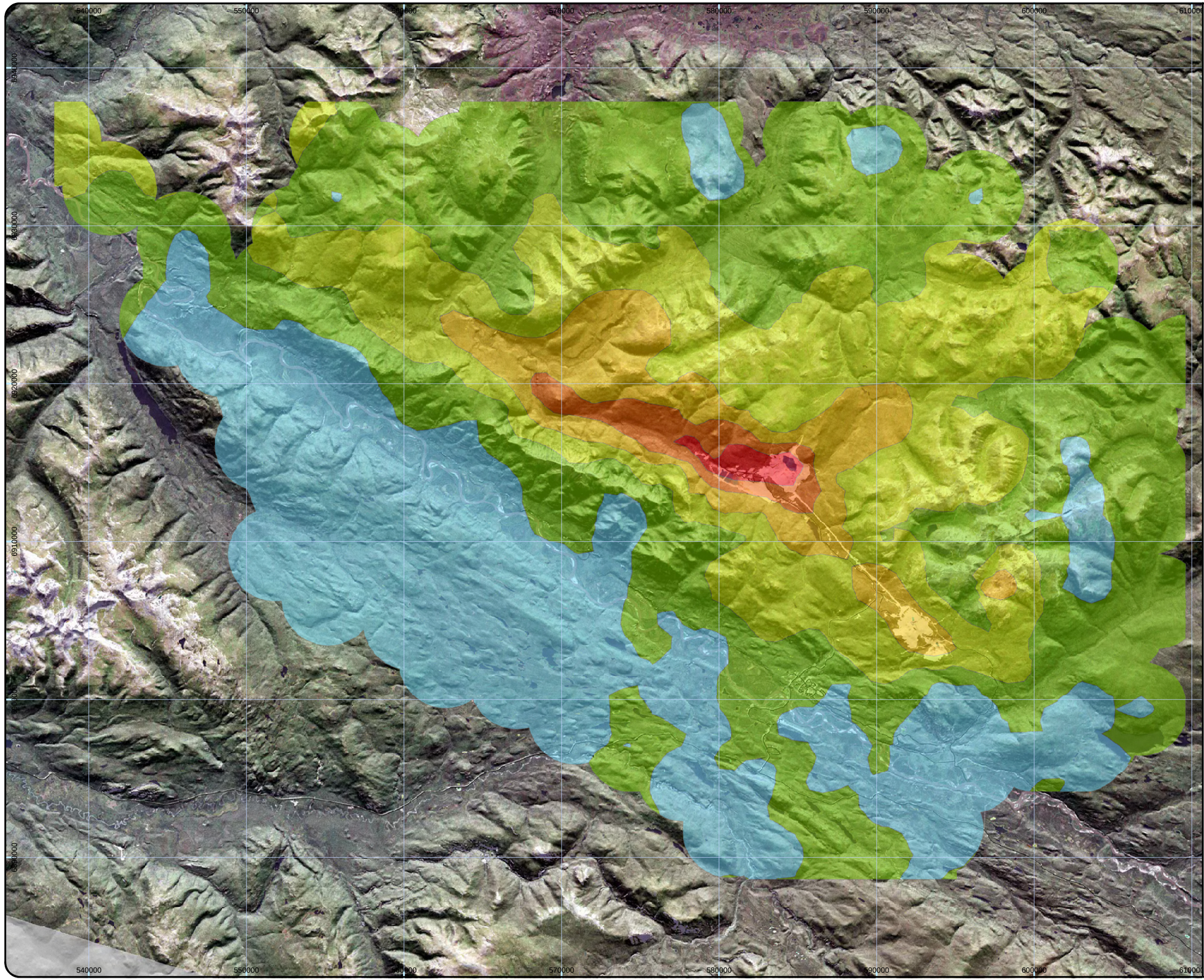
The information collected in the terrestrial environment shows that past operations at the Faro Mine Complex have resulted in metal concentrations in the mine area that are greater than the reference/background levels. For example, lead concentrations near the mine are up to 450 times those at reference sites and the lead isotope analysis indicates that the majority of the lead deposited in the study area was from mine ores. The concentrations of metals that originated from the mine site are generally higher near the mine and decline with distance from the mine. Deposition of some metals from the mine site is still occurring in the immediate area, mostly during the snow-free period. Metal concentrations that were greater than the reference/background levels were detected in plants, small mammals and other wildlife in the area.

The discussion of the results for each component of this study is presented below.

Characterization of the Spatial Distribution of Elevated Elemental Concentrations

Because lead is the least mobile of the “heavy” metals (as opposed to zinc, which can be highly mobile in both soils and plants), it likely represents the best historical record of elevated elemental levels resulting from operations at the Faro Mine Complex. Lead in lichen tissue was therefore considered the principal indicator of the spatial distribution of elevated elemental levels from the Faro Mine Complex. High lichen lead levels in the integrated 2002 / 2004 / 2005 data set are evidence of significant mine-generated accumulations. Some lead levels near the Faro tailings impoundment / mill complex were 150-450 times baseline values.

The zone of elevated concentrations (Figure 8.1-3(14 from the original report)) extends to the Blind Creek Valley / Swim Lake basin to the southeast (1-10 km from the Grum / Vangorda mine areas), to the Pelly River Valley to the southwest (5-10 km from the mine site) and a minimum of 20 to 25 km from the mine complex up the North Fork Rose Creek drainage. Elevated concentrations of elements also extend a minimum of 40 to 50 km from the mine complex down the Rose / Anvil / Pelly drainages; however, the 1975 tailings dam breach may have contributed to the extent of the area of impact in this direction. Lichen lead levels measured at several locations in the study area are higher than published reference levels for lichens, and are comparable to some of the higher levels documented worldwide in vascular vegetation at sites contaminated with lead. Although the area sampled for lichens was expanded in the 2004 and again in 2005, the maximum spatial extent of elevated lichen-lead concentrations could not be determined for all directions from the mine.



LEGEND

Lead Concentration (ppm)

0.2 - 1.6	Zone 1
1.6 - 4.6	Zone 2
4.6 - 17	Zone 3
17 - 61	Zone 4
61 - 210	Zone 5
210 - 748	Zone 6
Road	

DATA SOURCES AND DISCLAIMERS:

Kriging surfaces compiled by Gartner Lee Ltd. Kriging is an interpolation technique based upon a generalized least-squares algorithm using distance-variance relationships as weighting functions. It is used to produce unbiased estimates of concentrations in unsampled areas. The prediction is constrained to one-third of the total prediction standard error.

Updated Road Network compiled by Government of Canada, Natural Resources Canada (NRCan).

Shaded relief colour orthorectified image at 15m resolution compiled by Yukon Territorial Government, Dept. of Infrastructure, Yukon Geomatics, from Landsat 7 image 59-16, bands 3, 2, & 1.

Created By: AS/EG

Reviewed By: MG/DS

Date Issued: March 2006

Project Number:

File Name:S:\GIS_Proj\Y2005\P 50712\report_mar06\50712_lead_lichen_11x17_fig14.mxd

Revision: 1

Projection: UTM Zone 8 NAD83

0 2 4 8 12
Kilometers

Scale 1: 225 000

ENVIRONMENTAL ASSESSMENT OF THE CLOSURE AND REMEDIATION PLAN FOR THE FARO MINE COMPLEX

Standard Geostatistical Kriging of Lead in Lichen

Gartner Lee | JONES

Figure **8.1-3**

Soils were also examined to determine if elevated elemental levels could be attributed wholly or partly to the influence of underlying mineralized soils. Although patterns for lead and zinc in surface soils are similar to those for lichens, no similar pattern exists in subsurface organic or mineral soils. Furthermore, there is no apparent relationship between concentrations in underlying materials and surface horizons. These findings support the hypothesis that the spatial pattern of elevated elemental levels has been caused by deposition from the Faro Mine Complex and cannot be attributed to natural effects that predate mining.

The lead isotope analysis of dust, soil and moss samples from the study area further support the conclusion that elevated elemental levels are caused by the mine. In addition, sequential extractions performed on a subset of soil samples indicate that substantial fractions of total lead concentrations exist in a weakly complexed form, which becomes relatively mobile when associated compounds decompose or degrade. The implications are that lead deposited from the mine site is not environmentally inert. Instead, it can be expected to have some mobility through plant uptake and leaching through to lower soil horizons, where it will likely become more permanently fixed. Following is a summary of results.

- **High Elevation Relative to Reference Levels – Lead and Arsenic.** Maximum lead and arsenic concentrations in areas affected by the mine were 450 and 250 times the Swim Lake maximum, respectively. Equivalent-to-reference levels were reached to the southwest of the mine site, across the Rose mountain range, and around the perimeter of the study area from the southeast to north. To the northeast and northwest, however, equivalent-to-reference concentrations are at least 20 to 25 km and 40 to 50 km, respectively, from the Faro Mine area. The total area in which lead concentrations in lichens are at least 3 times the observed Swim Lake maximum is approximately 769 km2 (76,900 ha).
- **Moderate Elevation Relative to Reference Levels – Zinc, Copper, Iron, Silver, and Thallium.** Maximum concentrations of these elements in areas affected by the mine were 15 to 75 times higher than Swim Lake maxima. Equivalent-to-reference concentrations were generally reached at distances of 0 to 2 km from the Vangorda / Grum mine areas, to the northeast along the exposed (mine-side) slopes of Mount Mye, and to the southwest along the exposed slopes of Rose Mountain. Elevated elemental levels generally extend to the northeast along North Rose Creek, to the north up and past Mount Aho, and to the northwest down the Rose Creek valley.
- **Low Elevation Relative to Reference Levels – Barium, Chromium, Mercury, Nickel, and Selenium.** Maximum concentrations for most of these elements in mine-affected areas were three to nine times the Swim Lakes maxima and zones of elevated elemental levels are generally smaller than those for lead and other elements in the High and Moderate categories. Although selenium concentrations near the mine were 25 times the Swim Lake maximum, this element has been placed in the “low elevation” category because the area affected by elevated concentrations is very small.
- **Marginal Elevation Relative to Reference Levels – Antimony, Cadmium, and Cobalt.** There is some evidence that elevated concentrations of these elements are associated with the Faro Mine Complex. Concentrations of these elements, however, are either within reported Yukon reference ranges for lichens (antimony and cobalt), or are similar to other high levels in the study area that appear to be unrelated to the presence of the mine (cadmium).

- **No Elevation Relative to Reference Levels – Boron, Molybdenum, Titanium, Vanadium, Aluminium, Beryllium, Calcium, Magnesium, Manganese, Phosphorus, Potassium, Silicon, Sodium, Tellurium, Tin and Uranium.** Elevated concentrations of these elements either occurred in areas that were not affected by the mine or else there was no apparent pattern of elevated levels. Consequently, elevated concentrations of these elements cannot be attributed to operations at the Anvil Range Mine.

Timing of Deposition of Mine-Related Dust

The exposure of moss bags for different time periods from August 2004 to August 2005 indicated that mine-generated deposition for a number of elements is ongoing. Lead had the highest amount of deposition and the pattern was generally similar to that for accumulated lead levels in lichens (i.e., elevated levels are concentrated in the vicinity of the tailings impoundment / mill complex and northwest down the Rose Creek valley). The results of the moss bag monitoring program indicate that over the study period, deposition occurred primarily between August and November, and again between late January and mid-August. This suggests that deposition occurs primarily during the snow-free period.

Concentration patterns of elements other than lead in moss bags are somewhat different from the observed cumulative patterns recorded for lichens. For example, arsenic has the second highest cumulative elemental concentration in lichens relative to reference levels but there appears to be little current deposition. In contrast, barium and nickel accumulations in lichens are low but these elements were among those with high levels of deposition in moss bags. Furthermore, aluminium, manganese, silicon, and uranium levels were elevated in moss bags but there was no evidence of mine-generated accumulations in lichens. Disparities between observed cumulative elemental elevation and current elemental deposition suggest that:

- the contribution of current mine-site elemental dust sources is different than historical contributions, due to different operational and closure conditions; and / or
- the period monitored by moss bag exposure does not reflect the entire range of conditions that have contributed to cumulative elemental elevation in the study area.

Moss bags are useful indicators of current airborne deposition and can also provide a general indication of where sources of deposition are located. However, they do not indicate specific sources or provide empirical measurements of ambient elemental concentrations in the air. Consequently, lead isotope analysis and ambient air-sampling using mini-vols was conducted in 2005.

Elemental Concentrations in Vegetation and Mineral Licks

- **High Elevation Relative to Reference Levels – Lead.** Lead concentrations for all plant species groups were greatly elevated in the zone immediately adjacent to the tailings impoundment / mill complex, which indicates that the presence of the mine has affected lead concentrations in vascular plants and mushrooms as well as in lichens and soils. Lead levels near the mine, ranged from 2.5 (horsetails) to 410 (tree sap) times Swim Lake reference

means. Willows, grasses, forbs, horsetails, mushrooms and bear root all had lead levels above reference ranges. There are no reference levels for comparison for tree sap.

- **Moderate Elevation Relative to Reference Levels – Zinc.** Zinc levels were significantly elevated in berries, willows and forbs collected next to the tailings impoundment / mill complex. The magnitude of elevation ranged from three times the Swim Lake reference mean for berries to 20 times for forbs. In most zones affected by the mine, zinc levels in forbs, willow, mushroom and bear roots exceeded documented Yukon background ranges.
- **Low Elevation Relative to Reference Levels – Copper, Nickel, Silver, Mercury and Thallium.** These elements all had isolated occurrences of significantly elevated concentrations compared to Swim Lake reference levels. Concentrations ranged from approximately two (copper in willows) to nine times (silver in willows and thallium in Labrador tea) Swim Lake reference means. It should be noted, however, that for lichens, there was no conclusive evidence of a link between elevated nickel levels and the Anvil Range mine.

There is some evidence that concentrations of antimony, arsenic, barium, cadmium, chromium, cobalt, iron and mercury are elevated in northern rough-stemmed mushrooms, bear root and tree sap collected in mine-affected areas compared to Swim Lake or Yukon reference levels. Most notably, maximum arsenic concentrations in northern rough-stemmed mushroom and tree sap in mine-affected areas were 11 times reference levels and maximum iron concentration in tree sap was 22 times reference levels.

Soil samples were collected from two mineral lick sites, one in the vicinity of the Faro Mine Complex (Mineral Lick Site 2) and one within a reference area (Mineral Lick Site 1). The analysis of soils collected at Mineral Lick Site 2, which is within lichen lead zone 2, indicates that there is potential for the ungulates to consume soils containing marginally elevated levels of mine-related elements, particularly lead; however, the effect of the mine is expected to be small. Lead levels at Mineral Lick Site 2 are no higher than Swim Lake or published maxima.

Sources of Elevated Lead Concentrations

The results of the lead isotope study indicate that ore from the Faro Mine Complex is by far the most important source of lead deposition in the study area. Although lead from the ore is mixed with non-ore lead in some areas, lead from the ore is widespread in the study area and often comprises over 90% of that found in both soils and moss bags. Lead from Faro Mine Complex ores is also comprises 60 to 90% of the lead found in soils at sampling sites in the Anvil Creek floodplain.

Lead that occurs in floodplain soils is probably largely the result of the tailings dam breach, which occurred in 1975. Moss bag sampling indicated that mine ores are the source of almost 100% of the lead that is currently being deposited in the study area.

Moss bags at all sampling sites contained lead from mine ores. Such sites included those near the Town of Faro and in the Swim Lake reference area; however, lead concentrations in moss bags in those areas were low.

Vegetation Baseline Summary

Vegetation Cover Baseline Summary

A 81.2 km^2 vegetation LSA was established to map the distribution and diversity of vegetation associations in the Project area. The LSA includes the area within a 1 km wide buffer around mine facilities, infrastructure and road corridors. A vegetation map of the area was developed at a scale of 1:20,000, using aerial photography and field data.

Vegetation associations in this mountainous area include forested and wetland associations in the low elevation valley bottoms and low-lying terrain of the boreal zone, below 1200 m. The boreal zone contains a number of associations linked to morainal and glacio-fluvial terrain and influenced by fire. Closed forests of white spruce/willow cover the largest portion 45% of the LSA. There are small areas of pine, mixed coniferous-deciduous and deciduous forests. Also present are shrub associations of dwarf birch and willow. Poorly drained lowland sites support dwarf birch, willow, sedge and graminoid associations. The areas of the Project LSA above 1200 m are in the subalpine zone, which is dominated by tall shrub vegetation. Scattered open spruce and fir forests occur at the lower limits, grading into lower stature shrub, herb and lichen communities at upper elevations.

Native vegetation has historically been removed from a 1612.7 ha (16.1km^2) area by the development of the Faro Mine Complex.

There are currently no records for rare or at risk plant species in the Project LSA. Surveys for rare vascular plant species will occur in any areas where new disturbance to previously undisturbed native plant communities is planned.

Vegetation Health Baseline Summary

The results of the terrestrial effects study for the Faro Mine Complex show clearly that the presence of the mine has resulted in elevated concentrations of several elements both at the mine site and in the surrounding area. For example, lead concentrations in lichens near the mine were up to 450 times those in reference samples. A lead isotope analysis showed that a large proportion of the lead found in terrestrial media in the study area is from mine ores; this is the case for 61 to 100% of the dusts and soils collected from the study area, and 65 to 90% of the soils collected along Anvil Creek. In addition, the study showed that over 90% of the lead currently being deposited in the study area is from mine ores. Thus, very little of the deposited lead is transported from outside sources. Other lines of evidence confirm that the mine is the principal source of elevated elemental concentrations. Geo-statistical analyses indicated that most elements had distinct patterns of elevated concentrations, with the highest levels occurring near the mine and decreasing as distance from the mine increased. The analysis of soils indicated that elemental concentrations in vegetation and surficial soils were not related to the degree of mineralization in underlying soil horizons.

The area affected by some elements is large. For example, concentrations of lead are elevated in an area that is known to be at least and which is probably greater than 1,760 km2. The study, however, was unable to delineate the entire area in which concentrations of some elements are elevated despite expanding the sampling program in 2004 and again in 2005. For example, the limit of deposition for lead is not known for the area to the northwest and northeast, which includes the Rose, Anvil and Pelly drainages, although it is believed to extend 40 or 50 km from the mine. Similarly, the limit of elevated lead concentrations is unknown in the area to the north and east of the mine; however, the data suggest that lead concentrations in this area are likely to approach background levels approximately 20 km away. In contrast, lead is known to decline to background levels approximately 5 to 10 km to the south of the Anvil Range Mine complex.

Although the mine appears to be the source of almost all elevated elements detected in the study area, two distinct sources are associated with the mine and mining operations. The mine itself is the source of most elemental deposition; however, a breach of the tailings dam in 1975 resulted in the deposition of tailings along watercourses to the northwest of the mine site. These tailings deposits, which occur discontinuously, may provide a secondary source of water- and air-borne deposition, which could extend the area affected by elevated elemental concentrations. Moreover, there is potential for the affected area to continue to expand as a result of the fluvial and airborne transport of tailings materials.

The presence of elevated elemental concentrations in plants consumed by humans and animals indicates that these elements are entering the environmental food chain and also have the potential to be incorporated into the human food chain.

8.2 Wildlife

8.2.1 Introduction

The diversity, distribution and migration patterns of wildlife play an important role in ecosystem function. Wildlife abundance and distribution on the land are influenced by habitat patterns, climate, forage, terrain, and predator-prey relationships.

The objectives of the wildlife baseline assessment for the Closure and Reclamation Plan for the Faro Mine Complex (the Project) are to identify the current baseline condition of wildlife. In particular, those conditions include population, distribution, abundance, migration patterns (at a local scale), and baseline contaminants presence (although earlier work has documented contaminants presence in wildlife from the Faro Mine Complex in detail [Gartner Lee Limited 2006a]).

The environmental assessment of the effects of the Project will then:

- identify effects of the Project on the baseline condition of identified wildlife;
- identify mitigation measures;

- evaluate the predicted residual effects and their significance; and
- identify wildlife monitoring requirements.

8.2.1.1 Regional Setting - Wildlife

The Faro Mine Complex is located within the Yukon Plateau-North Ecoregion, in the Boreal Cordillera Ecozone of the Yukon (Environment Canada 2005). Vegetation is predominantly white spruce with willow, dwarf birch, ericaceous shrubs, and occasionally, lodgepole pine. Characteristic wildlife includes woodland caribou (*Rangifer tarandus caribou*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), thinhorn sheep (*Ovis dalli*), moose (*Alces alces*), beaver (*Castor canadensis*), red fox (*Vulpes vulpes*), wolf (*Canis lupus*), snowshoe hare (*Lepus americanus*), common raven (*Corvus corax*), rock and willow ptarmigan (*Lagopus muta* and *L. lagopus, respectively*), and golden eagle (*Aquila chrysaetos*). Many wildlife species are important in the area for both economic and socio-economic reasons. Major communities in the area include Faro, Keno Hill, Mayo, and Ross River (Environment Canada 2005).

8.2.1.2 Issue-Focused Approach

The approach of this baseline documentation was focused to provide information relevant to those issues identified as important to stakeholders in the study area, and issues that may be associated with project impacts. While impact assessment is pending, a preliminary issue identification that considered potential project impacts took place to guide the baseline documentation. Key issues were identified through community meetings and regulatory consultation with First Nations (Selkirk First Nation and Ross River Dena Council), the Town of Faro, Government of Yukon biologists, local residents, and scientific opinion of Project scientists.

8.2.1.3 Summary of Project Activities/Impacts

There is a range of possible activities associated with the Project that will result in potential impacts to wildlife. These are important to identify early in the baseline documentation and impact assessment process so that information or data necessary to address issues are available. Although a preferred option for closure has not been selected, review of the various alternatives was completed to identify potential project-environment interactions.

Activities associated with the Project that would have the greatest relevance to wildlife include the use of heavy equipment to construct soil or water covers on tailings, relocation of tailings, revegetation of tailings, construction of soil covers and revegetation of waste rock, re-contouring and/or relocation of waste rock dumps, berm and dam construction, and removal of dams, buildings, and roads. Additionally, closure activities will result in increased human presence at the site as well as an increase of traffic to and from the site, and will require activities to manage human-wildlife interactions. An increased population base in the area may also result in more hunting pressure on wildlife species.

The potential impacts to wildlife for Project related activities include sensory disturbance, change in habitat availability, change in mortality risk, and change in contaminant releases. Activities may

result in both direct and/or indirect effects. Direct effects are often measured and assessed at the local scale of a project (such as on-site habitat disturbance), while indirect effects are often predicted and measured at a regional scale (such as habitat change due to sensory disturbance [noise or dust], or changes in hunting pressure due to increased community populations).

Preliminary Wildlife Concerns and Issues

Preliminary issue identification has taken place, and is provided below for a context in understanding the focus of baseline efforts to date. The issues below are preliminary, and reflect the issues anticipated from First Nations (Selkirk First Nation and Ross River Dena Council), the Town of Faro, and Governmental agencies (such as Health Canada, Government of Yukon, Environment Canada, etc.)

Anticipated Issues from Communities and First Nations

Wildlife Contamination:.....quality and health of country food sources

Moose Populations:.....impacts to the abundance and distribution of moose

Sheep Populations: .....impacts to the abundance and distribution of sheep and impacts to migratory routes

Furbearing Species: .....impacts to the abundance and distribution of furbearing species

Anticipated Issues from Regulators

Wildlife Contamination:.....quality and health of country food sources

Migratory Birds and Waterfowl: .impacts to abundance, distribution and migration of birds.

Species at Risk Impacts:.....impacts to abundance, distribution, and migration of any Species at Risk

Problem Wildlife Management: ..mortality risk to grizzly and black bears, wolverine, foxes and wolves.

Sheep Populations: .....impacts to abundance, distribution, and migration, and mortality risk of sheep

Caribou Populations:.....impacts to abundance, distribution, and migration, and mortality risk of caribou

Moose Populations:.....impacts to abundance, distribution and mortality risk of moose

Small Mammals:.....the impacts to abundance and distribution of small mammals

8.2.2 Valued Ecosystem Components

Valued Ecosystem Components (VECs) can be defined as environmental attributes or components that are perceived as important for ecological, social, cultural, and/or economic reasons. The intent of selecting VECs is to focus the baseline programs (and subsequent impact assessment) on those species or species groups that are most closely associated with the issues identified by communities, First Nations, and/or regulators. Several species of mammals, birds, and amphibians may occur in the Project area on a year-round or seasonal basis. Preliminary VECs for this project were selected by incorporating information from numerous sources and considering a number of criteria, including:

- the legal status of the species at the Federal and Territorial levels;
- known presence and relative abundance within the study area;
- socio-economic value (hunting, trapping, wildlife viewing, public profile) and regional importance (regional conservation concerns);
- concerns of First Nations, local communities, and regulators;
- the professional judgment of project scientists;
- VECs chosen for previous environmental assessments and current wildlife monitoring programs in the region;
- vulnerability to potential project effects; and
- the role as an indicator species for a specific wildlife group.

The following is a preliminary list of VECs considered representative of important wildlife species:

- Fannin sheep (thinhorn sheep colour variant)
- Grizzly bear
- Moose
- Woodland caribou
- Furbearers
- Small mammals
- Migratory birds

This list will be finalized through consultation and the collection of Traditional Knowledge data.

Among the VECs identified, moose, furbearers and Fannin sheep were considered especially important for their economic and cultural values, and subsistence harvest uses. It should be recognized that the list of VECs presented herein is preliminary, and further issue scoping and consultation associated with the impact assessment may refine the VECs selected at a later date.

8.2.3 Study Area

The Study Area used in this baseline description was limited to the immediate project footprint and surrounding areas (i.e., within a 1 km radius surrounding the site). This area totals 81.2 km^2, of which 16.1 km^2 is made up of the footprint of the current mine infrastructure and roads. The intent

of this study area delineation, usually termed a 'Local Study Area' is to capture direct effects on wildlife from the project activities in project impact assessment. Herein, all references to a 'Study Area' refer to this local scale.

Regional scale data collection, description, and assessment were beyond the scope of this work. However, it was necessary to include regional data where feasible and appropriate, primarily to provide a context for local scale data. In most cases, there were no data available that were specific to the local area, and regional scale data were used to form conclusions regarding local conditions.

8.2.4 Wildlife Baseline Conditions

8.2.4.1 Data Collection Methods

As no project-specific wildlife field studies occurred relating to the baseline, data collection methods were limited to incidental sightings of wildlife during a vegetation classification survey conducted in August of 2007, and the use of existing data sources. Those sources included published literature, government reports, reports from previous studies and Environmental Impact Assessments (EIAs), incidental sightings, and available Community and Traditional Knowledge reports.

8.2.4.2 Baseline Conditions

Woodland Caribou

Both barren-ground and woodland caribou are found within the Yukon. In the Faro area, caribou belong to the Northern mountain population of woodland caribou (*Rangifer tarandus caribou*). The Northern Mountain woodland caribou populations are listed as Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006), and federally designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007); additionally they are listed as Special Concern on Schedule 1 of the *Species at Risk Act (SARA)*. The caribou in the Faro area are likely from the Tay River caribou herd, of the Northern Mountain population. There are three other populations within the Region including the Finlayson herd located southeast of the Study area, the Pelly herd located south of the Study Area and the Moose Lake herd located west of the Study Area.

The Government of Yukon Department of Renewable Resources has formed a Caribou Management Team to develop interim caribou management guidelines for the Yukon. The guidelines outline management principles, concepts and assumptions regarding woodland caribou (Department of Renewable Resources, Government of Yukon 1996a). Commitment to caribou populations within the Faro region is demonstrated in the "Integrated Wildlife Management Plan - Ross River Traditional Territory" (Kaska Dena Traditional Territory, 1997). However, the management plan focuses on the management of the Finlayson caribou herd population rather than the Tay River herd, therefore demonstrating a concern for caribou but not one specific to the Tay River herd. The management plan also presents other caribou concerns, including harvesting

parturient wildlife and meat wastage caused by late rut harvesting, untrained hunters or the wrong ammunition.

Population

The total number of woodland caribou in the Yukon is estimated between 30,000 and 35,000 (Department of Renewable Resources, Government of Yukon 1996a). These caribou are found within one of 23 recognized herds in Yukon, whose populations range in size from about 100 to 10,000 (Department of Renewable Resources, Government of Yukon 1996a). Woodland caribou in the Yukon occur at densities well below habitat carrying capacity and are held there by predation and human harvest (Department of Renewable Resources, Government of Yukon 1997a).

The population of the Tay River herd was last estimated to be 3,758 +/- 571 animals, based on a 1991 survey conducted by the Government of Yukon Department of Renewable Resources, (1997a). This equates to approximately 0.15 caribou per square kilometre, although densities are likely much higher on winter ranges where caribou may congregate. An attempt to resurvey the area in 2003 was hampered by poor weather conditions, and no recent estimate is available (J. McLelland, pers. comm. 2007).

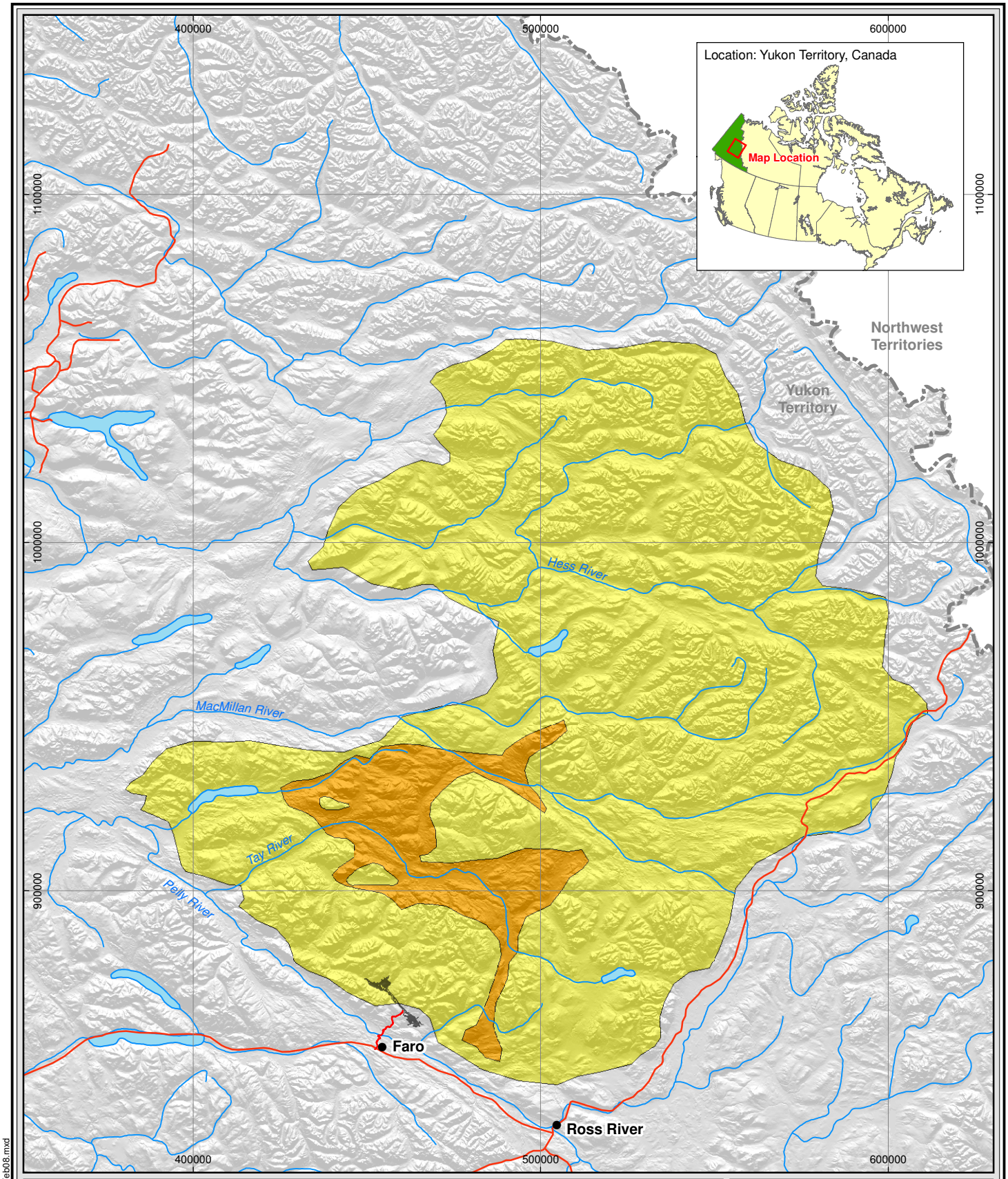
Within the Study Area for this Project, only a handful of caribou are likely found at any time of the year, although the wintering distribution of caribou may result in concentrations of wintering caribou occurring close to the site.

Movements and Distribution

The range of the Tay River herd is approximately 25,000 km^2, covering the area north of the Pelly River, west of North Canol Road and south of the upper Stewart River (Figure 8.2-1; Department of Renewable Resources, Government of Yukon 1997a). The majority of caribou in the Tay River herd are found along the Tay and South Macmillan rivers (Department of Renewable Resources, Government of Yukon 1997a).

Tay River caribou move between winter ranges, and generally non-distinct calving, post-calving, and summer ranges over the course of the year. Cows in the Tay River herd calve and spend the post-calving period over an extensive area (Department of Renewable Resources, Government of Yukon 1997a). Surveys conducted twice a year from 1989 to 1991 found all calving locations for the herd to be located south of the upper Stewart River and north of the Pelly River. No calving locations fell within the Study Area for the project; the closest recorded calving locations were within 50 km of the Project. The Tay River herd's summer and rutting distribution largely defines the outer boundaries of the herd range, and encompasses the Project Study Area.

The winter range for the Tay River herd tends to be in the snow shadow region between mountain ranges where forage is more accessible. Winter distribution is generally characterized by a northward movement out of mountainous areas towards the forested drainages north of the Study Area. The herd's winter range does not encompass the Study Area, however the southwest toe of the winter range falls within close proximity to the Project. During the winter of 1991, a census found a concentration of caribou within 10 km of Faro town site, indicating a potential for wintering caribou to occur within the Study Area.



Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Branch.
Project footprint delineated by Gartner Lee Limited.
Tay river caribou herd range provided by Gartner Lee Limited.
Boundaries are approximate.

N
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10 5 0 10 20 30 Km

1:1,500,000

Yukon Albers

Legend

Existing Features
- Community
- Road

Tay River Caribou Herd Range
- Herd Range
- Winter Range

Boundaries
- Territorial Boundary
- Project Footprint

Hydrological Features
- Watercourse
- Waterbody

Range of theTay River Caribou Herd

19 February 2008

Gartner Lee

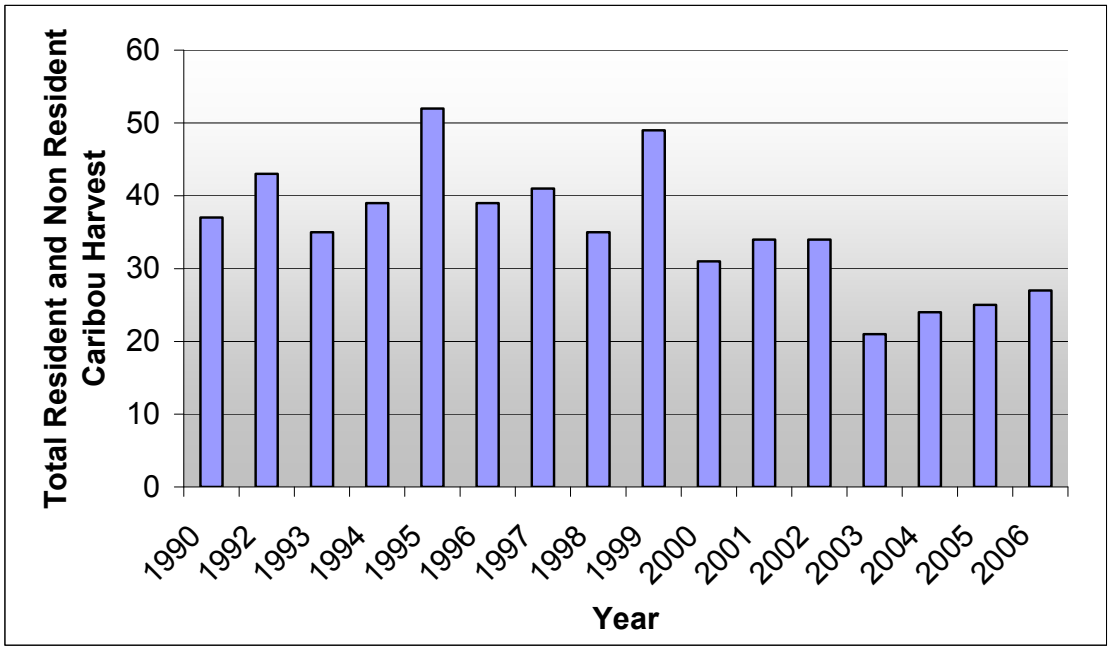
Figure 8.2-1
Version 1

File: 70384 C1 Fig 4.2-1 TayRiverCaribouRange 19Feb08.mxd

Harvest

The harvest of caribou from the Tay River herd is relatively low, and is assumed to be limited by access in the fall hunting season. Over the past 16 years, the harvest ranged from 21 to 52 animals annually (Figure 8.2-2), with a mean annual harvest of 35.4 (Department of Renewable Resources, Government of Yukon 1997a; excluding subsistence harvest). This annual harvest is approximately one percent of the population, and is considered sustainable (i.e., <3% of adults, Department of Renewable Resources, Government of Yukon 1996a). Harvest of caribou in fall is typically via spur roads from the North Canol Road, and fly-in hunts based out of Ross River or Faro. Access to the winter range is minimal, and as such First Nation's harvest in winter is assumed to be quite low (Department of Renewable Resources, Government of Yukon 1997a). While harvest of caribou in the Study Area is likely very low, it is a highly accessible area, therefore creating potential for harvest.

Figure 8.2-2. Harvest of the Tay River Caribou Herd, 1990 to 2006



Habitat Use and Diet

During calving surveys conducted from 1989 to 1996 cows tended to be solitary (Department of Renewable Resources, Government of Yukon 1997a) and most often found in alpine habitats. These same alpine habitats were generally selected during the post-calving season. During the rut, caribou were found in many of the same areas chosen during the summer months, but with a wider distribution. In winter, caribou tended to move out of the alpine and mountainous areas and into drainages north of Faro. Collared caribou from the Tay River herd were found to be more confined

to valley bottoms in late winter than compared with early winter (Department of Renewable Resources, Government of Yukon 1997a).

Spring and summer diets of caribou are generally varied, with use of sedges, forbs, grasses, mushrooms, and most nutrient-rich young shoots of willows, birch, or horsetails (Banfield 1974). Winter food for woodland caribou consists primarily of lichen, and most Yukon herds have about 70% lichen in the diet (Department of Renewable Resources, Government of Yukon 1997a). To date no specific data are available on the diet of caribou in the Tay River herd, however it is likely to be similar to that identified by Banfield (1974).

Summary

The Tay River caribou herd is relatively small and widely dispersed, but appears generally stable in population levels given the current harvest pressure. The Department of Renewable Resources, Government of Yukon (1997a) identified the conservation of the winter range as crucial to the long-term survival of the herd. In consideration of the development of the Mine Closure Project, it expected that a potential increase in hunting pressure (due to potential Community population changes), and potential indirect impacts to the winter range, would necessitate mitigation planning to reduce potential Project impacts.

Moose

Moose are the largest and one of the most widespread mammals in the Yukon. Currently, moose are listed as Secure in the Yukon (Yukon Wildlife Act 2007), and federally they are listed Not At Risk (COSEWIC 2007; SARA 2007). Moose have high socio-economic value in the Yukon as a game and subsistence species.

The Government of Yukon Department of Renewable Resources has developed interim moose management guidelines for the Yukon (Department of Renewable Resources, Government of Yukon 1996b). The guidelines focus on the protection of key habitats by establishing protected areas through the development and implementation of land use guidelines. The 1996 management plan committed to regular population and composition surveys. The plan also highlights concerns related to over-hunting in high priority areas. The moose populations in and near the Project are considered a high management priority (R. Ward, pers. comm. 2007), although no Key Wildlife Areas have been designated within the Faro area.

Population

Moose populations in the Yukon are managed among Game Management Subzones (GMS), and moose in the Faro area generally occur within GMS's 4-42 to 4-46 (Figure 8.2-3). Compared to other regions in the Yukon, moose in the Faro area occur at very high densities; approximately 405 moose per 1,000 km^2 (Department of Environment, Government of Yukon 2004). Earlier surveys conducted in 1997 and 1998 limited to a portion of the region documented extremely high densities of moose (Department of Environment, Government of Yukon 1997b, 1998). The 1997

survey documented the highest moose density in the Yukon; 586 moose/1,000 km^2, although the survey area was smaller than that of the 2004 survey. While the actual population of moose in the Study Area is unknown (and may fluctuate during among years), regional data indicates that relative to other parts of the Yukon, high densities of moose are consistently present in the area.

Movements and Distribution

Although moose may use different habitats among seasons, there are no distinct seasonal ranges for moose in the Faro area (R. Ward, pers. comm. 2007). A satellite-telemetry study done in the Faro area (Ward 2003b) found home range among the moose collared spanned from 64 km^2 to 274 km^2, with no obvious relationship between moose sex and home range size. Home range sizes and daily movement distances tended to be greater in the spring/summer period than in the winter period. Moose that summer in the sub-alpine tended to migrate a longer distance in comparison to moose that summer in the lowlands (Ward 2003a).

Harvest

The average annual reported harvest in the Game Management Subzones of the Faro region (4-41 to 4-46) is approximately 2% of the estimated moose population within the region. The sustainable range of harvest for moose populations in the Yukon is 3-4% (Government of Yukon Department of Renewable Resources 1996b), and overall harvest throughout the region is estimated to be within sustainable limits. From 1979 to 2006, total harvest (excluding subsistence First Nations harvest and unreported illegal kills and harvest) has averaged 34 moose per year, ranging from 10 to 61 animals (Data provided by Government of Yukon Department of Environment (unpublished data; Table 8.2-1 below).

Table 8.2-1. Total Resident and Non-Resident Moose Harvest in Game Management Subzones near the Faro Mine Area

GMS	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
4-41	1	1	0	4	5	11	9	6	7	11	8	6	8	4	7	3	14	10	15	18	12	9	15	7	2	1	5	4
4-42	1	2	0	5	5	5	5	4	1	2	2	3	5	0	4	0	5	7	6	6	6	3	3	6	5	6	7	4
4-43	1	2	1	1	0	0	1	2	3	1	0	1	2	0	6	1	2	0	1	0	0	1	6	0	1	2	0	0
4-44	1	4	3	6	1	2	7	5	3	7	3	0	1	1	2	1	0	4	9	6	1	6	2	0	1	3	3	2
4-45	3	2	6	5	6	9	5	11	3	6	14	4	7	3	14	10	23	13	19	21	15	20	21	9	21	16	24	36
4-46	2	3	4	8	1	3	1	1	3	4	3	1	1	1	2	6	3	2	4	6	7	0	10	2	6	6	7	3
4-47	0	2	1	5	4	3	1	0	0	2	5	2	5	1	3	2	1	2	3	4	1	1	1	2	2	4	4	3
4-51	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	1	0
Total	**10**	**17**	**15**	**35**	**22**	**33**	**29**	**29**	**20**	**33**	**36**	**20**	**31**	**12**	**41**	**25**	**48**	**38**	**57**	**61**	**42**	**40**	**58**	**26**	**38**	**38**	**51**	**52**

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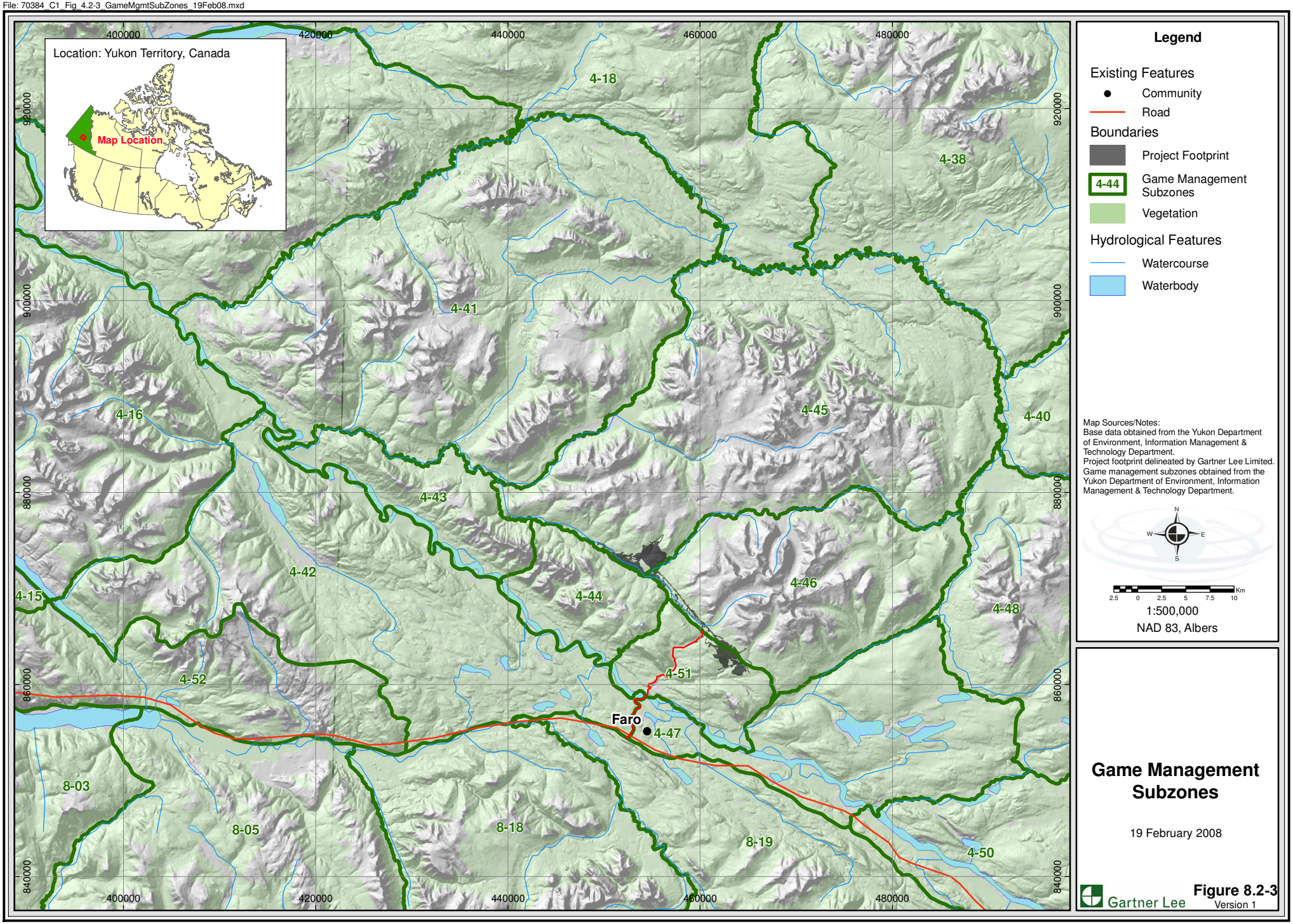

Legend

Existing Features
- Community
- Road

Boundaries
- Project Footprint
- 4-44 Game Management Subzones
- Vegetation

Hydrological Features
- Watercourse
- Waterbody

Map Sources/Notes:
Base data obtained from the Yukon Department of Environment, Information Management & Technology Department.
Project footprint delineated by Gartner Lee Limited.
Game management subzones obtained from the Yukon Department of Environment, Information Management & Technology Department.

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NAD 83, Albers

Game Management Subzones

19 February 2008

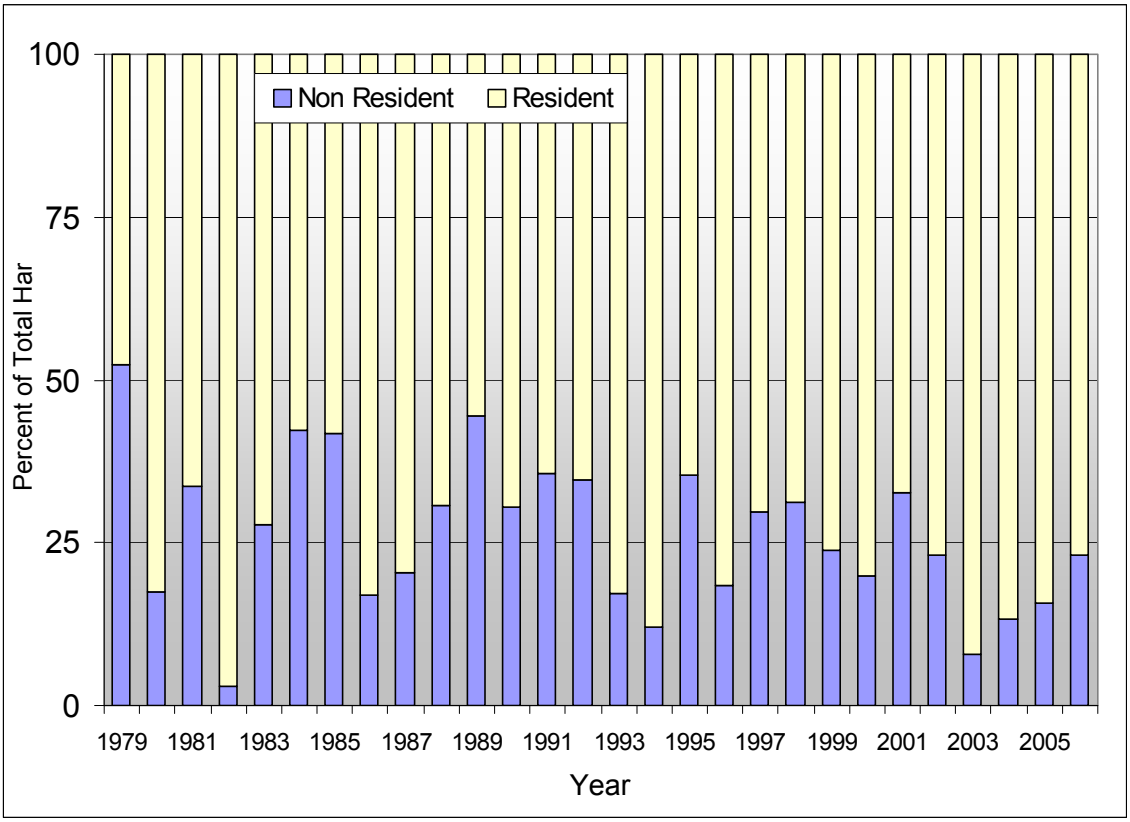
Gartner Lee

Figure 8.2-3
Version 1

However, due to access, harvest in the subzones north and west of Faro is at or above 5% of the estimated moose population, which is above the recommended maximum allowable rate (Department of Environment, Government of Yukon 2004). This is primarily within GMS 4-45, which is both an important rutting and post-rutting area for moose, and an important hunting area for Faro residents (Department of Environment, Government of Yukon 2004). There is concern that if this trend continues and becomes more widespread, the local moose populations may be at risk of declining (Department of Environment, Government of Yukon 2004).

Moose are harvested by resident and non-resident (guided) hunters alike. Local inhabitants of the Town of Faro have expressed concern regarding the amount of non-resident hunting in the area. The average number of moose taken annually by non-residents (of the Yukon) in the Faro area averages approximately 25% of the total harvest (ranging from 3% to 52%, excluding First Nations; Figure 8.2-4).

Figure 8.2-4. Percent of Total Moose Harvest by Yukon Residents and Non-Resident, 1979 to 2006.



Habitat Use and Diet

Satellite-telemetry data from 2002 and 2003 indicated that during the spring and early summer, moose spend the much of their time in the lowland areas (Ward 2003a). As summer progressed, moose generally moved from lowlands to sub-alpine habitats, although some remained in lowland areas year round (Ward 2003a). During the rut, moose concentrated in sub-alpine habitats. In the Faro area moose were observed in the sub-alpine plateau north of the Faro townsite (2004 rut and post-rut survey; Department of Environment, Government of Yukon 2004). As winter commenced, moose in the Faro area moved into adjacent lowlands and/or concentrated in sub-alpine/willow and older post-burn habitats (Ward 2003a).

Terrain within the Study Area tends to be primarily sub-alpine mid slope with lowland and high shrub cover areas riparian areas near most drainages and rivers. Seasonally, moose would most likely be found within the low-lying areas in the spring, and in lowland and sub-alpine areas in summer. However, evidence of moose browse and pellets were observed in all habitat types near the mine site however, and animals were observed on two occasions (in summer) in riparian lowland habitats during a vegetation classification survey conducted in August 2007.

Summary

Government, First Nations, and stakeholders consider moose populations in the area near Faro a high priority to manage and conserve. Moose densities are relatively high in the area, as is harvest pressure in some parts of the range. Thus far, the Government has closely regulated and monitored populations that encompass the Study Area. In consideration of implementation of the Project, it is expected that the potential increases in hunting pressure (due to Community population changes) would necessitate mitigation planning to reduce potential Project impacts.

Thinhorn Sheep

Thinhorn sheep in the Yukon include two recognized subspecies; Dall sheep (*Ovis dalli dalli*), which are white in colour, and the generally darker Stone sheep (*Ovis dalli stonei*). In the Pelly Mountains and Ogilvie Mountains of the Yukon, a colour variant of thinhorn sheep that is somewhat intermediate between Dall and Stone sheep occurs, and are known as fannin sheep. The genetic and evolutionary distinctions and subspecies designations among Dall, Stone, and fannin sheep are currently in question (Loehr *et al.* 2005, Worley *et al.* 2004), but locally in the Study Area only fannin sheep are present, and are characterized by their saddle-shaped colourations. Fannin sheep in the Study Area generally occur on Sheep Mountain, Rose Mountain, and Mount Mye, although presence varies by season, as discussed below. Currently, thinhorn sheep are recognized as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006), and federally they are listed Not At Risk (COSEWIC 2007). However, fannin sheep have high socio-economic value in the Yukon as a game and subsistence species, and for their non-consumptive value (wildlife viewing) shown in the sheep and sandhill crane (*Grus canadensis*) viewing festival currently supported by the Town of Faro.

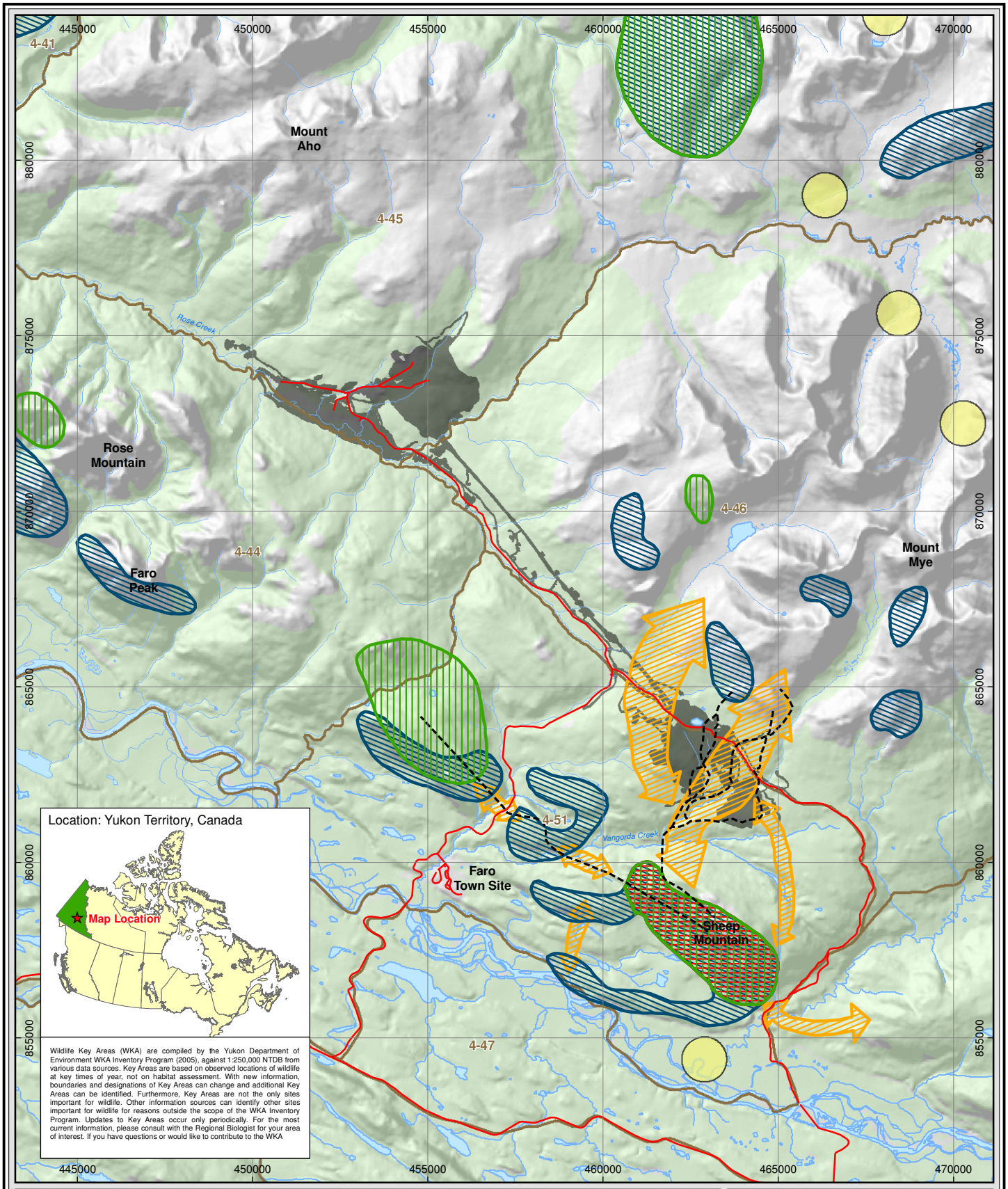
The Government of Yukon Department of Renewable Resources developed sheep management guidelines for the Yukon in 1996 (1996c), and prepared a Management Plan Proposal for the Sheep Mountain population in 1988 (Department of Renewable Resources, Government of Yukon 1988). The primary objective of the management guidelines is the "conservation of sheep populations and their habitat within the framework of ecosystem biodiversity" (Department of Renewable Resources, Government of Yukon 1996c). Locally, interest in Fannin sheep has grown, and is demonstrated by the development of infrastructure and interpretative trails that support wildlife viewing near the Town of Faro. Managers have also focused efforts to reduce disturbance on wintering sheep, by declining woodcutting applications and barricading areas to deter snowmobile access.

Population Status

There are approximately 22,000 thinhorn sheep in the Yukon, with densities ranging from less than two sheep/100 km^2 to more than 30 sheep/100 km^2 (Department of Renewable Resources, Government of Yukon 1996c). The sheep are believed to be at, or near, historic population levels, and have recolonized some ranges where they had previously disappeared (Department of Renewable Resources, Government of Yukon 1996c). Of the Yukon thinhorn sheep population, about 2,500 are Fannin sheep (Department of Renewable Resources, Government of Yukon 1996c). Sheep population abundance is particularly affected by winter weather, and snow conditions affect both birth rate and lamb survival (Department of Renewable Resources, Government of Yukon 1996c).

Sheep have been studied near Faro since the mid-1970s. Estimates of the number of sheep utilising Sheep Mountain, Mount Mye and Rose Mountain (see Figure 8.2-5 for mountain locations) have been made through a combination of aerial surveys (Montreal Engineering Company Ltd. 1976; McLeod 1981; Department of Renewable Resources unpublished survey data (1980, 1987, 2002); Hoeffs 1988, 1990; Horejsi 1988; Department of Renewable Resources, Government of Yukon 2002) and field observations (detailed in Schweinsburg 1990). The number of sheep counted within each survey area has varied depending on factors such as season, technique, intensity, and survey conditions, and as a result, it is difficult to extrapolate demographic trends from those data sources.

The only recent estimate of sheep abundance in and near the Study Area took place in 2002 (Department of Renewable Resources, Government of Yukon 2002), and included surveys of GMS 4-41, 4-43, and 4-44. In GMS 4-41 (largely to the northwest and beyond the Study Area), 183 sheep were observed, including 94 nursery sheep (assumed to be ewes), 31 lambs, and 58 rams. While difficult to compare directly, the 2002 survey indicated that since 1981, the number of nursery sheep in GMS 4-41 increased from 44 to 94 (an annual increase near 3.5%), which was attributed in part to animal movements at the time of surveys (Department of Renewable



Map Sources/Notes:
National Topographic Database (NTDB) provided by the Government of Canada, Natural Resources Canada at 1:50,000 scale.
Hillshade imagery obtained from the Yukon Department of Environment, Information Management & Technology Department.
Project footprint delineated by Gartner Lee Limited.
Sheep key areas and game management subzones obtained from the Yukon Department of Environment, Information Management & Technology Department.

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Yukon Albers

Legend

Existing Features
- Road

Thinhorn Sheep Key Areas
- Spring Lambing
- Early Winter Rut
- Winter Range
- Movement Corridor
- Mineral Lick

Migration Routes
- Sheep Migration Route

Boundaries
- Project Footprint
- Vegetation
- Game Management Subzones

Hydrological Features
- Watercourse
- Waterbody

Thinhorn Sheep

19 February 2008

Gartner Lee

Figure 8.2-5
Version 1

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Resources, Government of Yukon 2002). In portions of GMS 4-43 and 4-44 combined (i.e., Rose Mountain area, also largely to the west and beyond the study area), 73 sheep were observed (45 nursery sheep, 17 lambs, and 11 rams). Populations were considered stable in 4-43 and 4-44 due to similarities to a 1991 survey (71 sheep counted), and in 2002 all GMS's populations were not thought to be over harvested.

It is believed that the sheep population using the ranges on Sheep Mountain and on Mount Mye (within GMS 4-51 and 4-46, respectively) remained relatively stable in the 1980s (Schweinsburg 1990) at between 60 and 80 individuals (Department of Renewable Resources, Government of Yukon 1987, 1988). Observed recruitment levels in the late 1980s (indicated by proportion of lambs/yearling in the population) were considered to be indicative of a growing population (Schweinsburg 1990), but given the variations in range use, it is difficult to be certain that sheep counts conducted over the years on Mount Mye and/or Sheep Mountain are representative of one sheep population. Prior to the work of Schweinsburg (1990) it was thought that one population of sheep wintered on Sheep Mountain and summered on Mount Mye. However, it appears that sheep that winter on Sheep Mountain can be found on either Sheep Mountain, Mount Mye or on the mine site (Vangorda) during summer as well as potentially in other areas, e.g., Rose Mountain (Schweinsburg 1990). There also appears to be some sheep that are independent of the Mount Mye/Sheep Mountain group that summer in areas around Blind and Swim lakes (approximately 15 km to the southeast of the Vangorda pit) and winter on windswept slopes near to their summer range (Schweinsburg 1990).

Movements and Distribution

Fannin sheep in the Study Area occupy relatively distinct seasonal ranges during the early winter and rut, mid to late winter, lambing, and summer, and several identified migratory routes have been documented that link these areas in the Study Area. Most migratory routes and winter, early winter and rut, and spring lambing ranges have been identified as Key Wildlife Areas by the Fish and Wildlife Branch of the Department of Environment (Figure 8.2-5).

Seasonal Ranges

- *Winter Range*

  Winter habitat use patterns have been determined from: inferences based on habitat characteristics and local knowledge (Montreal Engineering Company Ltd. 1976); aerial counts of sheep during winter (Department of Renewable Resources, Government of Yukon 1980, 1987); inferences based on the interpretation of field sign and observations made by field worker and locals (McLeod 1981), radio tracking (nine ewes were radio tracked between 1989 and 1990), and visual observations of sheep and interviews with locals (Schweinsburg 1990).

  The southern slopes of Sheep Mountain have been identified as an area of sheep winter range (Figure 8.2-5; Montreal Engineering Company Ltd. 1976; Department of Renewable Resources, Government of Yukon 1980; McLeod 1981; Department of Renewable Resources,

Government of Yukon 1987; Schweinsburg 1990). Telemetry locations and field observations indicate that nursery sheep (ewes, lambs and yearlings) spent early winter on the upper slopes of Sheep Mountain while rams spent this time on the western edge of Sheep Mountain.

Other wintering areas are located on Faro Peak and bluffs to the northwest of Sheep Mountain. The southern slopes of Mount Mye have also been designated as winter range, and are the closest wintering areas to the project, within 1 km of the Grum pit. Additional wintering areas include: the windswept slopes near Blind and Swim Lakes (Schweinsburg 1990), Pelly River Bluff, 2.5 km east of Faro (Schweinsburg 1990), Rose Mountain (GMS 4-43 and 4-44), and potentially areas northeast of Faro on Vangorda Creek (McLeod 1981; Schweinsburg 1990).

- *Lambing Range*

The location of lambing areas was determined from aerial surveys; inferences based on the interpretation of field sign and observations made by field worker and locals (McLeod 1981), radio tracking (nine ewes were radio tracked between 1989 and 1990), visual observations of sheep and interviews with locals (Schweinsburg 1990).

Initial studies indicated that lambing areas on Sheep Mountain were found downslope of the early winter range (Montreal Engineering Company 1976). Schweinsburg (1990) later argued that ewes move from the lower slopes of Sheep Mountain in late winter, to lamb at higher elevations. There is also some indication that ewes may lamb on Mount Mye (Schweinsburg 1990).

- *Summer Range*

Summer distribution of sheep has also been described based on aerial surveys, radio tracking, and visual observations of sheep (Schweinsburg 1990). Sheep were generally dispersed more widely over their summer range than the winter range. A large area has been identified as summer range and includes Mount Mye (Montreal Engineering Company Ltd. 1976, McLeod 1981, Hoeffs 1988, Hoeffs 1988, Schweinsburg 1990), Rose Mountain (McLeod 1981), Blind Creek and Swim Lakes area (Schweinsburg 1990), Sheep Mountain and the Anvil Mine Complex (Schweinsburg 1990). The summer range is not identified as a Wildlife Key Area, perhaps because of the more general and wider distribution of sheep.

- *Early Winter and Rutting*

Location of rutting areas was determined from visual field observations (Schweinsburg 1990). Rams were observed rutting on Sheep Mountain (Schweinsburg 1990) presumably during fall/early winter. Other rutting areas may be possible, as less study and observations have taken place during the rut, and given the relatively wide distribution of sheep in summer and the documented winter ranges, rutting is very likely not limited to Sheep Mountain.

Migratory/Movement Routes and Timing

Twice a year Fannin sheep migrate through the infrastructure of the Vangorda/Grum area of the Faro Mine Complex. Spring migration occurs between mid-May and late June, when Sheep migrate from their winter ranges to summering areas, often on Mount Mye (McLeod 1981; Schweinsburg, 1990). Fall migration takes place in mid-September to mid-October, when sheep move from summer range to early winter and rutting areas on Sheep Mountain. Nursery herds tend to migrate earlier than rams (Schweinsburg 1990). Sheep in the Study Area have tended to show some resilience to disturbance and continue to re-use migratory routes (such as migrations through Vangorda mine area), despite ongoing anthropogenic disturbances.

Several migration routes have been documented by studies in the area. Three such routes are documented that navigate terrain between Mount Mye and Sheep Mountain through the Study Area that are used in both spring and fall (Figure 8.2-5). They include:

a) The main migration route (termed Route E in McLeod (1981)) between Mount Mye and Sheep Mountain for spring and fall migration goes from Sheep Mountain to the confluence of Shrimp Lake and Vangorda Creek, crosses the haul road 1 km west of Vangorda Creek and then continues to the base of Mount Mye (Montreal Engineering Company Ltd. 1976; McLeod 1981; Horejsi 1988; Schweinsburg 1990). This route directly passes between the Vangorda and Grum deposits.

b) A second route (Route F in McLeod (1981)) was also identified by Montreal Engineering Company Ltd. (1976), McLeod (1981), and Schweinsburg (1990). From Sheep Mountain, this route goes to the confluence of Shrimp Lake and Vangorda Creek, it then follows a cat road, crosses the airstrip to the site of the proposed Vangorda open pit and continues to Mount Mye via the west side of Vangorda Creek.

c) A third route (Route D in McLeod (1981)) was also identified by McLeod (1981), Horejsi (1988), and Schweinsburg 1990). From Mount Mye, this route goes south from Mount Mye and crosses the haul road 1 km east of the Grum Camp. The route then follows down to the confluence of Shrimp Lake and Vangorda Creek to on to Sheep Mountain.

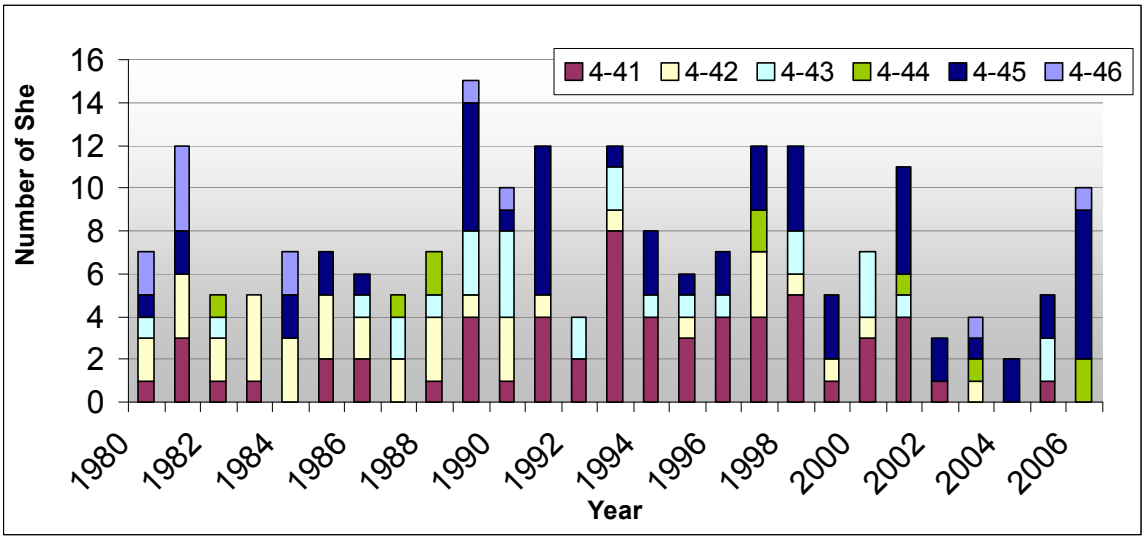
McLeod (1981) also identified one addition migration route (route A), which is southwest of the Study Area and runs parallel to the project, following west from Sheep Mountain along the ridge to Rose Mountain.

Harvest

Licensed harvest of sheep in the Yukon is relatively small at less than 2% of the total estimated population (Department of Renewable Resources, Government of Yukon 1996c). In the Game Management Subzones (GMS) 4-46 and 4-47, licensed hunting has been closed since 1982 (J.

Carey, pers. comm. 2007). Game Management Subzone 4-46 encompasses Mount Mye, and is the zone in which the most western part of the Study Area occurs. Harvest in subzones 4-41 to 4-45 is open to licensed and regulated harvest; in these zones the average total harvest is 7.9 sheep/year (range 3-15) (see Figure 8.2-6), including harvest recorded in 4-46 (It is not clear as to whether these harvests are legal as the area has been closed since 1982). Although total population estimates are uncertain, the harvests are assumed to be sustainable at current levels, as the number of sheep taken is relatively stable (Department of Environment, Government of Yukon 2004) and indices of sheep abundance also indicate stable to possibly increasing populations (Department of Environment, Government of Yukon 2004).

Figure 8.2-6. Total Harvest of Fannin Sheep in Game Management Subzones 4-41 to 4-46, 1980 to 2006



Habitat Use and Diet

Sheep typically require windblown and grassy slopes as winter range; steep, secure areas where ewes can safely bear their lambs; steep rugged cliffs where they can escape from predators; and access to mineral licks in spring (Government of Yukon Department of Renewable Resources 1996c). Because such habitats are used on a seasonal basis, areas of movement between the ranges is also recognized as important movement corridors. Unfortunately, there has been no formal habitat mapping conducted on sheep habitat within the Study Area (i.e., within 1 km of the Project), or on Mount Mye, Rose Mountain, Blind Creek or Swim Lakes. Although Staniforth (1988) classified vegetation communities on Sheep Mountain, there is no comprehensive and consistent habitat map of the Study Area available. Thus, the boundaries of seasonal ranges are possibly imprecise.

In general terms, both Mount Mye and Rose Mountain are composed of upland vegetation types within alpine, subalpine and boreal forest habitats, while Sheep Mountain is composed of upland and lowland (riparian) vegetation types, within the a primarily boreal forest habitat type. The area around the Faro Mine Complex itself (i.e., the Study Area) is largely comprised of upland boreal habitat. Sheep Mountain and the western slopes above Blind Creek were burned in 1969, as were the areas near and covering the Vangorda – Grum deposits at the eastern extent of the Study Area.

Vegetation mapping was conducted at a scale of 1:20,000 using 27 sample plots within an area of 42.7 km^2 on Sheep Mountain (Staniforth 1998). Vegetation characteristics were noted, as was the presence of water, litter, coarse woody material, elevation, slope, aspect, topography, and drainage. Staniforth (1998) identified three habitat units significant to sheep during winter. It is likely that the communities could be extrapolated to other areas within the Study Area:

1. a Sage-Graminoid community that occurs on the open windswept south-facing slopes and is considered the most important to sheep, as it would be the most snow-free during winter;
2. a Rose/Forb community found mainly at the edges of south-facing aspen (*Populus tremuloides*) groves, in low-lying gullies and high snow accumulation areas; and,
3. a Grass-Forb community that occurs at the edge of the aspen groves but on the more northerly aspects.

Rocky outcrops that provide escape terrain occur in association with all three of the important winter range communities outlined above. As these vegetation communities occurred in very small patches, they could consistently be differentiated and were grouped into one habitat type, termed Rock/Grass/Forb, by Staniforth (1998). This unit covered a total of 4.9 km^2 or 11% of the Sheep Mountain study area. The Sheep Mountain study area was located south of the Vangorda Grum area.

In spring, sheep that winter on the southern slopes of Mount Mye are found on the lower slopes of Sheep Mountain to feed on sage (*Artemesia frigida*) and later on new herbaceous growth and aspen leaves (Schweinsburg 1990a).

Summary

Fannin sheep are highly important to stakeholders as an economic resource within the region, and are the most-visible species that interact directly with the project. The population appears generally stable, given the current harvest regulations, and a reasonable understanding of seasonal ranges and movement patterns is available. In consideration of the implementation of the Project, it is expected that the potential direct impacts to migrating sheep will be scrutinized, and will necessitate detailed mitigation planning.

Grizzly Bears

Grizzly bears (*Ursus arctos*) are found throughout the Yukon, and belong to the northwestern population of Canadian bears (Ross 2002). The northern interior grizzly population range encompasses northern British Columbia, most of the Yukon and into the southern Mackenzie District of Northwest Territories. The Government of Yukon Department of Renewable Resources developed interim management guidelines for grizzly bears in 1997 (1997c), and identified a primary principle of "the conservation of grizzly bears as an integral part of northern ecosystems and biodiversity". Federally, grizzly bears are designated as Special Concern (COSEWIC 2007) due to habitat loss, low reproduction, and slow recovery rates. Under the *Species at Risk Act* grizzly bears are not currently scheduled, although they were proposed for inclusion under Schedule 1 in 2004. Currently, grizzly bears are considered Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006).

Population

To a large degree, the availability and quality of forages, in addition to mortality rates, influences reproductive rates and population densities of bears. Northern interior grizzly bears in the Yukon have the lowest recruitment rates of all terrestrial mammals, due to low reproduction rates and litter size, and high mortality (Department of Renewable Resources, Government of Yukon 1997c). The current territory-wide estimate of grizzly bears in the Yukon is 6,000 to 7,000 grizzly bears (Department of Renewable Resources, Government of Yukon 1997c). This is consistent with the 6,300 bears estimated by Banci (1991, in Ross 2002). Since 1991, the grizzly population in the Yukon is considered to have remained stable, with some local exceptions (Ross 2002).

The population of the Study Area is arguably too small a scale to estimate abundance within, as the Study Area (81 km^2), is much smaller than the average grizzly bear home range. It would not be uncommon to have up to a few bears occur on occasion in the Study Area, but in general, few bears (if more than one) are expected to be present within the Study Area at any one time. Seasonal changes in bear foraging may result in more or less bears in the area, such as during times when bears may pursue moose calves or sheep lambs.

Harvest

The harvest of grizzlies is regulated by the Yukon Hunting Regulations. Harvest data available from 1980 to 2001 (Department of Environment, Government of Yukon, unpublished data; Table 4.2-2) indicates that the average bear mortality in the GMS's that encompass the study area (4-44 to 4-46, 4-51) ranged from 0.34 to 0.83 bears/year (more current data has been requested, and was pending at the time of this report preparation). Within GMS 4-51, in which the Vangorda/Grum deposits are located, all mortalities (10 bears between 1990-2001) were due to problem kills rather than hunting. Most other GMS's had predominately hunting related mortalities (Table 8.2-2). According to the Yukon Grizzly Bear Management Guidelines (1997c), females are being harvested in many areas at, or above sustainable levels while fewer than the allowable males are taken. In the Faro area, the overall male to female harvest ratio for all GMS's is approximately 2:1,

although more female bears were taken than in males in GMS 4-45. As population estimates are unknown in the region, is difficult to comment on whether the harvest is sustainable, but the area-based mortality measure of 6.31 bears/year/1,000 km^2 in GMS 4-51 is exceedingly high in comparison to neighbouring GMS's.

Table 8.2-2. Reported Grizzly Bear Mortalities from 1980 – 2001

GMS	4-41		4-42		4-43		4-44		4-45		4-46		4-47		4-51*		All GMS's**	
Area (Km2)	1299.8		825.5		170.3		147.9		1035.8		422.5		420.8		132		4454.6	
Sex	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Reported Hunts	15	8	8	5	1	2	6	0	5	6	4	2	2	1	0	0	41	24
Problem kills, Defence of Life/ Property	3	1	1	2	0	0	2	0	0	1	1	0	1	0	6	4	14	8
Annual Mortality (bears/year)	0.82	0.41	0.41	0.32	0.05	0.09	0.36	0.00	0.23	0.32	0.23	0.09	0.01	0.05	0.50	0.33	2.5	1.46
Annual Mortality (bears/year/1,000 km^2)	0.63	0.31	0.50	0.39	0.27	0.53	2.46	0.00	0.22	0.31	0.54	0.22	0.32	0.11	3.79	2.52	0.56	0.33
Total Annual Mortality (bears/year/1,000 km^2)	0.94		0.89		0.80		2.46		0.53		0.76		0.43		6.31		0.89	

Notes: * *Includes data between 1990 and 2001 only.*
** *Although GMS 4-51 included data only between 1990 and 2001, it was assumed that mortalities recorded represented data from a time period equal to that of other GMS's in order to calculate annual mortality rates. Thus, the total annual mortalities/year, and total annual mortalities/year/1,000 km^2 are slightly underestimated.*

Movements and Distribution

Grizzly bears are known to utilize large home ranges averaging over 1682 km^2 for males and 491 km^2 for females (Department of Renewable Resources, Government of Yukon 1997c). The Study Area (81 km^2) would comprise only 16% of a female home range, and less than 5% of a male bear's home range.

Habitat associations of grizzly bears generally reflect local plant phenology and are strongly seasonal. In a mountainous region like Faro this may result in elevational movements in response to seasonal changes in vegetation (LeFranc *et al.* 1987). Bears may den at relatively high-elevations and in spring descend to valley bottoms to forage on young plants, previous-year berry crops, and pursue ungulates or ungulate carcasses. Then, as snowmelt proceeds, they may ascend upslope to follow the emergence of fresh vegetation (Ross 2002).

Terrain within the Study Area is primarily made up of moderately sloped upland areas with low-lying and riparian habitats around the Rose and Vangorda creeks, and several tributaries and drainages. Seasonally, grizzly bears may found within the low-lying areas in the spring and on mid to upper slopes in early summer, and in upland areas of berry production in later summer and fall.

Habitat Use and Diet

Grizzly bears typically have a wide-ranging diet that is primarily herbivorous in most areas. MacHutchon (1996) quantified grizzly bear food habits in Ivvavik National Park in the Yukon, and found important spring foods to include hedysarum roots (*Hedysarum spp*.) and over-wintered berries. Summer diet focused on horsetails (*Equisetum spp*.) and bearflower (*Boykinia richardsonii*), while ripened berries primarily made up the diet in fall, with a focus on roots when berries were not available. Prey included arctic ground squirrels (*Spermophilus parryii*) during summer and fall and caribou when migrating through in spring and summer. Bears within the Faro Region would likely have comparable food habits, although the growing season in the southern Yukon is comparably longer than in the north, therefore an increase in plant diversity and food availability may be expected. Bears in the Study Area would likely still rely heavily on berries, and berry-laden bear scat (Figure 8.2-7) was observed during a vegetation classification survey conducted in the Study Area in July 2007. Bears in the Study Area would also likely prey on alternative ungulate species as sheep and moose are much more common to this area than caribou.

Figure 8.2-7. Bear Scat Observed, August 2007, Vangorda/Grum Area

Summary

With the exception of harvest data, there is a general lack of specific information regarding grizzly bears in the Study Area. However, the habitats within the Study Area appear to support high densities of prey species such as moose and thinhorn sheep, in addition to vegetation cover that often included berry-producing plants. Combined with the unfortunate but regular problem kill rates of near one bear/year in the Study Area GMSs, it is likely that the area including and surrounding the Study Area has a relatively high production and/or density of grizzly bears. Clearly though, project mitigation planning should carefully address methods to reduce human-bear conflicts as the project progresses.

Furbearers

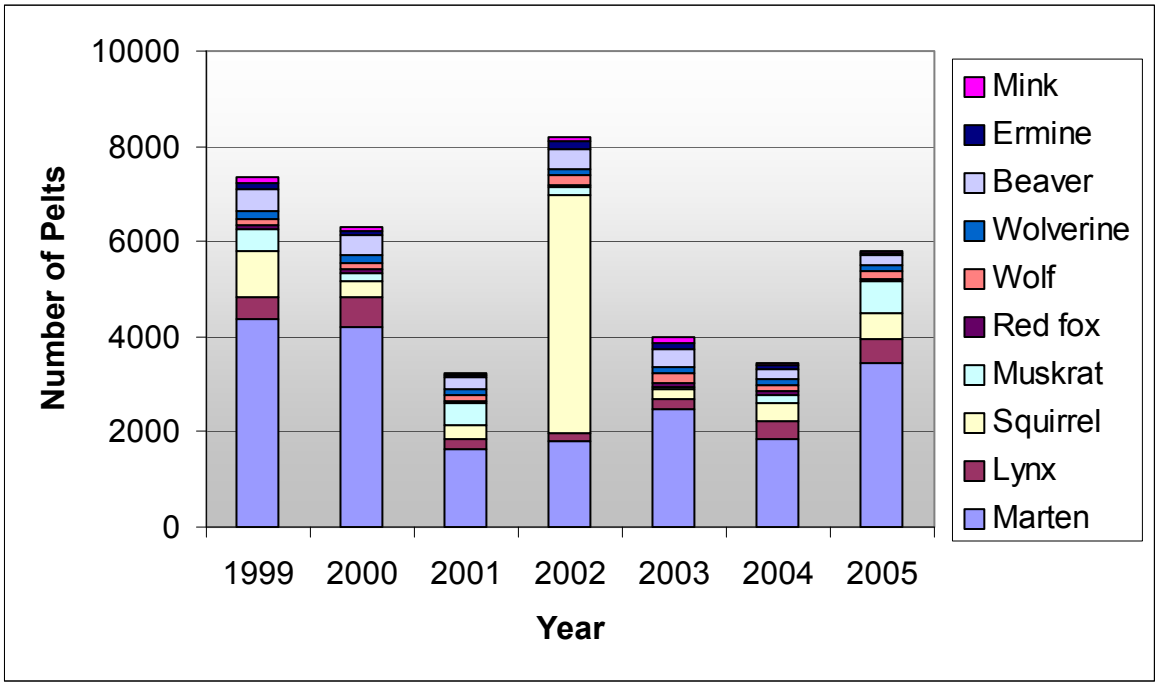
Trapper harvest of furbearers is an important economic activity in much of the Yukon, including in and near the Study Area. The largest portion of trappers' incomes is from the sale of lynx (*Lynx canadensis*) and marten (*Martes americana*) pelts, but wolverine (*Gulo gulo*) red fox (*Vulpes vulpes*), wolf (*Canis lupus*), muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*) are also important. As indicated in Figure 8.2-8, relatively few lynx are taken but their high pelt prices means greater income. Other species of furbearers harvested by trapping may include mink (*Mustela vison*), ermine (*Mustela erminea*), and red squirrel (*Tamiasciurus hudsonicus*).

From 1999 to 2005, Territory-wide trapping records collected by Statistics Canada (2007) indicated that the number of marten trapped annually far exceeds all other species, with the exception of squirrel in some years (Figure 8.2-8). Annual marten harvest's ranged from 1,646 to 4,362. Although not necessarily an indication of abundance (as harvest numbers are influenced by pelt prices, trapper effort, and other factors), trapping records can indicate species presence, and potentially broad population trends (Poole and Mowat 2001).

All of the furbearers identified above occur in the Faro area, and could potentially occur in the Study Area. Among these animals, wolverines are listed as Sensitive in the Yukon (Canadian Endangered Species Conservation Council, 2006) and as Special Concern by COSEWIC (2007). All other species are considered Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006), although no population or abundance surveys for furbearers have taken place in the Faro area in recent years (H. Slama, pers. comm. 2007). Local data on fur harvest was still pending at the time of issuance of draft report.

Furbearer habitat preference varies by species. Marten tend to be associated with late successional coniferous stands, especially those dominated by spruce (*Picea spp*.) and fir (*Abies spp.*), similar to that of the Study Area, which is composed of a mixture of mature spruce and fir forests on upland slopes.

Figure 8.2-8. Number of Wild Harvested Fur Pelts in the Yukon Territory, 1999-2005



Birds

Of the territory's 279 know bird species (60 of which are casual or accidental; Birds of the Yukon Database, Canadian Wildlife Service 2007), 68 species have been recorded in or near the Study Area (see

Table 8.2-3 and Table 8.2-4), based on data records compiled for NTS mapsheets 105K3 and 105K6 (Canadian Wildlife Service 2007). These data include bird records from the 1860s to 1998, and are a compilation of incidental sightings and survey data.

The most common birds in the CWS database include dark-eyed junco, common raven, American robin, Swanson's thrush, lesser yellowlegs and the sandhill crane. None of the birds are currently listed in under the *Yukon Wildlife Act* or scheduled federally under *SARA*. Five species have been listed by COSEWIC as "Not at Risk" including: American coot, common loon, golden eagle, bald eagle and great grey owl. One species, rusty blackbird, has been listed by COSEWIC as Special Concern.

Table 8.2-3. Status of Waterbird Species Potentially Present in the Local Study Area (Canadian Wildlife Service 2007)

Species	Scientific Name	Species Status		
		Yukon	SARA Schedule	COSEWIC
American coot	*Fulica americana*	Not currently listed	Not currently scheduled	Not at risk
American wigeon	*Anas americana*	Not currently listed	Not currently scheduled	Not assessed
Arctic tern	*Sterna paradisaea*	Not currently listed	Not currently scheduled	Not assessed
Barrow's goldeneye	*Bucephala islandica*	Not currently listed	Not currently scheduled	Not assessed
Blue-winged teal	*Anas discors*	Not currently listed	Not currently scheduled	Not assessed
Bonaparte's gull	*Larus philadelphia*	Not currently listed	Not currently scheduled	Not assessed
Bufflehead	*Bucephala albeola*	Not currently listed	Not currently scheduled	Not assessed
Common loon	*Gavia immer*	Not currently listed	Not currently scheduled	Not at risk
Glaucous gull	*Larus glaucescens*	Not currently listed	Not currently scheduled	Not assessed
Green-winged teal	*Anas crecca*	Not currently listed	Not currently scheduled	Not assessed
Herring gull	*Larus argentatus*	Not currently listed	Not currently scheduled	Not assessed
Hooded merganser	*Lophodytes cucullatus*	Not currently listed	Not currently scheduled	Not assessed
Horned grebe	*Podiceps auritus*	Not currently listed	Not currently scheduled	Not assessed
Lesser scaup	*Aythya affinis*	Not currently listed	Not currently scheduled	Not assessed
Lesser yellowlegs	*Tringa flavipes*	Not currently listed	Not currently scheduled	Not assessed
Mallard	*Anas platyrhynchos*	Not currently listed	Not currently scheduled	Not assessed
Mew gull	*Larus canus*	Not currently listed	Not currently scheduled	Not assessed
Northern pintail	*Anas acuta*	Not currently listed	Not currently scheduled	Not assessed
Northern shoveler	*Anas clypeata*	Not currently listed	Not currently scheduled	Not assessed
Pacific loon	*Gavia pacifica*	Not currently listed	Not currently scheduled	Not assessed
Redhead	*Aythya americana*	Not currently listed	Not currently scheduled	Not assessed
Ring-necked duck	*Aythya collaris*	Not currently listed	Not currently scheduled	Not assessed
Ruddy duck	*Oxyura jamaicensis*	Not currently listed	Not currently scheduled	Not assessed
Sandhill crane	*Grus canadensis*	Not currently listed	Not currently scheduled	Not assessed
Semipalmated plover	*Charadrius semipalmatus*	Not currently listed	Not currently scheduled	Not assessed
Sora	*Porzana carolina*	Not currently listed	Not currently scheduled	Not assessed
Spotted sandpiper	*Actitis macularius*	Not currently listed	Not currently scheduled	Not assessed
Tundra swan	*Cygnus columbianus*	Not currently listed	Not currently scheduled	Not assessed

Based on the CWS database, ten species have confirmed breeding status in Faro area, however it is likely that most of the 68 species recorded near the study area are breeding birds. Much of the data available is sourced through road-based surveys, and breeding confirmation is likely difficult. The ten confirmed breeding species include; pacific loon, American widgeon, Northern shoveler, lesser scaup, Barrow's goldeneye, golden eagle, American coot, spotted sandpiper, violet-green swallow and red-winged blackbird. None of the species are listed as At Risk under the *Yukon Wildlife Act*, *SARA*, or COSEWIC.

Table 8.2-4. Status of Landbird Species Potentially Present in the Study Area (Canadian Wildlife Service 2007)

Species	Scientific Name	Species Status		
		Yukon	SARA Schedule	COSEWIC
Alder flycatcher	*Empidonax alnorum*	Not currently listed	Not currently scheduled	Not assessed
American pipit	*Anthus rubescens*	Not currently listed	Not currently scheduled	Not assessed
American robin	*Turdus migratorius*	Not currently listed	Not currently scheduled	Not assessed
American tree sparrow	*Spizella arborea*	Not currently listed	Not currently scheduled	Not assessed
Bald eagle	*Haliaeetus leucocephalus*	Not currently listed	Not currently scheduled	Not at risk
Bank swallow	*Riparia riparia*	Not currently listed	Not currently scheduled	Not assessed
Belted Kingfisher	*Ceryle alcyon*	Not currently listed	Not currently scheduled	Not assessed
Bohemian waxwing	*Bombycilla garrulus*	Not currently listed	Not currently scheduled	Not assessed
Boreal chickadee	*Poecile hudsonica*	Not currently listed	Not currently scheduled	Not assessed
Chipping sparrow	*Spizella passerina*	Not currently listed	Not currently scheduled	Not assessed
Cliff swallow	*Petrochelidon pyrrhonota*	Not currently listed	Not currently scheduled	Not assessed
Common raven	*Corvus corax*	Not currently listed	Not currently scheduled	Not assessed
Common Yellowthroat	*Geothlypis trichas*	Not currently listed	Not currently scheduled	Not assessed
Dark-eyed junco	*Junco hyemalis*	Not currently listed	Not currently scheduled	Not assessed
Golden eagle	*Aquila chrysaetos*	Not currently listed	Not currently scheduled	Not at risk
Gray jay	*Perisoreus canadensis*	Not currently listed	Not currently scheduled	Not assessed
Gray-cheeked thrush	*Catharus minimus*	Not currently listed	Not currently scheduled	Not assessed
Gray-crowned rosy finch	*Leucosticte tephrocotis*	Not currently listed	Not currently scheduled	Not assessed
Great Gray Owl	*Strix nebulosa*	Not currently listed	Not currently scheduled	Not at risk
Great Horned Owl	*Bubo virginianus*	Not currently listed	Not currently scheduled	Not assessed
Hermit thrush	*Catharus guttatus*	Not currently listed	Not currently scheduled	Not assessed
Lapland longspur	*Calcarius lapponicus*	Not currently listed	Not currently scheduled	Not assessed
Lincoln's sparrow	*Melospiza lincolnii*	Not currently listed	Not currently scheduled	Not assessed
Northern flicker	*Colaptes auratus*	Not currently listed	Not currently scheduled	Not assessed
Northern shrike	*Lanius excubitor*	Not currently listed	Not currently scheduled	Not assessed
Northern waterthrush	*Seiurus noveboracensis*	Not currently listed	Not currently scheduled	Not assessed
Red-winged blackbird	*Agelaius phoeniceus*	Not currently listed	Not currently scheduled	Not assessed
Ruby-crowned kinglet	*Regulus calendula*	Not currently listed	Not currently scheduled	Not assessed
Rusty blackbird	*Euphagus carolinus*	Not currently listed	Not currently scheduled	Special concern
Savannah sparrow	*Passerculus sandwichensis*	Not currently listed	Not currently scheduled	Not assessed
Swainson's thrush	*Catharus ustulatus*	Not currently listed	Not currently scheduled	Not assessed
Three-toed Woodpecker	*Picoides dorsalis*	Not currently listed	Not currently scheduled	Not assessed
Townsend's solitaire	*Myadestes townsendi*	Not currently listed	Not currently scheduled	Not assessed
Tree swallow	*Tachycineta bicolor*	Not currently listed	Not currently scheduled	Not assessed
Violet-green swallow	*Tachycineta thalassina*	Not currently listed	Not currently scheduled	Not assessed
White-crowned sparrow	*Zonotrichia leucophrys*	Not currently listed	Not currently scheduled	Not assessed
White-winged crossbill	*Loxia leucoptera*	Not currently listed	Not currently scheduled	Not assessed
Yellow warbler	*Dendroica petechia*	Not currently listed	Not currently scheduled	Not assessed
Yellow-rumped warbler	*Seiurus noveboracensis*	Not currently listed	Not currently scheduled	Not assessed

Waterbirds

Many waterbirds are migratory and, as such are protected under the federal *Migratory Birds Convention Act* (*MBCA*). Areas of the Yukon make up the Pacific Flyway, a migratory route known to provide critically important areas for large numbers of waterfowl that migrate north to nest and raise young. Waterbird species that have been observed in the Faro region either through survey or by incidental sightings are found in Table 8.2-3. The most abundant birds included the sandhill

crane and the lesser yellowlegs, with nine sightings of the sandhill crane and six sightings of the lesser yellowlegs (Canadian Wildlife Service 2007). Several gulls (unknown species) were observed at the mine site near the tailing areas, where pooled water in the containment areas may provide habitat in the Study Area. The observations were recorded during a vegetation classification survey conducted in August 2007.

Waterbirds need suitable habitat for staging and congregation behaviours. These tend to be areas that have abundant food and are ice-free in early spring. Waterbird habitat in the Study Area is restricted to the lowland areas around Rose, Next and Vangorda creeks as most of the Study Area is made up of mid slopes that do not provide suitable habitat for waterbirds. Most creeks in the Study Area are too small for much of the staging and congregation behaviours exhibited by waterbirds.

Waterbirds are of low concern in the development of the project as the Study Area is not likely to contain much suitable habitat. Upland breeding birds a higher concern as they utilize a wide variety of habitats some of which are likely to be contained within the Study Area.

- *Trumpeter Swan*

  Currently the trumpeter swan (*Cygnus buccinator*) is listed as Specially Protected under the Yukon Wildlife Act, and warrants some discussion. Federally, it is not listed under the *Species at Risk Act* and COSEWIC (2007) designates it as Not at Risk. COSEWIC de-listed the bird in 1996 from its previous rank of Vulnerable as its populations recovered. The trumpeter swan is usually found on lakes and marshes with permanent water and or slow moving creeks or rivers with semi-permanent flow, having emergent and submergent vegetation (Sinclair *et al.*, 2003). Prime breeding, brood rearing or moulting habitat can be found within the shallow wetlands of river floodplains. The Rocky Mountain population utilizes central and southeastern portions of the Yukon Territory as breeding habitat (Sinclair *et al.*, 2003), and there have been 76 confirmed breeding bird records of trumpeter swans in the Yukon (Yukon Zinc Corporation 2005), although none of these records were located within the Study Area. The Study Area contains only three relatively small creeks, and is unlikely to contain suitable trumpeter swan habitat.

Landbirds

Many landbirds (including upland game birds, passerines, woodpeckers, and raptors) are migratory, and, as such are protected under the federal *Migratory Birds Convention Act* (MBCA). Landbird species that have been observed in the Faro region either through survey or by incidental sightings (Canadian Wildlife Service 2007) are identified in Table 4.2-4. The Study Area is made up primarily of upland areas containing mature spruce, fir, and pine forests, and likely contains suitable habitat for many landbirds, and the bird species observed in the region (Table 8.2-4) could be considered potentially present in the Study Area. The most abundant birds included the common raven, Swainson's thrush, American robin and dark-eyed junco, with nine sightings of the

common raven, eight sightings of the dark-eyed junco and five sightings each for the American robin and Swainson's thrush (Canadian Wildlife Service 2007).

A Harlan's hawk (*Buteo jamaicensis harlani;* a red-tailed hawk subspecies) was also observed on site (Figure 8.2-9) in August of 2007. Although not recorded previously in the Faro region, the sighting is not unexpected; the dark morph of the hawk occurs regularly in northwest Canada and Alaska (Preston and Beane 1993). The red-tailed hawk is considered Not at Risk by COSEWIC (2007), and is identified as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006). As a subspecies of the red-tailed hawk the Harlan's hawk was not referenced by either COSEWIC or the Yukon Government.

Figure 8.2-9. Harlan's Hawk Observation, Haul Road Between Faro and Vangorda/Grum Deposits, August 2007

A colony of bank swallows was also observed on the mine site (Figure 8.2-10), along a road cut adjacent to the water retention ponds in the Tailings Impoundment. The cut created a small, sandy cliff that appears to provide suitable nesting habitat for swallows, which typically nest in cut banks of rivers and other waterbodies. The Study Area is within the known range of bank swallows (Garrison 1999), and they have been previously documented in the region (Table 8.2-4). Bank swallow's are not listed by COSEWIC (2007), and are identified as Secure in the Yukon (Canadian Endangered Species Conservation Council, 2006).

Figure 8.2-10. Bank Swallow Colony Observation, Faro Tailings Area, August 2007

Small Mammals

Small mammals are considered an important species in the Yukon due to their significance as both furbearing species (primarily squirrels) as well as prey species for carnivores. In a contaminant-related study conducted from 2004 to 2005 Gartner Lee Limited (2006a) documented the presence of several small mammal species. These species included northern red-backed vole (*Clethrionomys rutilus)*, common shrew (*Sorex cinereus*), heather vole (*Phenacomys intermedius*), deer mouse (*Peromyscus maniculatus*), Siberian lemming (*Lemmus sibiricus helvolus*), and least chipmunk (*Tamias minimus*). During this study, four trapping programs were conducted. A total of 121 small mammals were trapped including: 77 small mammals in September 2004; 12 in November 2004 (in the Swim Lake reference area, beyond the Study Area); 29 in July 2005; and 3 in September 2005. Few samples were collected in September 2005, as the trapping program focused on shrews from under-represented sites. Of the total small mammals trapped, the most common species collected were northern red-backed vole (65), followed by common shrews (30), deer mouse (15), heather voles (6), least chipmunk (2), and Siberian lemming (1). All species observed in 2004 and 2005 are considered Secure by the Government of Yukon (Canadian Endangered Species Conservation Council 2006).

Amphibians

While amphibians were not identified as a preliminary VEC, it should be noted that a wood frog (*Rana sylvatica*) was observed on site during a vegetation classification survey conducted in July 2007 (see Figure 8.2-11). Wood frogs are likely the only amphibian present in the Study Area, although western toads (*Bufo boreas*), boreal chorus frog (*Pseudacris maculata*), Columbia spotted frog (*Rana luteiventris*) and long-toed salamander (*Ambystoma macrodactylum*) have also been observed in the Yukon (Department of Environment, Government of Yukon 2005), although primarily at the far southern extent of the Yukon.

Figure 8.2-11. Wood Frog Observation, Vangorda/Grum Area, August 2007

8.2.5 Contaminants in Wildlife

8.2.5.1 Data Collection Methods

The influence of the current state of the Faro Mine on terrestrial resources, including wildlife, was evaluated in a multi-year study, completed in 2006 (Gartner Lee Limited 2006a). That work documented in detail the contaminant release pathways, and elevated concentration and deposition rates of contaminants in and beyond the Study Area in small mammals and hunted wildlife.

During this study, small mammals were collected and tested for heavy metal concentrations, including lead, zinc, copper, arsenic, iron, silver, thallium, barium, chromium, mercury, nickel, selenium, antimony, cadmium, and cobalt (Gartner Lee Limited 2006).

Among hunted and trapped wildlife, 10 species were collected for tissue analyses in 2004 and 2005 (Gartner Lee Limited 2006). Those species included woodland caribou, moose, sheep, American marten, hoary marmot (*Marmota caligata*), Arctic ground squirrel, muskrat, beaver, willow ptarmigan (*Lagopus lagopus*), and ruffed grouse (*Bonasa umbellus*). Ungulate tissue samples were obtained from animals hunted in fall 2004 and 2005; American marten and willow ptarmigan were obtained from local trappers, and the Faro Yukon Environment office provided the marmot, ground squirrels and two beavers (Gartner Lee Limited 2006a).

8.2.5.2 Baseline Conditions

The level of contaminants in wildlife (lead and zinc primarily, but also other metals) is an important wildlife issue associated with the current state of the mining facilities in Faro (Middler 2007). The airborne transportation of tailings related contaminants is likely the greatest source of elevated concentrations of mine-related contaminants in the Study Area.

Among small mammals sampled, the study concluded that lead was elevated in the muscle, liver and kidney of northern red-backed voles and in whole bodies of common shrews in areas affected by the mine. The magnitude of the elevated concentrations of lead in comparison to the reference area ranged from 11 times greater in vole muscle tissue to over 157 times greater in whole bodies of shrews. Moderately elevated levels of copper, iron, thallium and nickel were also observed in small mammals. Metal elevations considered low or similar to reference levels were observed for all other metals tested for.

Similar to the results for small mammals, high elevations of lead were detected in the liver and kidney of caribou, ranging from 1.1 to 1.6 times greater than samples from the Finlayson herd. The Finlayson herd, located east of the Study Area, are not likely exposed to the effects of the mining facility. Lead was also elevated in American marten, willow ptarmigan, and beaver. Lead elevations ranged from 4.6 times for beaver kidney to 18.7 for willow ptarmigan livers. Moderate elevations were also detected for mercury and selenium in American marten, willow ptarmigan, and moose. Low elevations, or samples that were difficult to statistically compare to reference samples, were

found for all other metals with the exception of antimony, in which no elevations were found in comparison to reference samples. However, elevations of iron in sheep kidney in comparison to the Yukon Hunter Survey data were 1.1 times greater, and silver concentrations were 5.1 times greater in woodland caribou muscle than in the nearby Finlayson herd.

8.2.6 Summary

Based on a review of existing literature and known data sources, this report summaries baseline condition of wildlife in the area of the Faro Mine. Grizzly bears and wolverine are the only listed species that may occur within the Study Area on a regular basis. However, it is difficult to assess the predictable numbers of those species that may occur in the Study Area, as site-specific studies for those and most other species do not exist in the Study Area. From known distributions and breeding habitat, it is unlikely that any bird species of concern will occur within the Study Area. Small mammals have been found throughout the study area in abundance and are not likely a concern in the development of the project.

Fannin sheep are a species of concern to stakeholders of the Project, as both an economic resource within the region, and because they are the most-visible species that interact directly with the project. A reasonable understanding of seasonal ranges and movement patterns is available, as sheep are known to migrate directly through the Study Area.

Ungulate winter range for caribou and sheep is a management concern due to heavy snowfall in the region. The Tay River herd and fannin sheep range have the greatest potential to interact with the Study Area in winter, as those Key Wildlife Area ranges are in the closest proximity to the Study Area. Information is available on winter range distribution and population for both Fannin sheep and the Tay River herd, and may be used to develop project mitigation plans.

Increased harvest pressure on moose, grizzly bear and caribou is a concern of both local stakeholders and the Yukon Government. The moose harvest rate in particular in the GMSs near the Study Area tends to be near the limit of sustainable levels. The Tay River population appears stable, however because the herd is small and widely dispersed an increase in hunting pressure may have more immediate impacts. Grizzly bear populations face pressure as there is a high problem kill rate in several of the Study Area GMSs. Careful project mitigation planning should be employed to address an increase in hunting pressure and to reduce human-bear conflicts.

The presence of contaminants in wildlife from the Faro Mine is summarized, as were known from a previous study (Gartner Lee Limited 2006). High elevations of levels of lead are present in red-backed voles and shrews, and moderately elevated levels of copper, iron, thallium and nickel were also observed in most small mammals. Among hunted and trapped wildlife, elevations of lead were found in caribou, American marten, willow ptarmigan, and beaver. Moderate elevations were also detected for mercury and selenium in American marten, willow ptarmigan, and moose.

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10. Standardized Terms and References

10.1 Standardized Terms

Faro Mine Complex	Includes the Faro Mine Area and the Vangorda/Grum Area
Tailing Impoundment	Tailing areas on site of the Faro Mine Complex
Wildlife	
Biodiversity	The variety of life, from genes and species to communities, ecosystems, functions, and processes
Critical levels	The concentration of pollutants in the atmosphere above which direct adverse effects on receptors such as plants and ecosystems may occur according to present knowledge. Critical levels relate to direct effects on plant physiology, growth and vitality and are expressed as atmospheric concentrations or cumulative exposures over a given period of time (WHO, 2000).
Critical load	A quantitative estimate of an exposure in the form of deposition for one or more pollutants, below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. Critical loads relate to ecosystem structure and functioning and are expressed as annual depositions of mass or acidity. Typically, critical loads relate to the potential effects over periods of decades.
Ecosystem	An integrated and stable complex of living organisms and the non-living components of their environment, functioning together to circulate nutrients and create energy flow.
Environmental receptors	Living and non-living components of the environment that can absorb pollutants.
Ericaceous shrub	Low woody shrubs that are part of or related to the heather family (*Ericaceae*)
Exotic	A species that has been moved beyond their natural range as a result of human activity.
Forb	A non-woody, leafy plant not related to the grass-like plants.
Herbaceous	Non-woody
Indicator	A measurable parameter through which change can be measured.
Phenology	The seasonal timing of growth, flowering, maturation and death related to changes in light, temperature, etc.
Riparian	The area adjacent to and influenced by a water body such as a river
Senescence	The process of aging, such as occurs in shrubs before they shed leaves
Stomata	Microscopic pores in the outer layer of leaves and stems used for gas exchange.
Substrate	An abiotic material or physical surface
Threshold	A level beyond which unacceptable change may occur.

Term	Descriptor
TSP	Total suspended particulate matter (dust) - refers to all particles in the atmosphere. Particles can range in size from 0.005 - 500 micrometers or microns
Understorey	Vegetation layers beneath the canopy layer.
Valued Ecosystem Component (VEC)	Characteristic or feature that represents important environmental components of an ecosystem.
Vegetation Association	Homogeneous groupings of vegetation identifiable on aerial photos and of sufficient size to map at a 1:20,000 scale, often linked with particular substrates, moisture regimes, nutrient regimes and terrain.
Hydrogeology	
Active layer	Material that freezes in the winter and thaws in the summer, located above permafrost.
Discontinuous permafrost	A region has continuous permafrost if all land is covered by permafrost at some depth
Hydraulic conductivity	A measure of the ease with which water can move through the pore spaces in a material. Hydraulic conductivity is a function of fluid properties and of the size and shape of pore spaces in a rock or soil.
Hydraulic gradient	The change in groundwater pressures over a certain distance (e.g., the slope of the water table).
Hydraulic head	A measure of the energy of groundwater per unit weight. Hydraulic head represents the pressure exerted by a fluid and is the sum of gauge pressure and elevation.
Overburden	The amount of material lying above bedrock.
Permeability	A measure of the ability of a material to transmit fluid.
pH	A measure of acidity based on the presence of hydrogen ions. Acidic waters have a pH less than 7 and alkaline waters have pH greater than 7.
Packer Testing	Method used to characterize properties of a formation at discrete intervals within a groundwater well or borehole.
Piezometer	An instrument used to measure the hydraulic head of groundwater at a specific depth
Recharge area	A region receiving water, defined by downwards moving flow.
Tailings	Waste material left over from processing rock, often from material extraction.
Thermistor	An instrument (thermal resistor) used to measure changes in temperature; a semiconductor whose resistance changes predictably with temperature.
Till	Sediment containing a range of grain sizes, deposited by a glacier.
Total Dissolved Solids	A measure of the combined content of inorganic ionized constituents in a liquid.

10.2 Abbreviations

Abbreviation	Term
amsl	Above Mean Sea Level
bgs	Below Ground Surface
CCME	Canadian Council of Ministers of the Environment
CESCC	Canadian Endangered Species Conservation Council
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DOC	Dissolved Organic Carbon
btoc	Below Top Of Casing (referring to well casing for groundwater wells – usually ground level plus well stickup)
ha	Hectare
K	Hydraulic Conductivity (see glossary)
km	Kilometre
µg	Microgram
µg/L	Micrograms per Litre
µS/cm	Micro Siemens per Centimeter
LSA	Local Study Area
m	Metre
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre
RSA	Regional Study Area
SARA	Species at Risk Act
TDS	Total Dissolved Solids
TSP	Total Suspended Particulate (dust)
TSS	Total Suspended Soils
VEC	Valued Ecosystem Component
WHO	World Health Organization
Zn	Zinc

Appendix A

Hydrology

Appendix B

Hydrogeology

B1. Figures

B2. 2000-2007 Groundwater Quality Data
- Table 1. Groundwater 2000-2007 Non Metal Parameters
- Table 2. Groundwater 2000-2007 Dissolved Metal Parameters

B3. 2001-2007 Water Level Data

Appendix C

Surface Water Quality

C1. Benchmark Sources

C2. 2005-2007 Surface Water Quality Data Faro Creek Drainage
- Table 1. Reference Sites Physical and Routine Parameters
- Table 2. Reference Sites Total Metals
- Table 3. Reference Sites Dissolved Metals
- Table 4. Mine Runoff and Effluent Physical Routine Parameters
- Table 5. Mine Runoff and Effluent Total Metals
- Table 6. Mine Runoff and Effluent Dissolved Metals
- Table 7. Receiving Environment Surface Water Physical and Routine Parameters
- Table 8. Receiving Environment Total Metals
- Table 9. Receiving Environment Dissolved Metals

C3. 2005-2007 Surface Water Quality Data Vangorda Creek Drainage
- Table 1. Reference Site Physical and Routine Parameters
- Table 2. Reference Sites Total Metals
- Table 3. Reference Sites Dissolved Metals
- Table 4. Mine Runoff and Effluent Physical and Routine Parameters
- Table 5. Mine Runoff and Effluent Total Metals
- Table 6. Mine Runoff and Effluent Dissolved Metals
- Table 7. Receiving Environment Surface Water Physical and Routine Parameters
- Table 8. Receiving Environment Total Metals
- Table 9. Receiving Environment Dissolved Metals

C4. Pelly River Data

Appendix D

Aquatic Resources

D1. Raw Benthic Data Rose Creek
D2. Raw Benthic Data Vangorda Creek
D3. Rose Creek Sediment Data
D4. Vangorda Sediment Data

Appendix E

Vegetation

E1. Vegetation Association Surveyed in 2007
E2. Vegetation Association Descriptions for the Local Study Area and Vegetation Photos
E3. Vascular Plant Species in the Yukon Territory Ranked by the General Status of Species in Canada
E4. Rare and Threatened Vascular Plant Species Tracked by the Yukon Government