APPENDIX 3

2008 ABANDONMENT AND RESTORATION PLAN

LUPIN MINE
NUNAVUT, CANADA

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EXECUTIVE SUMMARY

This document has been prepared to satisfy the request of the Nunavut Water Board in its letter of assignment to Wolfden resource, now Zinifex Canada Inc., for the submission of a revised Abandonment and Restoration Plan. This document is derived from the 2004 Lupin Abandonment and Restoration Plan, submitted to the Nunavut Water Board in February 2005. At present, Zinifex Canada Inc. closure plan will remain consistent with the previously submitted 2004 Lupin Abandonment and Restoration Plan. In April 2005 Kinross requested the Water Board and Indian and Northern Affairs (INAC) to consider the mine site and Tailings Containment Area (TCA) as separate entities for the remediation permitting process in order to expedite a decision on the remediation activities on the TCA portion. Zinifex Canada Inc. does not recognize an advantage to treat the mine site and TCA as separate entities as an expedited decision on the reclamation activities is not needed. As such the information on the TCA and the mine site reclamation activities is presented in this document. Currently the Lupin Mine site is under care and maintenance, while Zinifex Canada Inc. continues to investigate the feasibility of re-opening the mine and milling operation.

Lupin is located on the west shore of Contwoyto Lake, approximately 285 km southeast of Kugluktuk, Nunavut, the closest northern community. Due to its isolation, the mine site is totally self-contained, with all operating personnel living on site in bunkhouse accommodations. The only year-round access to the site is via aircraft. During February and March each year, the mine is supplied via a 570 km ice road, which runs from Tibbitt Lake, north of Yellowknife, to Contwoyto Lake.

Lupin is an underground mine and has been in operation since 1982, with temporary suspensions of activities between January 1998 and April 2000, and again between August 2003 and March 2004. The operation has produced over 3.3 million ounces of gold from 12.8 million tons of mined ore.

Throughout its operation, Lupin has been an innovator in such areas as:

- remote site construction and operation
- northern transportation infrastructure development
- creating employment relationships with northern communities
- mining in permafrost conditions
- the implementation of hydraulic drilling technology
- mechanized narrow-vein mining
- the utilization of paste backfill

EXECUTIVE SUMMARY

Due to its location, approximately midway between Yellowknife and the Arctic coast, and its well developed infrastructure, including a 1,900-metre gravel airstrip, Lupin has also evolved to be an important transportation and logistical hub for the exploration and research community in the north.

The Lupin Mine is presently operating under Water License NWB1LUP0008, granted by the Nunavut Water Board in July 1, 2000 and extending to June 30, 2008. An Interim Abandonment and Restoration plan for the property was approved by the Nunavut Water Board following a public hearing in 2001. Annual reports submitted to the Water Board have described progressive reclamation activities carried out at the mine each year.

Mining and milling operations have now been suspended at the Lupin Mine, as existing developed ore has been depleted. The property is on care and maintenance for an indefinite period while other mining and economic options are being assessed. This report provides technical descriptions of the reclamation activities that have been and that will be carried out within the Tailings Containment Area. This report includes details on a number of studies that have been undertaken to support the saturated granular cover method for exposed tailings remediation.

The approach to the reclamation and closure of the Lupin site is to conduct the work in an efficient manner, and to follow the *Mine Site Reclamation Policy for Nunavut (2002),* as well as the *Guidelines for Abandonment and Restoration Planning for Mines in the Northwest Territories (1990),* as specified in the Water Licence*.*

The reclamation work will utilize the natural conditions as much as possible to ensure the secure, long-term closure of the entire mine site. Mine tailings will be covered by a one (1) metre layer of non-reactive esker material. The partially saturated condition of the cover will provide an effective barrier to oxidation of the underlying tails during the short period of thaw. This practice has been successfully implemented to remediate the mine tailings since the first cell (1A) was covered in 1988.

Following the final closure of the mine, some of the key reclamation measures that are proposed to take place on the TCA are:

1. Cover all exposed tailings with a layer (1.0 meter) of esker material to isolate the tailings from the environment.
2. Construct an engineered outflow spillway on Dam 1A, designed to provide environmental protection against an extreme flood (100-year event).

3. Contour cover material to direct snowmelt towards the internal lakes (Cell 4, Pond 1, Pond 2) so that all water will exit the TCA through the Dam 1A spillway.
4. Scarify all cover material and roads to enhance natural revegetation.
5. Removal of all buildings (arsenic treatment plant, tailings dump stations, powder magazines) and tailings pipe from the TCA and transport back to Lupin minesite for shipment off site or disposal in debris landfill.
6. Continue periodic environmental monitoring of the site to confirm long term stability and success of the reclamation measures.

Monitoring of the TCA is scheduled for a period of 7 years (a 2-year period of intensive reclamation work, followed by a 5-year post reclamation period). This work will include water quality, soil quality and ground temperatures monitoring, any required maintenance, general reclamation inspections and geotechnical inspections. The results of the monitoring programs will be reported to the Nunavut Water Board quarterly and annually.

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1. INTRODUCTION

1.1 Zinifex Canada Inc. Environmental Policy

Our aim is to achieve a high standard of care for the natural environment in all of the activities in which we engage.

We undertake to minimize our impact on the environment

We will:

- conduct our operations in compliance with all relevant environmental regulations, licenses and legislation as a minimum condition
- identify, monitor and manage environmental risks arising from our operations
- seek continuous improvement in environmental performance, production processes, waste management and the use of resources
- provide appropriate training and awareness for all employees on environmental issues
- communicate regularly with employees about our aim and about individual responsibilities
- inform our customers and suppliers of our aim and of their responsibilities in relation to our business
- communicate with shareholders, the community and governments about our environmental performance, and contribute to the development of laws and regulations which may affect our business.

1.2 Lupin Operation Background

The Lupin Mine is located on the west shore of Contwoyto Lake, approximately 285 km southeast of Kugluktuk, Nunavut and approximately 400 km northeast of Yellowknife, N.W.T. The coordinates are $65^0$46' Latitude and $111^0$15' Longitude, and the mine lies approximately 80 km south of the Arctic Circle. The location is shown in Figure 1, in Appendix 1.

The Lupin gold deposit was discovered in 1960 as a result of reconnaissance sampling and mapping programs conducted by the Canadian Nickel Company Ltd., a subsidiary of Inco Limited. Between 1961 and 1964 the Canadian Nickel Company Ltd. conducted exploration in the Lupin area, which included geological mapping,

geophysical surveying, trenching, stripping and channel sampling.

In February 1979, Echo Bay obtained an option on the Lupin property from Inco and proceeded with an underground exploration program. The geological information indicated enough ore reserves to provide six years of production, based on the potential to develop in excess of two million tons of ore with a mill designed to process an average of 950 tons per day.

In August 1980, the decision was made to proceed with development and construction of the Lupin Mine. Construction was completed on schedule in March 1982 and preproduction commissioning began.

From 1983 through to 1993, the mine and mill operations were expanded to increase capacity to a nominal 2,300 tons per day. In December, 1994, the paste backfill plant was completed, which provided critical ground support in production areas while reducing the amount of tailings reporting to the Tailings Containment Area. Operations were temporarily suspended at Lupin between January 1998 and April 2000, and again from August 2003 to March 2004. Mill throughput in the last year of operation, March 2004 to February 2005, averaged approximately 1200 tons per day, significantly less than in previous years, In 2006 Wolfden Resources, now Zinifex Canada Inc., acquired the Lupin Mine site. The site is currently under care and maintenance while future mining and milling options are being explored.

1.3 Licences

The Lupin Operation is presently permitted by Water Licence NWB1LUP0008 for water use and waste disposal in a mining and milling undertaking. The Licence was received from the Nunavut Water Board on July 1, 2000, and expires on June 30, 2008.

A list of the land leases pertaining to the Lupin Mine is presented in Table 1, below.

Table 1 - Mineral and Surface Leases, Lupin NU

Name	Type	Desc.	Expiry	Area (ha)
2428	Mineral Lease	Lot 1 Group 1216	12-Jul-2013	2,831.59
3275	Mineral Lease	L. 1003 Quad 76E\11	27-Sep-2009	927.13
3276	Mineral Lease	L. 1002 Quad 76E\11	27-Sep-2009	891.92
3277	Mineral Lease	L. 1004 Quad 76E\11	27-Sep-2009	959.10
3278	Mineral Lease	L. 1001 Quad 76E\11	27-Sep-2009	1,148.09
76E/14-1-9	Surface Lease	Minesite, TCA	31-Mar-2012	1,035.79
76E/14-2-10	Surface Lease	Airstrip	31-Mar-2012	53.16
76E/11-2-4	Surface Lease	Quarry, access road	31-Mar-2012	137.80
76E/11-3-4	Surface Lease	Waterlot - dock	31-Mar-2012	0.43
76E/14-10-3	Surface Lease	Navigation aid	31-Mar-2012	0.09

1.4 Geology

The Lupin gold deposit is situated in an Archean metaturbidite sequence of the Contwoyto Formation, part of the Yellowknife Supergroup of supracrustal metasedimentary and metavolcanic rocks of the Slave Geologic Province. The rocks have been subjected to both regional and contact metamorphism and to several phases of deformation and intrusion.
The Lupin ore unit is composed of the Centre Zone, East Zone, West Zone and L19 Zone, all of which are contained within a continuous, isoclinally folded, steeply dipping unit of amphibolitic iron formation within the Contwoyto Formation. This unit has been followed for a strike length of 3000m and a dip length of 1500m. Several phases of deformation have resulted in steeply plunging fold noses and steeply dipping fold limbs. The resulting pattern is 'M' shaped, consisting of a northerly-plunging syncline and adjacent anticlines to the west and east. The West Zone forms the west limb of the west anticline, the Centre Zone the west limb of the syncline and the East Zone the east limb of the syncline. Most of the gold occurred in the West Zone and Centre Zone. A lesser amount was found in the East Zone. The L-19 Zone did not contain economic concentrations of gold and was not mined.

The iron formation is a well laminated unit and consists of both silicate facies and sulphide facies metamorphosed to an amphibolite + quartz rich rock. The gold is found primarily within the sulphide rich iron formation. The ore at Lupin consists of amphibole, quartz, garnet, pyrrhotite, arsenopyrite, minor pyrite and traces of chalcopyrite. The gold is fine grained (generally less than 100 microns in diameter) and is associated mainly with the pyrrhotite and arsenopyrite. Although not common, visible gold is sometimes found and is usually in close proximity to quartz veining.

Also found in trace amounts are scheelite, apatite, epidote, calcite, tourmaline, and some arsenides (notably loellingite). Arsenopyrite occurs as metacrysts, up to 2 cm in diameter, which often have loellingite cores. Much of the gold associated with these arsenides occurs at the arsenopyrite - loellingite boundaries within these metacrysts. Gold is also finely disseminated within pyrrhotite and silicates, and is rarely visible to the naked eye.

The McPherson Zones (M1 and M2) are in iron formation lenses separate from the main Lupin ore unit, contain economic quantities of gold, and were mined. They trend parallel to the West Zone at approximately 60m and 80m east of it near the latitude of the shaft. The M1 and M2 Zones contain a higher proportion of pelitic beds than the main Lupin ore unit. Gold is locally present in the pelitic beds, and visible gold is more common in the M1 and M2 Zones than in mineralized zones of the main ore body.

Tailings are primarily composed of the gangue minerals amphibole and quartz, which account for over 80% of the volume. Pyrrhotite and arsenopyrite make up an additional 17% (Klohn 1995). The tailings have been shown through various studies to be capable of generating acid upon oxidation. The waste rock is composed mostly of quartzite, phyllite, and minor amounts of carbonate, and has very low sulphide content. Column leach studies have shown the waste rock to have little potential for development of acid rock drainage (ARD) (Klohn 1992a).

1.5 Local Environment

1.5.1 Climate

Table 2, below, shows the monthly precipitation from snow and rain, as measured at the Lupin weather station, between 1982 and 2004.

Table 2 – Monthly Precipitation at Lupin, NU

Total Monthly Precipitation (mm water equivalent; 1 cm snow = 1 mm water)													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
1982	no readings taken			13.2	12.8	43.9	35.0	62.6	36.6	21.6	14.1	15.0	
1983	24.3	5.5	16.8	16.5	18.0	10.4	77.8	75.4	77.0	41.8	10.4	6.0	379.9
1984	6.8	19.4	16.2	19.3	17.8	60.0	69.6	53.7	19.8	25.5	13.2	9.2	330.5
1985	9.2	11.6	10.4	25.8	10.2	19.4	89.0	46.6	44.5	24.0	9.4	6.6	306.7
1986	20.0	9.2	4.6	19.7	29.2	17.5	18.0	100.8	30.0	28.0	13.6	12.8	303.4
1987	11.6	6.6	5.6	6.6	8.7	67.8	41.8	47.0	35.0	34.1	45.0	25.4	335.2
1988	1.6	3.6	4.4	6.0	10.8	50.3	32.0	18.7	43.4	32.2	22.2	8.2	233.4
1989	20.0	4.0	10.2	3.3	36.1	6.3	35.0	27.5	33.7	12.0	14.4	16.6	219.1
1990	11.8	6.0	12.0	8.3	2.4	23.5	23.3	54.0	48.5	20.1	9.2	14.7	233.8
1991	7.9	13.2	12.4	26.1	14.0	12.4	49.8	76.2	46.5	26.4	18.0	19.4	322.3
1992	11.8	8.6	9.8	20.4	21.5	22.2	14.8	47.0	31.2	43.8	15.4	4.2	250.7
1993	3.3	14.2	13.2	6.2	28.4	27.8	87.0	28.8	29.9	19.4	14.8	12.0	285.0
1994	3.4	2.2	22.0	8.2	15.4	39.2	13.8	47.2	43.4	29.2	11.0	14.8	249.8
1995	5.2	3.4	38.8	6.6	8.4	20.8	40.2	79.0	49.4	36.0	7.4	23.8	319.0
1996	5.8	18.4	4.4	8.0	24.8	54.0	57.5	130.8	68.8	13.0	13.6	6.6	405.7
1997	6.0	6.6	6.8	12.8	27.2	21.2	18.2	58.7	25.6	46.2	12.6	18.6	260.5
1998	5.2	8.2	5.6	17.8	19.2	38.4	57.4	55.2	62.6	52.2	17.0	21.6	360.4
1999	9.8	6.6	14.4	25.0	25.6	19.6	62.4	57.2	84.2	23.8	13.4	30.8	372.8
2000	3.8	5.4	8.0	12.4	18.6	4.6	27.2	49.2	58.6	44.2	14.0	7.8	253.8
2001	6.4	7.6	26.4	30.2	48.2	6.4	45.0	46.4	9.4	20.0	27.6	12.0	285.6
2002	7.6	2.2	6.2	15.8	4.4	43.6	67.0	93.8	52.2	15.2	20.2	11.4	339.6
2003	3.8	0.4	19.8	3.4	23.4	18.6	43.8	68.6	36.0	28.4	31.3	15.6	293.1
2004	10.8	12.4	9.2	19.6	6.0	21.2	12.2	111.0	61.2	30.0	30.2	3.4	327.2
Avg	8.9	8.0	12.6	14.4	18.7	28.2	44.3	62.4	44.7	29.0	17.3	13.8	303.1

Climate in this region is classed as semi-arid subarctic, with an average annual precipitation of just over 300 mm and a mean daily temperature of -11.0^{O}C. Average temperature for the months of May through September is 4.6 ^{O}C (Canadian Climate Normals 1961-2000)**.** Precipitation is heaviest in the months June through September. Snowfall can occur during any month, although heaviest snowfalls generally occur in October. The average annual snowfall is 138.1 cm. The prevailing winds in the Lupin area are from the northwest.

Snowmelt is generally complete by the end of June. Break-up on Contwoyto Lake begins
in mid-July, although in some years the lake is not ice-free until early August. Small

lakes in the region are ice free by early July. Ice starts to reform on small lakes of the surrounded area in late August or early September. Complete freeze-over of Contwoyto Lake occurs in October. Table 3 shows the monthly temperature at Lupin, as measured at the Lupin weather station.

Table 3 – Monthly Temperature at Lupin, NU

Mean Monthly Temperatures (deg. C) at Lupin, NU													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Avg**
1982	-36.0	-28.5	-27.5	-19.8	-5.6	4.9	11.5	7.3	0.9	-7.2	-26.0	-29.8	-13.0
1983	-28.8	-33.4	-28.8	-17.1	-14.0	5.3	10.3	9.3	2.4	-9.4	-13.9	-27.1	-12.1
1984	-32.2	-25.8	-25.2	-12.0	-3.9	8.1	12.7	9.7	-0.1	-9.2	-21.8	-32.4	-11.0
1985	-27.7	-34.7	-26.5	-19.6	-1.6	6.6	7.7	6.3	0.8	-10.0	-23.3	-25.1	-12.3
1986	-31.8	-26.9	-27.6	-19.0	-5.7	3.0	10.4	7.0	1.5	-9.6	-24.1	-24.9	-12.3
1987	-24.7	-25.5	-26.1	-15.4	-7.4	5.4	10.1	5.4	4.1	-8.1	-21.1	-19.5	-10.2
1988	-31.6	-31.7	-22.7	-15.4	-10.1	7.1	11.5	10.4	3.7	-8.3	-25.5	-27.5	-11.7
1989	-33.4	-22.5	-29.7	-15.3	-8.2	7.8	12.3	12.7	1.8	-8.0	-26.0	-29.1	-11.5
1990	-32.9	-34.6	-21.3	-14.6	-7.3	4.3	11.0	6.1	1.2	-9.3	-25.0	-31.2	-12.8
1991	-31.5	-30.6	-28.1	-13.9	-1.8	7.4	11.4	10.1	0.0	-10.6	-22.7	-27.8	-11.5
1992	-29.4	-29.0	-22.9	-17.5	-5.8	4.3	11.0	8.2	-1.2	-8.4	-18.5	-25.9	-11.3
1993	-25.6	-28.3	-21.4	-17.0	-5.7	4.7	10.4	9.2	0.3	-8.9	-21.9	-29.0	-11.1
1994	-34.5	-33.6	-21.7	-17.5	-2.5	8.1	13.9	10.5	2.2	-5.0	-18.5	-28.6	-10.6
1995	-24.9	-28.3	-25.6	-15.3	-7.2	8.5	8.9	8.7	0.8	-9.3	-20.6	-29.9	-11.2
1996	-31.7	-26.3	-25.8	-16.3	-7.1	9.8	14.2	7.5	5.2	-9.6	-20.4	-26.9	-10.6
1997	-30.3	-27.5	-27.6	-16.2	-6.5	6.0	13.4	9.9	4.8	-10.6	-15.1	-23.0	-10.2
1998	-33.5	-25.6	-22.0	-10.2	-0.4	8.3	13.8	11.4	3.5	-4.0	-12.9	-22.2	-7.8
1999	-28.6	-23.2	-19.6	-13.5	-5.0	6.8	8.4	8.7	2.3	-8.9	-16.9	-24.9	-9.5
2000	-26.2	-24.9	-22.4	-15.5	-3.9	7.4	15.0	9.0	1.1	-8.5	-18.8	-29.6	-9.8
2001	-25.5	-27.0	-23.8	-15.9	-4.6	3.9	12.3	8.5	5.9	-9.6	-20.5	-23.2	-10.0
2002	-28.3	-31.3	-25.5	-19.9	-8.3	7.3	12.1	8.1	2.5	-9.0	-17.4	-20.2	-10.8
2003	-27.3	-32.1	-26.1	-13.5	-5.2	5.6	13.5	10.3	3.7	-4.3	-18.9	-25.0	-9.9
2004	-32.3	-28.5	-28.4	-18.9	-11.1	5.2	11.6	6.2	0.8	-10.4	-21.7	-29.7	-13.1
Avg.	-29.9	-28.7	-25.1	-16.1	-6.0	6.3	11.6	8.7	2.1	-8.5	-20.5	-26.6	-11.1

The winter climate at this latitude is severe in intensity and duration and is followed by a short, warm summer. In winter, between 1 and 3 m of ice develop on the surface of the lakes and it is the rate of melting of this ice that greatly influences summer conditions. The interaction between climate and morphology of the individual lakes gives rise to great differences in the thermal regime of the lakes.

1.5.2 TOpography

The site is in the tundra zone of the Canadian Shield, an area of continuous permafrost. Terrain in the vicinity of the site is generally low and undulating, ranging between 470 and 505 m elevation. Numerous shallow lakes and streams occur in depressions throughout the area.

1.5.3 Vegetation

The Lupin mine is located in the barren land tundra of Nunavut. It is typified as having a generous amount of low lying vegetation extremely tolerant and well adapted to the climatic conditions. Some of the more prevalent types of habitat that can be found throughout the area include upland and lowland tundra, wet meadows and gentle slopes.

Plentiful and diverse amounts of vegetation can be found everywhere consisting of grasses and sedges; ground cover such as mosses, labrador tea, cranberry, bilberry, bearberry, arctic white heather. In wet areas, predominant species include cotton grass, bog rush, and other aquatic grasses. Dwarf birch and willows populate trenches, and colourful flowering plant species include fireweed, lapland rosebay, azalea and saxifrage to list a few.

1.5.4 Hydrology

Contwoyto Lake is the major water body in the region, with a surface area of approximately 95,900 ha and a drainage area of 8,000 km^2. Contwoyto Lake has two outlets in the Burnside River, which flows from the northwest end of the lake towards Bathurst Inlet, and Back River at the southeast end of the lake, which flows into Pellatt Lake. The main body of Contwoyto Lake lies to the east and south of the mine site. To the north of the mine, a portion of the lake extends to the west and south, terminating in a narrow bay (Sun Bay) which lies directly west of the mine site.

Aquatic habitat in the receiving environment immediately downstream of the tailings area is comprised of three shallow lakes (colloquially referred to as Dam 2 Lake, Dam 1a Lake, and Unnamed Lake), two streams (Seep Creek and Concession Creek), two shallow ponds, and two embayment areas of Contwoyto Lake (Inner and Outer Sun Bay). With the exception of Dam 2 Lake, all of the small lakes and ponds freeze to the bottom in winter. Much of Inner Sun Bay also freezes to the bottom. Due to low winter flows, both Seep Creek and Concession Creek freeze to the bottom in winter. As a consequence, over wintering habitat for fish is limited primarily to Outer Sun Bay and the main body of Contwoyto Lake (RCPL/RL&L 1985).

Concession Creek drains Concession Lake via Unnamed Lake to Inner Sun Bay. Seep Creek enters the Sun Bay drainage system along the east side of Unnamed Lake. Lower Concession Creek (i.e., that section between Unnamed Lake and Inner

Sun Bay) varies in width between 25 and 75 m, depending on seasonal discharges. Side channels are active during spring freshet. Stream depth generally is less than 1 m, except during spring freshet when depths approach 1.5 m. The substrate is primarily large boulder with large and small cobble occupying the interstices.

Seep Creek is approximately 6.5 km in length, flowing from its source in Dam 2 Lake and Dam 1a Lake (via separate branches which join about 2 km downstream) to Unnamed Lake. The stream channel in upper Seep Creek generally is poorly defined, often flowing through marshy areas, or between large boulders or through bedrock fractures. This section of the creek generally is less than 0.5 m in depth and less than 2 m wide. The dominant substrate type is boulders, although localized areas of cobble and gravel are present. Lower Seep Creek (i.e., the 400 m section upstream of Unnamed Lake) is characterized by a well developed channel varying in width from 1 to 4 m, although during freshet, maximum wetted width was about 20 m. The dominant substrate type is boulder, with localized areas of cobble and gravel (RCPL/RL&L 1985).

Inner Sun Bay (approximate area of 150 ha) is primarily shallow (mean depth of 1.7 m), with a maximum depth of about 6.5 m. Over 91% of the surface area is shallower than 3 m, and much of the bay freezes to the bottom in winter. Outer Sun Bay is deeper (greater than 10 m).

2. OPERATIONAL HISTORY

2.1 Construction

In the summer of 1980, prior to a production commitment, a 5,000-foot (1525 metre) gravel landing strip capable of handling a C130 Hercules was prepared. Plant design was based on being able to air freight all the components to site. Mine site construction started in August 1980 and was completed on schedule in March 1982 when pre-production commissioning began. The transportation of personnel to the site was accomplished with a Convair 640, which also carried a total of 7 million pounds of supplies such as perishables and repair parts during construction.

During the twenty-month construction period, the Hercules aircraft made some 1,100 flights, carrying 25 tons of construction material per trip. This material included all the contained machinery and construction equipment, 2,200 tons of structural steel and the cement required to mix 9,500 cubic yards of concrete. The floor area of the main complex was 100,000 square feet (9290 m^2). During peak periods, the construction crew numbered up to 400 people on site.

Engineering, procurement and construction management of the surface facilities was contracted to Bechtel Canada Limited, while the contract for mine development and underground construction was awarded to J.S. Redpath Limited. The Lupin Mine was constructed and commissioned for a total cost of $135 million dollars.

During 1983, a construction program was completed to expand the capacity of the mill from the original 1,000 tons per day, to a new nominal capacity of 1,200 tons per day. This construction phase included the installation of a rod mill in the grinding circuit, an additional 1,000-ton fine ore storage bin, additional filters and an extension to the maintenance bay.

From 1983 to 1993, the Lupin Mine underwent a number of other expansions and operational changes to increase milling capacity to a nominal 2,300 tons per day. The main production shaft was deepened on two separate occasions to a final depth of 1,210 metres below surface and the old sinking compartment was converted into a cage compartment. In April 2001, a production winze was commissioned between 1050 level and 1340 level. This infrastructure allowed mucking below the elevation of the crusher to be carried out more productively, thus extending the depth, and life, of the mine. The -15% decline drift, or ramp, which permits mobile equipment to access all the mine levels, extends from surface to the 1560-metre level. The lowest developed level in the mine is at the 1550-metre elevation.

2.2 Site Facilities

Other than the transportation requirement for materials and supplies necessary to sustain the workforce and industrial operations, the Lupin site is completely self-

contained and relatively compact. There are two main areas of the camp - the residential complex consisting of accommodations, kitchen and recreation centre, and the industrial complex comprised of milling and maintenance areas, headframe, hoistroom, powerhouse, warehouse and office facilities. The freshwater pumphouse is situated approximately 1.6 kilometres northwest of the camp, on the shore of Contwoyto Lake.

In association with the above, there are a number of support areas consisting of shops and yards (maintenance, surface, backfill, carpentry), storage/laydown areas (cold storage buildings 1-3, explosives magazine, fuel tank farms), camp sewerage facilities, mill tailings line, and a weather/aircraft control office with exploration shack. The Tailings Containment Area (TCA) is situated approximately 3 kilometres south of the mine site. The only physical connections between the TCA and the mine site are a road and the 8-inch diameter insulated tailings line, used to transport the tailings slurry from the mill to the deposition point in the tailings cells.

2.3 Mining

Shaft sinking began in 1982 to an original depth of 370 metres below the surface collar. The shaft has been deepened twice since then, first to the 780-metre elevation during 1984-86 and the second time to its final depth of 1,210 metres during 1988-90. The 2-drum ASEA production hoist, originally installed in 1987, was upgraded to 1,720 horsepower in 1992. This allowed 10-ton capacity skips to be hoisted in the two skipping compartments. In 1992, the manway compartment above the 250-metre level and the sinking compartment below the 250-metre level were converted to a cage compartment. The hoistroom was modified to accommodate a fully automated cage hoist.

The Lupin Mine is also serviced by an access ramp, which extends from surface to the bottom of the mine. For the most part, the ramp is a closed spiral and is located under the plunging south nose of the ore body. The 5m wide x 3.5m high ramp grades at -15% over its entire length. The termination of the ramp is at the 1,560m level horizon. The ramp provided for movement of men and materials within the mine and allowed for efficient deployment of resources as required.

A 1,000 horsepower, 84-inch diameter Joy axivane fan mounted on surface, supplies fresh air to the mine via a 3-meter diameter fresh-air raise. A similarly sized Joy fan is also mounted on surface, over a 3.4 metre x 3.4 metre raise, and helps exhaust contaminated air from the mine.

Almost all of the lateral and ramp development at Lupin was accomplished with electric-hydraulic drills and diesel scooptrams. A number of sublevels were developed with pneumatic drills and slushers during the last few years.

Standard mechanized drift dimensions were as follows:
Ramp:5.0m wide x 3.5m high, -15%

Access Drifts: 4.6m wide x 3.5m high
CZ Ore Drifts: 4.0m wide x 3.5m high +2% grade
WZ Ore Drifts: 2.0m wide x 3.2m high +2% grade

Raises up to 20m in length (stope slots, millholes, vent raise extensions) were driven by conventional open raising methods, longhole drop raises or longhole inverse raises. Longer raises were driven with an Alimak or raise boring machine.

Production mining at Lupin began with sublevel longhole open stoping in the Centre and East Zones. Stope heights were typically 80m and were as long as the strike of the ore body. Every fourth sublevel was developed as an extraction horizon complete with a haulageway, drawpoints, ore pass and waste pass. All of the mining above 810m in these two zones was done by this method. The West Zone is the narrowest zone at Lupin. It was first mined by shrinkage and later by a "Raise Platform Mining" method, which involved driving closely spaced raises and then breasting between them from an Alimak raise climber. This method was in turn replaced with sublevel longhole stoping similar to the Centre Zone but utilizing much smaller equipment.

As mining progressed to greater depths and the accumulated volume of stope excavation increased, rock stress and ground control issues became an increasing concern. The stoping method was modified to integrate both waste and paste backfill into the mining cycle. Stope dimensions were decreased in both height and strike length as one technique used to control dilution. The method involved longitudinal retreat mining 20m high panels over a relatively short strike length (20m maximum in the Centre Zone and 15m in the West Zone), remote mucking the stope empty, then filling with paste before mining the adjacent panel. This mining method has been used at the mine since 1995.

The paste backfill plant was commissioned in October 1994 and was one of the first such systems operating in Canada at that time. The process involves taking the filter cake from the second stage filters in the mill (tailings), conveying it to the paste plant where it is mixed in a pan mixer with cement and water to create the paste. The paste is pumped to the shaft utilizing one of two positive placement pumps. Once delivered to the shaft, the paste flowed by gravity through the 6- inch diameter fill line and was distributed throughout the mine. Design capacity of the paste system was 120 short tons per hour. Between January 1995 and December 2004, over 1.8 million tons of paste backfill, equating to more than 30% of all tailings produced by the mine in that time period, were placed in the underground stopes.

During the last few years of mining, the crown pillars of the Lupin orebody were recovered. The crown pillars were the portions of the East, Centre and West zones between surface and 27-metre level, that were left behind when the initial mining was carried out. The East Zone crown pillar was recovered in 1997 and completely backfilled with waste rock and non-hazardous waste material in 1998. Mining of most of the Centre Zone crown was completed in 2003 and it was backfilled with pastefill

that same year. A small portion of the Centre Zone crown pillar was mined during 2004 and remains open for the deposition of non-hazardous waste material. The West Zone crown pillar was mined between 1996 and 2004, and has been left open for the future disposal of demolition debris and soils. The crown pillar openings will be completely filled in, and the surface capping material contoured, during reclamation activities at the mine site.

2.4 Metallurgical Processing

The Lupin milling process remained basically consistent throughout the life of the mine. It utilized the Merrill-Crowe process for gold recovery, whereby a powdered zinc mixture is added to a gold bearing cyanide solution to precipitate out the gold. Lead nitrate is used in low doses to activate the zinc. The gold precipitate is then dried and melted in a furnace, and poured into dore bars. The crushing, grinding, pre-aeration, leaching, filtration and recovery stages are described below.

2.4.1 Crushing

The ore from the mine was crushed underground to 5.5 inches by a primary jaw crusher. It was then skipped to a 600-ton coarse-ore bin on surface. A vibrating feeder and conveyor belt transported the ore to a secondary cone crusher. After being reduced to -1.5 inch, the ore passed over a double-deck vibrating screen. Any material larger than 5/8 inch was fed into the tertiary cone crusher and re-circulated over the vibrating screen until it passed through the 5/8-inch openings. The ore passing this screen was conveyed to two 1, 000-ton fine ore bins, which fed the grinding circuit. The crushing circuit had the capacity to operate at a rate of 240 tons per hour.

2.4.2 Grinding

Liberation of the gold from the host rock was done by further reduction of the ore size. This was accomplished with a 9.5-ft. diameter x 12-ft. long rod mill feeding two 8-ft. x 24-ft. long ball mills in parallel. The ore was fed into the rod mill from the fine ore bins via belt feeders and conveyors. The ball mill discharge slurry was pumped to a common ball mill discharge or cyclone feed pump box, then to a cluster of cyclones which classifies the material. Cyclone underflow (+200 mesh material) was fed back into the ball mills. The cyclone overflow slurry (-200 mesh material) was pumped to the pre-aeration circuit at about 30% solids. The grinding circuit operated at a maximum rate of 2,300 tons per day, with the target-grind being 57% passing -400 mesh.

2.4.3 Pre-Aeration

The cyclone overflow was fed to the center well of the pre-aeration thickener, a 50-ft diameter shallow settling tank. The thickener overflow solution flowed by gravity to the recycle water tank and was recycled back to the grinding circuit. The thickener

underflow slurry (60% solids) was pumped to the first of three 82,000 USG pre-aeration tanks. These tanks provided air to oxidize sulfide minerals, which would otherwise consume large amounts of cyanide and oxygen, thus hindering the leaching reaction. The circuit was tuned for efficient mechanical and chemical performance by operating under alkaline conditions (pH 10), adding lead nitrate reagent, and by using primary filtrate to dilute the thickener underflow density to 45% solids.

2.4.4 Leaching

The liberated gold particles were leached into solution through the reaction of cyanide, oxygen and water. Slurry from the pre-aeration circuit was leached in six consecutive agitated and aerated tanks. Lime was added to the circuit to maintain a constant pH of about 10. These six tanks in series gave the circuit 30 hours of retention time. The overflow from Leach Tank No. 6 feeds the cyanidation thickener. Thickener overflow solution is loaded with gold and flowed to the pregnant solution tank. The underflow, also containing some gold in solution, was pumped to the filtration circuit.

2.4.5 Filtration

A two-stage filtration system separated the dissolved gold from the waste solids of the cyanide thickener underflow. Each stage consists of four vacuum drum filters 8 ft. in diameter and 14 ft. long. In the first stage, the cyanidation thickener underflow slurry contacts the outside of the filter unit and the solution is drawn through the filter while the filter cake is washed with barren solution. The solution is returned to the cyanidation thickener or pumped to pre-aeration as dilution water. The filter cake passes through a repulper to a second stage. The second stage filter cake is washed with either barren or raw water and the solution is again returned to the cyanidation thickener. The filter cake is repulped with barren or raw water and flows by gravity to the tailings disposal pump box.

2.4.6 Recovery

The pregnant solution from the cyanidation thickener overflow was clarified and de-aerated, precipitated and refined to obtain dore bullion in a conventional Merrill-Crowe system. Three pressure clarifiers removed suspended solids from the solution, and then the oxygen was removed prior to precipitation in a de-aeration or Crowe tower. Zinc dust was added to the clarified de-aerated solution and the precipitated gold was collected in precipitation presses. The now barren solution was bled to tailings and recirculated throughout the plant. Once the filter press became loaded with precipitate, the feed was transferred to the other presses and the loaded press was emptied. After being mixed with suitable fluxes, the precipitate was smelted in the bullion furnace to produce dore bullion and slag. The slag was returned to the mill to be reprocessed. The bullion contained approximately 85% gold and 12% silver, the balance being base metals.

3. Requirement of an Abandonment and Restoration Plan

Echo Bay Mines Ltd., Lupin Operation applied for and received a Water Licence renewal from the Nunavut Water Board effective July 1, 2000 through to June 30, 2008. Within Licence Number NWB1LUP0008, Part I Item 3 requires that a Final Abandonment and Restoration Plan be submitted to the Board.

3.1 Objectives of the Abandonment and Restoration Plan

This Plan has been prepared to indicate to the Board the direction and procedures that Zinifex Canada Inc. intends to implement to fulfil obligations with regard to abandonment and restoration at the Lupin Operation. The objective of the plan follows the "*Guidelines for Abandonment and Restoration Planning for Mines in the Northwest Territories, September 1990*" as specified in the water licence, and the more recent "*Mine Site Reclamation Policy for Nunavut (2002)*". Government regulations will be complied with to ensure that once abandonment & restoration has been completed,

- there is no danger to public health or safety;
- the requirement for long term maintenance and monitoring associated with the tailings area is minimal or nil;
- contaminant loadings to the environment from the Tailings Containment Area are minimized or prevented;
- the cumulative degradation of abandoned areas affected by the mining activities is prevented, and natural recovery of disturbed lands is enhanced; and
- the affected areas will be returned to a condition that is compatible with the surrounding, original undisturbed area with respect to its future potential/productivity uses.

The Lupin operation has conducted progressive reclamation within the TCA since 1988. Kinross initiated a major tailings reclamation program in the summer of 2004, in which the majority of the exposed tailings in the TCA were covered by a 1-metre thickness of esker material. This project will operate until all the exposed tailings in the TCA are covered.

4. ABANDONMENT AND RECLAMATION PLAN

4.1 History

The following provides a quick reference background to the reclamation plan requirements for the Lupin Operation since construction/production began.

1983 Commercial production began and the first "conceptual" Abandonment and Restoration Plan was submitted to DIAND to fulfil requirements of Water Licence N7L2-0925 and Land Lease No.'s 3593 and 3594.

Revisions were requested clarifying certain areas of the Plan.

1984 In December the A&R Plan was re-submitted in two parts;

Part "A" was prepared by consultants Reid Crowther and Partners Ltd. and contained a review of current technologies for reclamation applicable to the Lupin Mine as well as potential problems and conditions that may develop as a result of the operation.

Part "B" was prepared by Echo Bay Mines Ltd. and outlined the plan of action with respect to the conditional requirements outlined in the Water Licence and the Federal Land Leases.

1985 The A&R Plan was resubmitted to include revisions required under the amended Water Licence and was accepted with the exception of the plans for the Tailings Containment Area. Regulatory authorities indicated that it would be unwise to commit to a specific plan of action at that time due to advancing technology and the anticipated mine life.

1987 - 1995 Annual updates and revisions to the Plan were submitted for approval along with the results of various studies/reports undertaken during operations. A complete revision of the Plan incorporating new information/changes in scope was not requested until the 1995 Water Licence renewal.

1995-2000 Licence renewal granted on June 01, 1995 by the NWT Water Board and a revised "Interim" Abandonment and Restoration Plan was submitted in January 1996.

Annual updates and revisions to the Plan were submitted to the Board for approval along with results of various studies completed to date. Transfer of authority to the Nunavut Water Board.

2000	Licence renewal granted on June 01, 2000 (NWB1LUP0008) by the Nunavut Water Board, with expiry on June 30, 2008.
2001	Approval of revised Interim Abandonment and Reclamation Plan.
2001 - 2006	Annual updates on progressive reclamation activities, and the results of various studies completed to date, were provided to the Board.

5. ABANDONMENT AND RESTORATION PLANNED ACTIVITIES

The facilities and specific disturbed areas of concern with regard to the Lupin Operation that require abandonment/restoration activities and special management are covered in the following section. The goal of specific restoration practices is to minimize or preferably eliminate degradation of disturbed areas and to initiate, encourage and accelerate the natural recovery.

Conducting reclamation activities concurrent with the mining operations is an important part of Zinifex Canada's Environmental Policy. There may be some aspects of the reclamation activities identified in this plan that will take place prior to closure which may not have been indicated as an immediate concern. Examples of this are the reclamation work completed on past spill locations and covering portions of the tailings impoundment to facilitate study prior to closure, etc.

Prior to backfilling and sealing any raises or portal all non-hazardous wastes generated through the closure activities that are considered to be uneconomically salvageable (buildings, equipment etc.) would be dismantled and disposed of via these routes into the mine workings. All materials would be previously washed (eg. mill components) and inspected (eg. mobile equipment for batteries, lubricants, other hazardous materials) prior to disposal. Backfilling of the opening would utilize remaining waste-rock from surface and esker material for final cover to incorporate the material within the permafrost.

The goal of the restoration practices in the TCA is to minimize or preferably eliminate degradation of disturbed areas and to initiate, encourage and accelerate the natural recovery.

Conducting reclamation activities concurrent with the mining operations was an important part of the Echo Bay and Kinross Environmental Policies. These activities have been ongoing since the late 1980's, and have been described in the annual submissions to the Board. Examples of this are the mitigation work completed on past spill locations, covering portions of the exposed tailings containment area with esker material, demolition/salvage of un-needed structures, etc.

5.1 Buildings and Contents

5.1.1 Mill Complex; Mill, Administration, Maintenance, Powerhouse, Warehouse

Mill - Upon cessation of operations, the mill portion of the complex will be given a complete wash down with the intent of gold recovery (visible gold that settles within

the system) and removal of any residual contaminants (from chemical use) to the tailings impoundment. The crusher area is normally washed down on a regular schedule while operating, and will also be completed at closure.

All equipment and internal components from the mill would be dismantled and removed from the building. These would either be transported off-site for use at other facilities or salvaged where possible. Non-hazardous materials with no salvage value will be deposited at the open stope and buried. The metal frame structure will be dismantled and salvaged where possible. Any concrete walls/footings will be bulldozed level and used to infill the mill sumps or removed to the mine workings.

Paste Backfill Building - As part of the mill, this building would undergo similar cleanup procedures with all residues reporting to the tailings sump and being disposed of at the tailings containment. The larger cement storage building is simply a steel clad shelter and designed to house the cement supply for the paste system. Equipment from the plant would be removed for resale, salvage or disposal. The steel frame structure would be dismantled and stored for shipment off site or disposal within the mine workings.

Administration/Warehouse - These areas will have all salvageable/hazardous materials removed prior to dismantling. Demolition will take place in a similar fashion to the mill building and all materials that cannot be salvaged will be disposed of into the mine workings.

Powerhouse - the powerhouse facility will remain operational for a reasonable time frame to support the reclamation process. A staged dismantling and removal of salvageable equipment will take place ending with limited power generation in the latter stages. The emergency power house will remain to provide minimal power requirements once major power consumers are removed (ie. mills, hoist). Early removal of emergency power can take place if portable power generation is available during final closure.

Power distribution throughout the site is both above and below ground. Power lines would all be removed for salvage or disposal. Transformers containing low level PCB's were transported off site in 1994. No other PCB material is known to be at Lupin.

5.1.2 Other Major Buildings

Maintenance/shops - All outbuildings will be evacuated, inspected for hazardous materials and dismantled for salvage or disposal. These include the carpentry shop, surface shop, mobile maintenance, 777 shop, cold storage buildings and cement storage.

Arsenic Treatment Facility - This facility, a steel frame/metal clad building, is

located at the Tailings Containment Area. It is used for mixing of reagents (ferric sulphate and lime) for water treatment operations. All components (always flushed after use) and the structure will be removed from the TCA and salvaged if economical or disposed of within the mine workings.

ANFO Storage - The explosives storage magazine consists of a steel frame/metal clad building as well as numerous Sea-Containers. After removal of remaining ANFO, the main building would be dismantled and transported to the Lupin site. The Sea-Containers would be decontaminated if required at the tailings ponds and stored at the main compound for transportation uses. Any remaining ANFO would be evaluated for use at other sites, returned to the supplier or will be disposed of by controlled burning at the site. Proper site selection and approval through consultation with authorities prior to burning would take place.

Accommodation Facilities - The major component of the accommodations is the sleeping and eating quarters which consist of over 200 modular units and separately framed areas to form the complex. The other components consist of recreation and gymnasium facilities which are steel frame/metal clad construction.

The steel frame buildings would be dismantled and removed from site or disposed of within the stope. The re-sale of the accommodations is highly unlikely unless they are to be used in-place. There has been little interest in the past for used accommodation trailers at Lupin. In the event of disposal on site, the units would be evacuated of all salvageable items and potential contamination prior to burning. The remaining residues would be removed to the mine workings.

5.2 Infrastructure Support

5.2.1 Freshwater Supply

The freshwater for the site is obtained from Contwoyto Lake approximately 1.5 km from the complex. A causeway/breakwater extending out into the lake supports a pumphouse building and docking facilities. See Figure 4 in Appendix 1.

Upon closure the building, electronics, pumps and approximately 1.5 km of six inch insulated pipeline will be removed and salvaged where possible. The docks will be removed, however the breakwater and causeway will be left in place due to the increased disturbance that the lake would incur during removal. Non-salvageable materials would be disposed of within the mine workings.

5.2.2 Tailings Lines

Currently two steel tailings lines exist between the mill complex and the Tailings Containment Area. The initial six inch line and the newer eight inch line, both of which are insulated, extend the entire six kilometre distance to the impoundment.

The eight inch line extends further within the impoundment for an additional 2.5 km. See Figure 5 in Appendix 1 for tailings line route location. Various small buildings along the line house valves for either dumping of the line to controlled sumps or switching flow direction.

The entire length of six inch line and associated buildings are to be removed from the tailings line route prior to closure. The eight inch line will be flushed thoroughly with clean water prior to being dismantled along with associated buildings. If salvageable, the pipe will be sold or reused in another application. If salvage is not viable, the piping would be disposed of within the mine workings.

In addition to the tailings lines there are two dump stations (shallow sumps) located along the tailings line route (Figure 5). These stations allow the emergency dumping of line contents in the event of an unplanned mill shutdown. These stations will be cleaned of all existing tailings materials which will be disposed of at the TCA. Berms would be flattened and pushed into the depressions to become consistent with the surrounding topography.

5.2.3 Fuel Storage

The fuel storage facilities at Lupin include both a main and day tank farm which consist of eleven 350k gallon storage tanks for diesel fuel and one 350k gallon tank for Jet-A; three 187k gallon and three 18k gallon P50 fuel tanks. It is expected that most of the fuel will be consumed during the final reclamation activities. Any remaining fuel will be removed from site. The empty tanks would then be disposed of after consultation with regulatory authorities.

The tank farm areas would be stripped of any fuel laden sand to be disposed of at the TCA. Fuel rich material may be ignited prior to disposal in a separate, isolated area. Materials (esker sands) that contain residual hydrocarbons may be subjected to landfarming for natural remediation or burial. The technology is currently in the developmental stage for microbial action in northern climates but may be applicable when abandonment at the Lupin site takes place.

The underlying plastic liner material would be cleaned if necessary and disposed of within the mine. Foundation material would be surveyed for hydrocarbon contamination and handled accordingly with the same options as the sand at the surface. The remainder of the site would be graded to conform with the surrounding natural topography.

5.2.4 Chemical Storage

The mine site carries an inventory of chemicals which include; cyanide, lime, lead nitrate, zinc dust, flocculants and ferric sulphate in major quantities and miscellaneous refinery reagents in much lesser quantities. It is expected that the

majority of reagents will be consumed through normal usage during final operations. Inventory that remains would be sold to an alternate user or returned to the supplier. Any chemicals that could not be removed through these methods would be disposed of in an environmentally acceptable manner after consultation with the appropriate authorities.

The grounds in the immediate vicinity of the chemical storage areas including the floors of the cold storage buildings are comprised of crushed waste rock. These areas would be sampled and contaminated materials either treated in-situ or removed to the tailings impoundment for disposal.

5.2.5 Roads and Airstrips

A considerable amount of roadway exists at the mine with the largest portion being the access to the explosives magazine and the access road to the Fingers Lake esker. All roadways will be left intact with the exception of areas of drainage control by culverts. The removal of culverts and the backsloping of the opening would ensure that minimal erosion takes place and proper drainage is achieved. Any other areas of water pooling along the roads during spring melt would be opened up to provide unlimited drainage.

The roadways are probably the third most prominent feature change (next to the TCA and Mine Site) at the mine and will remain clearly visible for an indefinite period of time. In order to promote natural growth of vegetation, the road surfaces would be ripped/scarified to provide microclimate sites for seed deposition.

The old airstrip used during construction had been used as a laydown area since the new airstrip was built. This area was slowly phased out as a storage location and in 1998 the gravel/esker fill strip was graded to conform to the natural landscape with cuts and backsloping applied where necessary to promote natural drainage and reduce erosion. The surface was prepared as per the roadways utilizing a grader with a ripping attachment.

The main airstrip is 6400 feet in length and is constructed of crushed waste rock produced from development underground. The drainage course in the area has been altered slightly in a lateral direction, however all runoff from both the east and west sides of the strip report in a northerly direction, eventually to Contwoyto Lake.

Removal of the airstrip will not be carried out, however, access roads will be cut and backsloped to allow uninhibited drainage along its parallel. All ancillary equipment including signs, marker lights, strobes (associated wiring) and weather station/traffic control building will be dismantled and removed. The major components consisting of the radio beacon VOR (VHF Omni Range) and tower (Non-direction Beacon) will be removed unless other arrangements are made through the Department of Transportation and/or the City of Yellowknife.

5.2.6 Sewage and Refuse Disposal Facilities

The existing sewage facilities consist of several lift stations within the camp and an 800 metre six inch insulated steel pipeline to the first of two sewage lakes. A "permeable" type dam with an emergency overflow exists between the first and second lake. Annual discharge from the second lake is controlled with a gated culvert and the use of a syphon. See Figure 8 in Appendix 1.

Upon closure, the steel pipeline would be flushed with clean water, dismantled and removed from the site for reuse or sold for salvage if economically feasible. Components with no salvage value would be disposed of within the mine workings for burial.

The dam structure between the upper and lower lakes would be breached at the culvert location (lowest natural location) and backfilled with rip-rap (waste rock) to provide erosion control. Dam slopes would be graded to reduce erosion at the water level. The control culvert at the lower lake would be removed (again the lowest location) and the dam graded to reduce erosion and improve aesthetics.

The refuse disposal area used at the site is located to the southeast of the mine and north of the second sewage lake. All non-burnable waste (scrap metal, plastics, residue from burning) is disposed of and buried with waste rock on a regular basis. It is expected that a portion of this facility will remain active until restoration is near completion. At this time the area will be graded with waste rock/esker sands to promote diversion of surface runoff, prevent water ponding on the surface and provide erosion control around the perimeter. The grounds in the immediate vicinity of the chemical storage areas including the floors of the cold storage buildings are comprised of crushed waste rock. These areas would be sampled and contaminated materials either treated in-situ or removed to the tailings impoundment for disposal.

5.2.7 Quarry; Fingers Lake Esker

The quarry material used for road and dam construction as well as the cover projects in the TCA is obtained from the Fingers Lake esker located approximately 11 kilometres from the mine or 3 km from the tailings impoundment. The frozen nature of the material within the esker dictates that only shallow layers of material can be removed during excavation and hauling. In general this results in a larger area of the esker surface being disturbed but allows for easier restoration work on cessation.

After any seasonal use of the esker for ongoing operations, the disturbed areas of the esker are contoured with the remaining ground for erosion control and to limit ponding of water at the surface. After completion of restoration plans at the mine and tailings impoundment, the final contour of the esker will be developed to be compatible with the natural topography and control potential erosion through sloping. The surface will be "roughed" with dozer cleats or otherwise scarified to enhance the

natural re-establishment of indigenous vegetation.

5.3 Underground Mine

The Lupin underground workings include a 1210 metre vertical shaft and a decline to a depth of 1250 metres. A secondary hoist system (WINZE) was installed in 2001 allowing hoist access to 1340 metres. The current mine depth is 1410 metres with potential deepening to 1640 metres. Incorporated into the underground facility are maintenance shops, an electrical shop and a primary crushing station. Once mining has been terminated, all equipment will be considered for recovery and shipment to another site for reuse or sold for salvage value.

Where salvage is not economical, all equipment and materials will be inspected for, and any hazardous materials (eg. batteries, fuel, lubricants etc.) removed, prior to being abandoned within the mine. The hazardous materials, as mentioned, would be disposed of (or shipped off site) in an environmentally acceptable manner after consultation with the proper authorities. Any materials acceptable to being left within the mine will be moved to the upper levels to be contained within the permafrost region.

Materials to be left in-place, as is, are those related to the structure of the mine and shaft/raises, the shop facilities and crusher facilities (with motors etc. removed). Any materials being moved to the underground openings will be placed in the permafrost region to limit contact with water that may collect within the lower levels. If it is determined that rockfill bulkheads be placed at various levels to encourage water movement away from the disposal levels, then construction of these may take place prior to final closure of the mine.

All portals, raises, shafts or other entrances to the underground mine will be sealed using engineered concrete plugs and caps to prevent access. Where applicable, these areas will also be backfilled and graded to conform with the surrounding area.

5.4 Waste Rock

The waste rock generated at Lupin contains very little sulphide and is considered to have a low potential for generating acid. The sulphide content of 0.5% or less and the presence of an excess neutralizing potential compared to maximum potential acidity lowers the concern for ARD.

The production of waste rock was considerable during the early development stages of the mine and a stockpile was generated. In the latter stages of the mine life excess waste rock generation has been lower and the waste rock produced is normally moved to other areas of the mine as backfill material wherever possible.

Very little development is currently taking place within the waste.

Waste rock has generally been used throughout the site as roadbed materials, in dam construction, airstrip stabilization, underground backfill or for other purposes such as building foundation preparation. At closure, there is not expected to be a large waste rock stockpile. Any remaining waste will be hauled the short distance to the open crown pillar and used to backfill the opening. If for some reason all waste rock cannot be accommodated within this area, then the remaining stockpile will be graded to conform to the surrounding terrain.

5.5 Tailings Containment Area

5.5.1 Infrastructure

Arsenic Treatment Facility - This facility, a steel frame/metal clad building, is located at the Tailings Containment Area. It was used for mixing of reagents (ferric sulphate and lime) for water treatment operations during the early 1990's and has been inactive since 1996. All components were flushed after use, but will be rewashed and the structure will be removed from the TCA and salvaged, if economical, or disposed of within the surface landfill located at the mine site.

Explosives Magazine - The explosives storage magazine is located 2 kilometres west of the TCA and consists of 2 steel-frame/metal clad buildings for ANFO storage, as well as numerous Sea-Containers for the storage of stick powder and other blasting products. After removal of the remaining ANFO, the main building will be dismantled and transported to the Lupin mine site. The Sea-Containers will be transported to the mine site, washed and stored at the main compound for transportation uses. Any remaining ANFO will be evaluated for use at other sites, returned to the supplier or will be disposed of by controlled burning at the site. Proper site selection and approval through consultation with authorities prior to burning will take place.

Tailings Lines - The eight-inch insulated pipeline between the mill complex and the Tailings Containment Area extends for six kilometres to the impoundment, and for an additional 2.5 km within the impoundment. See Figure 5 in Appendix 1 for tailings line route location. Various small buildings along the line house valves for either dumping of the line to controlled sumps or switching flow direction.

The eight inch line will be flushed thoroughly with clean water prior to being dismantled, along with the associated buildings. If salvageable, the pipe will be sold or reused in another application. If salvage is not viable, the piping will be disposed of by burial in the surface landfill.

In addition to the tailings line, there are two dump stations (shallow sumps) located

along the tailings line route (Figure 5). These stations allowed for the emergency dumping of tailings line contents in the event of an unplanned mill shutdown. These stations will be cleaned of the small amount of tailings materials, which will transported and disposed of at the TCA. The sump berms will be flattened and pushed into the depressions. The former sump area will then be covered by a 1-metre thick layer of esker material, contoured and scarified to promote re-vegetation.

Roads - A considerable amount of roadway exists at the TCA, with the largest portion being the access to the explosives magazine and the access to the Fingers Lake esker. All roadways will be generally left intact with the exception of areas where drainage is controlled by culverts. The removal of culverts and the backsloping of the opening would ensure that minimal erosion takes place and proper drainage is achieved. Any other areas where water has pooled along the roads during spring melt would be opened up to provide unlimited drainage. In order to promote natural ingrowth of vegetation, the road surfaces would be ripped/scarified to provide microclimate sites for seed deposition.

Fingers Lake Esker - The sand and gravel used for road and dam construction, as well as the cover projects in the TCA, is obtained from the Fingers Lake esker located approximately 10 kilometres south of the mine (4 km south of the tailings impoundment). The frozen nature of the material within the esker dictates that only shallow layers of material can be removed during excavation and hauling. In general this results in a larger area of the esker surface being disturbed but allows for easier restoration work upon cessation.

After any seasonal use of the esker for ongoing operations, the disturbed areas of the esker are contoured to blend in with the surrounding landscape in order to achieve erosion control and to limit ponding of water at the surface. After completion of restoration plans at the mine and tailings impoundment, the final contour of the esker will be developed to be compatible with the natural topography and control potential erosion through sloping. The surface will be "roughed" with dozer cleats or otherwise scarified to enhance the natural re-establishment of indigenous vegetation.

Water Quality Monitoring- Water quality monitoring within the tailings impoundment is necessary to track the performance of the system and/or identify any anomalies that may arise. The water fill phase of the ponds is expected to provide time in which to develop a contingency plan should monitoring indicate that the water quality will not meet discharge requirements. During the preceding licence term, treatment at the TCA has been reduced to that of the addition of lime to the ice in the spring prior to spring melt. The treatment facility, which was originally designed for the addition of ferric sulphate for the removal of arsenic, has only been used for supplemental addition of lime since 1997. The water quality within Pond No.1 had improved during the years prior and treatment for the removal of arsenic was not required. If the trend to lower levels continues during the current operations, then it can be expected that during closure and subsequent infilling of the TCA, water quality would not change

significantly. Lime addition might be required for pH control.

Water quality monitoring would also be carried out at the sewage lakes system, the main site facilities pad runoff and leachate from the waste rock piles or building foundations. The main Lupin site is situated on high relief and surface runoff collects in two directions:

1) to the sewage lakes
2) to Contwoyto Lake in the vicinity of the pumphouse.

Monitoring of general site conditions and runoff may be required during the period leading up to the final A&R plan being prepared. Dependent on results from the initial survey of the site following restoration work, and remedial action required at that time, follow-up monitoring may be required at the various petroleum/chemical storage areas that existed prior to the closure.

5.5.2 General Description

The Tailings Containment Area (TCA) is located approximately six kilometres south of the Lupin mine, and covers an area of about 361 hectares within the 750 hectare lease. The containment is divided into three main components: solids retention cells (cells 1 through 5), polishing ponds (Pond No.1 and Pond No.2) and the End Lake area (not used). This disposal area would be considered as a "High Impact" facility as it meets at least one of the listed criteria (ie. greater than 100 hectares) listed in the "Guidelines for Abandonment and Restoration Planning for Mines in the Northwest Territories".

A detailed history of the design and operation of the TCA is contained in the attached Holubec (2005) report (Appendix 2).

The cells within the impoundment allow for separation of the liquid from the solid tailings as well as providing treatment through natural degradation. Cell 4, which is used as the initial polishing pond, receives decant water from the cells and retains solutions for approximately ten months prior to transfer by gated culvert into Pond No.1. Water is retained for another year in Pond 1, prior to siphoning into Pond 2. Pond No.2 then retains the water for an additional eleven months prior to discharge to the environment.

The TCA is impounded through natural terrain relief and a series of engineered retaining structures (Figure 3 - Lupin Mine Tailings Area, 2004, Appendix 1). The main water retaining perimeter dams are Dam 1a and Dam 2, which contain Pond 2, and Dam 4 in Cell 4. Dams 5 and 6 within Cell 3 are low level dams. No tailings or water has been impounded against Dams 1B, 1C, or 5 and no water head will be placed on these structures upon closure. The tailings impounded against Dam 3 (Cell 1A) and Dam 6 (Cell 3) were covered by 1 metre of esker material in 1988 and

2004, respectively.

All perimeter dams have been designed with a synthetic liner for initial control of seepage and temperature monitoring of the dams shows that the cores remain frozen year-round. K-Dam, which is an internal structure, was also designed with a synthetic liner for initial seepage control. A tailings beach, approximately 10 metres in depth, has been placed on the upstream side of this dam and temperature monitoring indicates that the core remains frozen year-round.

Tailings Cells 1 and 2 are separated from Pond 1 by Dam 3D. The stability of this esker fill dam was enhanced in 1995 by the addition of a 10-metre wide downstream berm, constructed of 75,000 cubic metres of quarried waste rock, placed at a slope between 1.5H:1V to 2.0H:1V. The addition of this waste rock has also increased the erosion protection of the dam.

Ponds 1 and 2 are separated by J-Dam, which was constructed with esker material and mine development waste rock. Two 18-inch diameter syphons have been placed over this dam to permit the annual transfer of water from Pond 1 to Pond 2. Following the final transfer of water to Pond 2, and as one of the final activities during closure, J Dam will be breached and a spillway established at elevation 481.0m to permit a controlled flow of water into Pond 2.

5.5.3 Impoundment Stability

The perimeter and internal structures that were originally constructed to impound water or tailings solids within the TCA will become essentially earthen embankments after the completion of abandonment activities. The perimeter dams that currently impound water are Dam 1A, Dam 2, and Dam 4. With the construction of spillways through J Dam and Dam 1A, and a natural flow of water from the Cell 4 pond, water in Pond 2 will not encroach on either Dam 1A or Dam 2 and will only reach the toe of the internal dam N Dam. Dam 4, which presently separates Long Lake from the Cell 4 pond, will have water against each toe, but this is a wide (>45 metres toe-to-toe) structure that will be further enhanced by additional riprap on the sides to bring the slope to at least 2.5H:1V.

Dam Safety Guidelines were developed by the Canadian Dam Association (1999) to apply to dams that are at least 2.5 m high and which have at least 30,000 m^3 of reservoir capacity. The guidelines also apply to tailings dams if the reservoir contents could be released and have an unacceptable impact on the environment. If a dam falls under the dam safety guidelines, it has to meet the physical stability criteria given by a minimum factor of safety for static condition of 1.5, and generally 1.1 for seismic conditions.

The construction of the impoundment structures has been assessed with respect to

present conditions and long term stability on final abandonment. Stability analyses of the main perimeter dams (1A, 2, and 4) were conducted as part of a Dam Safety Review in 2004 (Golder 2004c).

Material parameters for unfrozen construction materials were used in the analyses, as opposed to using parameters for frozen materials. This was done to ensure that results would be conservative and to reflect the possibility of long-term global warming. A very conservative assumption for seismic amplification safety factor of 4 (i.e. g = 0.064) was used for the perimeter dams. Also, the analyses assumed that groundwater levels corresponded to the tailings pond elevation at the crest of the dam, dropping through the dam to the toe drain. This too is a conservative assumption, as there is currently significant freeboard on all 3 dams and on abandonment there will be no head at all.

The stability analyses indicate that all 3 perimeter dams presently satisfy the criteria for stability in the Dam Safety Guidelines for both static and pseudo-static loading conditions. Results of the stability analyses can be seen in Table 4, below.

Table 4 – Results of Perimeter Dam Stability Analyses

Dam	Calculated Factor of Safety		
	Static	g = 0.016	g = 0.064
1A	1.61	1.54	1.33
2	1.69	1.61	1.41
4	1.74	1.67	1.49

These results, calculated using very conservative assumptions, show that there is no concern for the stability of these perimeter structures following abandonment.

The physical stability of Dams 3D, K, M and N do not need to meet the minimum CDA factor of safety for static condition of 1.50 since they will not fall under the dam classification (retaining water) after abandonment. Highway embankments that are 4 to 5 m high are normally designed with a minimum Factor of Safety (FS) greater than 1.3, so this FS would be more appropriate for the perimeter dam application. Regardless, a minimum FS of 1.5 will be expected of the internal dams after abandonment. The stability of these dams was analysed by Holubec Consulting, as part of a report on the overall history and closure of the TCA (Holubec 2005). The stability of the structures was analysed for three conditions:

- Present - frozen core and foundation.
- Existing structures - thawed core and foundation due to global warming
- Closure design - thawed core and foundation due to global warming.

Results of the stability analyses of the 3 main dams can be seen in the following

table.

Table 5 – Results of Internal Dam Stability Analyses

Dam	Existing frozen dam		Thawed dam with different ground water levels			Closure geometry Berm slopes		
	Thru Rock berm	Thru Esker Section	Hi WL	Lo WL	Likely	Static		Seismic
						2h:1v	2.5h:1v	2.5h:1v
K Dam		8.8	0.96	1.21		1.63	2.11	2.02
3D Dam	1.4	8.5			1.51		2.04	1.95
M Dam		8.1			1.32	1.62	1.91	1.82

The existing structures have very high minimum factors of safety (8.1 to 8.8) under the present frozen condition. K Dam shows the worst "thawed condition" FS. Depending on assumed groundwater surface within the dam, the minimum factor of safety would be between 0.96 (high groundwater level) and 1.21 (low groundwater level). Placing a rockfill stabilizing berm on the existing downstream face however will raise the minimum factor of safety to 1.63 for a downstream slope of 2 horizontal to 1 vertical (2H:1V), and to 2.11 for a slope of 2.5H:1V. Riprap will be added to the downstream face of K Dam to flatten the slope to 2.5H:1V.

Dam 3D and M Dam show higher "thawed condition" factors of safety with their present geometries, but these dams will also be enhanced by adding riprap to the downstream faces in order to reduce the slopes to between 2H:1V and 2.5H:1V.

Seismic stability analyses were also conducted on the final closure design geometry. The results shown for final slopes of 2.5H:1V show the static minimum factors of safety to drop about 5% when earthquake acceleration is applied to these earth structures. Considering that much lower minimum factors are accepted for earthquake loading, the final closure design structures will have very satisfactory minimum factors of safety.

The details of this study are contained in the report "Closure Plan for the Lupin Tailings Containment Area", completed by Igor Holubec Consulting (Holubec 2005). This report is provided in Appendix 2.

5.5.4 ARD (Acid Rock Drainage) Potential of Tailings

Extensive studies completed in the past have shown that the Lupin tailings, given the proper conditions, will oxidize and produce the by-products necessary for the formation of acidic runoff. Typical Lupin tailings contain approximately 3% sulphur (total) and have a Neutralizing Potential to Maximum Potential Acidity (NP/MPA) ratio of less than three.

Included in these studies were a 1991-1992, 30 week column leach program (kinetic test) and a follow-up16 week leaching program in 1993 on mitigative measures for Cell 5 (then known as Area 3) tailings (Klohn 1992a). In addition, a 1992 study was completed on the assessment of water chemistry and remedial measures for the Lupin Tailings Management System with regard to the affects of the (formerly) exposed tailings within Pond 2 (Klohn 1992b and Klohn 1993). One of the results of this study was the decision to build M Dam, which now separates Cell 5 from Pond 2, and prevents any further contamination of the Pond by the inflow of raw tails.

In 1994, Echo Bay Mines Ltd. retained the services of Klohn-Crippen Consultants Ltd. for the engineering, geophysical and data interpretation of a test plot area on Cell 1 (Klohn 1995). Results of the geophysical portion of the study were inconclusive; however considerable background information was generated with regard to the chemistry of the tailings prior to covering.

In 1995, a continuation of the 1994 study incorporated the more standard physical measurement techniques of thermistors, frost probing and frost tubes at the study area. The scope was broadened when the decision to expand the esker cover program was made and Cell 1 was covered. This data, along with that generated by the additional thermistors installed in the following years, provided excellent information of the thermal response of the covered tails.

Because of the potential for acid generation from the tailings, all exposed tails will be covered by a 1-metre layer of non-reactive, highly durable, saturated esker material. This layer will prevent any contact with the surface environment and the saturated zone at the tails interface will provide an effective barrier to oxidation.

5.5.5 Planned Restoration Activities

Restoration for the Tailings Containment Area will involve two physical methods for remediation and control of potential contamination from the materials that are held within its boundaries. These methods are:

1. maintaining water cover over areas that are currently used for water retention and low elevation tailings deposition (ponds); and
2. mechanical covering of the higher elevation areas containing tailings (cells)

with esker material.

Of the 750 hectares within the lease area, an estimated 177 hectares has been affected directly by the deposition of tailings solids. The closure concept adopted by Kinross in the restoration of this area is to encapsulate the tailings (which are potentially acid generating) within a water saturated esker material cover. This would effectively isolate the tailings from the environment and limit oxygen transfer through to the sulphide contained in the tailings and so prevent acid generation.

These cells, with their respective disturbance coverage areas and approximate watershed, are listed in 6, below, along with the two ponds and their intended surface areas at closure.

Table 6 - Lupin Tailings Containment, Areas

LOCATION	SURFACE AREA m^2	WATERSHED AREA m^2
CELL NO.1	330,000	410,100
CELL NO.1a	61,900	63,800
CELL NO.2	169,000	208,550
CELL NO.3	458,150	667,600
CELL NO.4	447,600	543,220
CELL NO.5	365,200	558,050
POND NO.1 (elev 481)	218,000	451,820
POND NO.2 (elev 480)	1,627,000	2,120,660
TOTAL	3,676,850	5,023,800

In the TCA, the total watershed area is such that accumulation of spring meltwater takes place. Even though a close to neutral evaporation environment exists, the large watershed results in an average annual increase in pond water elevation of approximately 0.5 metres.

At final closure, a system of riprap spillways will be constructed to permit natural water flow to the environment. Typical water elevations in the ponds, prior to and after annual discharge, are shown in Table 7, below:

Table 7 – TCA Water Elevations

	Before Discharge (el.)	After Discharge (el.)
Cell 4	486.8	485.0
Pond 1	484.6	481.0
Pond 2	483.0	480.0

Currently, a gated culvert controls the flow of water between Cell 4 and Pond 1. The topographic channel between these two ponds is at 485 metres elevation and will provide a natural gradient when the culvert is permanently removed during closure activities. Ponds 1 and 2 are separated by J Dam, and water is presently transferred between the two ponds using a syphon. After the final transfer of water into Pond 2, J Dam will be breached and a spillway will be constructed at an elevation of 481.0m. Limiting maximum water level to this elevation will reduce the impoundment of water against Dam 3D and maintain a natural gradient for flow from the Cell 4 watershed. The final elevation of the water in Pond 2, following the syphon discharge to the environment, will be at a maximum of 480 metres elevation. After final syphon discharge, the syphons will be removed and a spillway will be constructed through Dam 1A at an elevation of 480 metres. This would allow any accumulated water from spring freshet and seasonal rain to leave the impoundment area and flow through its original natural course via Seep Creek and eventually into Inner Sun Bay of Contwoyto Lake. At a maximum water elevation of 480 metres, no water will be impounded against the sides of Dam 1A, Dam 2, or M Dam.

Prior to activation of the spillway, an evaluation of the water chemistry will be made to ensure that when outflow occurs, all water quality guidelines are met. The outflow would amount to an estimated annual average water volume of approximately 250,000 m^3, the majority of flow occurring in June and early July. As there is an elevation difference of approximately 3 metres from the planned outflow to the receiving stream, the channel will be easily designed to prevent the migration by fish species (eg. arctic grayling) into the containment area through the use of a natural vertical barrier.

In addition to maintaining a water cover in the current holding pond areas of the TCA, the areas that will require the esker cover at closure are limited to the tailings cells where direct deposit of tailings solids takes place. Because there is very little additional watershed associated with the closed cells and the esker cover will be contoured to promote controlled drainage, flooding and erosion will not be a concern and the moisture retention of the cover assists the insulating value at depth and prohibiting oxidation of the underlying tails.

In general, with all the cells being situated around the perimeter of Ponds 1 and 2, there is a natural slope and drainage that results in collection within the ponds. The accumulated snow and its associated runoff naturally flows towards the two Ponds. Presently in Cell 1, runoff enters Pond No.1 at the eastern end where a slight

depression in the Dam 3D access road has been made to allow flow.

The source of esker material for the cell cover, as well as most of the TCA construction programs at Lupin, has been the Fingers Lake Esker, located approximately four kilometres to the southeast of the TCA. This borrow source has been used for construction of K dam, Dam 4, Dam 5, Dam 6, Dam 3C and 3D, L dam and M dam, as well as an underground backfill program which utilized over 300,000 m^3 of material. The variety in the size and segregation of the material allows for selection to suit the construction required without additional screening. Historically there has been in excess of two million cubic metres of material removed from this source. Visually, this has impacted only a small fraction of the material present and the amount of material remaining (in the nearest section of the esker) is more than adequate for the 650,000 square metres of exposed tails that remain to be covered at the TCA. Drilling associated with the installation of a thermistor (2000) at the esker had shown depths greater than 10 metres, with no major ice lenses encountered.

In addition to covering all exposed tailings, a major program of dam enhancement is planned during the closure activities. The sides of all the dams will be brought to at least a 2.5H:1V slope by the addition of quarried waste riprap. This will significantly enhance both the stability and erosion protection of all the dams.

Presently, the only perimeter dams that impound water are Dams 1A, 2, and 4. After construction of the Dam 1A spillway, Dams 1A and 2 will no longer impound water, as the base of both dams is at the 482m elevation and the water level will be maintained at or below the 480m elevation. The upstream and downstream sides will be re-sloped to provide geotechnical stability and erosion protection. The upstream side of Dam 4 is already at a minimum of 3H:1V slope, and as much as 4.5H:1V at the west abutment. With the amount of waste rock present on the upstream side, Dam 4 is essentially a shoreline.

The sides of the internal dams will also be re-sloped to a minimum of 2H:1V. Pond 2 is currently in contact with the sides of K Dam, M Dam, and N Dam, while Pond 1 water contacts Dam 3D. The downstream side of K Dam, currently built with a slope averaging 1.6H:1V, will be enhanced with riprap to a 2.5H:1V slope to provide additional geotechnical stability to the dam. The dam base is at 482 metres elevation and, since the final water elevation in Pond 2 will be at 480 metres, no water will be impounded against the side at closure. Pond 2 will also not be in contact with M Dam at closure. The sides of M Dam are built at a slope averaging 1.5H:1V, and stability will be enhanced by adding riprap to achieve a final 2H:1V slope. N Dam is a low containment at the north east end of Pond 2, adjacent to the end of M Dam. This dam will be in contact with Pond 2 and additional riprap armour will be placed on this dam, to achieve a 2H:1V slope (the slope is currently 1.8H:1V). Dam 3D separates Pond 1 from Cells 1 and 2. It is already a substantial structure, over 30 metres wide, having been reinforced with over 75,000 cubic metres of riprap in 1995. It is geotechnically stable and does not require any additional material.

5.5.6 Alternative Covers

An all inclusive water cover option for the closed cells had been considered. However, the additional cost of raising perimeter dams to provide the required water depth and freeboard, the added stability risk of water retaining structures, and the need for continued monitoring indicated that other options would be more practical.

Investigations into alternatives to the granular saturated zone cover option have been considered. Among these is the incorporation of an ice lens or layer, under the placed cover, to reduce heat transfer and thereby maintain cold conditions below the cover. This could be accomplished by constructing the insulating layer during the winter, over entrapped ice and snow. The problem with this alternative is that the esker can only be farmed during the summer, while it is thawed. Winter conditions would require blasting of the esker material, and would result in a very inefficient placement of the cover.

Another alternative considered was the use of coarse waste as the cover medium. This cover incorporates the concept of convective heat transfer to promote more rapid freezing of the tailings while preventing summer thaw. Rather than using a well graded fine grained material, such as the esker material, this alternative utilizes a 1 to 2 metre thickness of poorly graded, open-work waste rock to create a natural thermosyphon. Optimum size of the waste pieces would be in the order of 30 to 50 cm diameter, with minimal fines, to provide for large void spaces. The disadvantage of this alternative is that the resulting landscape would be impassable for animals and resistant to revegetation, since it is effectively a boulder field. Also, drilling, blasting and hauling of rock are significantly more expensive than farming esker material.

5.5.7 Revegetation

The harsh environments associated with the area can make it difficult, if not impossible, to carry out a successful revegetation program. The research department of Alberta Environment (Alberta Environmental Centre) has completed studies on indigenous plants for high alpine reclamation projects. Their studies have shown that the native plants are better adapted and provide a more consistent cover over the long term than introduced species. An assumption that local species will later re-invade an area revegetated with generic commercial mixes and take over the site is not always correct, as some foreign species can be competitive and persistent. A variety of alpine grasses are commercially available but they have not been tested in arctic environments.

The technology for commercial seed production is available to some extent, however the resources are small and a number of years are required in order to produce enough supply for any major project. As well, a seed mixture is the preferable method of revegetation, which requires additional preparation.

The areas at the Lupin site which may require revegetation enhancements are limited in type (covered tailings, abandoned roadways etc.), most being raised above the surrounding terrain, windswept and dry. The lack of suitable growth medium and unavailable soil amendments for post use reclamation make it much more difficult. The esker deposit is the major material type that would be used in restoration activities and lacks the organic/nutrient content that the surrounding vegetation has established. This is another reason why the native grasses etc., have considerably more success at re-establishment. The tailings cells that were covered by esker material in 1988 and 1995 have both started to re-vegetate on their own.

The procedure of scarifying reclaimed surfaces, as carried out successfully on Cell 1A, the old airstrip, and the East Zone crown pillar cover, will be continued in order to provide a microclimate for natural plant growth. Providing a rough surface enhances seed entrapment, moisture retention and wind protection.

An alternative to natural re-establishment and alien species use is the practice of native sod transplanting. This procedure involves the transplanting of blocks of soil to the restoration area which contain both the plant species and associated microflora. These "sod islands" provide a nuclei that plants and microorganisms can emigrate from. Many plant species produce rhizomes, suckers or shoots that are responsible for propagation. This is especially true in harsh, northern conditions where seed production may be minimal due to the short (and variable) growing season, moisture (lack of or excess) and other variables.

Sod transplanting may be a viable method of revegetation, and has been successful on Cell 1A, however, in an area with minimal growth medium in combination with a shallow active surface layer, the placement of sod for the restoration of one site may not justify the removal of sod from another established area.

For areas that have been restored with the use of esker material, the best practical technology available is to provide the most suitable substrate by surface preparation. This includes addition of heavy (large grain sized quarry material), surface scarification and contouring to provide proper drainage patterns to avoid erosion and ponding of water.

5.6 Tailings Containment Area Reclamation - Supporting Studies

A number of studies were carried out in 2004 which support the tailings area reclamation plan that Lupin has developed. Summaries of the final reports for these studies are given below.

5.6.1 Saturated Granular Zone Cover

As part of ongoing restoration activities, and as described in the 1988, 1995, 2003 and 2004 Annual Reports to the Nunavut Water Board, Lupin has continued to cover the exposed tailings in completed cells with between 1.0m to 2.0m of esker material. To date, approximately 880,000 square metres of exposed tails have been covered. It was planned (Kinross) to cover the remaining exposed areas, approximately 650,000 square metres, in 2005 and 2006; however, as the mine is now in care and maintenance, the remaining exposed areas will be covered at the time of closure

The previous abandonment and restoration plans prepared by Lupin proposed that the potentially acid-generating mine tailings would be encapsulated within permafrost upon closure of the mine. A suitably thick cover of esker material would be placed over the exposed tails, such that permafrost would aggrade through the tailings and into the base of the esker cover. The seasonal active layer would then be limited to within the inert esker cover. The permanently frozen condition of the tails would prevent the oxidation of the sulphides contained in the tails and the mobility of any metals contained in the tailings pore water.

As indicated in Holubec (2005), the mean annual air temperature (MAAT) at Lupin has been rising since the first measurements were taken at the Contwoyto weather station in 1951 and the rate of increase has amplified since 1980, as has been observed in Alaska and the Northern Global hemisphere. Based on a general relationship observed between ground temperature and MAAT (Smith & Burgess, 2000), a ground temperature of 0º C is observed at a MAAT of –4.4º C. A trend line for MAAT data from the period 1960 to 2004 shows that the MAAT of –10.3º C observed at Lupin in 2004 will warm to -4.4º C (i.e. .0º C ground temperature) in about 110 years. However, the trend line for the 1980 to 2004 data shows that the -4.4º C point will be attained in approximately 30 years.

The thawing index, which governs the thaw depth, or thickness of the active zone, has been increasing in relation to the MAAT. This trend indicates that the thawing index increased from about 850 degree-days to nearly 1000 degree-days from 1980 to 2004. The trends of the MAAT and thawing index indicate that the longevity of using permafrost encapsulation for the Lupin tailings may be limited to a lifespan of between 30 to 110 years.

Based on the possibility that this global warming trend should continue, and using design concepts described in MEND Report 2.21.1 (1992), MEND Report 6.1 (1993), and Holubec (2003), Lupin decided to change their tailings ARD mitigation strategy from one of permafrost encapsulation to that of encapsulation beneath a partially saturated granular cover.

Research on open water covers over tailings deposits has shown that the depth of the water cover is not governed by a criterion to create an oxygen barrier but to prevent the

mobilization of the tails by wave action and ice scour (Atkins et al, 1997). Research done by Noranda Technology Centre (Li et al 1997) found that 0.3 m depth of stagnant water over tailings is sufficient to inhibit their oxidation. As well, Li reports that even a thin (2mm) laminar layer of saturated inert granular material at the tailings interface could significantly reduce the amount of oxygen reaching the tails. If the saturated granular layer were as thick as 10cm, it is reported that the oxygen flux is decreased by more than two orders of magnitude. Column testing by CANMET (MEND 2.21.1) demonstrated that a saturated zone within an esker cover provides the same benefit as an open water cover, whereby tailings oxidation is prevented even if the tailings are unfrozen.

The saturated zone cover design at Lupin consists of two layers:

- A surface layer that restricts the rate of evaporation of the saturated esker material at the base; and
- A basal saturated layer of esker material that prevents oxidation of the underlying tailings.

This thin partially saturated granular cover has many advantages:

- It provides an oxygen barrier that is not dependent on having permafrost within the tailings;
- It is not sensitive to annual temperature changes or global warming;
- It will support vegetation because the water table will be closer to the surface in a thin layer of esker material;
- It decreases the required volumes of esker material and thereby reduces the disturbance of the esker deposits.

From the initial tails cover program in 1988, Lupin had continued to monitor the covered tailings to assess the effectiveness of the covers. As a result, Lupin has collected an extensive database on the performance of covered cells in permafrost areas.

As described in later sections of this report, various studies (Golder 2004a) have determined that the physical and chemical durability of the cover material is acceptable, that a positive water balance will be maintained within the cover during drought conditions, and pore water expulsion potential from the compacted tailings during thaw conditions is not an issue.

Data collected from the monitoring programs over the past 16 years includes ground temperatures, water levels within the cover, water quality within the cover, slope of tailings surface, thickness of tails deposition, moisture content of the cover, and particle size analyses of tailings and cover materials. Also, test pits have been excavated through the cover to the tails surface to examine for evidence of cryoturbation, oxidation at the tailings interface, presence of ice lenses, and condition of the tails/cover interface.

Ground temperature monitoring has shown that the annual thaw depth through the

esker cover into the tails varies from 0.2m to 0.9m below the tails surface, and that the unfrozen condition, in our present climate, lasts for less than 3 months. The thaw depth was seen to be greatly influenced by the thickness of the saturated zone within the esker material, such that the thicker the saturated zone was in the esker, the less the thaw depth penetrated into the tails. As explained above, this depth of thaw will increase if the global warming trend continues.

In 2002, nine water monitoring pipes were installed in Cell 1. Holes were dug through the esker cover and 15cm-diameter perforated pipes, lined with a geotextile filter, were installed so that their bases were approximately 15cm above the tails/esker interface. Water levels were measured in these pipes during the summer, from August 2002 to September 2004, when the saturated zone thawed. The results of this monitoring show that the saturation zone thickness in the esker cover of Cell 1 varied from an average of about 0.2 m around the perimeter of Cell 1, where tailings discharge took place, to an average of about 0.6 m in the central portion of the cell.

Nine test pits were dug with an excavator at several locations in Cells 1A, 1, 2 and 3 in September 2004 to gain information on esker cover thickness, presence and extent of a saturated zone within the cover, penetration of tailings into the esker material as evidence of cryoturbation, and the presence and degree of oxidation of tailings. The test pits were logged, photographed and selected samples were taken for moisture content and particle gradation determination. Esker cover thickness was observed to vary from about 0.9 to 1.3 m in areas where the tailings were not covered with a waste rock layer. In the two tests pits in the northwest corner of Cell 1, the esker cover was measured to be about 0.7 m. However, in this area the esker material was underlain by a layer of waste rock approximately 0.5m thick. In 8 of the 9 test pits, a saturated zone with free water was observed at the base of the esker material. The only pit not to show any saturation is located in Cell 3 in an area covered only 2 weeks prior to the pit excavation, so it did not have time to create a saturated zone by rainfall water infiltration.

No penetration of tailings into the esker material, or evidence of cryoturbation, was observed in any of the test pits. In the 7 test pits that encountered the tails interface, there was a clear horizontal linear boundary between the tails and sand, with no intermixing evident.

In two of the seven tests pits where esker material covers the tailings surface, minor oxidation of the tailings was observed. In both cases the tailings surface had been exposed for several years before a cover was placed and the depth of oxidation was judged to be less than 5 mm.

Moisture contents varying from 7.2% to 9.8% were determined from four samples of esker material taken from test pits in Cells 1A and 2. These samples were taken from vertical sections through the top 2/3rds of the esker cover in each pit, in the unsaturated

zone. As stated earlier, the zone at the base of the esker cover contained visible free water.

Water quality within the saturated zone of the esker cover has been monitored since 1998. The results of this monitoring are compared in the following table (Table 8) to the quality of ponded water atop the esker cover in Cell 1, and that of Ponds 1 and 2 to illustrate the improvement in water quality as it slowly filters through to the discharge point. The concentrations shown are averages of the results obtained in each of the areas over this period.

Table 8 – Water Quality Data Progression (average values)

Parameter	Units	NWB		Wells	Pit 2a	Cell 1	Pond 1	Pond 2
		Max Avg:	Max Grab:			ponded W		
Arsenic	mg/L	0.5	1	1.864	0.071	0.054	0.062	0.038
Cadmium	mg/L	n/a	n/a	0.003	0.002			
Copper	mg/L	0.15	0.3	0.171	0.283	0.027	0.049	0.013
Cyanide	mg/L	0.8	1.6	0.021	0.005	0.002	0.068	0.099
Lead	mg/L	0.1	0.2	0.062	0.006	0.002	0.001	0.001
Nickel	mg/L	0.2	0.4	1.212	0.875	0.123	0.094	0.087
Zinc	mg/L	0.4	0.8	0.425	0.437	0.123	0.262	0.193
pH		6.0 to 9.5	6.0 to 9.5	4.7	3.7	3.8	7.7	6.9

The results of the monitoring illustrate the following points:

- Water quality within the saturated esker zone generally exceeds the Nunavut Water Board discharge limits. However, the volume of water within this zone is small and will take considerable time to be flushed out.
- As the saturated zone water emerges at the Cell 1 pond, the water quality meets the NWB metals limits.
- Additional improvement in water quality, to that of meeting discharge standards, is found in Ponds 1 and 2.

The details of the many investigations in support of the saturated zone cover design are contained in the report "*Closure Plan for Lupin Tailings Containment Area*", completed by I. Holubec Consulting (Holubec 2005). This report is provided in Appendix 2.

5.6.2 Gravel Material Properties

Condition I.1.d in the Water License requires "*a comprehensive assessment of material*

suitability, including geochemical and physical characterization and availability for restoration needs, with attention to top-dressing materials, including maps, where appropriate, showing sources and stockpile locations of all borrow materials ".

The Fingers Lake esker borrow pit, located approximately 3 km south of the TCA, has been the source of the esker material used for covering the cells since 1995, and will provide the cover material for the restoration of the remaining cells. A comprehensive assessment of the properties of the gravel material was conducted by Golder Associates in 2004. The following laboratory tests were completed on representative samples of the esker material:

- Grain size distribution and maximum and minimum density to generally characterize the esker material;
- Cyclic wetting and drying to assess the physical stability of the esker material;
- Chemical analysis of the tailings decant water; and
- Chemical analysis of leachate fluid from a mixture of esker material and tailings decant water to assess the chemical stability of the esker material.

The following conclusions are reported by Golder (2004a):

- *The results of sieve analyses indicate that the esker material is classified as gravely sand according to the Modified Unified Soil Classification System.*

- *The results of 20 cycles of wetting and drying indicate that the percentage of mass lost by the specimen over the course of the test was 0.31 percent. This value is considered to be within the accuracy of the testing method; consequently, the results indicate that the esker material is physically stable.*

- *Comparisons of the results of chemical analysis of the tailings decant water with that of the tailings decant water after it was leached through the esker material show negligible change in metals content. Based on these results, it does not appear that the esker material will physically degrade on exposure to the tailings decant water. Further, it appears that the chemistry of the tailings decant water will change relatively little if this fluid leaches through the esker material. It is, therefore, concluded that the esker material is a suitable cover material for the tailings deposition cells.*

The details of this study are contained in the report "Studies Related to Water Licence Requirements and in Support of Reclamation Planning", completed by Golder Associates (Golder 2004a). This report is provided in Appendix 3.

5.6.3 Cell / Pond Interaction

Condition G.1.d in the Water Licence requires a "*study of the potential for interaction between covered cells and flooded areas of the Lupin Tails Containment Area (TCA), including thermal analyses and modeling of the interaction between the ponds, the frozen-core perimeter dykes, and frozen tailings within cells, as well as the thermal effects of proposed pond elevations*".

This thermal analysis was carried out in a project conducted by Golder Associates in the summer of 2004. A number of scenarios were examined in the study. The effects of a fluctuating Pond 2 water elevation upon K Dam and the frozen tailings impounded by it in Cell 3, as well as the effects on Dam 1A, were evaluated. The results of the thermal analyses indicate that, after an elapsed period of 20 years, the thaw zone does not extend to the frozen tailings when as much as 8.5 m of water is impounded against the downstream face of K Dam. This is a conservative assessment, as it is only possible at present to store a maximum of 5.5 m of water against the dam. The extent of thaw progression should be greater in gravely sand esker material, silty sand till and run-of-mine waste than in frozen tailings. The results are, therefore, considered as reasonable and a somewhat conservative representation of the interaction between flooded areas and other internal dams within the TCA.

The results of this study are moot, however, considering that the elevation of Pond 2 will be regulated by a spillway constructed at Dam 1A, which will limit the water level in the pond to a maximum of 480m elevation. This is the elevation of the base of K Dam, so no water will be impounded against this dam. The base of M Dam is variable between 482m to 483m elevation, so no water will be impounded against this dam either.

The details of this study are contained in the report "Studies Related to Water Licence Requirements and in Support of Reclamation Planning", completed by Golder Associates (Golder 2004a). This report is provided in Appendix 3.

5.6.4 Pore Water Expulsion Potential

Condition I.3.b in the Water License requires "*an outline of methods to contain potential pore water expulsion from the TCA*".

This study was carried out by Golder Associates during the summer of 2004.

In order to design containment methods, the mechanisms that could potentially lead to the expulsion of pore water from the TCA must be analyzed. These were determined to be:

- Loss of pore water from the TCA via talik seepage at depth;
- Consolidation of unfrozen tailings situated against a perimeter dam (due to increased loading and/or thawing); and

- Leaching of pore water as a result of infiltration through the active layer within the tailings and cover.

The talik seepage mechanism refers to seepage of pore fluid through an unfrozen zone which has developed beneath a frozen core dam, where the unfrozen zone is the result of warming due to adjacent impounded water. Thermistors installed in all the dams which impound water in the TCA show that no thaw zones exist under these dams at present. The results of the thermal analysis conducted for the Pond/Cell interaction study indicate that, after 20 years with a maximum depth of impounded water in a pond, such a talik would not form.
Golder (2004a) concludes that "*it is not anticipated that impounded water within the TCA would result in unfrozen zones that underlie the tailings impoundment structures. The potential mechanism of pore water expulsion from the TCA as a result of talik seepage is considered unlikely."*

The consolidation mechanism refers to pore water expulsion resulting from consolidation of unfrozen tailings due to the loading from the overlying esker cover layer. The active zone within unfrozen tailings extends for a depth of 2 metres below the tails surface. Using known consolidation and physical properties of the tailings, and a 1-metre thick esker cover, the Golder study determined the release of tailings water from the pore voids due to consolidation to be approximately 0.03 m^3 of pore water for each 1 m^3 of tailings within the active layer, or 0.06m^3 of pore water for the 2 metre active zone depth. It was also determined that the tails would reach maximum consolidation, due to the loading of the overlying cover, within 30 days following the placement of the cover. This consolidation mechanism would only be active for a brief period and would not persist into subsequent seasons.

The thermal analyses conducted in the Golder study indicate that there is a potential of lateral
pore water flow through the active layer and over the crest of the frozen dam core. This potential for lateral pore water flow and leaching is limited to the periphery of the tailings cells, adjacent to the impoundment dams, and would exist only when there is sufficient surface water infiltration (due to rainfall in the summer) to generate a significant lateral hydraulic gradient within the active layer. Two conditions must be present for this lateral flow mechanism to be active. First, sufficient infiltration must occur into the esker cover material to provide a water table within the active layer. Second, the water table within the active layer must be higher than the frozen core of the dam. The probability of the above conditions being present at the same time depends upon the climate, the amount of rainfall and its timing.

The highest net precipitation levels occur in May and June, due to the combination of spring freshet and rainfall. However, the active layer within the esker cover materials is shallow during this period and the potential for pore water to leach into the active layer water is, therefore, low. The maximum depth to the frozen dam cores beneath the dam crests is expected to be in later summer/early fall; however, based on the

results of the climate and hydrology studies, evaporation typically exceeds precipitation during this period. Consequently, the potential for a water table within the active layer that is higher than the elevation of the frozen dam core is relatively low. The conclusion that can be drawn from this is that expulsion of pore water from the TCA via leaching and lateral flow would occur only with a combination of warm spring/summer and high precipitation events in the late summer/early fall, and the extent of the leaching would be limited to the periphery of the tailings cells adjacent to the dams.

Although the potential for expulsion of pore water from the TCA via the lateral flow and leaching mechanism is low, a number of approaches may be considered to further reduce it. The first approach would be to limit the active layer in the esker covered tails at the periphery of the cells by providing an additional metre of esker cover, a few metres wide, at the upstream edge of the cell, adjacent to the dam. This would maintain the tailings in a frozen state and raise the active zone to within the esker cover. The other approach would be to raise the height of the dam crest, so as to raise the level of the frozen core to an elevation above the level of the active zone in the tails. The thermal models indicate that more material would be required to carry this out than for the first alternative, and dam stability could also be affected due to the increased loading.

Implementation of the first alternative was performed as follows: A peripheral strip of esker was added to the upstream edge of Dam 3D, adjacent to Cell 1, during the cell covering program in 2004. Another peripheral strip was added to the upstream edge of Dam 6, at the west edge of Cell 3. K Dam, which separates Cell 3 from Pond 2, was constructed with an impermeable liner, and therefore does not require additional material. Additional strips of esker cover will be added to unlined dam/cell peripheries during 2005.

The details of this study are contained in the report “Studies Related to Water Licence Requirements and in Support of Reclamation Planning”, completed by Golder Associates (Golder 2004a). This report is provided in Appendix 3.

5.6.5 Climate and Hydrology Study

The granular esker material that is being used to cover the exposed tailings serves two purposes. It provides a cap on the exposed tails, thereby preventing wind dispersal of dried tailings dust, and the saturated base of the cover provides a barrier to oxidation of the underlying tails. It is critical that a positive water balance is maintained within the cover system for the oxidation barrier to be effective.

A climate and hydrological study was carried out by Golder Associates during the summer of 2004. The objectives of this study were twofold:

- Summarize the historical climate conditions of the Lupin Mine TCA; and

- Estimate the probability of maintaining a positive water balance over the surface of the TCA.

The water balance for the study area at Lupin was assessed on the basis of regional as well as site-specific information on temperature, precipitation (rainfall and snowfall), evaporation and runoff. Climatic data have been collected at the Lupin weather station, under contract to Environment Canada, on a daily basis since 1982. Monthly summaries of the temperature and precipitation data for Lupin are presented in Tables 3 and 4, in Section 1.5.1. An evaporation station has only recently been installed at Lupin, so mean annual and mean monthly evaporation data were derived from data recorded at the Norman Wells Airport, which is located at the same latitude as Lupin and has a similar precipitation profile. Differences in mean temperature between Lupin and Norman Wells did not allow for direct transfer of evaporation data. A relationship between mean monthly temperature and total monthly evaporation was established for Norman Wells. This relationship was used to calculate pan and lake evaporation for Lupin using mean monthly temperatures. Evaporation was only calculated where the monthly mean temperatures were greater than zero.

For the purposes of the water balance analysis at Lupin Mine, it was assumed that the amounts of snowfall "under-reported" and snow accumulation lost to sublimation were comparable and, thus, no adjustments to the recorded snowfall values were deemed necessary.

A monthly water balance was conducted based on a 21-year series of monthly precipitation and evaporation data derived for the study area. The objective of the analysis was to characterize the availability of inflow into, or the runoff from the TCA.

Golder (2004a) reached the following conclusions in the study: *"The water balance results indicate that there are relatively high probabilities of surface moisture deficit during any one summer month at the Lupin Mine TCA. However, the results also indicate that the probability of surface moisture deficits in two consecutive summer months is relatively low. More specifically, the results indicate that the cumulative surface moisture deficit in two consecutive summer months is unlikely to exceed 50 mm. Given the proposed cover thickness of 1 m, the probability of drying out the entire cover is considered low. In other words, it is considered likely that partial saturation can be maintained within the cover system for the given climate and hydrological conditions at the Lupin Mine area, and the cover layer is anticipated to perform as an oxidation barrier."*

The details of this study are contained in the report "Studies Related to Water Licence Requirements and in Support of Reclamation Planning", completed by Golder Associates (Golder 2004a). This report is provided in Appendix 3.

5.6.6 Ecological Risk Assessment

The main purpose of the granular cover is to isolate the underlying tailings from the surface environment. This will prevent wind dispersal of dried tails, minimize contact with the fauna, and prevent oxidation of the tailings by creating a barrier layer of saturated sand over the tails. In order to gain a better understanding of the ecological implications of this reclamation strategy, a risk assessment was conducted to evaluate the likelihood of adverse ecological/environmental effects occurring as a result of the mobility of the tailings fluids within the TCA. Aquatic risks were not evaluated because Ponds 1 and 2 are not intended to be aquatic habitat, and spillways will be constructed to prevent fish movement into the ponds. The ecological risk assessment, conducted by Golder Associates (2004b), examined:

- The identification of potential ecological receptors
- The identification of constituents of ecologic concern
- The identification of toxicity and bioavailability of constituents of concern
- The identification of potential exposure pathways, including potential migration into the surrounding ecosystem through overtopping of, or limited transmittal through, the containment structures
- Ecological risk analysis and assessment, including a discussion of the uncertainties associated with the assessment, and
- Remediation alternatives, if necessary.

The following wildlife receptors were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);
- fox (*Vulpes vulpes*);
- wolves (*Canis lupus*);
- hare *(Lepus arcticus*);
- arctic ground squirrel (*Spermophilus parryii*);
- ptarmigan (*Lagopus lagopus*);
- rough legged hawk (*Buteo lagopus*);
- snipe (*Gallinago gallinago*); and,
- long-tailed duck (*Clangula hyemalis*).

The risk assessment focused on the potential risks to wildlife health due to exposure to food (vegetation, invertebrates and prey, as applicable), water and incidental soil ingestion. Risks to human health were also evaluated based on consumption of caribou that may have the potential to be exposed to metals and cyanide from the TCA. Humans are not expected to be directly exposed to metals and cyanide in the

TCA by incidental ingestion of tailings or by drinking effluent.

Exposure to metals and cyanide by wildlife that may inhabit areas near the mine, and by people that may consume caribou meat, was estimated by determining the following:

- the concentrations of substances in soil, sediment, plants and water;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the mine or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with substances (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the mine site (i.e., days/year);
- typical soil, sand, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and,
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the hazard potential of substances was estimated by considering the following:

- determining whether the quantity of substances in soil, sediment and water exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each substance; and
- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (toxicity benchmarks).

Results of this ecological risk assessment show that:

- Exposure to humans and wildlife via water from within the capped tailings is not significant. Based on the results of the engineering feasibility of covering exposed tailings with esker material, it is not expected that any appreciable amount of pore water will seep into the ponds. Nor is it expected that water at the tailings interface will move upward into the root zone of plants growing at the surface of the esker material (Golder 2004a).

- There is no risk to human or predator health due to the ingestion of meat from caribou that migrate through the TCA. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all potential receptors would be safe from exposure to metals from the study area.

- A potential for risk was identified for individual shorebirds and waterfowl (snipe and long-tailed duck) due to potential exposure to arsenic and cyanide in invertebrates in Ponds 1 and 2. However, it is very unlikely that substantial numbers of invertebrates are present in the ponds, and the numbers that might be present are unlikely to fully support dietary needs of the birds. None of the sediment samples taken from Ponds 1 or 2 for this study were seen to contain any benthic invertebrates. Risks to populations of shorebirds and waterfowl, as opposed to individuals, are unlikely due to the low numbers of birds that make use of the ponds as a resting place. Based on a literature review, 15 pairs of shorebirds and 8 pairs of ducks may use the Lupin Mine TCA as a nesting and feeding area during a given season. Again, because conservative assumptions and many layers of safety were applied to the wildlife health risk assessment, it is unlikely that any significant risk exists to shorebirds and waterfowl.

The details of this study are contained in the report “Ecological Risk Assessment for the Lupin Mine Tailings Containment Area”, completed by Golder Associates (Golder 2004b). This report is provided in Appendix 4.

6. RIP RAP QUARRY

A rip rap quarry will be developed within the footprint of the TCA to provide the course broken rock needed to enhance dam stability, provide additional armour for the faces of the embankments, and for use as inert cover material. Approximately 100,000 cubic metres of broken rock will be required. The quarry location, refer to Figure 3 – 2004 Lupin TCA, will be on a hilly barren outcrop of phyllite just north of Cell 3 and east of the perimeter road.

Four rock samples were taken from the area and tested for ARD potential. The table below lists the results of this testing. All samples show that the rock will be well suited to be used as cover material and will not be a concern for possible ARD generation.

Table 9 - Rip Rap Quarry Sample ARD potential Test Results

Sample	Fizz	NNP	NP	pH	MPA	NP:MPA	S%
50133	1	3	5	7	1.6	3.20	0.05
50134	1	14	15	8.6	0.6	24.00	0.02
50135	1	5	5	7.8	0.5	16.00	0.01
50136	1	8	8	8.1	0.5	26.88	0.01

An area of approximately 25,600 square metres (160m x 160m) will be excavated by blasting to a depth of 2.5 metres. There is little to no overburden in the footprint of the quarry area, so stripping will not be required. Access to the quarry site is immediately off the road to the west of K Dam, so any affect on the tundra will be minimized.

As the quarry location is a hill top, there will be little to no depression remaining after completion of the operation. The quarry will essentially remove the top of the hill. All drainage off the existing hill drains into Pond 2. The quarry will be configured such that this drainage pattern will not change. Quarry activities (drill, blast, muck, haul) will take place during the summer of 2006.

7. CLOSURE MONITORING PLAN

The Guidelines for Abandonment and Restoration Planning in the Northwest Territories (1990) state that *"the goal of restoration is to prevent progressive degradation, and to enhance the natural recovery of areas affected by mining"*. This closure monitoring plan will measure the effectiveness of the reclamation activities, and provide the means of assessing when the activities have reached the stated goal.

7.1 Timeframe

The frequency of data collection will vary depending on the phase of reclamation activity. During the 2005 care and maintenance period, when reclamation activities are continuing, regular monitoring will be carried out, appropriate to the activity being monitored. During the final reclamation phase, when demolition and cleanup activities in the mine site area are underway, this rigorous monitoring schedule will be continued. Some of the monitoring activities will be dictated by provisions in the present water license, i.e. daily and weekly water sampling at SNP stations during TCA water effluent discharge to the environment. Ground temperatures (thermistors) and water levels and quality within the TCA area will also be monitored on a frequent basis. The present operation plan is for Lupin to remain on care and maintenance status at least through 2008.

Once the reclamation and closure activities have been substantially completed, the frequency and type of monitoring will be reduced and will focus on assessing the performance of the reclamation measures. As the site will be abandoned after the final demolition phase, periodic site visits will be scheduled for these assessments. This closure phase of monitoring is anticipated to last for 5 years after site abandonment.

7.2 Data Collection and Reporting

The following components will be monitored over the reclamation and closure periods:

- Water quality of effluent discharge and surrounding lakes, as per parameters stated in the water license;
- Seasonal water levels;
- Thermal condition of the earthworks and tails;
- Geotechnical inspections of earthworks, as appropriate.

As required by the Metal Mining Effluent Regulations (MMER), an environmental effects monitoring (EEM) study design was submitted to Environment Canada. The components of that biological monitoring study design include a site characterization, a fish population study, a fish tissue study, and a benthic invertebrate community study. The study was carried out in the summer of 2005 in reference and exposure areas of the TCA. The full report is available in Appendix 5.

Figure 6 (Appendix 1) shows the locations of the various sites that were used in the water quality monitoring program. Figure 7 shows the location of the thermistors, as well as of the major earth structures, within the TCA that will continue to be monitored.

In addition to the tailings cell cover program, other remediation activities, such as scarification of unneeded roads and abandoned storage areas, removal of associated culverts and removal of obsolete tails line and structures from the TCA will be undertaken. The progress of all reclamation activities will be monitored, documented, and reported to the Nunavut Water Board in the normal monthly reporting process.

Monitoring results will be reviewed by Zinifex Canada Inc, as the data is received. Where action is required to correct any deficiency identified by the sampling results, that action will be carried out in a timely manner. Throughout the reclamation phase, reporting to the NWB will be carried out as required by the water licence, in the case of effluent release, and at least quarterly for the other components. Throughout the closure phase, monitoring will take place quarterly and will be reported on as such. A comprehensive annual report will be prepared for submission by March 31 of the following year, which will describe the reclamation activities conducted over the previous year, the results of the current monitoring programs, a compilation of data from the monitoring programs, and a presentation of the plan of activities for the coming year. As the monitoring demonstrates that the reclamation program is achieving its objectives and that the area is environmentally stable, Zinifex expects that long term monitoring requirements will be reduced.

7.3 Water Quality Management and Monitoring

Water management and monitoring at the Lupin site is a requirement of the water licence. A total of 8 Surveillance Network Plan (SNP) station locations with sampling frequencies and sampling parameters are specified in Schedule 1 of the current water licence. Part D of the water licence specifies the conditions applying to waste disposal, including the maximum average allowable concentrations of various parameters. Sample collection and reporting from the majority of these stations is normally done just prior to, during, and just after discharge to the environment.

Lupin is under care and maintenance and water discharge is kept to a minimum. The

only reason for discharge will be to relieve the system of excess water from spring freshet and precipitation. Zinifex Canada Inc. believes that a discharge of water may be needed in 2008. It is planned that this discharge will correspond with the timing of the EEM study planned for 2008.

Water analyses have been performed by an outside, accredited laboratory since 1998. Prior to that time, an internal Lupin lab processed all the samples, with check analyses sent to an outside lab on a regular basis.

Table 10 lists the location of the current SNP monitoring stations. These locations are illustrated in Figure 6 (Appendix 1). UTM coordinates are provided for each sample point to ensure consistency in the sampling location (in Sun Bay, for example).

Table 10 – Water Quality Monitoring Stations Location

Station No.	Type	UTM Coordinates		Location Description
925 - 01	SNP	7294940N	490040E	Freshwater intake from Contwoyto Lake
925 - 10	SNP	7289704N	485907E	Pond 2 discharge at Dam 1A
925 - 14	SNP	7293018N	490182E	Decant structure from the sewage lakes disposal system
925 - 20	SNP	7290077N	480314E	West end of Seep Creek before discharge into Unnamed Lake
925 - 21	SNP	7290020N	479760E	North end of Concession Creek before discharge into Unnamed Lake
925 - 22	SNP	7291356N	479200E	Inner Sun Bay near centre
925 - 24	SNP	7292964N	478947E	Inner Sun Bay near narrows
925 - 25	SNP	7293182N	478450E	Outer Sun Bay

7.3.1 Reclamation Period Monitoring - Care and Maintenance

During any discharge period, all monitoring requirements and frequencies stipulated by the water licence will be carried out. In addition to this monitoring, Lupin will also be conducting a biological, effluent and water quality monitoring program as required, adhering to EEM requirements. A study design for the 2nd phase of the EEM program will be submitted to Environment Canada before Feburary 2008.

7.3.2 Reclamation Period Monitoring – Demolition Activities

If no further mining options are available, the activities necessary to remove the Lupin infrastructure could commence in 2006, based on approval of a final site closure plan. These activities include:

- demolition of all structures,

- development of the demolition debris landfill,
- development of a waste rock quarry in the TCA,
- soil and PAG rock remediation/removal,
- placement of remaining cover on Cell 5,
- final discharge from Pond 2 to the environment,
- removal of syphons from Dam 1A,
- final discharge from sewage pond to the environment,
- removal of syphons from lower sewage dike,
- spillway construction on Dam 1A and sewage dike,
- culvert removal,
- scarify all roads,
- demobilize all salvage and equipment (winter road 2007).

As stated in Section 8.3.2 above, an MMER study design will be submitted to, and approved by, Environment Canada 6 months prior to starting the field program. This study will be carried out in 2008.

During any discharge period, all monitoring requirements and frequencies stipulated by the water licence will be carried out. An environmental site assessment of the mine site area will be carried out to help identify areas of the Lupin site that may require specific remediation. The monthly reports to the water board will contain the details of all remediation activities and monitoring results.

7.3.3 Closure Period Monitoring

Once the final demolition and remediation activities have been completed, the site will be completely abandoned. Monitoring activities through the closure period will extend for a five-year duration and will focus on collecting information necessary to evaluate the effectiveness of the reclamation activities. As there will no longer be personnel at the site, water quality monitoring and geotechnical assessments of the spillways during the first 2 years of the closure period will be conducted during monthly site visits between June and September, when there is open water. If the results of the site assessments over this initial 2-year period are acceptable, the frequency of site assessment and sampling will be reduced to discrete visits in July and September in subsequent years.

7.3.4 Progressive Reclamation Activities

Reclamation at the Lupin mine has been on-going since the initial tailings cell (Cell 1) was filled to capacity in 1995. Prior to this, a test portion of Cell 1, referred to as Cell 1a, had been filled and covered with esker material as a final cover layer. Temperature monitoring thermistor strings were installed at various depths in this area to provide an indication of the amount of esker material needed to maintain the

tailings frozen and allow the active thaw zone to be restricted to the esker cover.

In 1995, a one metre layer of esker material was placed on Cell 1 and a portion of Cell 2 with thermistor strings installed to monitor the temperature below the ground surface. In 1997, additional cover work was completed on Cell 2 which is currently 3/4 complete with a one metre cov

In 1998, while under care and maintenance, further reclamation work was completed in another area. The Crown Pillar area, the area where the ore zone is present near the surface, was reclaimed to the extent possible through filling in the mined out areas of the East Zone and Centre Zone. These areas had been mined from the surface in 1996 and 1997. A portion of the Centre Zone and the West Zone remain to be mined. Once completed, these area too will be reclaimed and the entire area contoured to the natural topography.

In addition to the above, general reclamation has taken place in numerous other areas including many unused roads, and equipment storage areas. This also included the original Twin Otter airstrip located south of the mine site parallel with the second sewage lake. All associated piping was removed from the original construction camp water supply lake and the roadway taken out of service by re-grading and scarifying the roadbed to promote natural re-vegetation of the ground.

Near future reclamation will include the final addition of cover material to the exposed area of Cell 2 and some minor leveling of an area in Cell 1. Further closure of other cells is currently being reviewed with the assessment of mine life and the capacity of the cells. Cell 3 is near capacity, however if the review study determines that the cell should be upgraded and capacity increase, then closure would come near the end of mine life.

The Centre Zone Crown Pillar open stope, which was previously open from the 27-metre level to surface, was filled with cemented tailings paste backfill during 2003. Approximately 100,266 dry short tons of paste, at a cement content of close to 1%, were placed in the opening. Once the paste dried, it was then topped with surface material that had been stored when the original ground cover was removed to obtain access for mining. This activity has served a dual purpose by backfilling of one of the open crown pillars at surface as a step towards reclamation of the site, and by reducing the amount of tailings directed towards the surface TCA impoundment.

Progressive reclamation activities in the TCA during 2003 saw two areas within Cell 3, designated cells 3a and 3b, covered by approximately 1.0 metre of esker gravel. The work was carried out between August 5 and September 23, 2003, with a total area covered of approximately 62,350 square metres. The esker material is an effective cover medium that serves to eliminate dispersal by wind of dry tailings, and the embedded moisture layer prevents oxidation of the underlying tails and provides support for plant growth.

In 2003, additional site information was accumulated in support of the "Partially Saturated Granular Cover" program for tails reclamation. Monitoring of pore water quality and the saturation status of the esker cover in Cell 1 continued from the previous year. Further to this work, a test pad was constructed in Cell 1 by effectively isolating a 20 metre by 40 metre area from the rest of the cell. This was accomplished by installing an impermeable liner in a 2.4 metre-deep trench surrounding the area, anchored well below the active zone. A thermistor and 2 water sample pipes were installed within the test pad area. The information gathered from this exercise in 2003 and ensuing years will be added to that previously obtained in support of the Partially Saturated Granular Cover program endorsed by Igor Holubec, geotechnical specialist.

Progressive reclamation activities in the TCA during 2004 saw a major portion of Cell 3, the remainder of Cell 2, and a small portion of Cell 5 covered by a minimum of 1.0 metre of esker gravel. The work was carried out between July 6 and September 19, 2004, with a total area covered of approximately 328,794 square metres. The esker material is an effective cover medium that serves to eliminate wind dispersal of dry tailings, and the embedded moisture layer prevents oxidation of the underlying tails and provides support for plant growth. Examples of the tailings cover activity undertaken in 2004 can be seen in photos 3 through 8. Figure 3 shows the extent of the covered cells in the TCA at the end of 2004

In 2004, additional site information was accumulated in support of the "Saturated Granular Zone Cover" program for tails reclamation. Monitoring of pore water quality and the saturation status of the esker cover in Cell 1 continued from the previous 2 years. Further to this work, a series of 9 pits were excavated through the esker cover in Cells 1, 1A, 2 and 3 to check for cover thickness, moisture content, and condition of tails/cover interface. This work confirmed that a saturated zone exists at the base of the esker cover (see photos 9 and 10), which effectively isolates the underlying tailings from an oxidizing environment. A detailed description of this program is contained in the 2004 Abandonment and Restoration Plan, previously submitted to the Board.

Reclamation activities in the TCA during 2005 saw a major portion of Cell 5 and another portion of Cell 3 covered by a minimum of 1.0 metre of esker gravel. The work was carried out between June 23 and September 28, 2005, with a total area covered of approximately 383,001 square metres. The esker material is an effective cover medium that serves to eliminate wind dispersal of dry tailings, protects against contact with exposed tails by fauna, and the embedded moisture layer prevents oxidation of the underlying tails and provides support for plant growth.

Approximately 250,000 square metres of exposed tailings remain to be covered. This work was scheduled to be completed during the summer of 2006; however, due to the premature shutdown of the 2006 winter road, Lupin did not receive enough fuel

to carry out the program in 2006. The Lupin property was been sold to Wolfden Resources Ltd in turn is now owned by 2007 Zinifex Canada Inc. Any future reclamation activities carried out on the site are now the responsibility of Zinifex Canada Inc. Figure 3 also shows the extent of the covered cells in the TCA at the end of 2005.

8. REFERENCES

Atkins R.J., Hay D., and Robertson J.; *Shallow Water Cover Design Methodology and Field Verification*; Proc. of 4th Int'l Conf. on Acid Rock Drainage, Vancouver B.C., Vol 1; 1997

CanZinco Ltd.; *Nanisivik Mine 2004 Reclamation and Closure Plan*; Feb 2004

Darroch, B.A., Woosaree, J. and James, B.T.; *Native Grasses For Reclaiming Mine Sites In Alberta*; Paper presented at Sudbury '95, Conference on Mining and the Environment; May 1995.

DIAND; *Mine Site Reclamation Policy for Nunavut*; 2002

DIAND; *Guidelines for ARD Prediction in the North*; Sep 1992.

Echo Bay Mines Ltd., *Lupin Operation; Interim Abandonment and Restoration Plan*; Apr 2001.

Gartner Lee Ltd.; *Nanisivik Mine Reclamation and Closure Monitoring Plan*; Feb 2004

Golder Assoc.; *Studies Related to Water Licence Requirements and in Support of Reclamation Planning (Lupin Mine)*; Dec 2004a

Golder Assoc., *Ecological Risk Assessment for Lupin Mine Tailings Containment Area*; Dec 2004b

Golder Assoc.; *2004 Dam Safety Review, Perimeter Tailings Dams*; Dec 2004c

Holubec, I. and Hohnstein, D.; *Partially Saturated Granular Cover for Reactive Tailings in Permafrost*; paper presented at 7th International Symposium of Mining in the Arctic, Iqaluit, NU; Apr 2003.

Holubec Consulting; *Covers for Reactive Tailings Located in Permafrost Regions Review* (Draft); prepared for Mine Environment Neutral Drainage (MEND) Program; May 2004

Holubec Consulting; *Lupin Operation – Closure Plan for Tailings Containment Area*; Jan 2005

Klohn Leonoff; *Acid Rock Drainage Study, Lupin Mine, Northwest Territories*; Mar. 1992a.

Klohn Leonoff; *Assessment of Water Chemistry and Remedial Measures for the Lupin Tailings Effluent System*; Jul 1992b.

Klohn Leonoff; *Column Leaching Study, Evaluation of ARD Control Measures*; Dec 1993.

Klohn-Crippen; *Tailings Reclamation Test Cover Program, 1994 Report of Activities*; Aug.
1995.

Li, M.G., Aubé, B., and St-Arnaud, L.; *Considerations in the Use of Shallow Water Covers for Decommissioning Reactive Tailings*, Proceedings - Fourth International Conference on Acid Rock Drainage, Vancouver, B.C., Canada; May 1997

MEND 2.21.1; *Development of Laboratory Methodologies for Evaluating Effectiveness of Reactive Tailings Covers*; Univ. of Waterloo and Noranda Technology Centre; Mar 1992.

MEND 6.1; *Preventing AMD by Disposing of Reactive Tailings in Permafrost*; Geocon; Mar 1993.

Northwest Territories Water Board; *Guidelines for Abandonment and Restoration Planning in the Northwest Territories*; Sep 1990.

Price W.A., and Errington J.C.; *Guidelines for Metal Leaching and Acid Rock Drainage at Minesites in British Columbia*; Aug 1998.

Reid, Crowther & Partners: RL&L Environmental; *Report on Aquatic Studies Program for Echo Bay Mines Ltd*; Feb 1985

URS Corporation; *ARD Assessment*, Lupin Mine; Jan 2005.

APPENDIX I

FIGURES

APPENDIX II

HOLUBEC REPORT

Kinross Gold Corporation

LUPIN OPERATION

CLOSURE PLAN FOR

TAILINGS CONTAINMENT AREA

JANUARY 2005

I. Holubec Consulting Inc.

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1.0 INTRODUCTION

Lupin Operations, now part of Kinross Gold Corporation, has operated a gold mine on the northwest side of Contwoyto Lake, Nunavut, since 1982. It is presently operating on a renewed Water License NWB1LUP0008 that extends until June 30, 2008. This report presents the history of the tailings containment area, the proposed remediation of this area and supporting information for the proposed esker covered tailings design. It is presented in support of the 2004 Abandonment and Restoration Plan submitted by the Lupin Operations (Lupin) to the Nunavut Water Board in January 2005.

A Tailings Containment Area (TCA) was developed in a rolling topography approximately 6 km south of the Lupin mine and mill complex. This site was selected after Kilborn and Geocon (Geocon 1980a & 1980b) had conducted two site selection exercises that showed the existing site had the largest storage capacity requiring limited dam construction. After about 10 years of operation the other areas would have required much larger dams and considerably longer dams extending along its perimeter.

It was created in 1981 by the construction of four small height dams and two smaller divider dikes creating a self-contained watershed from where excess water is discharged annually under controlled conditions.

The TCA was operated as a contained water facility until 1985. Increased production of ore resulted in the adoption of a tailings management strategy that deposits the tailings within cells (Wilson 1989). Excess water from these cells is directed into two ponds in tandem within the TCA that improves the water quality before the water is discharged. Since 1985, water was discharged from a downstream polishing pond to control the water level within ponds. This tailings management strategy has been in practice to this date. The mine was shutdown during 1998 and 1999 for a shorter period over the winter months in 1993/94.

Progressive reclamation was started in 1988, when one of the filled cells (Cell 1A) was covered with 0.5 m of sand and gravel from a nearby esker. An additional 0.5m of esker cover was placed on Cell 1A in 1995, and a 1.0 m esker cover was placed on Cell 1 and most of Cell 2 during the same period. Cells 3A and 3B, two small contained areas within Cell 3, were covered by 1.0 m of esker in 2003. Approximately 60% of the remainder of Cell 3 was covered during 2004.

This report presents the background information of the TCA, the proposed closure plan of the TCA and back-up information for the proposed tailings cover design that has been collected over many years of monitoring.

The report contains large quantity of information that is given within the main text of this report and four Appendices. The main report contains key photos and figures that provide an overview of the Lupin site, extensive monitoring that has been done and all the tables. The Appendices provide more detailed information as follows:

Appendix A. - Photographs
Appendix B –Supporting figures
Appendix C – Ground temperature profiles
Appendix D – Stability analysis results

In the text, photos that are given in Appendix A are listed as Photo 1 etc and all figures that are located given in the Appendices B, C and D are given as Figure 1B, Figure 1C or Figure 1D respectively.

2.0 TAILINGS AREA BACKGROUND

2.1 Geomorphology and geology

The Contwoyto Lake area lies within the Upland unit of the Kazan physiographic region of the Canadian Shield. The area was glaciated during the Pleistocene Epoch (Blake 1963). The area is overlain by predominantly a silty sand till, with gravel and boulders, occasionally overlain by glacio-fluvial and glacio-lacustrine sand and gravel deposits. Esker and abandoned beaches are common landforms. Bedrock belongs to the Yellowknife Super group of the Achaean Epoch. The rock consists of a mixture of low grade metamorphosed argillite, siltstone, slate, greywacke and quartzite; generally described as phyllite.

2.2 Climate

Contwoyto Lake area is located in the continuous permafrost region with mean annual air temperature (MAAT) being –12.0ºC based on 1951 to 1980 Canadian Normals (Environment Canada 1982). Monitoring was conducted at the Contwoyto Lake climate station at 65º 29’ N and 110º 22’ W from 1959 to 1981, and subsequently at the Lupin mine weather station at 65º 47’ N and 111º 12’ W from 1982 to the present.

The MAAT has been rising since the first measurements were taken in 1951 and the rate of increase has amplified since 1980 as has been observed in Alaska and the Northern Global hemisphere (Anisimov & Fitzharris 2001). The combined MAAT measurements from the Contwoyto Lake and Lupin climate stations are shown in Figure 2-1. Based on a general relationship observed between ground temperature and MAAT (Smith & Burgess 2000), a ground temperature of 0º C is observed at a MAAT of –4.4º C. Based on the two trend lines, one for 1960 to 2004 data and the second for the 1980 to 2004 data, the MAAT of –10.3ºC at 2004 will warm to
-4.4º C in about 110 years based on the long-term temperature records but only about 30 years based on the MAAT trend since 1980.

The thawing index that largely governs the thaw depth, or thickness of the active zone, has been increasing correspondingly with the MAAT, as shown on Figure 2-2. The trend shown on Figure 2-2 indicates that the thawing index increased from about 850 C-degree-days to nearly 1000 C-degree-days from 1980 to 2004. The cumulative number of degree-days above 0ºC during one year provides thawing index. The trends of the MAAT and thawing index indicate that the durability of using permafrost encapsulation for the Lupin tailings has a limited lifespan between 30 to 110 years.

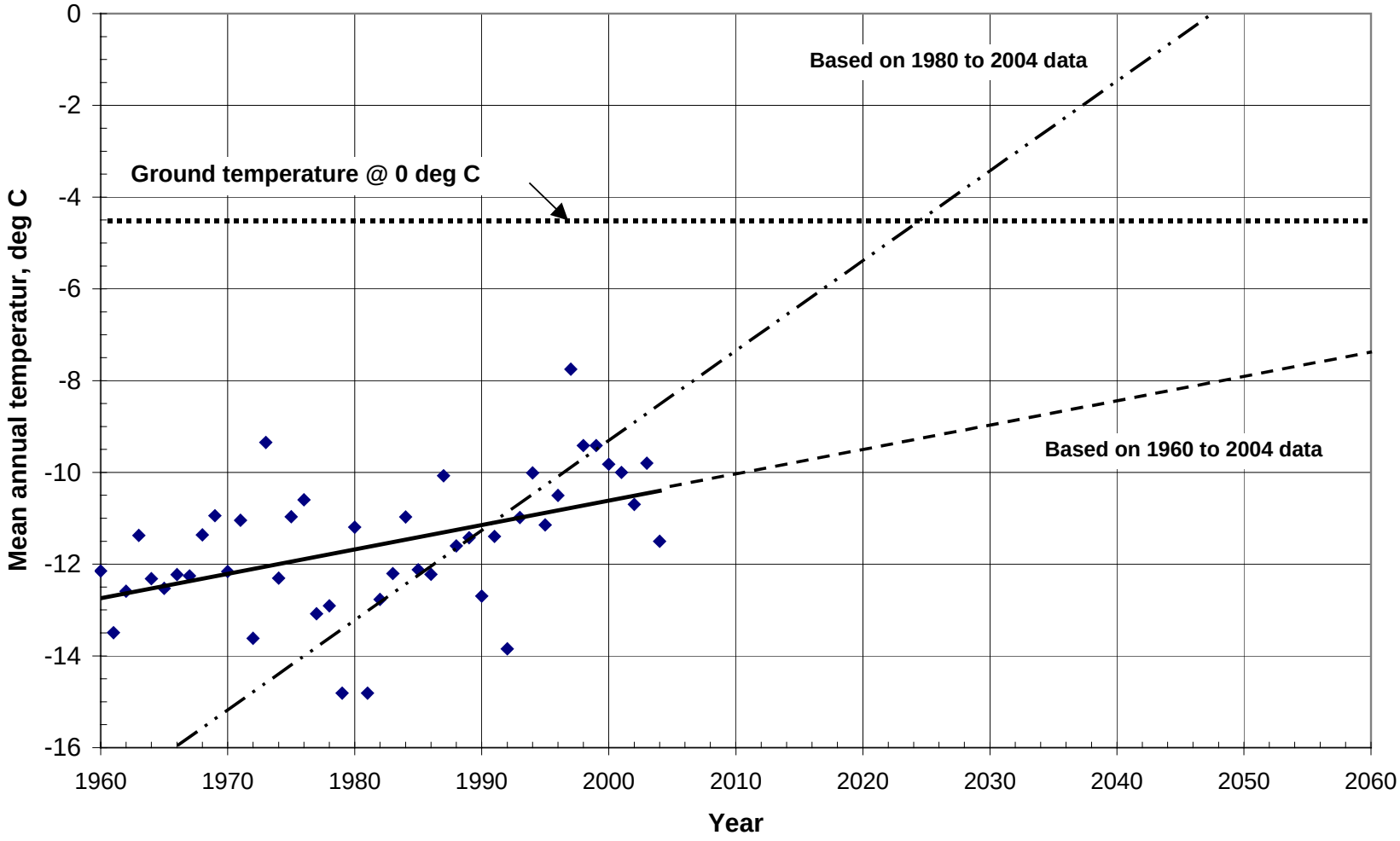

Figure 2-1. Mean annual air temperature trend at Lupin

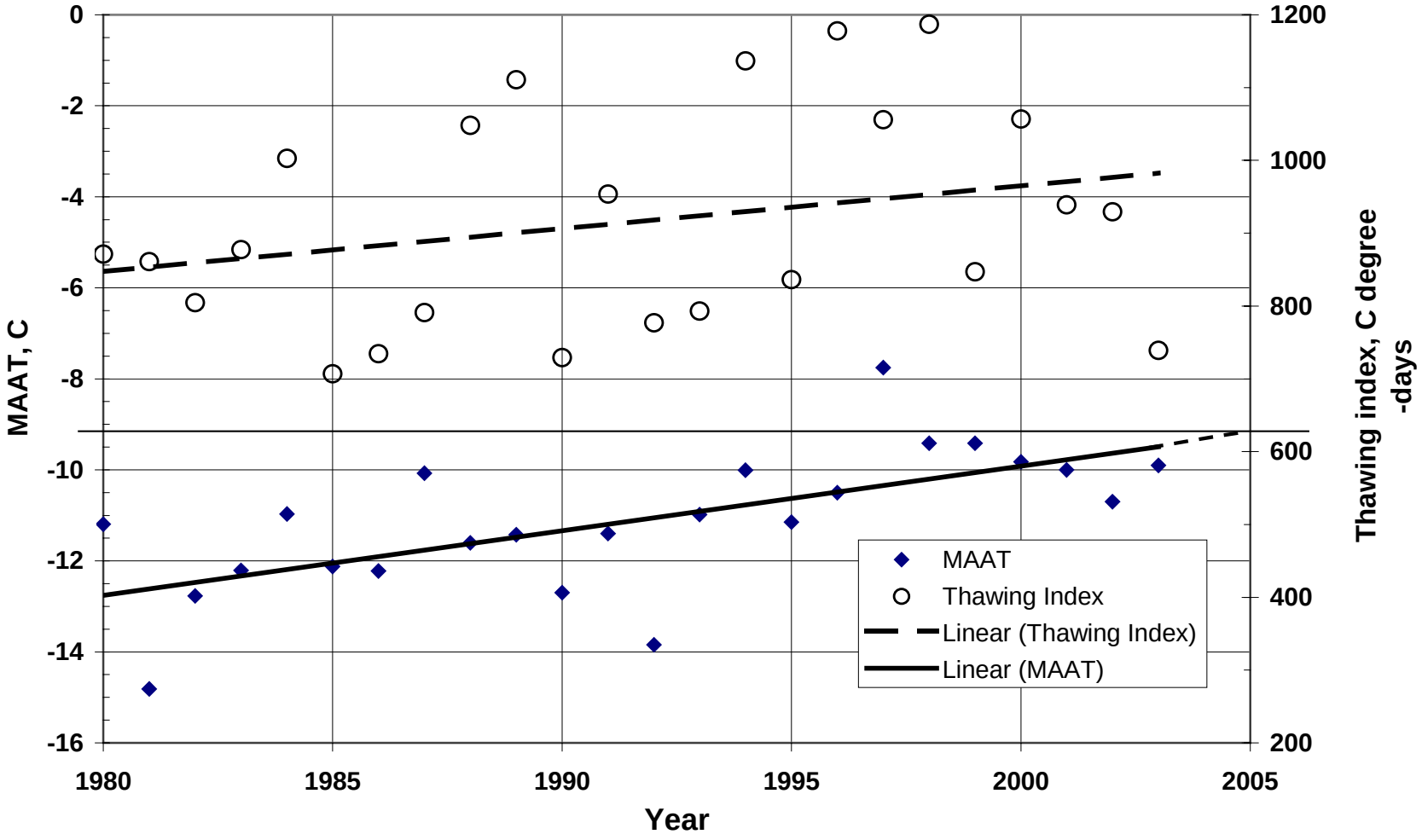

Figure 2-2. MAAT and Thawing Index trends since 1980

Precipitation at Lupin has experienced a smaller change over the mine operation period from 1982 to 2004. The total precipitation has been about 303 mm distributed about equally between rain (163 mm) and snow (140 mm). The variation in precipitation over the project time is shown in Figure 2-3.

Monthly air temperatures, rainfall and snow averages for the initial and final 10 year periods are given in Table 2-1.

Table 2-1. Two Ten year averages for air temperature, rainfall and snow, Lupin

Air Temp. C	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1983 - 1992	-30.4	-29.5	-25.9	-16.0	-6.6	**5.9**	**10.8**	**8.5**	**1.4**	-9.1	-22.2	-27.1	-11.7
1994 - 2003	-29.1	-28.0	-24.0	-15.4	-5.1	**7.2**	**12.6**	**9.3**	**3.2**	-7.9	-18.0	-25.4	-10.0

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1983-1992					6	26	44	51	25	3			154
1994-2003				0	6	23	43	67	32	1			172

Snow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1983-1992	13	9	10	15	11	3	1	4	16	26	17	12	138
1994-2003	6	6	15	14	16	4	0	2	17	29	17	16	142

Rain + Snow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1983-1992	13	9	10	15	17	29	45	55	41	29	17	12	291
1994-2003	6	6	15	14	22	27	43	69	49	31	17	16	314

2.3 Watershed Description

The area has numerous shallow lakes and marsh-like depressions. The drainage pattern is deranged or poorly defined but ultimately, the streams drain to Contwoyto Lake. Water within these lakes generally varies between 1 to 6 m.

The TCA was developed in a rolling topography with majority of the terrain lying between El 480 m and 490 m and the high ground being on the north side with maximum elevation being about at El 505 m. The construction of two relatively small dams on the west side and a saddle dam on the east side created an enclosed watershed with an area of 616 ha. The watershed contained 18 small lakes varying in surface area from about 0.6 ha to 19.7 ha illustrated in pre-construction air photo shown on Figure 2-4.

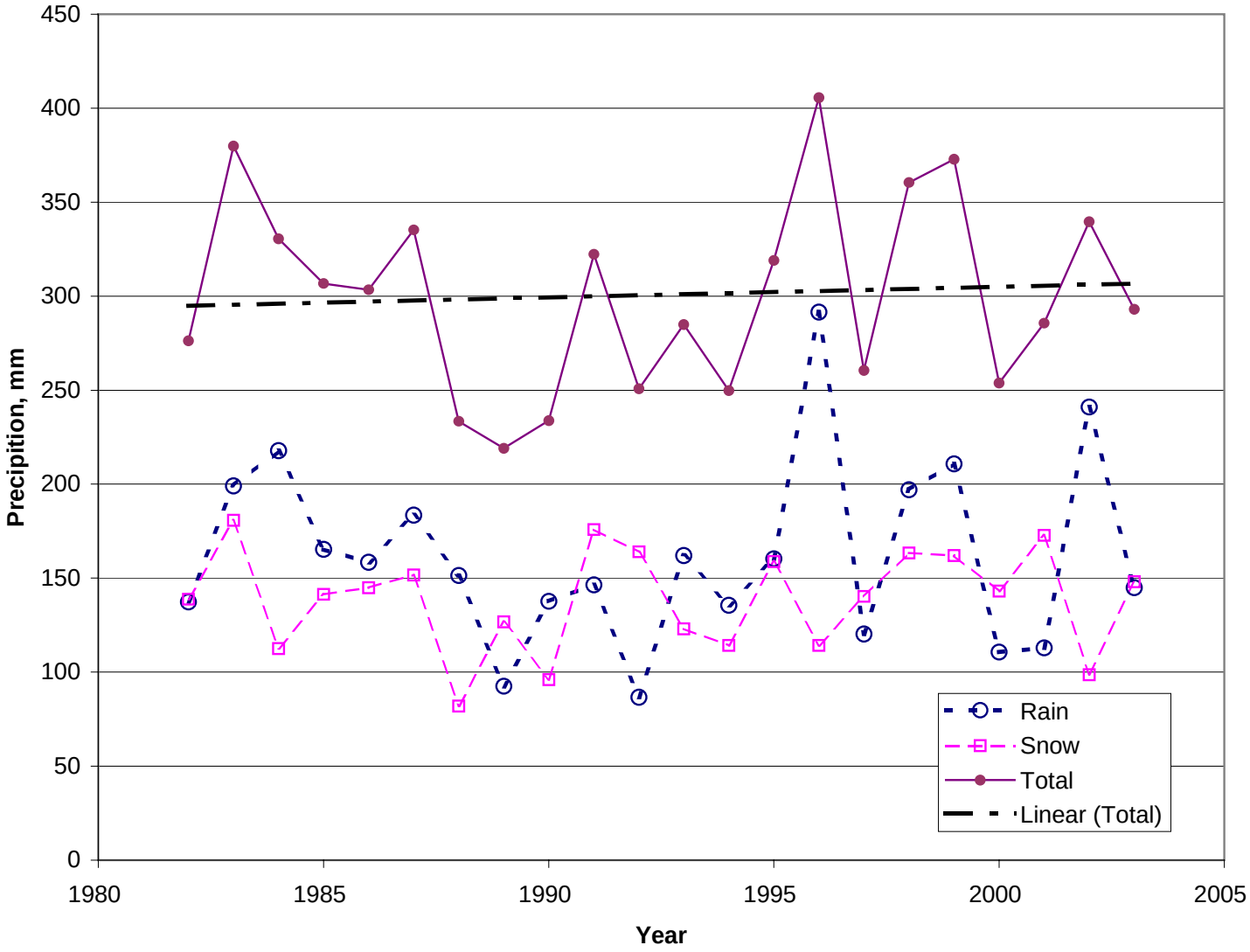

Figure 2-3. Annual rain, snow and total precipitation from 1982 to 2003, Lupin

The contained watershed was created by the construction of Dam 1a between lakes ‘a’ and ‘r’ shown on Figure 2-4 and the saddle Dam 4 between lakes ‘x’ and ‘l’. Before the construction of the saddle, lake x was part of the watershed contained by Dam 1a.

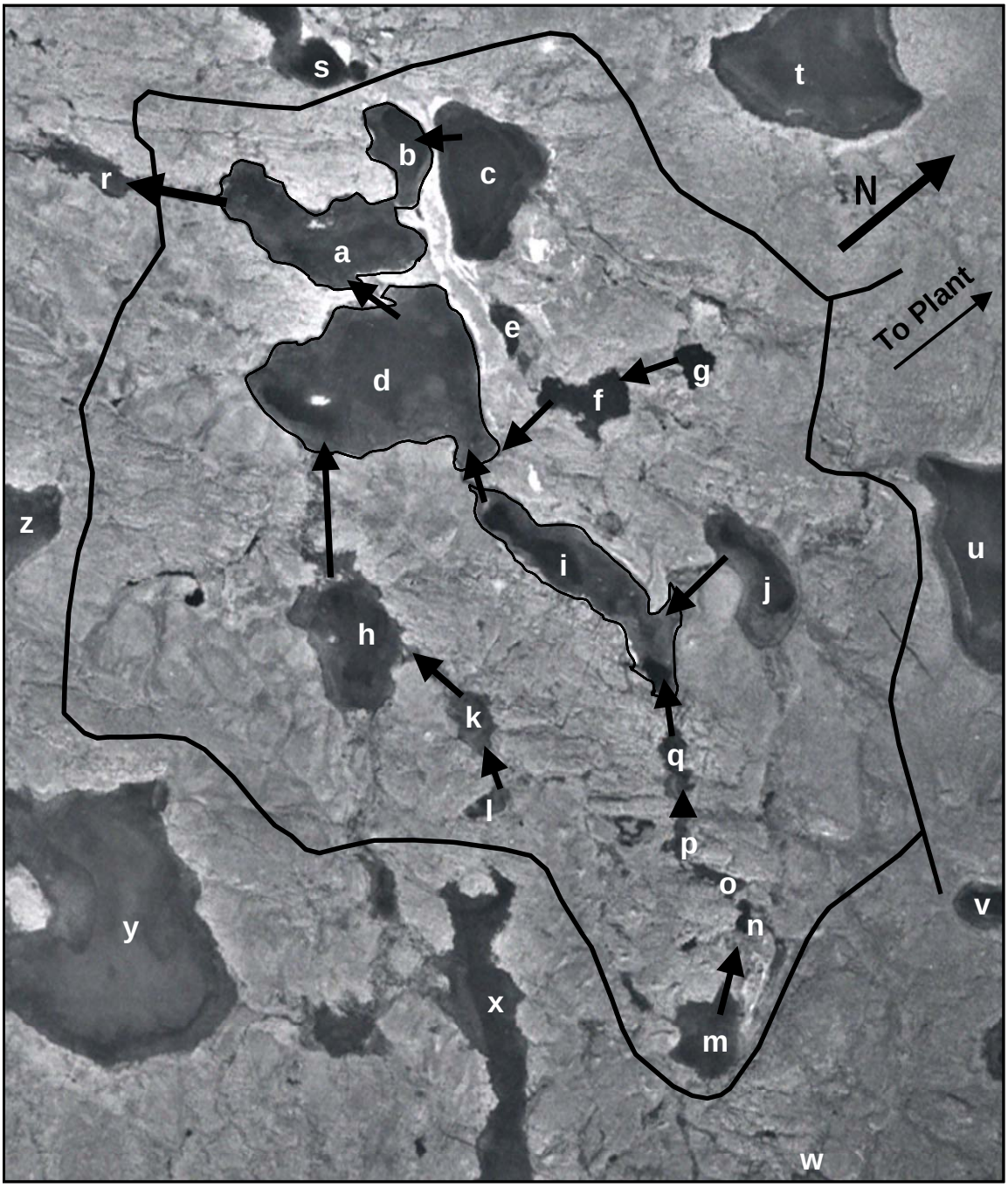

Figure 2-4. Tailings Area watershed and historic lakes and drainage

The areas and before construction water elevations of the lakes and the flow pattern is given in Table 2-2.

Table 2-2. Lakes, elevations and areas of lakes

Lake	WL, El. m	Area, ha
l	480.4	0.9
k	480.2	2.0
h	479.8	11.5
d	477.9	19.7
g	482.6	
f	481.9	
d	477.9	
e	479.5	1.0
c	477.8	11.7
b	477.8	4.1
a	477.8	13.9
Downstream of outlet		
r	477.7	

Lake	WL, El m	Area, ha
m	485.9	4.7
n	484.4	0.6
o	484.0	0.9
p	484.0	1.2
q	483.9	1.4
i	478.0	12.1
j	478.5	7.1
i	478.0	12.1
d	477.9	19.7
Lakes outside of watershed		
s	478.2	
t	494.0	
u	484.5	
w	482.7	
x	482.8	
y	481.7	

2.4 Tailings Deposition History

The Tailings Containment Area (TCA) was developed in 1981 by the construction of two main dams, Dam 1a and Dam 2, on the west side of the tailings watershed (Holubec et al 1982). Dam 1a was constructed across the watershed outlet stream and Dam 2 across an adjacent low saddle. The plan for the TCA was to operate it as a contained facility for the first few years. This would provide an opportunity to establish the tailings pond excess water quality and determine any need for treatment before discharge would commence.

Ore milling commenced in 1982 and the tailings slurry was discharged from the northern edge of the TCA to form one large pond against Dams 1a and 2 as shown in a photograph in Figure 2-5. This operation strategy continued until 1985. Increased production of ore resulted in the adoption of a revised tailings management strategy that deposits the tailings within cells. Excess water from these cells is directed into two ponds in series within the TCA that improves the water quality before the water is discharged. Since 1985, water has been discharged from a downstream polishing pond to control the water level within ponds.

This tailings management strategy has remained in practice to this date. Progressive reclamation of the filled cells started in 1988, when Cell 1A was covered with a layer of esker sand.

Figure 2-5. Photo of initial TCA in 1983, looking northeast

The history of the construction of dams, filling of the cells and placing covers over the cells is in Table 2-3. The location of perimeter and internal dams, ponds and the identification of the cells is provided on Figure 2-6.

The initial discharge of tailings occurred from an elevated point along the perimeter of the TCA that was closest to the Plant. The tailings were discharged over sloping ground that is labeled as Cell 5 and all excess water was contained within the TCA impoundment.

Due to increased ore milling and the need to discharge excess water from the TCA, Lupin mine decided to encourage natural contaminant degradation by settling out the tailings solids within cells and passing the excess tailings slurry water through two ponds in a series before discharge out of the TCA. This was accomplished by constructing an internal Dam 3C to form an initial Cell 1a, subsequently replaced by constructing a larger internal Dam 3D downstream to form the larger Cell 1, and the internal Dam J to create Pond 1 and Pond 2. This allowed the tailings to be settled in first Cell 1a and then Cell 1, and excess water to be

held during the operating year in Pond 1. After checking the water quality in Pond 1, the excess water was siphoned into Pond 2. If the Pond 1 water quality did not meet design conditions at this time, iron salt solution was injected into the siphon between the two ponds. After allowing the water to improve for one more year in Pond 2, and checking that it met discharge water quality criteria, the excess water in Pond 2 was discharged annually across Dam 1a.

This concept of storing the tailings in internal cells and passing the excess water through Ponds 1 and 2 before discharging continued from 1985 onwards. The only changes were that as Cell 1, and subsequently Cell 2, were filled, additional Cells 3, 5 and N were constructed.

Cell 3 was developed in 1990 by the construction of internal Dam K. In this case, as the tailings were settled out in Cell 3, water was allowed to flow into Cell 4 from where it progressed into Ponds 1 and 2. Cell 4 provided an additional clarification pond. A small dike and a gated culvert at its north perimeter controlled its water level, before discharging excess into a natural channel and small lakes flowing into Pond 1.

In 1992, internal Dam L was constructed to prevent tailings in Cell 3 from contaminating Cell 4 as Cell 3 was being filled. Furthermore, Dam M was constructed to allow tailings to be discharged again in Cell 5, where the earliest tailings discharge occurred. Dam M would contain the tailings within a controlled area, prevent the encroachment of the tailings on Pond 2 and cover the original placed tailings in this area.

Finally, internal Dam N was constructed in 1997 to allow the containment and covering of a small area of tailings from the initial years that were located on the Pond 2 side of Dam M, to be covered.

Placing of a gravelly sand esker cover over the tailings commenced in 1988 by the covering of Cell 1a. In 1995 Cell 1 and part of Cell 2 were covered. In 2003 Cells 3a and 3B, 2 mini-cells in the westerly section of Cell 3, were covered. In 2004, the remainder of Cell 2 and about half of the remaining exposed tails in Cell 3 were covered. It is planned to complete covering of all the exposed tailings in 2005 and 2006.

The physical condition of the TCA in 2004 is illustrated in Figure 2-7.

Table 2-3. TCA development and tailings disposal history

Year	Tailings	Disposal in Cells, in months					Operation Notes
	in m^3	1	2	3	5	N	
1981							Construct Dams 1a & 2
1982	202,000				12		Construct Dam 3
1983	354,000				12		
1984	257,000				12		
1985	254,000	12					Construct internal dams 3C & J
1986	263,000	12					
1987	276,000	12					
1988	277,000	6	6				Cover Cell 1A
1989	281,000	6	6				
1990	282,000	6	6				Construct internal Dam K
1991	296,000	2		10			
1992	309,000	2		10			Construct perimeter dams 4, 5 & 6
							Internal dams L & M
1993	341,000			8	4		
1994	332,000	1		10	1		Cover Cell 1 partially (waste rock)
1995	156,000		2	10			Cover Cell 1 & part of Cell 2
1996	201,000		2	9	1		
1997	216,000			10	2		
1998	9000				1		Shut down in January
1999	4,000						Closed
2000	173,000			3	9		Resume in April, raise Dam M
2001	212,000			4	8		
2002	209,000			6	6		
2003	13,000				8	2	Reopen March, Cover Cells 3a and 3b
2004	68,000			7	3	2	Complete cover Cell 2 & start Cell 3
Total	5,120,000						

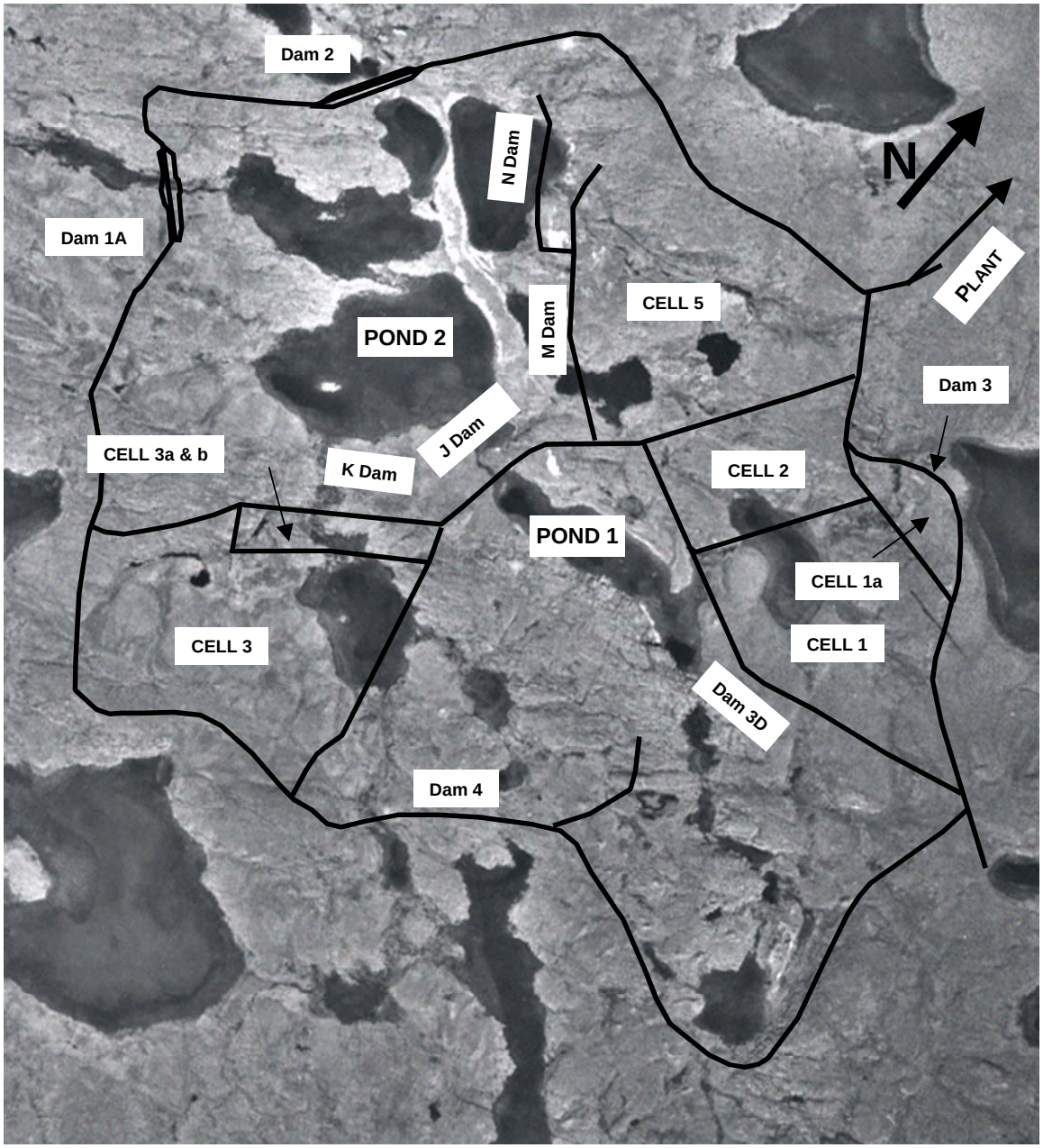

Figure 2-6. Locations of TCA dams, ponds and cells

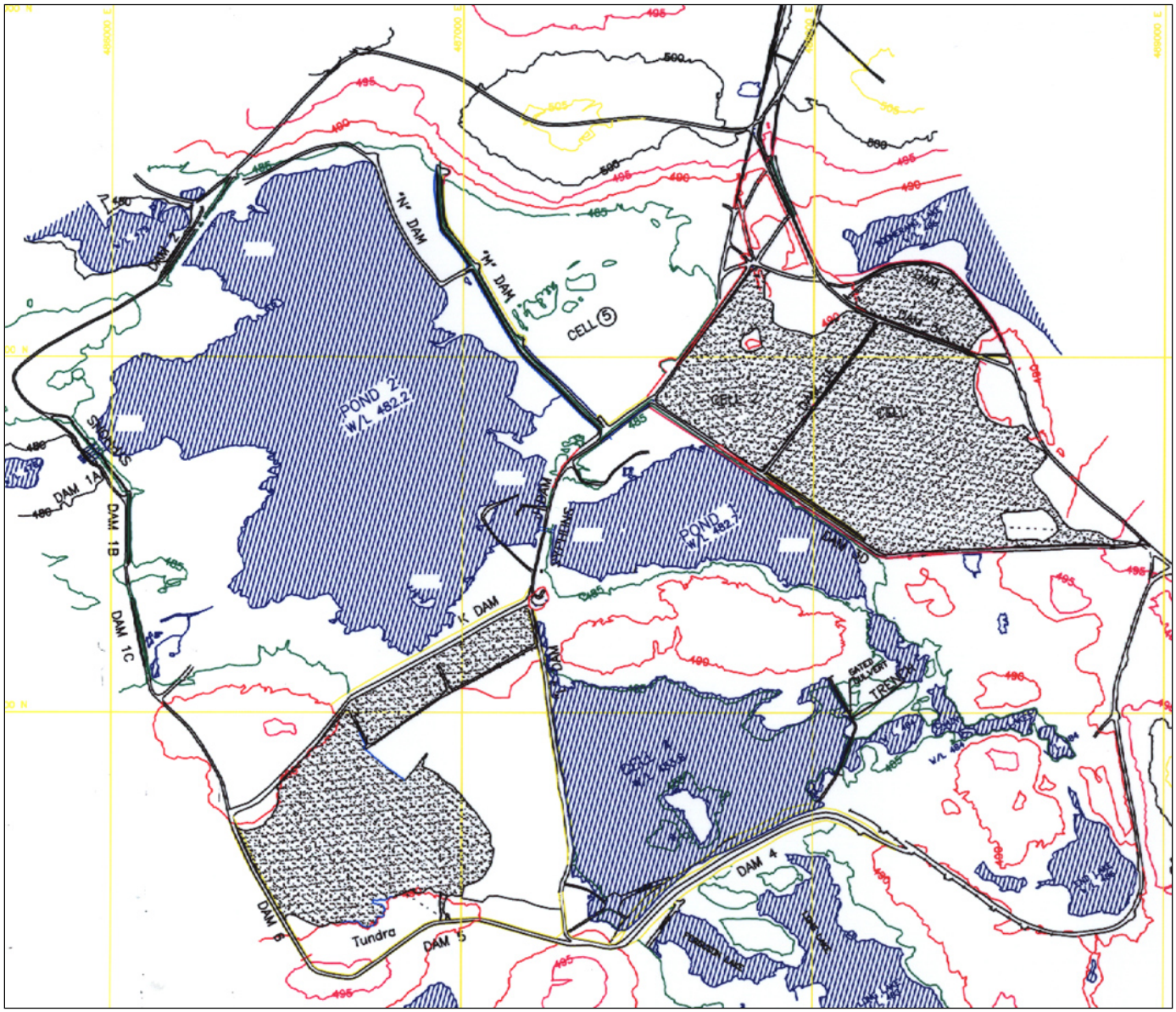

Figure 2-7. TCA Plan 2004

3.0 DAMS

3.1 General

Lupin TCA was created by the construction of 18 dams as given in Table 3-1 and shown on Figure 2-6 and Figure 2-7. The dams can be characterized as 6 main perimeter dams that contain either water or tailings within the TCA, 2 small saddle dams that were constructed to contain Pond 2 water in case of high water levels within Pond 2 and 9 internal dams to form cells that store tailings. All these dams have presently a frozen dam structure that is founded on frozen foundations. The perimeter and internal dam design section differ in that the perimeter dams include an internal liner that was incorporated to prevent internal seepage during the first years after construction and also acts as a design backup for the frozen dam section. The internal dams do not have a liner since some seepage during the development of the frozen zone was acceptable since any seepage was contained within the TCA area.

The foundation conditions, design, construction and performance are briefly discussed in the following sections. Photos of the tailings area with cells and major dams are provided in Appendix A; dam profiles and design sections are given in Appendix B and ground temperature profiles through the major dams are given in Appendix C.

Table 3-1. List of Lupin TCA perimeter and internal dams

Perimeter Dams

Dam	Year built	Crest El	Ground El	Ht, m	Design
1a	1981	485.0	478.5	6.5	Esker gravely sand with liner
	1984	486.4	478.5	7.9	" – "
2	1981	485.5	480.2	4.7	Esker gravely sand with liner
	1984	486.1	480.2	5.9	" – "
3	1983	490.2	486.9	3.3	Esker gravely sand with liner
4	1992	489.5	485.6	3.9	Esker gravely sand with liner
5	1992	491.6	489.7	1.9	Esker gravely sand with liner
6	1992	490.3	489.3	1.0	Esker gravely sand with liner

Small Perimeter Saddle Dams

Dam	Year built	Crest El	Ground El	Ht, m	Design
1b	1981	485.8	483.135	2.5	Esker gravely sand with liner
1c	1981	485.7	483.5	2.2	Esker gravely sand with liner

Internal Dams

Dam	Year built	Crest El	Ground El	Ht, m	Design
3C	1985	491.2	485.5	5.7	Esker, tailings on both sides
3D	1986	487.5	480.0	7.5	Esker, tailings on cell side
	1988	490.5	480.0	9.5	
3E	1985	491.2	480.0	11.2	Esker, tailings on both sides
J	1985	490.5	481.4	9.1	Esker, tailings on cell side
K	1990	490.7	480.0	10.7	Esker, liner with tailings on cell side
L	1992	490.8	479.8	11.0	Esker, tailings on cell side
M	1992	488.8	481.8	7.0	Esker, tailings on cell side
N	1997	483.9	478.0	5.9	Esker, tailings on cell side

3.2 Perimeter Dams

3.2.1 Basic Design

The design concept for all perimeter dams is illustrated on Figure 3-1. It consists of a low permeability of homogeneous dam with a liner on the pond side anchored in a trench on the pond side. The dams were constructed in the summer. Since it was difficult to predict if the dam section would freeze completely over the first winter, a liner was provided to stop seepage until the main dam section developed permafrost. The dam section was armoured against erosion with mine rock on either the pond side only or both the pond and downstream sides.

Dams constructed in 1981 used local thawed silty sand till for the main zone and a gravelly sand esker material to cover the liner on the pond side. The remainder perimeter dams were constructed solely from gravelly sand esker material and they have an internal liner.

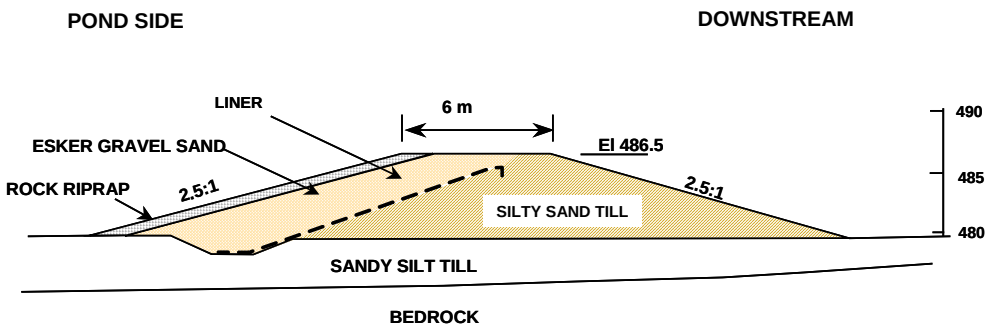

Figure 3-1. Design concept of perimeter dams

The internal dams were constructed from a gravelly sand esker material. Minor content of silt in the esker material and the fact that tailings a beach was developed against the upstream dam face, created low permeability dams. The low seepage, that did not pose any water quality problems since it was trapped within the TCA and improved before discharge, allowed the gradually freezing of the dam cross sections as discussed in detail in the next sections.

Both the perimeter and internal dams were armoured with mine rock on sides that has water ponding.

All perimeter dams were constructed on natural ground consisting of either silty sand till or bedrock. With the exception of Dams 1a and 2, the foundation consisted of relatively thin till, less than 2 m thick, underlain by bedrock. The silty sand till, below the active layer that existed during the summer, had little or no excess ice and thereby formed competent foundations in either frozen or thawed state. Water content of thawed till was measured to be between 14 and 18 percent.

3.2.2 Perimeter Dams 1a and 2

The main and first dams constructed at the site were Dams 1a and 2. They were constructed at the west end of the TCA watershed that drained towards the west at Dam 1a. The outlet stream at Dam 1a controlled the water level at the three adjacent lakes at El 478.5 m. The base of Dam 2 was about 1.7 m higher at El 480.2 m. The locations of these dams are illustrated on Photo 8 in Appendix A.

The presence of relatively deep silty sand till foundations at Dams 1a and 2, led to designing the dams with a homogeneous low permeability core that would freeze and coalesce with the frozen foundations. Since it was anticipated that the dam fill material could take one to two years to freeze completely, an impermeable liner, anchored into permafrost, was included with the dam section. These dams were constructed in two stages: in 1981 the dam crests were built to El 485.0 and El 485.5 m (Dams 1a and 2 respectively) and then raised in 1984 to El 486.4 and El 486.1 m respectively. The cross sections are shown in Figures B 2 and B 3 and soil conditions along the dam profiles of the dams are shown in Figures B 4 and B 5 respectively in Appendix B.

The dams experienced two minor problems during the initial years. Dam 1a showed some seepage near the north abutment in 1982, likely due to excessive thaw during the summer construction in an area with smaller depth of the silty sand over bedrock. This was managed by adding some low permeability silty sand on the upstream slope of the dam.

In 1984 seepage was observed at the abutments of Dams 1b and 1c. The reason was that the water level against the dam had risen above the elevation of the annual thaw depth within the bedrock in the abutments of the dams. Lowering Pond 2 water level by siphoning over Dam 1a and stricter control of the reservoir water level thereafter stopped the seepage.

Both dam sections and the foundations froze completely by the second year (1983) and the ground temperature below the dam crest has remained stabile at around –3.5 ºC for the past 20 years. No other seepage was reported aside of the two instances during the initial years.

3.2.3 Saddle Dams 1b and 1c.

Saddle Dams 1b and c were constructed along the drainage divide to contain Pond 2 water in case of high water level conditions. The dams are 2.5 and 2.2 m high respectively.

Their design is similar to the basic homogeneous low permeability section with a liner illustrated in Figure 3-1.

3.2.4 Dam 3

Dam 3 was constructed in 1983 to reduce the main watershed area of the TCA and to create Cell 1a for tailings storage. Dam 3 rerouted the drainage from adjacent Boomerang Lake. The drainage from this sub-watershed was routed by the construction of a 1 m deep outlet channel towards the east. Design of this dam again was the same as in Figure 3-1.

3.2.5 Dam 4

This dam is located at the watershed divide of the TCA. While a permanent dam was constructed at this location in 1992, a temporary dam was in existence since 1983. The initial dam was constructed using a homogenous silty sand design because only a small height of water would be impounded on the downstream side. This dam experienced annual sloughing of the downstream slope and required continuous maintenance.

In 1992, a permanent 3.9 m high dam with the common design was constructed as shown in Photo 8. The design is shown in Figure 6 B. Both the upstream and downstream faces of the improved dam were armoured with development waste to prevent the sloughing problem of the previous years.

3.2.6 Dams 5 and 6

These two dams are low height dams constructed along the drainage divide at the southwest side of the TCA. They are about 1.9 and 1.0 m high respectively. The design sections of these two dams are shown on Figures B 7 and B 8 respectively.

3.3 Internal Dams

3.3.1 General

Internal dams were constructed within the TCA watershed boundary and therefore any seepage occurrence would not be critical since all water was being retained. Some of these dams were constructed using an esker homogenous zone only and some included a liner within the esker zone.

3.3.2 J Dam

Through a pilot plant study in 1984 and 1985, it was determined that prolonging the retention of excess water within ponds could enhance that natural degradation process. As a result, it was decided to collect tailings within cells and provide two ponds in series to provide up to two years retention of water before discharge. This would lower cyanide and metal concentrations to Water License limits. To further enhance the lowering of arsenic

concentration, an iron salt solution was introduced during the transfer of water between Ponds 1 and 2 (Wilson 1989).

To create the two ponds, J Dam was constructed between two original Lakes 'd' and 'i' shown on Figure 2-4. The proposed route of the dam was on land that had a thin till cover over bedrock. It did cross a small stream that drained Lake 'i' into Lake 'd' shown on Figure 2-6. At this time, the original proposed alignment of Dam J was already flooded by the filling of the TCA reservoir as shown in Figure 2-5.

Dam J was built from minus 150 mm mine waste rock that was dumped through ice during the winter of 1985. Since the rock-fill dam section was relatively permeable, the upstream side of the dam was covered with a layer of gravelly sand esker followed by tailings during the summer. Some seepage through the Dam J was acceptable since this dam was within the TCA. The southern section of Dam J, including the siphons used to transfer water from Pond 1 to Pond 2, can be seen in the lower left corner of Photo 4.

Dam J section is shown in Figure B-9 and the foundation profile in Figure B 10. Figure B 10 shows that at the lowest valley point, the dam base is at the same elevation as former Lake 'd'.

3.3.3 Cell 1 Dams

Along with the construction of Dam J, cells started to be constructed on the north side of TCA to store tailings. The cells were formed by the construction of the TCA perimeter Dam 3 and internal dams 3A, 3B, 3C, 3D and 3E to form Cells 1a, 1 and 2 shown in Figure 2-7. Dams 3A and 3B are not shown in this figure since these were intermediate small dams that were covered with tailings in Cell 1a. Also, no dam is identified between Cells 2 and 5 because the division between these two dams is formed by high ground. A road indicates the boundary between these two cells.

General arrangement of the dams bounding Cells 1a, 1 and 2 is shown on Photo 3 in Appendix A. In this photo, Pond 1 is in the foreground, Cells 1 and 2 are shown on right and left respectively and Cell 1a and Boomerang Lake are visible in the top of this photo.

The major internal dam in this area is Dam 3D built in 1986 to create Cell 1. It has a maximum final height of 9.5m. It was built across internal higher ground as shown in Figure 2-6 with the exception of a small length that crosses the outflow of former Lake 'j' Figure 2-4.

The dam was constructed from a gravelly sand esker to form a homogenous cross section. Seepage occurred through the dam during operation as expected since the gravelly sand was relatively permeable. As the operation continued, sloughing of the downstream slope and the need to increase storage capacity of Cell 1, resulted in buttressing the downstream slope of Dam 3D with about 10 m of mine rock on the downstream side and adding additional

esker material on top of the dam to raise its final elevation to El 490.4 in 1988. Photo 9 in Appendix A shows the downstream rockfill zone of Dam 3D.

The geometry of Dam 3D is shown on Figures B 11, B 12 and B 13. These show the massive esker & rock-fill construction of the dam in Figure B11; the foundation profile in Figure B 12 and an exaggerated vertical to horizontal section normal to the Dam 3D in Figure B 13. This shows that on an average Dam 3D is about 9.5m high and presently its downstream slope is submerged in Pond 1 water to a depth of about 5 m. Presently Dam 3D is frozen as measured by thermistor 3D3-1 discussed in the following section.

Internal Dam 3E has ceased to exist since it is buttressed by tailings on both sides as illustrated on Photo 4.

3.3.4 Dam K

Dam K was built in 1990 to develop new tailings storage area. It was constructed from esker and tailings on competent dry ground. Pond 2 water level did not cover the dam route during construction. The design consists of building a gravelly sand esker embankment that is buttressed by a 100 m wide tailings zone on the upstream side. The tailings buttress was created by means of discharging tailings from both Dam K edge and a berm constructed on the upstream side as shown on Figure B 14 in Appendix A. The upstream berm was constructed and over time raised from settled tailings. The area between Dam K and the downstream berm is called Cells 3a and 3b. The tailings beach formed by Cells 3a and 3b form a wide low permeability zone. The downstream slope was covered with mine rock for erosion protection.

Dam foundation profile is shown on Figure B 15 and the dam along with the upstream contained tailings are shown in section in Figure B 16. Dam K along with the tailings cells 3a, 3b and 3 are shown in Photo 4 and the Dam K downstream slope in Photo 10, Appendix A.

3.3.5 Dam L

Dam L was constructed in 1992 to contain tailings within Cell 3 and create an additional water treatment pond in Cell 4. Dam L is shown on the left side in Photo 4 in Appendix A. The dam was constructed in two stages from esker material. Upstream and downstream slopes of this dam were protected by mine rock riprap as shown in Figure B 17. A small dike and a gated culvert on the northeast side of Cell 4 have regulated the water level in Cell 4. However, the difference in water levels between Cells 3 and 4 is small. Foundation profile of this dam is shown on Figure B 18.

3.3.6 Dam M

Dam M was constructed in 1992 to provide additional tailings storage in Cell 5 without compromising the water quality of Pond 2. It also provides greater operational flexibility in allowing the discharge of tailings closer to the plant during winter. Dam M, with tailings beach in the background, is shown in Photo 2.

The dam was constructed from gravely sand esker material and the downstream slope adjacent to Pond 2 was covered with a thick layer of mine rock riprap as shown in Photo 11. A section view of the dam, with the contained tailings and the dam foundation profile, is shown on Figures B 19 and B 20 respectively.

3.3.7 Dam N

Dam N was constructed to allow the covering of a small area of exposed tailings beyond Dam M alignment with an esker cover. This dam, in section, consists of a homogenous esker zone covered with mine rock riprap on the downstream side. Photo 5 in Appendix 5 shows Dam N on the right side.

4.0 TAILINGS STORAGE

4.1 General

From the start of the Lupin operation in 1982 to end of 2004, approximately 1,770,000 tonnes or 5,120,000 m^3 of tailings were stored in within the TCA. The tailings were stored in four major cells (Cells 1, 2, 3 and 5) and one smaller Cell N according to the disposal history given in Table 2-3. These cells occupy an area of about 145 ha within the total TCA watershed area of about 616 ha. Estimated statistics of the cells and contained tailings are given in Table 4-1.

Table 4-1. Statistics of cells and contained tailings

Cell	Cell's Watershed, ha	Tailings surface area ha	Mean tailings depth, m	Tailings volume stored, m3
Cell 1a	6	6.3	1.7	107,000
Cell 1	41	36.1	3.5	1,263,000
Cell 2	21	15.0	3.0	450,000
Cell 3	67	50.0	4.0	1,724,000
Cell 5	56	34.3	4.5	1,544,000
Cell N	3	3	1.0	32,000
Totals	194	144.7		5,120,000

The tailings volumes were estimated from production records as given in Table 2-3, Specific Gravity of 2.90 and an estimated void ratio of the deposited tailings of 0.70.

4.2 Cell 1

Cell 1 was developed in two stages. First a small Cell 1a was constructed against Boomerang Lake on the north side of the main Cell 1. It was formed by the small perimeter Dam 3 and a small internal Dam 3E.

Cell 1 was created by the construction of internal Dam 3D. This dam was constructed northeast of Lake i (Figure 2-4) that became Pond 1. It created a suitable storage area by its topography and its enclosure of Lake j. While the depth of tailings over the whole Cell 1 surface area averages about 3.5m, the actual depth varies greatly as can be seen from Figures B12 and B13. The maximum depth against Dam 3D is approximately 6 metres and in the area occupied by the previous Lake j it is about 11m.

Deposition in Cell 1a and 1 was started in 1985 and continued until 1992. The areas were covered with a gravelly sand esker material in 1988 and 1995.

4.3 Cell 2

Cell 2 is an extension of Cell 1 towards the west. It was constructed by extending internal Dam 3D. The depth of tails in Cell 2 is not as high as in Cell 1, containing about 6 m of tailings. Cell 2 was used between 1988 and 1990, and in 1995 and 1996. The bulk of the cell was covered with esker material in 1995, with the remainder covered in 2004.

4.4 Cell 3

Cell 3 was constructed at the most southerly location of the TCA and it stores the greatest volume of tailings. It was developed by the construction of K Dam in 1990 and was used from that time until 2004. To allow additional the raising of K Dam and increase the massiveness of this dam, sub Cells 3a and 3b were developed upstream of the main K Dam. The berm upstream of K Dam that contained the tailings within Cells 3a and 3B was constructed predominantly from settled tailings. These sub cells can be seen in Photo 4 in Appendix A.

Cell 3 area contained a large Lake h that enhanced its storage capacity. While K Dam is about 9 m high, depression of Lake h created a sizeable bowl where up to 10 m of tailings could be stored. The tailings were discharged from a berm forming the southeast side of Cells 3a and 3b and from the southeast high ground. A section through this cell can be seen in Figure B16. Cell 3 stores about 1,724,000 m^3 of tailings.

Reclamation of Cell 3 began in 2003, when Cells 3a and 3b were covered with esker sand and gravel. The reclamation continued in 2004, with over half of the exposed tailings being covered during this year. It is planned to complete covering the tailings in this cell in 2005.

4.5 Cell 5

Cell 5 has the most varied use history of the four main tailings cells. It was the main tailings storage area during the start up years from 1982 to 1984. During this period, Lupin operated the TCA as a single storage pond with the tailings being discharged from the northern perimeter of the TCA. About one third of the tailings stored in this cell were discharged in the first 3 years. From 1985, the TCA operation changed to storing the tailings within discreet cells and improving the decant water quality by means of extended storage in two polishing ponds.

Storage in Cell 5 did not restart until 1993. From this point on, the cell was mainly used during the wintertime because of its proximity to the plant. Tailings have been discharged into this area until 2004. Aside from the proximity of this cell, tailings also have been discharged to level the cell for a final cover and to cover the older tailings with fresh tailings.

Cell 5 area is generally sloping towards the south and previously contained several small lakes that increased its storage capacity. The cell was created by the construction of M Dam, which is about 5m high with the exception of a section across the outlet of the closest former lake, where the dam height is about 8m.

It is planned to cover Cell 5 in 2005 and 2006.

4.6 Cell N

Cell N is a northerly extension of Cell 5 and was formed by the construction N Dam in 1997 to cover a small exposed tailings beach that was created during initial operation between 1982 and 1984. The construction of Dam N allowed the placement of fresh tailings over the old tailings beach, so that the water quality of Pond 2 would not be compromised. The exposed tailings in Cell N will be covered in 2005.

5.0 PERMAFROST WITHIN DAMS AND TAILINGS

5.1 General

Permafrost is defined as a thermal condition in soil or rock with a temperature below 0ºC that persists over at least two consecutive winters and the intervening summer (Everdingen 1998). Moisture in the form of water or ground ice may or may not be present. The definition does not include the presence of frozen soil or rock within the stratigraphy, its temperature, or water/ice content that may determine physical and chemical properties. Nor does it consider the depression of the freezing point that may be relevant to the oxidation of reactive tailings.

Two parameters that are important to the evaluation of the permafrost conditions at the TCA are the annual depth of thaw (active layer) and the ground temperature at zero annual amplitude (MAGAT). These parameters and the ground temperature regime is illustrated in Figure 5-1.

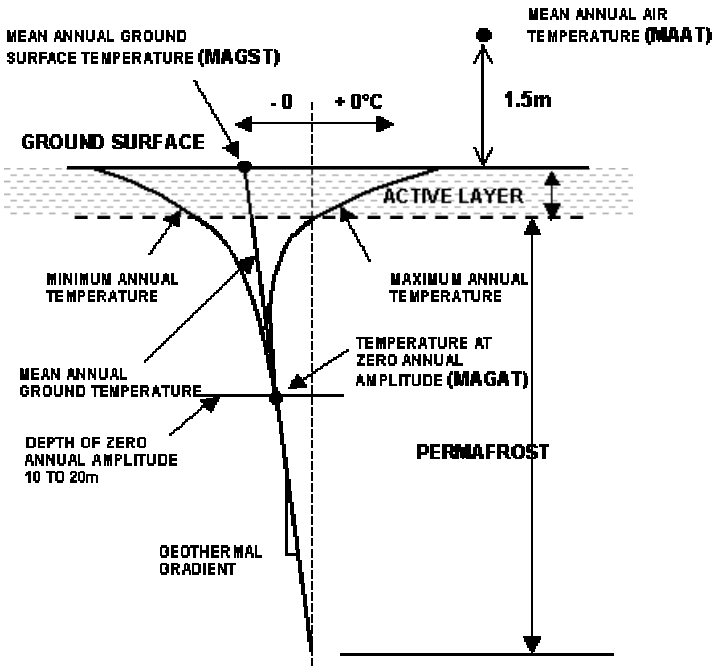

Figure 5-1. Ground temperature regime in permafrost

The thickness of the active layer or thaw depth is important in the stability of dams and the design of the tailings cover if permafrost encapsulation is the closure design for the tailings.

In case of the dams, the thaw depth indicates the zone of thawed material below the dam crest that could allow seepage during the summer thaw period if water level rises above the thaw elevation and a liner is not provided. Critical areas could be in the abutments if the liner is not extended far enough into the abutments.

In case of tailings encapsulation, the thaw depth determines the design and thickness of the cover to ensure that the thaw remains within the cover.

MAGAT provides an indicator that the dam core and foundations are frozen and thereby prevent seepage that may not be acceptable because of water quality or that could undermine the stability of the dam. Also the changes of the MAGAT can be used to evaluate the changes of permafrost temperature over time. MAGAT occurs normally at a depth of about 15 m. At locations with no organic cover, the MAGAT may be located at a greater depth; then the mean annual ground temperature (MAGT) at depths greater than 10 m provides a similar value.

Lupin has been monitoring the ground temperatures in dams since 1982 and in covered cells since 1985. The results of this monitoring have been provided annually to the Water Board and have been published in several papers. This chapter summarizes the most recent permafrost conditions at the site. These are based on relatively deep thermistor cables, 12 to 20 m, located at thirteen locations as shown in Figure 5-2. Four of these thermistor cables were installed in the summer of 2004 and therefore do not provide reliable MAGT values. Plans where the ground temperatures were measured, and last years temperature profiles, are given in Appendix C. Ground temperature profiles are not shown for 3 thermistors: D1-00-02n and D2-0003s because of malfunction of two temperature sensors near the ground surface and TC 3-1 because of recent installation.

5.2 Thaw Depth

Thaw depths were determined from ground temperature profile fluctuations as shown in Figures C9 to C18 in Appendix C. Note that the thaw depths could not be determined at 2 of the 13 thermistors because of the malfunction of some of the near ground surface temperature sensors. The determined thaw depths are summarized on Table 5-1.

The temperature records show that the thaw depths below the dam crests varied from 2.0 to 3.1 m. (average 2.5 m) and below the covered tailings area, including in one thermistor installed in the esker borrow area, from 1.3 to 1.6 m (average 1.4 m). Different thaw depths were obtained below the dam crests and below the covered cells due to moisture content of materials at these locations. The geometry of the dam sections and the presence of the liner at Dams 1a, 2 and 3 keep the ground below the dam crest relatively dry that encourages thick active layer or large thaw depth. Dam safety in Dams 1a, 2 and 4 is maintained by the presence of a liner within the dam section and keeping sufficient freeboard. Dams 3D, M and

N, do not have liners but are internal dams with massive, relatively low permeability, esker zones that buttress tailings. Dam K also buttresses tailings but contains a liner.

The thaw depth in the covered tailings cells and in the esker borrow area is shallower than in the dams because of the flat geometry in these areas. The flat geometry and the underlying permafrost keep the groundwater high which in turns limits the annual thaw. As a result the maximum thaw depth averages 1.4 m, with a range of 1.3 to 1.6 m.

Table 5-1. Summary of thaw depths and MAGT

Dams Thermistors	Max'm Depth	Thaw D m	MAGT @ Max d	Note
D1-1s	20	3.0	-4.1	
D1-2n	20.3	na	-3.9	
D2-3s	20	na	-3.5	
D2-2n	20	2.3	-4.5	
D4-1	12	2.4	-4.3	
D4-3	12	2.7	-3.6	
D4-4	12	2.2	-4.5	
DK-3	19.6	3.1	-2.9	Fall 2004
D3D	20	2.0	-2.1	Fall 2004
	Avg	2.5	-4.1	Exclude
	Range	2.0 - 3.1		Fall 2004

Tails & Esker Thermistors	Max'm Depth	Thaw D m	MAGT @ Max d	Note
TC1-3	13	1.2	-5.2	1995
TC3-1	20	1.4	-3.9	Fall 2004
TC1-6	20	1.3	-5.1	2003
Esker	14.3	1.3	-6.5	
TC1-7	20	1.6	-4.3	Fall 2004
	Avg	1.4	-5.8	Exclude
	Range	1.3 - 1.6		Fall 2004

5.3 Mean Annual Ground Temperature (MAGT)

The presently monitored thermistors provide a good picture of the permafrost conditions within the dams and covered cells because of their large depths ranging from 12 to 20 m. Nine of the 13 thermistors were used to assess the MAGT because 4 of the thermistors were installed only in the summer of 2004. These four most recent installations do not have temperature records for the whole year to determine the mean annual ground temperatures.

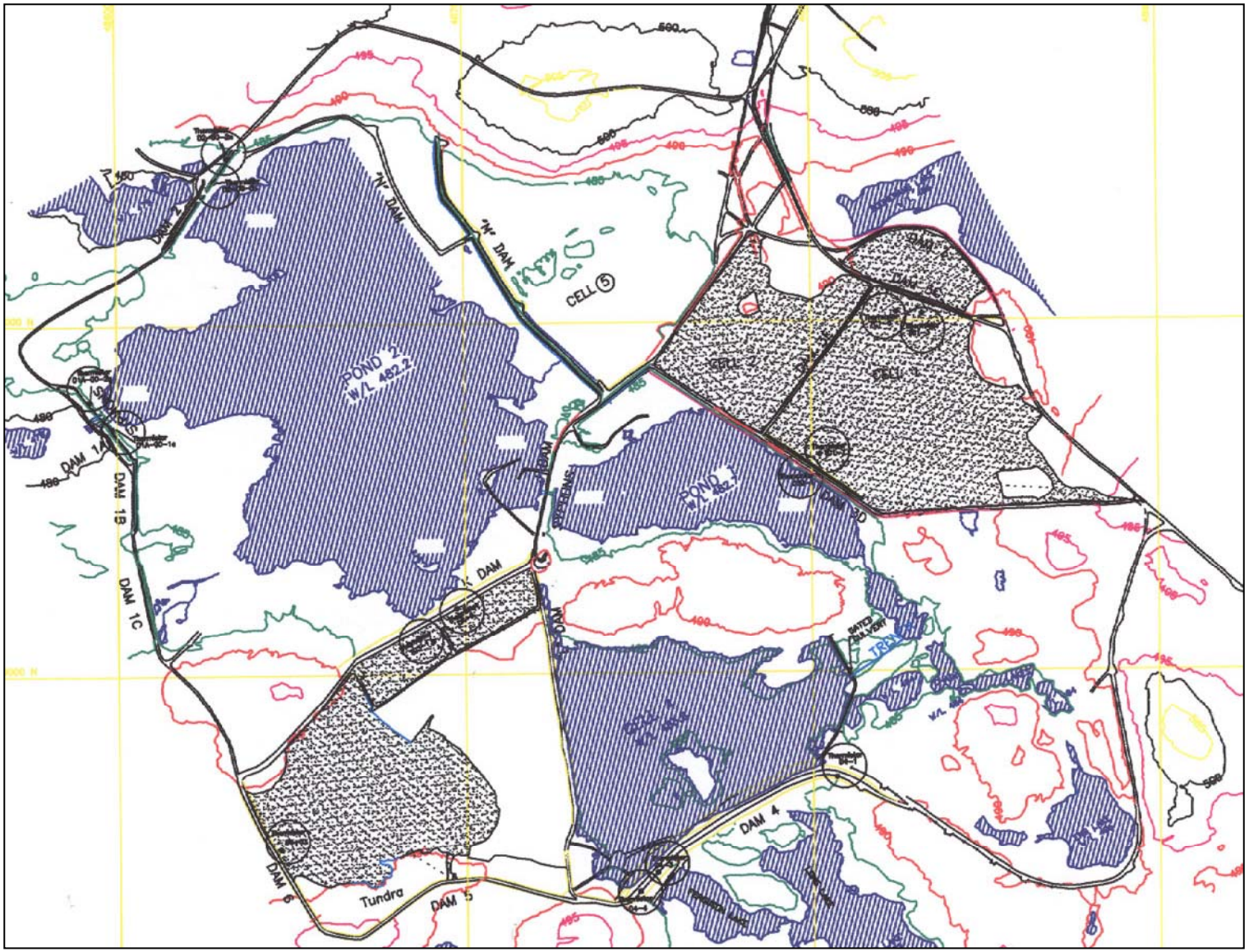

Figure 5-2. Locations of active thermistors

Estimated MAGT below Dams D1a, D2 and D4, average at –4.1ºC and range from –3.5ºC to –4.5ºC. The warmer MAGT as compared to the thermistors in the tailings and the thermistor installed in the esker with an average of -5.8ºC is due to the presence of water in the adjacent ponds.

It is of interest to view the ground temperature changes at 20 m depth measured in Dams 1a and 2 shown on Figure C-7 in Appendix C. The coldest MAGT (-4.5ºC) was measured in thermistor D2–02n that is furthest from Pond 2 water, being located at the abutment. It can be concluded that all dams have sufficiently cold permafrost regimes to prevent seepage or pose stability problems in the TCA operating phase.

The variation of MAGT at the tailings can be explained by several facts. MAGT below Cell 3b tailings, thermistor TC3-1 is the warmest at –3.9ºC because of the influence of the most recent tailings deposits and possibly the proximity to Pond 2. Similarly the warmer MAGT at TC1-7 is likely due to the proximity to Pond 1.

The coldest MAGT in the tailings cells was observed at the northeast part of Cell 1, at thermistor TP1 that is located within a recently installed test pad. The colder MAGT in Cell 1 (–5.1ºC) can be explained by the fact that the tailings disposal was completed in 1985 and the tailings at the location of the thermistor are only about 3 m deep and therefore the ground would have cooled relatively rapidly. The magnitudes and changes with time of ground temperatures between the depths 13 to 20 m at five of the thermistor locations can be seen on Figure C-8 in Appendix C.

Adjacent to the Test Pad in Cell 1 is another relatively deep thermistor, TC1-3, that has been monitored since 1996, thereby providing MAGT information for 9 years. The MAGT from 1996 to 2004 shown in Figure 5-3 shows the ground at 13 m depth has warmed from -6.7ºC to –5.2ºC in the nine years. To see how the permafrost warming corresponds to the mean annual air temperature (MAAT), MAAT from 1980 to 2004 is also shown in this figure. Furthermore, since Sharon and Burgess (2000) have shown a direct relationship between MAAT and MAGT that is offset by 4.4ºC, a 4ºC offset was added to the MAAT from 1980 to 1995 and plotted on Figure 5-3.

Reviewing the three curves in Figure 5-3 show:

- A good relationship between MAAT and MAGT
- MAGT has been following the same warming trend as the MAAT.
- During the last 5 years MAAT has been cooling and this cooling trend has stopped the warming of the MAGT trend during the last two years.
- However, the last five year MAAT trend is not significant enough to discount global warming.

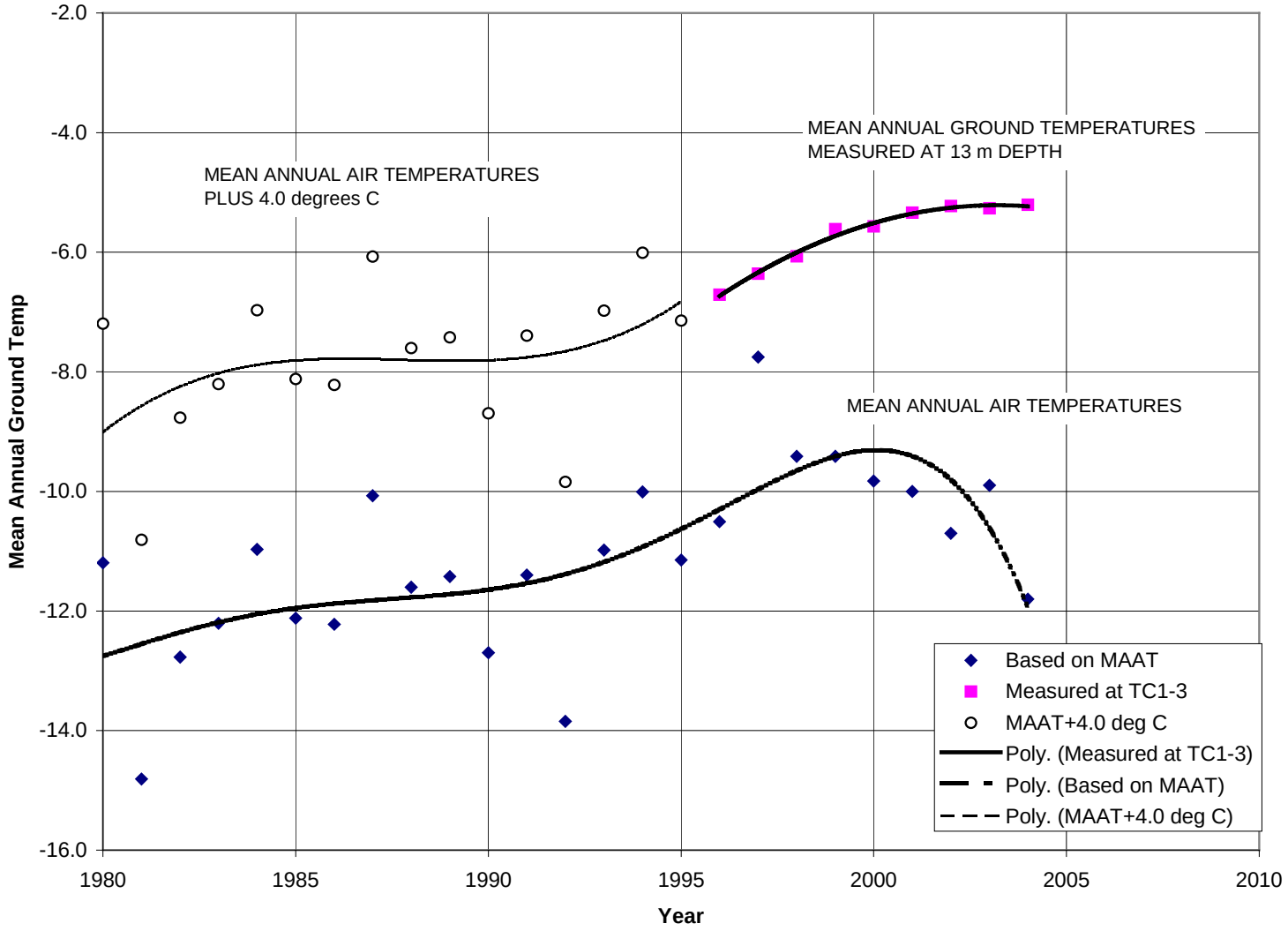

Figure 5-3. Mean annual ground temperatures in Cell 1 from 1980 to 2004

6.0 SURFACE WATER

6.1 General

The TCA is located within a relatively large watershed of about 616 ha that contained about 18 small lakes with a total area of about 974 ha before the construction of the TCA. It is located near the headwater of watershed draining into the West Arm of Contwoyto Lake as shown in Figure 6-1. An easterly area containing Long Lake was also contained originally within the TCA watershed but was redirected to flow eastward into Shallow Bay and subsequently to Contwoyto Lake by the construction of a saddle dam at Dam 4 location.

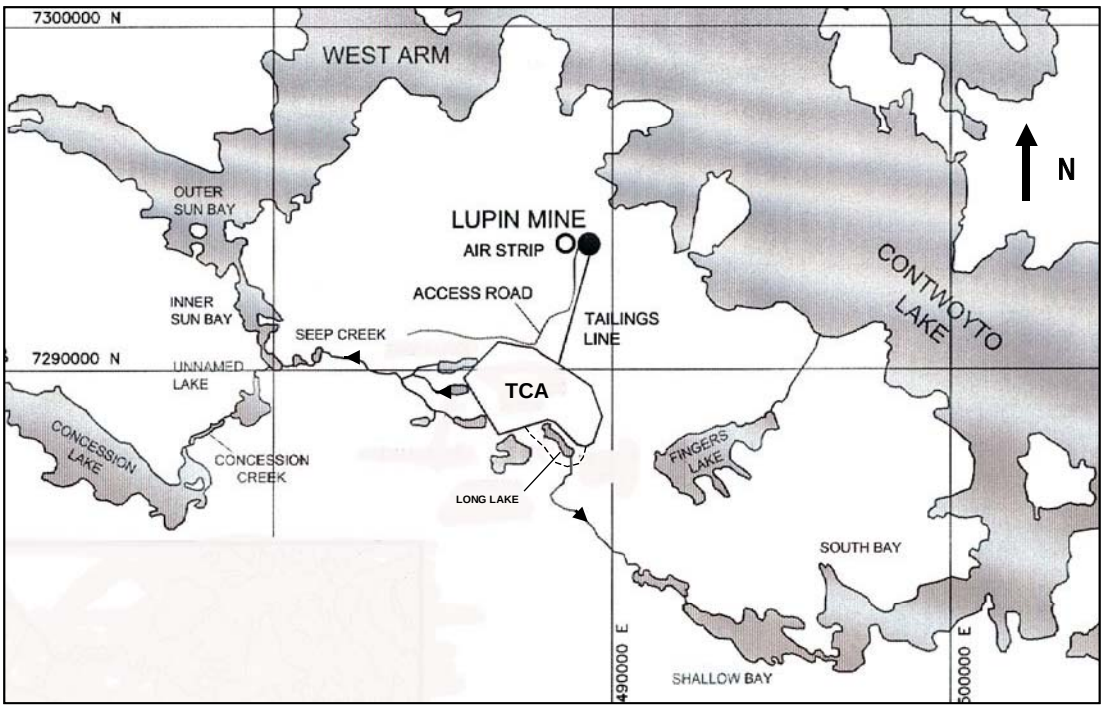

Figure 6-1. Location of TCA within Contwoyto drainage system

The construction and operation of the TCA has changed the water flows from this area and will change again upon closure. The water surfaces and flows within the TCA are shown in Figure 2-4 (before), Figure 2-7 (during operation in 2004) and Figure 6-7 (after closure). The mean annual water balances, and therefore the flows out of the TCA, were estimated for: before, during operation, and after closure.

The water balance is a function of the annual precipitation, runoff from the land areas, evaporation from water surfaces, excess water from tailings slurry and outflow from the TCA if there is excess water. The climate and a description of the TCA watershed were provided in

Sections 2.2 and 2.3. Precipitation values used in the water balance are the mean values for the before and closure conditions as given in Table 6-1.

Table 6-1. Mean annual precipitation and evaporation

Item	Value
Annual rainfall	165 mm
Annual snowfall	140 mm
Total annual precipitation	305 mm
Lake water evaporation	280 mm

For operational water balance, the water balance for the years of 1985 to 2004 was estimated and for this estimate the actual annual precipitation values shown in Figure 2-3 were used.

The land and water surface areas are different for the three stages of the TCA. The estimated areas that were used in the calculations are given in Table 6-2.

Table 6-2. Land and water areas during three stages of TCA

Type	Pre TCA	Operation	After Closure
Land area, ha	519	281	543
Water area, ha	97	335	73
Total TCA, ha	616	616	616

Different runoff coefficients of 0.50 and 0.60 were used for the before and operation stages respectively of the land area. The reason being that before TCA, the land area contained low-lying areas with swamp vegetation that would retain water. These low areas were covered with tailings and subsequently covered with esker sand that would promote higher runoff.

The volumes slurry water and water that was trapped within the tailings were calculated using the values as given in Table 6-3.

Table 6-3. Tailings slurry and tailings properties

Tailings properties	
SG	2.90
Void ratio	0.77
Slurry ratio	0.40

It should be noted that normally a small watershed in the Lupin area experiences two runoff periods. The first runoff period, representing the largest concentrated flow, takes place during the spring snow melt, occurring generally in late May. Snow melt occurs over a short period of about a week, naturally depending on the air temperature changes. The second runoff period occurs during rainfall events, and is the greatest in July and August and trailing off into September. The snowmelt produces the largest flows but the flows within small watersheds occur over frozen ground. Runoffs from rainfall over small watershed produce smaller flows with a relatively small erosion.

6.2 Water balance before TCA construction

The initial watershed area of the TCA before the construction the diversion of the easterly portion of the watershed was about 710 ha. Diversion of the Long Lake watershed reduced the TCA watershed to 616 ha. The small lakes within the TCA represented about 97.4 ha of water surface. The pre-TCA lakes and water flow directions are shown on Figure 2-4 and the areas of these lakes and the elevations of the water surfaces (based on 1980 survey) are given in Table 2-2.

The water balance of this area is illustrated in Figure 6-2...

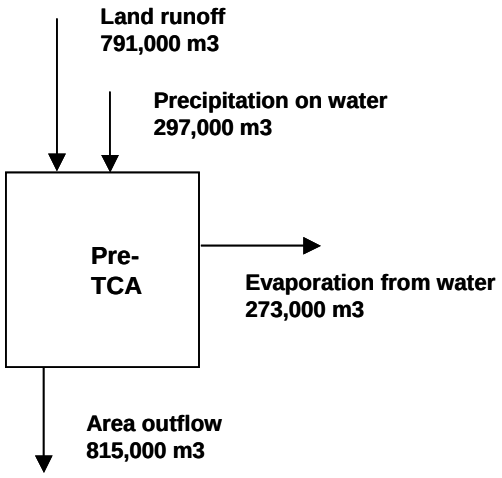

Figure 6-2. Pre TCA construction water balance

Before TCA operation, the area had an inflow of 791,000 m^3 from runoff and 297,000 m^3 total precipitation on the lake surfaces. The latter assumed that the greater snow accumulation on the low lying area was about equal to snow sublimation. The lake water surface lost about 273,000 m^3 of water due to lake evaporation, thereby leaving 815,000 m^3 of water to flow out of the TCA area.

6.3 Water management during operation

Construction of Dams 1a, 2 and 4 changed the water management of TCA. During the initial 5 years, all water inputs into the TCA, precipitation and slurry water were retained within the TCA. This resulted in forming a large pond against Dams 1a and 2 as illustrated in Figure 2-5. From 1985, Lupin began storing the tailings in cells and managing excess water by passing it through a series of ponds to improve the water to meet discharge quality before siphoning the water over Dam 1a annually. Layout of the TCA during 2000 is portrayed in an aerial photo taken in 2000 in Figure 6-3.

During 2000 and the years to the present the tailings were discharged into either cells 2, 3 or 5 (including N) and all excess water, from both precipitation and excess slurry reported to Pond 1, from where it was siphoned annually to Pond 2 and finally after about two years residency in Pond 2, excess water was siphoned over Dam 1a into the West Arm of Contwoyto Lake. Water from individual cells was transferred into Pond 1 as follows:

- Excess precipitation water from Cell 1 flowed through a small channel and culvert located at the easterly end of Dam 3D into the adjacent small lakes and then to Pond 1.
- Excess precipitation and tailings water from Cell 2 seeped through Dam 3 into Pond 1.
- Excess precipitation and tailings water from Cell 3 was siphoned over Dam L into Cell 4 pond from where it was allowed to flow under controlled conditions into the adjacent small lake system that directed the water into Pond 1.
- Excess precipitation and tailings water from Cell 5 was pumped into Pond 1.

The large Ponds 1, 2 and Cell 4 pond increased the water surface of the TCA and inversely decreased the land surface. This in turn increased the precipitation on water surface and correspondingly evaporation from the water. The water balance was further changed by the introduction of tailings slurry water and subsequent storing some of this water within the tailings pores.

Excess water within the TCA was stored temporarily within Ponds 1 and 2. When water levels became high in these ponds and water quality within Pond 2 met the discharge quality criteria, some of the excess water within Pond 2 was siphoned out. The changes in the water levels in Ponds 1 and 2 are given in Figure 6-4.

Figure 6-3. Aerial view of TCA in 2001

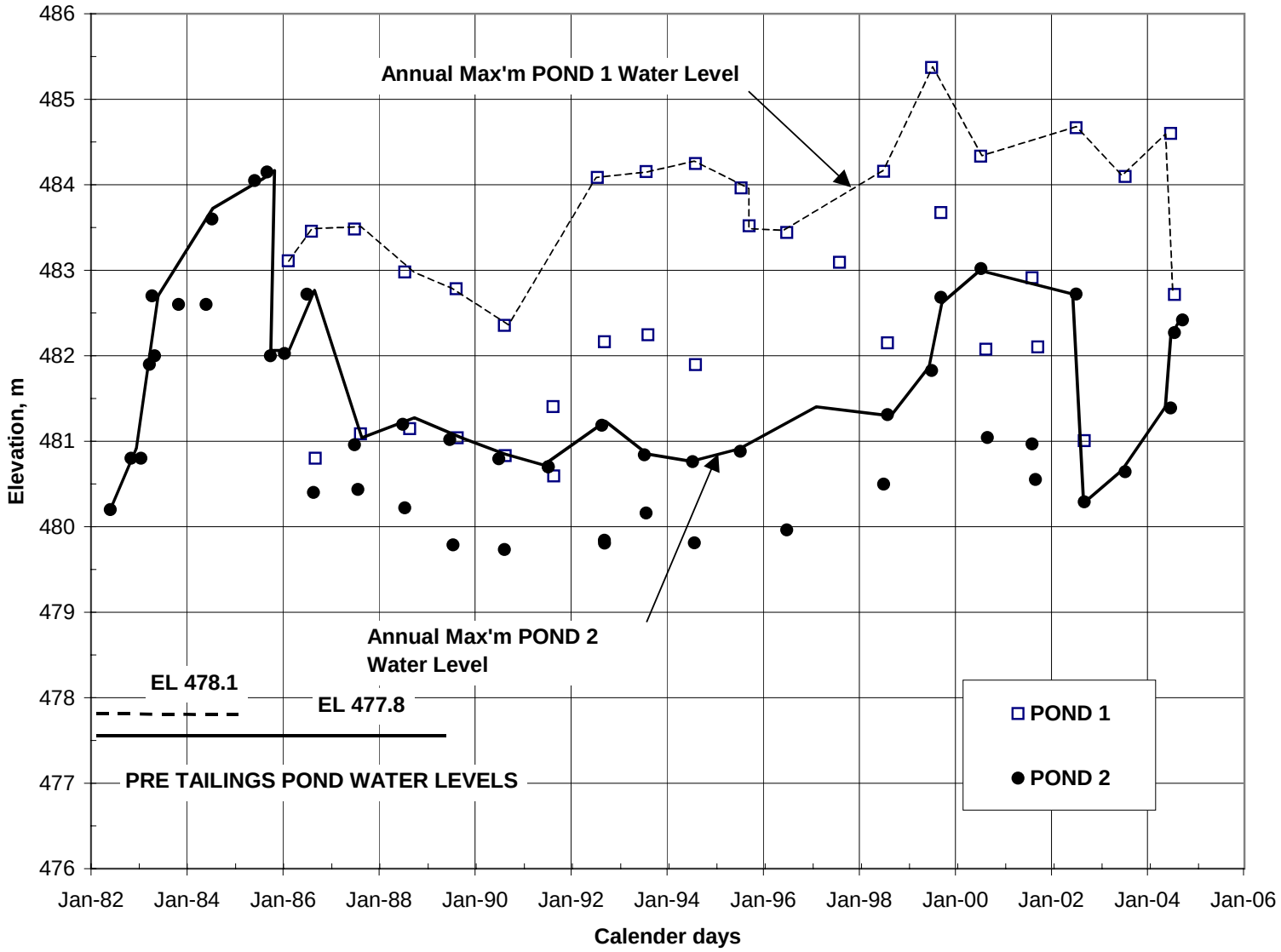

Figure 6-4. Water level fluctuations in Ponds 1 and 2

Water balance analysis over the period from 1985 to 2004 was performed in order to calibrate the parameter used for the water balances before and after construction. A long period of tracking of water in and out of the TCA was necessary because of large fluctuation of tailings production and water discharge from Pond 2 over the years. Tailings discharge into the TCA varied from a maximum of 248,000 and 239,000 tonnes in 1983 and 1993 respectively to minimum values of 6,400 and 3,000 tonnes in 1998 and 1999 respectively. Correspondingly the volume of water that was discharged from Pond 2 varied from 4,400,000 m^3 and 3,100,000 m^3 in 1985 and 2002 respectively to no water discharge in 1998, 1999, 2001, 2003 and 2004.

To obtain the mean annual water balance at the TCA during operation, a spreadsheet calculation was used to follow the continuous water balance from 1982 to 2004. In this calculation, an initial water volume of 2,000,000 m^3 was assumed stored within the existing and the various water balance components were calculated using the actual annual total precipitation, tonnes of tailings solids discharged into the TAC and water volumes that were siphoned out of the TCA.

The results given in Table 6-3 show the final accumulated volume of water over the original lake to be 4,900,000 m^3. This volume corresponds to the increased water level in Pond 2 that is about 5 m above the original water level. This means that the water balance assumptions and parameters that were used in the before and after TCA water balance are realistic. The mean annual water balance at the TCA during operation is shown in Figure 6-5.

The water balance shows that on an mean annual basis, Pond 2 accumulated water at a rate of 212,600 m^3. This resulted in the accumulation of excess stored water volume of 4,900,000 m^3 that will have to be discharged to restore to original water level at Pond 2 and before Dam 1a is breached.

6.4 Surface water after closure

At closure the surface water flows will be returned to pre-TCA construction period as much as possible. This will be done by completing the covering of all tailings with esker sand to prevent potential oxidation of the tailings, breaching Dams 1a and J to re-establish the pre-TCA lakes as far as possible. Erosion of the covered tailings cells will be eliminated by the fact that each cell represents a small watershed, and therefore it will produce only small water flows. Channels through bedrock will direct these flows to the re-established lakes. Lakes and flows of water after closure are illustrated on Figure 6-7.

Year	Total Precip	Precip water	Land Runoff	Lake Evaporation	Tails solids	Slurry water	Storage in tails	Net water, m3	Accumulated water	Discharge m3	Net Accumulated Water, m3
	mm	m3	m3	m3	tonnes	m3	m3	2,000,000			
1982	305	1,022,885	1,127,285	939,042	141,734	212,601	37,633	1,386,097	3,386,097		3,386,097
1983	379.9	1,274,078	1,404,117	939,042	247,960	371,940	65,838	2,045,256	5,431,353		5,431,353
1984	330.5	1,108,404	1,221,534	939,042	***180,000***	270,000	47,793	1,613,104	7,044,457		7,044,457
1985	306.7	1,028,586	1,133,569	939,042	178,018	267,027	47,267	1,442,873	8,487,330	4,413,507	4,073,823
1986	303.4	1,017,519	1,121,372	939,042	183,764	275,646	48,793	1,426,702	9,914,032	4,126,199	1,374,326
1987	335.2	1,124,167	1,238,905	939,042	193,204	289,806	51,299	1,662,538	11,576,570	1,142,687	1,894,177
1988	233.4	782,758	862,651	939,042	193,592	290,388	51,402	945,353	12,521,923	1,163,214	1,676,316
1989	219.1	734,800	809,798	939,042	196,509	294,764	52,177	848,143	13,370,066	1,162,239	1,362,220
1990	233.8	784,100	864,129	939,042	197,318	295,977	52,391	952,773	14,322,839	837,246	1,477,747
1991	322.3	1,080,904	1,191,227	939,042	206,893	310,340	54,934	1,588,495	15,911,334	771,280	2,294,962
1992	250.7	840,778	926,592	939,042	216,302	324,453	57,432	1,095,349	17,006,682	1,214,636	2,175,674
1993	285	955,810	1,053,365	939,042	238,696	358,044	63,378	1,364,800	18,371,482	704,575	2,835,899
1994	249.8	837,759	923,265	939,042	232,189	348,284	61,650	1,108,616	19,480,098	863,868	3,080,647
1995	319	1,069,837	1,179,030	939,042	130,930	196,395	34,764	1,471,456	20,951,554	938,715	3,613,388
1996	405.7	1,360,604	1,499,475	939,042	141,013	211,520	37,441	2,095,115	23,046,669	1,139,233	4,569,270
1997	260.5	873,644	962,813	939,042	151,240	226,860	40,157	1,084,118	24,130,788	2,892,289	2,761,100
1998	360.4	1,208,681	1,332,045	939,042	6,381	9,572	1,694	1,609,561	25,740,349		4,370,661
1999	372.8	1,250,267	1,377,876	939,042	2,993	4,490	795	1,692,796	27,433,144		6,063,456
2000	253.8	851,174	938,049	939,042	120,831	181,247	32,083	999,346	28,432,490	2,701,360	4,361,442
2001	285.6	957,822	1,055,583	939,042	148,355	222,532	39,391	1,257,505	29,689,996		5,618,948
2002	339.6	1,138,923	1,255,168	939,042	146,022	219,033	38,771	1,635,311	31,325,307	3,102,895	4,151,364
2003	293.1	982,975	1,083,303	939,042	88,620	132,930	23,530	1,236,637	32,561,943		5,388,000
2004	337.8	1,132,887	1,248,515	939,042	47,359	71,039	12,575	1,500,824	34,062,767		6,888,824
Total					3,589,923			32,062,767		27,173,943	
Avg	303.55	1,018,233	1,122,159	939,042	156,084	234,125	41,443	1,394,033		1,181,476	

Annual Average		212,558
Total water volume differer		4,888,824

Table 6-4 . Spreadsheet of annual water balance components at TCA from 1982 to 2004

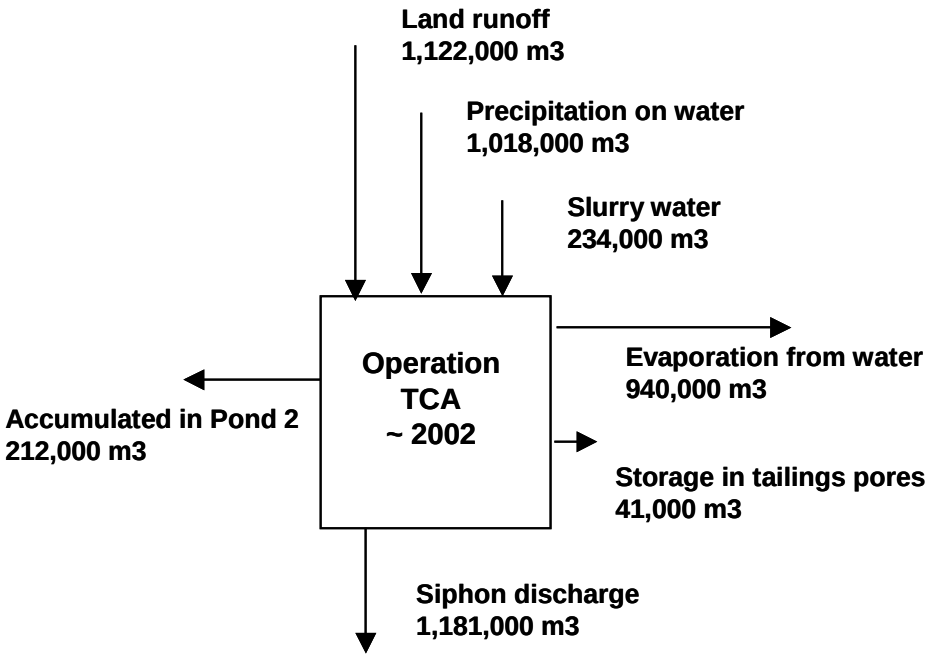

Figure 6-5. Mean TCA water balance during operation

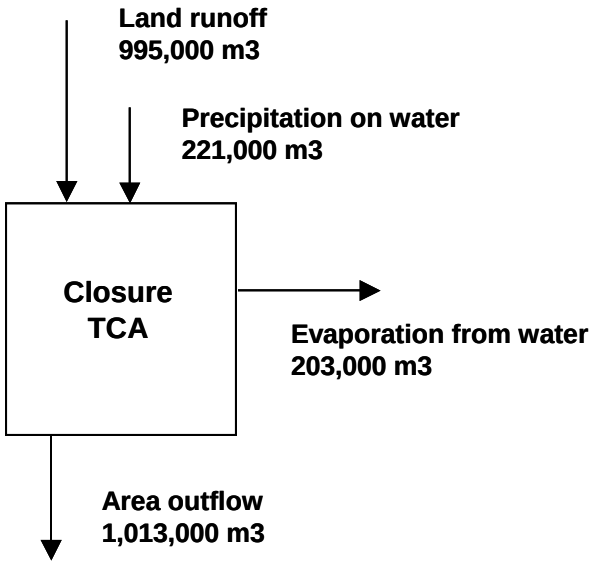

Figure 6-6. TCA water balance after closure

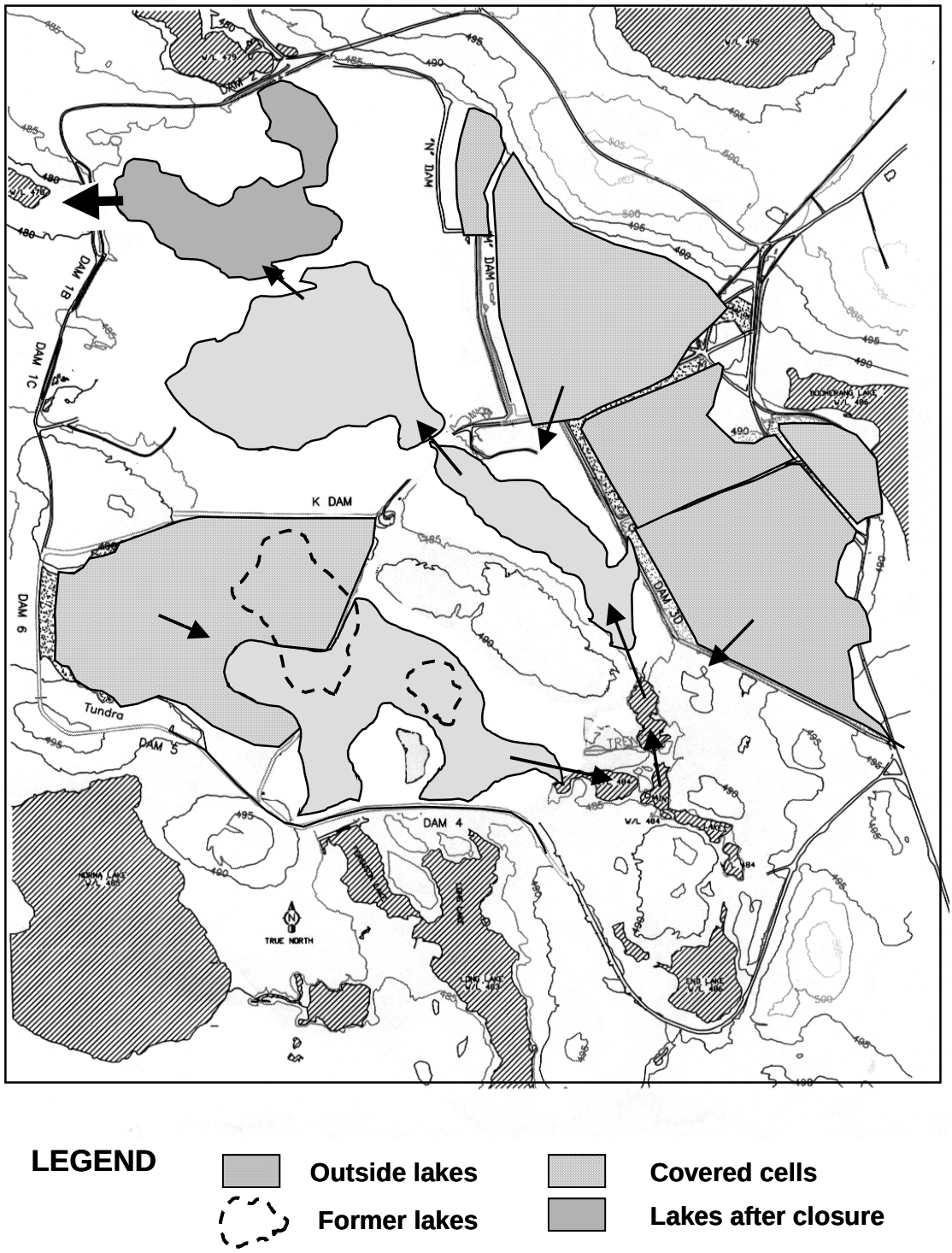

Figure 6-7. Surface water management after closure

6.5 Observations

The results of the annual water balance before, during operation and after closure at the TCA are summarized in Table 6-5.

Table 6-5. Summary of annual water balance before, during operation and after closure at the TCA

WATER TO TCA	Pre tailings	Operation ~2002	After Closure
Precipitation land runoff	790,870	1,122,159	994,427
Precipitation on water	297,070	1,018,233	221,430
Slurry water		234,125	
Total in	1,087,940	2,374,518	1,215,857
WATER LOSS			
Evaporation from water	272,720	939,042	203,280
Storage in tailings pores		41,443	
Mean annual syphon out		1,181,476	
Mean TCA outflow	815,220		1,012,577
Total out	1,087,940	2,161,960	1,215,857
Annual water accumulation in Pond 2		212,558	

The observations that can be made from these results are:

- The operation phase experience much greater water inflows into the TCA and this was compensated by much larger evaporation from water surfaces; the total water surface being more than three times the before TCA and storage of water within the tailings pore space.
- After closure, the TCA will discharge about 12 percent more water from the same watershed as before TCA construction. The reason for this is that there will be correspondingly smaller water surface for evaporation.

7.0 LONGTERM STABILITY OF EARTH STRUCTURES

7.1 General

The TCA contains a number of earth structures that are referred to as dams. The dams were classified as perimeter dams, small perimeter saddle dams and internal dams in Table 3-1. The purpose, physical structure and condition of these dams are different for the perimeter and internal dams.

7.2 Perimeter Dams

Perimeter dams were constructed to retain water during the operation phase and it is proposed to terminate their function as water retention structures at the closure of TCA. Dams 1a and 2 are the largest of the 8 perimeter dams, including the two small perimeter saddle dams 1b and 1c. The maximum height of these two dams is 7.9 m and 5.9 m respectively. After closure of operations, and after water quality within Pond 1 and Pond 2 meets discharge limits, water will be lowered in the two ponds to about pre-project levels by breaching both Dam 1a and J Dam. Lowering of the water level in Pond 2 will result in Dam 2 becoming an earth berm resting on ground above the pre-project water level.

Dam 3 was constructed to isolate Boomerang Lake from the TCA. In 1985, the area behind Dam 3 was developed as a tailings storage cell (Cell 1a), filled with tails, then capped with an esker cover to Dam 3 crest level. The Dam 3 section has become an earth buttress containing a small height (about 2m) of tailings.

Dam 4 was constructed to redirect the flow of water from Long Lake watershed eastward. It acts as a saddle that causes water to flow either west to Pond 1 or east towards Contwoyto Lake. Dam 4, which is 40 to 50 m wide toe to toe, will be left in place between the two adjacent watersheds.

Dams 5, 6, 1b and 1c are small perimeter dams with total height varying between 1 and 2.5 m. They are located along the TCA watershed perimeter and were constructed to contain water in case of extreme water level rise within the TCA. There will be no need to provide high water level protection once Dam 1a is breached. After closure these dams will become higher ridges along the watershed divide.

7.3 Internal Dams

There were eight perimeter dams (Table 3-1) during the operation of the TCA.

- Two of these dams (3C and 3E) have been absorbed within tailings and esker cover material when these materials were placed on both sides of these dams.
- Two dams (J and L) will be breached upon closure of the TCA.
- Remaining dams 3D, K, M and N will be converted into earth buttresses containing solid tailings; without any ponded water.

7.3.1 3D Dam

This dam is a massive earth berm that retains tailings. Figure B 11 illustrates the cross section of this dam. It consists of a gravelly sand (esker) berm with a crest of more than 10 m buttressed by about 10 m of mine rock. Tailings and an esker cover were placed to be level with the dam crest. Presently Pond 1 water saturates the downstream face of 3D Dam. However, upon closure when J Dam and Dam 1a are breached, the Pond 1 water level will drop to just above the toe of the remaining structure with the exception of a short distance that was the outlet of a small lake that was covered by Cell 1 tailings.

The proposed closure plan of the Cell 1 tailings area is to keep draining the surface water from Cell 1 by means of a channel through bedrock at the east end of Dam 3D and grade small part of the mine rock zone to ensure long-term stability of the Dam 3D structure. Since this dam will not retain water, it can be considered as an earth structure.

7.3.2 K Dam

This dam was constructed as a wide earth structure, with an upstream liner, from which tailings were discharged into Cell 3. The resulting tailings Cell 3 is shown in Figure B 16.

Upon closure, Pond 2 water level will drop by about 2 m and thereby resulting in the entire K Dam downstream slope being above water. Tailings within Cell 3 are being presently covered. Figure B 16 shows that the K Dam earth structure will be more than 400 m from any upstream water.

It is proposed to place a rock fill blanket/buttress, at a 2.5H:1V slope, on the downstream side of K Dam to ensure long-term physical and erosion stability of this earth structure. The geometry of the rock fill was developed by slope stability analyses discussed in a subsequent section.

7.3.3 M Dam

This dam was constructed to contain tailings within Cell 5. It consists of gravelly sand fill lined with rock fill riprap on the downstream side. The profile of this dam with contained

tailings is shown on Figure B 19. At closure the remaining water upstream of M Dam will be replaced by tailings and gravelly sand cover. All surface water will be discharged from Cell 5 by a channel constructed through bedrock located at the southeast corner of Cell 5. The downstream slope of M Dam will be covered with blanket/buttress of rock fill, at a final 2:1 slope.

At closure of the TCA, M Dam will become an earth zone that provides physical and erosion stability for Cell 5 tailings. The long-term stability is discussed in a later section.

7.3.4 N Dam

This dam is the smallest of the internal dams containing tailings. It will receive similar closure treatment to the M Dam and become a buttressing berm to M Dam.

7.4 Stability of internal dams

7.4.1 General

The physical stability of the four internal dam structures will change as operation phase changes to reclamation and abandonment, and as the effect of global warming will likely thaw the permafrost. Presently all four internal dams (3D, K, M and N) are frozen. This results in the foundation and dam section to be impermeable and creating strong physical stability due to high strength of the frozen materials. Lupin has chosen to consider the likelihood that global warming may thaw the permafrost at the site and will modify the downstream slopes of the internal dams to be physically stable in the unfrozen condition. To develop the final geometry design of these dams, thawed dams were first analyzed with existing geometry and than a final geometry was developed based on long-term physical and erosion stability.

7.4.2 Dam Safety

Dam Safety Guidelines were developed by the Canadian Dam Association (1999) to apply to dams that are at least 2.5 m high and which have at least 30,000 m^3 of reservoir capacity. The guidelines also apply to tailings dams if the reservoir contents could be released and have an unacceptable impact on the environment.

If a dam falls under the dam safety guidelines, it has to meet the physical stability criteria given by a minimum factor of safety for static conditions of 1.5, and generally 1.1 for seismic conditions. It also has to be able to pass maximum flood flows and have a minimum freeboard. Dams require annual geotechnical inspections (required by Water Boards) and Dam Safety Reviews every 5 to 10 years depending on consequence category given by the Dam Safety Guidelines.

The above dam safety requirements are practically impossible to meet at a closed facility on a long-term basis because of access and unknown changes. Therefore it is highly preferable not to leave any dams behind once a mine site is closed.

The internal Dams 3D, K, M and N do not fall under the Dam Safety Guidelines because they do not, and will not, store any water behind the earth structure after closure, and a physical failure of any of these structures will have practically no environmental impact. Dams 3D, M and N will not have any reservoirs since all surface water will be directed out of the watershed areas by channels.

The physical stability of the 3D, K, M and N earth structures do not have to meet the minimum Factor of Safety for static assessment of 1.50 since they will not fall under the dam classification (retaining water) after abandonment. The Lupin earth structures, that are now buttressing tailings with no pond, correspond to earth embankments that are designed with smaller minimum factors of safety than 1.5. For instance, highway embankments with similar height are normally designed with a minimum Factor of Safety greater than 1.3 (author's experience). Another argument for smaller minimum factor of safety is obtained from Dam Safety Guidelines recommending that the dam embankment, at the end of construction before reservoir filling, should have a minimum of 1.3.

Lupin has adopted a minimum Factor of Safety for the long-term stability of earth structures, such as the 3D, K, M and N, which will be equal to or greater than 1.50.

7.4.3 Stability conditions and assumed material properties

Stability conditions of 3D, K, M and N earth structures have been analyzed for three conditions, namely:

- Present, frozen core and foundation.
- Existing structures, thawed core and foundation due to global warming
- Closure design, thawed core and foundation due to global warming.

Selection of strength parameters of frozen materials for the slope stability analyses is difficult because the frozen strengths are dependent on particle matrix, ice content and temperature of the frozen material and the selected design creep rate. The frozen materials with high ice content creep under stress and therefore a creep frozen strength based on a creep rate has to be used. Because of the difficulty to determine appropriate frozen strength, normal practice is to base the frozen strength on a broad spectrum of published test results and confirmed with some creep strength testing. This method was adopted in the Diavik PKC (tailings) dams that were constructed on ice rich soils and will have a final height of 42 m. A relationship between frozen creep strength of three types of soils and different ice contents is shown in Figure 7-1.

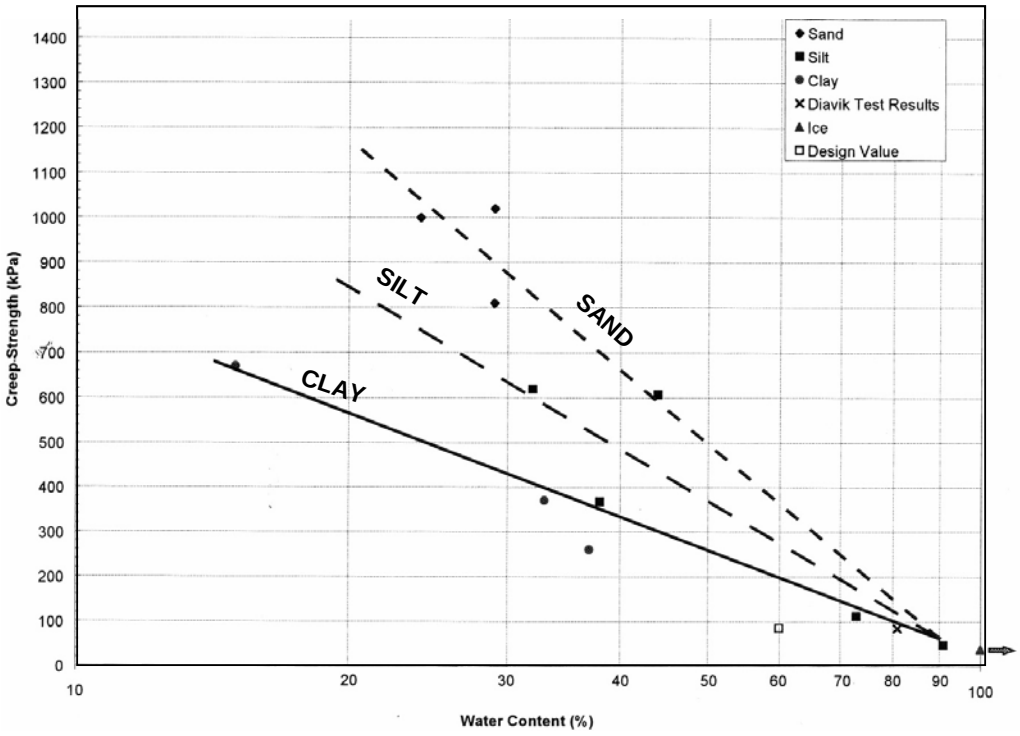

Figure 7-1. Frozen creep strength at –2º C versus ice content given in terms of water content (Diavik 1999)

For the stability analyses of the Lupin earth structures, the earth structures can be represented by three materials: a) sandy esker dam core and the underlying thin silty sand foundation as one material, b) tailings and c) downstream rock fill zone as rockfill. These structures are founded on bedrock that is assumed infinitely strong. The frozen strength is based on the mean temperature of the earth structure during summer to be –2º C and the creep rate is 1 m over a 10-year period. The frozen creep strength (very conservative) and strength properties selected for the three materials are given in Table 7-1.

Table 7-1. Parameters selected for stability analyses

Material		Frozen		Thawed	
	Unit Weight kN/m^3	Cohesion kPa	Friction angle degrees°	Cohesion kPa	Friction angle degrees
Rockfill	20	0	40	0	40
Tailings	16	200	0	3	30
Esker & silty sand	20	300	0	0	33
Bedrock		Infinitely strong			

7.4.4 Stability analyses results

Stability analyses of the three main earth structures (3D, K and M dams) were conducted for the three conditions (frozen, thawed and closure design, thawed). The analyses were conducted using the G Slope program prepared by Mitre Software Corporation. The results are given in Appendix D and summarized in Table 7-2.

Table 7-2. Summary of stability analyses

Dam	Existing frozen dam		Thawed dam with different GWL			Closure geometry Berm slopes		
	Thru Rock berm	Thru Esker Section	HWL	LWL	Likely	Static		Seismic
						2h:1v	2.5h:1v	2.5h:1v
K Dam		8.8	0.96	1.21		1.63	2.11	2.02
3D Dam	1.4	8.5			1.51		2.04	1.95
M Dam		8.1			1.32	1.62	1.91	1.82

Comments of the results are:

7.4.5 K Dam earth structure

The existing structure has a very high minimum factor of safety (8.8) under the existing frozen condition. However, if the geometry of the K Dam was left as it exists, it would have poor stability under thawed conditions that would develop under a global warming condition. Depending on assumed groundwater surface within the dam, the minimum factor of safety would be between 0.96 (high groundwater level) and 1.21 (low groundwater level).

Placing a rockfill stabilizing berm on the downstream face will raise the minimum factor of safety to 1.63 for a downstream slope of 2 horizontal to 1 vertical, and to 2.11 for a

slope of 2.5 horizontal to 1 vertical. Both downstream slopes are satisfactory. Final closure slope will be between 2H:1V and 2.5H:1V to be determined by the construction equipment.

As with K dam, the existing 3D Dam under the present frozen condition has a very high minimum factor of safety of 8.5. Upon global warming thawing, the stability of the dam will decrease to a minimum factor of safety of 1.51 that would be adequate for an earth structure. However, because of the presence of a 10 m wide rockfill berm on the downstream side, it is proposed to re-grade this berm to form a slope of 2.5H:1V which will raise the minimum factor of safety to 2.04.

7.4.6 M Dam earth structure

As with K and 3D dams, the existing dam under the present frozen condition has a very high minimum factor of safety of 8.1. Upon global warming thawing, this earth structure will have a marginal minimum factor of safety of 1.32 for the long-term closure condition. It is proposed to place a rockfill zone on the downstream face. A rockfill zone of 2H:1V will produce a minimum factor of safety of 1.62, and a 2.5H:1V slope will raise the minimum factor of safety to 1.91. Final closure slope will be between 2H:1V and 2.5H:1V to be determined by the construction equipment.

7.4.7 Seismic Conditions

Seismic stability analyses were conducted on the final closure design geometry. The results shown for final slopes of 2.5H:1V show the static minimum factors of safety to drop about 5% when earthquake acceleration is applied to these earth structures. Considering that much lower minimum factors are accepted for earthquake loading, the final closure design structures will have very satisfactory minimum factors of safety.

8.0 TAILINGS COVER

8.1 General

Tailings at Lupin were observed to have a potential for acid drainage, if the tailings were exposed to prolonged weathering (Klohn-Crippen 1995). Lupin started to cover exposed tailings in completed cells in 1988 and monitoring the covered tailings to assess the effectiveness of the covers. As a result, Lupin has collected the most extensive and longest observed performance records of covered cells in permafrost areas.

Data collected includes ground temperatures, water levels within the cover, water quality within the cover, slope of tailings surface, thickness of tailings deposition, moisture content of the cover, and particle size analyses of tailings and cover materials. Various studies have determined the durability (physical and chemical) of the cover material, water balance within the cover during drought conditions, and pore water expulsion potential from the compacted tailings during thaw conditions (Golder 2004). Test pits excavated through the cover to the tailings surface were examined for evidence of cryoturbation, oxidation at the tailings interface, presence of ice lenses, and condition of the tailings/cover interface.

Based on this data and research on tailings covers in southern areas, Lupin proposed to place a p*artially saturated granular cover* over the tailings. The concept was described in a paper (Holubec, 2003a) and as a report (Partially Saturated Granular Cover for Lupin Mine Tailings, Holubec 2003b) transmitted to Nunavut Water Board in March 2004 as an Appendix to the *2004 Lupin TCA Management Report*. Since the submission of that report, the name of the cover has been modified to *saturated zone cover*, which represents a more accurate description of the design.

In 2004, Lupin continued to monitor the various covered cell instrumentation, and has collected additional information to validate the effectiveness of the saturated zone cover.

8.2 Saturated Zone Cover

Oxidation of potentially acid drainage tailings needs to be prevented to avert metal loading into receiving waters. In southern regions with no permafrost, this is accomplished with dry or water covers. Since these are not viable in continuous permafrost regions, such as exist at Lupin, many mines in continuous permafrost have been adopting the concept of encapsulating tailings in permafrost. This involves placing a granular cover over the tailings that will maintain the annual thaw zone (active layer) within the cover. Field test cover trials at 3 mines in Nunavut and northern Quebec (Holubec 2004) have shown that increased saturation within the cover will decrease the required cover thickness. The saturation within the cover provides the same benefit as a water cover, whereby tailings oxidation is prevented even if the tailings are unfrozen. While I. Holubec Consulting Inc. (Holubec 2003b) suggests a saturated

zone of 0.3 m, any depth of water over the tailings will provide an adequate oxygen barrier to prevent oxidation.

The saturated zone cover concept consists of two layers;

a) A surface layer that lowers the rate of evaporation of the saturated base esker material, and
b) A lower saturated layer that prevents oxidation of the tailings.

It is based on a *stagnant water cover* design concept investigated by Li et al (1997) and column testing by CANMET (MEND 5.4.2d) demonstrating that in absence of water movement, even a small depth of water greatly inhibits oxidation.

The proposed thin partially saturated granular cover has many positive attributes, such as:

- Provides a water oxygen barrier that is not dependent on having permafrost within the tailings.
- Is not sensitive to annual temperature changes or global warming.
- Will support vegetation because of the proximity of the water surface to the top of the cover.
- If esker material is used for cover material, it decreases the required volumes and thereby reduces the disturbance of the esker deposits. Eskers serve as a preferable animal habitat.

8.3 Past Cell 1a and 1 Monitoring

Cells 1a and 1 were covered with a sandy material in 1988 and 1995. This material was obtained from a large esker deposit, Fingers Lake Esker, which is located about 5 km south of the TCA. The cover thickness varies from about 0.6 to 1.5 m. In 1988 Lupin started a monitoring program to increase their understanding of: a) development of permafrost within the covered tailings; b) effect of cover thickness on the active layer, and c) water quality within the cover system and ponded water within the cell.

Since 1988, five monitoring programs have been instituted on the covered cells to confirm the final cover design. The instrumentation used to monitor the cells consisted of the following:

a) Three thermistors installed in Cell 1a in 1988.
b) In 1995, two thermistor strings were installed in Cell 1a (to replace the inactive 1988 strings), 3 were installed in Cell 1 and 1 was installed in Cell 2.
c) In 1998 two water-sampling pipes were installed within the esker material in Cell 1 to monitor the water quality within the pores.

d) In the summer of 2002 nine additional pipes were installed in the esker cover material in Cell 1 to monitor the water level and water quality within esker cover of Cell 1.
e) At the end of spring 2003, a test area was constructed in Cell 1 to monitor the water balance within the esker cover under more controlled conditions.

The first set of thermistors installed in 1988 in Cell 1a, adjacent to Boomerang Lake, showed the tailings to be frozen one year after cover placement. The tailings thickness was relatively thin, averaging about 3 m.

In October 1995 six thermistor strings were installed in Cells 1 and 2 to monitor the seasonal fluctuation of the active layer in areas where the tailings were covered with esker sand (Klohn-Crippen 1997). The location of these strings is shown on Figure 8-1. The operational life of these thermistors varied from 1 to 5 ½ years, with one still in operation after 9 years. Thermistor identification, location, and the last monthly reading, are given in Table 8-1. All these thermistor strings were installed to a depth of 13m.

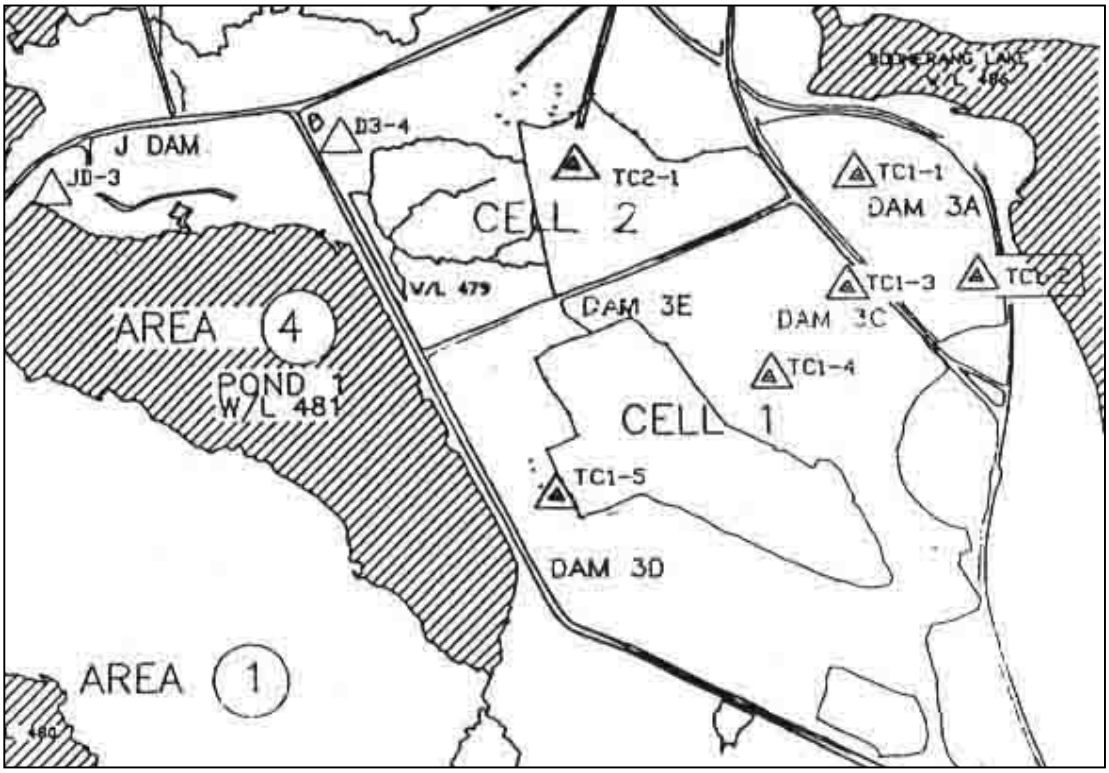

Figure 8-1. 1995 Thermistor installation in Cells 1a and 1

The maximum thickness of the active layer and the 'steady' ground temperature observed in 1996 are summarized in Table 8-2. It should be noted that the location of the groundwater surface at these locations is not known.

Table 8-1. 1995 Thermistor string installation summary

Thermistor	Location	Cover Thickness, m	Tailings Thickness, m	Stopped Operating
TC1-1	Cell 1a	0.9	+13	Oct 2000
TC1-2	Cell 1a	1.2	+13	Dec 1997
TC1-3	Cell 1	1.2	4.6	Operating
TC1-4	Cell 1	0.6	10.6	Dec 1999
TC1-5	Cell 1	1.6	11.7	Dec 1997
TC2-1	Cell 2	0.9	5.3	Dec 1999

Table 8-2. Permafrost performance at 6 locations observed in 1996

Thermistor	Cover Thickness, m	Active layer Thickness, m	Temperature at 13 m, ºC
TC1-1	0.9	1.5	-5
TC1-2	1.2	1.7	-6
TC1-3	0.6	1.2	-7
TC1-4	0.6	1.7	-3
TC1-5	1.6	1.8	-4.5
TC2-1	0.9	1.8	-6

Relating the active layer (thaw depth) to the thickness of esker cover in Figure 8-2 shows that by increasing the cover thickness, the active layer or depth thaw becomes greater.

In the absence of knowing the groundwater depth at each of these thermistors, water content of the saturated zone and the moisture content of the surface unsaturated zone, it is difficult to make definite comments on the Figure 8-2 relationship. Generalized conclusions that can be made are from the observations that: 1) the groundwater surface was at or is near the bottom of the esker cover and 2) tailings beneath the cover are completely or nearly fully saturated. Based on these assumptions, the relationship in Figure 8-2 indicates the following for the Lupin site:

a) Saturated tailings without a cover would experience a thaw depth of 1.3m.
b) To encapsulate the tailings completely with sand and gravel would require a minimum 2m cover plus additional thickness for warm years and other uncertainties.

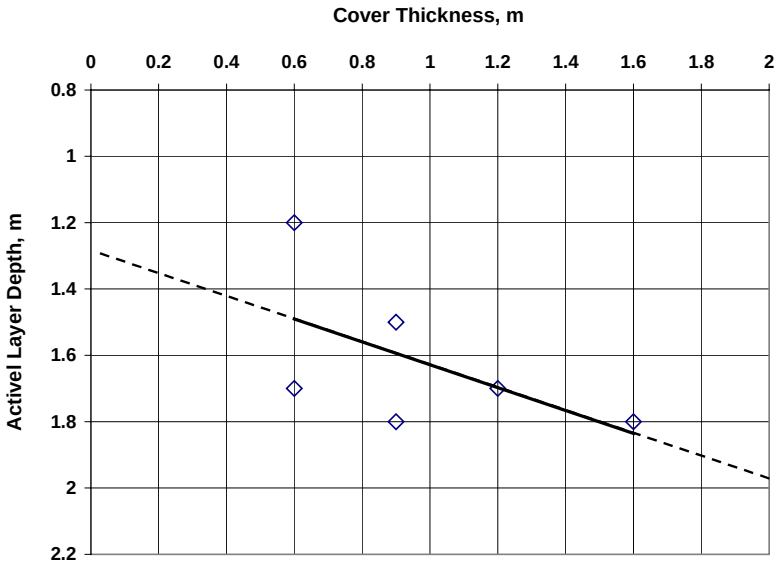

Figure 8-2. Thaw depth related to Lupin esker cover thickness

The progression of the active layer in and out of the cover and its changes over the years can be seen in the data of thermistor string TC1-3, which has been providing data since November 1995. The thaw depth progression for the 7 years between 1996 and 2002 is shown on Figure 8-3. At this location the thaw depth varied from 1.15 to 1.35 m during this period of monitoring. The cover at this location is 1.2m.

Figure 8-3 also illustrates that: a) thaw depth penetrated into the tailings by about 0.4m, b) unfrozen conditions lasted for less than 3 months and c) during this period the temperature within the thawed tailings reached a maximum of 5ºC. This temperature was interpreted from individual thermistor bead locations and likely due to the variation of snow cover.

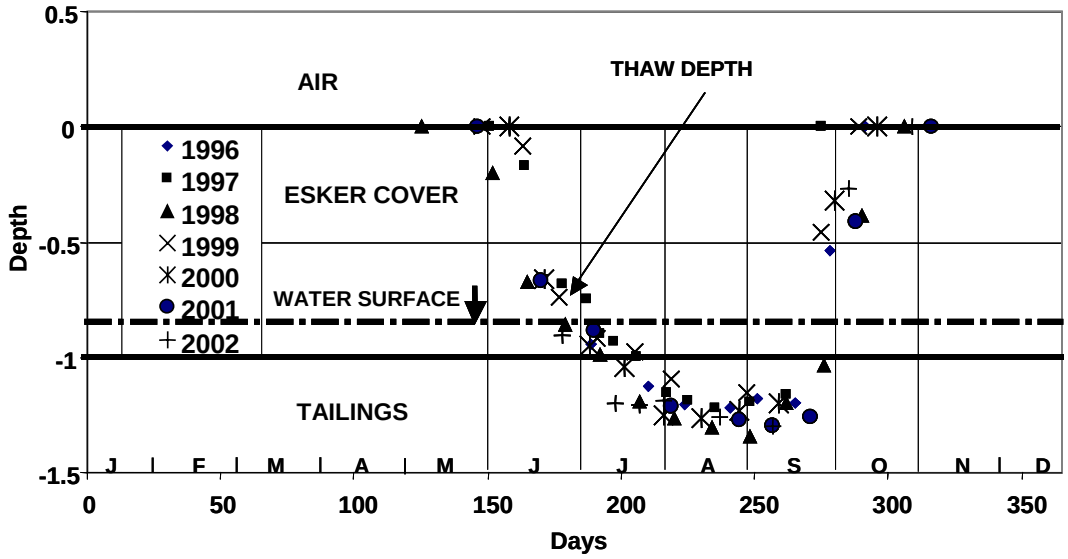

Figure 8-3. Thaw depth changes in esker covered tailings over a 7 year period, TC1-3

The thaw depth for the seven years (1996 to 2002) was plotted against the thawing index at Lupin for the same years respectively (Figure 8-4). This shows a good relationship between thaw depth and thawing index. The fluctuation of the data near the trend line can likely be attributed to the changes observed for the saturation of the esker material.

Monitoring of the esker covered tailings in Cell 1a and Cell 1 shows the following:

- Thickness of the esker varied from 0.6 to 1.6m.
- Active layer (thaw) depth varied from 1.2 to 1.8 m.
- Thaw depth was greatly influenced by the thickness of the saturated zone within the esker material.
- Good correlation between thaw depth and the thawing index.
- Thaw depth will fluctuate because of the variation of summer temperatures (thawing index) from year to year.
- Below the active layer, the tailings were completely frozen with ground temperatures ranging from- 3ºC to - 7ºC at a depth of about 13m.

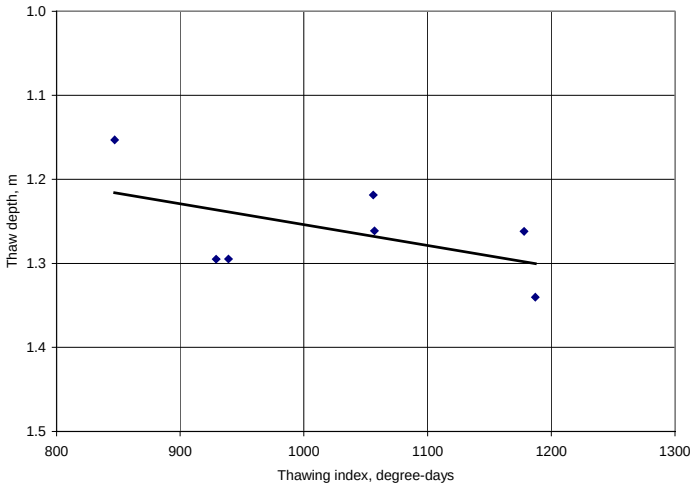

Figure 8-4. Thaw depth as a function of thawing index

8.4 2002 Esker cover groundwater monitoring

Lupin decided to pursue the saturated zone cover concept in 2002 and oriented its field testing and monitoring to confirm the validity of this concept. Nine 1.5-metre long pipes were installed within Cell 1 (Figure 8-5) in the summer of 2002 to:

- Determine accurately the thickness of the esker cover at Cell 1.
- Monitor the saturation level within the esker.
- Obtain water samples from the saturated esker zone.

To ensure that water samples were collected from within the esker pores, the pipes bases were installed about 150mm above the tailings surface. Thickness of the esker cover at the nine pipe locations is given in Table 8-3. Measurements of the esker cover during the installation of the pipes showed that the esker cover thickness varied between 1.0 to 1.3m with an average of 1.1m.

Water levels were measured in these pipes during the summer when the thaw depth reached the saturated zone. The results of this monitoring that extends over three summers, from August 2002 to September 2004, are given in Table 8-4 and are shown in Figure 8-6.

Figure 8-5. Location of pipes installed in 2002

Table 8-3. Esker thickness and saturation level in Cell 1 pipes (Measured in August 2002)

Pipe	Esker Thickness, m
1	1.2
2	1.1
3	1.0
4	1.3
5	1.2
6	1.0
7	1.2
8	1.1
9	1.0
Average	1.1

The saturation zone thickness monitoring in the esker cover of Cell 1 varied from an average of about 0.2 m around the discharge perimeter of Cell 1 (P-1, P-2, P-4 and P-5) to an average of about 0.8 m in the central portion of the Cell (P-5 and P-6). The least saturation was measured in P-2 in August 2004. The variation of the saturation is illustrated in Figure 8-6.

Table 8-4. Thickness of saturated zone in field pipes

Base Data	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8	P-9
Cover Thickness	1.17	1.07	0.98	1.30	1.17	1.02	1.23	1.07	1.00
Water saturation depth, m									
03-Aug-02			0.16	0.30	0.89	0.53		0.36	0.16
27-Aug-02		0.25	0.23	0.51	1.12	0.79		0.56	0.18
28-Jul-03	0.20	0.25	0.17	0.32	0.79	0.48	0.17	0.33	0.18
04-Jul-04	0.25	0.32	0.33	0.64	0.80	0.66	0.49	0.38	0.28
08-Aug-04	0.16	0.29	0.16	0.42	0.84	0.50	0.08	0.32	0.16
09-Sep-04	0.18	0.48	0.27	0.74	1.17	0.75		0.56	0.25
10-Sep-04							0.11		
Average thickness of saturated zone	0.20	0.32	0.22	0.49	0.94	0.62	0.21	0.42	0.20

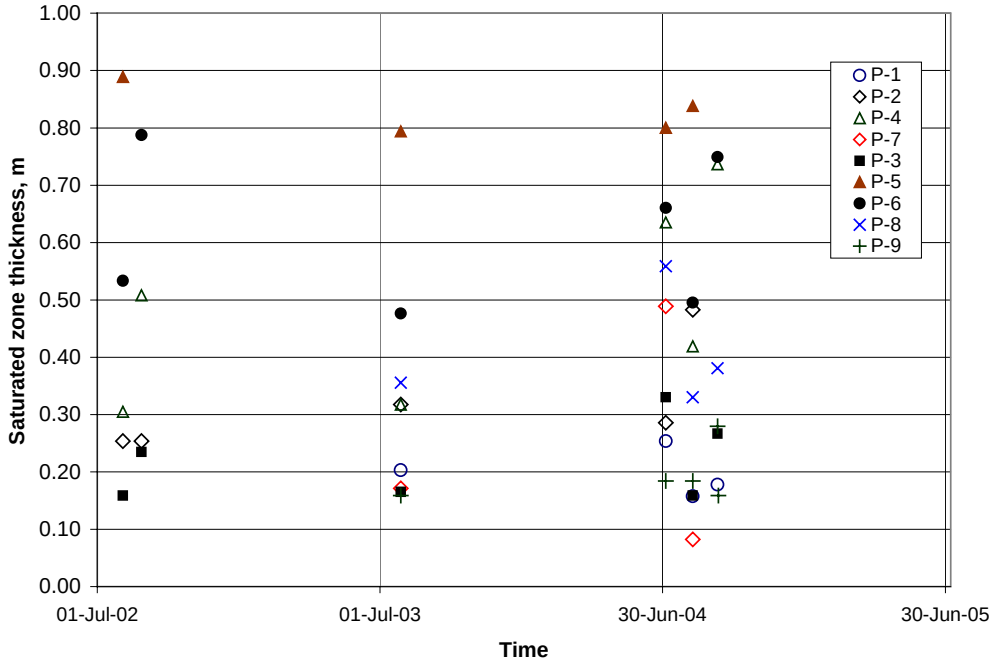

Figure 8-6. Changes of saturation zone thickness in 9 installed pipes

The groundwater profile within the esker cover in Cell 1 is illustrated on four figures (B21, B22, B23 and B24) in Appendix B and in Figure 8-7 that is a repeat of Figure B22. These figures illustrate the groundwater levels within the esker cover on the August 8, 2004.

Figure 8-7 illustrates that groundwater levels drop from a high at the northern edge of Cell 1 to a low near 3D Dam. The greatest depth of saturation is located at the center of Cell 1 at pipes P5 and P6. The reason for the greatest thickness of saturation is that this area presents both the middle of Cell 1 where the finer tailings would settle and also an area that is underlain by a former lake resulting in the greatest thickness of tailings. These two factors would have caused past consolidation of the tailings and depression of the tailings surface that can be seen by the lower base of the esker cover at pipes P5 and P6. The three north-south profiles in Figures B21 to B23 illustrate that the groundwater within the esker cover, when it is thawed during the summer, slopes towards Pond-1.

The four profiles show how the saturated zone within the esker cover varies and demonstrates that the esker cover has a saturated zone at its base.

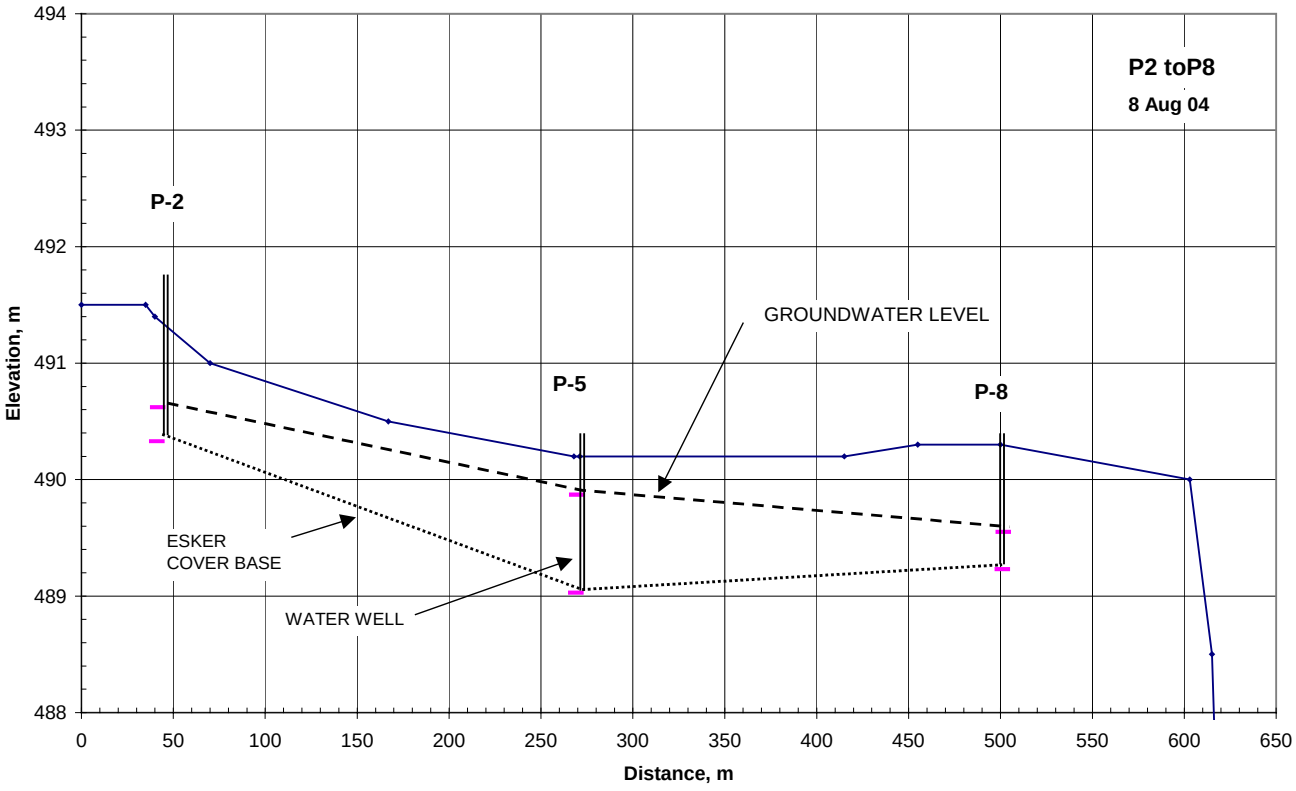

Figure 8-7. Groundwater profile along pipe section P2 to P8

8.5 2003 Test Pad Installation

In May 2003, an isolated test area was developed in the northwest corner of Cell 1. The purpose of the test pad was to determine groundwater level fluctuations due to water recharge and evaporation within the esker zone (saturated zone). The reason for a controlled test pad was that it is difficult to establish this value within the nine installed pipes. This difficulty arises because along the Cell 1 perimeter, where the tailings slurry was discharged, the tailings surface slopes towards the center of the cell and the esker groundwater would flow towards the center. Therefore, the perimeter pipes likely experience a low groundwater level and the central pipes would have high groundwater level. The location of the test pad is shown in Figure 8-8.

The test pad is a 10 m by 50 m enclosure that contains all climatic water within a HDPE wall that is anchored into permafrost. A schematic of the test pad along the long dimension is shown in Figure 8-9. A photo of the test pad installation is shown in Figure 8-10.

At the test pad location the stratigraphy is not completely representative of Cell 1 but it is suitable to provide the water balance within the esker information. At the test pad location, waste rock was placed on top of the tailings prior to being covered with about 0.75 m of esker gravelly sand in 1995. The presence of waste rock was determined during the construction of the test pad after blasting of the trench for the HDPE wall. It is estimated that the waste rock thickness is likely about 1.3 m thick and covers about 5 m of tailings.

The test pad is instrumented with two 1.5m long pipes to be used for measuring groundwater level and obtain water samples for water quality testing, and a 20 m deep thermistor string with 16 temperature sensors.

The two water pipes showed the groundwater level to be about 0.65 m below the ground surface. The groundwater levels in 2003 fluctuate near the base of the pipe because the pipes were not installed sufficiently deep, due to the presence of the waste rock overlying the tailings. In September 2004, the pipes were reinstalled with their base being nearly 1 m deep that gave better results.

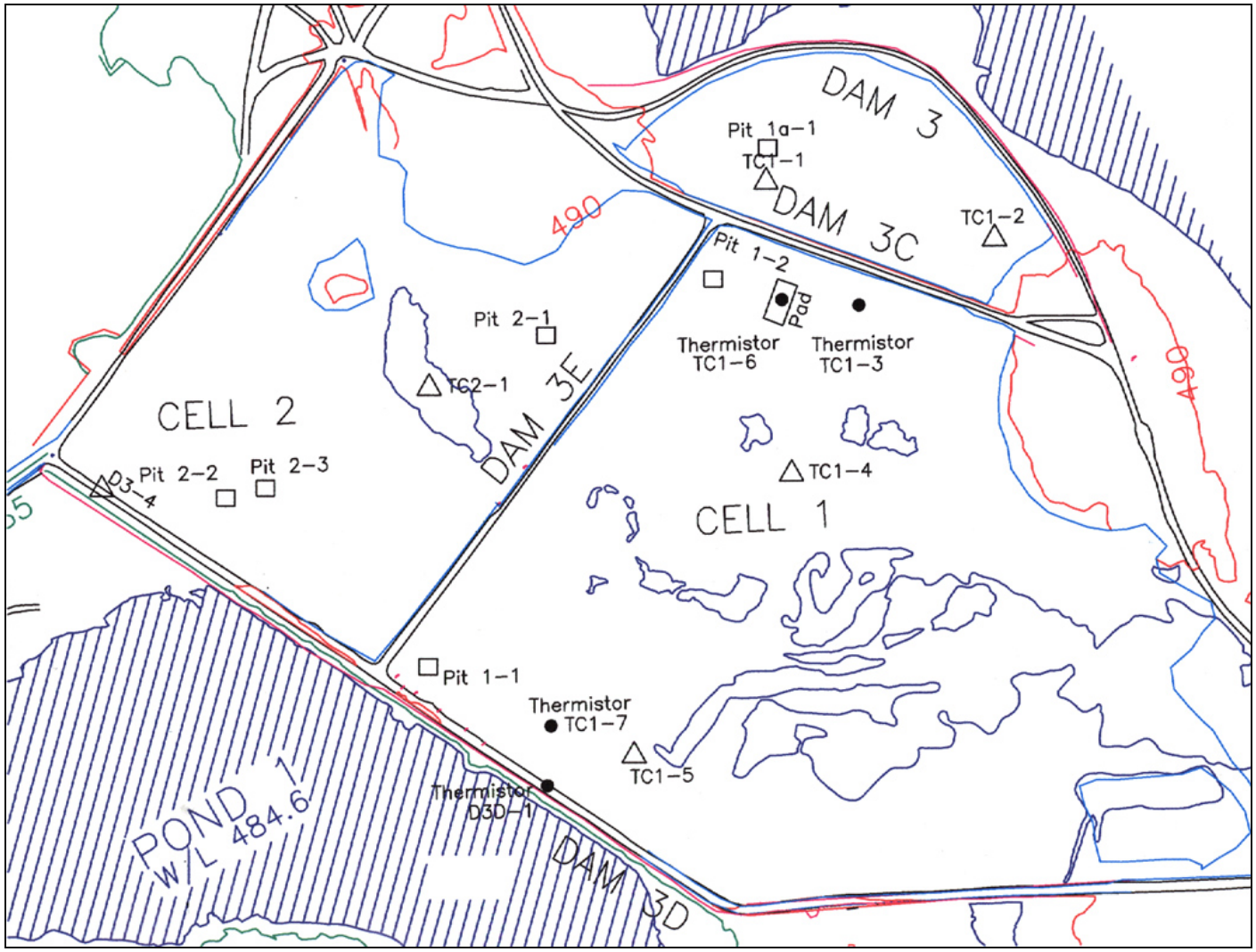

Figure 8-8. Test Pad and monitoring locations

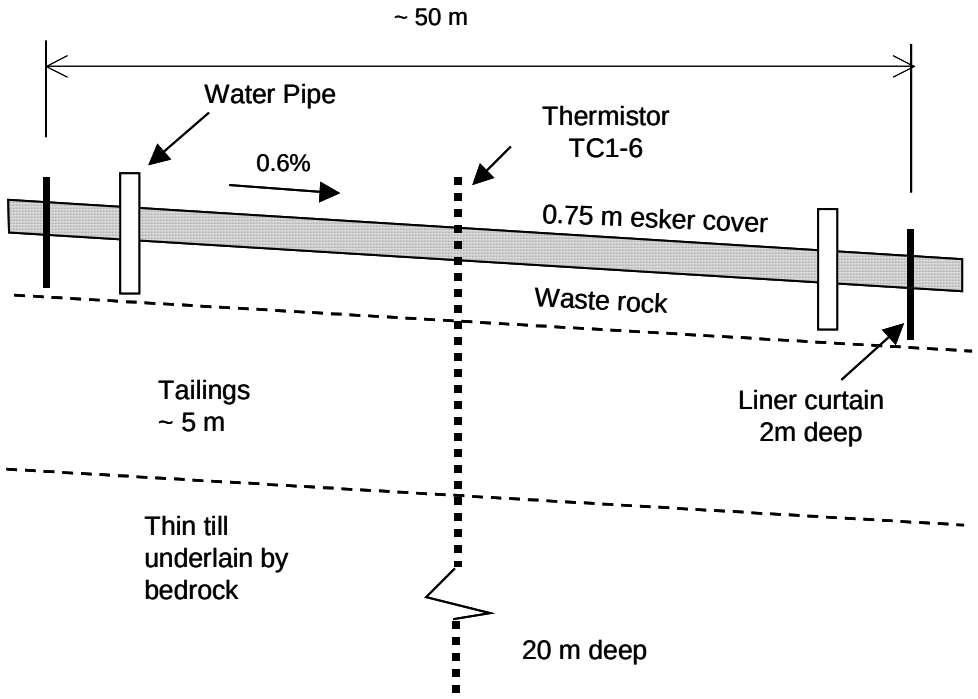

Figure 8-9. Schematic test pad section

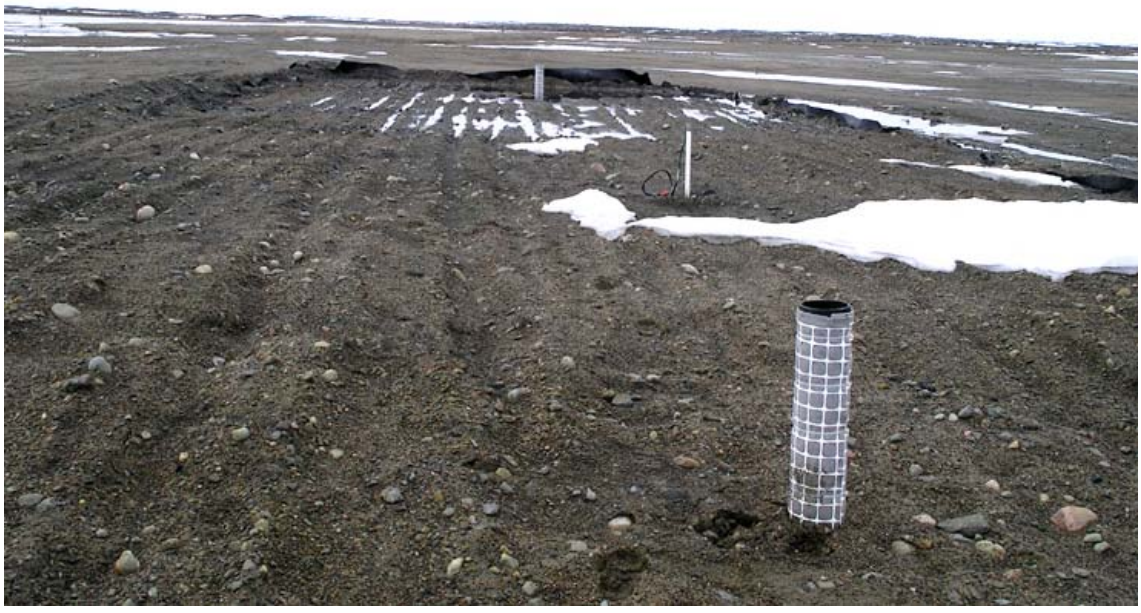

Figure 8-10. Photo of test pad instrumentation

Assuming an average measured esker cover thickness of 1.1 m at Cell 1, the height of the esker saturation zone at the perimeter, test pad and central part of the cell would be:

At cell perimeter	0.20 m
At test pad	0.45 m
At central pond area	0.56 m

Ground temperature measurements at the test pad showed the tailings to be completely frozen, with the active zone reaching a depth of 1.30 m. The ground temperature at the maximum thermistor depth of 20 m, where close to zero ground temperature fluctuation is exhibited, was measured to be -5.1ºC. Ground temperature profile fluctuations measured in 2004, and the thaw depth estimated from the ground temperature profiles, are shown in Figure C 15 and Figure 8-11.

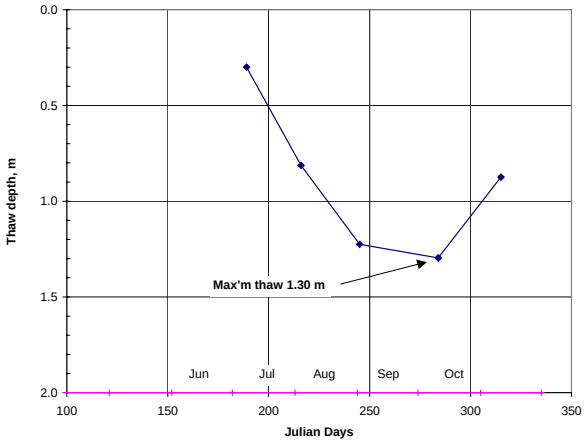

Figure 8-11. Thaw depth changes at test pad (TC1-6)

8.6 Test Pits

8.6.1 General

Nine test pits were dug with an excavator at several locations in Cell 1a, 1, 2 and 3 in September 2004 to gain information on several technical issues. The technical issues were:

- Determine the esker cover thickness and presence of a saturated zone within the cover.
- Penetration of tailings into the esker material as evidence of cryoturbation.
- Presence and degree of oxidation of tailings.

During this program the test pits were logged, photographed and selected samples were taken for moisture content and gradation determination. List of the test pits, their locations, thickness of esker material and brief notes are given in Table 8-5.

Table 8-5. List of test pits

Test Pit	Cell	Esker Thickness (m)	Notes
1-1	1	1.30	Test pit dug to install Pipe 7 to a greater depth. Esker saturated for 0.20 m.
1-2	1	0.76	Reached waste rock layer of unknown thickness at 0.76 m. Encountered water at waste rock interface. Relocated Pipe 1 to Cell 3.
1-3	1	0.69	Dug out pipe at south end of test pad. Encountered waste rock. Re-installed pipe to 0.81 m depth. Encountered high water.
1a-1	1a	1.30	Test pit in Cell 1A (covered in 1988). Base of esker wet; unknown saturation thickness. Esker consists of coarser material.
2-1	2 north	0.90	Base of esker wet; unknown saturation thickness. Minor oxidation at tailings surface. Cell covered in 1995.
2-2	2 south	0.86	Esker saturation zone at least 0.2 m. Base of esker collapsing due to wetness. Fine esker material.
2-3	2 south	1.00	Pit located close to ponded surface water. Fine grained saturated esker material at base of cover; collapsing.
3-1	3	1.30	Test pit located at recently placed (2 weeks previous) cover. Minor oxidation of tailings at surface.
3b-1	3b	0.97	Coarser esker material. Base of test pit collapsing due to material wetness.

The test pit locations are shown on Figure B25 for Cells 1a, 1 and 2 and Figure B26 for Cell 3 and 3b.

8.6.2 Test Pit Description

Test Pit 1-1 was dug in Cell 1 in order to reposition water Pipe 7 that periodically had insufficient water to obtain water samples. At this location the esker thickness was 1.30 m and there was no evidence of tailings penetrating the esker material. Photo 14 shows the test pit excavation with a solid smooth un-oxidized tailings surface at the base. Pipe 7 was installed 0.30 m deeper to a burial depth of 1.30 m.

Test Pit 1-2 was dug in Cell 1 in order to reposition water Pipe 1 that periodically had insufficient water to obtain water samples. The test pit showed that the esker was underlain by waste rock of unknown thickness and water was observed within the waste rock (Photo 15). This pipe location was discontinued because of the presence of the waste rock zone. Better information was available from the nearby Test Pad that had two water pipes.

Test Pit 1-3 was dug in the Test Pad to install the two water pipes at greater depths. Test Pit 1-3 was dug at the south water pipe. Waste rock was encountered at a depth of about 0.69 m below the esker surface. Water was encountered above the waste rock. Thickness of waste rock could not be determined with the limited capacity of the small backhoe. Photos 16 and 17 illustrate the high water table at this location.

Test Pit 1a-1 was dug to investigate the cover thickness and saturation level of the esker in Cell 1a. The thickness of the esker in this location was 1.30 m and its base was wet. The test pit was not open long enough to determine the groundwater level. The top of the tailings and the wet condition at the base of the excavation is shown in Photo 18.

Test Pit 2-1 was dug in the northern area of Cell 2 that received tailings in early 1990 and was covered in 1995. Minor oxidation of tailings at the surface of the tailings was observed, as shown in Photo 19. Esker cover at the base was moist to wet. The presence and thickness of the saturation level could not be determined during the short period of test pit excavation. Esker cover was 0.90 m thick at this location.

Test Pits 2-2 and 2-3 were excavated in the southern area of Cell 2 that was more recently filled with tailings. These test pits were south of a depression that contained pooled water. Test Pit 2-3 was nearly adjacent to the pooled water. The significance of the pooled water is that this area was located near the center of the cell where the smallest tailings particles would have settled and therefore represented the likeliest areas where tailings penetration into the esker could occur. Photos 20 and 23 show that there was no evidence of tailings penetrating the esker material and a high level of saturation portrayed by the collapse of the test pit. The esker cover thickness was 0.86 m and 1.00 m thick respectively.

Test Pit 3-1 was located in an area that was covered by esker material only several weeks earlier. This means that there was not enough time to create a saturated zone by rainfall water infiltration. The dryness at the esker-tailings contact indicates that water was not squeezed out of the tailings by the weight of the esker cover. A water pipe was installed adjacent to this test pit for future water level monitoring.

Test Pit 3b-1 was excavated in Cell 3b that was covered a year earlier in 2003. The esker material was observed to be saturated in the lower third of the cover, with the cover thickness being 0.97 m. Oxidation of the tailings was not observed, as can be seen in Photo 23.

8.6.3 Summary of Test Pit Observations

a) Esker Cover thickness and presence of saturated zone within the esker.
Esker cover thickness was observed to vary from about 0.9 to 1.3 m in areas where the tailings were not covered with a waste rock layer. In the two test pits in the northwest corner of Cell 1, the esker cover was measured to be about 0.7 m. However, in this area the esker material was underlain by a layer of waste rock; approximately 0.5m thick.

b) In all test pits, with the exception of Test Pit 2-1, saturated zone with free water was observed at the base of the esker material. In Test Pit 2-1, free water was not observed during the short exposure of the esker cover base.

c) Penetration of tailings into the esker material and evidence of cryoturbation.
Tailings penetrating into the esker material or evidence of cryoturbation were not observed in any of the test pits. In all test pits, there was a clear linear boundary between these two materials.

d) Presence and degree of oxidation of tailings.
In two of the seven test pits where esker material covers the tailings surface, minor oxidation of the tailings was observed: Test Pits 2-1 and 3-1. In both cases the tailings surface had been exposed for several years before a cover was placed and the depth of oxidation was judged less than 5 mm.

8.7 Laboratory Test Results

8.7.1 Tailings

The most extensive sampling of tailings was done in 1994 (Klohn-Crippen, 1995). During this program 42 tailings samples were taken at various locations from the tailings slurry discharge as shown on Figure B 27. Particle analyses of these samples showed the tailings to have predominantly silt sized particles, representing 73 % of the material. The range of particle sizes are illustrated on Figures B28 and B29. The numbers behind the sample identifications are the depths from which the samples were taken.

A summary of the silt content of these samples is provided in Figure 8-12.

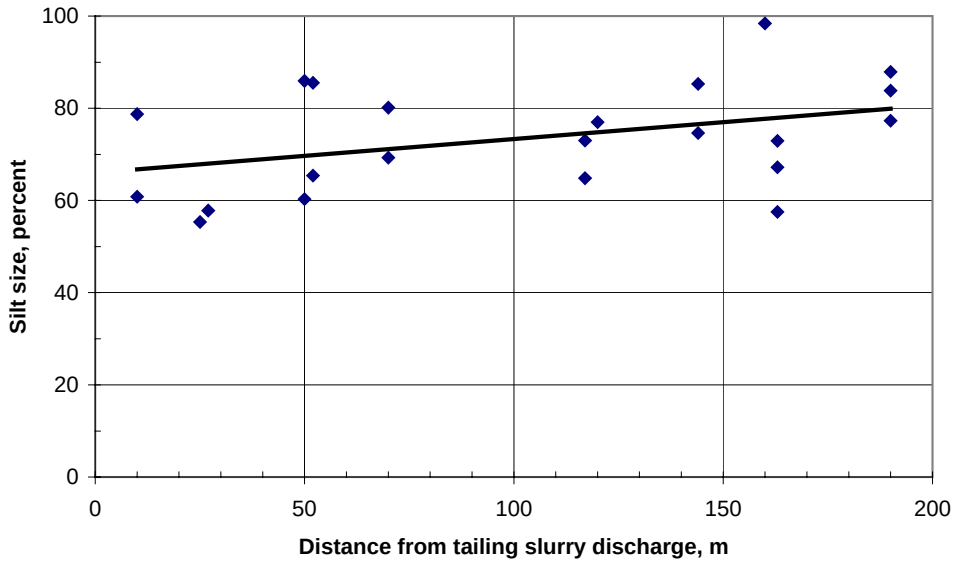

Figure 8-12. Summary of percent silt size particles in tailings (Klohn-Crippen 1995)

Three tailings samples were taken during the 2005-year test pit program and sieve analyses conducted. The results shown on Figure 30B provide similar results.

8.7.2 Esker material

Six samples were taken during the 2004 test pit program and sieve analyses were conducted. The particle size distribution curves of the total samples are shown on Figure B31 and particle distribution curves for sand and smaller material are shown on Figures B32 and B33. It should be noted that the samples were taken from a long vertical section of the test pit faces in order to obtain representative samples.

The results of these total samples given in percentage of gravel, sand and silt sizes are given in Table 8-6.

Table 8-6. Particle size distribution of esker material

Location	Particle sizes in %			
	Gravel	Sand	ilt	Material Description
Cell 1 - Top	40	58	2	Gravelly sand
Cell 1 - Base	48	50	2	Gravelly sand
Cell 3	30	68	2	Gravelly sand
Cell 3b	38	60	2	Gravelly sand
Cell 1a	50	47	3	Sandy gravel
Cell 2	25	69	6	Gravelly sand, silty
Average	39	59	3	

The particle size distribution tests show that the esker material in Cells 1a, 1, 2 and 3 is a well graded gravely sand with minor amount of silt sizes that represent about 2 % of the total. Only one sample from Cell 2 was somewhat coarser, being a gravelly sand with little silt (silt content 6%). Its Unified Soil Classification Symbol is GW.

Moisture contents were determined from four samples and they varied from 7.2% to 9.8%. These moisture contents represent the unsaturated esker material since the samples were taken above the saturated zone. Location and the individual water contents are given in Table 8-7

Table 8-7. Esker material water contents measured in 2004

Location	Water content %
Cell 1a-1	8.1
Cell 1a-2	7.2
Cell 2-1	9.8
Cell 2-2	8.5

8.7.3 Summary of tailings and esker properties

A summary of the index properties is given in Table 8-8.

Table 8-8. Summary of tailings and esker properties

Property	Esker	Tailings
Particle size		
Gravel	38 %	0
Sand	59 %	34 %0
Silt	3 %	66 %
Description	Gravelly sand well graded	Sandy silt poorly graded
Unified Soil Classification	GW	ML

8.8 Ground Temperatures in Tailings

Lupin has one of the most extensive and longest running ground temperature monitoring databases in the Canadian north. The first thermistors were installed in 1988, although they are no longer operating Additional thermistors were installed in 1995 (Cells 1, 1a, 2, and Dam 4), 2000 (esker, Dams 1a, 2), 2003 (Dam 6, Cell 1 test pad), and in 2004 (Dams 3D and K, Cells 1 and 3). Ground temperatures within the dams and tailings were presented and discussed in Chapter 5.0.

All of the thermistors have shown the tailings to be frozen. In this section the ground temperatures presentation is given in relation to the tailings. Ground temperature profiles measured in 2004 for the thermistors presented in this section are given in Appendix C.

Key information on the maximum depth of thermistor and mean annual ground temperatures at this depth; depth to the base of tailings; thaw depth observed in 2004, and the year the thermistor installed are summarized in Table 8-9.

Table 8-9. Summary of ground temperatures in tailings

Thermistor	Max'm Depth	MAGT @ Max depth	Base of Tailings, m	Thaw Depth, m	Install Year
Cell 1					
Interior					
TC1-3	13	-5.2	4.6	1.2	1995
TC1-6	20	-5.1	6	1.3	2003
At 3D Dam					
TC1-7	20	-4.3	10.9	1.6	Jun-04
D3D	20	-2.1		2.0	Jun-04
Cell 3b					
TC3-1	20	-3.9	16.4	1.4	Jun-04
DK-3	19.6	-2.9		3.1	Jun-04
Reference thermistor at esker					
Esker	17	-6.5		1.3	2000

Ground temperature profiles in Appendix C and the mean annual ground temperature (MAGT) at maximum depth show the ground temperatures being between - 3.9º C and -5.2ºC. The warmer ground temperatures at TC3-1 and TC1-7 (-3.9ºC and - 4.3ºC) were measured near dams where the adjacent water and the downstream embankment have a warming influence. At these two locations the tailings were frozen for the total tailings thickness that varied from 10.9m at TC1-7 to 16.4m at TC3-1.

At more distant location, northern part of Cell 1, MAGT at maximum depth were measured to be -5.1ºC and -5.2ºC at TC1-6 and TC1-3 respectively.

The maximum thaw depth in TC1-3, TC1-6 and TC3-1 varied between 1.2 m to 1.4 m. The small thaw depth is explained by relatively high groundwater level at these locations. The thaw depth at TC1-7 is deeper (1.6 m) because of slightly lower groundwater at this location. This thermistor is located near Dam 3D, which has no liner to maintain a high groundwater level at the periphery of the cell.

The thaw depths below the crests of Dams 3D and K are greater, at 2.0m and 3.1m, again because of lower groundwater levels. The reason for greater thaw depth at Dam K is that this dam has a liner that keeps the core of the dam dry.

A comparison of the thaw depth development during 2004 at Dams 3D and K are shown Figure 8-13.

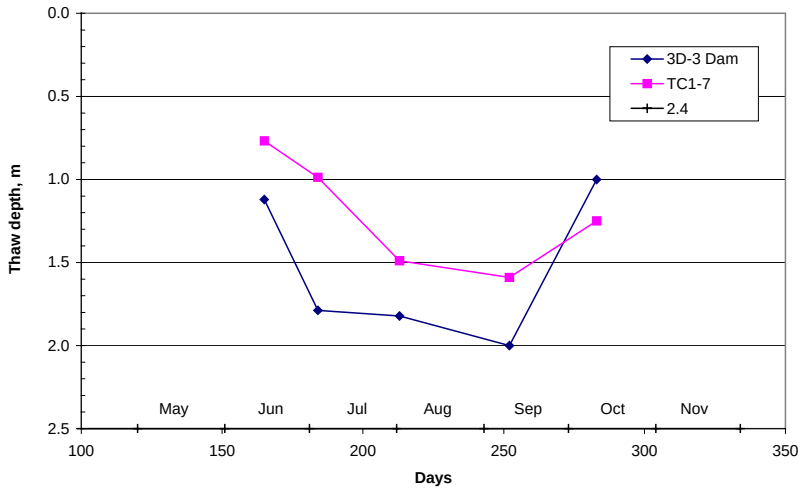

Figure 8-13. Thaw depth changes at Dam 3D, in 2004

The different thaw depths Dam 3D can be explained by the fact that the groundwater level below the dam crest (3D-3 Dam thermistor is lower, being closer to the downstream dam slope.

9.0 WATER QUALITY

9.1 General

Water quality within the saturated zone of the esker cover and the discharge water as it progresses from the saturated zone to ponded water on top of Cell 1, then to Pond 1 and Pond 2 respectively has been monitored to determine the likely water quality of water after closure.

9.2 Pipes installed in 1998

Water samples were taken in pipes TC1-1 and TC1-5 since 1998. Results given in Table 9-1 show that water quality data exceed the Water License limits in nickel, zinc and pH. It is likely that water quality improvement of the esker pore water is very slow because of the very slow migration of water through the esker-saturated zone. The slow migration is due to a small gradient of the tailings surface and the low permeability of the esker material.

Table 9-1. Pore Water Quality (ppm) in Esker Cover Pores Measured in 1998 Pipes.

Water License Parameter	Max'm Avg ppm	Average Values for TC1-1 & TC1-5				
		1998	1999	2000	2001[a]	2002[a]
Total Arsenic	0.5	0.41	0.01	0.01	0.02	0.012
Total Copper	0.15	0.80	0.77	0.04	0.05	0.21
Total Cyanide	0.8	<.002	<.002	<.002	<.002	<.002
Total Lead	0.1	NA	NA	NA	0.01	0.01
Total Nickel	0.2	3.99	3.15	1.14	2.20	3.06
Total Zinc	0.4	1.06	0.96	0.23	0.60	0.69
TSS	15					
pH	6 to 9.5	5.1	4.8	4.7	4.7	5.1

Note a): For Year 2001 only TC1-1 and for Year 2002 only TC1-5 are available.

9.3 Pipes installed in 2002

More extensive sampling and testing of the esker pore water was started in August 2002 to obtain a better understanding of water quality within the esker cover saturated zone and how this pore water affects the water as it emerges from the ground. For this purpose 9 pipes were installed in Cell 1 as shown in Figure 8-5.

The results from five water samples from the pipes installed in 2002 show that the total nickel exceedence is much smaller than measured in the 1998 test pipe TC1-5 and the total zinc met the discharge limits. It is likely that the lower metal concentrations were obtained because the newer pipes were installed about 0.15 m above the tailings surface. The values measured in the 5 pipes are shown in Table 9-2. Water samples could not be obtained in the remaining 4 pipes because of insufficient water within the pipes.

Table 9-2. Pore Water Quality (ppm) in Esker Cover Pores Measured in 2002 Pipes

Water License Parameter	Max'm Avg	Max'm Grab	P-2	P-4	P-5	P-6	P-8	Avg.
Total Arsenic	0.50	1.00	0.005	0.004	0.02	0.004	0.019	0.009
Total Copper	0.15	0.30	0.31	0.19	0.25	0.006	0.042	0.160
Total Cyanide	0.80	1.60	0.002	0.06	0.004	0.002	0.002	0.014
Total Lead	0.10	0.20	0.025	0.01	0.02	0.002	0.003	0.010
Total Nickel	0.20	0.40	1.32	0.85	3.51	0.015	1.11	1.361[a]
Total Zinc	0.40	0.80	0.62	0.32	0.91	0.035	0.300	0.437
TSS	15	30						
pH	6 to 9.5		3.96	5.7	5.0	5.9	4.9	5.09

Note a) Marginally above limits, L5x

The newer more extensive test results show the water quality of the esker pore is above the license limit for nickel and pH.

9.4 Water Quality Monitored in 2003 and 2004

Water quality within the pipes and in adjacent ponded water continued to be monitored in 2003 and 2004. Sampling in some pipes could not be obtained because of either no water or an insufficient water depth at the bottom of the pipes. Pipe P-1 was removed in 2004 because a waste rock layer was found below the esker that prevented the pipe from reaching the saturation zone and Pipe P-7 was installed to greater depth during the 2004 test pit excavation. The average water quality measurements from 7 of the 9 pipes installed are given in Table 9-3.

Table 9-3. Average water quality from pipe wells, 2003 & 2004

NWB License			Measurements	
Parameter	Unit	Max Avg:	28-Jul-03	08-Aug-04
Arsenic	mg/L	0.500	2.84	2.73
Cadmium	mg/L	n/a	0.00	0.00
Copper	mg/L	0.150	0.13	0.20
Cyanide	mg/L	0.800	0.03	0.02
Lead	mg/L	0.100	0.08	0.09
Nickel	mg/L	0.200	0.93	1.48
Zinc	mg/L	0.400	0.28	0.55
pH		6.0 to 9.5	4.6	4.5

The measurements of water quality in the esker saturated zone showed no significant change in metal concentrations but an increase arsenic was observed to have occurred from the 2002 measurements. This information indicates that the flushing of the saturated pore water is slow.

To study what happens to the saturated zone pore water as it emerges at the surface, a test pit was excavated beside pipe P-2 and sampled for water quality. Photo of the excavation beside P-2 is shown in Figure 9-1 and the monitored water quality results are given in Table 9-4.

Figure 9-1. Test Pit 2a used for water sampling beside P-2

Table 9-4. Water quality measurement in Test Pit 2a

NWB License			Measurements		
Parameter	Units	Max Avg:	28-Jul-03	04-Jul-04	08-Aug-04
Arsenic	mg/L	0.5000	0.073	0.041	0.099
Cadmium	mg/L	n/a		0.002	0.002
Copper	mg/L	0.150	0.302	0.292	0.255
Cyanide	mg/L	0.800	0.004	0.002	0.008
Lead	mg/L	0.1000	0.012	0.004	0.003
Nickel	mg/L	0.2000	0.544	1.170	0.912
Zinc	mg/L	0.400	0.498	0.463	0.350
pH		6.0 to 9.5	3.4	3.8	4.0

The Table 9-4 show much smaller concentration of arsenic but the remaining parameters are similar to the ones measured in the pipes.

The main impact of esker pore water on the receiving water can be determined from following the water quality from the pipes to areas where it emerges at Cell 1 ponded water surfaces and than progresses to the larger water bodies in Pond 1 and Pond 2. The ponded

water in Cell 1 is shown in Figure 9-2. Water quality measured in Cell 1 ponded water area (2004) and Ponds 1 and 2 in 2003 and 2004 are given in Table 9-5 and Table 9-6 respectively.

Figure 9-2. Ponded water in Cell 1, location of water sampling

Table 9-5. Water quality in Cell 1 ponded water (2004)

NWB License			Measurements		
Parameter	Units	Max Avg:	**13-Jun-04**	**13-Jul-04**	**8-Aug-04**
Arsenic	mg/L	0.500	0.116	0.026	0.020
Cadmium	mg/L	n/a	0.001	0.000	0.001
Copper	mg/L	0.150	0.006	0.030	0.044
Cyanide	mg/L	0.800			0.002
Lead	mg/L	0.1000	0.002	0.002	0.002
Nickel	mg/L	0.2000	0.063	0.134	0.172
Zinc	mg/L	0.400	0.063	0.134	0.172
pH			4.08	3.51	3.68

Table 9-6. Water quality in Ponds 1 and 2 (2003 & 2004)

Parameter	Units	NWB	Pond 1		Pond 2	
		Max Avg:	12-Oct-03	8-Aug-04	12-Oct-03	8-Aug-04
Arsenic	mg/L	0.5	0.058	0.067	0.062	0.013
Cadmium	mg/L	n/a	0.000	0.000	0.000	0.000
Copper	mg/L	0.15	0.027	0.070	0.007	0.018
Cyanide	mg/L	0.8	0.026	0.110	0.018	0.180
Lead	mg/L	0.1	0.001	0.001	0.001	
Nickel	mg/L	0.2	0.098	0.091	0.091	0.083
Zinc	mg/L	0.4	0.262	0.262	0.178	0.207
pH		6.0 to 9.5	7.6	7.8	6.6	7.3

The progression of water quality from pores in the saturated zone within the esker, to its emergence within Cell 1 ponded water, passing through Pond 1 and reaching Pond 2 from where it has been periodically siphoned out, is shown in Table 9-7.

Table 9-7. Water quality of esker pore water as it emerges, average values

Parameter	Units	NWB		Wells	Pit 2a	Cell 1 ponded W	Pond 1	Pond 2
		Max Avg:	Max Grab:					
Arsenic	mg/L	0.5	1	1.864	0.071	0.054	0.062	0.038
Cadmium	mg/L	n/a	n/a	0.003	0.002			
Copper	mg/L	0.15	0.3	0.171	0.283	0.027	0.049	0.013
Cyanide	mg/L	0.8	1.6	0.021	0.005	0.002	0.068	0.099
Lead	mg/L	0.1	0.2	0.062	0.006	0.002	0.001	0.001
Nickel	mg/L	0.2	0.4	1.212	0.875	0.123	0.094	0.087
Zinc	mg/L	0.4	0.8	0.425	0.437	0.123	0.262	0.193
pH		6.0 to 9.5	6.0 to 9.5	4.7	3.7	3.8	7.7	6.9

The summarized results in Table 9-7 illustrate the following:

- Water quality of the saturate esker zone is marginally above the Nunavut Water Board (NWB) License. The volume of water within this zone is small and will take considerable time to be flushed out.
- As the saturated zone water emerges at the Cell 1 pond, it water quality meets the NWB metal limits.
- Additional improvement in water quality is found in Ponds 1 and 2. Water quality parameter values of the License listed parameters in Ponds 1 and 2 vary from a half to about one fiftieth of the values in the esker-saturated zone.
- Presently about 58% of the exposed tailings have been covered.

10.0 SUMMARY

10.1 Tailings Area Background

The Lupin tailings containment area (TCA) was first constructed in 1981 and tailings discharge began in 1982. Tailings deposition will be terminated in early 2005. The TCA was created by the construction of 8 earth dams around the TCA watershed perimeter. The basic design consists of a frozen homogeneous dam, with an internal liner as back-up, supported on frozen foundations. The highest two dams have a height of 7.9 and 5.9 m. Two intermediate dams are 3.3 and 3.9 m high and the remaining dams are small, with their heights varying between 1.0 and 2.5 m.

Starting in 1985, tailings were discharged into four cells, counting Cell 1a and 1 as the same cell, and Cell N being a part of Cell 5. The statistics of these cells are given in Table 10-1.

Table 10-1. Summary of tailings cell statistics

Cell	Watershed, ha	Tailings surface area, ha	Mean tailings depth, m	Tailings volume stored, m3
Cell 1a	6	6.3	1.7	107,000
Cell 1	41	36.1	3.5	1,263,000
Cell 2	21	15.0	3.0	450,000
Cell 3	67	50.0	4.0	1,724,000
Cell 5	56	34.3	4.5	1,544,000
Cell N	3	3	1.0	32,000
Totals	194	144.7		5,120,000

The cells were formed by the construction of internal dams that were generally located along higher ground. As a result, the greatest tailings depths are located in former lakes within the cells and the mean depths of the tailings are relative small, varying between 1 to 4.5 m.

The total of the tailings surface area of about 145 ha represents about 24% of the total TCA watershed of 616 ha.

10.2 Permafrost

The mean annual air temperature at Lupin was about -12.5ºC when the TCA was constructed in 1981. This would have created a mean annual ground temperature of about -8ºC. This provided an ideal location for the construction of frozen dams on permafrost foundations and the use of permafrost to encapsulate the tailings. Since the start of the TCA operation, the mean annual air temperature has warmed to about -10.5ºC and a reference

thermistor located at a nearby esker shows a mean annual ground temperature of -6.5ºC. Ground temperature monitoring at Lupin, and scientific acceptance that global warming may destroy permafrost, shows that permafrost may not exist at Lupin some 100 years from now. This has to be considered in the closure design of the TCA.

10.3 Dams

All existing dams at the Lupin site, both perimeter and internal, have very high factors of safety against instability because they are frozen. Since the main body of the dam and the foundations consist of cohesionless soil, gravelly sands, and silty sands with some gravel and low ice content, their frozen strengths are very high. In addition, the dams and their foundations are, from a practical point of view, impermeable.

The stability and the seepage condition of these dams will diminish if the permafrost thaws over time. For this reason, and for the fact that dams would require inspection and maintenance in perpetuity, Lupin has selected not to have any dams after closure of the site.

The highest dam, situated at the historical discharge point of the TCA watershed, will be breached. As a result, no perimeter dams will remain after closure since they are located along the historical watershed divide and the upstream water will have dropped below the dam toes. The only dam that will have water on the present downstream side, is Dam 4, which is located along the present watershed divide. It will continue to form a watershed divide after closure, with natural water discharge courses on each side.

The internal dams that were constructed to contain tailings, will become rock-fill reinforced, esker-material earth structures that contain tailings on one or both sides. Since they will not contain any water, they will cease to be dams. Surface water from the cells will be allowed to runoff into the internal lakes through channels in bedrock.

10.4 Tailings Cover

Tailings at Lupin were observed to have a potential for acid drainage, if the tailings were exposed to prolonged weathering (Klohn-Crippen 1995). Many mines in continuous permafrost have been adopting the concept of encapsulating tailings in permafrost. This concept may not be viable in the future if permafrost keeps warming, as global warming is predicting.

Lupin has adopted a saturated granular zone cover design for the tailings. This design is based on the studies in southern climate areas that show only very small depth of water over the surface of tailings is necessary to practically stop any oxidation of tailings. Reasons for larger depths of water of 1.0 to 1.4 m over acid potential tailings in southern climates are to prevent disturbance of the tailings surface by waves and ice floes during ice break-up.

Lupin has selected to cover the tailings with 1.0 m of esker sand that will maintain a small depth of saturated water zone at the base of the esker. The overlying cover layer will minimize evaporation of water from this zone and the low permeability of the fine tailings, being more than 60 percent silt size, will prevent dropping of the groundwater level within the tailings due to future thawing

10.5 Cover Monitoring

Lupin started to cover exposed tailings in completed cells in 1988, and to monitor the covered tailings to assess the effectiveness of the covers. As a result, Lupin has collected the most extensive and longest observed performance records of covered cells in permafrost areas.

Data collected includes ground temperatures, water levels within the cover, water quality within the cover, slope of tailings surface, thickness of tailings deposition, moisture content of the cover, and particle size analyses of tailings and cover materials. Various studies have determined the durability (physical and chemical) of the cover material, water balance within the cover during drought conditions, and pore water expulsion potential from the compacted tailings during thaw conditions (Golder 2004a). Test pits excavated through the cover to the tailings surface were examined for evidence of cryoturbation, oxidation at the tailings interface, presence of ice lenses, and condition of the tailings/cover interface.

Some of the key findings from these studies and monitoring are:

- Thickness of the esker cover in Cells 1a, 1, 2 and 3 was observed to average 1.0m, ranging from 0.9 to 1.3 m. One smaller thickness of 0,7 m was found in an area where the tailings were covered with waste rock before the esker was placed.
- Depth of the saturated zone varied from 0.2 m at the perimeter of the cell to 0.6 to 1.0 at the central area.
- None of test pits excavated through the esker cover to the tailings interface showed any evidence of tailings having penetrated into the cover, either during construction or as a result of cryoturbation.
- The esker cover consists of a gravely sand with little silt. Esker above the saturated zone had a high moisture content, average being 8.4%. This high moisture content in the esker material above the saturated zone adds to the oxygen barrier.
- Extensive ground temperature monitoring in the tailings has shown that, in all locations, the tailings are completely frozen. The depth of the active layer averages about 1.2 m. and the thaw condition lasts for less than 3 months.
- Visual inspection of the esker cover has not found any signs of erosion caused by surface water.

10.6 Water Quality

Some findings from water quality monitoring are:

1) Water quality monitoring within the saturated esker zone showed the pore water in this zone being marginally above NWB License limits.
2) Water quality from ponded water on Cell 1 and at downstream locations in Pond 1 and Pond 2 are well below NWB License limits. At these locations the metal levels vary from 2% to 50% of the NWB License limits.
3) The existing water quality in Ponds 1 and 2 is for a tailings surface area that has, until the summer of 2004, been predominantly exposed. The present tailings surface area is now 58% covered by a layer of esker sand. Completing the cover for the whole area by 2006 will show considerable further water quality improvement in Ponds 1 and 2.

10.7 Surface Water Balance

Upon closure of the TCA, the surface water balance will be close to the pre-TCA conditions. Surface water input from the individual tailings cells will be small because of their small areas and it will flow out through bedrock-controlled channels. All perimeter dams will have been breached, so that all tailings buttress berms will be above water.

11.0 ACKNOWLEDGEMENT

The Lupin mine has been a Canadian pioneer in the design of dams in permafrost and the development of a cover for potentially acid generating tailings for remote permafrost areas that is affected by global warming. It has collected the most extensive and longest performance records of frozen dams and covered tailings cells in permafrost areas.

The writer has been privileged to be part in the design and analyzing of the performance data since 1980. He would like to thank all the Lupin management from 1980 to the present time for allowing the writer to participate in their project. He would like to thank especially Mr. Michael Tansey, Lupin's Reclamation Project Manager, for being most helpful in obtaining all requested information for the design and monitoring data of tailings cover.

Respectfully submitted,

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Geotechnical Specialist

12.0 REFERENCES

Anisimov, O.A. and Fitzharris, B. 2001. Climate Change 2001: Impacts, Adaptation, Vulnerability. Contribution to 3rd Assesment Rpt of the WG2 Intergovernmental Panel of Climate Change, Cambridge Univ Press, pp 801-841.

Blake,W. Jr. 1963. Notes on glacial geology, northeastern District of Mackenzie, Geological Survey of Canada, Paper 63-28.

Diavik Diamond Minds, 1999. PKC Facility, Design Report. Nishi-Khon/SNC-Lavalin

Environment Canada, Canadian Climate Normals, Temperature and Precipitation, The North - Y.T. and N.W.T., 1982

Everdingen, Robert van, ed. 1998. Revised January 2002. Multi-language Glossary of Permafrost and Related Ground-Ice Terms. In International Permafrost Association Standing Committee on Data Information and Communication (comp.) 2003.

Environment Canada, Canadian Climate Data, East & West, Web & CD - ROM, 2002.

Geocon (1975) Ltd, 1980a. Potential tailings disposal sites. Submitted to Echo Bay Mines, September 1980.

Geocon (1975) Ltd, 1980b. Geotechnical study of proposed tailings pond, Lupin Project, Conwoyto Lake, NWT. For Echo Bay Mines, November 27, 1980.

Geocon 1982. As-built tailings containment area, Lupin Project. Submitted to Echo Bay Mines Ltd., December 1982.

Golder Associates Ltd. 2004. Studies related to Water License Requirements and in support of reclamation planning. Draft Report, October 2004.

Holubec, I., Zehir,T. and Dufour, S. 1982. Earthfill dam design and construction in cold permafrost at Contwoyto Lake, N.W.T. 35th Canadian Geotechnical Conference, Sep 28-30, 1982. Montreal, Quebec.

Holubec, I. 1993. Preventing AMD by disposing of reactive tailings in permafrost. MEND Project 6.1. Canada Centre for Mineral and Energy Technology. December 1993.

Holubec, I. and Hohstein, D., 2003. Partially saturated granular cover for reactive tailings in permafrost, Lupin mine experience. 7th International Symposium on Mining in the Arctic, Iqaluit, NT, March/April 2003. Pp 382-402.

Holubec, I. 2003. Proposed partially saturated granular cover for Lupin mine tailings. Prepared for Echo Bay Mines Ltd., Lupin Operation, a subsidiary of Kinross Gold Corporation. Was submitted to Nunavut Water Board.

Holubec, I. 2004. Covers for reactive tailings located in permafrost regions review. MEND Report 1.61.4. October 2004. p 116.

Klohn-Crippen, 1995. Tailings reclamation test cover program, 1994 Report of Activities. Submitted to Echo Bay Mines Ltd., Lupin Operation, August 1995.

Klohn-Crippen 1997. 1996 Annual thermistor report, Cells 1 and 2, and Dam 2, Lupin Mine, N.W.T., prepared for Echo Bay Mines Ltd.

Li, M.G.and St-Arnaud, L. 1997. Considerations in the use of shallow water covers for decommissioning reactive tailings. Proc. Of 4th Int'l Conf. On Acid Rock Drainage, Vancouver, BC, Vol.1, pp 115-30.

MEND 5.4.2d, 2001. MEND MANUAL, Volume 4 – Prevention and Control, February 2001.

Smith. S.L., and Burgess, M.M. 2000. Ground temperature database for Northern Canada. GSC Open File 3954, October 2000.

Wilson, H.R. 1989. Tailings management program - an operating success, Echo Bay's Lupin Mine. Proceedings of the 1st International Symposium on Mining in the Arctic, Fairbanks, Alaska July 1989. A.A. Balkema 1989. pp 135 - 144.

APPENDIX A

PHOTOGRAPHS

PART

OF

CLOSURE PLAN FOR

TAILINGS CONTAINMENT AREA

Prepared for

Kinross Gold Corporation

LUPIN OPERATION

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Photo 1. Lupin tailings containment area, 2001

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Photo 19. Test pit 2-1 in northern section of Cell 2 with older tailings,; minor oxidation at tailings surface

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Photo 22. Test pit 3-1 in Cell 3. Minor oxidation of tailings. This part of cell was covered only weeks earlier.

Photo 23.Test pit 3b-1 in Cell 3b.

APPENDIX B

SUPPORTING FIGURES

PART

OF

CLOSURE PLAN FOR

TAILINGS CONTAINMENT AREA

Prepared for

Kinross Gold Corporation

LUPIN OPERATION

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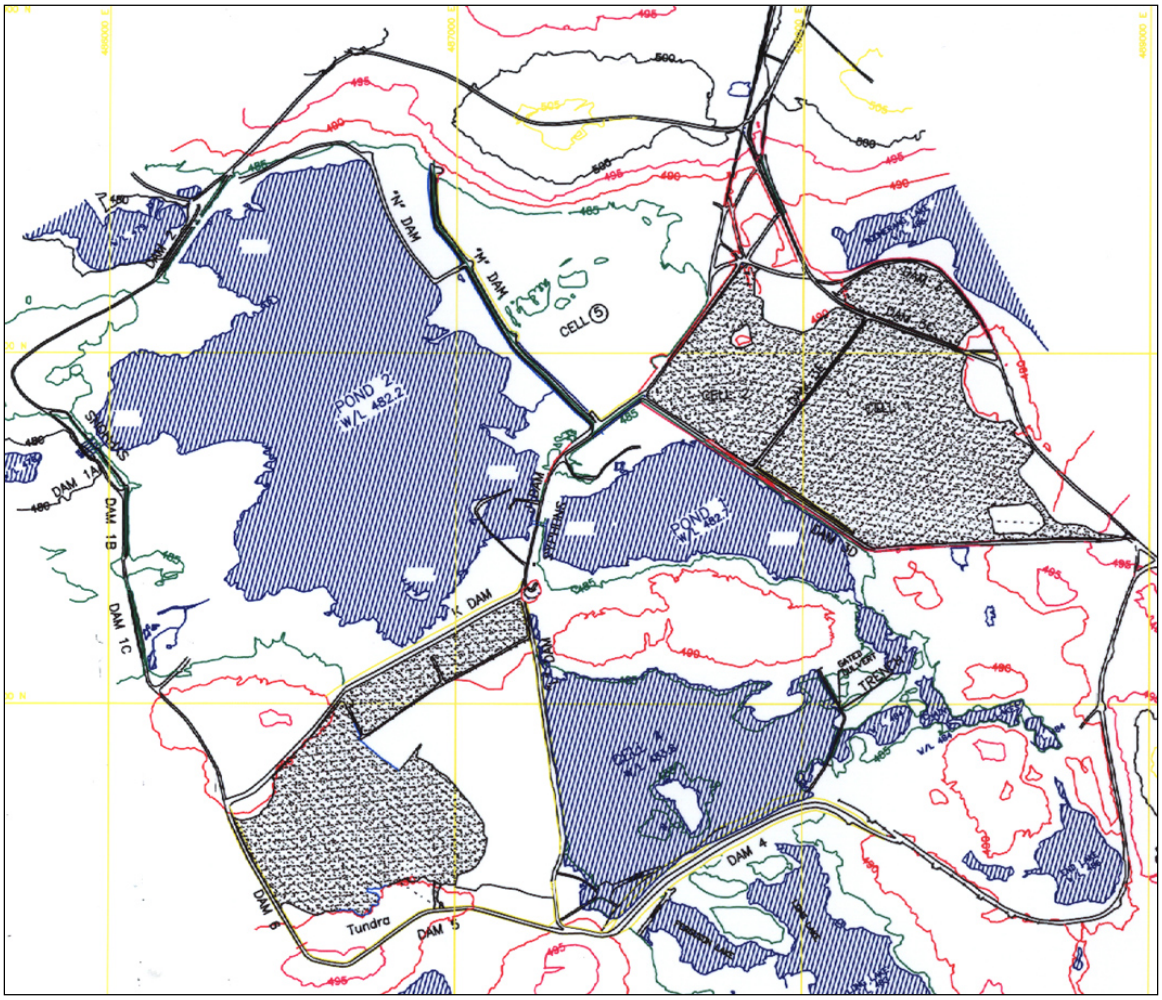

Figure B 1. Locations of Dams and Cells

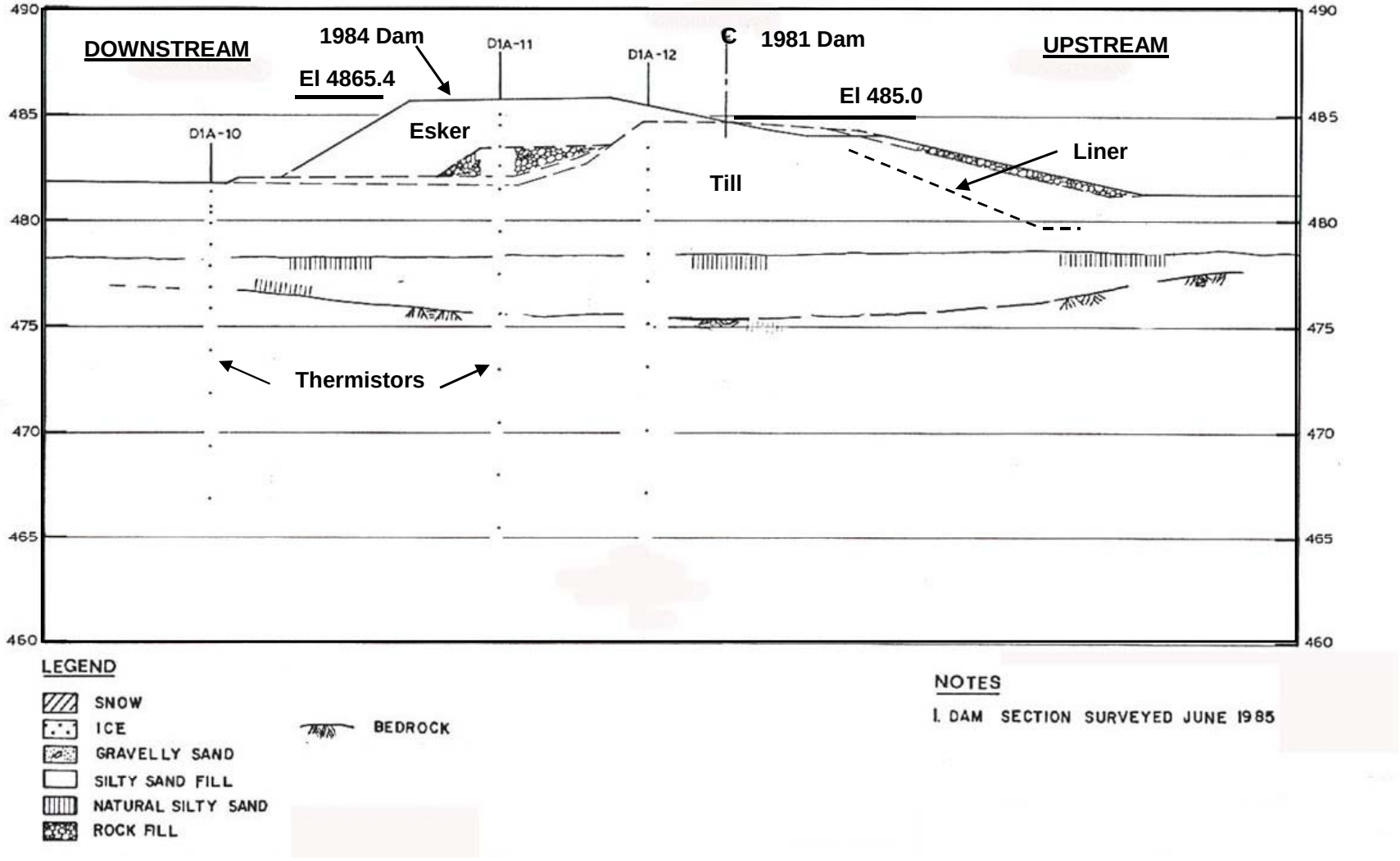

Figure B 2. Dam 1a Section

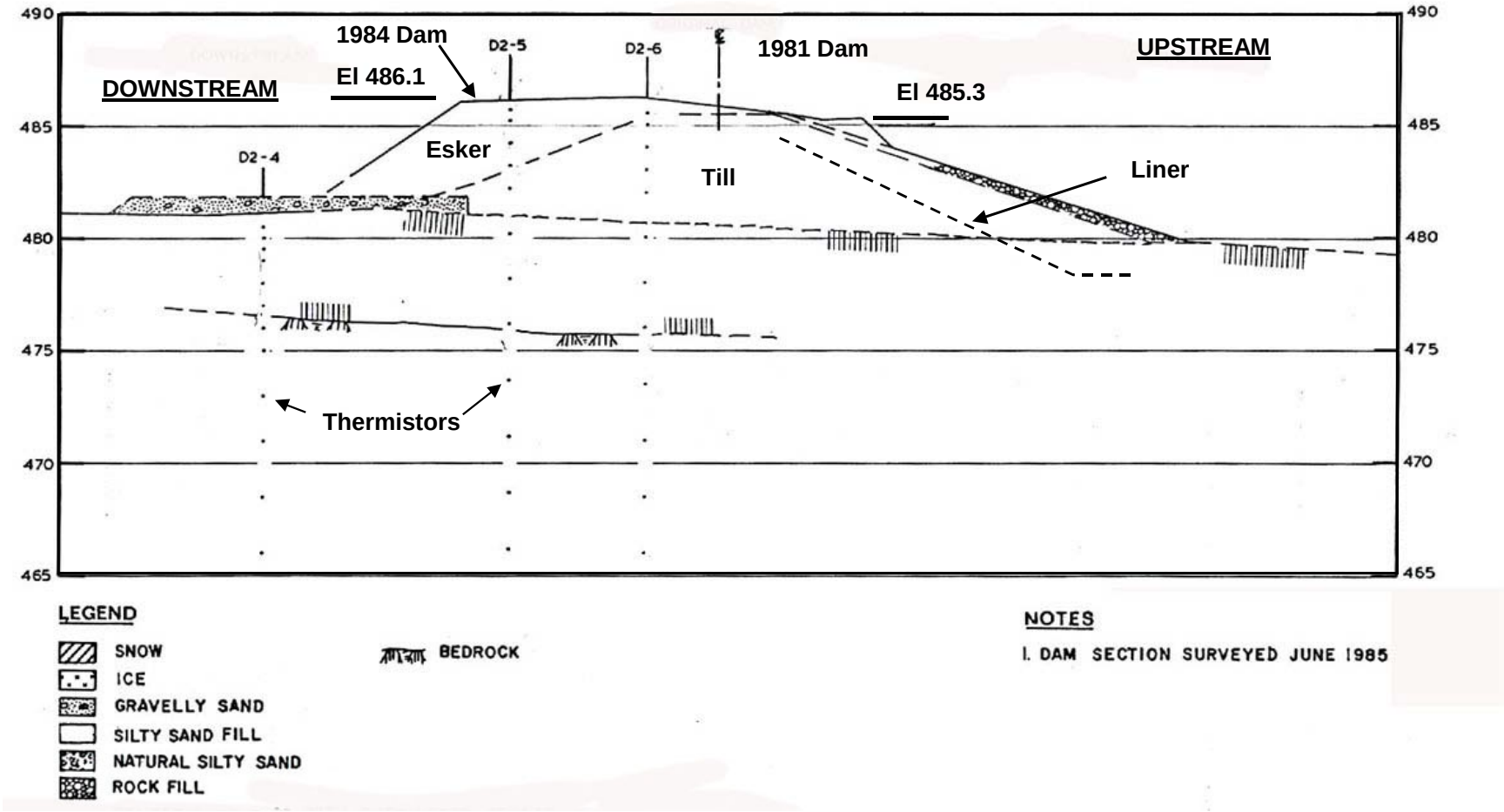

Figure B 3. Dam 1a Section Dam 2 Section

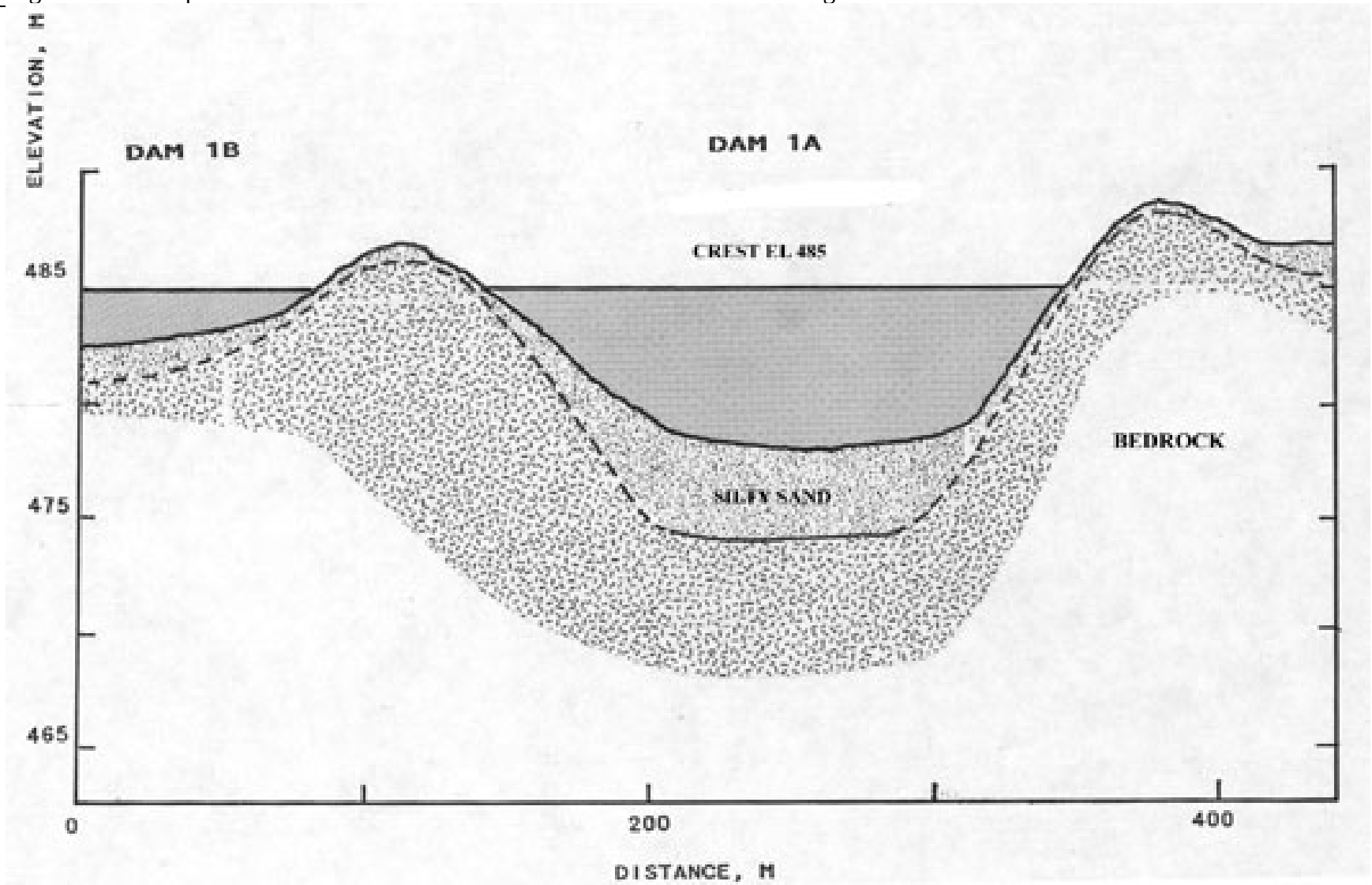

Figure B 4. Dam 1a foundation profile

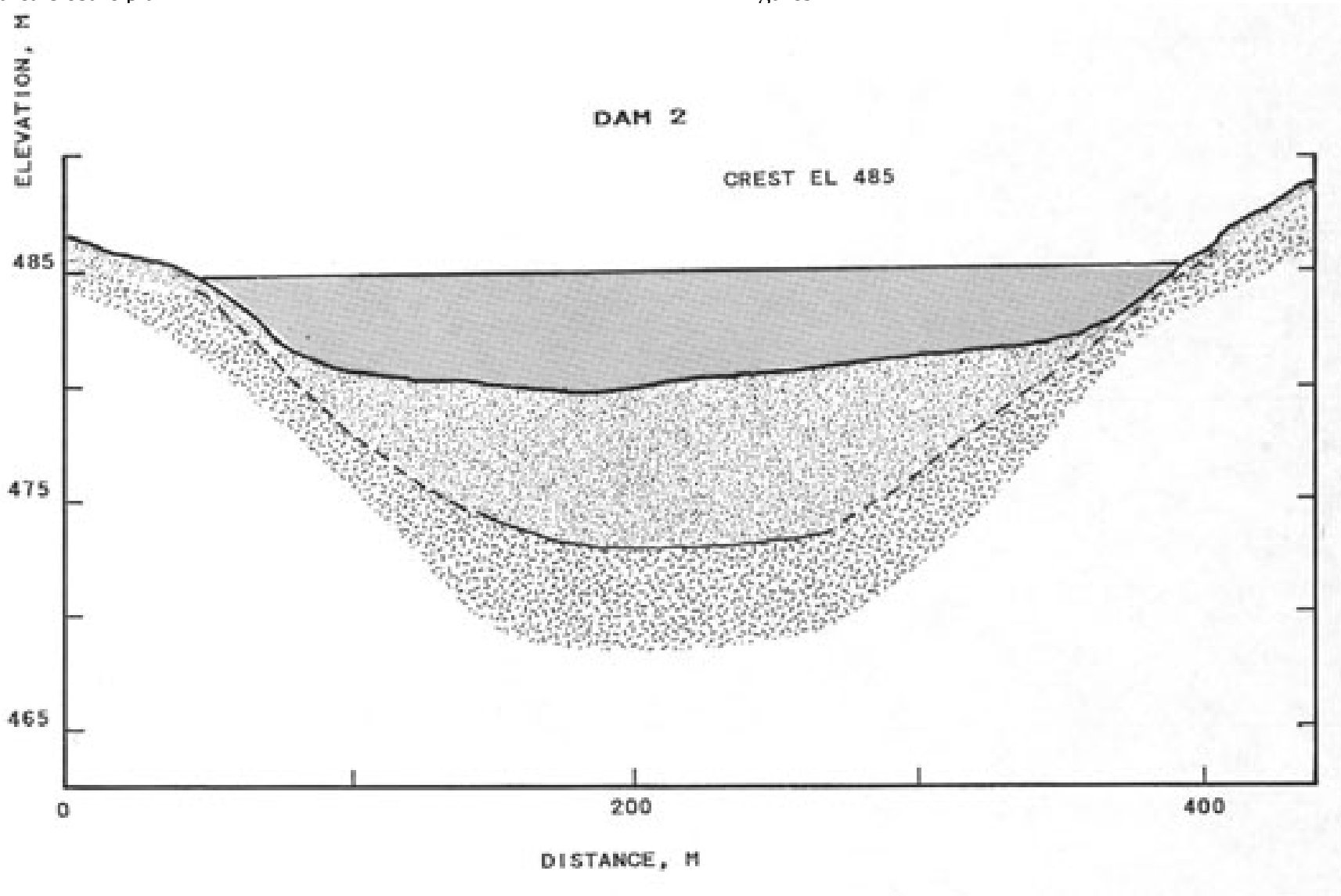

Figure B 5. Dam 2 foundation profile

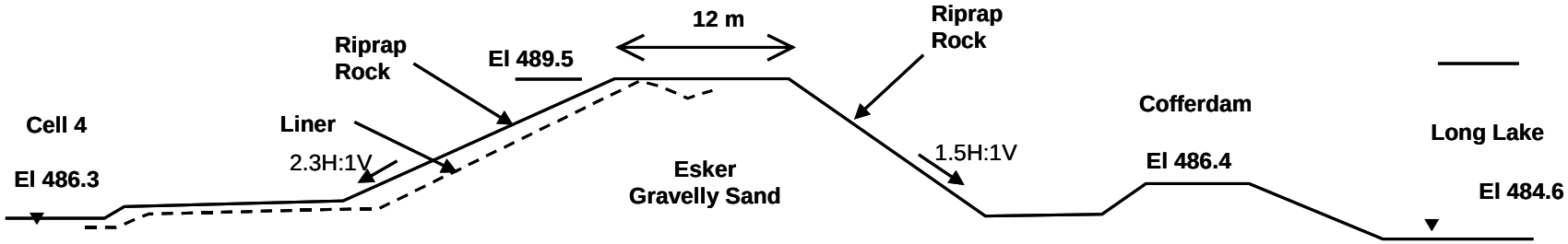

Figure B 6. Dam 4 section, facing northeast

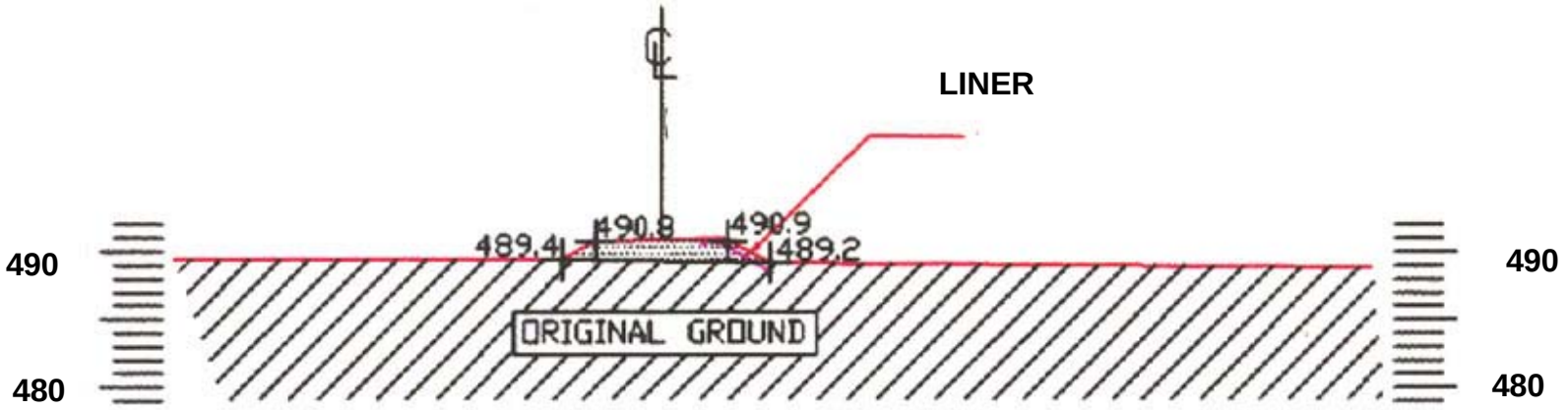

Figure B 7. Dam 5 section facing east

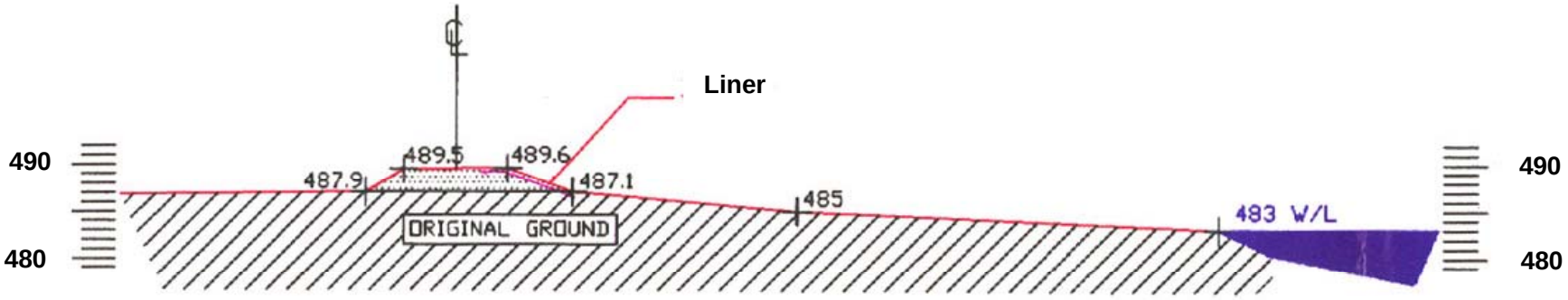

Figure B 8. Dam 6 section, facing northwest

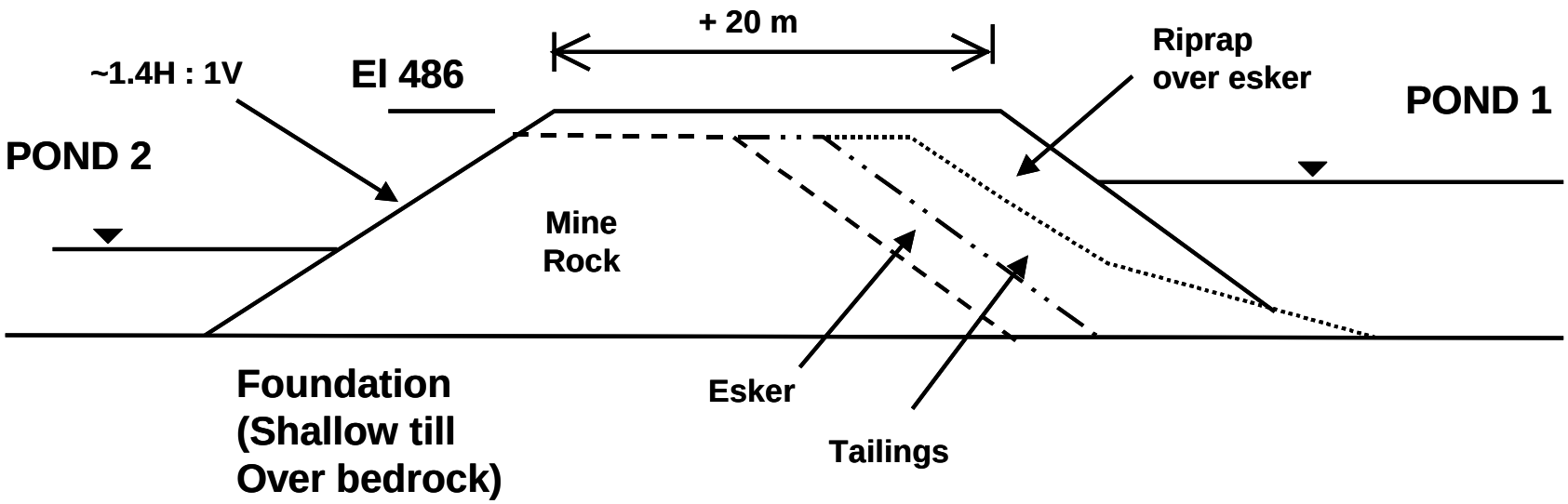

Figure B 9. J Dam section, facing north

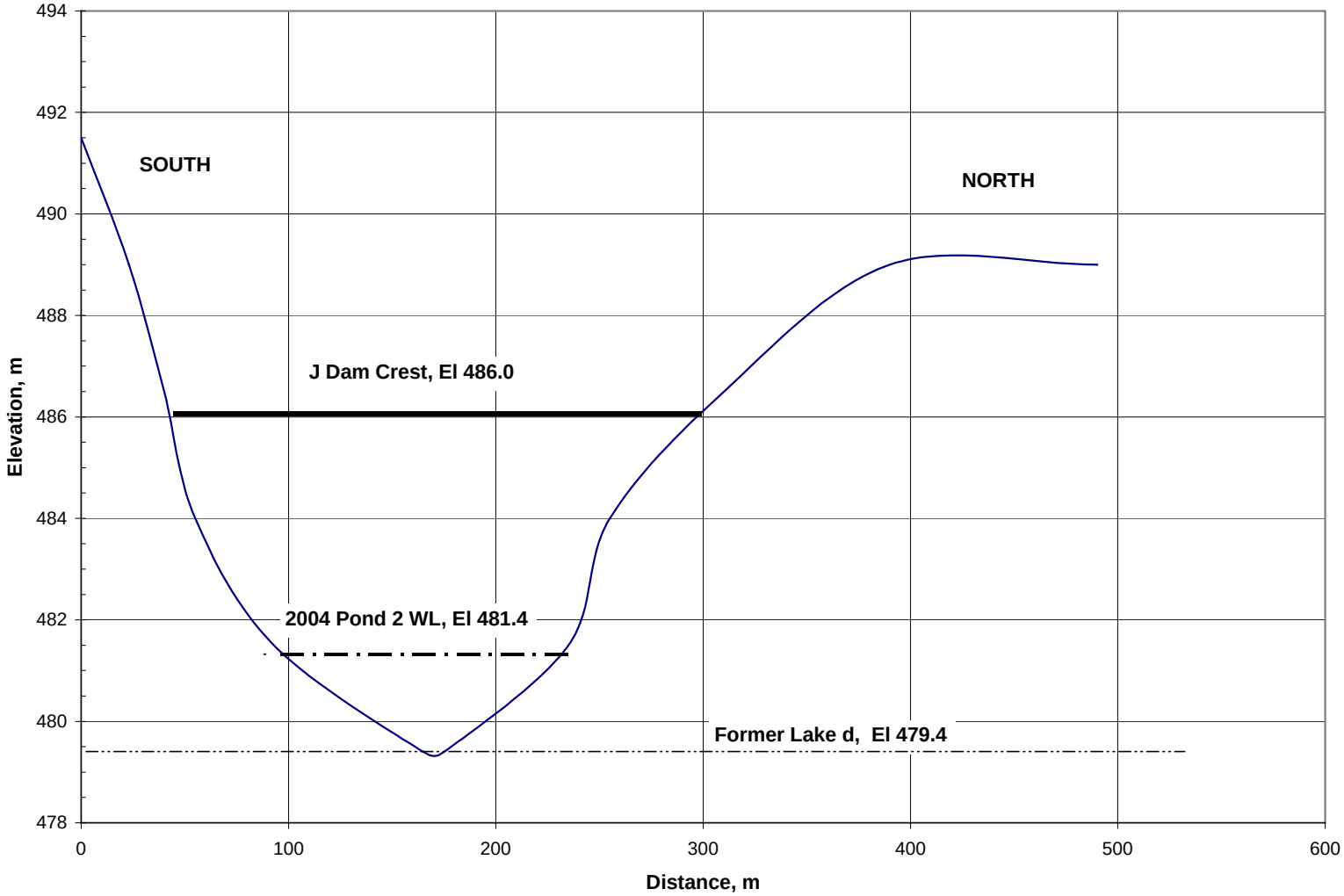

Figure B 10. J Dam foundation profile

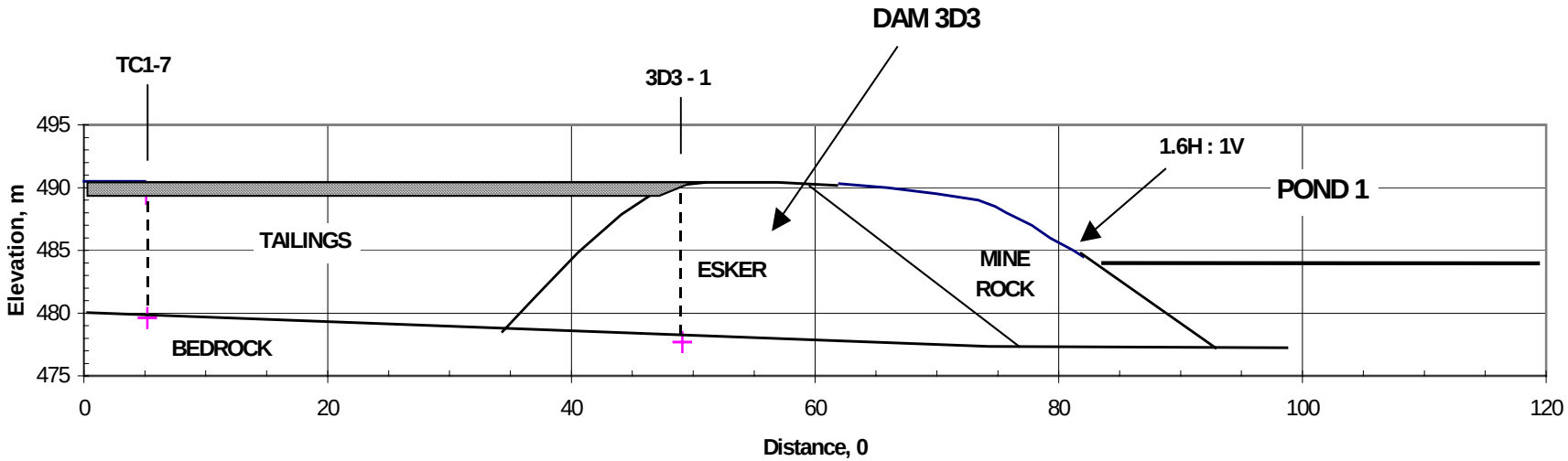

Figure B 11. Dam 3D section, facing east

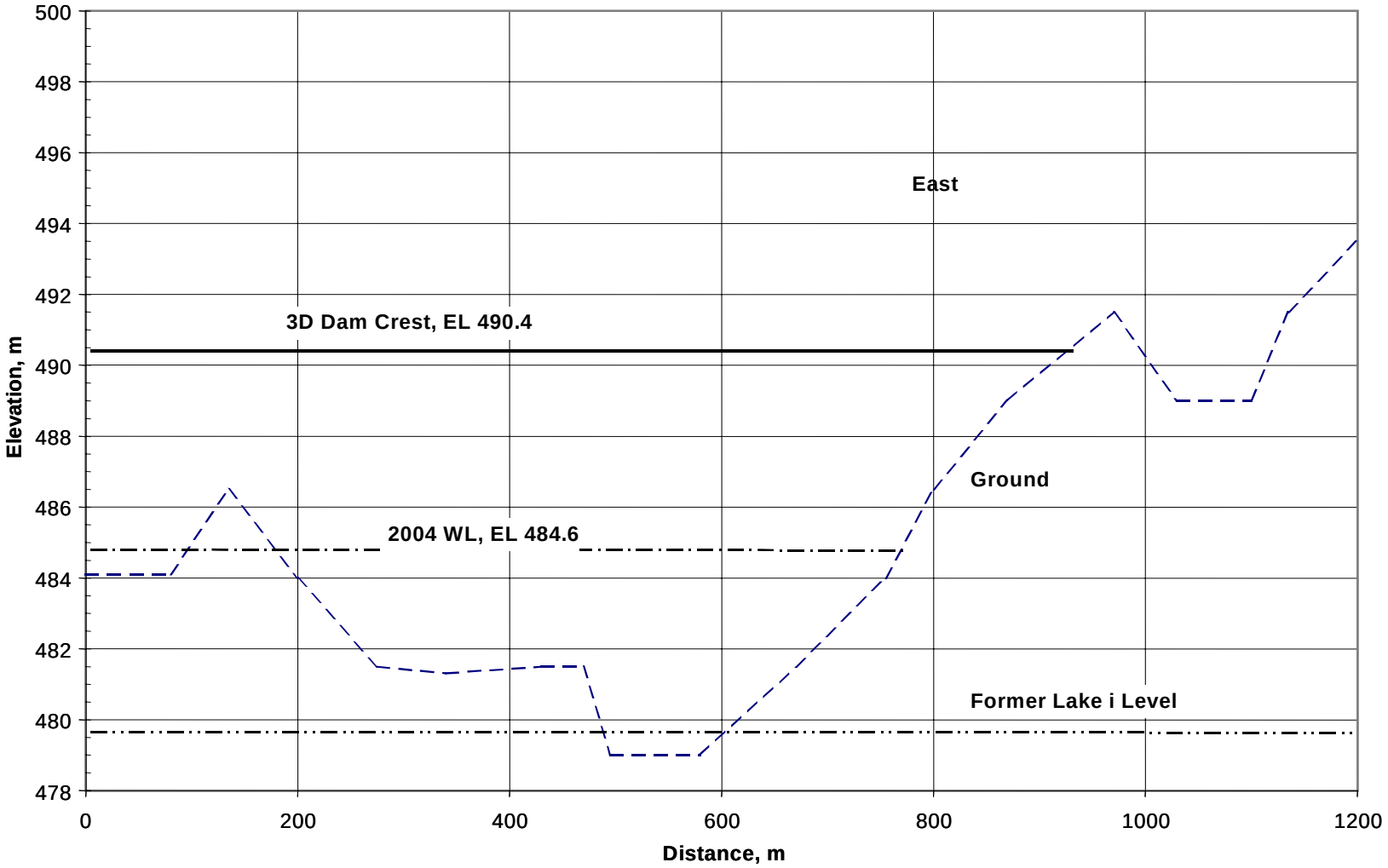

Figure B 12. Dam 3D foundation profile (against Cell 1)

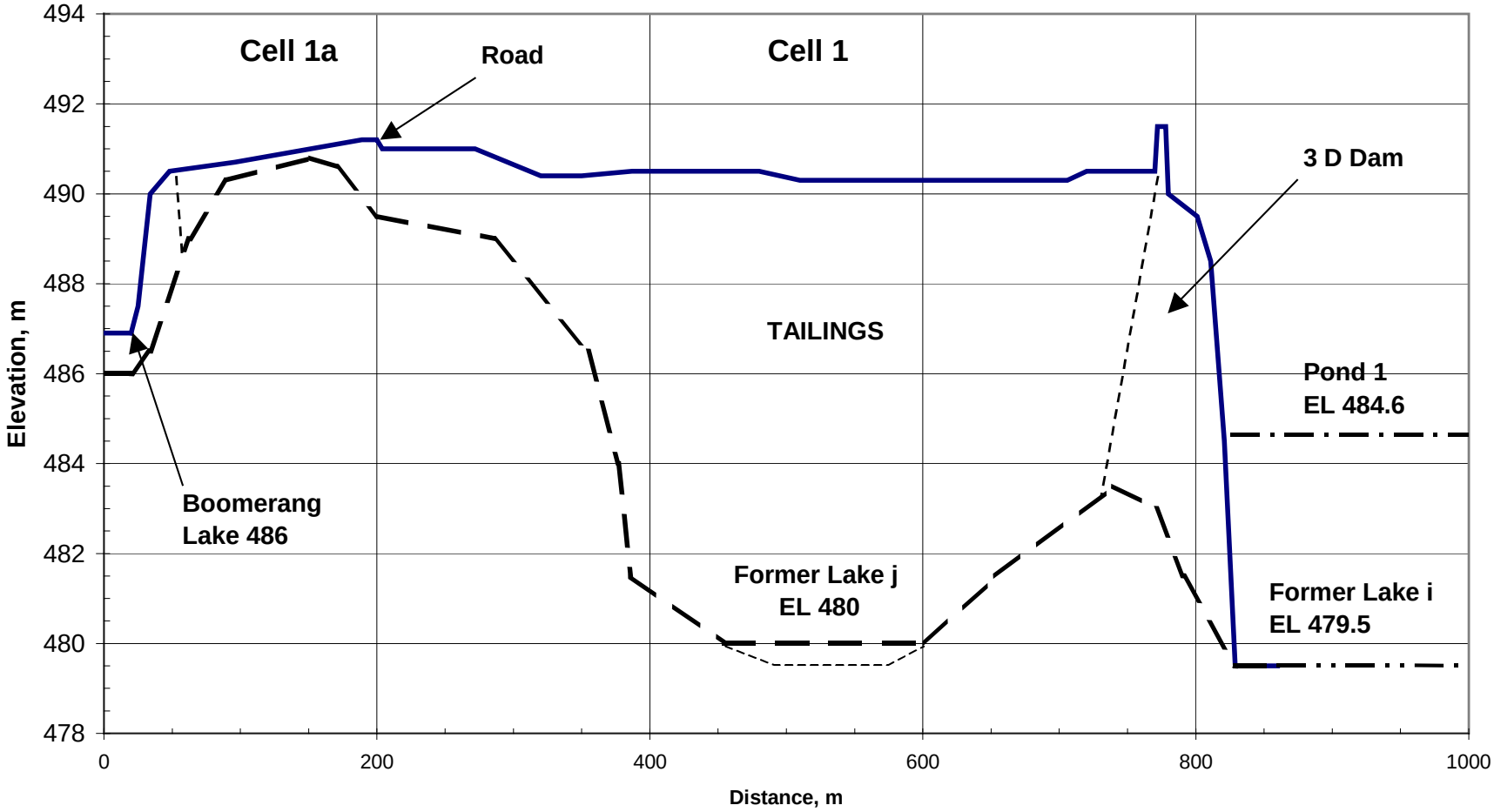

Figure B 13. Tailings contained by Dam 3D, section normal to dam

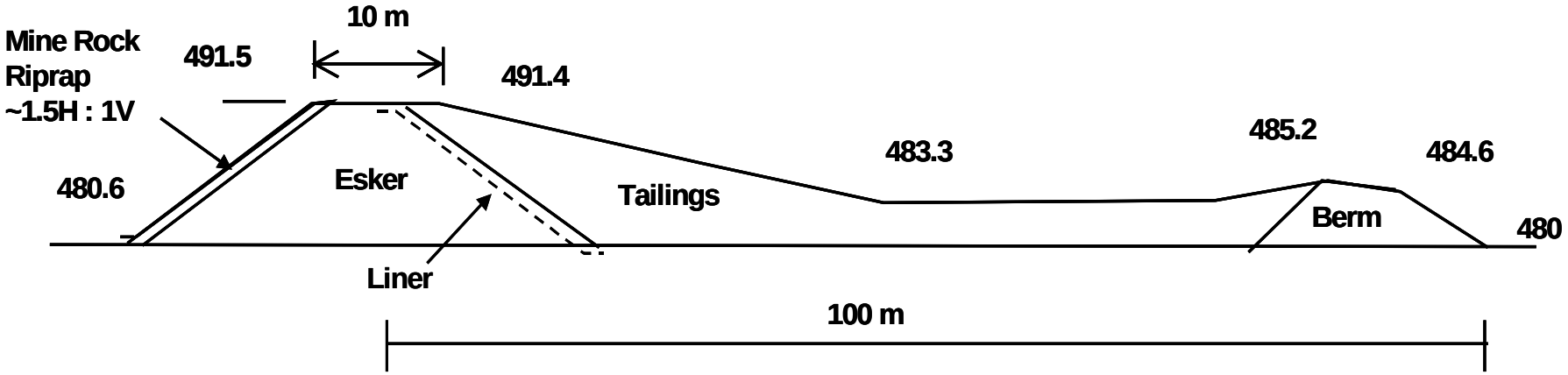

Figure B 14. K Dam section, looking northeast

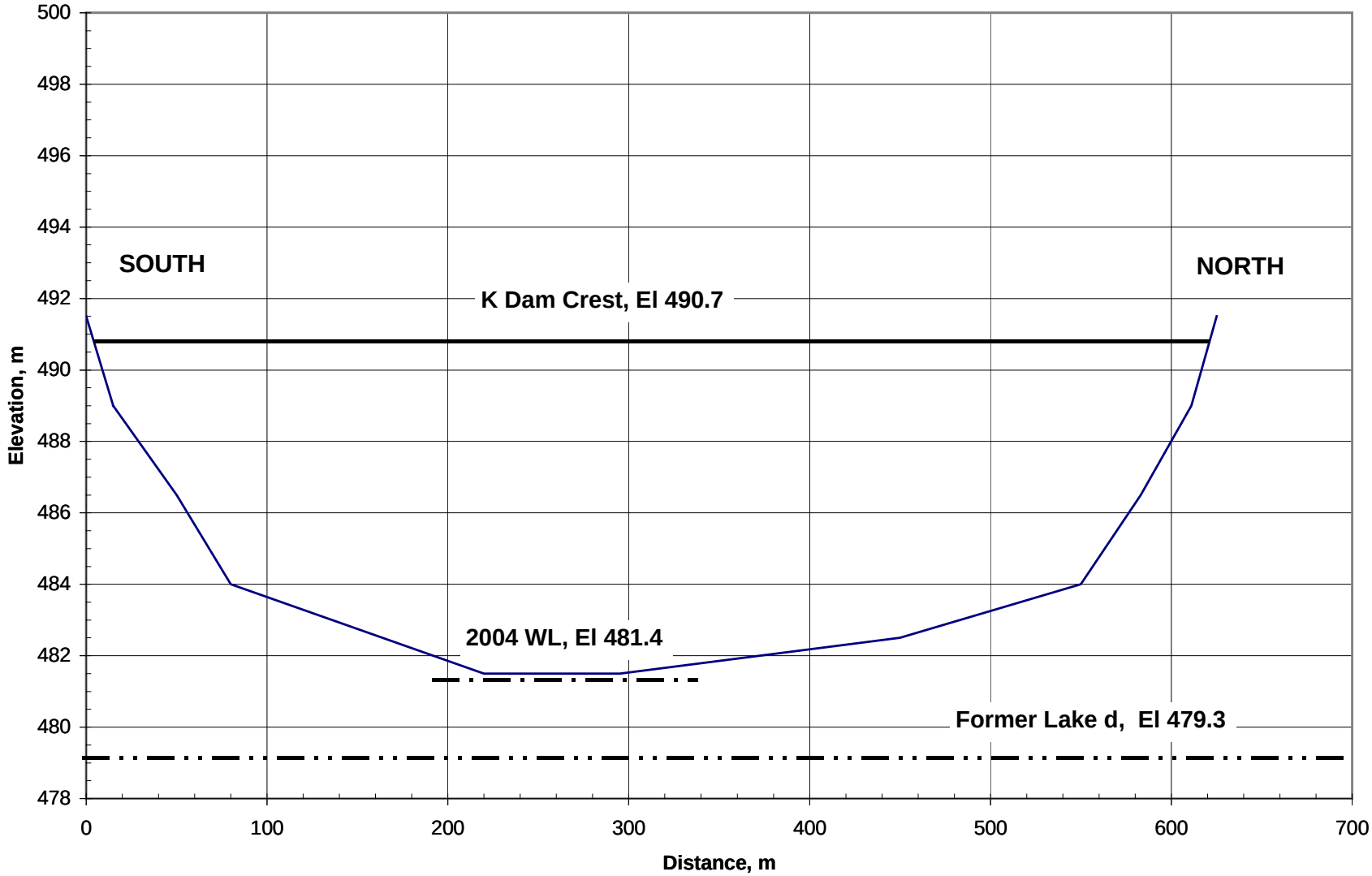

Figure B 15. K Dam foundation profile, looking west

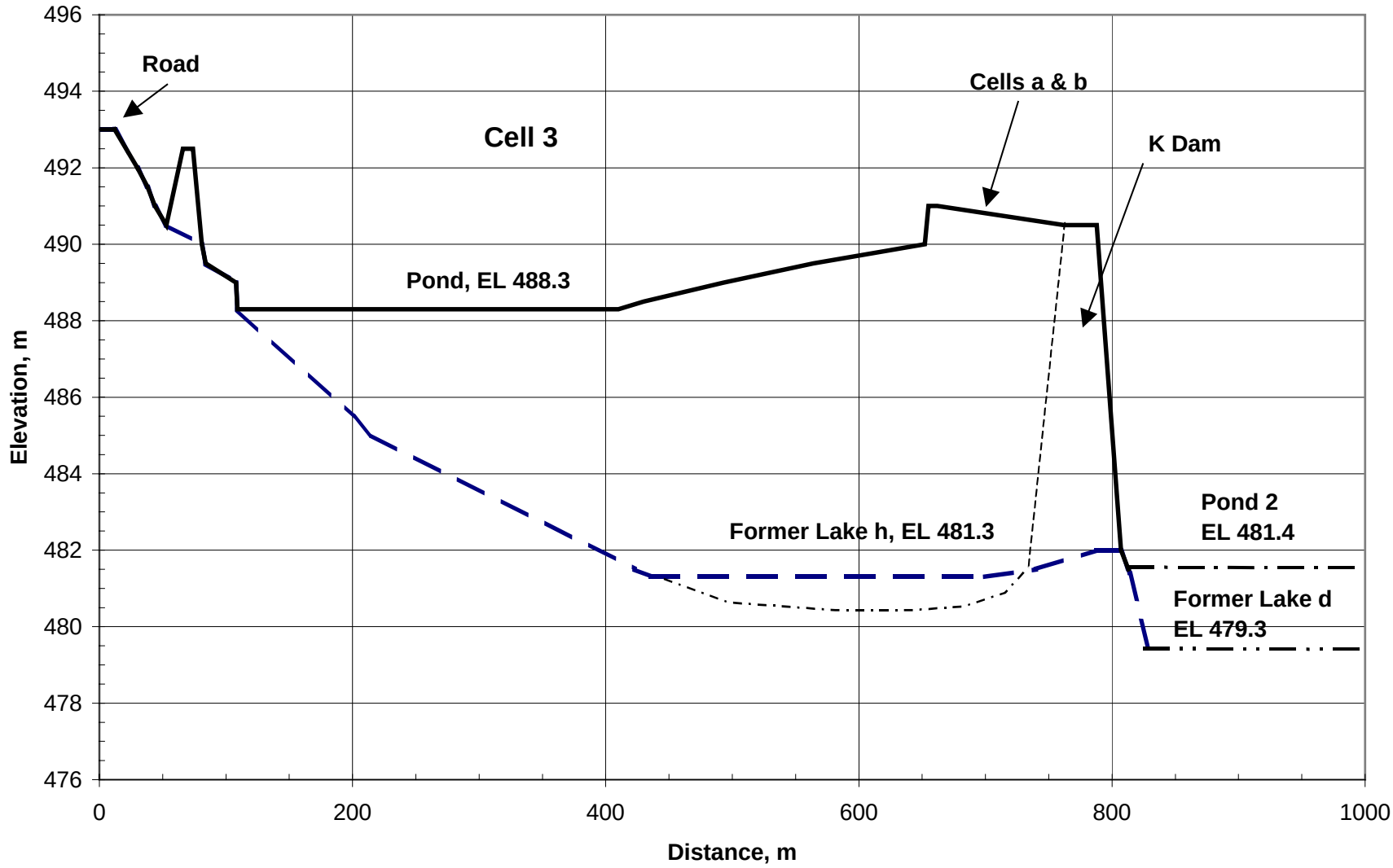

Figure B 16. Tailings contained by K Dam , section normal to dam

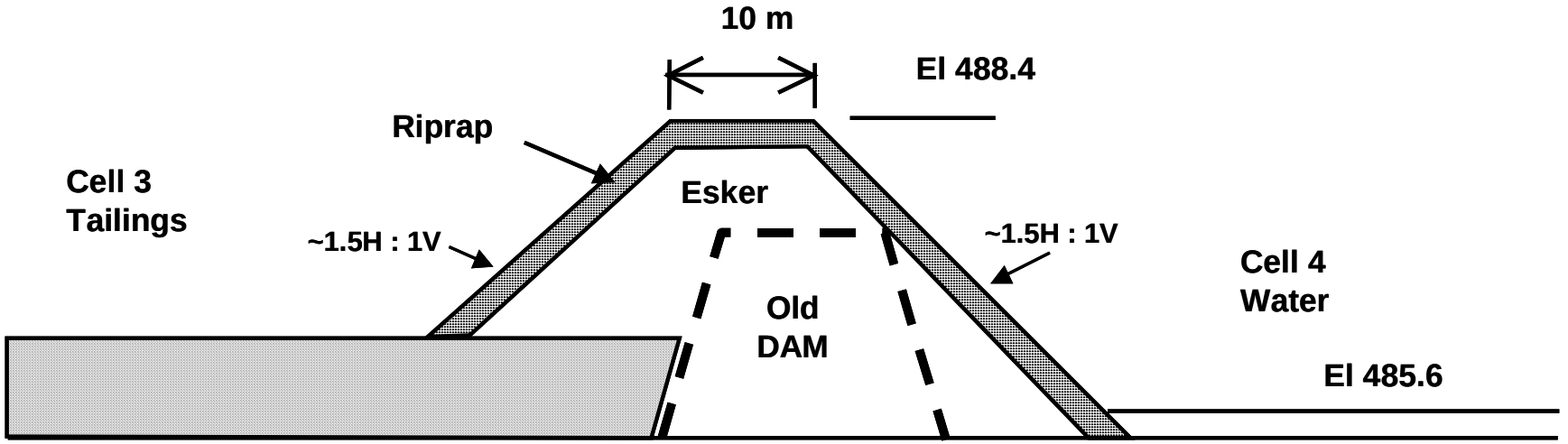

Figure B 17. L Dam section, looking northwest

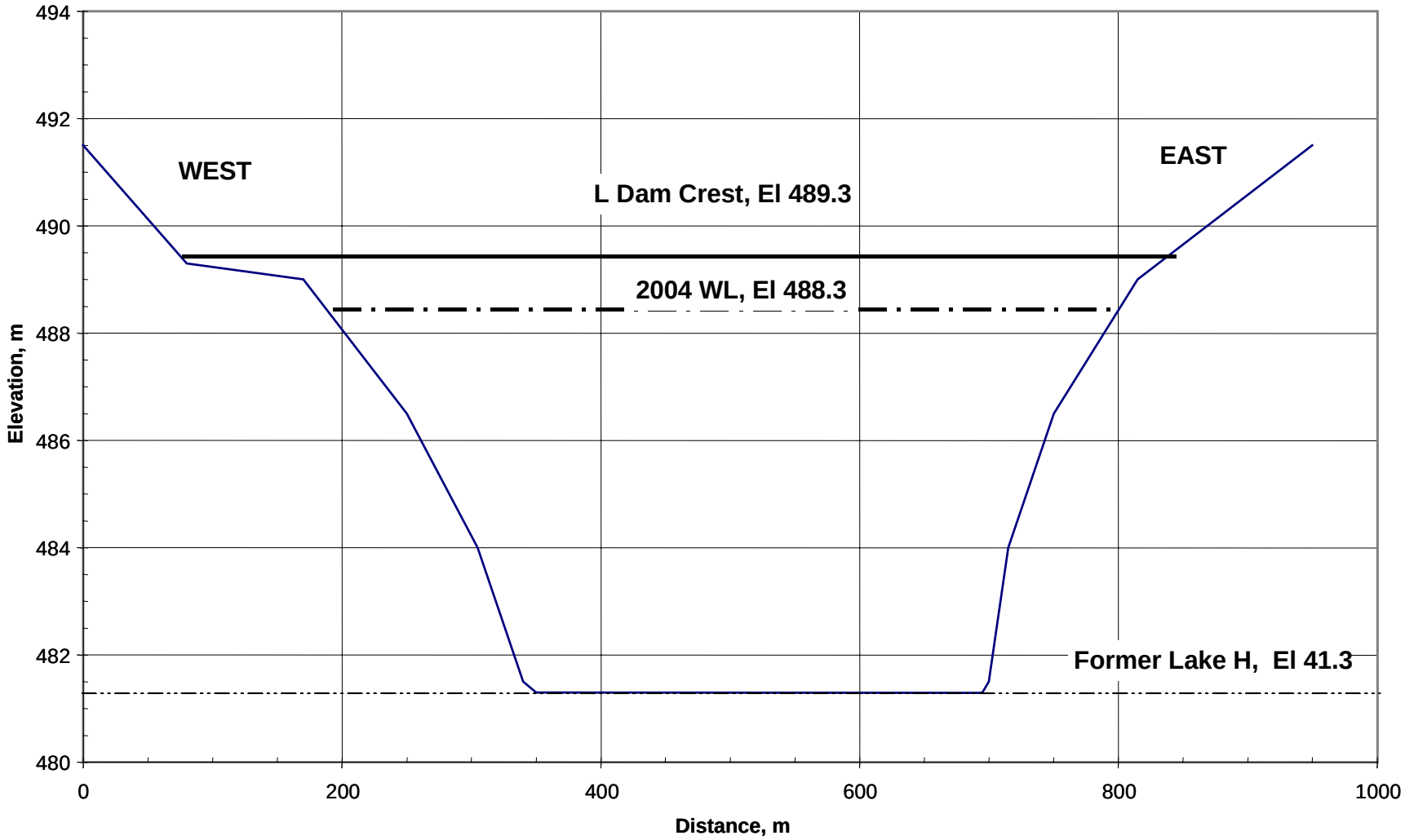

Figure B 18. L Dam foundation profile

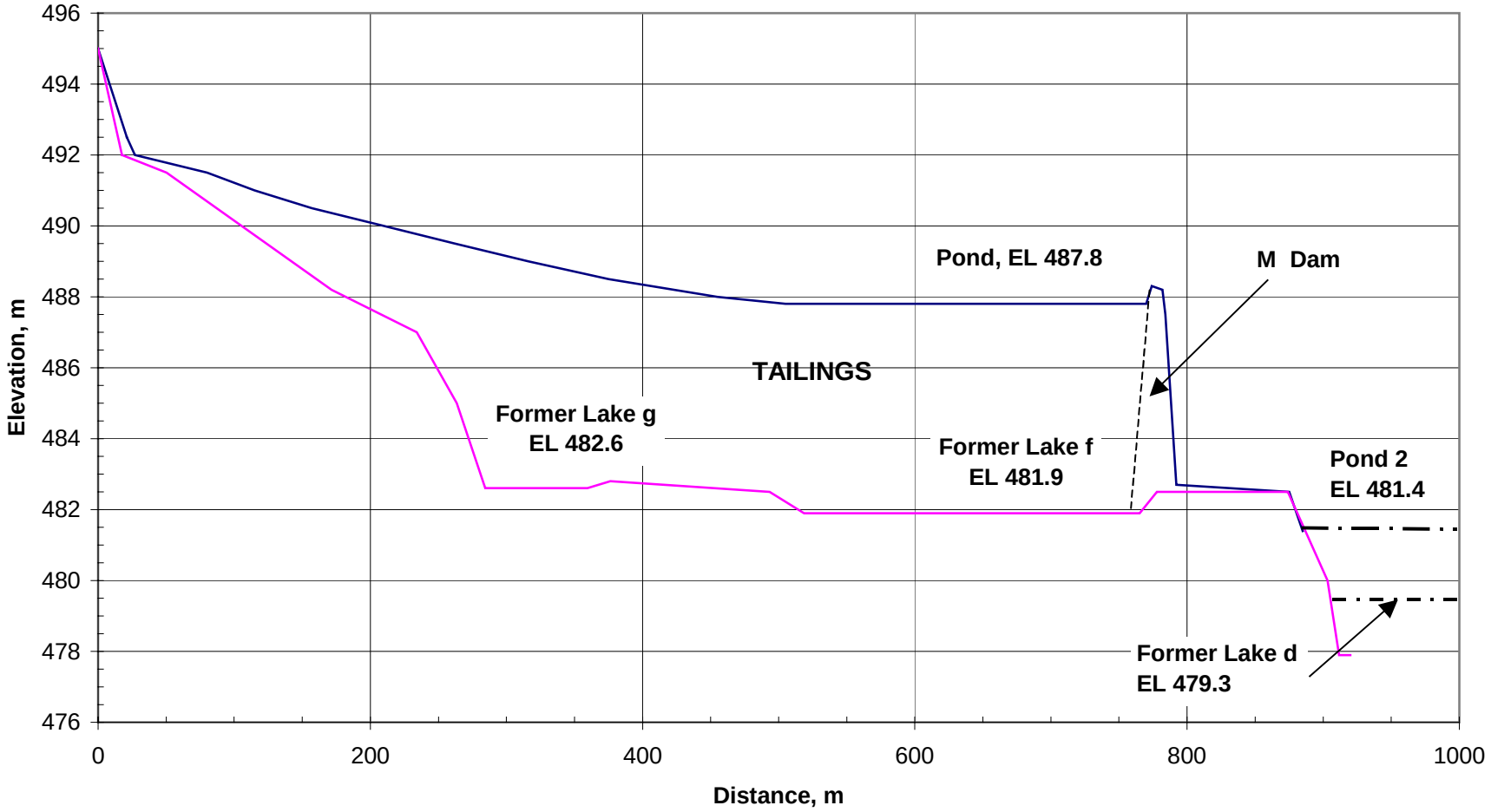

Figure B 19. M Dam section with contained tailings, looking east

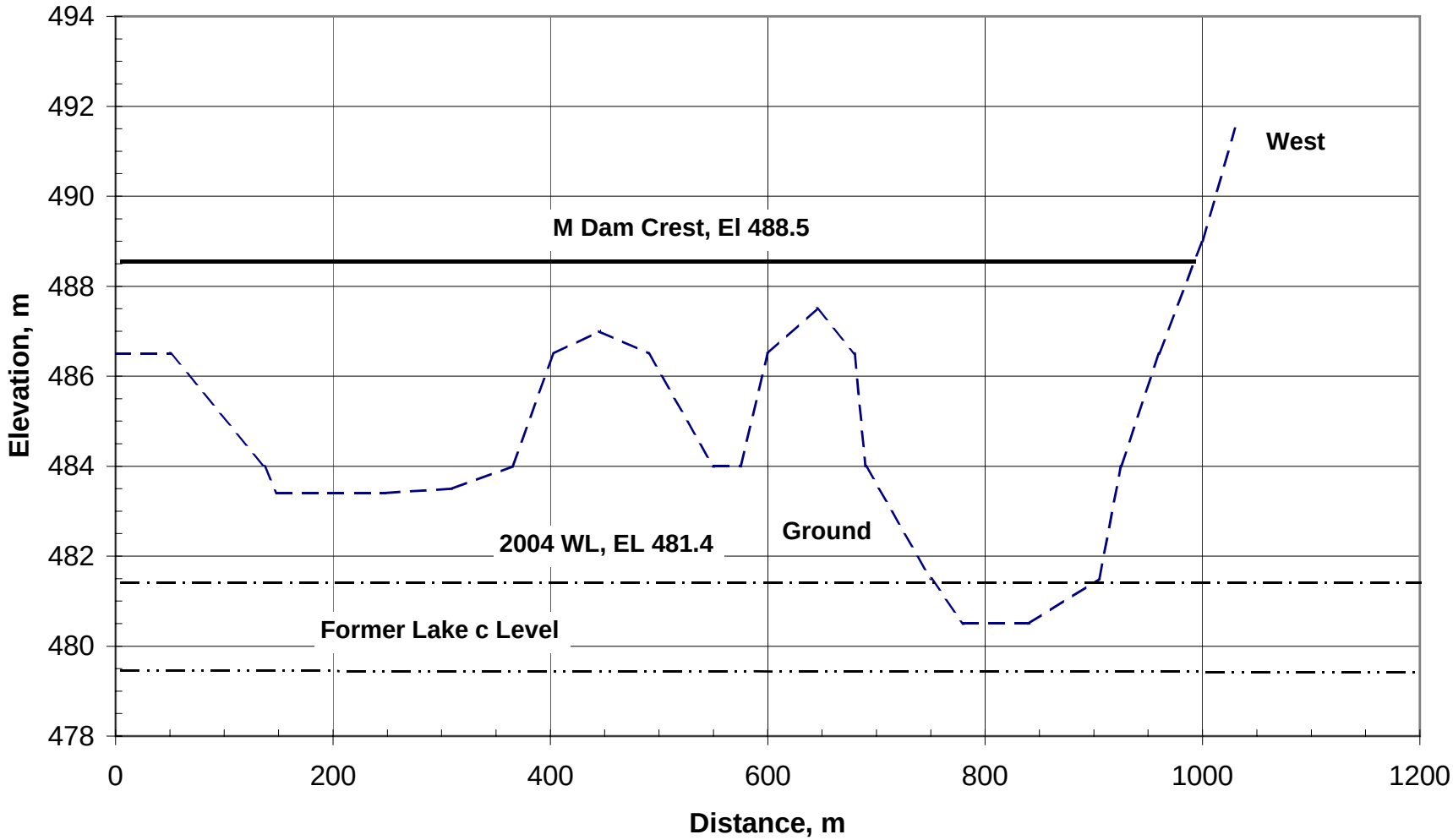

Figure B 20. M Dam foundation profile

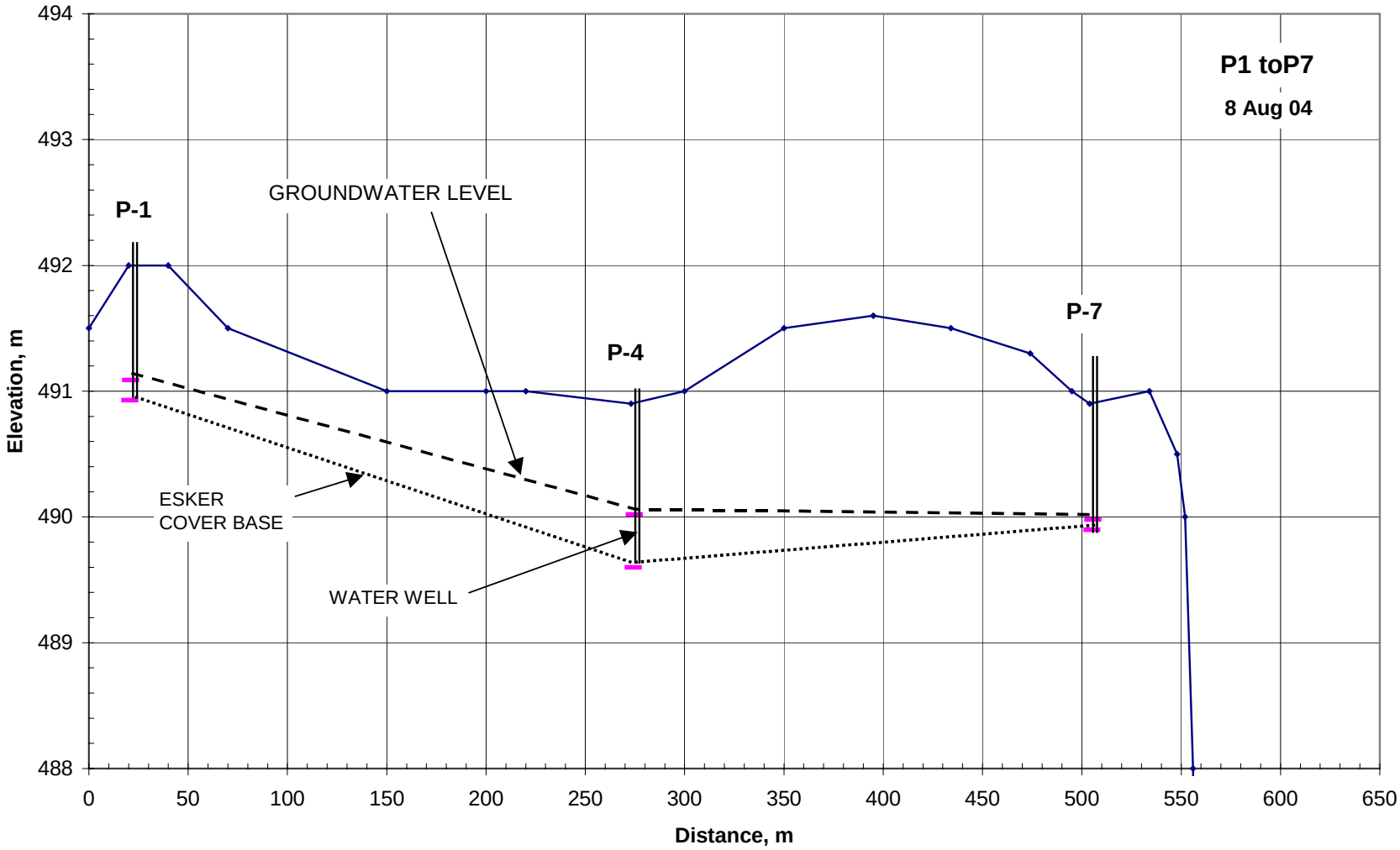

Figure B 21. Groundwater profile along pipe section P1 - P9

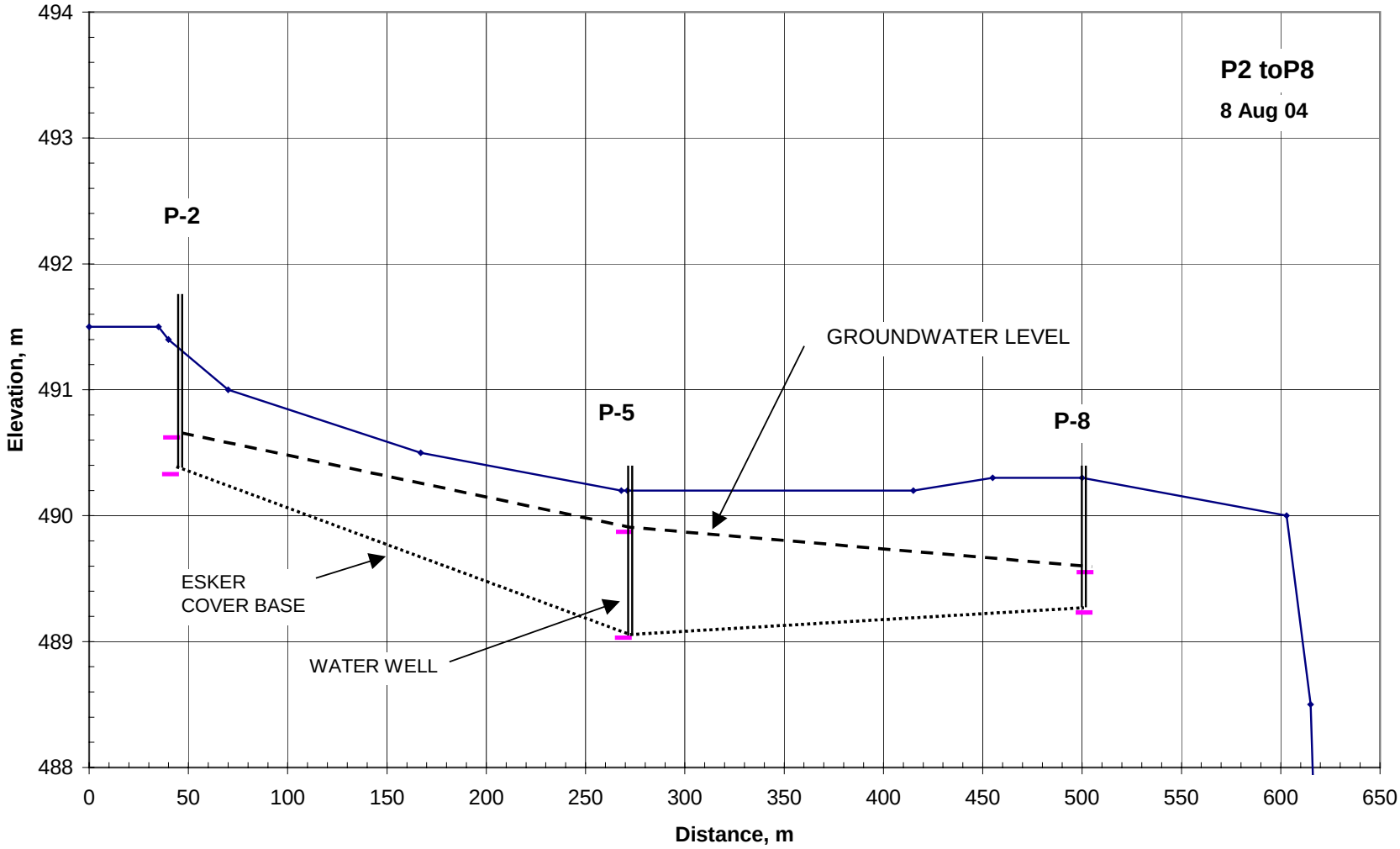

Figure B 22. Groundwater profile along pipe section P2 – P8

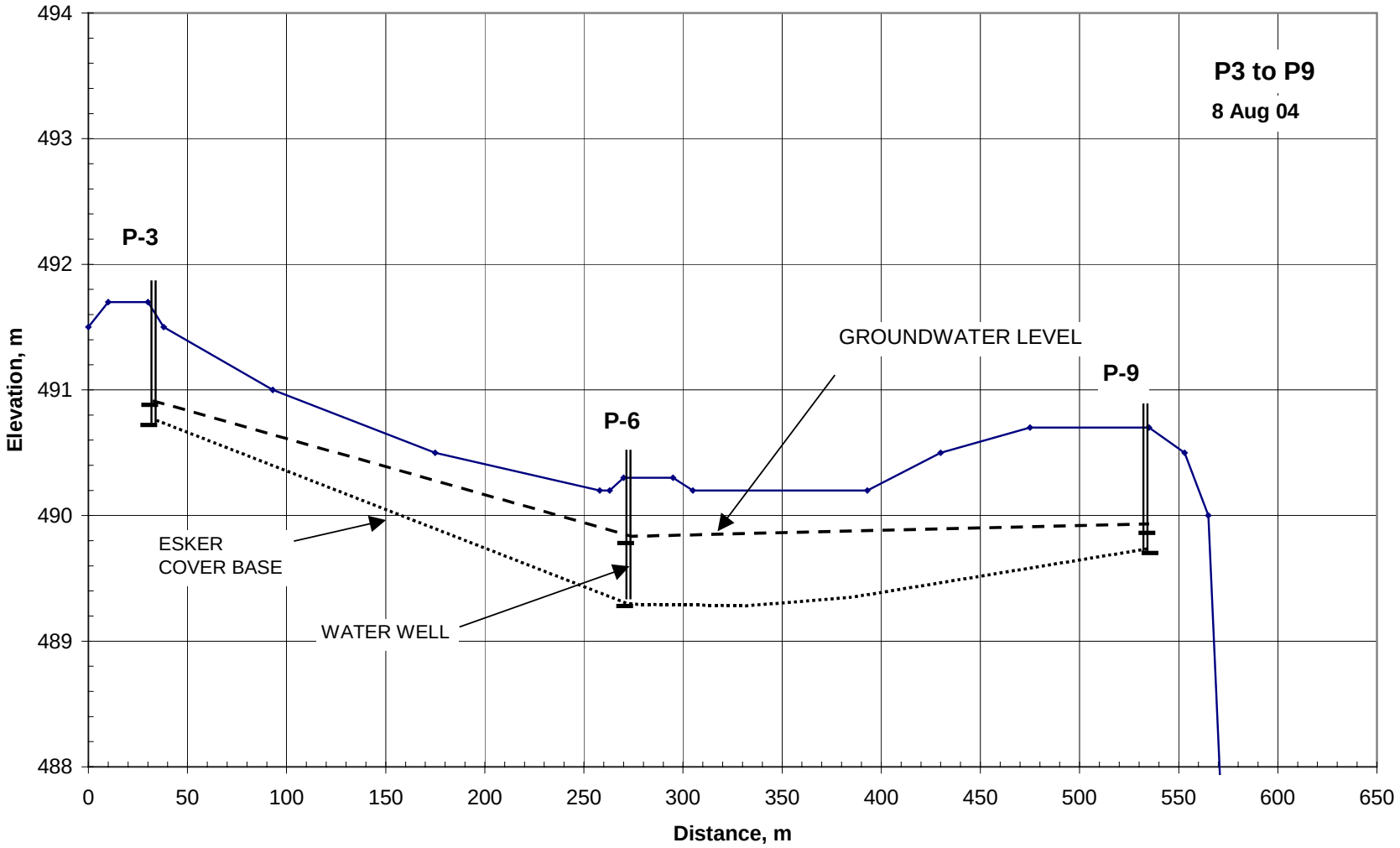

Figure B 23. Groundwater profile along pipe section P3 - P9

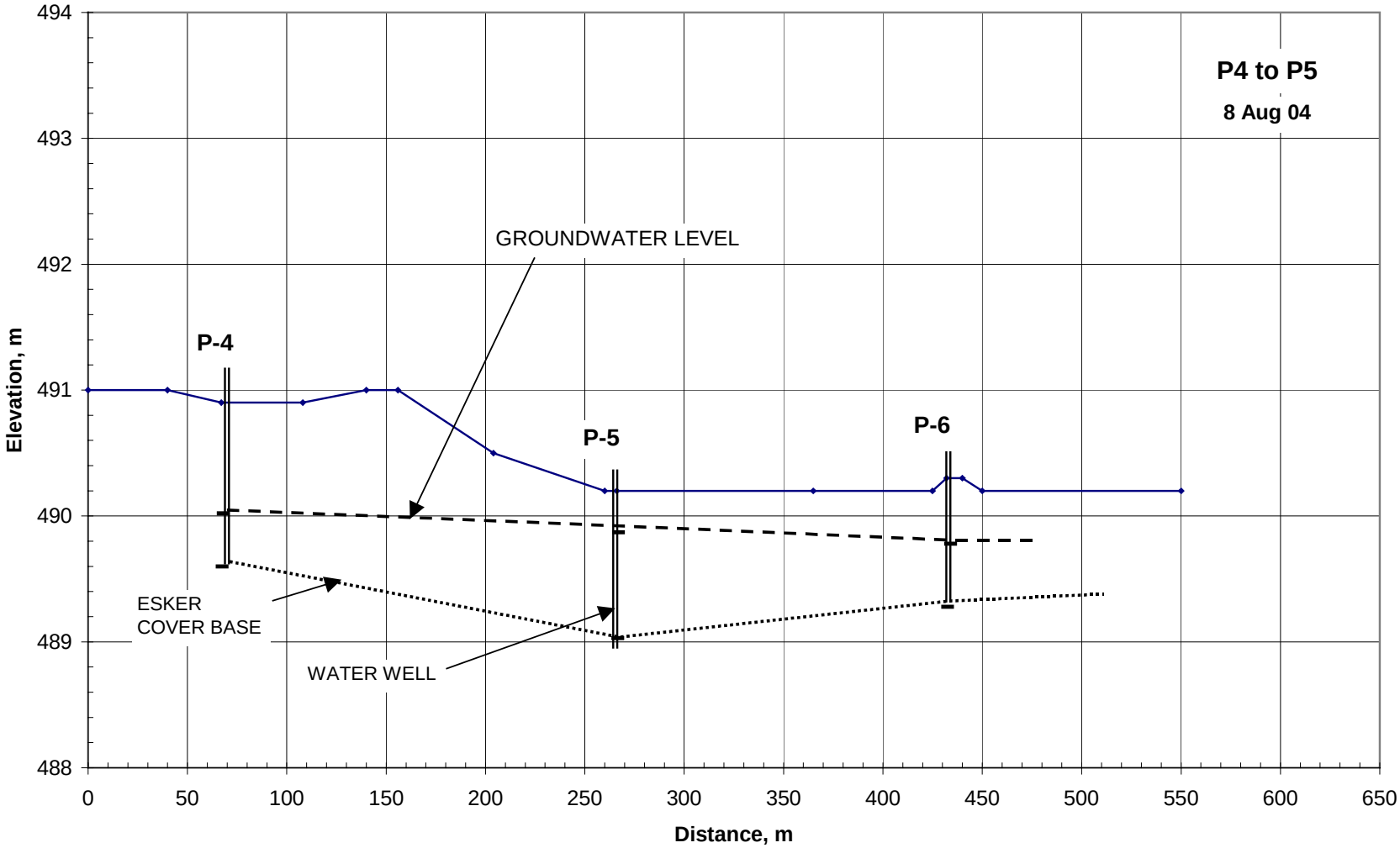

Figure B 24. Groundwater profile along pipe section P4 – P6

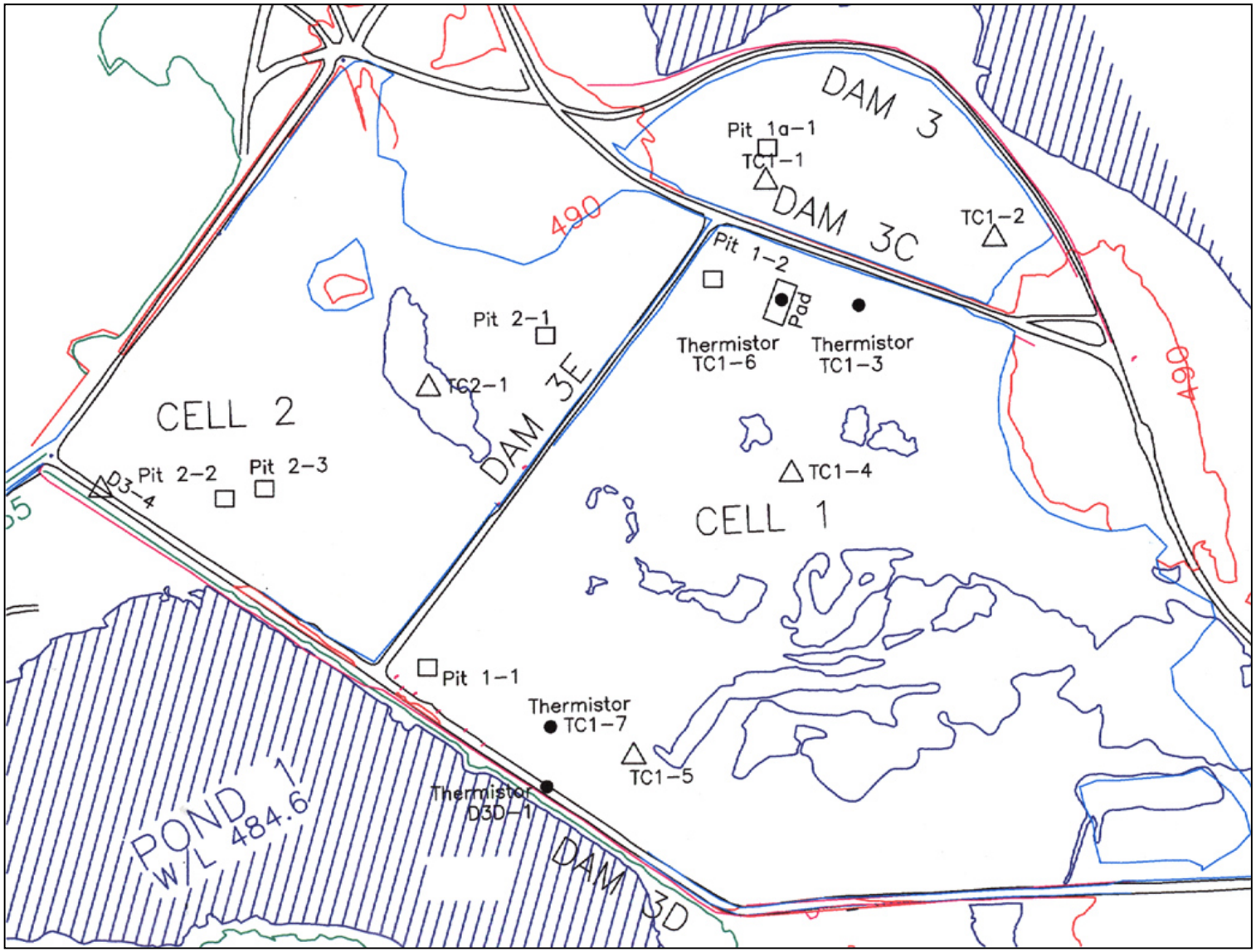

Figure B 25. Locations of thermistors and test pits in Cells 1 & 2

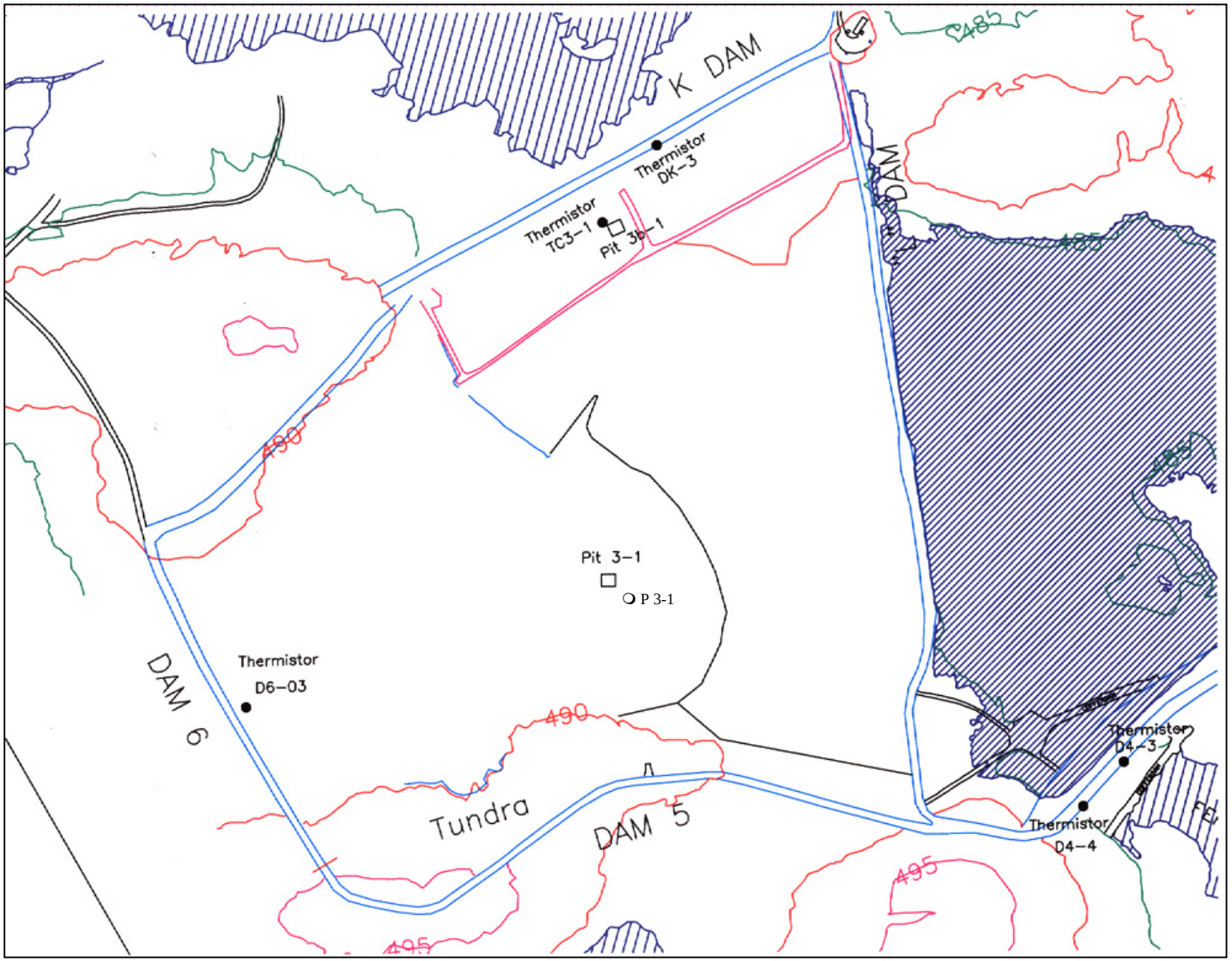

Figure B 26. Location of thermistors and test pits in Cell 3

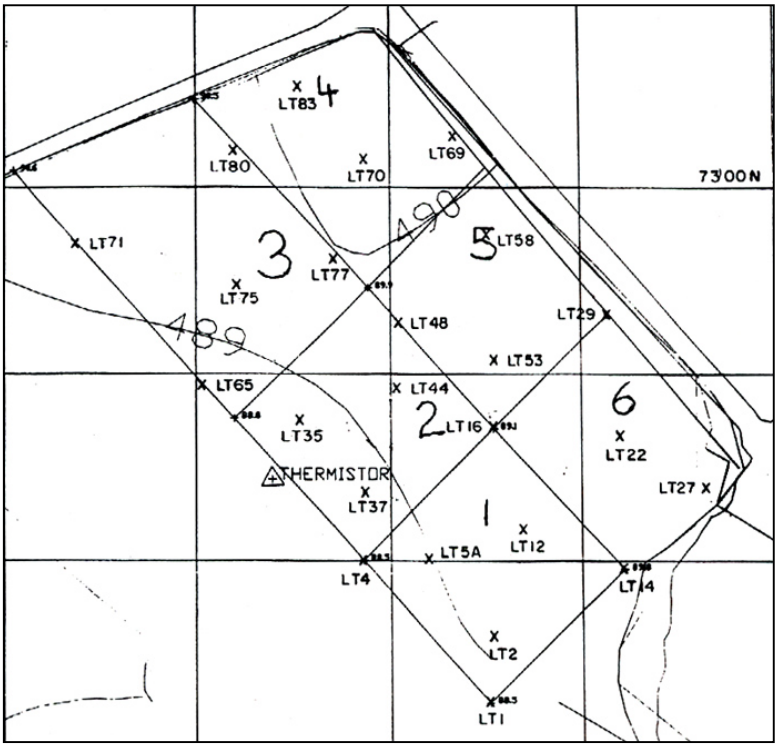

Figure B 27. Locations of tailings samples (Klohn-Crippen 1995)

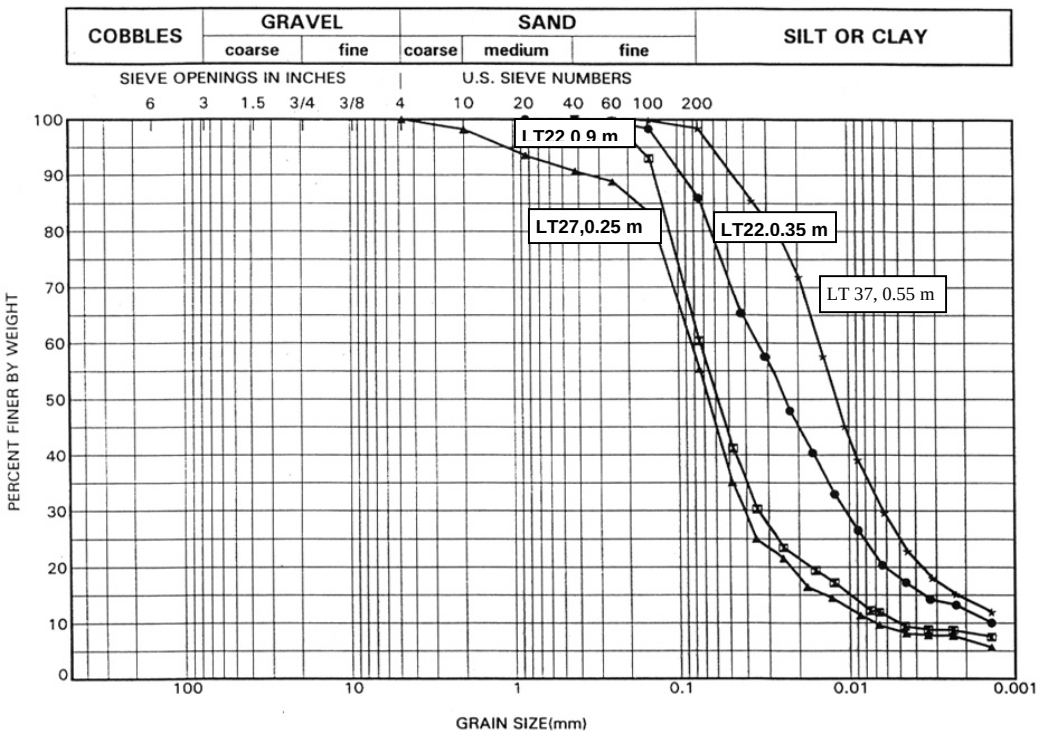

Figure B 28. Tailings Gradations (Klohn-Crippen 1995)

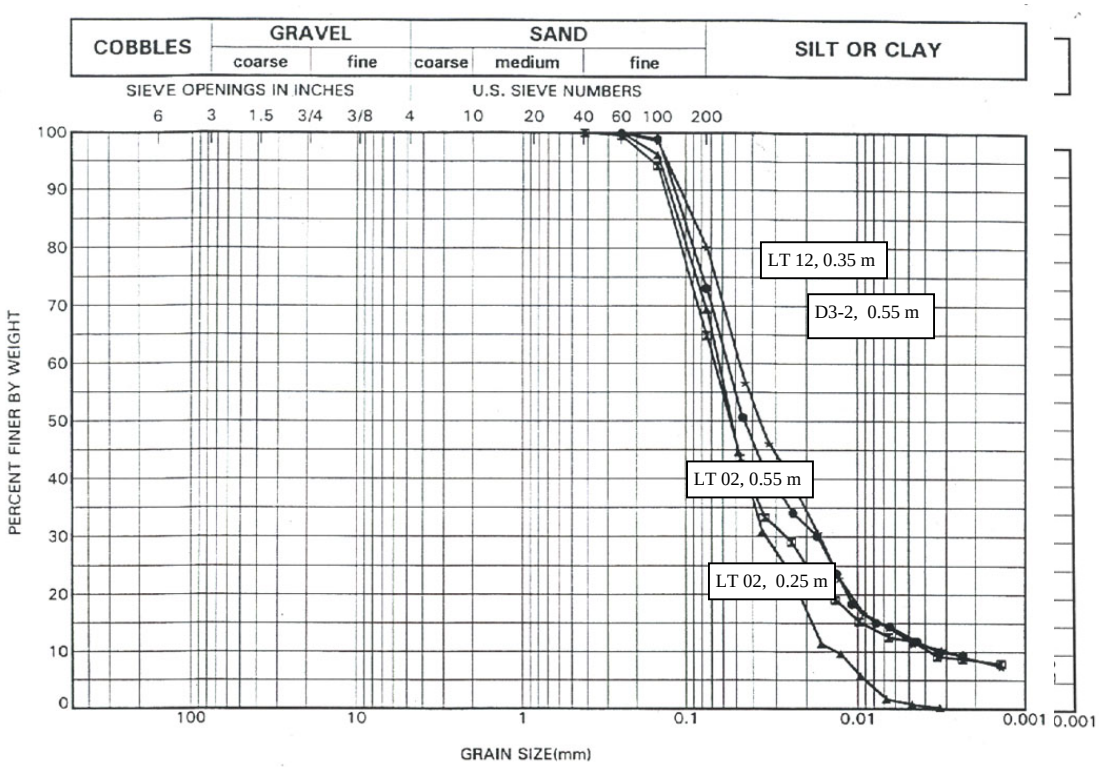

Figure B 29. Tailings gradations (Klohn-Crippen 1995)

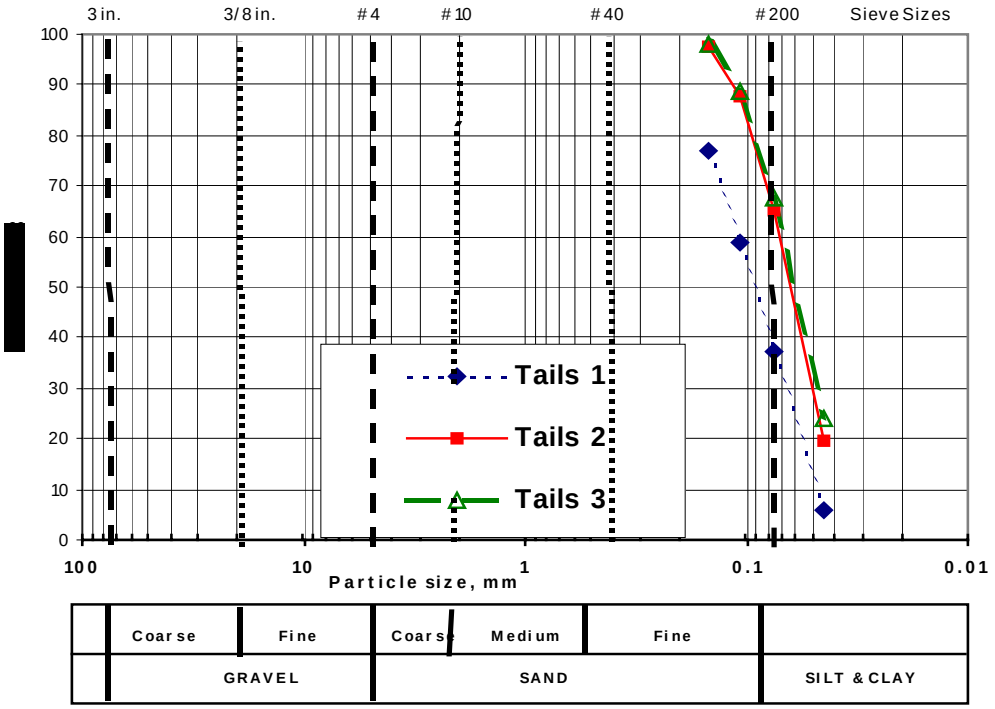

Figure B 30. Gradations of tailings measured in 2005

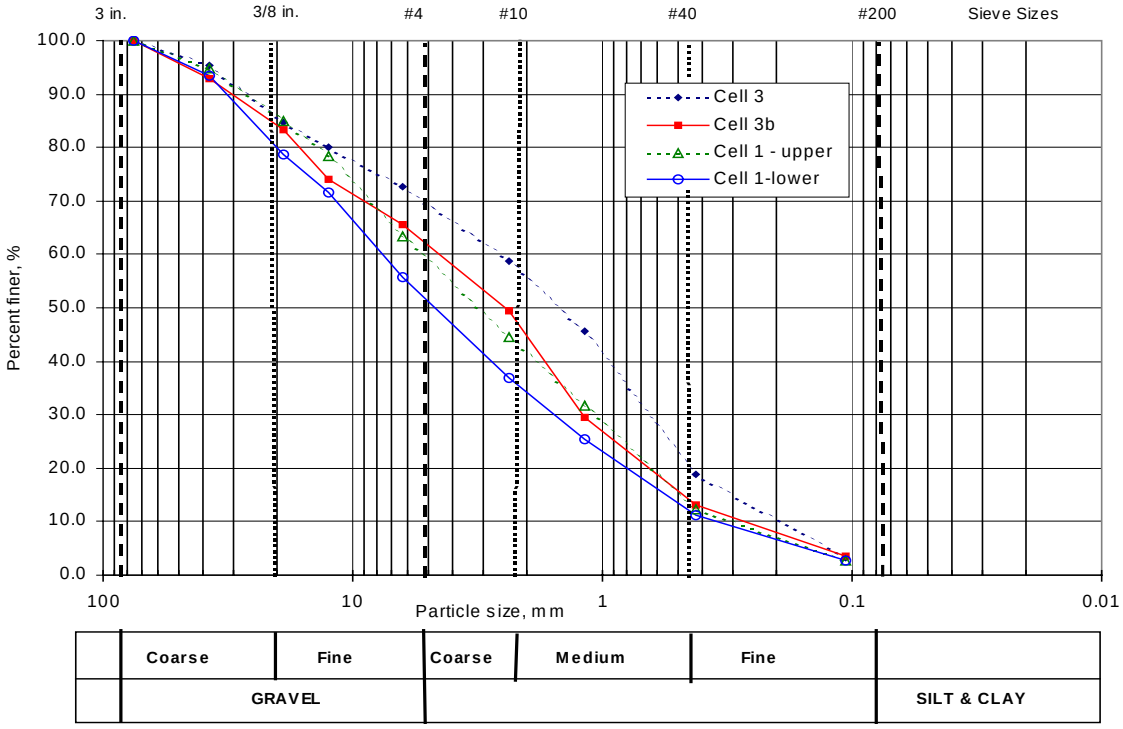

Figure B 31. Esker gradations, Pass 75 mm sample size

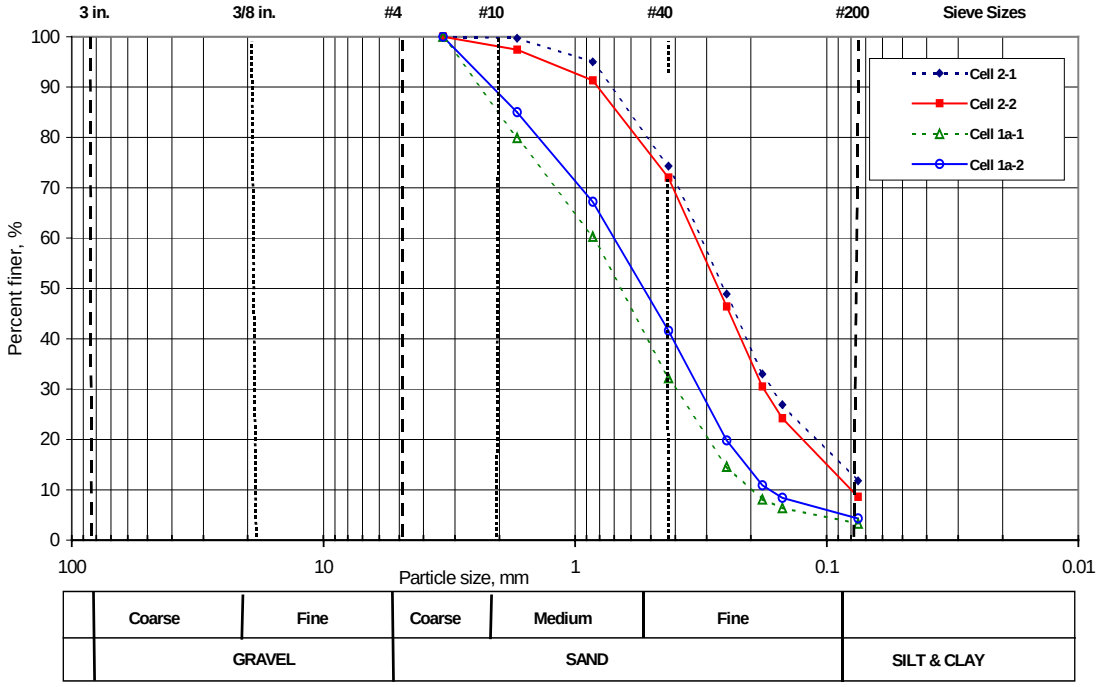

Figure B 32. Esker gradation, sand size material

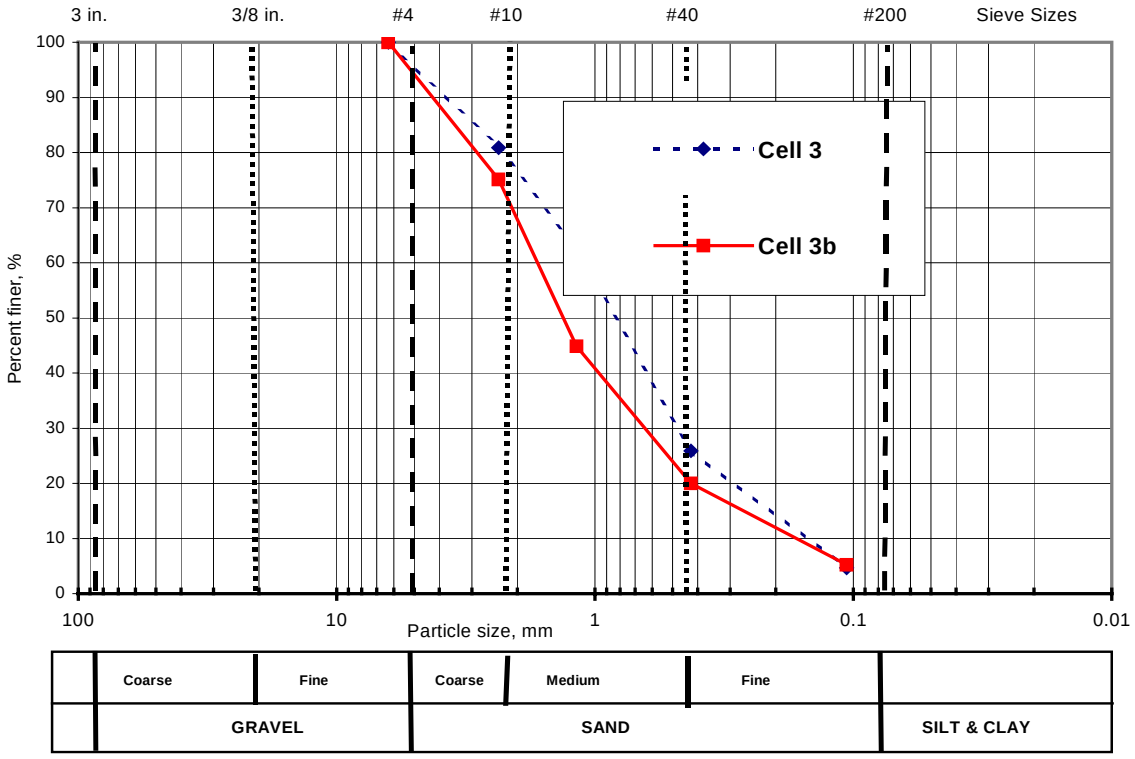

Figure B 33. Esker gradation, sand size material

APPENDIX C

GROUND TEMPERATURES

PART

OF

CLOSURE PLAN FOR

TAILINGS CONTAINMENT AREA

Prepared for

Kinross Gold Corporation

LUPIN OPERATION

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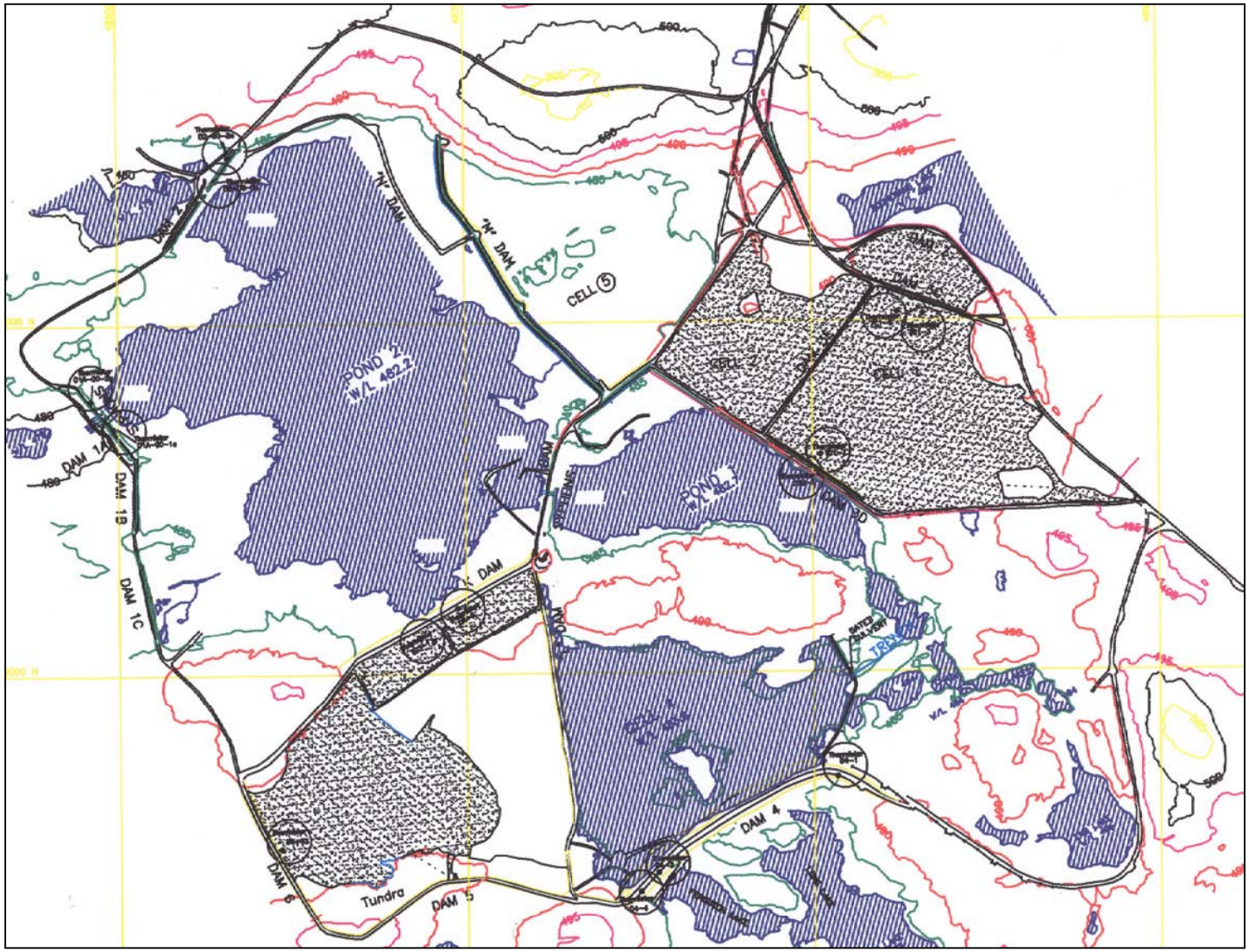

Figure C 1. General thermistor location plan

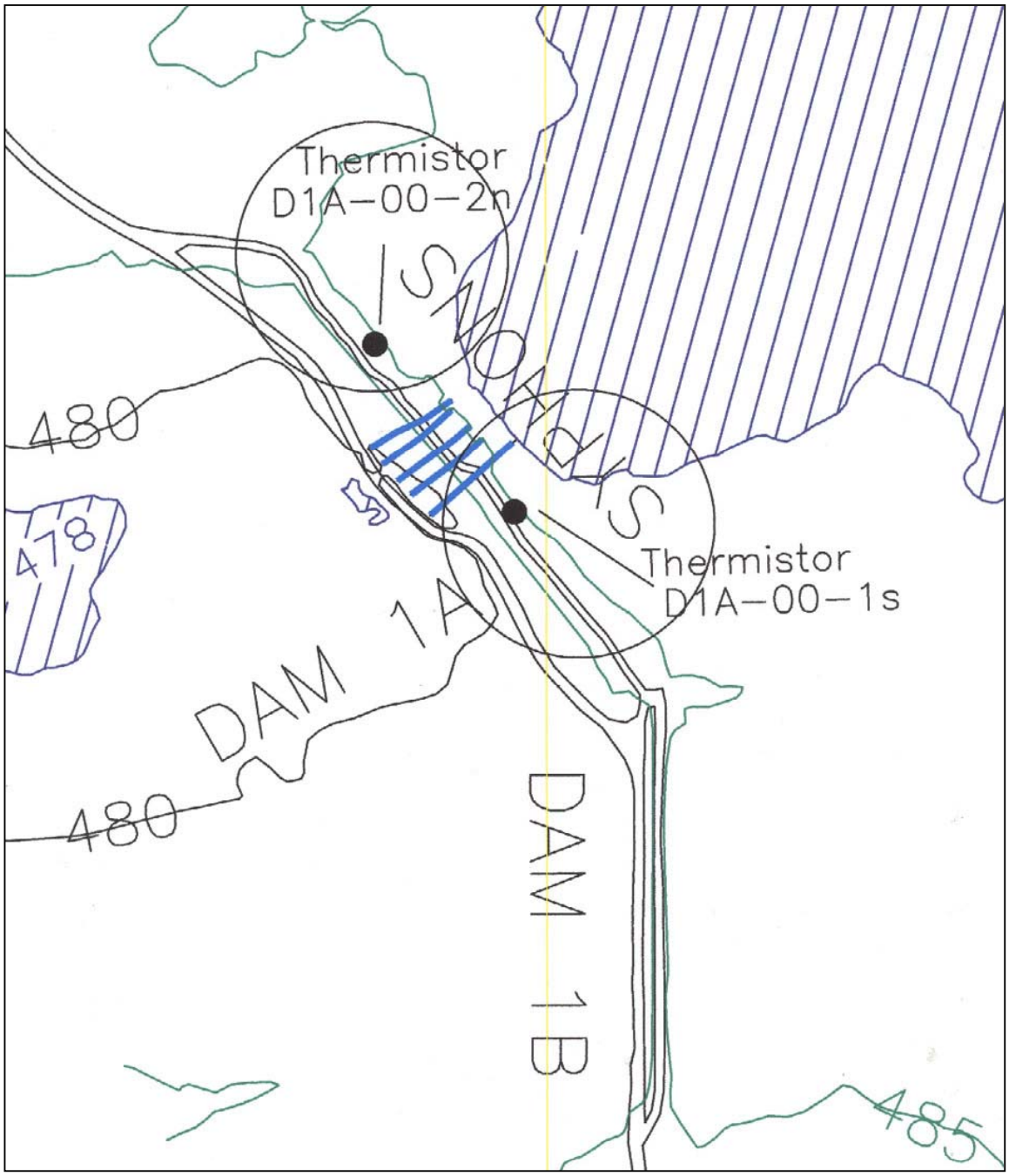

Figure C 2. Thermistors at Dam 1a

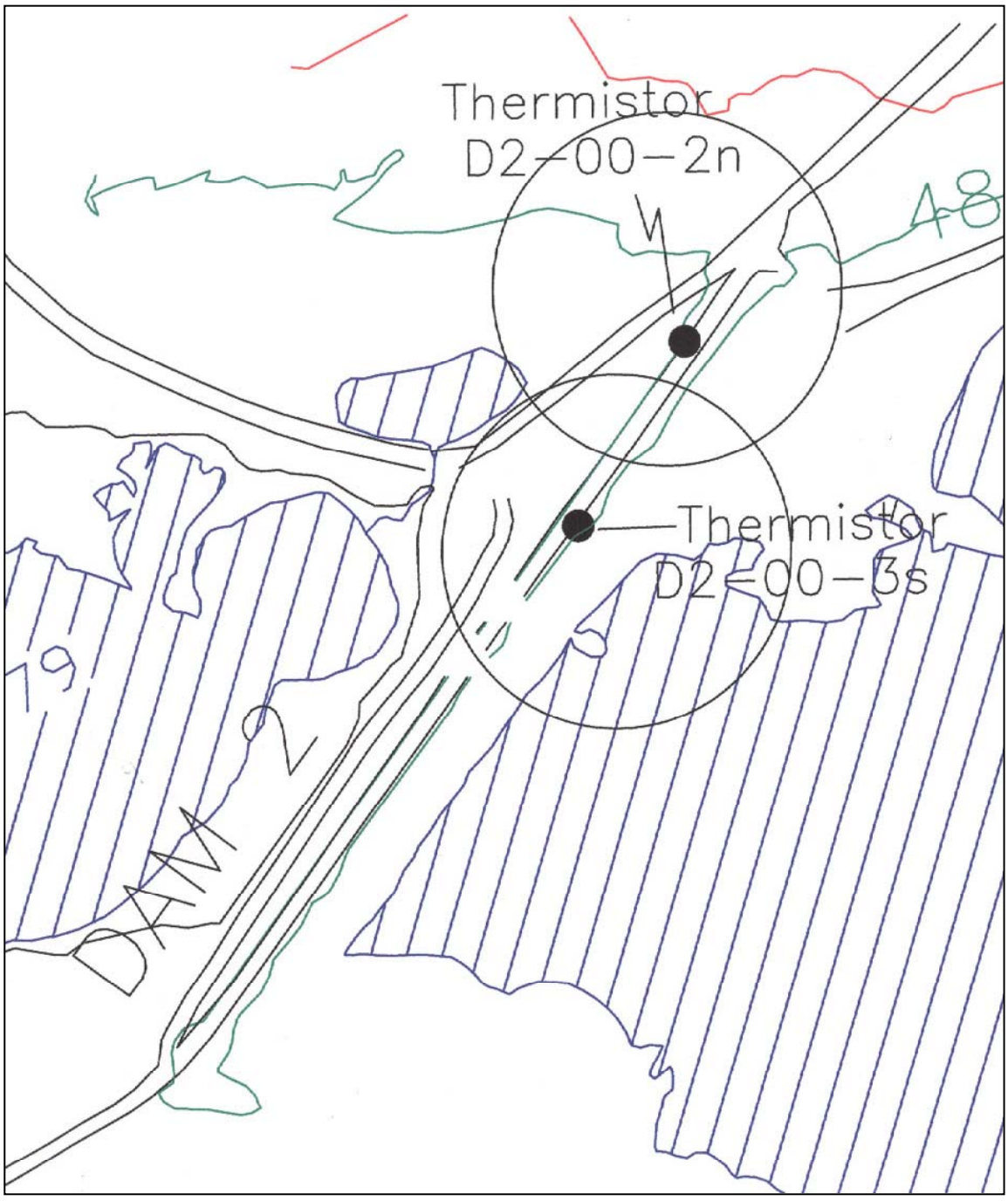

Figure C 3. Thermistors at Dam 2

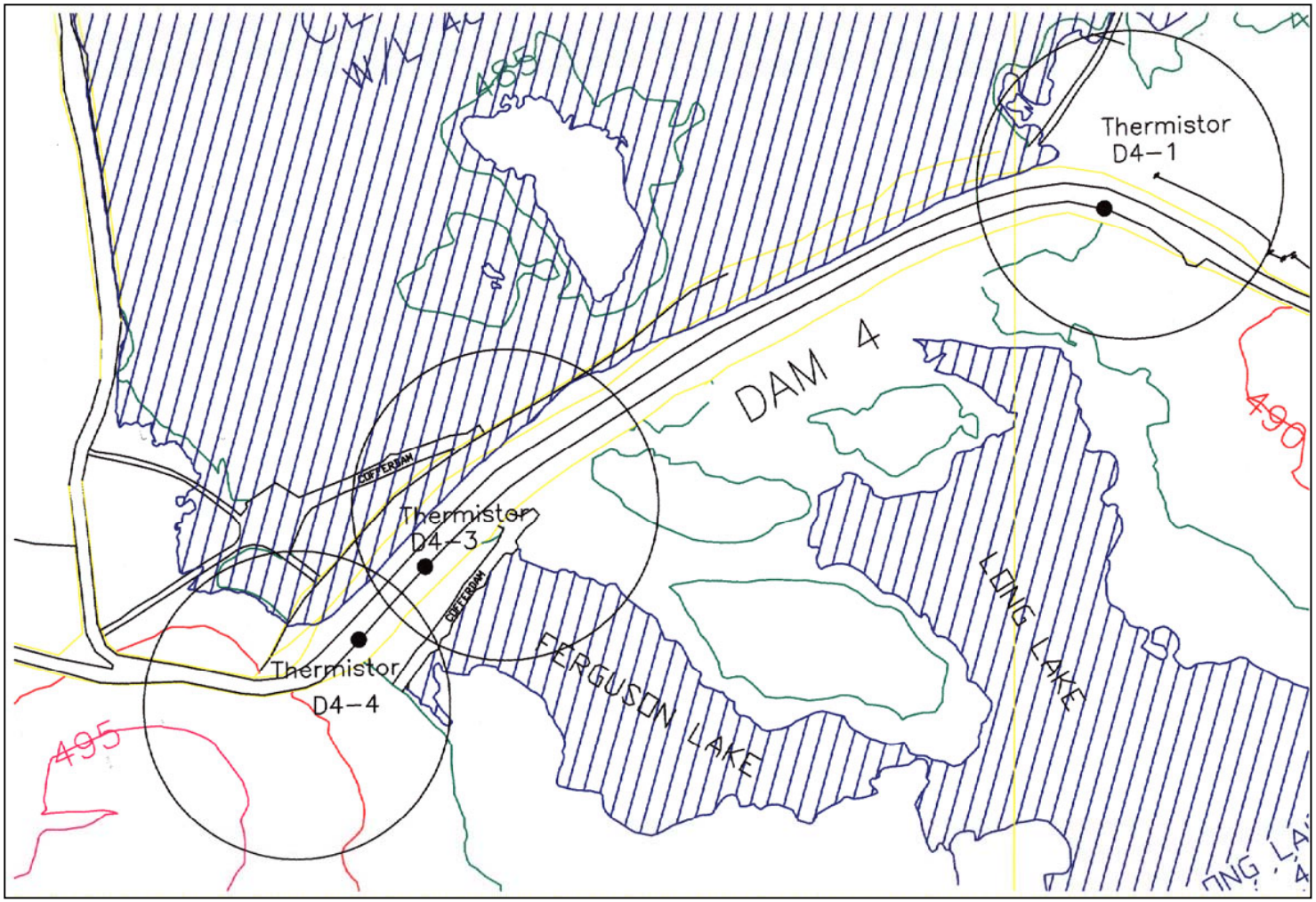

Figure C 4. Thermistors at Dam 4

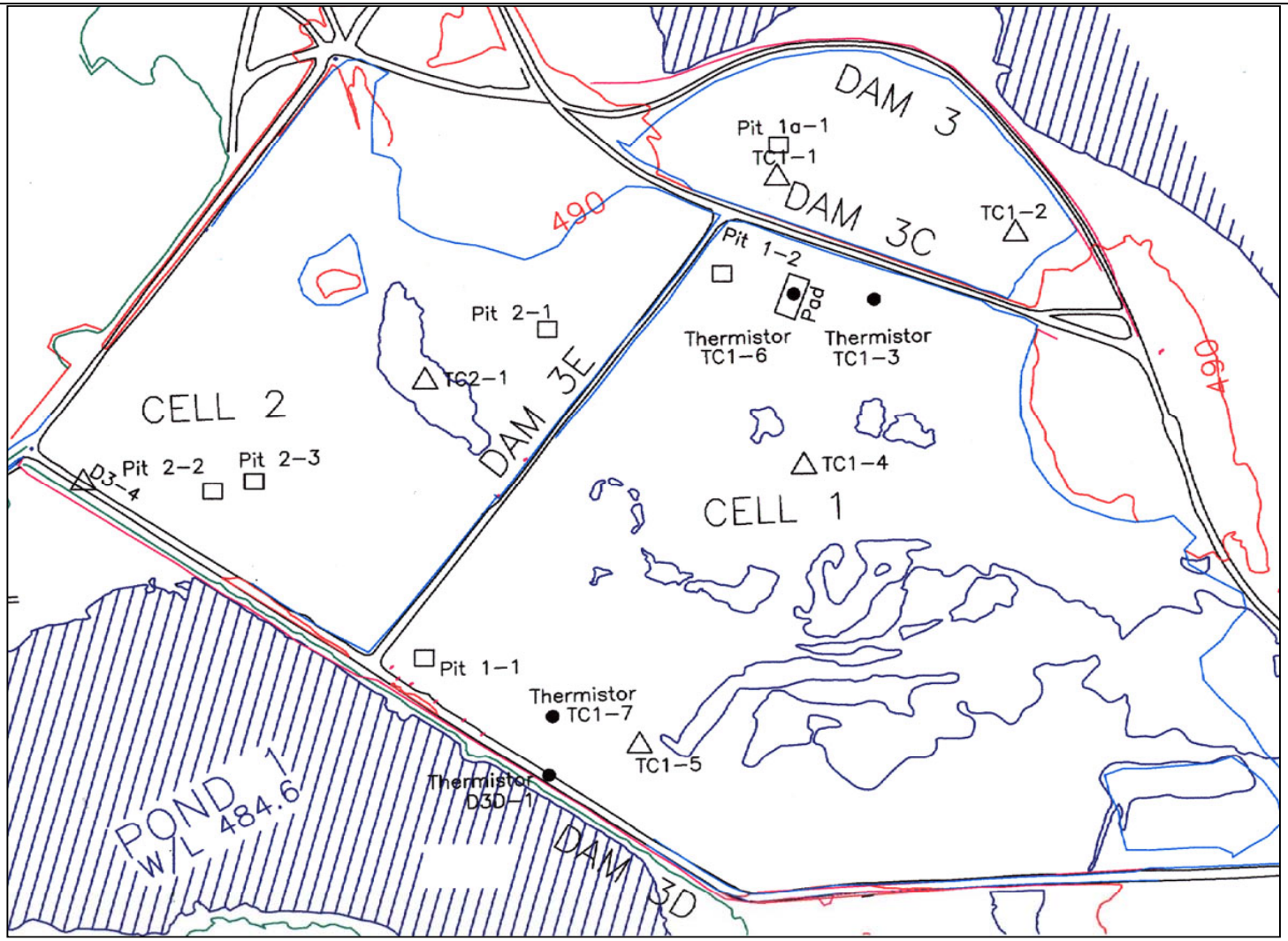

Figure C 5. Thermistors in Cell 1 and Dam 3D

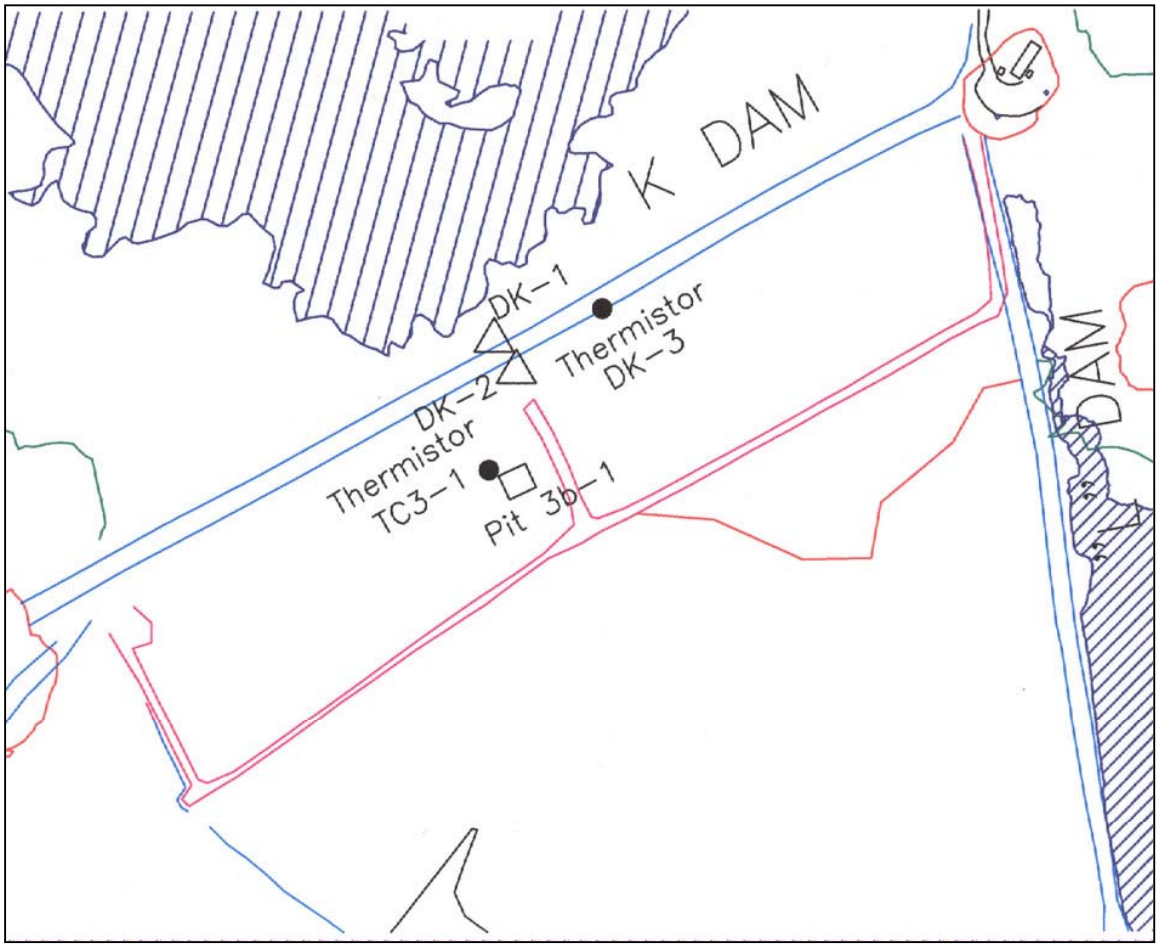

Figure C 6. Thermistors in Cell 3b and K Dam

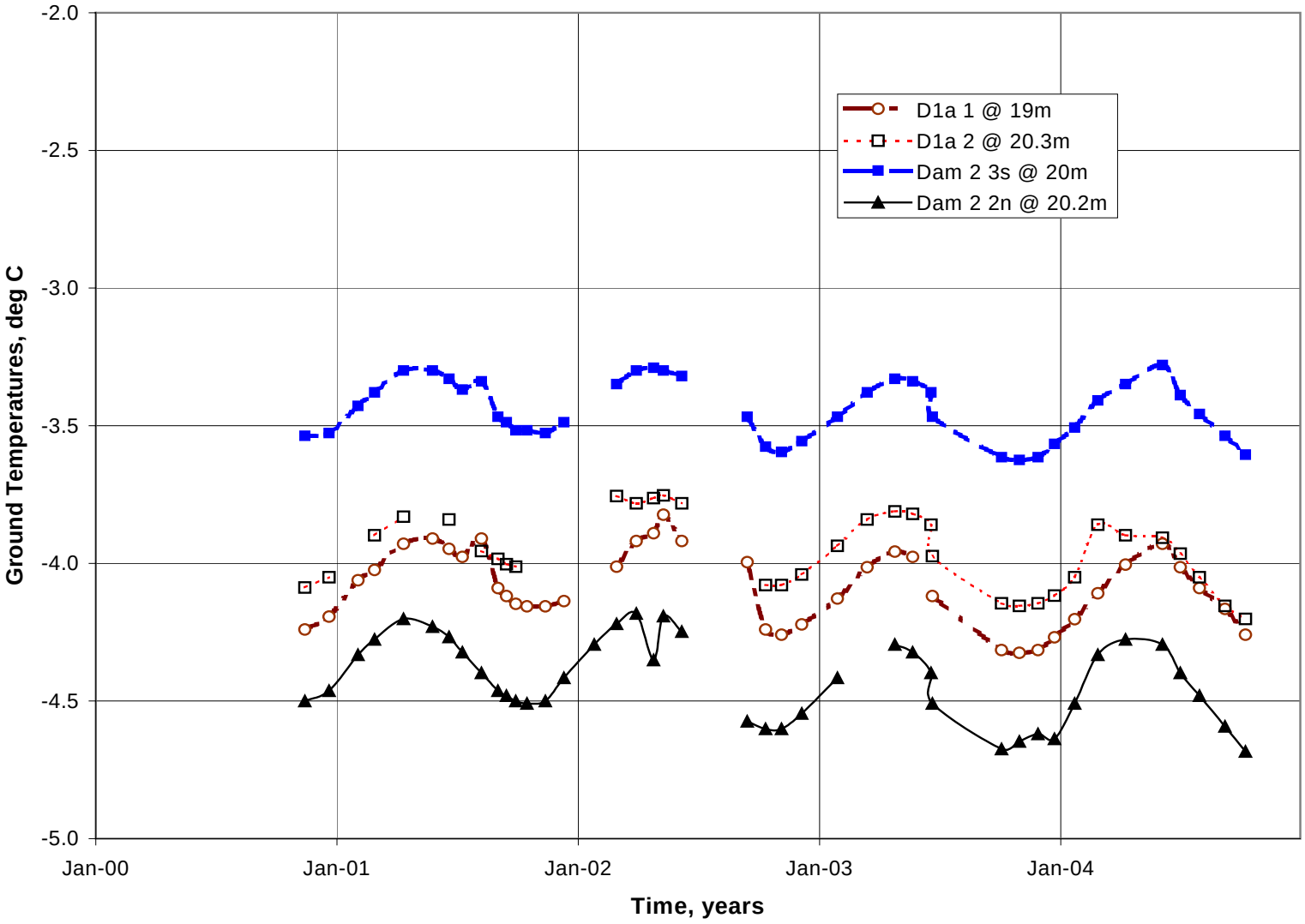

Figure C 7. Ground temperatures at 20m depth at Dams 1 and 2

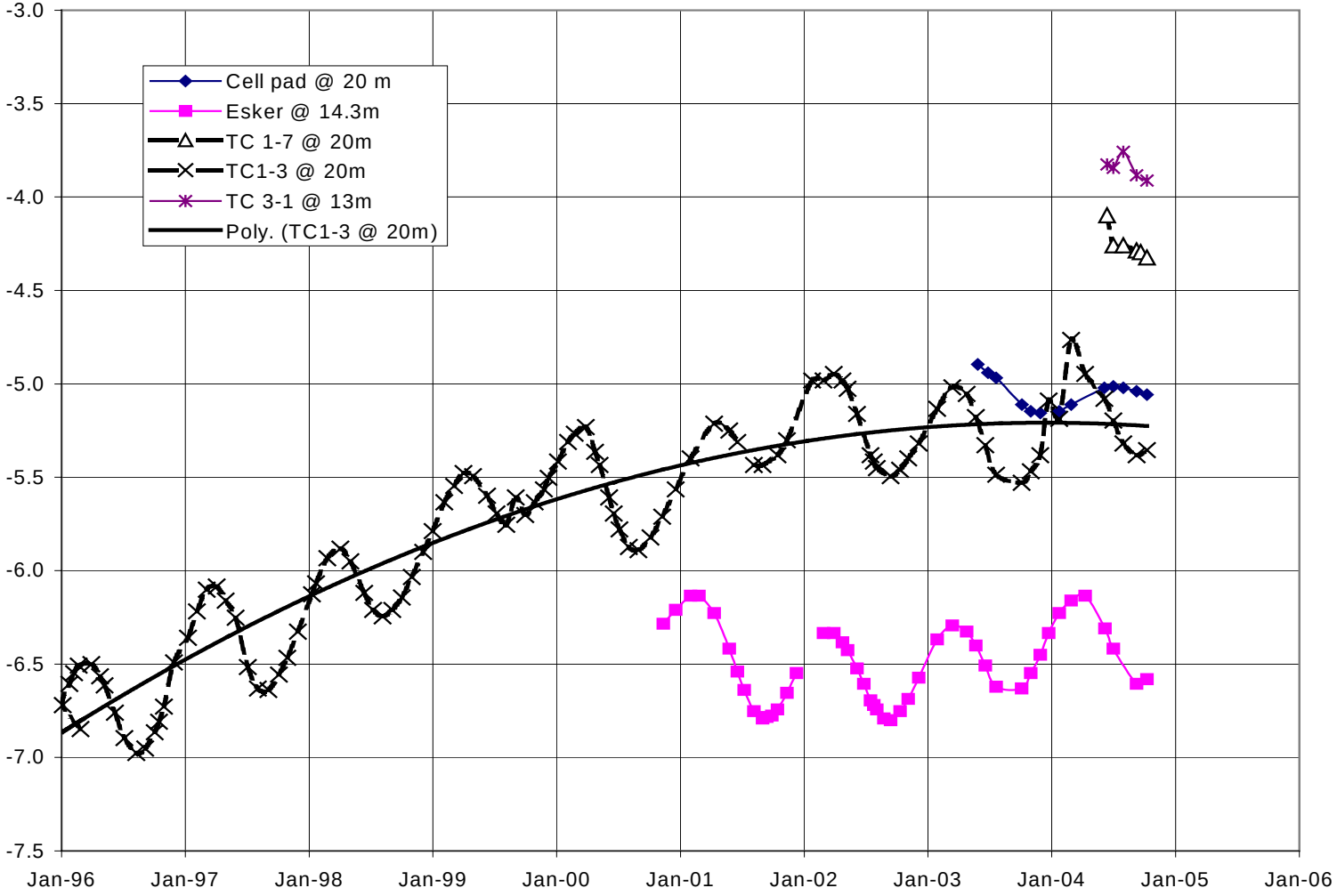

Figure C 8. Ground temperatures in Cells at 12 to 20m depth

ground temperatures in Cell 1 from 1980 to 2004

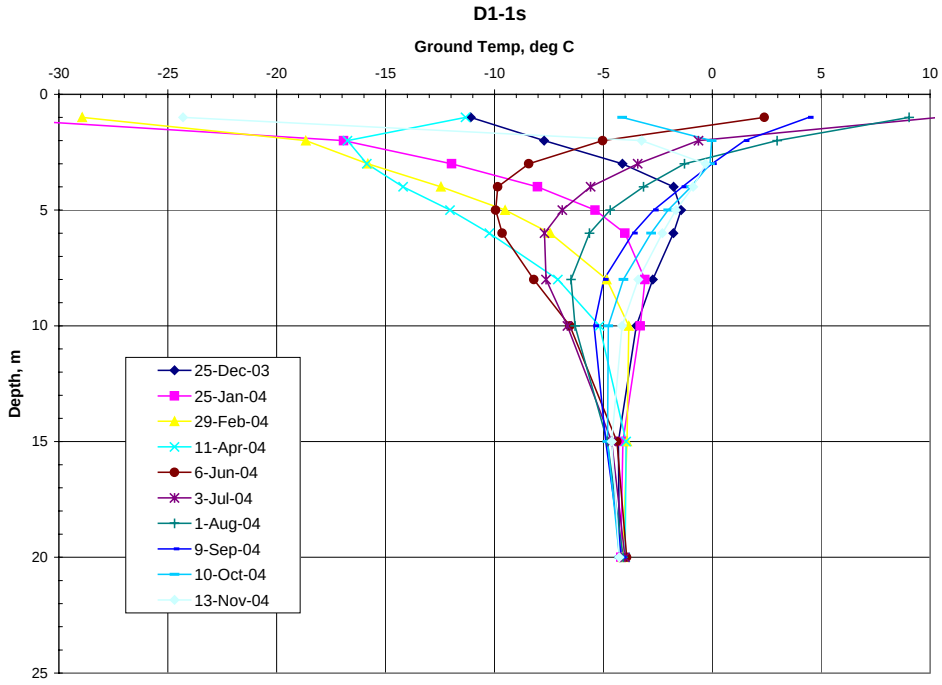

Figure C 9. Ground temperature regime at Dam 1a (Thermistor D1A-00-1s)

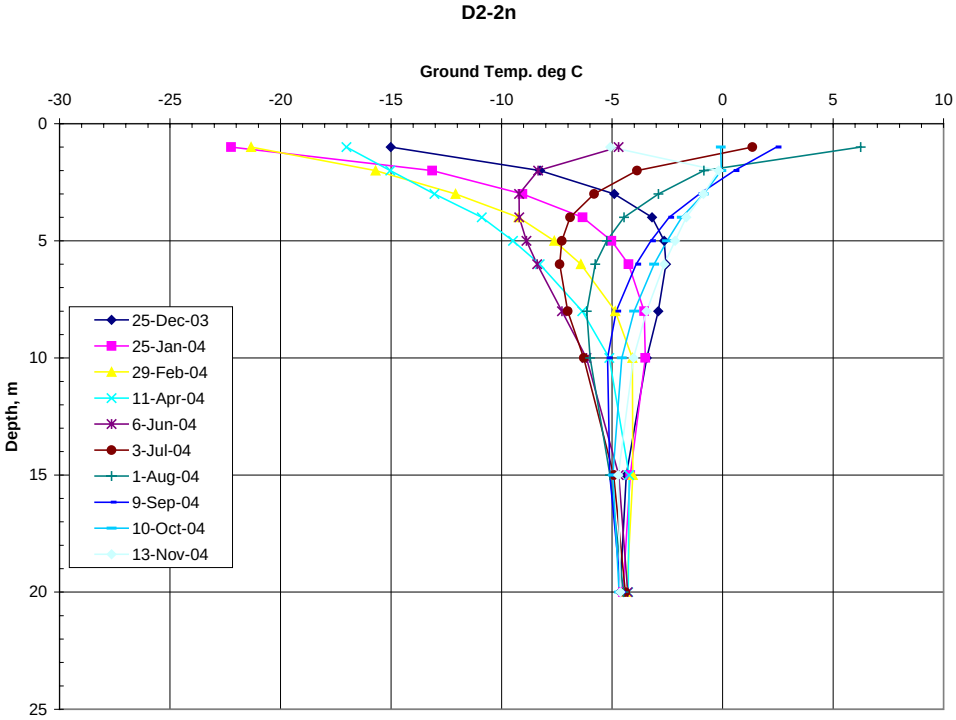

Figure C 10. Ground temperature regime at Dam 2 (Thermistor D2-00-2n)

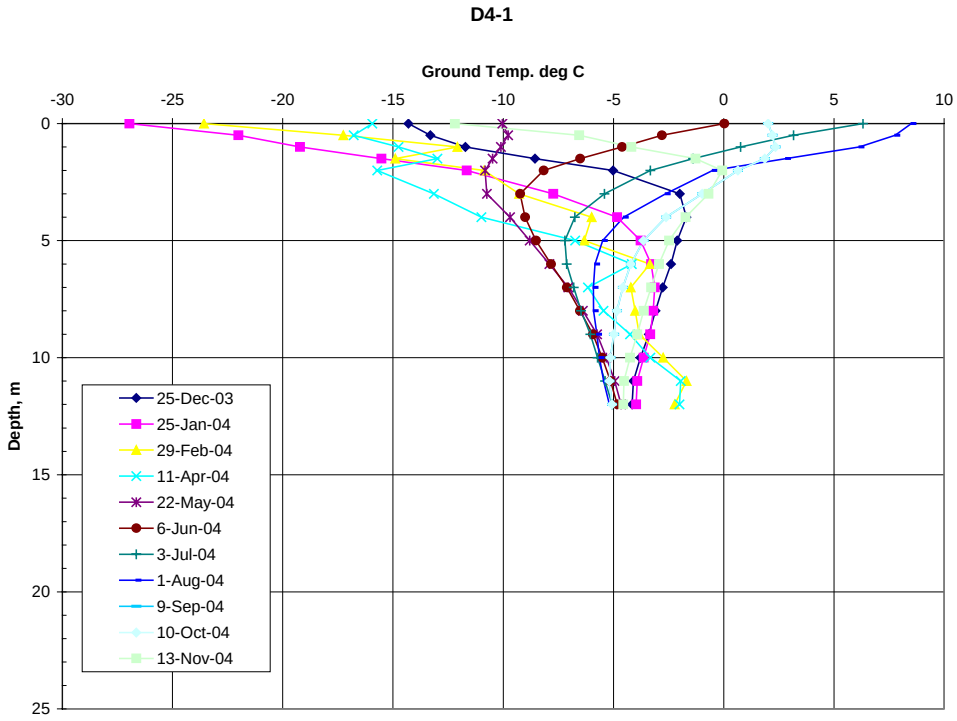

Figure C 11. Ground temperature regime at Dam 4 (Thermistor D4-1)

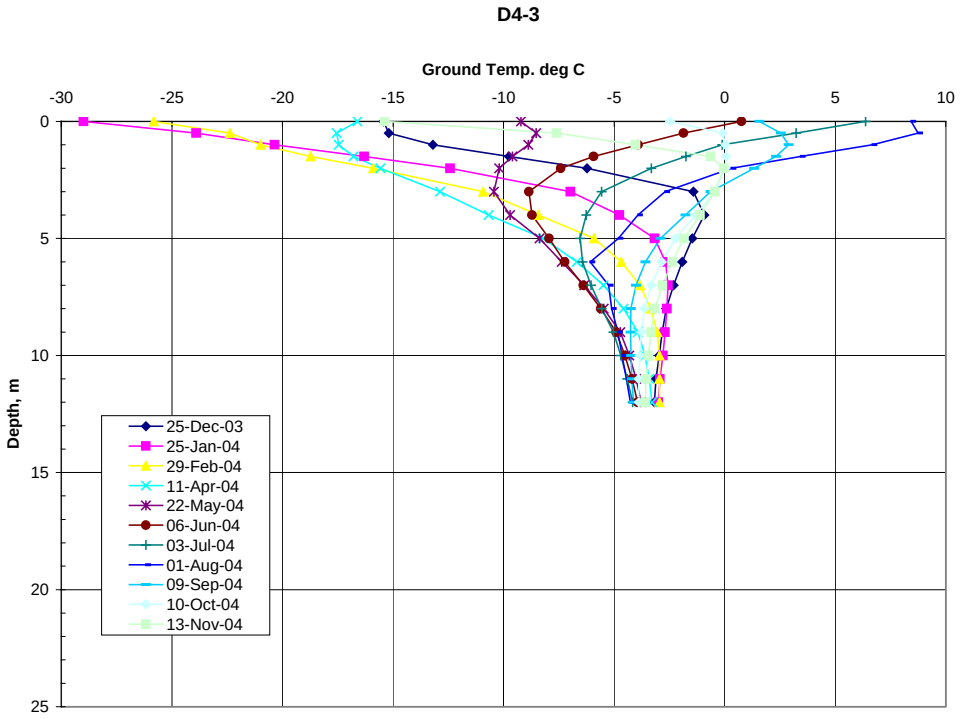

Figure C 12. Ground temperature regime at Dam 4 (Thermistor D4-3)

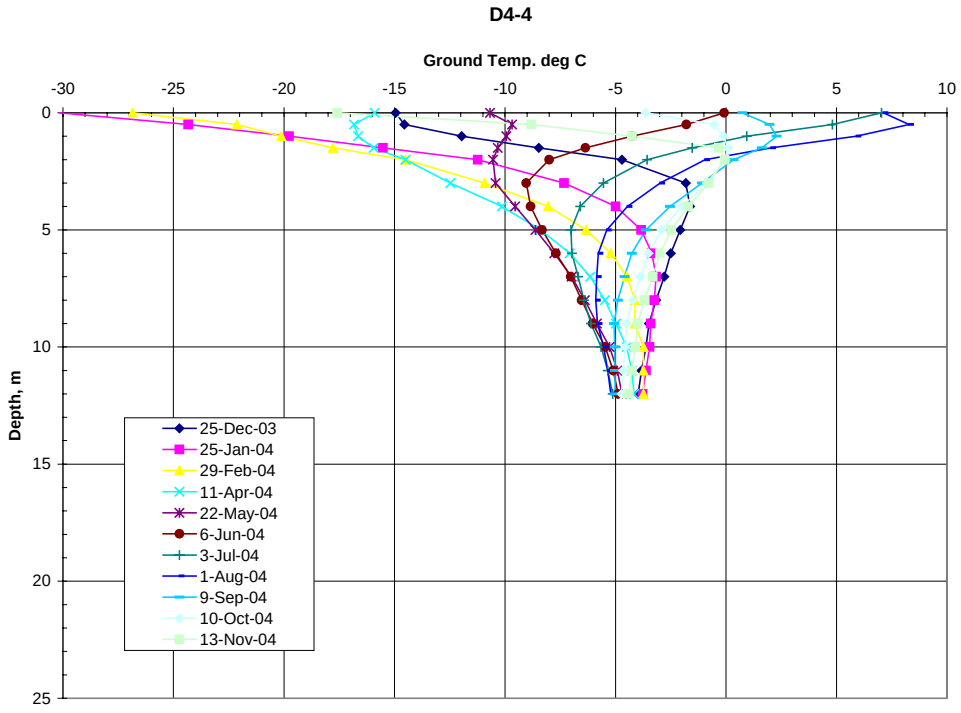

Figure C 13. Ground temperature regime at Dam 4 (Thermistor D4-4)

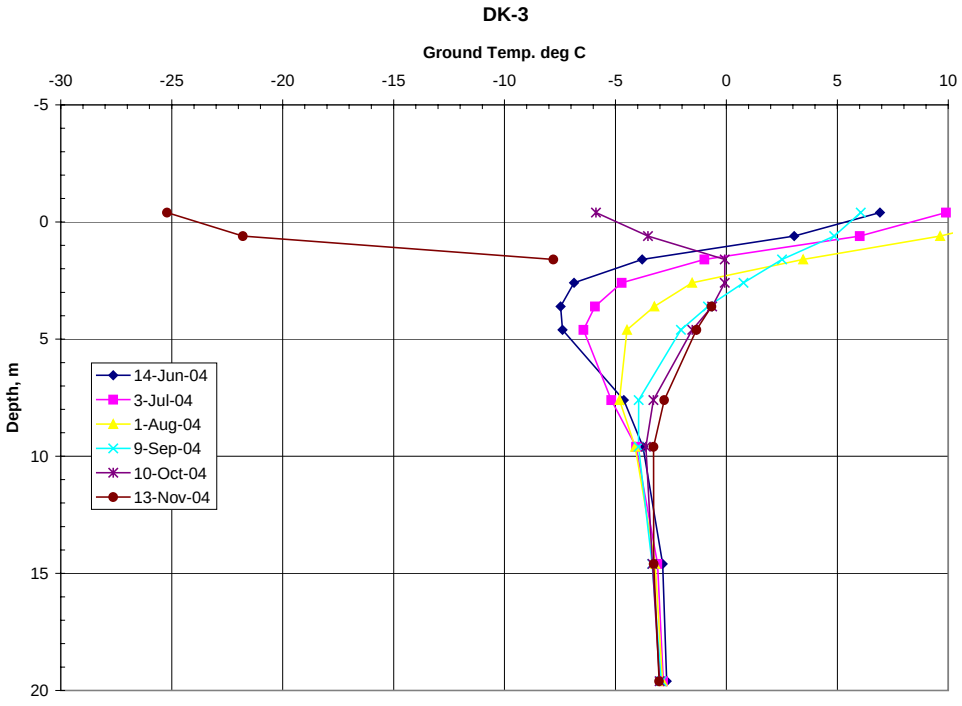

Figure C 14. Ground temperature regime at K Dam (Thermistor DK-3)

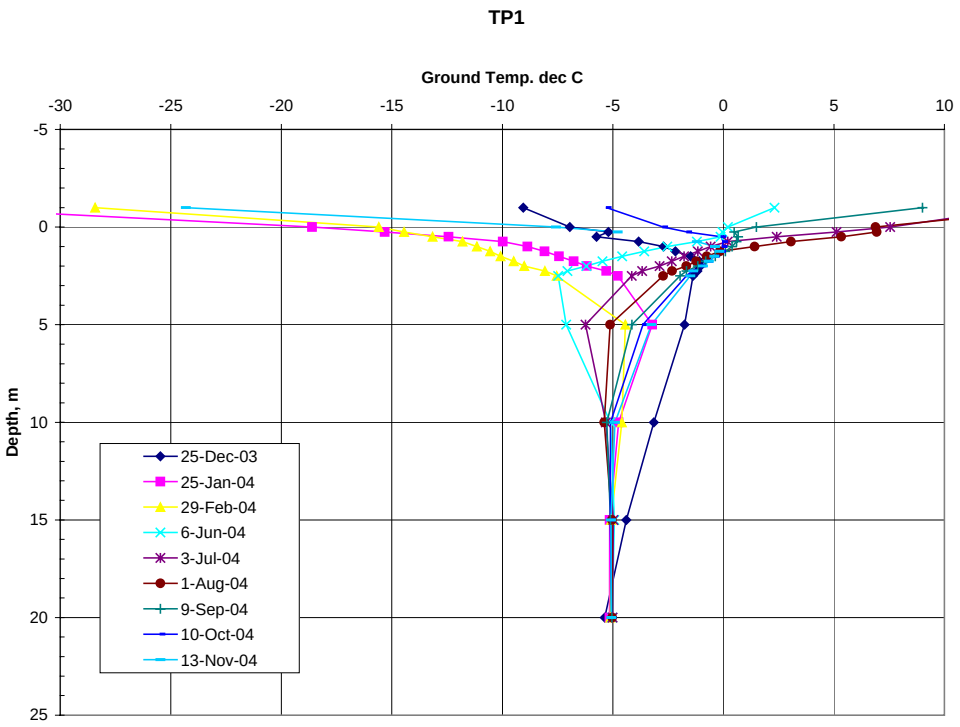

Figure C 15. Ground temperature regime at Cell 1 Test Pad (Thermistor TC1-3)

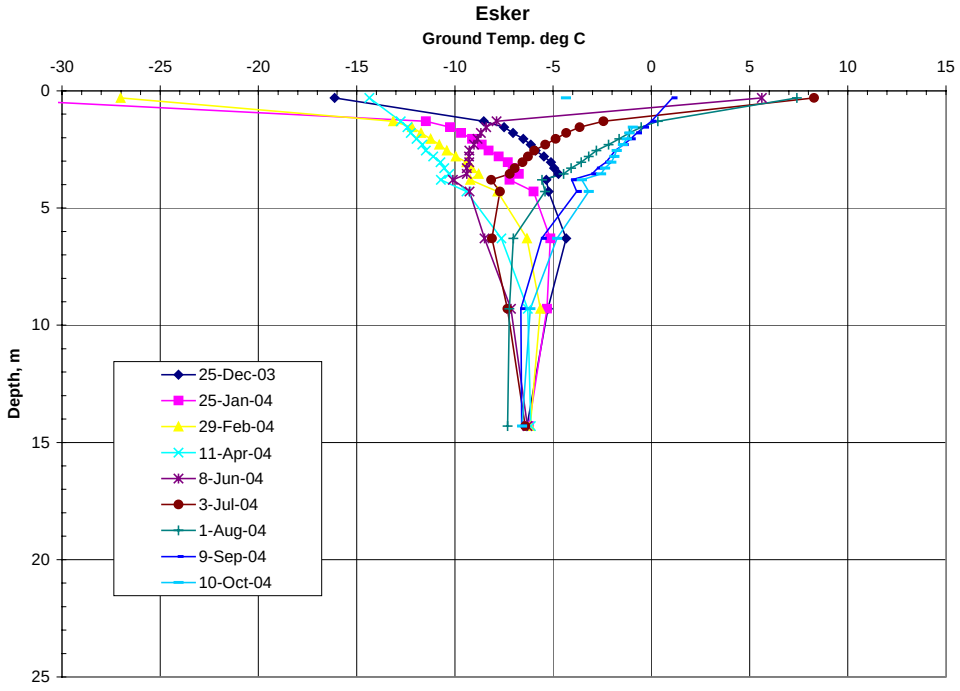

Figure C 16. Ground temperature regime at Esker (Thermistor)

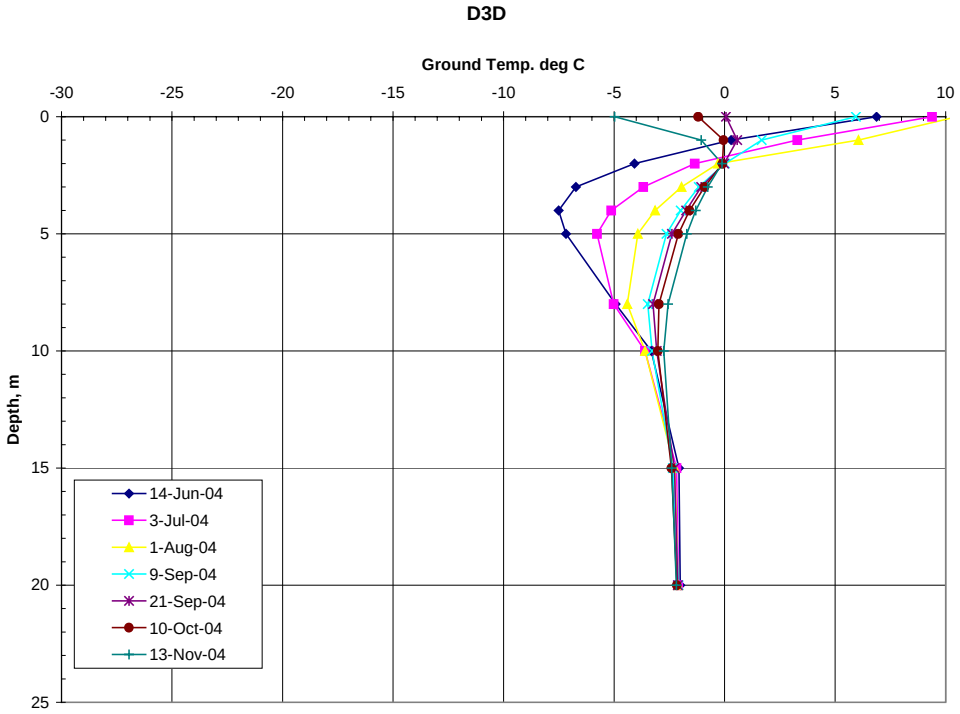

Figure C 17. Ground temperature regime at Dam 3D (Thermistor D3D -1)

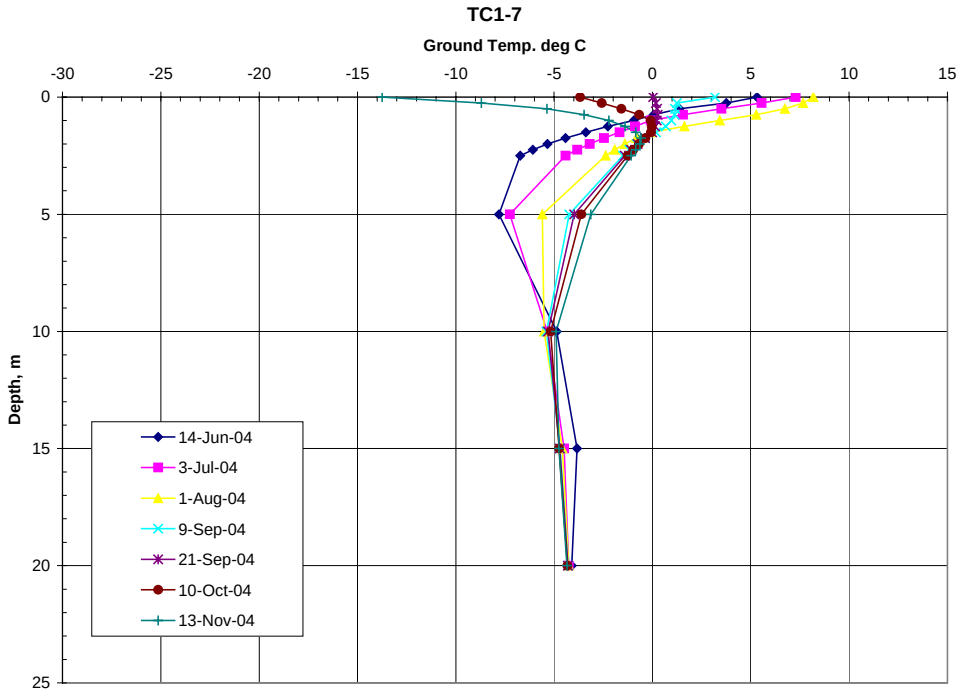

Figure C 18. Ground temperature regime in tailings Cell 1, near 3D Dam (Thermistor TC1-7)

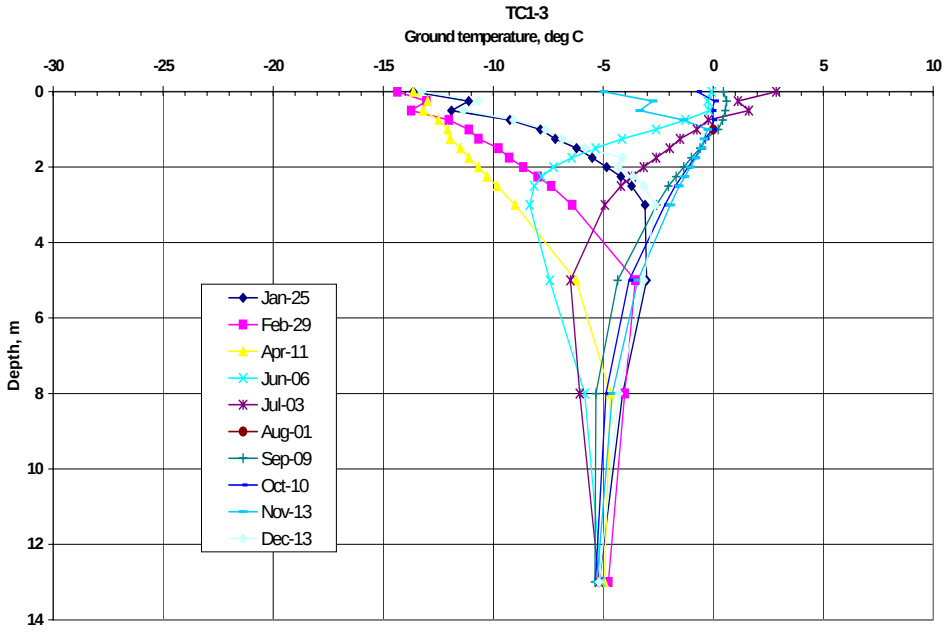

Figure C 19Ground temperature regime at Cell 1, north end (TC1-3)

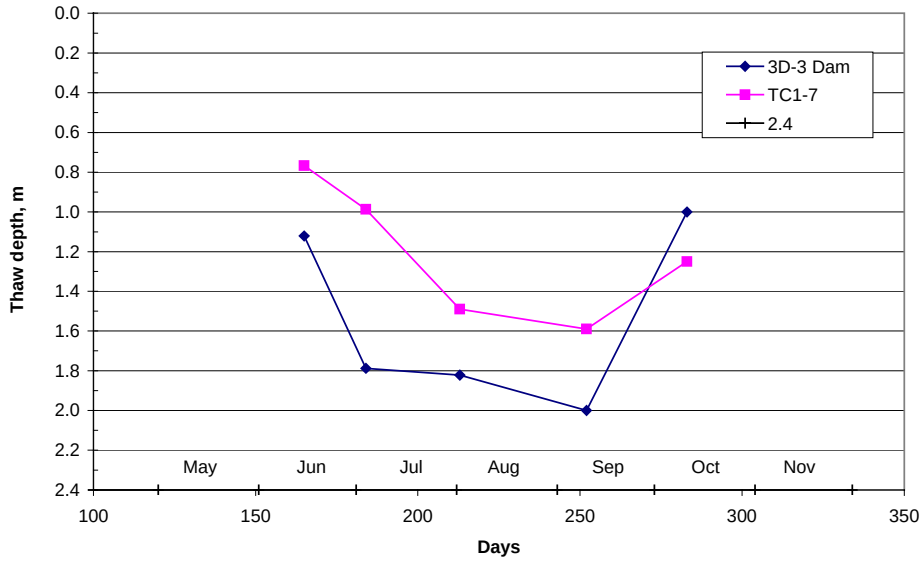

Figure C 20. Thaw surface progress with time near Dam 3D

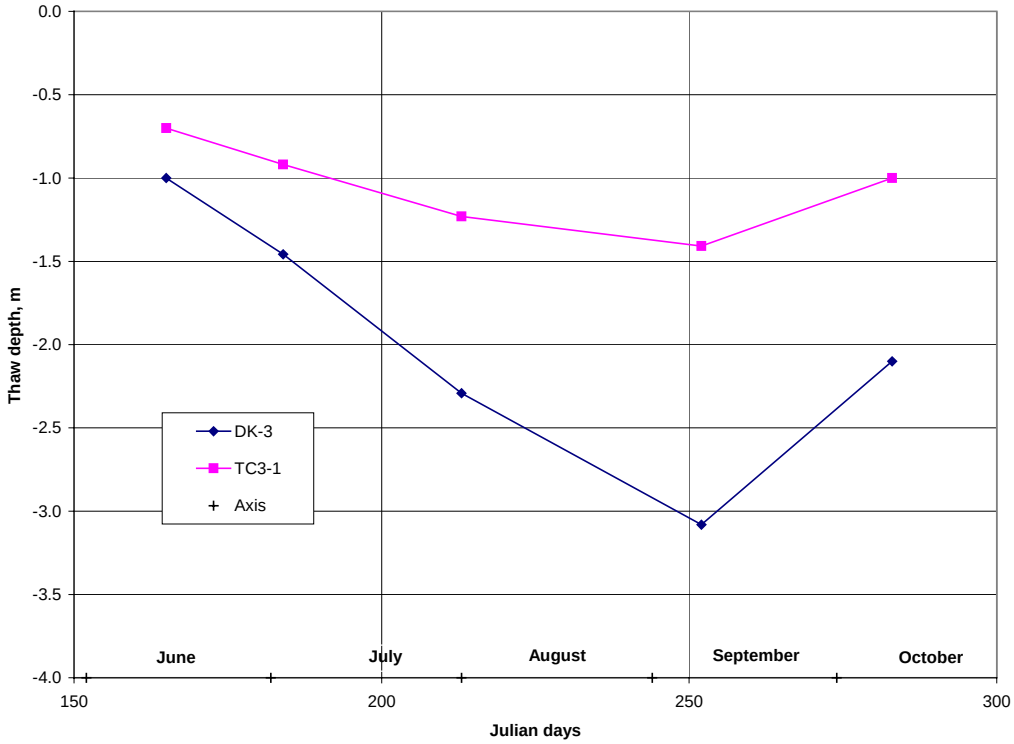

Figure C 21. Thaw depth with time at K Dam (Thermistors DK-3 and TC3-1)

APPENDIX D

DAMS AND EARTH STRUCTURES STABILITY ANALYSES

PART

OF

CLOSURE PLAN FOR

TAILINGS CONTAINMENT AREA

Prepared for

Kinross Gold Corporation

LUPIN OPERATION

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	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Tailings	16	200	0	0	0
Esker	20	300	0	0	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
K Dam
Dec 21, 2004
Frozen dam, 1.5 slope
Frozen strength, 300 kPa

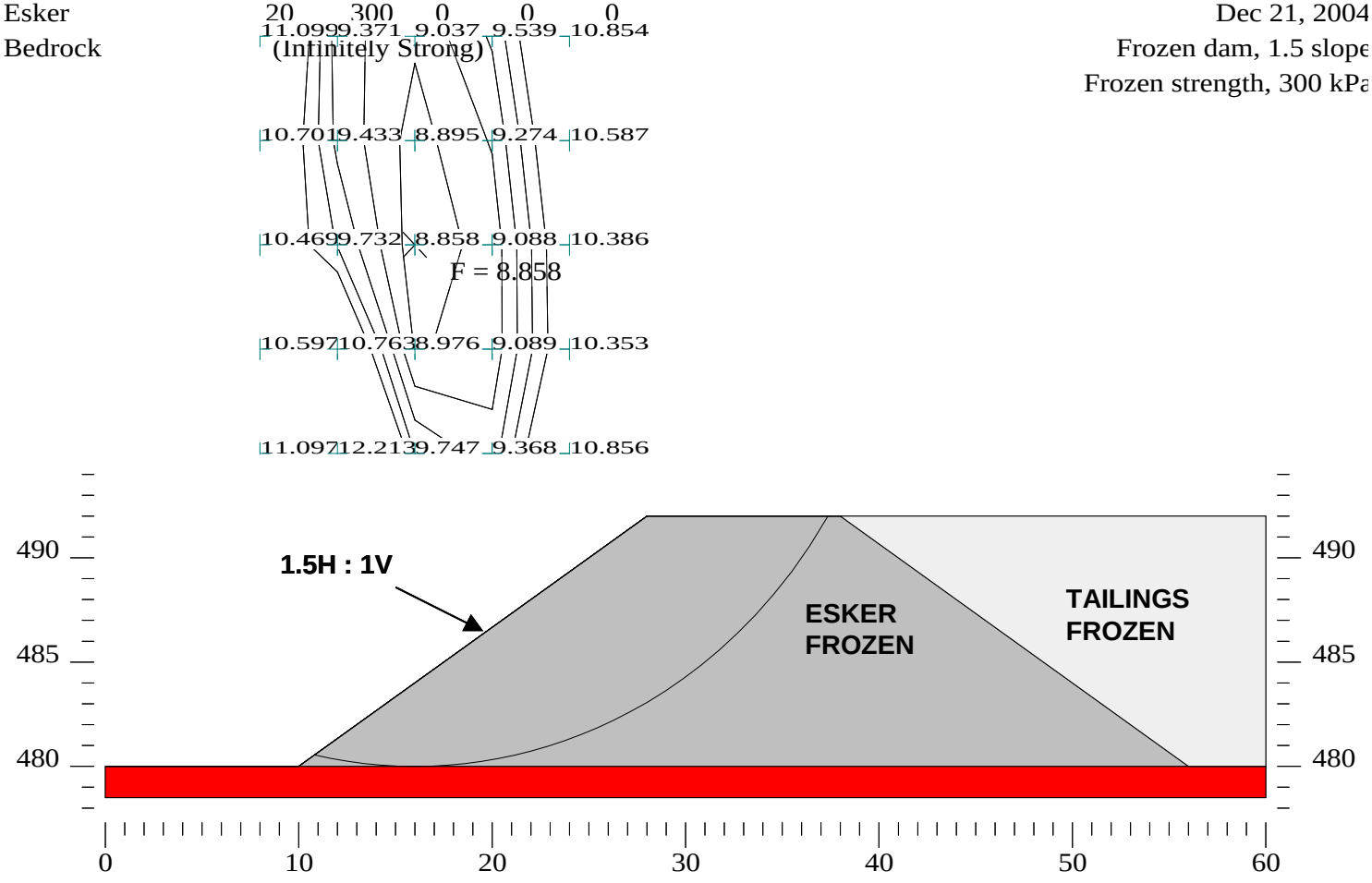

Figure D 1. K Dam stability analysis, Frozen Dam

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Tailings	16	0	31	1	0
Esker	20	0	33	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
K Dam
Dec 22, 2004
Thawed Dam
Low groundwater

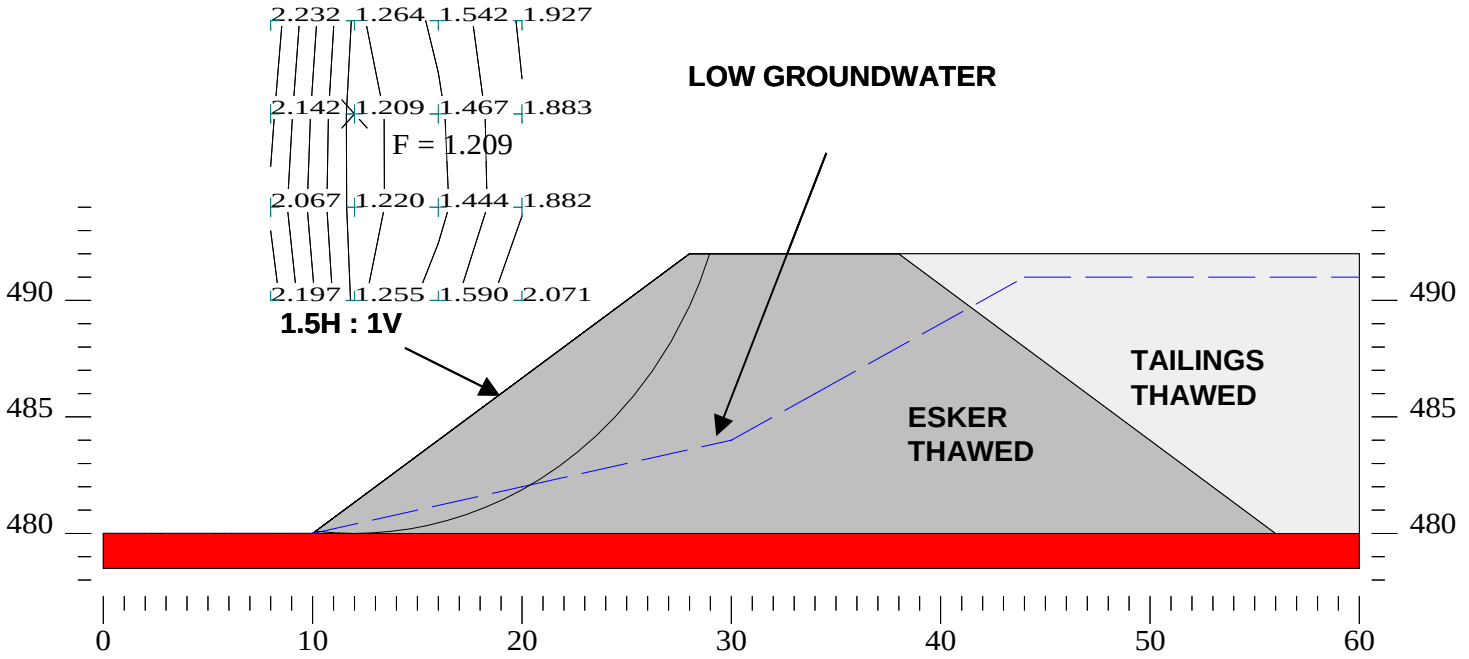

Figure D 2. K Dam stability analysis, thawed with low groundwater

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Tailings	16	3	30	1	0
Esker	20	0	33	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
K Dam
Dec 22, 2004
Thawed Dam
High Groundwater

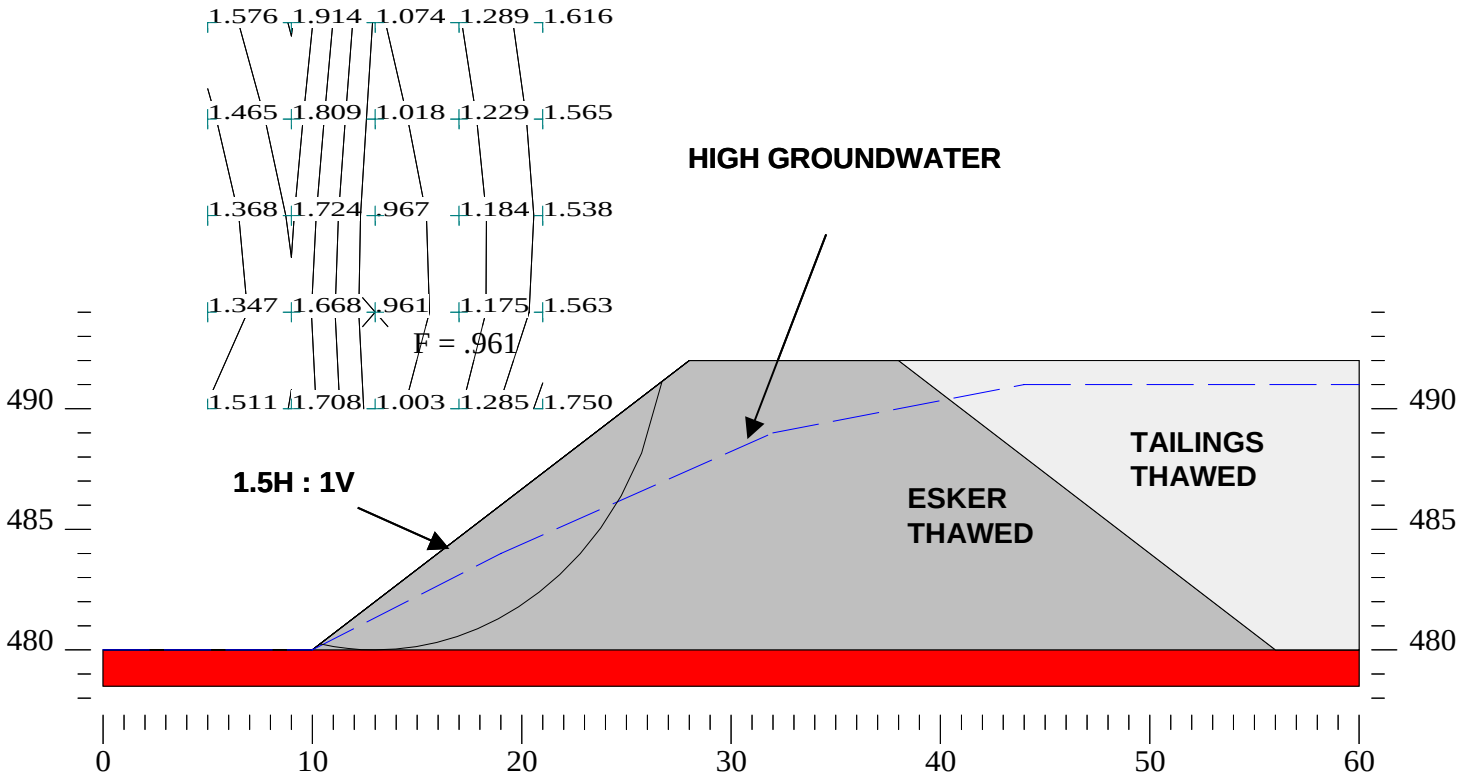

Figure D 3. K Dam stability analysis, thawed with high groundwater

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Rockfill	20	0	40	1	0
Tailings	16	3	30	1	0
Esker	20	0	33	1	0
Bedrock	(Infinite Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
K Dam
Dec 22, 2004
Thawed Dam
2.5:1 Rock Berm, HGWL

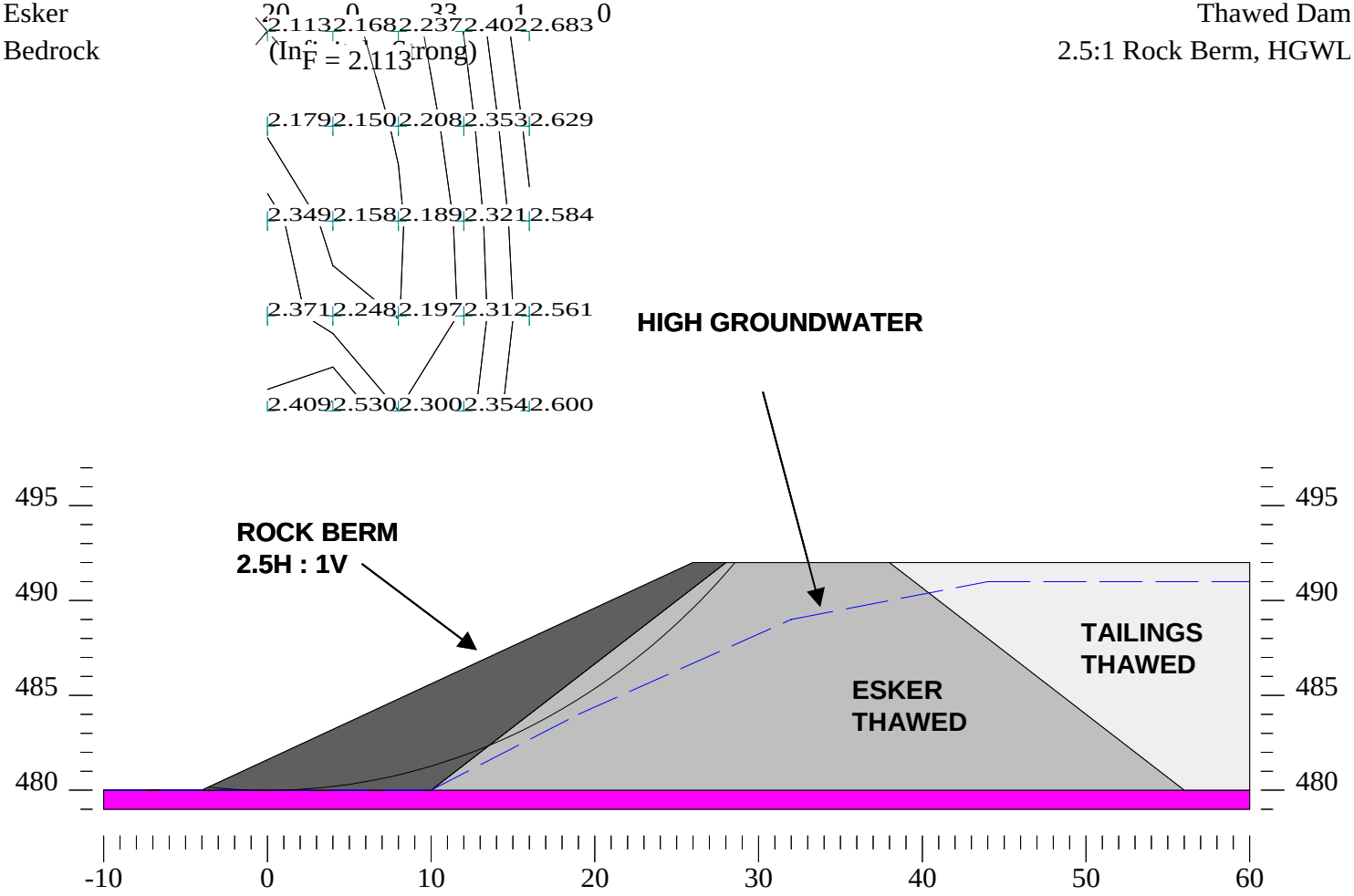

Figure D 4. K Dam stability analysis, thawed section with stabilizing berm and high groundwater

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.8	0	0	1	0
Rock	22	0	40	1	0
Tailings	16	200	0	1	0
Esker	20	300	0	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
3D Dam
Dec 22, 2004
With existing pond El 484.5
Frozen esker & tailings

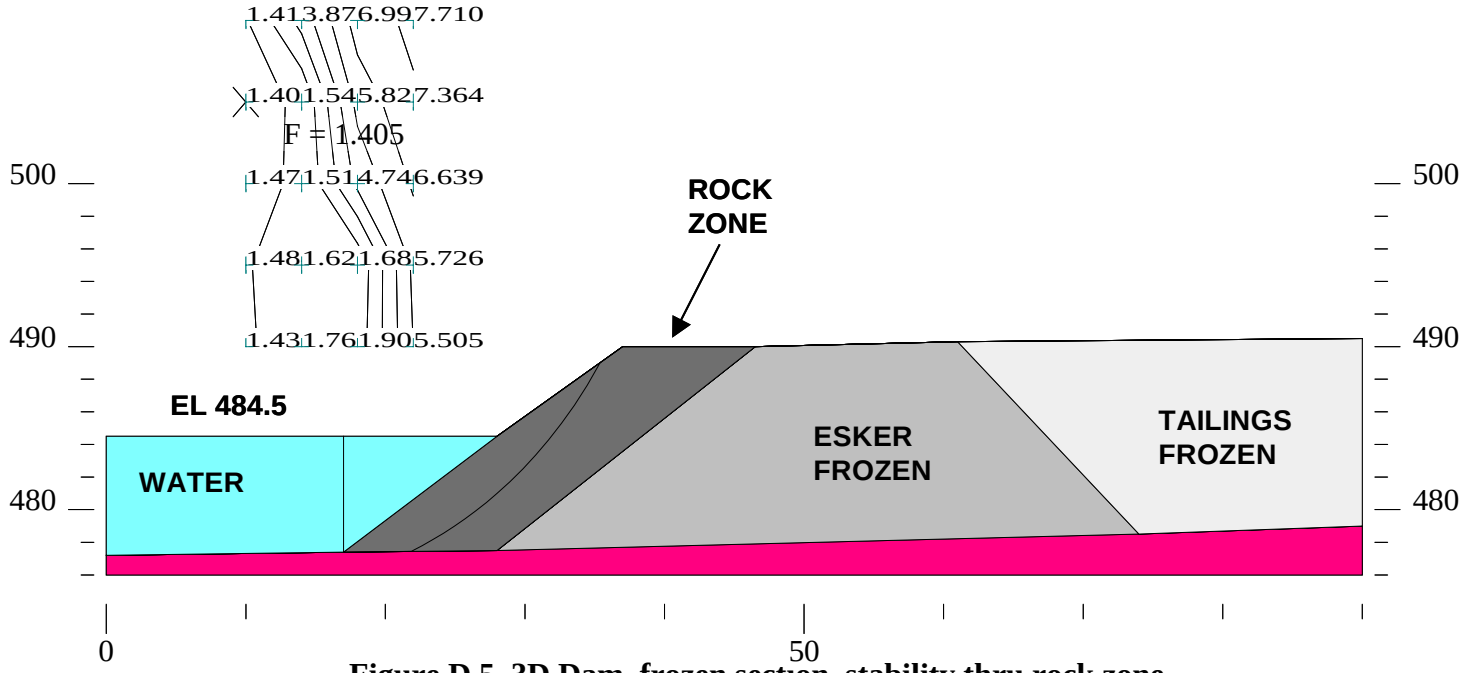

Figure D 5. 3D Dam, frozen section, stability thru rock zone

	Gamma	C	Phi	Piezo	Ru
	kN/m3	kPa	deg	Surf.	
Water	9.8	0	0	1	0
Rock	22	0	40	1	0
Tailings	16	200	0	1	0
Esker	20	300	0	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
3D Dam
Dec 22, 2004
With existing pond El 484.5
Frozen esker

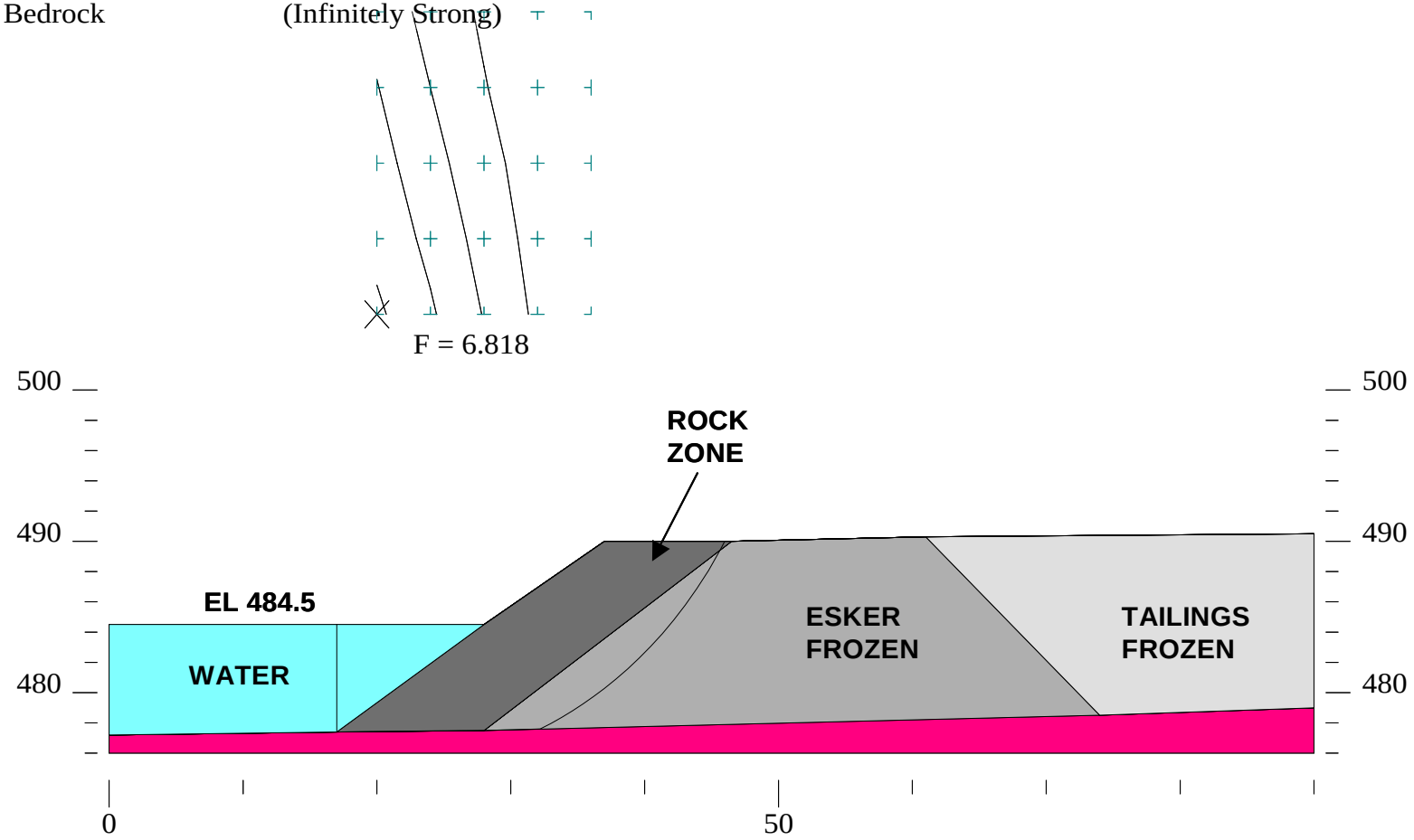

Figure D 6. 3 Dam, frozen section, stability thru frozen esker

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.8	0	0	1	0
Rock	22	0	40	1	0
Tailings	16	3	30	1	0
Esker	20	0	33	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
3D Dam
Dec 22, 2004
With closure pond El 479.5
Thawed section, existing slope

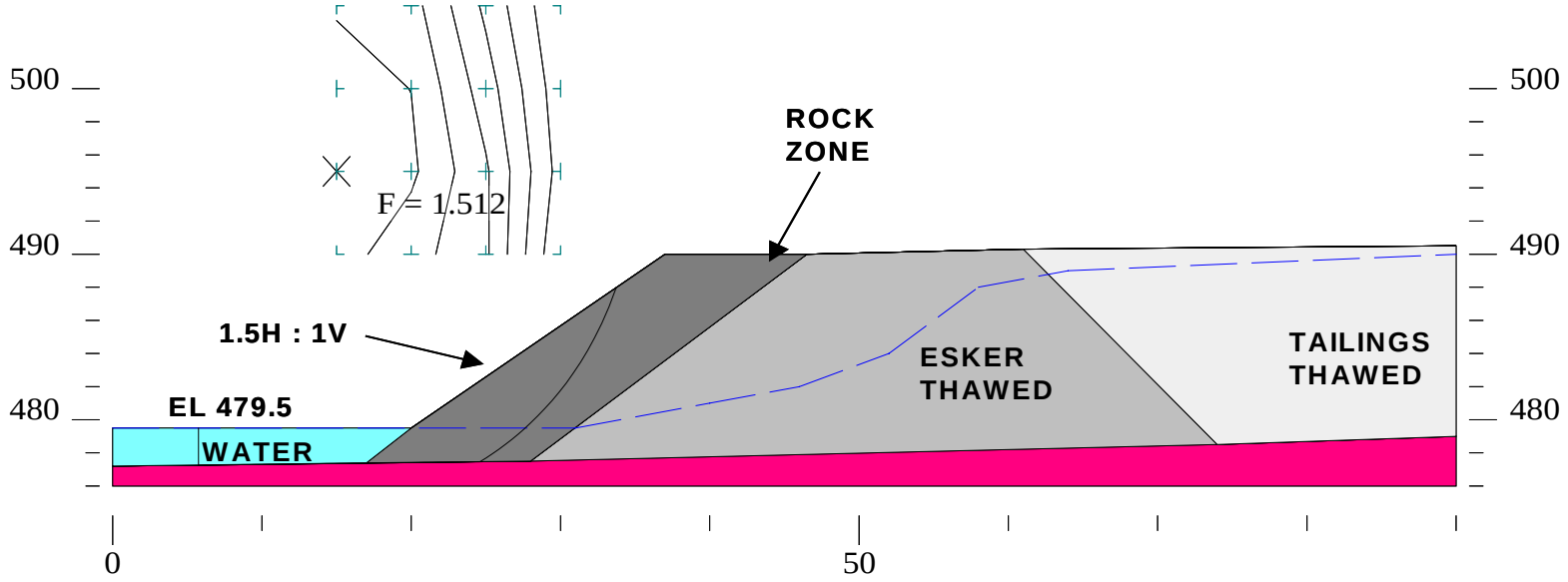

Figure D 7. 3Daam, thawed section, stability through rockfill

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Water	9.8	0	0	1	0
Rock	22	0	40	1	0
Tailings	16	3	30	1	0
Esker	20	0	33	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
3D Dam
Dec 22, 2004
With existing pond El 479.5
Thawed section, Slope 2.5:1

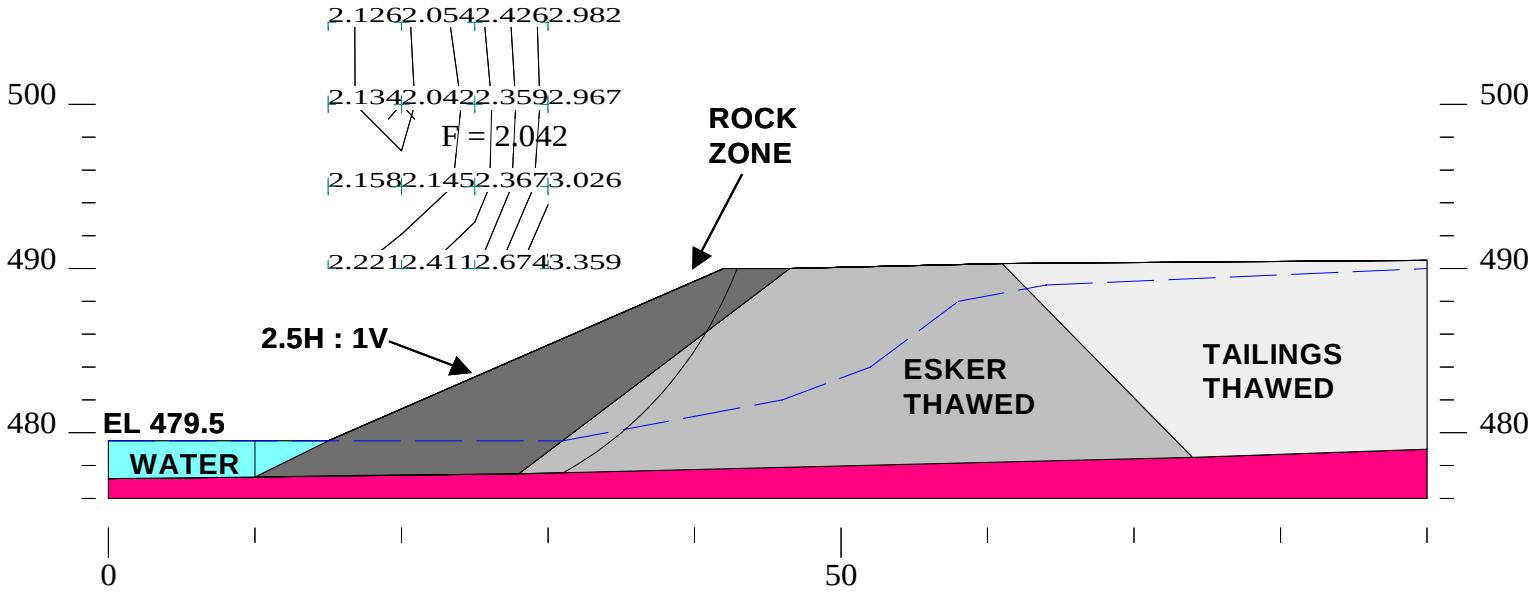

Figure D 8. 3 Dam. rock zone graded to 2.5h : 1v slope

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Upper tails	14	200	0	1	0
Esker	20	300	0	1	0
Rock	21	0	36	1	0
Lower tails	15	200	0	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
M Dam
Dec 22, 2004
Frozen conditions

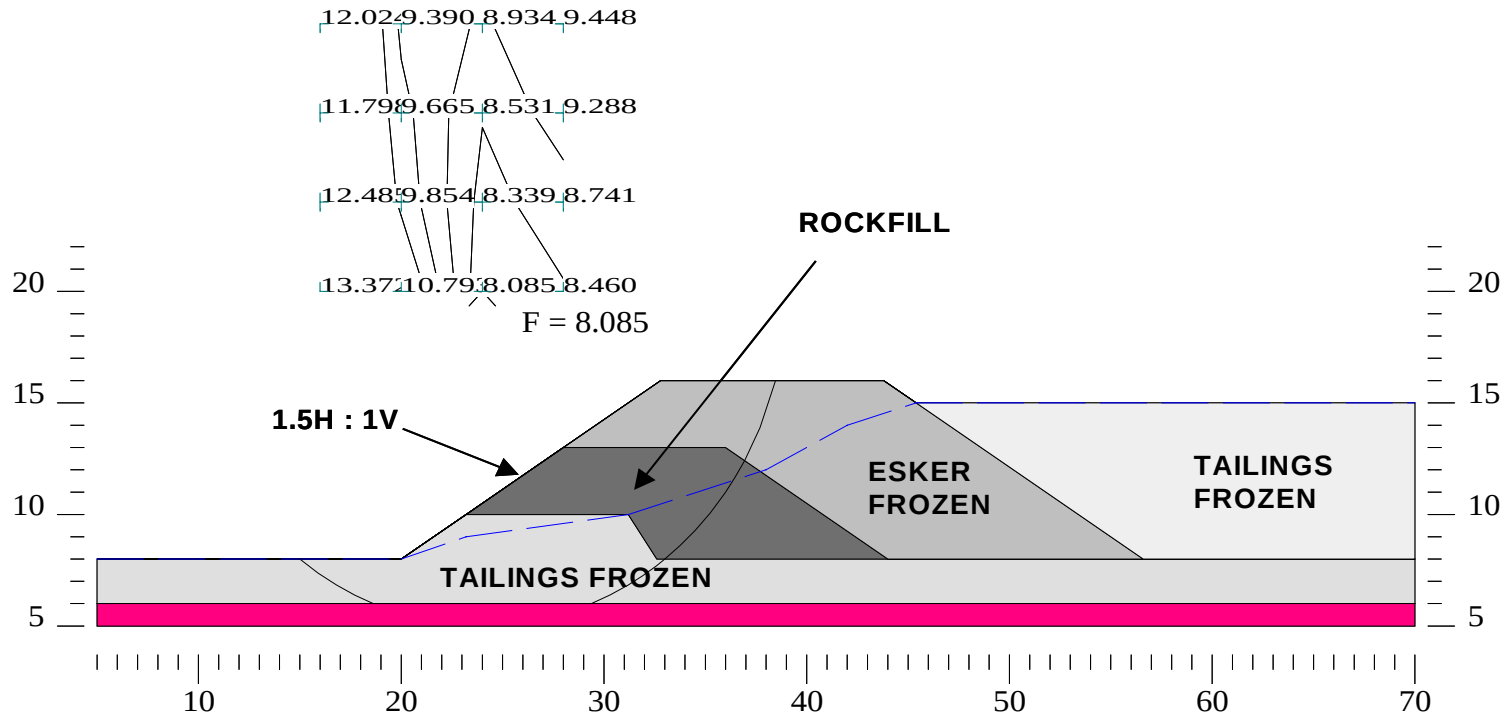

Figure D 9. M Dam, frozen section

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Upper tails	14	0	30	1	0
Esker	20	0	34	1	0
Rock	21	0	36	1	0
Lower tails	15	5	31	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
M Dam
Dec 22, 2004
Thawed conditions
Existing geometry

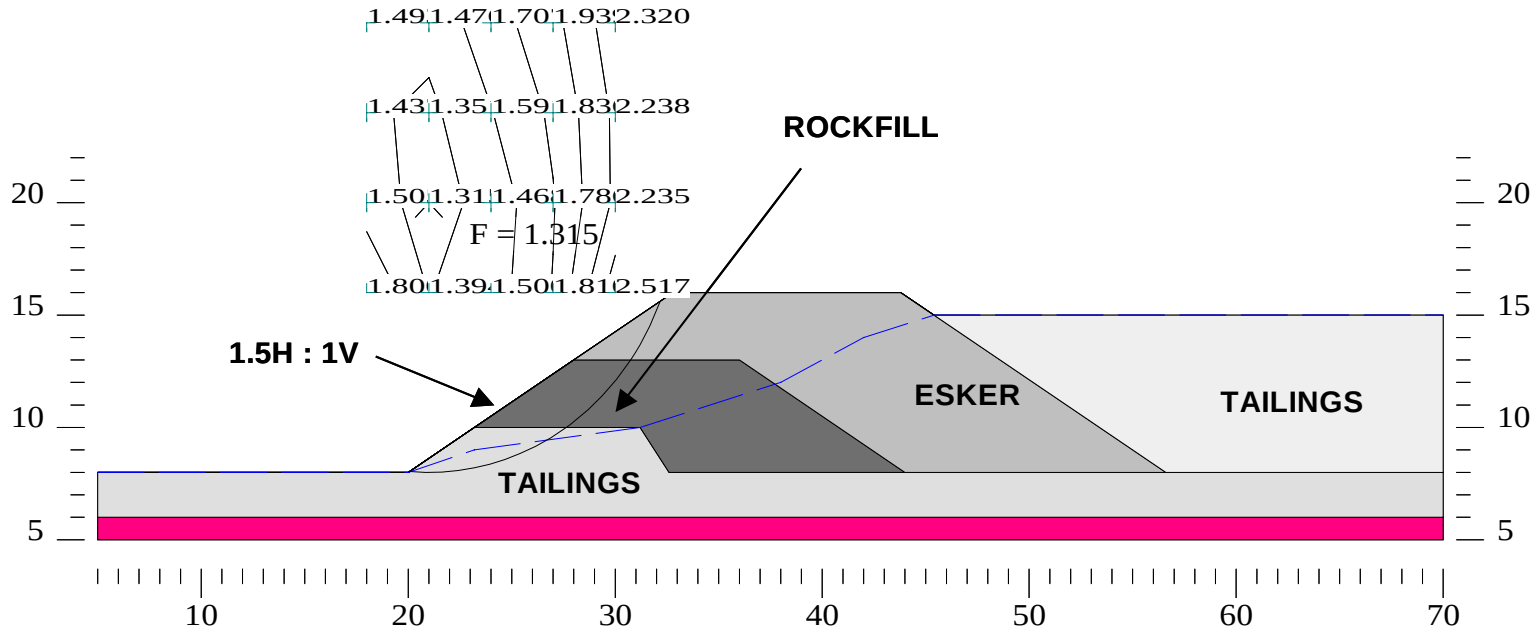

Figure D 10. M Dam, thawed dam

	Gamma	C	Phi	Piezo	Ru
	kN/m3	kPa	deg	Surf.	
Rock Berm	21	0	36	1	0
Upper Tailings	14	0	30	1	0
Esker	20	0	34	1	0
Rock	21	0	36	1	0
Lower Tailings	15	5	31	1	0
Bedrock	(Infinitely Strong)				

I. Holubec Consulting Inc. - Oakville ON
Lupin
M Dam
Dec 22, 2004
Thawed conditions
Reinforced dam, 2.5h:1v slope

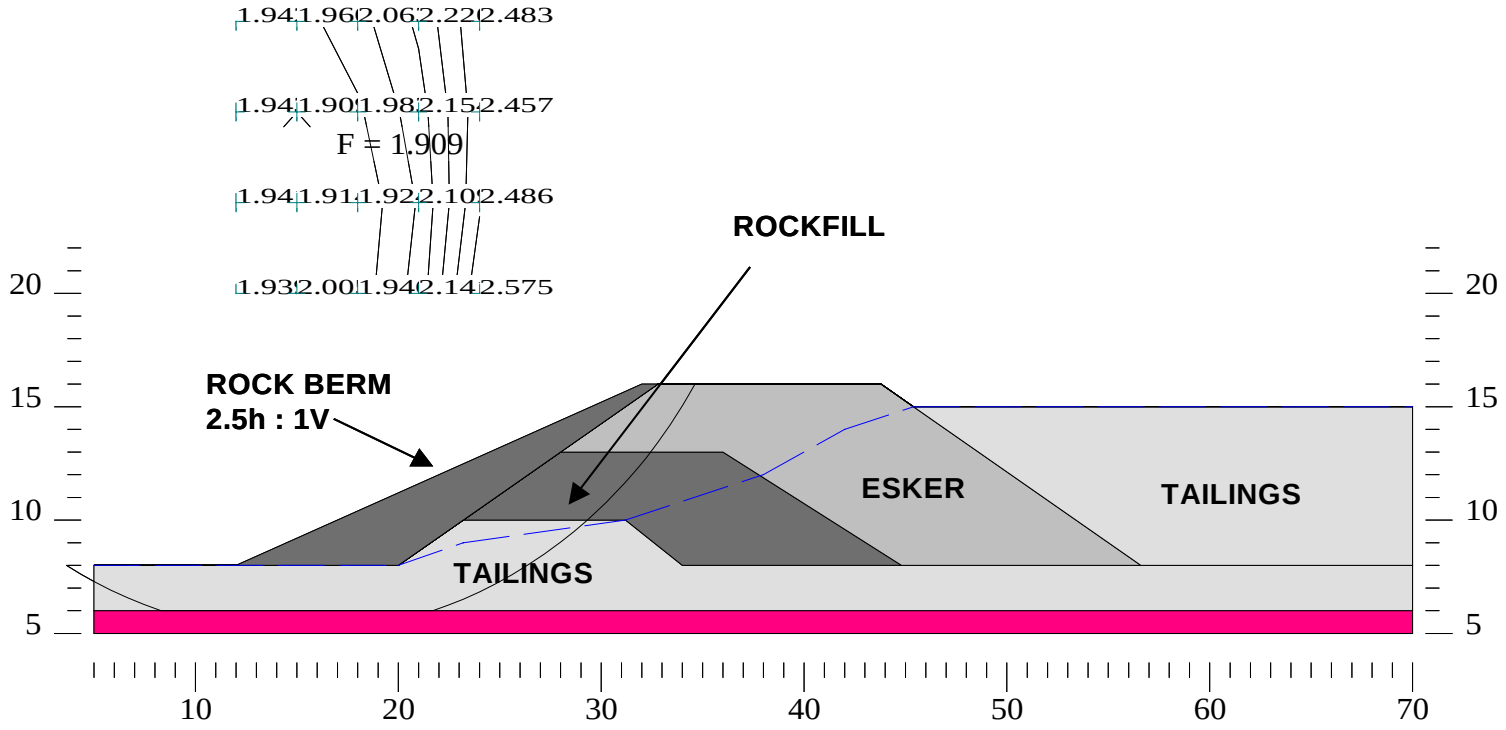

Figure D 11. M Dam, stabilized with 2.5h : 1v rock berm

ZINIFEX

APPENDIX III

STUDIES RELATED TO WATER LICENCE REQUIREMENTS AND IN SUPPORT OF RECLAMATION PLANNING - GOLDER ASSOCIATES, DECEMBER 2004

REPORT

STUDIES RELATED TO WATER LICENCE REQUIREMENTS AND IN SUPPORT OF RECLAMATION PLANNING

Submitted to:

KINROSS GOLD CORPORATION

DISTRIBUTION:

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2 Copies	**Golder Associates Ltd.** **Calgary, Alberta**

December 2004 **04-1321-022**

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Appendix A Laboratory test results

1. INTRODUCTION

Echo Bay Mines Ltd., a subsidiary of Kinross Gold Corporation (Kinross), owns and operates the Lupin Mine, located on the west shore of Contwoyto Lake in Nunavut. Kinross retained Golder Associates Ltd. (Golder) to complete a series of geotechnical and other related studies to satisfy the water licence conditions and to support reclamation planning for the mine.

As provided in the April 2004 proposal to Kinross by Golder (P42-2178), the scope of the geotechnical and other related studies includes the following components:

- Studies of the potential for interaction between covered cells and flooded areas of the Lupin Tails Containment Area (TCA);
- An outline of methods to contain potential pore water expulsion from the TCA;
- A comprehensive assessment of material suitability, including geochemical and physical characterization of borrow materials, for the proposed TCA cover layer; and
- A climate and hydrology study to determine if an oxidation barrier could be maintained over the TCA.

As outlined in the Kinross letter dated March 16, 2004, the above studies were completed predominantly using existing information. Some laboratory tests were conducted on an esker sample, but no field investigation was carried out as a part of this program. The existing information that was used includes the following:

- Geocon Inc. (1982). As-built Tailings Containment Area, Lupin Project. Project Number A1207/01186-3. Submitted to Echo Bay Mines Ltd. in December 1982.
- Klohn Leonoff Ltd. (1992). Acid Rock Drainage Study, Lupin Mine, Northwest Territories. Project Number PE5684 0101. Submitted to Echo Bay Mines Ltd. in April 1992.

- Golder Associates Ltd. (1986). Tailings Impoundment Area, 1985 Divider Dyke Construction and Pond 1 Operation, Lupin Gold Mine, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in March 1986.
- Golder Associates Ltd. (1987). Tailings Impoundment Area, 1986 J Dyke Performance and Pond 1 Operation, Lupin Gold Mine, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in June 1987.
- Golder Associates Ltd. (1985). Tailings Impoundment Area Divider Dyke Design and Syphon Decant Design, Lupin Gold Mine, Contwoyto Lake, N.W.T. Project Number 842-2052. Submitted to Echo Bay Mines Ltd. in March 1985.
- Golder Associates Ltd. (1995). Assessment of the Potential to Place Uncemented Tailings Paste Backfill in Slopes. Project Number 932-1460. Submitted to Echo Bay Mines Ltd. in May 1995.
- Golder Associates Ltd. (1998). 1998 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 982-2427. Submitted to Echo Bay Mines Ltd. in October 1998.
- Golder Associates Ltd. (1997). 1997 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 972-2417. Submitted to Echo Bay Mines Ltd. in October 1997.
- Golder Associates Ltd. (1996). 1996 Geotechnical Inspection of the Tailings Containment Perimeter Embankments, Lupin Mine, Contwoyto Lake, N.W.T. Project Number 962-2422. Submitted to Echo Bay Mines Ltd. in September 1996.
- Golder Associates Ltd. (1997). Closure Cost Estimate and Scoping of Mine Closure Issues, Lupin Mine, N.W.T. Project Number 972-2414.8000. Submitted to Echo Bay Mines Ltd. in December 1997.
- B.G.C. Engineering Inc. (2001). 2001 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, N.W.T. Project Number 0256-003-02. Submitted to Echo Bay Mines Ltd. in September 2001.

- B.G.C. Engineering Inc. (2000). 2001 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, N.W.T. Project Number 0256-001-01. Submitted to Echo Bay Mines Ltd. in October 2000.
- B.G.C. Engineering Inc. (2000). Thermistor Installation Program, Dam 1A, Dam 2, M Dam, Cell 1 and Esker, Lupin Mine, N.W.T. Project Number 0256-002-01. Submitted to Echo Bay Mines Ltd. in December 2000.
- B.G.C. Engineering Inc. (2002). 2002 Geotechnical Inspection of Perimeter Tailings Dams, Lupin Mine, Nunavut. Project Number 0256-004-02. Submitted to Echo Bay Mines Ltd. in October 2002.
- B.G.C. Engineering Inc. (2003). 2003 Geotechnical Inspection of Perimeter Tailings Dams and Waste Containment Dikes, Lupin Mine, Nunavut. Project Number 0256-007-01. Submitted to Echo Bay Mines Ltd. in September 2003.
- Natural Resources Canada (1998). Mine Environment Neutral Drainage (M.E.N.D.) Project 1.62.2, Acid Mine Drainage Behaviour in Low Temperature Regimes, Thermal Properties of Tailings. Submitted to Echo Bay Mines Ltd. in July 1998.
- SEACOR Environmental Engineering Inc. (1995). 1995 Thermistor Installation, Lupin Mine, N.W.T. Project Number H0442-001. Submitted to Echo Bay Mines Ltd. in December 1995.
- Klohn-Crippen Consultants Ltd. (1995). Tailings Reclamation Test Cover Program, 1994 Report of Activities. Project Number PM 6698 02. Submitted to Echo Bay Mines Ltd. in August 1995.
- B.G.C. Engineering Inc. (2003). Dam 6 Site Investigation and Raise Design. Project Number 0256-006-01. Submitted to Kinross Gold Corporation. in July 2003.
- Electronic data supplied by Kinross Gold Corporation to Golder Associates Ltd. that included thermistor measurement histories, tailings deposition volume histories, pond water elevation histories, plan maps and cross-sections.

2. SITE DESCRIPTION

2.1 Location and Topography

Lupin Mine is located at 65°46'N, 111°14'W in the north-central District of Mackenzie, west of Contwoyto Lake, and approximately 380 km northeast of Yellowknife, N.W.T. The tailings containment area (TCA) is located approximately 5 km southwest of the mine.

The Lupin Mine is situated in an area of gently rolling topography that has an elevation generally between 480 m and 520 metres. Contwoyto Lake is on a divide between two watersheds and has two outlets. The southern outlet is Contwoyto River, which joins Back River and reports to Chantrey Inlet. The northern outlet drains into Kathawchaga Lake and reports to Bathurst Inlet via the Burnside River (Kerr et al 2000).

The location of the Lupin Mine is illustrated on Figure 1.

2.2 Geological Setting

The Lupin Mine and TCA are situated within the Canadian Shield in an area that is underlain by the Yellowknife Supergroup and intrusive granitoid rock. The Yellowknife Supergroup comprises metaturbidites and intermediate to felsic metavolcanic rock. An iron formation within the above metaturbidites hosts the Lupin gold deposit. The intrusive granitoid rock comprises granite, granodiorite, diorite, tonalite, and gneiss (Kerr et al 2000).

The surficial geology of the TCA comprises metaturbidite bedrock outcrops, glacial till and glaciofluvial (esker) deposits. The glacial till occurs predominantly as a silty sand veneer that is less than 2 m thick (Kerr et al 2000).

The surficial geology of the TCA is shown on Figure 2.

2.3 Regional Climate and Permafrost Conditions

Based on climate station data that has been obtained since 1982, the mean annual temperature at the Lupin Mine is -10.8°C. The mean annual precipitation at the Lupin Mine is 297 mm, of which 161 mm is rainfall and 136 mm is snowfall.

The Lupin Mine and TCA are situated within the zone of continuous permafrost. This area exhibits predominantly low (less than 10%) ground ice and the mean annual ground temperature at the depth of zero annual amplitude is approximately -7.5°C. Measured permafrost depths in this area are on the order of 500 m (National Atlas Information Service 1995).

Measurements at depths of approximately 20 m within the TCA indicate permafrost temperatures between -4°C and -6°C.

2.4 Tailings Containment Area

The Tailings Containment Area (TCA) is situated in an area of gently rolling topography with generally indistinct drainage patterns. Surface elevations generally vary from 480 m near Contwoyto Lake to 520 m with local relief generally less than 15 metres.

The perimeter of the TCA comprises areas of high topography and a number of dams or dykes that span low areas of distinct drainage paths. The perimeter of the TCA includes dams 1A, 1B, 1C, 2, 3, 4 and 6 and access roads across locally higher topography connect these perimeter dams. These dams and access roads are constructed to crest elevations of between 485 m and 490 metres.

The layout of the TCA is provided on Figure 3.

Perimeter dams 1A, 1B, 1C, 2 and 4A were initially used to contain a single deposition area at the commencement of mining operations in 1982. Additional internal dams were constructed between 1985 and 1990 to retain tailings solids and facilitate increased efficiency in handling decant tailings water. Additional perimeter dams 4, 5 and 6 were constructed between 1990 and 1992 to facilitate increased tailings management capacity.

The interior of the TCA is compartmentalised by dams 3C, 3D, 3E, J, K, L, M and N and comprises two ponds and five tailings deposition areas (cells). The ponds provide staged handling of the tailings decant water. Current practice is to pump excess water (spring melt-water and accumulated tailings decant water) from Cells 3 and 5 into Cell 4, where it is stored for one year. The water in Cell 4 is transferred via a gated culvert to Pond 1, where it is stored for another year. The water in Pond 1 is then pumped over J-Dam, where it is stored for one year before release over Dam 1A.

The water surface elevations in Pond 1 and Pond 2 are generally 481 m and 480 m, respectively, after release and are approximately 484 m prior to release.

Cells 1, 2, 3 and 5 comprise the tailings deposition areas. Cells 1 and 2 have been inactive and covered with esker material since approximately 1995. Since 2000, summer tailings deposition has been into Cell 3 and the N-Dam portion of Cell 5, and winter deposition has been into the main body of Cell 5.

The depositional history of the TCA is summarised in Table 1.

Table 1
Summary of TCA History

Period	Comments
1982 – 1984	• Tailings deposition to Cell 5
1985 – 1989	• Construction of Dam 3C and J-Dam • Tailings deposition to Cell 1
1990 – 1992	• Construction of perimeter dams 4, 5 and 6 and internal dams K, L and M • Tailings deposition to Cell 1 and Cell 2
1993 - 1997	• Gravelly sand esker material cover placed over Cell 1 and Cell 2 • Tailings deposition to Cell 3 and Cell 5
1998 - 1999	• Mine in Care and Maintenance mode • Tailings deposition to Cell 5
2000 – 2002	• M-Dam raised • Gravelly sand esker material cover placed over Cell 3A and 3B • Tailings deposition predominantly to Cell 3 and Cell 5 with less volumes of tailings deposited to Cell 2 • Mine in Care and Maintenance August 2002
2003 – present	• Tailings deposition to Cell 5 and Cell 3

2.5 Dam Geometry and Construction

The performance of the frozen tailings cells and the TCA dams depends upon factors including earth material composition and moisture content, thermal properties, ground and air temperature, and thermal boundary conditions such as pond elevations and their variations.

The TCA dams are constructed using various combinations of silty sand till, gravelly sand esker material, tailings sand, and run-of-mine rock. The run-of-mine rock was derived from shaft deepening during mining operations. The geometry and construction of the various dams are described in greater detail below.

2.5.1 Perimeter Dams

Construction information for perimeter dams 1A, 1B, 1C, 2 and 4A (later part of Dam 4) is provided in the Geocon (1982) report. These dams were initially constructed to a crest elevation of 485 m and were later raised to an elevation of 486.5 metres. Dam 4 was later raised to a crest elevation of 490 metres. These dams are constructed of silty sand till cores with gravely sand esker material and rip rap materials on the upstream faces. A geosynthetic liner, which is keyed into the underlying permafrost, separates the silty sand till from the gravely sand. A silty sand drainage blanket is provided at the downstream toe.

Construction information for perimeter dams 4, 5 and 6 is provided in the Golder (1992) report. These dams are constructed of gravelly sand esker material and incorporate a geosynthetic liner within the upstream portion and a downstream toe drain comprised of run-of-mine material. The Dam 4 liner extends 15 m upstream from the upstream toe. The liners are keyed into the permafrost below Dam 5 and Dam 6.

The perimeter dams incorporate frozen cores in addition to the geosynthetic liners. Dam core temperatures of less than 0°C have been measured by thermistors installed in Dam 1A, Dam 2, Dam 4, Dam 5 and Dam 6.

2.5.2 Internal Dams

Construction information for J-Dam, the internal dam that separates Pond 1 and Pond 2, is provided in the Golder (1984 and 1985) reports. The dam core is constructed of run-of-mine rock. On the upstream side, the run-of-mine rock is covered with gravely sand esker material, which underlies the tailings sand that forms the upstream face. The run-of-mine rock extends from the base of the dam to approximately elevation 485.5 metres. The upper portion of the dam, between elevation 485.5 m and approximate elevation 487.5 m, is constructed of gravely sand esker material and tailings sand. Tailings decant water is transferred from Pond 1 to Pond 2 using 5 siphon pipes that run over the top of J-Dam.

Construction information for internal dams 3C, 3D, 3E, K, L, M and N has been provided to Golder by Kinross Gold. These dams are constructed of run-of-mine waste with gravely sand esker material on the upstream face.

The internal dams were designed with no specific seepage control measures. Temperature measurements of thermistors that have been installed in Dam 3D and K-Dam indicate that the cores of these dams are frozen below depths of approximately 3 m to 5 m below the dam crests. It is understood that no thermistors were installed in the other internal dams.

3. INTERACTION BETWEEN FLOODED AREAS AND TAILINGS CONTAINMENT AREA

The Lupin Water Licence requires a "*study of the potential for interaction between covered cells and flooded areas of the Lupin Tails Containment Area (TCA), including thermal analyses and modelling of the interaction between the ponds, the frozen-core perimeter dykes, and frozen tailings within cells, as well as the thermal effects of proposed pond elevations*".

The objectives of this study included the following:

- Estimate of material geo-thermal properties;
- Selection of a typical cross-section for thermal analysis; and
- Parametric thermal analyses of the interaction between flooded areas, frozen-core perimeter dams, internal dams and frozen tailings deposits.

It is understood that the reclamation activities include plans to construct a spillway through Dam 1A and to breach J-Dam. It would, therefore, be unlikely that any water would be impounded against the internal and perimeter dams that comprise the TCA, with the possible exception of Dam 3D. The parametric thermal analysis, of interaction between flooded areas and the TCA dams is, therefore, intended to be conservative.

3.1 Material Geo-Thermal Properties

3.1.1 Materials

The following materials comprise the TCA:

- Esker gravely sand;
- Silty sand till;
- Bedrock;
- Run-of-mine rock; and
- Tailings.

Grain size distributions for the unclassified tailings, silty sand till and esker gravely sand are provided in the Golder (1985) report and recent laboratory testing and are reproduced on Figures A-1, A-2, A-3 and A-4 in Appendix A. The esker gravely sand was sampled from northwest of Dam 2. The silty sand till was sampled from a borrow area within the TCA between Dam 1A and Dam 4. Grain size distributions for the run-of-mine rock are unavailable.

3.1.2 Estimation of Thermal Properties

Readily available information regarding the thermal properties of the earth materials is relatively sparse. Thermal properties of fresh (i.e. unconsolidated) Lupin Mine tailings were measured as part of MEND Project 1.62.2, which was a study of acid rock drainage potential at low temperatures. However, the measured thermal properties are not considered representative of consolidated or partially drained tailings materials. It was necessary to estimate material thermal properties through analytical methods.

Available information of material characteristics was used to develop preliminary estimates of the material thermal properties within the TCA. The above estimates were then refined using measured thermistor data and thermal numerical modelling (back analyses).

The thermistor data comprised temperature from thermistors TC1-3 and D1A-00-1S. Thermistor TC1-3 was installed in 1995 and is situated in the northeast corner of Cell 1. The approximate stratigraphy at TC1-3 comprises 1 m of esker material, overlying 4 m of tailings, overlying bedrock. Thermistor D1A-00-1S was installed in 2000 and is situated on the crest of Dam 1A, south of the siphons. The approximate stratigraphy at D1A-00-1S comprises 16 m of run-of-mine rock overlying bedrock. It is noted that the thermistors within the TCA have been installed using air-track drilling equipment that produces highly disturbed samples during drilling. The reported stratigraphy at each location is considered to be approximate.

The initial estimates of material thermal properties were refined using the above thermistor data and thermal numerical modelling. The numerical modelling was completed using TEMP/W v.5.19, a commercially available finite element program that is produced by Geoslope International Ltd. One dimensional finite element models were constructed with geometries that were consistent with the estimated stratigraphy at the locations of TC1-3 and D1A-00-1S.

Measured temperature profiles on a single day at these thermistors were used to establish initial conditions within the finite element models. The measured fluctuations in ground surface temperature over a period of several years at these thermistors were then applied to the upper surface of the thermal models as the boundary conditions. After simulating the ground thermal response over several years, the predicted temperature profiles were compared to the measured temperature profiles and the estimated thermal properties were revised, as necessary.

Comparisons between measured and predicted temperature profiles at thermistors TC1-3 and D1A-00-1S are provided on Figures 4 and 5. The estimated thermal properties are provided in Table 2.

Table 2
Estimated Thermal Properties

Material Type	Material Property				
	k_f MJ/m·d·°C	k_u MJ/m·d·°C	c_{vf} MJ/m^3·°C	c_{vu} MJ/m^3·°C	θ
Gravely sand (esker)	0.2	0.2	2.0	3.0	0.3
Silty sand till	0.2	0.2	2.0	3.0	0.3
Run-of-mine rock	0.2	0.2	2.0	3.0	0.3
Tailings	0.2	0.2	3.0	4.0	0.4
Bedrock	0.2	0.2	2.4	2.4	0.1

k_f frozen thermal conductivity
k_u unfrozen thermal conductivity
c_{vf} frozen volumetric heat capacity
c_{vu} unfrozen volumetric heat capacity
θ volumetric water content (ratio of the volume of water per unit total volume of material)

It is observed on Figure 4 and 5 that the measured and predicted temperature profiles compare reasonably well. The thermal properties provided in Table 2 were used in subsequent thermal analysis.

3.2 Selection of Cross Section for Thermal Analyses

As described in Section 2.5, several dam geometries have been constructed within the TCA. The dams are constructed of various combinations of run-of-mine rock, gravely sand esker material and silty sand till. The estimated thermal properties of materials comprising the TCA, as shown in Table 2, were used to establish a cross-section for thermal analysis of the interaction between

flooded areas and covered cells. In addition to the thermal properties, the embankment geometry and the presence (or absence) of impounded tailings were other variables that may impact the interaction between the flooded areas and TCA embankment structures.

It is observed in Table 2 that although the thermal conductivities of the materials are similar, the estimated volumetric heat capacity values of the gravely sand esker material, silty sand till and run-of-mine rock are less than the estimated volumetric heat capacity values of the tailings. Accordingly, it is expected that for a given embankment geometry the extent of thaw progression would be greater in embankments constructed of these materials than a geometrically equivalent embankment constructed of tailings. In other words, thermal analyses of a wide embankment of gravelly sand, silty sand or run-of-mine rock should provide a conservative (high) estimate of the extent of thaw penetration.

Based on the above discussion, K-dam was selected for parametric thermal analyses. K-Dam is a wide internal dam that is constructed of gravelly sand esker material and run-of-mine rock. This internal dam has a maximum height of approximately 11 m, a crest width of approximately 12 m, an upstream slope of approximately 3H:1V, and a downstream slope of approximately 1H:1V. The tailings impounded by K-Dam reach an elevation that is approximately 2 m below the dam crest. Pond 2 does not currently extent to the downstream toe of K-Dam. Based on the minimum existing crest elevation of the adjacent perimeter dams, the maximum depth of Pond 2 water that could exist adjacent to K-Dam is approximately 5.5 metres.

The geometry of K-Dam at the analysed cross-section is shown on Figure 6.

3.3 Analysis Methodology

The thermal analysis was completed using TEMP/W v.5.19 and two dimensional finite element models. The material thermal properties that are presented in Table 2 were used in the analysis.

3.3.1 Boundary Conditions

Bases on the existing geometry of the TCA, the maximum depth of Pond 2 water that could be impounded against the downstream face of K-Dam is approximately 5.5 metre. Impounded water depths of 5.0 m and 8.5 m were considered in the parametric thermal analysis.

Four sets of temperature boundary conditions were applied to the thermal models, at the following locations: The air-soil interface, the water-soil interface at the base of impounded water, the water-soil interface within the upper 2 m of impounded water, and at depth within the bedrock materials.

The temperature boundary condition at the air-soil interface was varied with time to reflect seasonal temperature variation. This temperature function was developed from measured surface temperatures at thermistor TC1-3 in Cell 1. The surface temperature measurements over the last 9 years, since this cell was covered with esker material, were used to derive the following ground surface temperature function:

$$T = -7.0 + 15.0 \cdot \sin\left(0.1 - \frac{2\pi\, t}{365}\right)$$

where T = ground surface temperature in °C and t = time in days, with $t = 0$ on November 5th.

The above temperature function is compared with measured surface temperatures at TC1-3 on Figure 7. It is seen on Figure 7 that the fitted temperature function compares well with the measured surface temperatures at TC1-3. The fitted temperature function on Figure 7 was used to approximate the variation in ground surface temperature with time during the numerical modelling.

A constant-temperature boundary condition was applied at the water-soil interface at the base of impounded water. The value of this boundary condition was determined using published sources. Studies of shallow Arctic lakes indicate that the temperature at depth reaches a nearly constant value of 3°C (Burn 2002). A more conservative value of 4°C was used as a constant temperature boundary condition at the water-soil interface at impounded water depths greater than 2 metres.

Studies of Arctic lakes indicate that the ice may reach a thickness of approximately 2 m each winter; consequently, temperatures within the upper 2 m of impounded water may reach subzero temperatures during the year (Burn 2002). A more conservative, constant-temperature boundary condition of 2°C was applied to the water-soil interface within the upper 2 m of impounded water in the numerical models discussed herein.

Published sources indicate that the permafrost temperature at a depth of 20 m near the Lupin Mine is between -4°C and -7°C. A more conservative, constant temperature boundary condition of -3.5°C was applied at a depth of 20 m below the original ground surface in the numerical models discussed herein. The value of this boundary condition is supported by measured values at a depth of 20 m within the TCA (e.g. thermistor D1A-00-02).

3.3.2 Initial Conditions

The initial temperatures at nodes of the finite element numerical models were estimated using steady state thermal analysis. The temperature of nodes at the uppermost soil boundary was set to -5°C as a constant-temperature boundary condition. The temperature at the base of the finite element models, at a depth of 20 m below the original ground surface, was assigned a constant temperature boundary condition of -3.5°C. Steady state thermal analysis was completed to determine the temperature variation with location under these boundary conditions. The calculated nodal temperatures were used to estimate the initial conditions within the finite element mesh during subsequent transient thermal analysis.

3.4 Results of Parametric Analysis

3.4.1 Interaction Between Flooded Areas and Covered Cells

Two scenarios were analysed to evaluate the interaction between flooded areas and covered cells. The first scenario considered water impounded to an elevation approximately half-way up the downstream face of K-Dam, with a water depth of 5 m at the downstream toe. The second scenario considered the maximum water depth that could be impounded against the downstream toe of K-Dam. Based on the lowest perimeter dam crest elevation adjacent to Pond 2,

approximately 485.5 m, the maximum depth of water that could be impounded against the downstream face of K-Dam is approximately 8.5 metres.

The initial temperatures and boundary conditions that were described in Section 3.3 were used to evaluate both of the above scenarios. The thermal modelling determined the calculated maximum depth of the 0°C isotherm, i.e. the maximum yearly thaw depth, for each year over the simulated duration of 20 years.

The calculated progression of the 0°C isotherm over a period of 20 years with 5 m of impounded water adjacent to K-dam is shown on Figure 8. It is observed on Figure 8 that the slope of the talik (unfrozen zone) near the downstream toe is steep. The estimated talik reaches a depth of approximately 17 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 5 m into K-Dam, measured horizontally from the downstream toe, and it is observed that the calculated talik does not extend into the frozen tailings after an elapsed period of 20 years.

The calculated progression of the 0°C isotherm over a period of 20 years with 8.5 m of impounded water adjacent to K-dam is shown on Figure 9. It is observed on Figure 9 that the slope of the talik (unfrozen zone) near the downstream toe is steep. The estimated talik reaches a depth of approximately 18 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 8 m into K-Dam, measured horizontally from the downstream toe, and it is observed that the calculated talik does not extend into the frozen tailings after an elapsed period of 20 years.

3.4.2 Interaction Between Flooded Areas and Dam 1A

The cross-section used to assess the interaction between flooded areas and the perimeter dams (such as Dam 1A) is the same as shown in Figure 6 with the exception that tailings were not impounded by this model embankment. The initial temperatures and boundary conditions are the same as described in Section 3.3. An impounded water depth of 8.5 m above the dam toe was evaluated.

The calculated progression of the 0°C isotherm over a period of 20 years with 8.5 m of impounded water is shown on Figure 10. It is observed on Figure 10 that the slope of the talik (unfrozen zone) near the dam toe is steep. The estimated talik reaches a depth of approximately 19 m below the original ground elevation after an elapsed time of 20 years. The estimated talik extends approximately 8 m into the analysed cross section, measured horizontally from the dam toe, and it is observed that the calculated talik does not extend through the entire dam core after an elapsed period of 20 years.

3.5 Comments

The results of the thermal analyses indicate that, after an elapsed period of 20 years, the unfrozen zone does not extend to the frozen tailings when 8.5 m of water is impounded against the downstream face of K-Dam. As discussed in Section 3.2, the extent of thaw progression should be greater in gravely sand esker material, silty sand till and run-of-mine waste than in frozen tailings. In addition, the maximum depth of Pond 2 water that could be impounded against K-Dam is approximately 5.5 m, based on existing dam geometrics. The above results are, therefore, considered a reasonable and somewhat conservative representation of the interaction between flooded areas and other internal dams within the TCA.

M-Dam, N-Dam and Dam 3D are internal dams that could be exposed to impounded water within Pond 1 and Pond 2. Like K-Dam, the above dams are constructed of gravely sand esker material, silty sand till, and run-of-mine waste. These dams are constructed with crest elevations between 488 m and 491 m, crest widths of approximately 12 m, upstream faces sloped at approximately 1H:1V, and downstream faces sloped at between 1H:0.7V and 1H:1V. The construction of Dam 3D is slightly different from the above dams, in that approximately 300,000 m^3 of quarried riprap material was placed on the downstream face in 1995. The above riprap placement increased the crest width of the dam to 20 m and flattened the downstream face to slopes between 1.5H:1V and 2H:1V.

The geometries of the above dams are similar to that of K-Dam. It is considered that the results of thermal analysis of K-Dam are, therefore, applicable to M-Dam, N-Dam and Dam 3D.

4. METHODS TO CONTAIN POTENTIAL PORE WATER EXPULSION FROM TAILINGS CONTAINMENT AREA

It is understood that Condition I.3.b in the Water Licence requires Lupin Mine to provide "*an outline of methods to contain potential pore water expulsion from the TCA*" post closure/abandonment of the mine operation. In other words, it is necessary to evaluate potential release of pore water from the tailings and its long term impact to the surroundings of the TCA is of concerns.

The objectives of this study were as follows:

- Identify potential mechanisms of pore water expulsion;
- Estimate the timing and potential impact of pore water expulsion under each mechanism; and
- Assess measures to contain potential pore water expulsion.

4.1 Potential of Pore Water Expulsion

There are three main mechanisms that could potentially lead to expulsion of pore water from the TCA:

- Loss of pore water from the TCA via talik seepage at depth;
- Consolidation of unfrozen tailings situated against a perimeter dam (due to increased loading and/or thawing); and
- Leaching of pore water as a result of infiltration through the active layer within the tailings and cover.

The analysis of the above mechanisms comprised an evaluation of the thermal modelling results in Section 3 from the perspective of potential pore water expulsion.

4.1.1 Talik Seepage Mechanism

The talik seepage mechanism refers to seepage of pore fluid through an unfrozen zone beneath a frozen dam core, where the unfrozen zone is resulted of warming from adjacent impounded water.

The thermal analysis in Section 3.4 included an assessment of talik development adjacent to K-Dam and Dam 1A resulting from the maximum depth of impounded water adjacent to K-Dam in Pond 2. The results of the thermal analysis indicate that, after 20 years with a maximum depth of impounded water within Pond 2, the resulting talik would not form an unfrozen zone that would underlie the frozen core of K-Dam or Dam 1A. As discussed in Section 3.5, it is anticipated that the above results are also applicable to the remaining internal and perimeter dams that comprise the TCA. In other words, it is not anticipated that impounded water within the TCA would result in unfrozen zones that underlie the tailings impoundment structures. The potential mechanism of pore water expulsion from the TCA as a result of talik seepage is considered unlikely.

4.1.2 Consolidation Mechanism

The consolidation mechanism refers to pore water expulsion resulting from consolidation of unfrozen tailings, due to the loading from the proposed esker cover layer. As discussed earlier, based on the results of the thermal analyses, it appears that consolidation of the tailings is only limited to portion of the deposit within the active layer.

The thermal analysis results discussed in the previous section indicate that the depth of the active layer in the tailings is about 2 m, but reduces to approximately 1 m with the esker cover. This value is supported by thermistor measurements that have been obtained within Cell 1 and Cell 2, which have been covered with esker material since 1995.

It is necessary to assess both the volume and rate of expelled pore water, so as to evaluate the impact of the consolidation induced potential pore water release. The results of consolidation tests on Lupin tailings reported Golder (1995), as shown in Figures A-5 to A-7, Appendix A, were used in the consolidation assessment.

The following assumptions were incorporated into the consolidation analyses:

- Phreatic surface is located at the base of the esker cover (which provides an upper bound estimate of effectives stresses in the tailings);
- Esker cover is 1 m thick;
- Active layer extends 2 m below the tailings surface;
- Specific gravity of the tailings solids is 3.1;
- Saturated unit weight of the fresh tailings is 17 kN/m^3; and
- Bulk unit weight of the esker cover is 20 kN/m^3.

Based on the above assumptions and using consolidation properties shown in Figures A-5 to A-7, the release of tailings water from the pore voids due to consolidation is estimated to be approximately 0.03 m^3 of pore water for each 1 m^3 of tailings within the active layer. Since the maximum thickness of the tailings within the active layer is 2 m (assuming a summer placement of the cover), the above results correspond to a release of 0.06 m^3 of pore water for each 1 m^2 of tailings that are loaded by the placement of the esker cover layer. The amount of pore water release is estimated to be 0.03 m^3 per 1 m^2 of tailings area if the esker cover is place in the winter (reduced active layer thickness due to the cover).

Based on the consolidation curves shown on Figures A-6 and A-7, the time to consolidate the tailings materials within the active layer due to the loading of the esker cover is estimated to be less than 30 days. In other words, the pore water that is released by loading of unfrozen tailings by the esker cover is expected to be complete by the end of the first thaw season subsequent to the cover placement.

4.1.3 Leaching and Lateral Flow Mechanism

The thermal analyses that were discussed in Section 3 indicate that there is a potential of lateral pore water flow through the active layer. It is observed on Figures 8 and 9 that the active layer extends in the covered cell extends between 1 m and 3 m below the dam crest, from the top of the esker cover to 1 m below the top of the tailings . It is also observed on Figures 8 and 9 that the crest of the frozen dam core is approximately 3 m below the dam crest. It is, therefore, possible

that pore water within the active layer could flow laterally, over the crest of the frozen dam core, through the downstream dam face materials.

The potential for lateral pore water flow and leaching is limited to the periphery of the tailings cells, adjacent to the impoundment dams. It is anticipated that this potential exists only when there is sufficient surface water infiltration (due to rainfall in the summer) that generates significant lateral hydraulic gradient within the active layer. The tailings pore water within the unfrozen portion of the deposit or in the bottom part of the esker cover may be "flushed out" under such lateral hydraulic gradient.

4.2 Reducing Potential Pore water Expulsion

As discussed above, the lateral flow and leaching mechanism is considered to potentially result in expulsion of pore water from the tailings containment area. Two conditions must be present for the lateral flow mechanism to be active. First, sufficient infiltration must occur into the esker cover material to provide a water table within the active layer. Second, the water table within the active layer must be higher than the frozen dam core. The probability of the above conditions being present at the same time depends upon the climate, the amount of rainfall and its timing.

Based on the results of climate and hydrology analysis that will be presented in Section 6, it is anticipated that the highest net precipitation levels will occur in the spring; however, the active layer is shallow (within the esker cover materials) during this period and the potential for pore water to leach into the active layer water is, therefore, low. The maximum depth to the frozen dam cores beneath the dam crests is expected to be in later summer/early fall; however, based on the results of the climate and hydrology studies, evaporation typically exceeds precipitation during this period. Consequently, the potential for a water table within the active layer that is higher than the elevation of the frozen dam core is relatively low. It is, therefore, anticipated that expulsion of pore water from the TCA via leaching and lateral flow would occur only with a combination of warm spring/summer and high precipitation events in the late summer/early fall. Again, the extent of the leaching would be limited to the periphery of the tailings cells adjacent to the dams.

Based on the above discussion, it is expected that the overall potential for expulsion of pore water from the TCA via the lateral flow and leaching mechanism is low. Where the potential for pore water expulsion by the lateral flow mechanism exists, two approaches may be considered to further reduce the potential for pore water flow. Both methods would involve modifying the thermal regime at the periphery of the covered tailings cells.

The first approach would involve limiting the active layer to within the esker cover at the periphery of the tailings cells. Additional esker cover would act as insulation that would raise the base elevation of the active layer and maintain the tailings in a frozen state. As a preliminary estimate, it appears that an additional 1 m to 1.5 m of esker cover (for a total thickness of 2 m to 2.5 m) may be sufficient to maintain the active layer within the cover materials. The second approach would involve raising the top elevation of the frozen dam cores through placement of additional insulating material upon the dam crest. Additional esker cover over the existing dams would raise the base of the active layer within the dam, thereby raising the elevation of the frozen dam core. Based on the results the thermal analyses, it is estimated that additional thickness of esker cover material would be required such that the new dam crest is 3 m higher than the top of the adjacent cell cover. It is noted that stability of the dams with the additional materials needs to be checked if this approach is implemented.

5. ASSESSMENT OF COVER MATERIAL SUITABILITY

It is understood that Lupin Mine is proposing to cover all exposed tailings with a 1-meter thickness of gravelly sand that will be obtained from an esker located several kilometres from the TCA. Condition I.1.d in the Water Licence requires *"a comprehensive assessment of material suitability, including geochemical and physical characterization and availability for restoration needs, with attention to top-dressing materials, including maps, where appropriate, showing sources and stockpile locations of all borrow materials"*

The objectives of this study were as follows:

- Identify gravel and other associated cover materials;
- Complete laboratory analysis of selected cover materials; and
- Assess the quantity and suitability, including potential environmental impacts, of these materials.

5.1 Identification of Cover Materials

It is understood that the gravely sand cover materials for Cell 1 and Cell 2 were obtained from the same esker sources that are proposed for use in covering Cell 3 and Cell 5. These esker borrow sources were examined by a Golder geotechnical engineer during the site visit in August 2004. Samples of the esker materials were provided to the Golder laboratory in Calgary by Echo Bay Mines.

5.2 Laboratory Analysis

The following laboratory tests were completed:

- Grain size distribution and maximum and minimum density to generally characterise the esker material;
- Cyclic wetting and drying to assess the physical stability of the esker material;
- Chemical analysis of the tailings decant water; and

- Chemical analysis of leachate fluid from a mixture of esker material and tailings decant water to assess the chemical stability of the esker material.

The grain size distribution and maximum and minimum density tests were completed as per ASTM D422, D4253 and D4254, respectively.

The cyclic wetting and drying test involved alternately soaking the esker material in water and drying the material at a temperature of 105°C. The above sequence was repeated 20 times using the same test specimen. Comparison of the initial dry mass to the final dry mass provides an estimate of the physical durability of the esker material.

Samples of tailings decant water from Cell 5 were provided to Golder by Kinross. Two sets of standard metals analysis results were obtained, the first for a specimen of Cell 5 tailings decant water and the second for a separate specimen of tailings decant water that was used in leachate testing of the esker cover material.

Tailings decant water was used as the leachate fluid for a leachate test that was completed as per the EPA 1311 Toxicity Leaching Procedure. This procedure is designed to determine the mobility of organic and inorganic analytes liquid, solid and multiphase waste materials. Pure (ASTM Type II) water or dilute acids are typically used as the reagent fluid during the EPA 1311 test. Tailings decant water was used as the reagent fluid for the results that are discussed herein.

The EPA 1311 test procedures for non-volatile compounds are summarised as follows:

- Reagent fluid (tailings decant water) and solid waste (esker material) were combined in a bottle extraction vessel (a borosilicate glass bottle);
- Bottle extraction vessel is rotated end-over-end at a rate of 30 ± 2 rpm for 18 ± 2 hours;
- Extract the fluid phase (leachate fluid) from the bottle extraction vessel using filtering methods; and
- Chemical analysis of the leachate fluid.

5.3 Results

Grain size distribution of the esker material that was provided to Golder by Echo Bay Mines is provided on Figure A-4 in Appendix A. The minimum and maximum dry densities of the gravely sand esker material, as per ASTM D4253 and D4254, were measured to be 1686 kg/m^3 and 1979 kg/m^3.

The initial dry mass of the specimen that was subjected to 20 cycles of wetting and drying was 963.29 grams. The final dry mass of the specimen was 960.35 grams. The calculated percentage decrease in specimen mass was 0.31 percent.

The results of chemical analysis of the tailings decant water and the tailings decant water after it was leached through the esker material are provided in Appendix A. The tailings decant water is labelled *Cell 5 Water* in Appendix A and the leachate fluid is labelled *Esker-SI*. The chemical analysis for specimens *Cell 5 Water* and *Esker-SI* are summarised in Table 3.

Table 3
Summary of Chemical Analysis Results

Component	Cell 5 Water (mg/L)	Esker-SI (mg/L)	Detection Limit (mg/L)
Total Trace Metals			
Silver	<0.0004	<0.0004	0.0004
Aluminum	0.02	<0.02	0.02
Arsenic	0.0769	0.0186	0.0004
Boron	0.21	0.21	0.02
Barium	0.0329	0.0370	0.0002
Beryllium	<0.001	<0.001	0.001
Bismuth	<0.0001	<0.0001	0.0001
Cadmium	<0.0002	0.0002	0.0002
Cobalt	0.0489	0.0591	0.0002
Chromium	<0.0008	<0.0008	0.0008
Copper	0.776	0.035	0.001
Molybdenum	0.0616	0.0573	0.0001
Nickel	0.296	0.237	0.0002
Lead	0.0002	0.0001	0.0001
Antimony	0.0018	0.0009	0.0004
Selenium	0.0005	0.0010	0.0004
Tin	<0.0004	<0.0004	0.0004
Strontium	2.45	2.33	0.0002
Titanium	<0.005	<0.005	0.005
Thallium	<0.0001	0.0002	0.0001
Uranium	0.0008	0.0006	0.0001
Vanadium	0.0011	0.0011	0.0002
Zinc	0.765	0.129	0.004
Total Major Metals			
Calcium	161	153	0.5
Potassium	21.7	21.5	0.1
Magnesium	8.0	8.5	0.1
Sodium	276	269	1
Iron	0.012	0.015	0.005
Manganese	0.072	0.172	0.001
Mercury	<0.0002	<0.0002	0.0002

5.4 Comments

It is observed on Figure A-4 that the esker material is classified as gravelly sand according to the Modified Unified Soil Classification System.

The results of 20 cycles of wetting and drying indicate that the percentage of mass lost by the specimen over the course of the test was 0.31 percent. This value is considered to be within the

accuracy of the testing method; consequently, the results indicate that the esker material is physically stable.

It is observed in that the measured amounts in the specimens *Cell 5 Water* and *Esker-SI* were similar. There was relatively little difference between the specimen of tailings decant water and the specimen of tailings decant water that was leached through the esker material.

Based on the results presented above, it does not appear that the esker material will physically degrade on exposure to the tailings decant water. Further, it appears that the chemistry of the tailings decant water will change relatively little if this fluid leaches through the esker material. It is, therefore, concluded that the esker material is a suitable cover material for the tailings deposition cells.

6. CLIMATE AND HYDROLOGY STUDY

Lupin Mine plans to develop a partially saturated granular cover over the exposed tailings area to provide a barrier to oxidation. It is critical that a positive water balance is maintained within the cover system for the oxidation barrier to be effective.

The objectives of this study were as follows:

- Summarizes the climate conditions of the study area of the Lupin Mine Tailings Containment Area (TCA); and
- Estimate the probability of maintaining a positive water balance over the surface of the TCA.

6.1 Climatic Conditions

The water balance for the study area at the Lupin Mine TCA was assessed on the basis of regional as well as site-specific information on temperature, precipitation (rainfall and snowfall), evaporation and runoff.

6.1.1 Climate Data

A climate station has been in operation at Lupin since 1982. Table 4 summarizes the mean annual and mean monthly temperature and precipitation (including rainfall and snowfall) calculated from observed data at Lupin, as well as mean annual and mean monthly evaporation derived from data recorded at Norman Wells Airport.

Air temperature is the variable most commonly used to characterize the climate of northern regions. Air temperature is a key factor in determining snowmelt rate during the spring runoff period. Mean annual temperatures in the region, based on climate normal information published by Environment Canada, range from -6.0°C at Normal Wells Airport to -10.5^{o}C in the north at Tuktoyaktuk. The mean annual temperature, based on recorded data at Lupin, is -10.8^{o}C. The mean monthly temperatures range from -29.9^{o}C in January to 11.6^{o}C in July. Mean monthly

temperatures are above the freezing mark from June (6.3°C) to September (2.2°C). The mean monthly temperature in August is 8.8°C.

Precipitation (including rainfall and snowfall) and temperature data are available from 1982 to present at Lupin. Precipitation and temperature data from 1982 to 2003 were used in this assessment. The mean annual precipitation at Lupin, based on the recorded data, is 297 mm. The mean annual precipitation at Normal Wells, located about 700 km to the west of Lupin but at the same latitude, is comparable at 316 millimetres. For northern basins, snow storage is an important part of the water cycle. Regionally, snow contributes a large part of the annual precipitation for eight months of the year, with snowfall accounting for about 45% to 70% of total annual precipitation. Snowfall occurs mostly between October and April, although it is possible for snowfall to occur in any month. The mean annual rainfall and snowfall amounts, based on recorded data at Lupin, are 161 and 136 mm, or about 54% and 46% of total annual precipitation, respectively.

The recorded snowfall estimates at Lupin do not take into account snowfall under-catch and sublimation. Studies indicate that snowfall under-catch can be substantial at gauges where windy conditions hinder the collection of snow and where trace amounts are not recorded. Recommended correction factors range from about 1.15 to 1.30. Conversely, sublimation can significantly deplete end-of-winter snow accumulation, thus reducing spring runoff. The amount of snow lost to sublimation is dependent upon wind and humidity conditions and is not easily estimated. As well, water equivalent of snow can decrease from the time of deposition due to sublimation. Both events decrease the amount of runoff that would be available from the winter months. For the purposes of the water balance analysis at Lupin Mine, it was assumed that the amounts of snowfall "under-reported" and lost to sublimation were comparable and, thus, no adjustments to the recorded snowfall values were necessary.

Evaporation is a key factor in determining the amount of precipitation that appears as runoff from a watershed, however, it is also the least understood of the major hydrologic region components, especially in northern areas. In general, evaporation is greatest in the summer when days are long and solar radiation is greatest. Daily energy input controls the evaporation rate for shallow-water systems. The relative importance of evaporation in the water balance of watersheds tends to increase in the north because of the decrease in precipitation at higher latitudes. No direct

measurements of evaporation were available for Lupin. Evaporation and temperature data from Norman Wells were used to assist in the water balance analysis. Both pan and lake evaporation data were available at Norman Wells from 1964 to 2003. Differences in mean temperature between Lupin and Norman Wells did not allow for direct transfer of evaporation data. A relationship between mean monthly temperature and total monthly evaporation was established for Norman Wells. The relationship was used to calculate pan and lake evaporation for Lupin using mean monthly temperatures. Evaporation was only calculated where the monthly mean temperatures were greater than zero.

Table 4
Climate Summary for Lupin

Month	Mean Temperature (^{o}C)	Mean Rainfall (mm)	Mean Snowfall (cm)	Mean Precipitation (mm)	Mean Lake Evaporation (mm)
Jan	-29.9	0.0	8.9	8.9	0.0
Feb	-28.7	0.0	7.7	7.7	0.0
Mar	-24.9	0.0	12.1	12.1	0.0
Apr	-15.9	0.1	14.0	14.2	0.0
May	-5.7	5.8	13.2	19.0	0.0
Jun	6.3	24.1	3.9	28.0	53.0
Jul	11.6	43.9	0.4	44.3	97.1
Aug	8.8	58.5	2.9	61.4	73.7
Sep	2.2	26.7	17.2	43.9	18.4
Oct	-8.4	1.8	27.1	28.8	0.0
Nov	-20.5	0.0	16.0	16.0	0.0
Dec	-26.3	0.0	14.1	14.1	0.0
Annual	*-10.8*	*161*	*136*	*297*	*242*

6.1.2 Hydrological Data

The hydrologic regime of the region around the study area is dominated by snowmelt, with peak surface runoff occurring in late May and June. Flows in streams typically recede gradually over the summer. Water yield, estimated by dividing the mean annual discharge from a watershed by its area, represents a runoff depth of water. This provides a useful measure with which runoff can be compared with precipitation. There is no local long-term stream gauging station at Lupin. Annual water yield in the region of the study area can range between 70 and 120 millimetres.

Runoff during the months of May and June accounts for about 70% of the annual runoff, with the remaining 30% occurring over the summer and fall months between July and September.

The mean annual precipitation, based on recorded data at Lupin, is 297 millimetres. This suggests that between 25% and 40% of the annual precipitation, after losses to evaporation and transpiration, results in runoff that appears as flows in streams.

6.2 Methodology

A monthly water balance was conducted based on a 21-year series of monthly precipitation and evaporation data derived for the study area. The objective of the analysis was to characterize the availability of inflow into, or the runoff from the TCA. The assumptions in the analysis were as follows:

- The snow accumulated over the winter months, which on average amounts to approximately 46 % of the annual precipitation, is held in storage until the spring melt.
- The gravel layer is frozen during most of May and the snow cover does not completely disappear until after the end of May.
- About 50 mm of the snowmelt in late May and June is used to bring the moisture content of the esker gravel layer to about 10% throughout its entire 1-metre depth. Any excess moisture input from snowmelt and rain is lost through evaporation and surface runoff. Evaporation is assumed to be 70% of the potential lake evaporation value estimated from the monthly mean temperature. The relatively high value of evaporation, about 70% of the potential lake evaporation, is based on the moist and saturated surface during May and June.
- The top 10 cm (approximately) of the esker gravel layer, which is exposed to wind and solar radiation, is continually losing water. Hence, a minimum of about 10 mm of moisture input is necessary to “wet” or satisfy the “deficit” in the top layer at the beginning of a rainfall event.
- The moisture lost through evaporation is about 30% of the potential monthly mean lake evaporation calculated from the monthly mean temperature during

the summer and fall months from July to September. The value of 30% reflects the dryer and moisture-limited conditions of the top portion of the upper gravel layer during these months.

- Seepage losses from the TCA are assumed to be about 10 mm per month. About 30% of the annual runoff in watersheds in the region of the study area occurs from July to September. Most of the runoff during these months is through groundwater flow. Assuming an average annual runoff of 100 mm, of which 70% occurs during May and June, then about 30 mm of runoff occurs between July and September. The month runoff is then about 10 mm and sustained through infiltration.
- The water balance is conducted on a monthly basis, with no carry-over from month to month. While not strictly accurate, this assumption provides a conservative assessment because the effects of the variability in amount, frequency, duration and inter-event period of rainfall events during any month has not been factored in the analysis.
- A surplus of moisture is necessary after evaporation losses, satisfaction of surface moisture deficits and infiltration/seepage losses to maintain the gravel layer partially saturated and a positive water balance over the underlying tailings layer during the summer and fall months from July to September. It is assumed that a deficit of more than 25 mm can cause the upper gravel layer to start drying up.

6.3 Results

The results of the water balance analysis are presented in two sets: (1) the deficit is defined as a monthly moisture imbalance of less than zero; and (2) the deficit is defined as a monthly moisture imbalance of less than 25 millimetres. Based on the 21 years of data at Lupin, the probability of:

<u>Deficit > 0 mm</u>

- A year with no deficit in any given month = 19%
- A year with a deficit of greater than 0 mm during any one month between July and September = 57%

- A year with a deficit of greater than 0 mm during any two months between July and September = 24%

Deficit > 25 mm

- A year with no deficit in any given month = 67%
- A year with a deficit of greater than 25 mm during any one month between July and September = 33%
- A year with a deficit of greater than 25 mm during any two months between July and September = 0%

6.4 Comments

The water balance results indicate that there are relatively high probabilities of surface moisture deficit during any one summer month at the Lupin Mine TCA. However, the results also indicate that the probability of surface moisture deficits in two consecutive summer months is relatively low. More specifically, the results indicate that the cumulative surface moisture deficit in two consecutive summer months is unlikely to exceed 50 mm. Given the proposed cover thickness of 1 m, the probability of drying out the entire cover is considered low. In other words, it is considered likely that partial saturation can be maintained within the cover system for the given climate and hydrological conditions at the Lupin Mine area, and the cover layer is anticipated to perform as an oxidation barrier.

7. SUMMARY AND CONCLUSIONS

A series of studies have been completed to satisfy the water license requirements and to support the reclamation planning at the Lupin Mine. The components of the studies include:

- Geo-thermal analyses to assess the interaction between fluctuating pond elevations and performance of frozen cores in perimeter tailings containment structures within TCA;
- Geo-thermal modelling and consolidation analyses to assess the potential pore water expulsion from the tailings deposits due to various mechanism;
- Laboratory tests to evaluate the esker material on its suitability as a tailings cover; and
- Climate and hydrology analyses to address the suitability of esker cover as an oxidation barrier.

Based on the findings from the above studies, the following conclusions are derived:

- Impoundment of water within Pond 1 and Pond 2 to an elevation 3 m higher than the maximum elevations, as limited by the crest elevations of the adjacent TCA perimeter dams, over a 20 year period would most likely not lead to thawing of the frozen cores in the perimeter dams. In other words, the performance of the frozen core perimeter dams will not be negatively impacted by fluctuating pond elevations under the current dam configurations. It is noted that the geo-thermal analysis, upon which this conclusion is derived, represents a "worst case" scenario for the TCA configuration at present time.
- The overall probability of significant long term pore water expulsion from the tailings deposits is considered low, for the following reasons:
  - The results of thermal analyses indicate that elevated pond elevations will not cause thawing of frozen tailings below the active layer, even when the maximum pond elevations are maintained for a 20 year period.
  - Consolidation of the tailings deposits as a result of esker cover placement is limited within the active layer. The amount of water release is estimated to range

approximately from 0.03 m^3 to 0.06 m^3 per 1.0 m^2 of the tailings area. The pore water expulsion due to consolidation in the active layer is anticipated to complete by the end of the first thaw season after esker cover placement.

- The potential of tailings pore water expulsion due to lateral flow and leaching through the active layer would occur only with a combination of warm spring/summer and high precipitation events in the late summer/early fall. Furthermore it is limited to the periphery of the tailings cells, adjacent to the impoundment dams. Approaches to minimize the leaching through lateral flow include increased cover thickness on the dams or over the tailings area immediately adjacent to the dams.

- Laboratory testing results indicate that the proposed esker material (gravely sand) is physically and chemically stable, and suitable for being used as a tailings cover.
- The results of the climate and hydrology studies indicate that there are relatively high probabilities of surface moisture deficits during any one summer month at the Lupin Mine TCA. However, the cumulative surface moisture deficit in two consecutive summer months is unlikely to exceed 50 millimetres. Given the proposed cover thickness of 1 m, the probability of drying out the entire cover is low. In other words, it is considered likely that partial saturation can be maintained within the cover system for the given climate and hydrological conditions at the Lupin Mine area, and the cover layer is anticipated to perform as an oxidation barrier.

8. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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9. REFERENCES

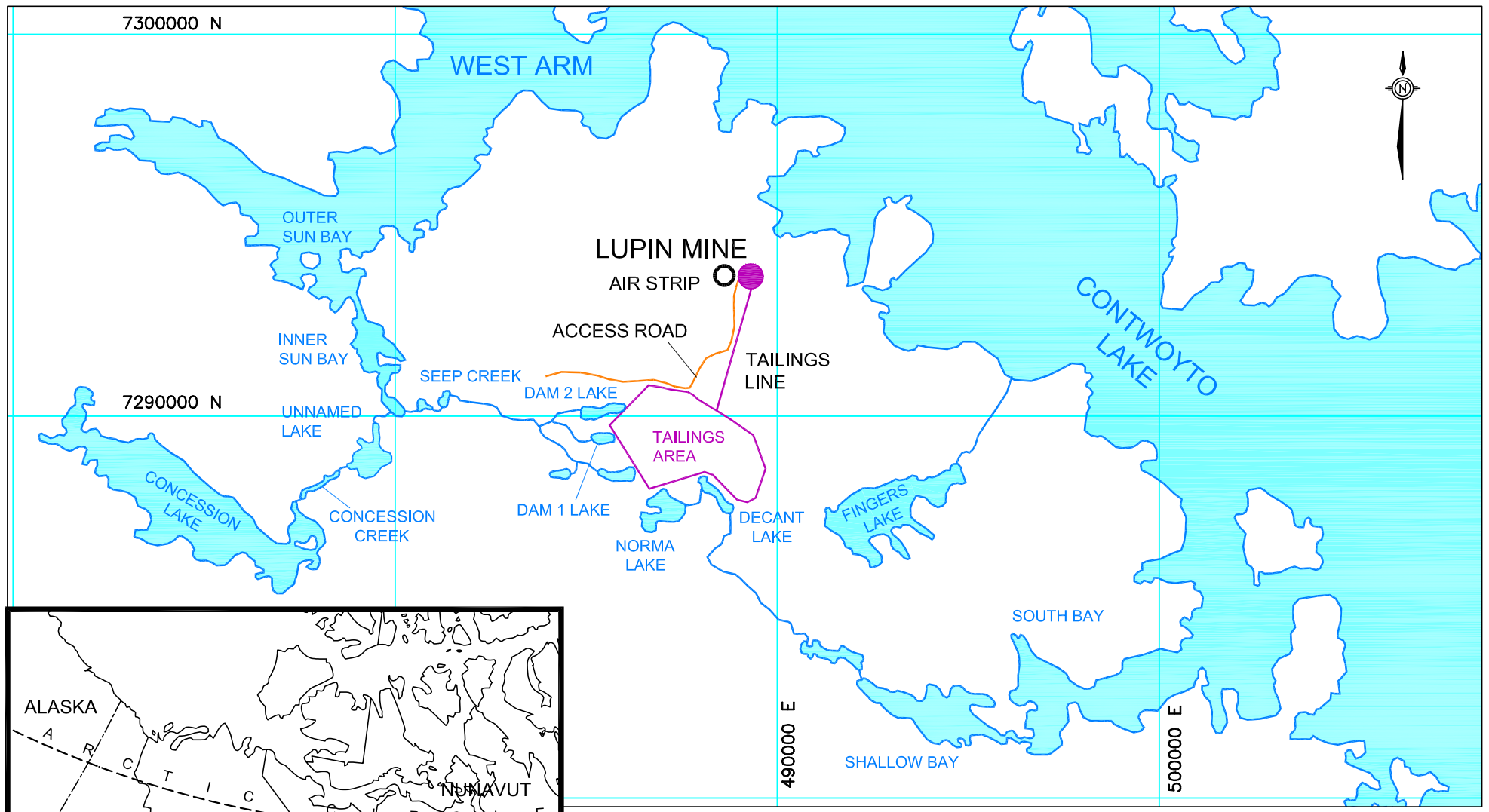
Burn, C.R. 2002. Tundra lakes and permafrost, Richards Island, western Arctic coast, Canada. Canadian Journal of Earth Sciences 39: 1281-1298.

Kerr, D.E., Ward, B.C. and Dredge, L.A. 2000. Surficial Geology, Contwoyto Lake, Northwest Territories-Nunavut. "A" Series Map 1978A. Geological Survey of Canada.

National Atlas Information Service. 1995. Canada: Permafrost, Map MCR 4177. In *The National Atlas of Canada 5th Edition.* Natural Resources Canada.

FIGURES

R:\CAD\2004\1330-Engin\1321\04-1321-022\1000\ Drawing file: Fig 1 LOCATION MAP.dwg Oct 29, 2004 - 10:37am



PROJECT

KINROSS GOLD CORPORATION
STUDIES RELATED TO WATER LICENCE REQUIREMENTS AND IN SUPPORT OF RECLAMATION PLANNING

TITLE

LUPIN MINE LOCATION MAP

Golder Associates
Calgary, Alberta

PROJECT 04-1321-022.1000			FILE No.		LOCATION MAP
DESIGN	PRT	21/10/04	SCALE	1:150000	REV. 1
CADD	PSR	21/10/04	FIGURE: 1		
CHECK	PRT	21/10/04			
REVIEW					

LEGEND

QUATERNARY
HOLOCENE

NONGLACIAL ENVIRONMENT

O — **ORGANIC DEPOSITS:** peat and muck up to 1 m thick; formed predominantly by the accumulation of vegetative material; occurs in depressions, along valley bottoms and in areas once submerged by glacial lakes where they may overlie fine-grained lacustrine sediments; may contain ice-wedge polygons. Small unmapped organic deposits occur in most terrain units

A — **ALLUVIAL DEPOSITS:** gravel to silt size sediment, 1 to 5 m thick, deposited by modern streams and rivers; deposits range from massive to well stratified; associated with meandering, braided, and floodplain environments

PLEISTOCENE (WISCONSIN GLACIATION)
GLACIAL ENVIRONMENT

L — **GLACIOLACUSTRINE DEPOSITS:** silt, sand, and gravel; 1 to 10 m thick; cross-stratified to planar bedded sands; deposited in temporary glacier-dammed lakes; associated with deltas and raised beaches indicated by symbols; may contain massive ground ice

GLACIOFLUVIAL DEPOSITS: sand, gravel, and minor silt; 1 to 20 m thick; sorting ranges from good to poor, and stratification from massive or cross-stratified to planar bedded; deposited by water flowing from, or in contact with, glacier ice; may contain massive ground ice

G2 — **Outwash:** rounded gravel and sand; massive to cross-stratified; probably less than 20 m thick; occurs as braided fans and outwash plains, commonly containing ice-wedge polygons

G1 — **Esker sediments:** sand, silt, and gravel; in planar, cross-stratified, and massive beds; 1 to 20 m thick; forms ridges with both sharp-crested and flat-topped segments, mounds, and flanking aprons; deposited at or behind the ice margin; formed subglacially or in subaerially exposed ice-walled channels. Zones of washed bedrock (meltwater scours) between esker segments, isolated kame deposits, and boulder lags are shown by symbols between esker segments

TILL DEPOSITS: unsorted glacial debris (diamicton), consisting of a silty sand matrix containing pebbles, cobbles, and boulders, with minor lenses of sorted sediments; deposited beneath or along the margin of glaciers as lodgment till, meltout till, and gravity flow deposits; may contain massive ground ice

T3 — **Hummocky till:** greater than 2 m thick; forms irregular to rolling terrain with relief up to 15 m, locally forming hills and ridges up to 3 km long; some areas have abundant small meltwater channels and lag concentrations of boulders in depressions. Stabilized retrogressive thaw flow slides may be indicative of ice-rich till

T2 — **Till blanket:** greater than 2 m thick; occurs as till plains or as drumlinoids. Small rock outcrops in this unit are shown by symbols

T1 — **Till veneer:** less than 2 m thick; rock structure is generally visible on airphotos; unit includes patches of bedrock and till blanket

PRE-QUATERNARY

BEDROCK: Archean metasedimentary, metavolcanic, granitic, and gneissic rocks; Proterozoic sedimentary rocks, mafic dykes and sills; may include patches of till veneer or glaciofluvial deposits; areas of shattered and frost-heaved rock are designated by symbols

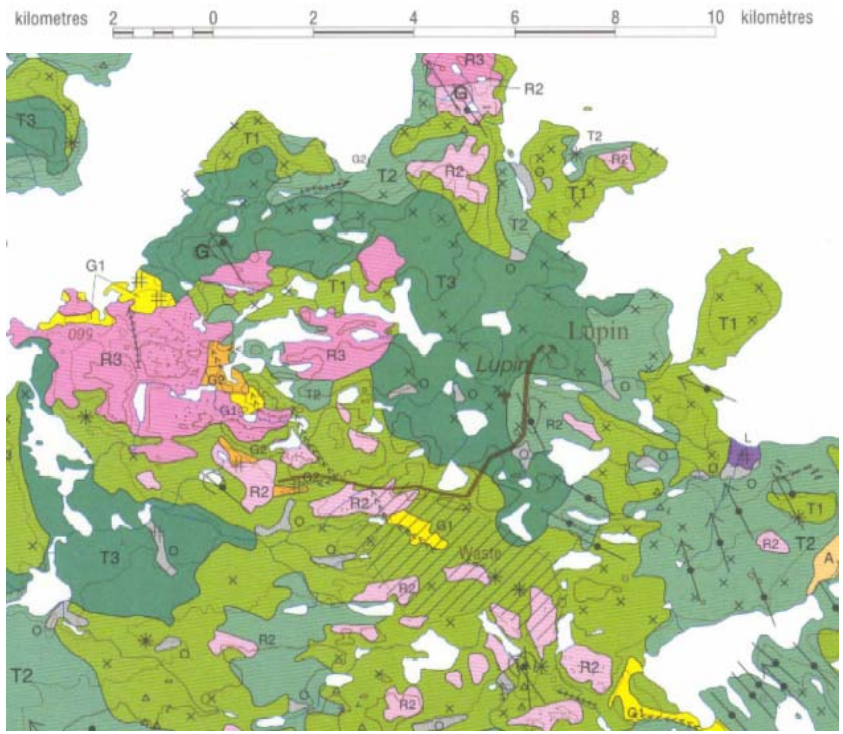
R5 — Gabbro sills

R4 — Sedimentary rocks

R3 — Granitic and gneissic rocks

R2 — Metasedimentary rocks

R1 — Metavolcanic rocks



Geological boundary
Retrogressive thaw flow slide
Solifluction lobe
Frost heaved and shattered rock
Thermokarst
Ice-wedge polygon
Raised beach
Area of meltwater scour
Lag concentration of glacially abraded boulders
Subglacial or proglacial meltwater channel
Esker (direction of flow known, unknown)
Kames
Moraine

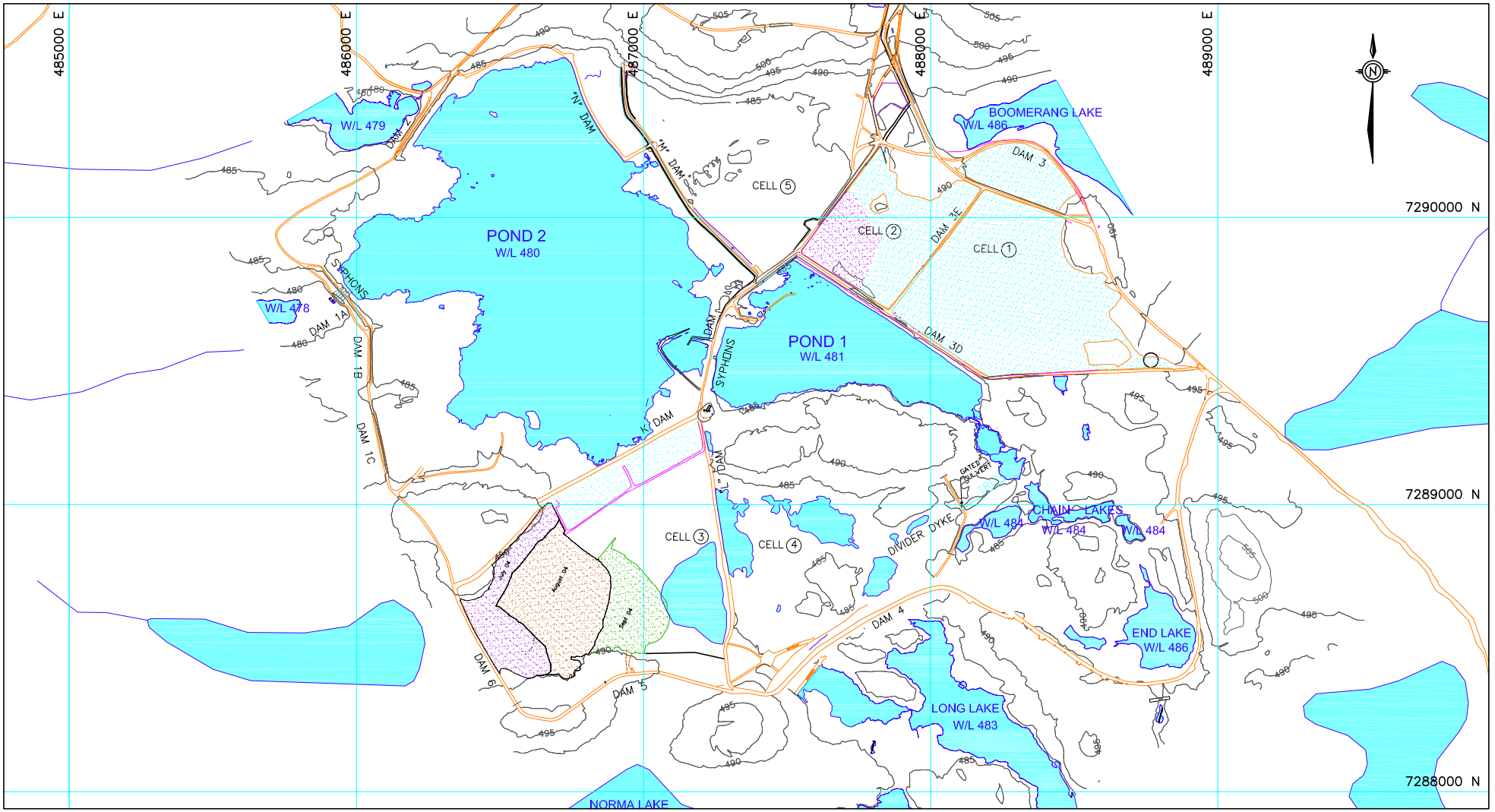
Drumlinoid till form
Crag-and-tail landform
Roche moutonnée or whaleback
Striation (ice flow direction known, 1 = oldest)
Gossan
Small rock outcrop
Sample site
Mine waste and settling ponds
(symbol overlies pre-development geology indicated on map)

Figure derived from:

Kerr, D.E., Ward, B.C and Dredge, L.A. 2000. Surficial Geology, Contwoyto Lake, Northwest Territories-Nunavut. "A" Series Map 1978A. Geological Survey of Canada.

Golder Associates	Kinross Gold Corporation Studies Related to Water License Requirements and in Support of Reclamation Planning	
Surficial Geology		
DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 2

R:\CAD\2004\1330-Engin\1321\04-1321-022\1000\ Drawing file: Fig 3 Lupin Tailings Area.dwg Oct 29, 2004 - 10:39am



LEGEND

ESKER COVER

REFERENCE

BASE MAP PROVIDED BY KINROSS GOLD CORPORATION

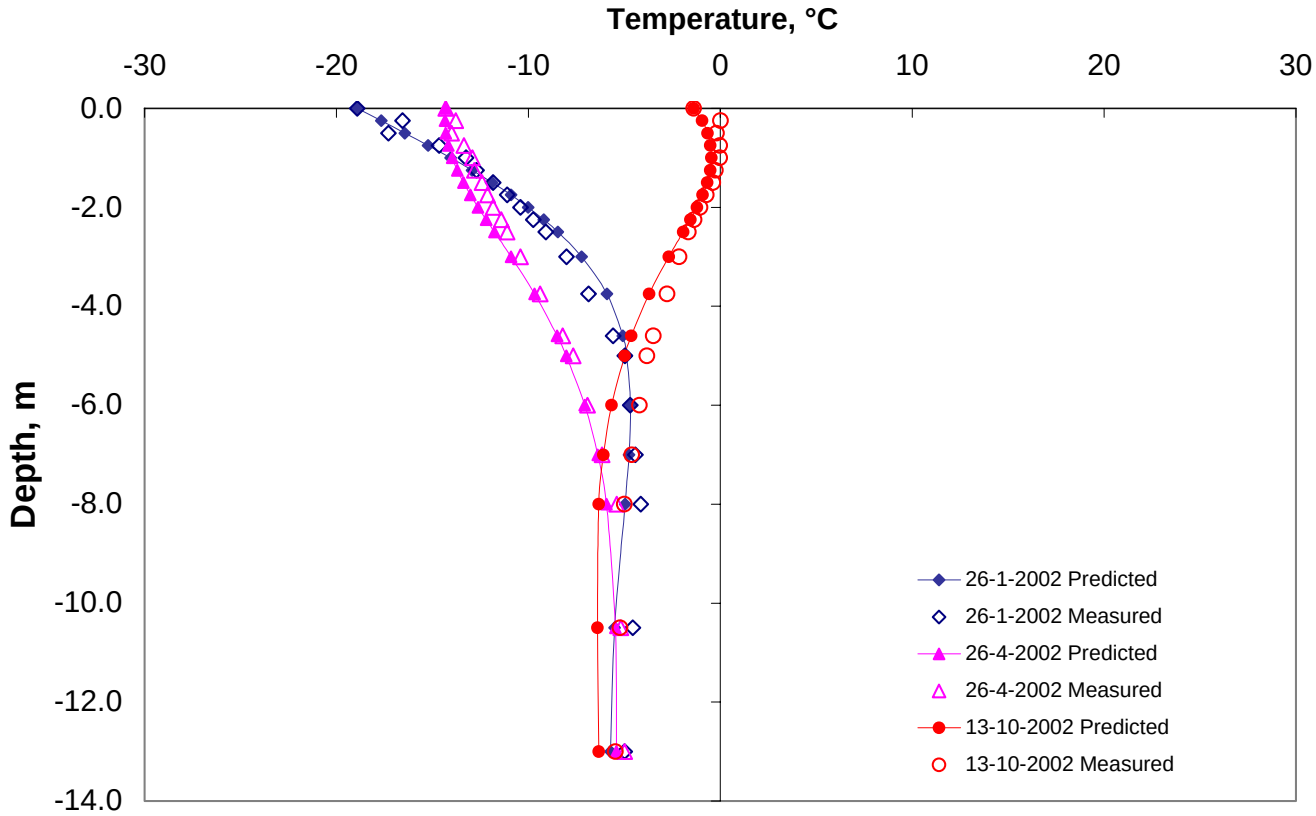
400 0 400
SCALE METRES

PROJECT
KINROSS GOLD CORPORATION
STUDIES RELATED TO WATER LICENCE REQUIREMENTS
AND IN SUPPORT OF RECLAMATION PLANNING

TITLE
LUPIN TAILINGS AREA

Golder Associates
Calgary, Alberta

PROJECT 04-1321-022.1000			FILE No. Lupin Tailings Area		
DESIGN	PRT	21/10/04	SCALE AS SHOWN	REV.	0
CADD	PSR	21/10/04	FIGURE: 3		
CHECK	PRT	21/10/04			
REVIEW					

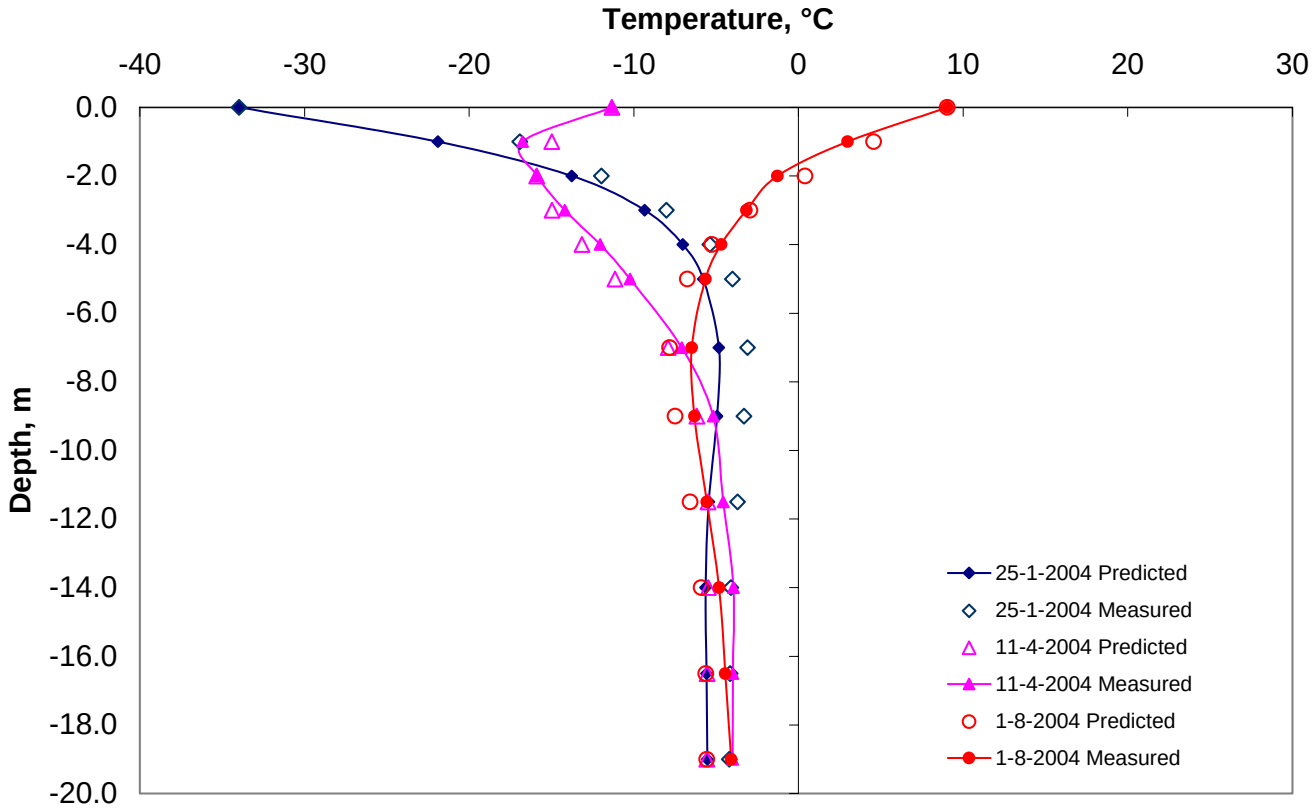


Golder Associates

Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Predicted Behaviour of Thermistor TC1-3

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 4

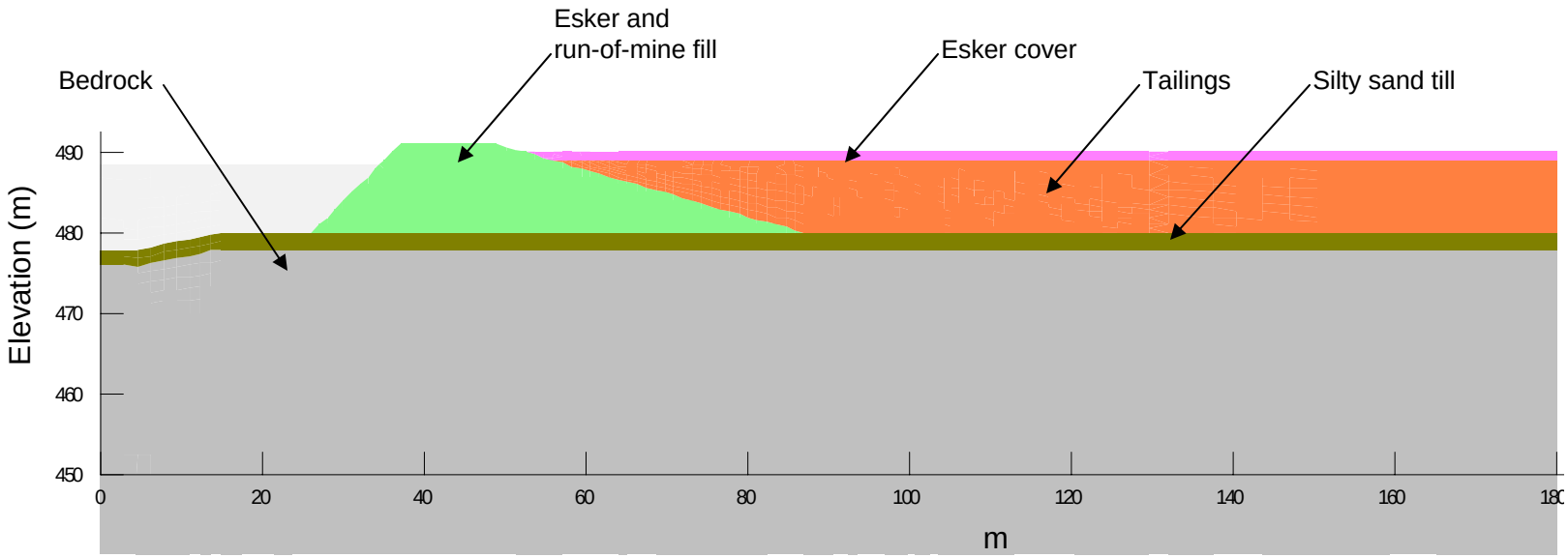


Golder Associates

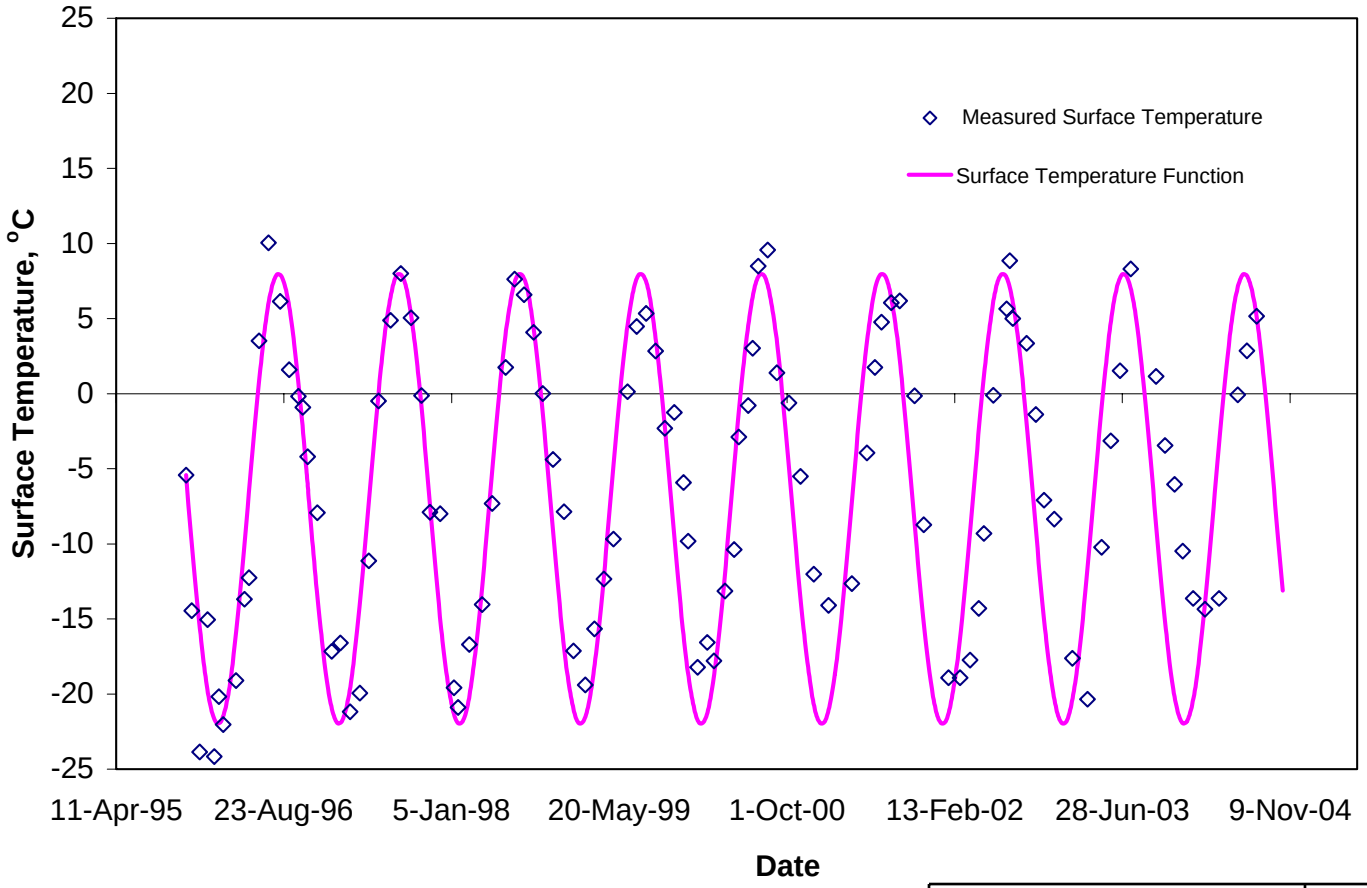
Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Predicted Behaviour of Thermistor D1A-00-1S

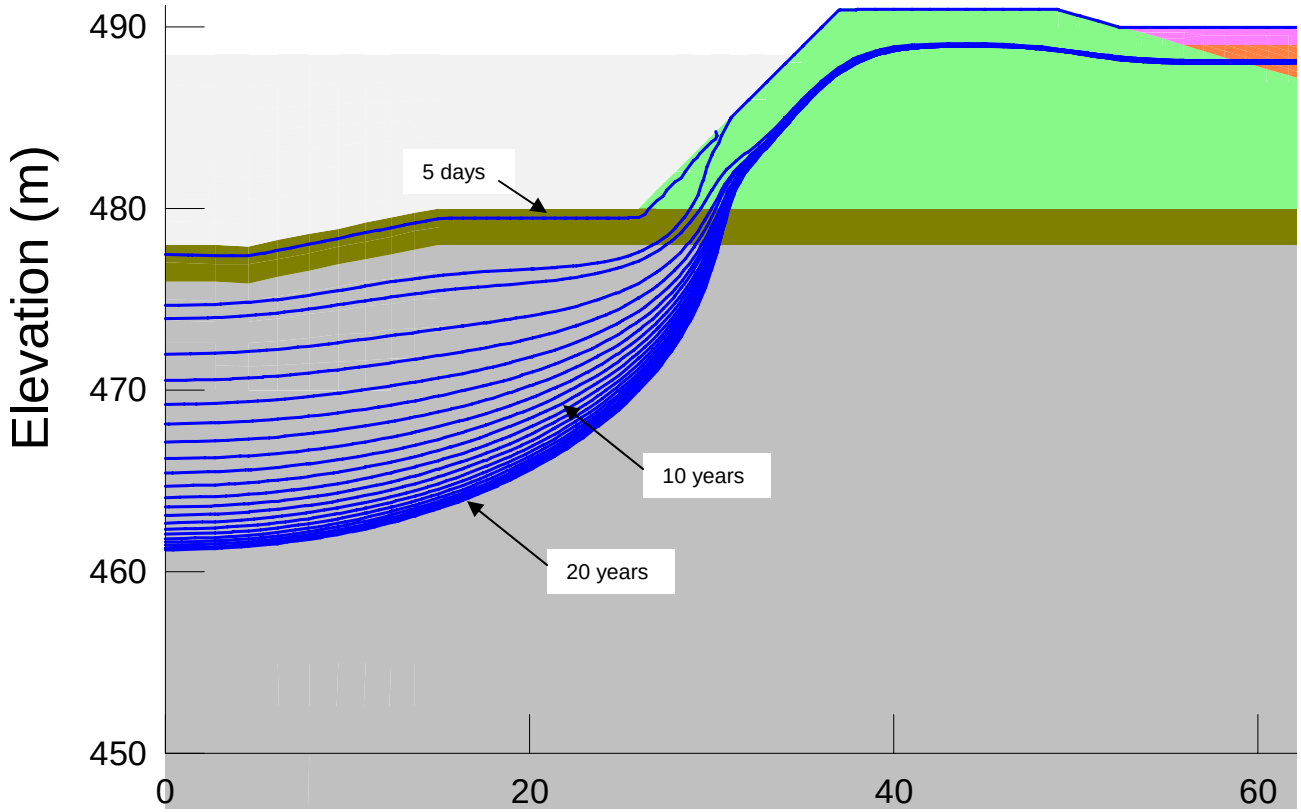
DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 5



Golder Associates	Kinross Gold Corporation Studies Related to Water License Requirements and in Support of Reclamation Planning
Analysed Cross Section: K-Dam	
DRAWN: PRT / APPROVED: / DATE: 21 October 2004	
PROJECT: 04-1321-022	FIGURE: 6



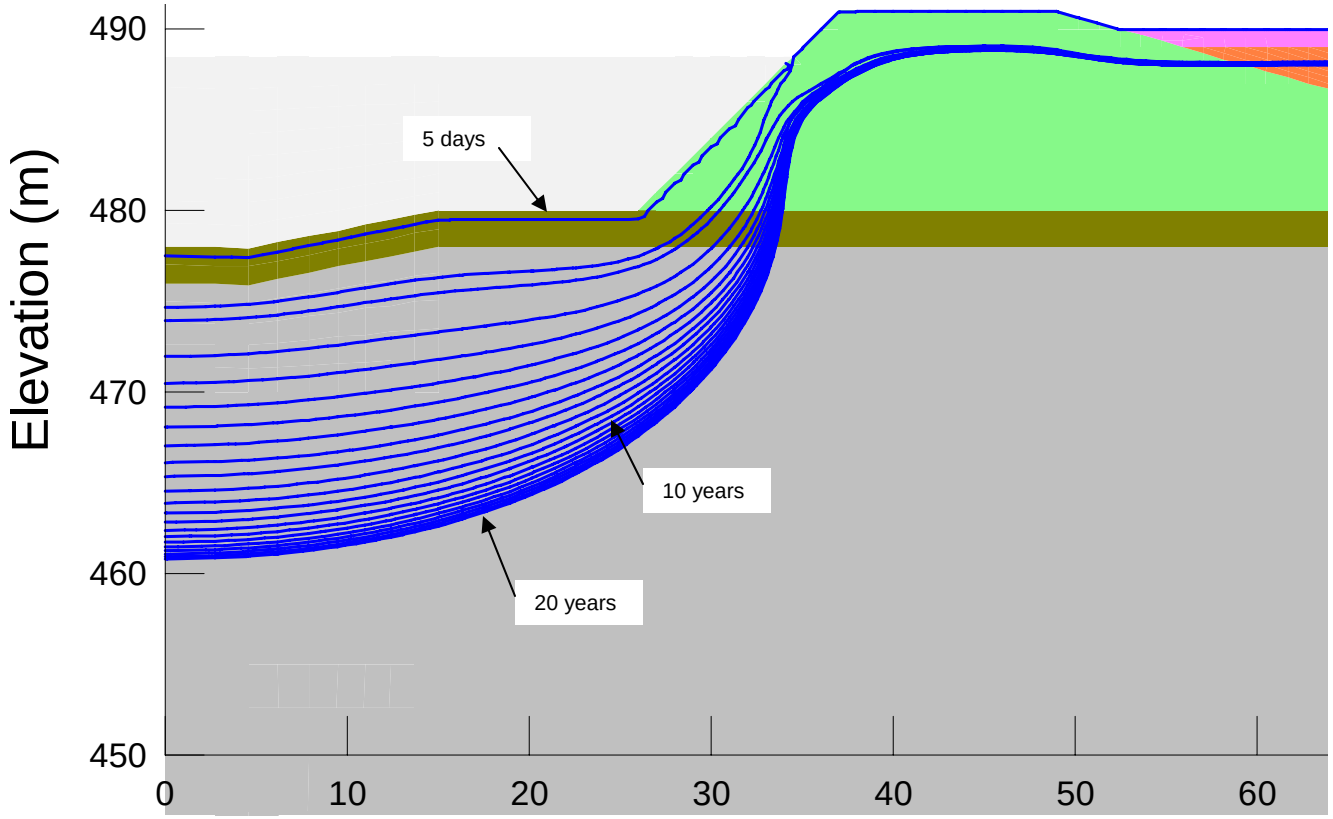
Golder Associates	Kinross Gold Corporation Studies Related to Water License Requirements and in Support of Reclamation Planning
Predicted Surface Temperature Thermistor TC1-3	
DRAWN: PRT / APPROVED: / DATE: 21 October 2004	
PROJECT: 04-1321-022	FIGURE: 7



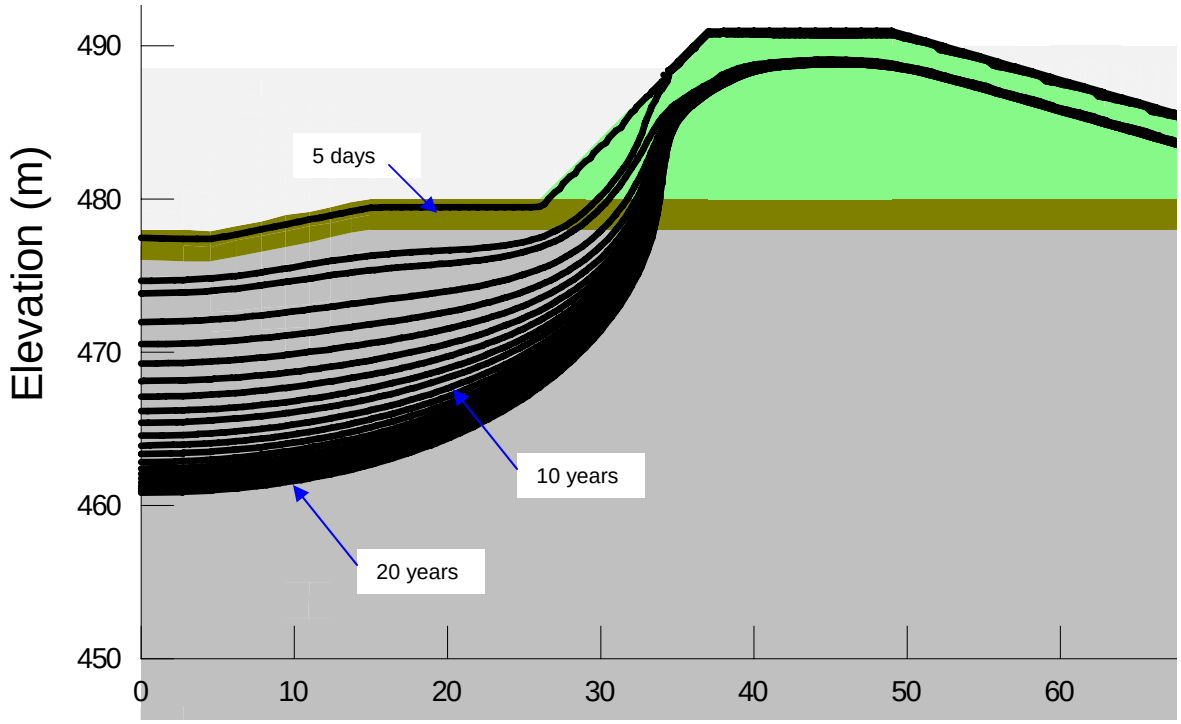
Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Progression of 0°C Isotherm
5 m of Water Downstream

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 8



Golder Associates	Kinross Gold Corporation Studies Related to Water License Requirements and in Support of Reclamation Planning
Progression of 0°C Isotherm 8.5 m of Water Downstream	
DRAWN: PRT / APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022	FIGURE: 9



Golder Associates

Kinross Gold Corporation
Studies Related to Water License Requirements and in Support of Reclamation Planning

Progression of 0°C Isotherm
8.5 m of Water Downstream
No Retained Tailings

DRAWN: PRT	APPROVED:	DATE: 21 October 2004
PROJECT: 04-1321-022		FIGURE: 10

APPENDIX A

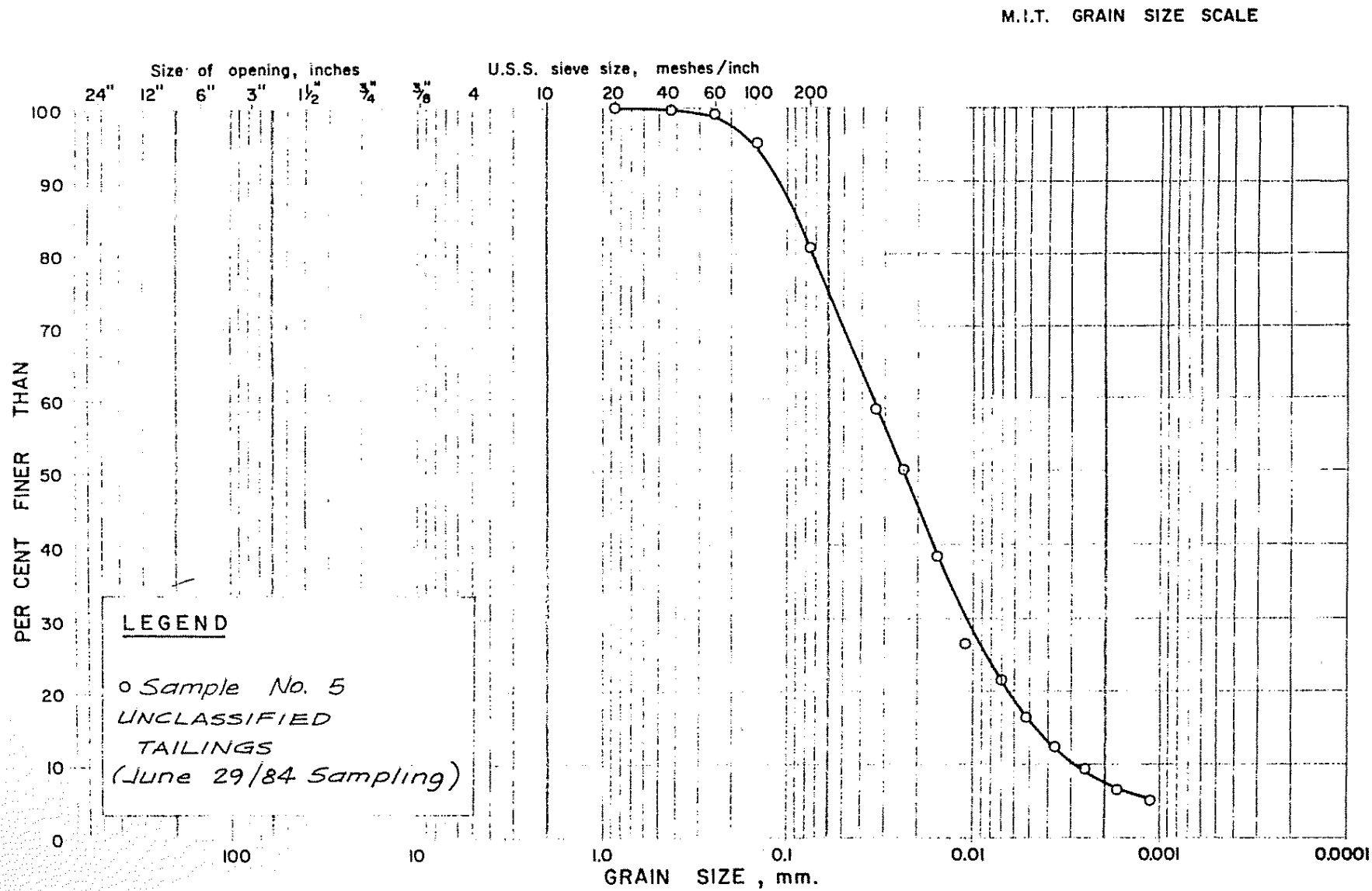
LABORATORY TEST RESULTS

Project No. 842-2052 Drawn RK Reviewed JS Date FEB '85

GRAIN SIZE DISTRIBUTION
TAILINGS

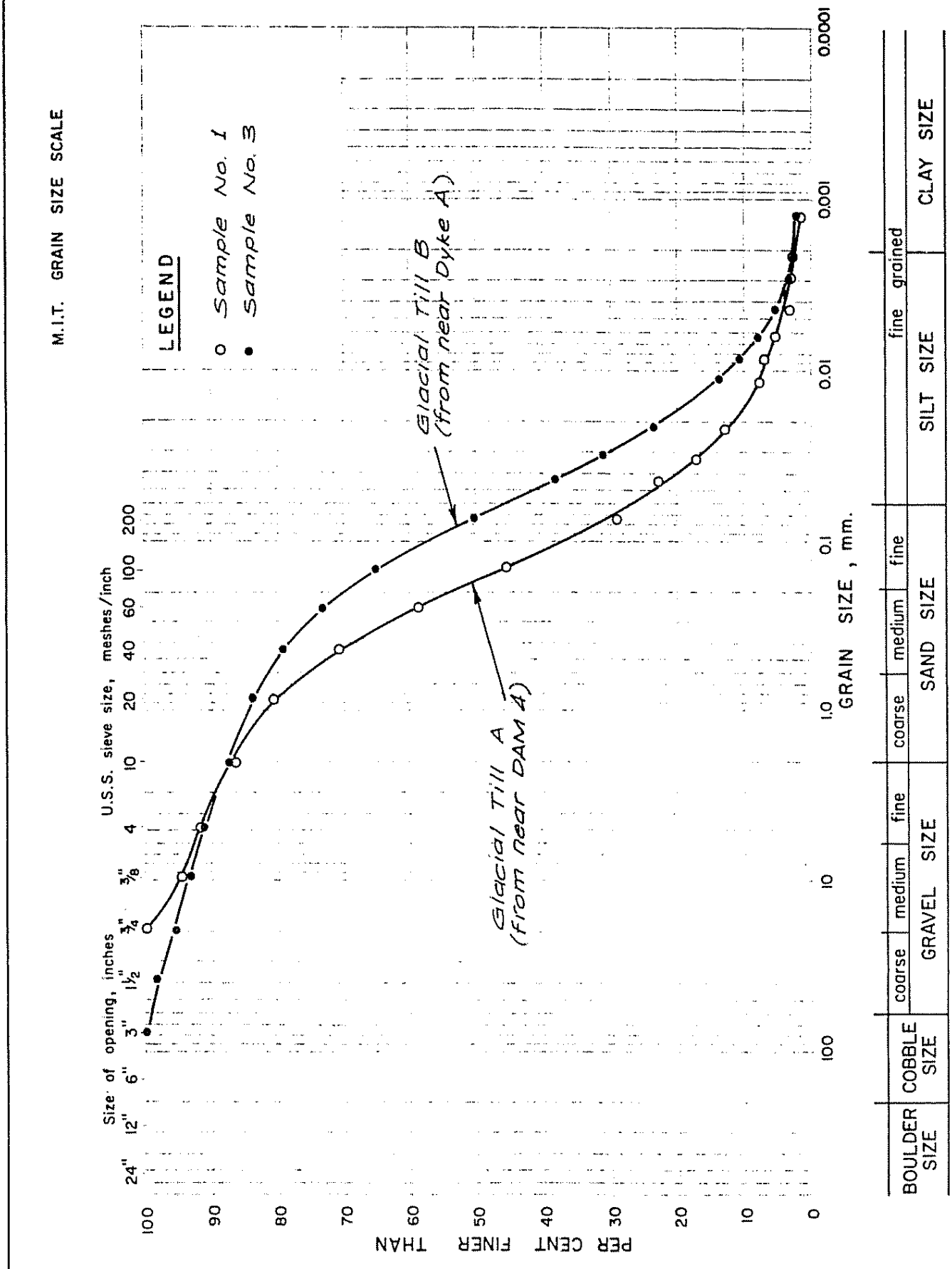
Figure A-1

Golder Associates



GRAIN SIZE DISTRIBUTION
GLACIAL TILL

Figure A-2

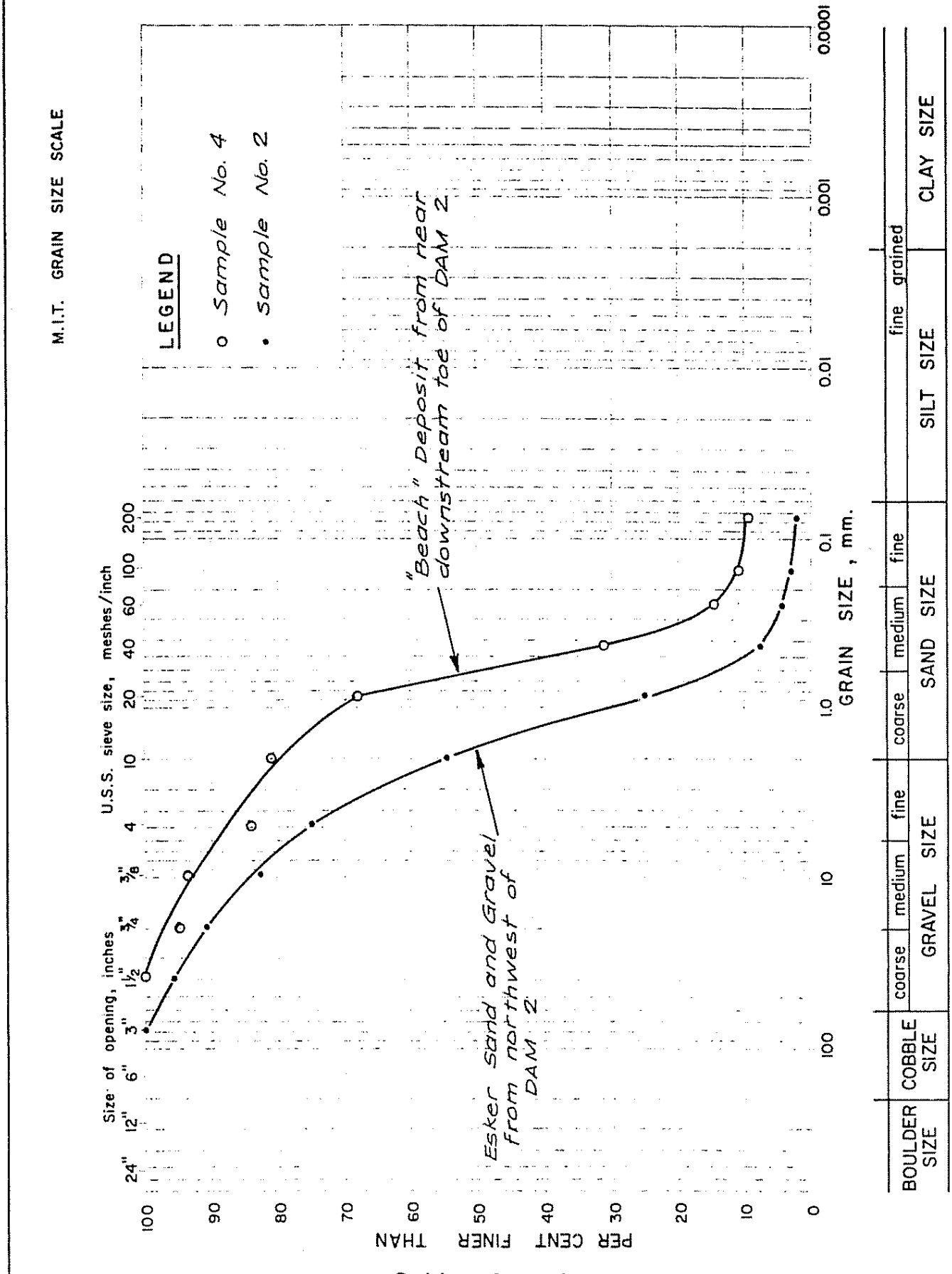


Project No. 842-2052 Drawn RK Reviewed Date FEB '85

Golder Associates

GRAIN SIZE DISTRIBUTION
ESKER SAND

Figure A-3



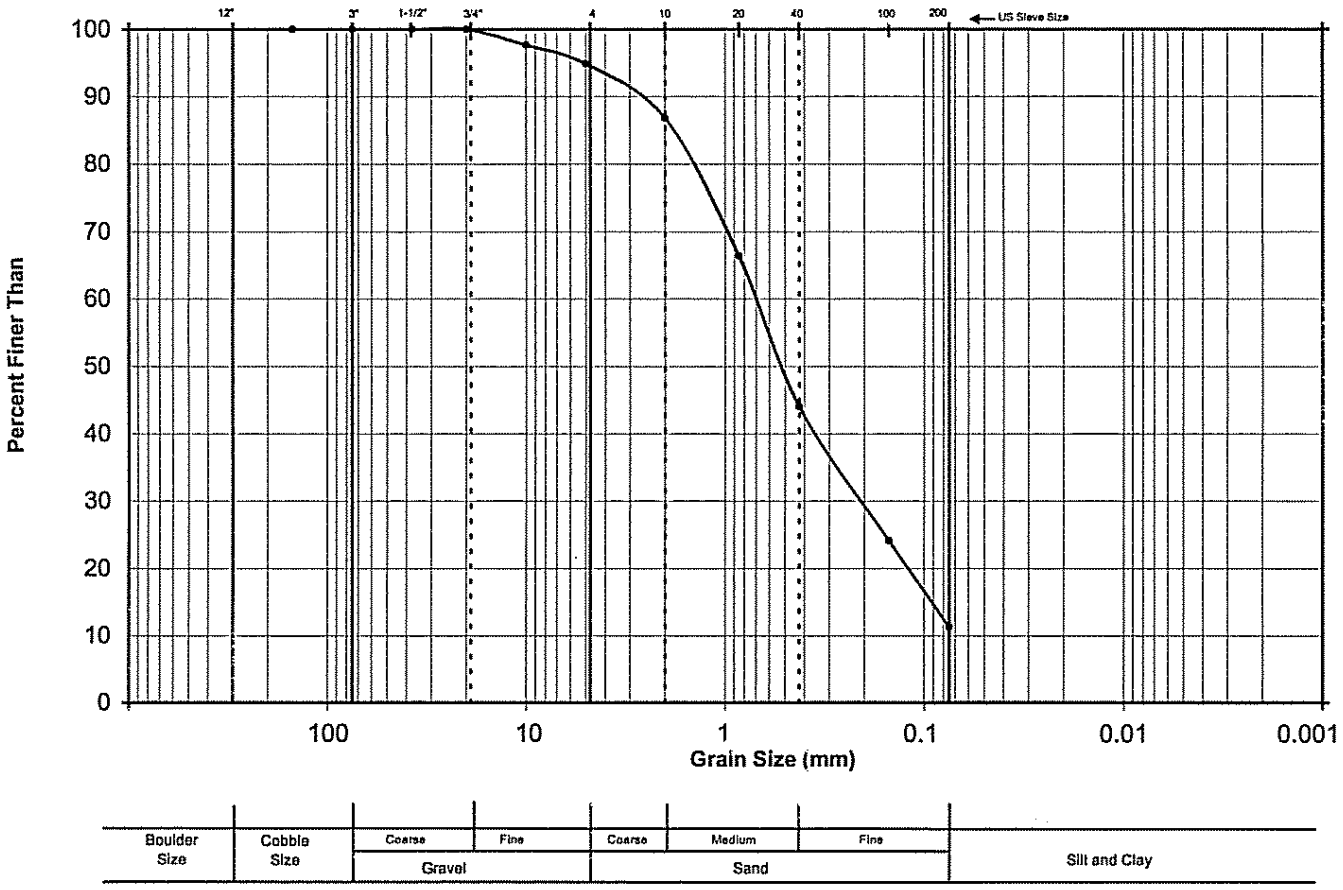
Project No. 842-2052 Drawn RK Reviewed JC Date FEB '85

Golder Associates

Golder Associates

PARTICLE SIZE ANALYSIS OF SOIL
(ASTM D422)

Project No.: 04-1321-022 Lab No.: 560401
Project Title: Lupin
Borehole: - Sample No.: Esker sample
Depth: -
Date Tested: 21-Sep-04 By: LT

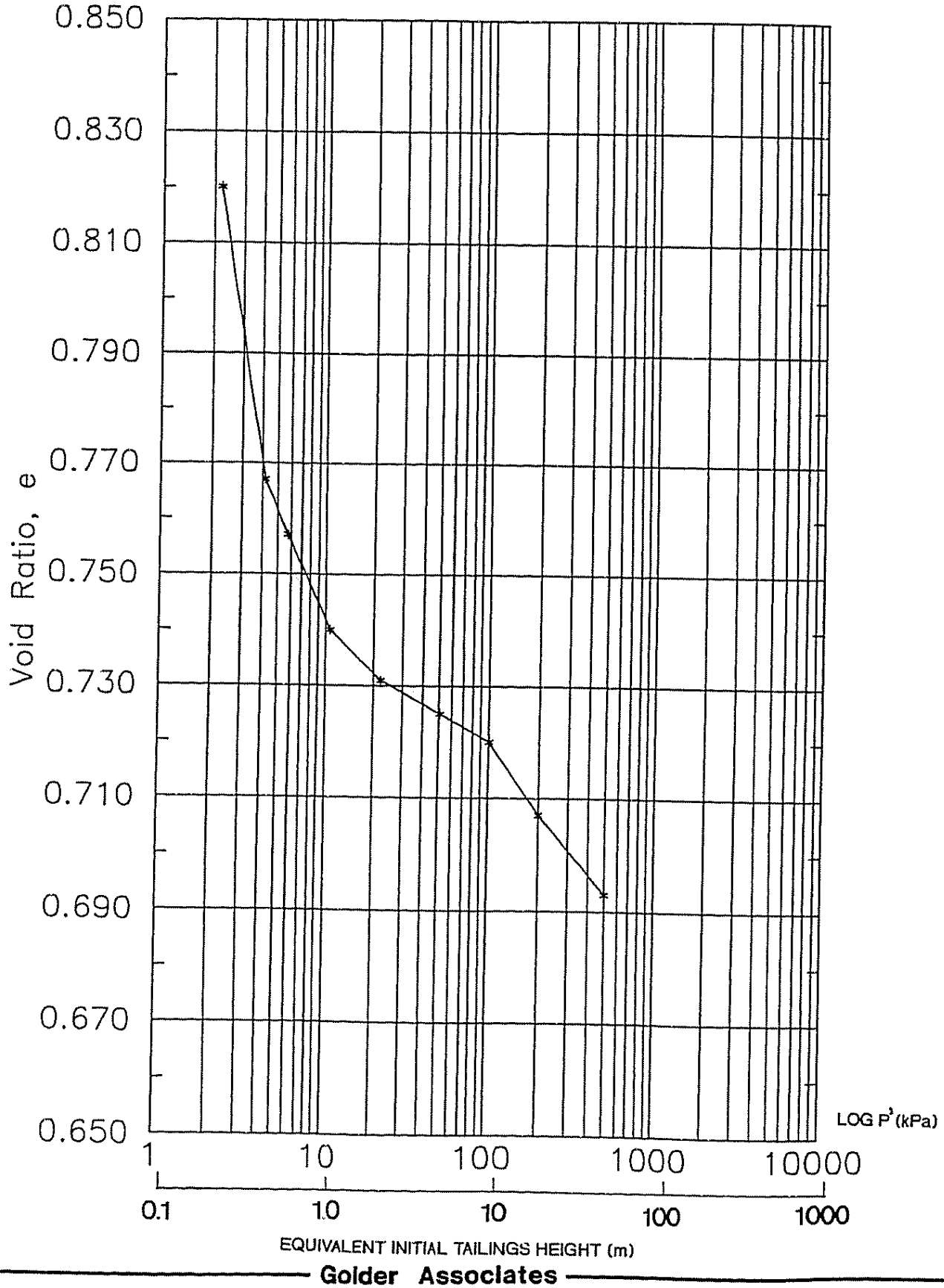


Diameter of Sieve (mm)	Percent Passing (%)
150.000	100.0
75.000	100.0
37.500	100.0
20.000	100.0
10.000	97.7
5.000	94.9
2.000	86.8
0.850	66.3
0.425	44.0
0.150	24.1
0.075	11.3

Comments/Limits:

OEDOMETER TEST RESULT SUMMARY
LUPIN TAILS TEST 3 (UNCEMENTED)
E LOG P

Figure A-5

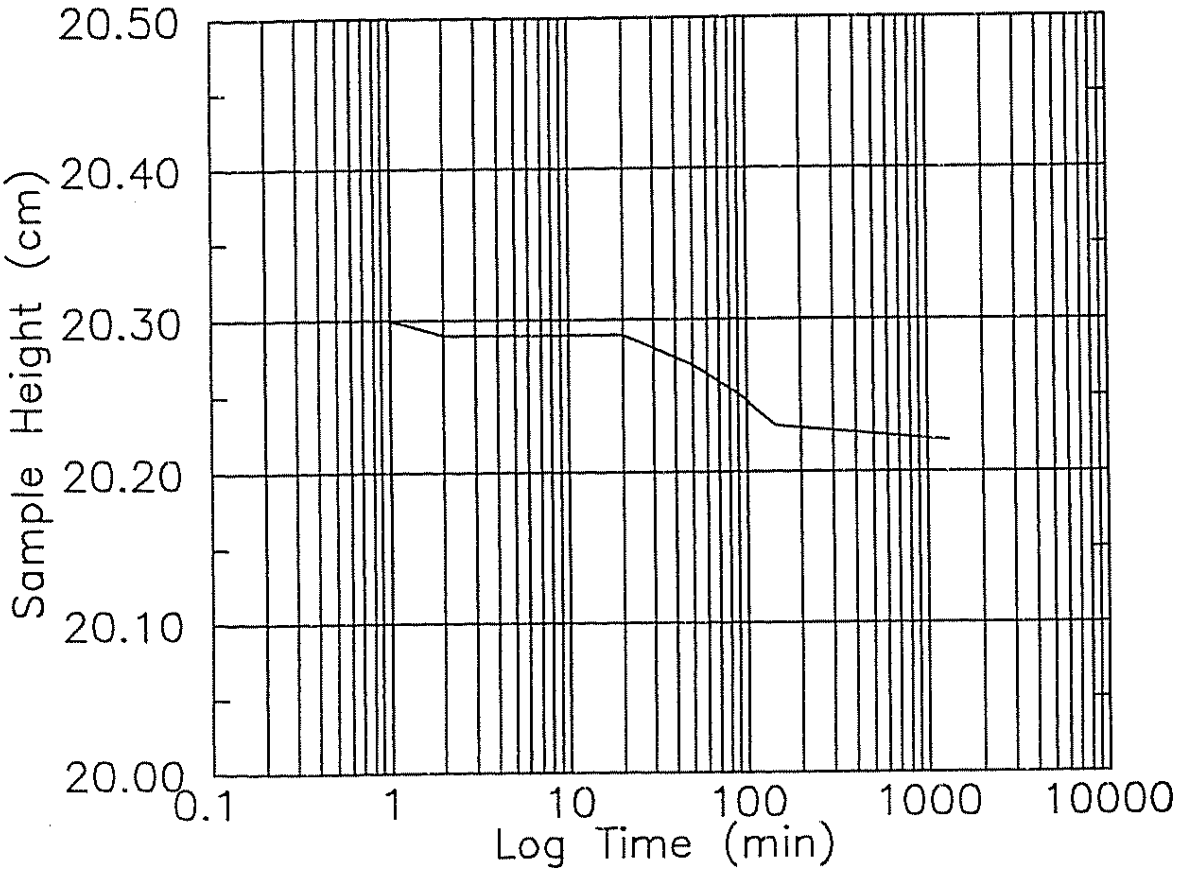


PROJECT No. 942-2436 DRAWN GCR REVIEWED DATE 20 APR 1995

Golder Associates

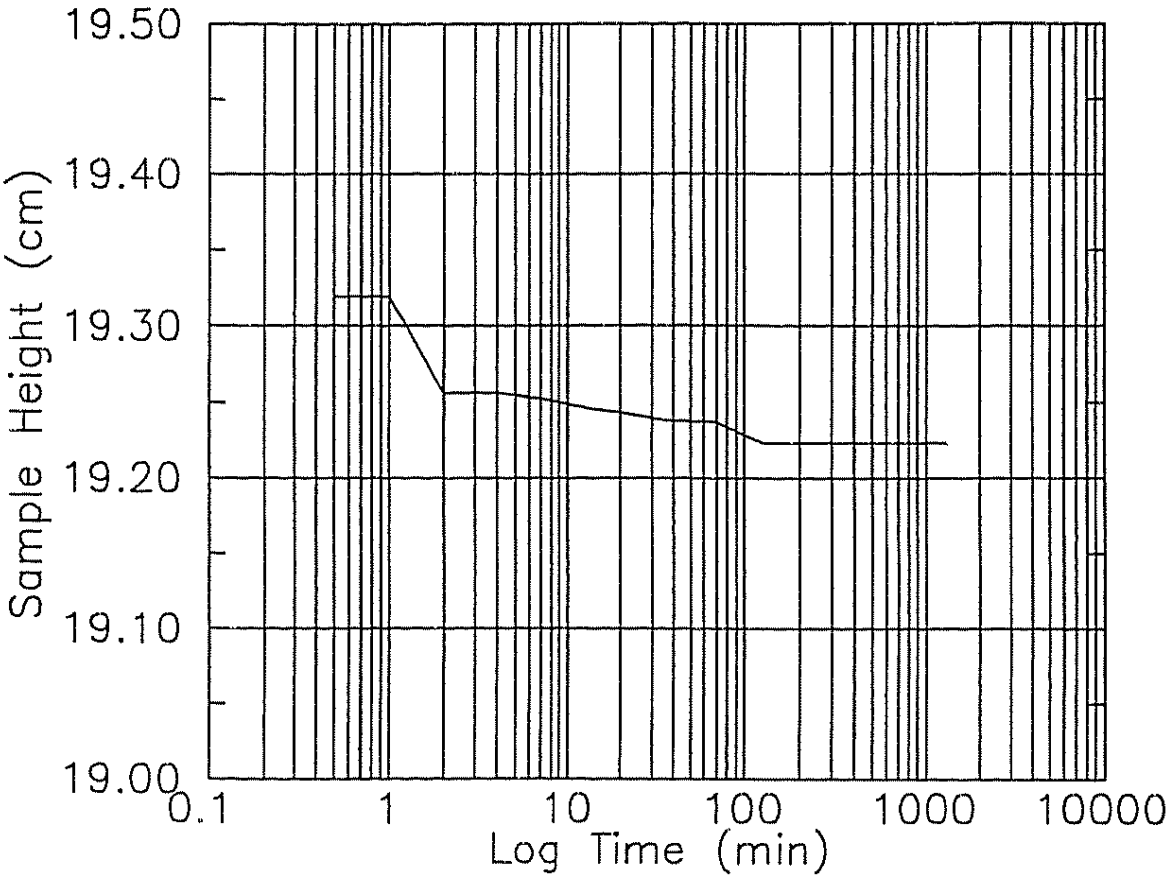
LUPIN TAILINGS TEST 3 (UNCEMENTED)
CONSOLIDATION TEST 2.20 kPa LOAD

Figure A-6



LUPIN TAILINGS TEST 3 (UNCEMENTED)
CONSOLIDATION TEST 22.12 kPa LOAD

Figure A-7



ETL EnviroTest
LABORATORIES
A DIVISION OF ETL CHEMSPEC ANALYTICAL LIMITED

ANALYTICAL REPORT

GOLDER ASSOCIATES LTD
ATTN: PETER THOMSON
9TH FLOOR 940 6 AVE SW
CALGARY AB T2P 3T1

DATE: 15-SEP-04 01:05 PM

Lab Work Order #: L201953 **Sampled By:** DJH **Date Received:** 30-AUG-04
Project P.O. #: NA
Project Reference: 04-1321-022

Comments: Method modification by client as follows: Sample -1 was extracted using -2 as the extraction fluid. Both samples were then run for Total Metals-Low Level.

RON MINKS
Director of Operations, Calgary

K. Robertson

KERRY ROBERTSON
Client Service Specialist

THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN AUTHORITY OF THE LABORATORY.
ANY REMAINING SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

LABORATORY ACCREDITATIONS:
- **STANDARDS COUNCIL OF CANADA IN COOPERATION WITH THE CANADIAN ASSOCIATION FOR ENVIRONMENTAL ANALYTICAL LABORATORIES (CAEAL)** FOR SPECIFIC TESTS AS REGISTERED BY THE COUNCIL (EDMONTON, CALGARY, GRANDE PRAIRIE, SASKATOON, WINNIPEG, THUNDER BAY, WATERLOO)
- **AMERICAN INDUSTRIAL HYGIENE ASSOCIATION (AIHA)** IN THE INDUSTRIAL HYGIENE PROGRAM (EDMONTON, WINNIPEG)
- **STANDARDS COUNCIL OF CANADA IN COOPERATION WITH THE CANADIAN FOOD INSPECTION AGENCY (CFIA)** FOR FERTILIZER AND FEED TESTING (SASKATOON) AND FOR MICROBIOLOGICAL TESTING IN FOOD (WINNIPEG)

LABORATORY RECOGNITIONS:
- **STANDARDS COUNCIL OF CANADA** - GLP COMPLIANT FACILITY (EDMONTON, OTTAWA)

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L201953-1 ESKER-SI								
Sample Date: 30-AUG-04								
Matrix: SOIL								
Total Metals								
Total Trace Metals (Low Level)								
Silver (Ag)	<0.0004	RAMB	0.0004	mg/L		08-SEP-04	MX	R216805
Aluminum (Al)	<0.02		0.02	mg/L		08-SEP-04	MX	R216805
Arsenic (As)	0.0186		0.0004	mg/L		08-SEP-04	MX	R216805
Boron (B)	0.21		0.02	mg/L		08-SEP-04	MX	R216805
Barium (Ba)	0.0370		0.0002	mg/L		08-SEP-04	MX	R216805
Beryllium (Be)	<0.001		0.001	mg/L		08-SEP-04	MX	R216805
Bismuth (Bi)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Cadmium (Cd)	0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
Cobalt (Co)	0.0591		0.0002	mg/L		08-SEP-04	MX	R216805
Chromium (Cr)	<0.0008		0.0008	mg/L		08-SEP-04	MX	R216805
Copper (Cu)	0.035		0.001	mg/L		08-SEP-04	MX	R216805
Molybdenum (Mo)	0.0573		0.0001	mg/L		08-SEP-04	MX	R216805
Nickel (Ni)	0.237		0.0002	mg/L		08-SEP-04	MX	R216805
Lead (Pb)	0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Antimony (Sb)	0.0009		0.0004	mg/L		08-SEP-04	MX	R216805
Selenium (Se)	0.0010		0.0004	mg/L		08-SEP-04	MX	R216805
Tin (Sn)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Strontium (Sr)	2.33		0.0002	mg/L		08-SEP-04	MX	R216805
Titanium (Ti)	<0.005		0.005	mg/L		08-SEP-04	MX	R216805
Thallium (Tl)	0.0002		0.0001	mg/L		08-SEP-04	MX	R216805
Uranium (U)	0.0006		0.0001	mg/L		08-SEP-04	MX	R216805
Vanadium (V)	0.0011		0.0002	mg/L		08-SEP-04	MX	R216805
Zinc (Zn)	0.129		0.004	mg/L		08-SEP-04	MX	R216805
Total Major Metals								
Calcium (Ca)	153		0.5	mg/L		07-SEP-04	HAS	R216301
Potassium (K)	21.5		0.1	mg/L		07-SEP-04	HAS	R216301
Magnesium (Mg)	8.5		0.1	mg/L		07-SEP-04	HAS	R216301
Sodium (Na)	269		1	mg/L		07-SEP-04	HAS	R216301
Iron (Fe)	0.015		0.005	mg/L		07-SEP-04	HAS	R216301
Manganese (Mn)	0.172		0.001	mg/L		07-SEP-04	HAS	R216301
Mercury (Hg)-Total	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
L201953-2 CELL 5 WATER								
Sample Date: 30-AUG-04								
Matrix: WATER								
Total Metals								
Total Trace Metals (Low Level)								
Silver (Ag)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Aluminum (Al)	0.02		0.02	mg/L		08-SEP-04	MX	R216805
Arsenic (As)	0.0769		0.0004	mg/L		08-SEP-04	MX	R216805
Boron (B)	0.21		0.02	mg/L		08-SEP-04	MX	R216805
Barium (Ba)	0.0329		0.0002	mg/L		08-SEP-04	MX	R216805
Beryllium (Be)	<0.001		0.001	mg/L		08-SEP-04	MX	R216805
Bismuth (Bi)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Cadmium (Cd)	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805
Cobalt (Co)	0.0489		0.0002	mg/L		08-SEP-04	MX	R216805
Chromium (Cr)	<0.0008		0.0008	mg/L		08-SEP-04	MX	R216805
Copper (Cu)	0.776		0.001	mg/L		08-SEP-04	MX	R216805
Molybdenum (Mo)	0.0616		0.0001	mg/L		08-SEP-04	MX	R216805
Nickel (Ni)	0.296		0.0002	mg/L		08-SEP-04	MX	R216805

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L201953-2 CELL 5 WATER								
Sample Date: 30-AUG-04								
Matrix: WATER								
Total Metals								
Total Trace Metals (Low Level)								
Lead (Pb)	0.0002		0.0001	mg/L		08-SEP-04	MX	R216805
Antimony (Sb)	0.0018		0.0004	mg/L		08-SEP-04	MX	R216805
Selenium (Se)	0.0005		0.0004	mg/L		08-SEP-04	MX	R216805
Tin (Sn)	<0.0004		0.0004	mg/L		08-SEP-04	MX	R216805
Strontium (Sr)	2.45		0.0002	mg/L		08-SEP-04	MX	R216805
Titanium (Ti)	<0.005		0.005	mg/L		08-SEP-04	MX	R216805
Thallium (Tl)	<0.0001		0.0001	mg/L		08-SEP-04	MX	R216805
Uranium (U)	0.0008		0.0001	mg/L		08-SEP-04	MX	R216805
Vanadium (V)	0.0011		0.0002	mg/L		08-SEP-04	MX	R216805
Zinc (Zn)	0.765		0.004	mg/L		08-SEP-04	MX	R216805
Total Major Metals								
Calcium (Ca)	161		0 5	mg/L		07-SEP-04	HAS	R216301
Potassium (K)	21.7		0.1	mg/L		07-SEP-04	HAS	R216301
Magnesium (Mg)	8.0		0.1	mg/L		07-SEP-04	HAS	R216301
Sodium (Na)	276		1	mg/L		07-SEP-04	HAS	R216301
Iron (Fe)	0.012		0.005	mg/L		07-SEP-04	HAS	R216301
Manganese (Mn)	0.072		0.001	mg/L		07-SEP-04	HAS	R216301
Mercury (Hg)-Total	<0.0002		0.0002	mg/L		08-SEP-04	MX	R216805

Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier key listed:

Qualifier	Description
RAMB	Result Adjusted For Method Blank

Methods Listed (if applicable):

ETL Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
HG-TOT-LOW-ED	Water	Mercury, (Hg)-Total	EPA3015	EPA 6020
MET1-TOT-LOW-ED	Water	Total Trace Metals (Low Level)	EPA3015	EPA 6020
MET2-TOT-LOW-ED	Water	Total Major Metals	EPA3015	EPA 200.7

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

L201953

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
ED	Enviro-Test Laboratories - Edmonton, Alberta, Canada		

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in enviromental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds. The reported surrogate recovery value provides a measure of method efficiency. The Laboratory warning units are determined under column heading D.L.
mg/kg (units) - unit of concentration based on mass, parts per million
mg/L (units) - unit of concentration based on volume, parts per million
< - Less than
D.L. - Detection Limit
N/A - Result not available. Refer to qualifier code and definition for explanation

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION
UNLESS OTHERWISE STATED, SAMPLES ARE NOT CORRECTED FOR CLIENT FIELD BLANKS
Although test results are generated under strict QA/QC protocols, any unsigned test reports, faxes, or emails are considered preliminary.

Enviro-Test Laboratories has an extensive QA/QC program where all analytical data reported is analyzed using approved referenced procedures followed by checks and reviews by senior managers and quality assurance personnel. However, since the results are obtained from chemical measurements and thus cannot be guaranteed, Enviro-Test Laboratories assumes no liability for the use or interpretation of the results.

APPENDIX IV

ECOLOGICAL RISK ASSESSMENT FOR LUPIN MINE TAILINGS CONTAINMENT AREA *- GOLDER ASSOCIATES, DECEMBER 2004*

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FINAL REPORT

ECOLOGICAL RISK ASSESSMENT FOR THE LUPIN MINE TAILINGS CONTAINMENT AREA

Submitted to:

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Reclamation/Projects Manager, Lupin
Kinross Gold Corporation
Edmonton, Alberta

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December 2004 **04-1373-026**

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EXECUTIVE SUMMARY

Introduction

Kinross Gold Corporation (Kinross) retained Golder Associates Ltd. (Golder) to conduct an assessment of human and ecological risks due to exposure to metals and cyanide at the Lupin Gold Mine site. As part of the closure plan for the Lupin Gold Mine Tailings Containment Area (TCA), water clarification ponds (Pond 1 and Pond 2) will remain in place and esker sand will be used to cover exposed tailings. The objective of this risk assessment was to estimate the potential human and wildlife risks after closure of the mine, based on the reclamation plan for the Lupin Gold Mine. Aquatic risks were not evaluated because Ponds 1 and 2 are not intended to be aquatic habitat, and controls will be constructed to prevent fish movement into the ponds. The results of the risk assessment can be used by Kinross as inputs to decisions regarding optimum remediation and/or mitigation strategies following closure of the mine.

Three main sources of metals and cyanide from the TCA were considered in the risk assessment:

- Tailings Containment Area: Tailings that have settled in Ponds 1 and 2 will remain during closure. These tailings may have contributed to elevated concentrations of metals and cyanide in water and sediment in Ponds 1 and 2.
- Seepage from Esker-Covered Tailings: The closure plan at the Lupin Gold Mine includes covering exposed tailings with esker sand. The additional weight of the sand may cause water to be pushed out of the tailings and move up into the esker sand where it can be taken up by plants growing at the surface. Seepage of water from tailings to nearby water bodies is considered to be unlikely (Golder 2004).
- Wind-Blown Tailings: Exposed tailings contained within Cells 3 and 5 may have blown to the clean esker cover in Cell 1 of the TCA. Wind-blown tailings will not be a source of metals after all the cells are covered, but this source may account for a significant portion of metals concentrations currently measured in vegetation and sand in Cell 1.

Risk Assessment Approach

The risk assessment focused on the potential risks to wildlife health due to exposure to food (vegetation, invertebrates and prey, as applicable), water and incidental soil ingestion. Risks to human health were also evaluated based on consumption of caribou that could be exposed to metals and cyanide from the TCA. All applicable and available data that have been collected from the TCA were considered for use in the assessment. Therefore, the risk assessment is based on currently available data. It was assumed that currently available data represent worst-case conditions since metals and cyanide concentrations are expected to decrease following closure of the mine.

The following wildlife receptors were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);
- fox (*Alopex lagopus*);
- wolves (*Canis lupus*);
- hare (*Lepus arcticus*);
- arctic ground squirrel (*Spermophilus parryii*);
- ptarmigan (*Lagopus lagopus*);
- rough legged hawk (*Buteo lagopus*);
- common snipe (*Gallinago gallinago*); and,
- long-tailed duck (*Clangula hyemalis*).

Humans are not expected to be directly exposed to metals and cyanide in the TCA at Lupin by incidental ingestion of tailings or via drinking effluent. Inhalation of dust containing wind-blown tailings was also eliminated as a pathway since exposed tailings will be covered with sand as part of the reclamation strategy, such that wind-blown tailings will not occur. The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2, since a spillway will be constructed to prevent movement of fish into the ponds.

Fish-bearing lakes outside of the TCA were not part of the scope of work for this risk assessment. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated for the human health risk assessment was ingestion of caribou, where caribou are assumed to have taken up metals and cyanide from drinking water, food, and incidental soil ingestion from the Lupin mine site.

Potential effects on human and wildlife health can be determined by assessing risk, which is defined by two components, exposure and hazard, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and,
- Hazard: the type of adverse health effect(s) that can occur as a result of exposure.

Exposure to metals and cyanide by wildlife that may inhabit areas near the mine and people that may consume caribou meat is estimated by determining the following:

- the concentrations of substances in soil, sediment, plants and water;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the mine or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with substances (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the mine site (i.e., days/year);
- typical soil, sand, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and,
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the hazard potential of substances is estimated by considering the following:

- determining whether the quantity of substances in soil, sediment and water exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each substance; and,

- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (called toxicity benchmarks).

Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present in the TCA at concentrations greater than concentrations measured in areas not impacted by the TCA were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. The following COCs were evaluated for all receptors and exposure pathways (i.e., soil, food and water ingestion for wildlife and meat ingestion for people) in the risk assessment:

- aluminum;
- arsenic;
- barium;
- boron;
- chromium;
- cobalt;
- copper;
- lead;
- manganese;
- molybdenum;
- nickel;
- selenium;
- silver;
- strontium;
- thallium;
- vanadium;
- zinc; and,
- cyanide.

Receptors may be exposed to substances from the Lupin mine via several pathways (Table 1).

Table 1
Ingestion Pathways Evaluated in the Risk Assessment

Receptor	Ingestion Pathways					
	Soil	Sediment	Water	Vegetation	Wild Game/ Prey	Benthic Invertebrate
People					√	
Caribou	√		√	√		
Muskox	√		√	√		
Grizzly bear	√		√	√	√	
Wolverine	√		√		√	
Fox	√		√		√	
Wolf	√		√		√	
Arctic hare	√		√	√		
Arctic ground squirrel	√		√	√		
Ptarmigan	√		√	√		
Rough-legged hawk	√		√		√	
Snipe		√	√			√
Long-tailed duck		√	√			√

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then mitigation measures that reduce exposure to metals in the TCA may need to be examined. Risk estimates were calculated as the exposure ratio (ER), which is a ratio of the estimated exposure of metals from the TCA to the toxicity benchmarks, as follows:

$$ER = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1 (or 1 in 100,000 for carcinogenic substances such as arsenic), then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects; rather that there is a potential risk. Further consideration may be necessary to reduce uncertainty in the risk assessment, especially if the ERs are only slightly greater than 1, since making risk management decisions

based on slight exceedances may result in unnecessary remediation action. If the ER is less than 1 (or 1 in 100,000 for arsenic), then we can be certain that no health effects or unacceptable risks would occur.

In some cases, it is necessary to reduce the acceptable ER value since other sources of exposure need to be considered. For example, since the earth's crust is made up of metals, they are all around us. They are in the food we eat, the air we breathe and the water we drink. Therefore, the ER calculated from exposure in the study area must be adjusted to consider exposure from other sources. For this assessment the acceptable risk threshold for the human health risk assessment was an ER of 0.2 because it is assumed that people are exposed to metals from multiple sources.

For wildlife, the acceptable risk threshold is an ER of 1 since the risk assessment conservatively assumed wildlife obtained all of their food, water and soil from the Lupin Gold Mine. No other significant exposure sources would occur while wildlife are in the vicinity of the mine site.

Layers of Safety

In this risk assessment, exposures and toxicity benchmarks were estimated from available information about how exposure might take place and the potential health effects that could result. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human and wildlife health will still be protected.

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. The assumption that all concentrations are at maximum accounts for the potential variability in concentrations in soil, water, sediment and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the TCA were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (365 days per year) from caribou that were exposed to maximum metals concentrations from the TCA for 10% of the year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals

from the study area is uncertain. For wildlife health, toxicity benchmarks were chosen from studies that were credible and that evaluated subtle health effects such as changes in blood chemistry and growth. For human health risk assessments it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower). This large margin of safety ensures that doses less than the toxicity benchmarks are safe and that minor exceedances of these benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that risk from exposure to metals at the TCA has not been underestimated.

Results

Wildlife Health

Based on the results of this preliminary risk assessment, there is a potential for risk to individual shorebirds and waterfowl due to arsenic and cyanide exposure. Risks to populations of shorebirds and waterfowl are unlikely. However, the characterization of risks to populations is uncertain. Risks are not expected due to any other COCs or for any other receptors.

Conservative assumptions and many layers of safety were applied to the wildlife health risk assessment that might have lead to an overestimation of risks for shorebirds and waterfowl. This is standard practice for a screening level risk assessment, which means that there is a high degree of certainty that risks have not been underestimated.

Human Health

For the human health risk assessment, for all of the metals evaluated in the assessment, estimated exposure was less than the toxicity benchmarks, with the exception of arsenic. It is very unlikely that the scenario used to estimate human exposure to arsenic via caribou ingestion would be realized. In addition, potential ERs of 0.3 for non-carcinogenic effects and 14 in 100,000 for carcinogenic effects are only slightly above 0.2 and 1 in 100,000; the levels for which no effects are expected. It is very unlikely that health effects would be observed based on these assumptions. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive

toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the study area.

What Does this Mean for the Lupin TCA Closure Plan?

The closure plan for the Lupin TCA includes two major features; covering exposed tailings with 1 m of esker sand and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2.

No wildlife or human health risks are expected due to placement of 1 m of esker sand over exposed tailings.

The exposure pathways related to covering exposed tailings with esker sand are direct soil ingestion and ingestion of plants growing on the tailings areas. This risk assessment shows that risks from sand-covered tailings are acceptable, both for humans and wildlife. This is because the exposure via these two primary pathways does not result in ERs greater than 1. Furthermore, exposure via water from within the capped tailings will not be a concern. This is because, based on the results of the engineering feasibility of covering exposed tailings with esker sand, it is not expected that excessive water will seep into the ponds. Nor is it expected that water will move upward into the root zone of plants growing at the surface of the esker sand (Golder 2004). Therefore, water quality is not expected to worsen in the future.

Risks to individual shorebirds and waterfowl were predicted due primarily to exposure to arsenic and cyanide in invertebrates living in ponds 1 and 2. This leads to the risk management questions:

- Should ponds 1 and 2 remain as features in the reclaimed landscape? and,
- If ponds 1 and 2 remain, should measures be taken to reduce exposure to arsenic and cyanide via invertebrates in contact with sediments?

These two questions cannot be answered with confidence because of the uncertainties in the risk assessment. The risks are very likely to be greatly over-estimated. Therefore, it would not be advisable to proceed to risk management since there may be a large mis-match between the cost

of remediation and the actual risk reduction achieved. Therefore, it is recommended that uncertainties in the assessment of risk to waterfowl and shorebirds be reduced. The following two steps should be considered as preliminary steps to reduce uncertainty:

(1) Sensitivity analysis of the exposure model to reveal which parameters "drive" the risk estimates; and,
(2) Collection of information from the Canadian Wildlife Service and other sources regarding migratory bird populations to better estimate the time that birds may actually spend during the breeding season in the area.

Completion of steps (1) and (2), will allow a re-examination of the level of conservatism in the exposure models, and will also allow a more confident characterization of risks to populations. If the combination of confirmation of highly-conservative risks to individuals plus a more confident prediction of no risks to populations results in a conclusion that risk management is not required, then no further work will be necessary. However, if risks to populations cannot be ruled out and/or if regulatory acceptance of risks to individuals (despite the lack of risks to populations) is not forthcoming, then proceeding with further reduction of uncertainty may be necessary. Further reduction of uncertainty would involve proceeding with additional data collection.

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1. INTRODUCTION

Kinross Gold Corporation (Kinross) retained Golder Associates Ltd. (Golder) to conduct an assessment of human and ecological risks due to exposure to metals and cyanide at the Lupin Gold Mine site. As part of the closure plan for the Lupin Gold Mine Tailings Containment Area (TCA), water clarification ponds (Pond 1 and Pond 2) will remain in place and esker sand will be used to cover exposed tailings. The objective of this risk assessment was to estimate the potential human and wildlife risks after closure of the mine, based on the reclamation plan for the Lupin Gold Mine. Aquatic risks were not evaluated because Ponds 1 and 2 are not intended to be aquatic habitat, and controls will be constructed to prevent fish movement into the ponds. The results of the risk assessment can be used by Kinross as inputs to decisions regarding optimum remediation and/or mitigation strategies following closure of the mine.

1.1 Background

The Lupin Gold Mine (65°46'N, 111°15'W) is on the west shore of Contwoyto Lake, Nunavut, 400 km northeast of Yellowknife and approximately 90 km south of the Arctic Circle (Figure 1). Access to the site is by air or by winter road (February to March).

The Lupin gold deposit was discovered in 1960 by Canadian Nickel Company Ltd., a subsidiary of INCO Ltd. In 1979, Echo Bay Mines Ltd. (EBM) obtained an option on the Lupin property from INCO and proceeded with an underground exploration program in 1979 and 1980. Mine site construction began in 1980 and was completed in 1982 when pre-production commissioning began. The Lupin Gold Mine operated continuously from 1982 to January 1998, when operations were suspended due to low gold prices. In November 1999, EBM re-opened the Lupin Gold Mine and production resumed in April 2000. In 2003, EBM merged with Kinross. Since the start of production in 1982, the Lupin Mine has produced over 3.3 million ounces of gold.

The Lupin mine site is comprised of two principal clusters of buildings: the residential complex, which consists of accommodations, a kitchen and recreation center; and the industrial complex, which houses the mine, mill, powerhouse, maintenance facility, warehouse and offices. Ancillary features include a sewage lagoon immediately to the south of the industrial complex, a 1.9 km long airstrip, and tailings area located approximately 5 km south of the mine (Figure 1).

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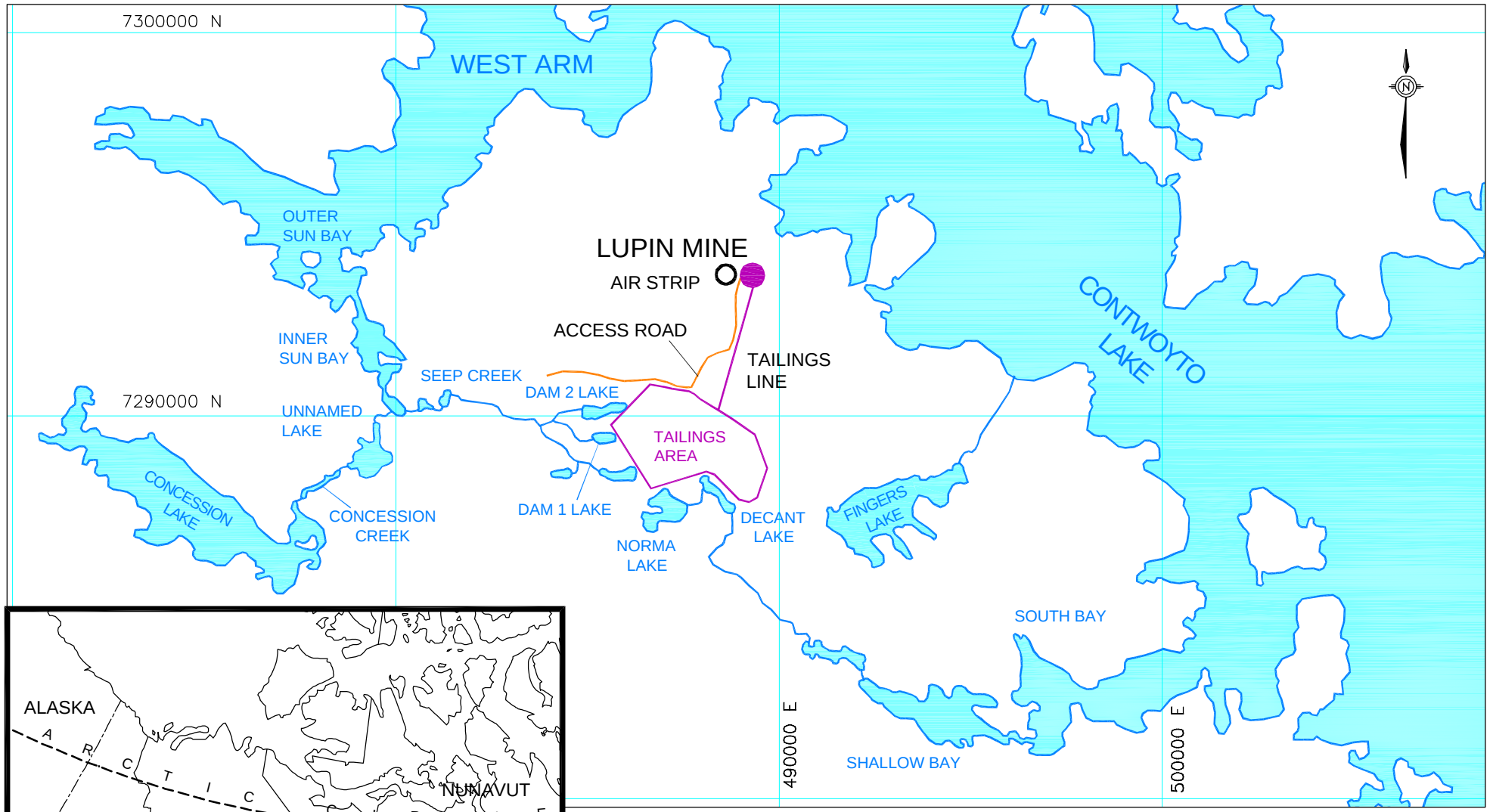

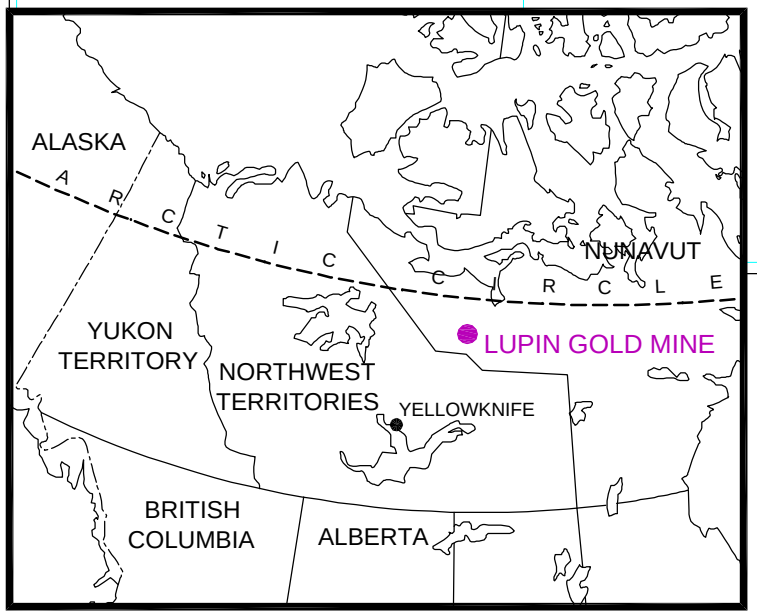

3 0 3
SCALE KILOMETRES

PROJECT
KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE
LUPIN MINE LOCATION MAP

Golder Associates
Calgary, Alberta

PROJECT 03-1373-026.1066			FILE No.		LOCATION MAP
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CADD	PSR	14/10/04			
CHECK	CR	25/11/04			
REVIEW	CR	25/11/04			

FIGURE: 1

1.2 Gold Mining Process at Lupin

The Lupin milling process incorporates crushing, grinding, pre-aeration, leaching, filtration, and recovery. The ore from the mine is crushed underground and then fed to a secondary crushing facility contained within the surface facilities. At peak production, the crushing circuit operated at a rate of 240 tonnes per hour (EBM 2001). Pre-aeration and leaching liberates gold particles into solution via the reaction of cyanide, oxygen and water. A two-stage filtration system separates dissolved gold from the waste solids (filter cake), which are pumped to the tailings containment area (TCA). Zinc dust and fluxes are used to recover any precipitate gold, which is returned to the mill to be reprocessed. The bullion contains approximately 85% gold and 12% silver, the balance being base metals (EBM 2001).

Originally, all liquid waste was contained within the tailings ponds; however, as mine capacity increased, it became necessary to expand the tailings ponds and discharge effluent from the tailings pond to the receiving environment. Beginning in 1982, water was discharged in mid-summer (when water quality achieved NWT Water Board Requirements or Metal Mining Effluent Regulations [MMER]), typically beginning on 15 July and continuing for periods that extended into early September. This practice will continue until mine closure. Effluent is discharged into Seep Creek, which drains into Contwoyto Lake at the south end of Inner Sun Bay (Figure 1).

Tailings from gold processing is in the form of a slurry that is pumped from the mill to one of two solids retention cells (currently, Cell 3 or Cell 5) where the solids settle. Each spring, meltwater and tailings water is decanted from Cells 5 and 3 into Cell 4. Water is held in Cell 4 for one year to allow natural degradation of cyanide by exposure to sunlight, air, and agitation by wind action. Water is released from Cell 4, through a gated culvert, into Pond 1, where it is held for an additional one-year period, before being siphoned into Pond 2. If necessary, the water is treated with ferric-sulphate during the siphoning process to precipitate arsenic in Pond 2. Depending on water level and water quality in Pond 2, water is released to the environment after 15 July of any year (as per Nunavut Water Board water license). The TCA is presented in Figure 2.

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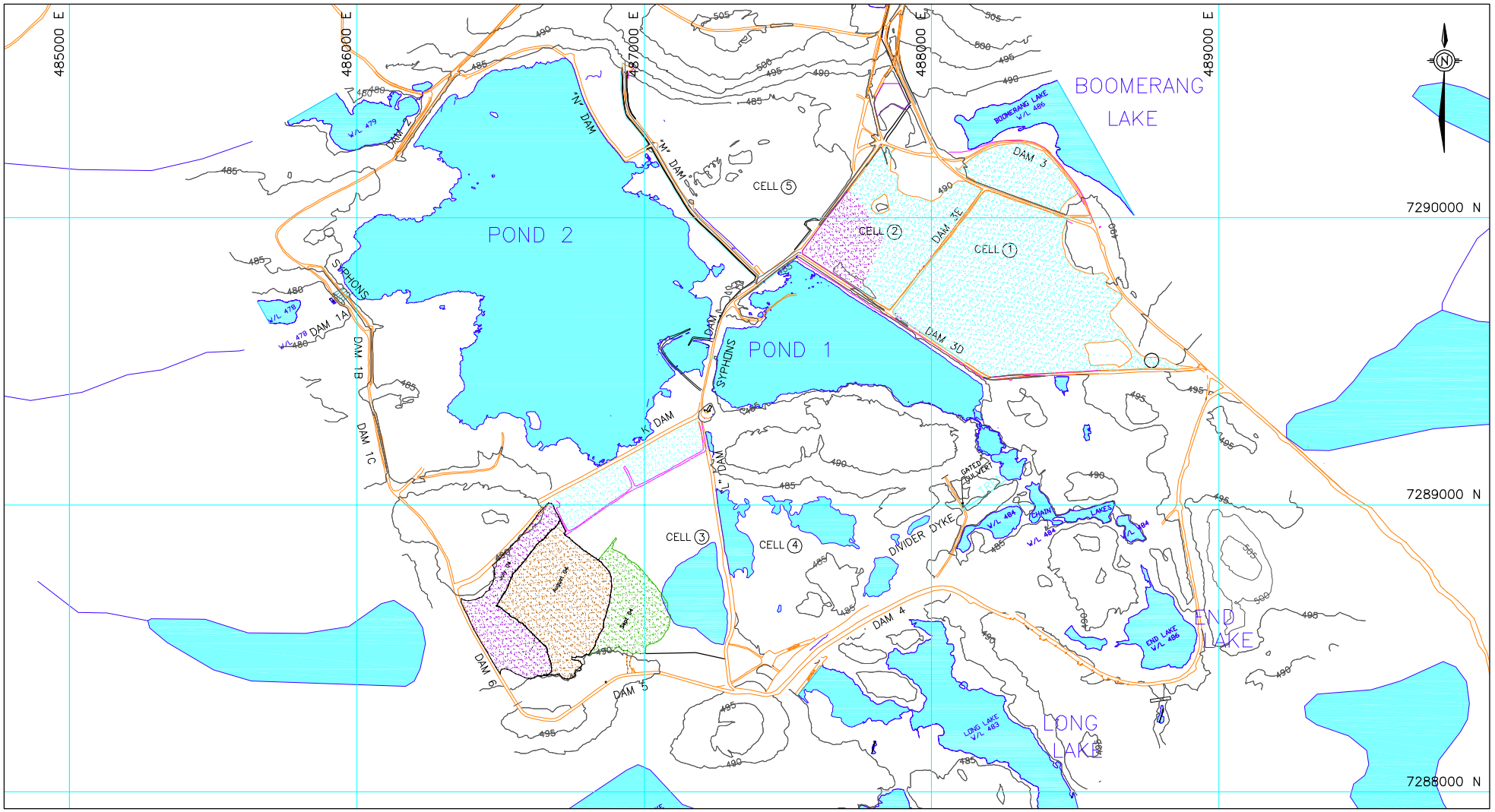


LEGEND

ESKER COVERED TILINGS

400 0 400
SCALE METRES

PROJECT

KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE

LUPIN TAILINGS AREA

Golder Associates
Calgary, Alberta

PROJECT 04-1373-026.1066			FILE No. Lupin Tailings Area	
DESIGN	CR	08/10/04	SCALE AS SHOWN	REV. 0
CADD	MJ	25/11/04		
CHECK	CR	25/11/04		
REVIEW	CR	25/11/04		

FIGURE: 2

1.3 Closure Plan

Reclamation activities have been ongoing at the Lupin Gold Mine since 1988, when tailings in Cell 1A were covered with up to 1 m of esker sand. The effect of this practice was to control acid rock generation by creating an oxygen barrier that, in turn, prevents oxidation of pyritic materials in the tailings. The sand layer also prevents access to surface tailings by wildlife in the area. In 1995, the remainder of Cell 1 and 75% of Cell 2 were similarly covered. The remainder of Cell 2, as well as a significant portion of Cell 3, was covered with esker sand in the summer of 2004. The remainder of Cell 3, and all of Cell 5, will be covered with esker sand during the summer of 2005 and, if necessary, summer 2006. Water in Cell 3 will be pumped to Cell 4, prior to covering with esker sand and water from Cell 4, after a suitable retention period, will be released to Pond 1.

Since structural dams require regular maintenance inspections, Kinross is planning to breach Dam 1A as one of the final stages of closure. The current plan is to construct a spillway through Dam 1A, at approximately the 480m elevation, following the final siphon discharge. At this elevation, Pond 2 will continue to provide a deep water cover over the pond sediments. The spillway will provide an outlet for annual precipitation buildup in Pond 2, which will be permitted to naturally flow into Dam 1a Lake. Water quality is expected to be within MMER guidelines. Although Ponds 1 and 2 will decrease in area, it is expected that volume will be 50% to 75% of current levels.

1.4 Sources of Metals and Cyanide Evaluated in the Risk Assessment

Three main sources of metals and cyanide from the TCA were considered in the risk assessment:

- Tailings Containment Area: Tailings that have settled in Ponds 1 and 2 will remain during closure. Metals are naturally-occurring and are present in mineral rocks. Areas with gold deposits also tend to have higher deposits of other metals, such as arsenic. Cyanide is used in gold processing to dissolve and concentrate gold from the ore. Although cyanide is typically recycled, some cyanide can be deposited with tailings. Cyanide is highly water soluble; therefore, cyanide is typically measured both in water and in sediment.

- Seepage from Esker-Covered Tailings: The closure plan at the Lupin Gold Mine includes covering exposed tailings with esker sand. The additional weight of the sand may cause water to be pushed out of the tailings and move up into the esker sand where it can be taken up by plants growing at the surface. Seepage of water from tailings to nearby water bodies is considered to be unlikely (Golder 2004).
- Wind-Blown Tailings: As described in Section 1.3, exposed tailings are contained within Cells 3 and 5. Part of Cell 3 was covered with esker sand in the summer of 2004; however, tailings from Cell 3 and the other cells may have blown to the clean esker cover in Cell 1. Wind-blown tailings will not be a source of metals after all the cells are covered, but this source may account for a significant portion of metals concentrations currently measured in vegetation and sand in Cell 1.

1.5 Previous Site Investigations

A comprehensive summary of previous site investigations conducted at the Lupin mine is provided in a historical report prepared by Golder (2003). The investigations summarized in the historical report include the following:

- fisheries and fish tissue analysis reports provided for the purposes of the on-going Environmental Effects Monitoring program at the Lupin Gold Mine (R.L.&L. Environmental Services Ltd. 1991; 1995; 1996);
- hydrogeology assessments of the Lupin mine and associated tailings (Klohn-Leonoff, 1992; Klohn-Crippen 1995);
- water chemistry, sediment chemistry and benthic macroinvertebrate community assessment (R.L.&L. Environmental Services Ltd. 1996; EVS Environmental Consultants 1996);
- summary report on water quality, benthic macroinvertebrate communities, and fish tissue data based on previous investigations of the Lupin mine (AQUAMIN 1996); and,
- annual reports produced by Echo Bay Mines in fulfillment of Water Licence Agreement NWB1LUP0008 (Echo Bay Mines 2000; 2001; 2003).

In addition to the above investigations, Kinross has collected water quality data in and around the Lupin Gold Mine. These data have been stored in the Lupin Gold Mine database and have not been reported previously.

1.6 Supplemental Field Work

Additional data were required to conduct the human and wildlife health risk assessments. Data gaps included metals concentrations in vegetation, sediment and soil. Environmental technicians from Kinross collected samples in August 2004 (sample locations are presented in Figure 3) and submitted the samples to an analytical laboratory for metals analyses (including mercury and arsenic). The following samples were collected:

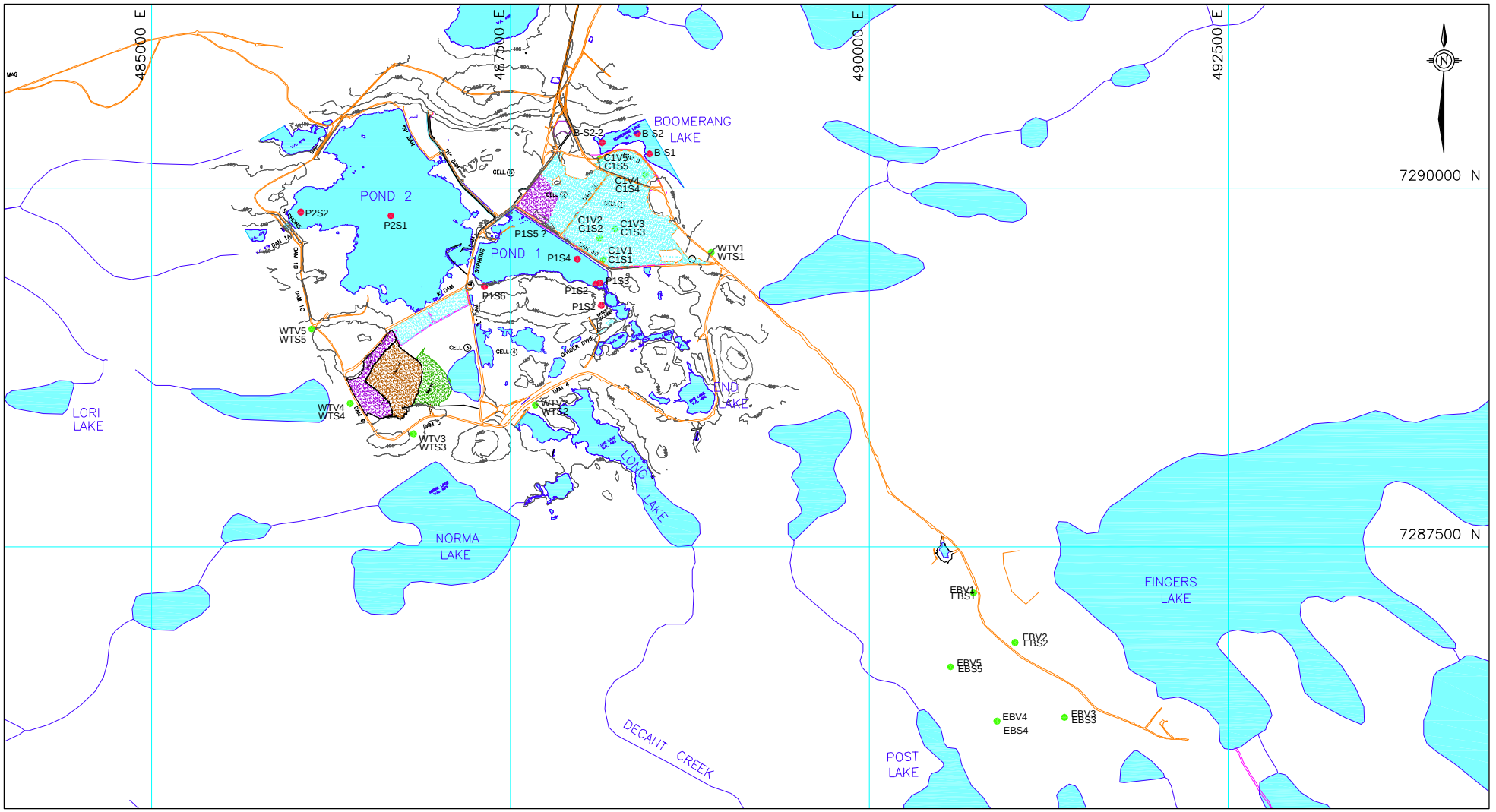
- vegetation growing on esker sand in Cell 1 and areas known to have been impacted by wind-blown tailings;
- vegetation from a reference location in the esker sand borrow area;
- esker sand from Cell 1 and the esker sand borrow area;
- soil from areas known to be impacted by wind-blown tailings; and,
- sediment from Pond 1, Pond 2, Boomerang Lake and a reference location in Shallow Bay.

Data from the supplemental field work are presented in Appendix I.

1.7 Scope of Work

The purpose of the risk assessment was to evaluate risks to wildlife and human health as a result of concentrations of metals expected to be present at the Lupin Gold Mine following closure. The overall goal for the risk assessment was to provide a risk-based evaluation in order to guide risk management and reclamation decisions, including guidance with respect to the adequacy of 1 m of esker sand cover over tailings. All applicable and available data that have been collected from historical investigations on the site and supplemental data collected for the purposes of this assessment were used in the risk assessment. It was assumed that currently available data represent worst-case conditions since metals and cyanide concentrations are expected to decrease following closure of the mine.

R:\CAD\2004\1370-Edmonton\1373-ES\04-1373-026\1066\ Drawing file: Fig 3 2004 Sampling Locations.dwg Nov 25, 2004 - 11:51am



LEGEND

P2S1 SEDIMENT SAMPLING LOCATION

WTV4 WTS4 PLANT AND SOIL SAMPLING LOCATION

1 0 1

SCALE KILOMETRES

PROJECT

KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE

2004 SAMPLE LOCATIONS

Golder Associates
Calgary, Alberta

PROJECT 04-1373-026.1066			FILE No. 2004 Sample Locs.	
DESIGN	CR	08/10/04	SCALE AS SHOWN	REV. 0
CADD	JEF	18/10/04		
CHECK	CR	25/11/04		
REVIEW	CR	25/11/04		

FIGURE: 3

The risk assessment method used to evaluate potential risks is considered to be a Level 1 (or screening-level) risk assessment, which is characterized by CCME (1996) as being a study that uses comparative methods and is focused mainly at the species level. Levels 2 and 3 are more sophisticated and complex evaluations that focus on the population and community levels. Level 2 and 3 risk assessments would only be required if a Level 1 risk assessment identified risks to individual animals and if an understanding of how potential health risks for individuals may impact populations is required.

1.8 Organization of Report

The remainder of the report is structured as follows:

Section 2 Site Description: provides a brief description of the environmental setting.

Section 3 Sources of Data: provides a summary of the data used in the risk assessment. A more detailed summary of the data is presented in Appendix I.

Section 4 Definition of Reference: provides a definition of the sources of the reference data used in the risk assessment.

Section 5 Risk Assessment Approach: provides a brief description of the approach and methods used to determine the potential for adverse effects on people and wildlife. Detailed methods are described in Appendix II.

Section 6 Risk Assessment Results: provides a summary of the results of the human and wildlife health risk assessments.

Section 7 Conclusions: provides a brief summary of the report.

2. SITE DESCRIPTION

2.1 Environmental Setting

The Lupin Gold Mine is on the west shore of Contwoyto Lake, Nunavut, in the southern arctic ecoregion. The site is in the tundra zone of the Canadian Shield, an area of continuous permafrost. Terrain is generally low and undulating, ranging between 470 and 505 m elevation. The tundra zone is characterized by typical barren ground vegetation. Moss, lichens, heather, and dwarf shrub communities are predominant in well-drained areas, while grasses and sedges are more dominant in wet ground adjacent to stream courses and around the perimeters of lakes (Golder 2003). Characteristic wildlife species include caribou, muskox, grizzly bear, hare, fox, wolf, raptors, shorebirds, and waterfowl.

Contwoyto Lake is the major water body in the region and has two outlets, the Burnside River on the northwest end of the lake, and the Back River at the southeast end of the lake. The main body of Contwoyto Lake lies to the east and south of the mine site. To the north of the mine, the West Arm of the lake extends to the west and south, terminating in Sun Bay, which lies directly west of the mine site (Golder 2003).

3. SOURCES OF DATA USED IN THE RISK ASSESSMENT

Risk assessment was used in this study to evaluate the potential for adverse effects on wildlife and people as a result of exposure to metals from the Lupin Gold Mine.

The risk assessment required information on metal and cyanide concentrations in the following parts of the food chain:

- reference water, soil, sand, sediment and native plant species for comparison and screening purposes;
- sediment from Ponds 1 and 2, and Boomerang Lake;
- soil from wind-blown tailings area;
- esker sand covering tailings containment cells;
- plants present in Cell 1 and in the wind-blown tailings area;
- water in the Pond 1 and 2 and Boomerang Lake;
- invertebrate tissue (calculated); and,
- animal tissue (calculated).

Reference water quality data were obtained from R.L. & L. (1995; 1996). In addition, water quality data from Kinross' database of monitoring results were used. Since no previous reference or study area data had been collected for soil or esker sand, and limited sediment data were available, samples were collected to fill these data gaps for the purposes of this assessment.

Animal tissue concentrations (i.e., caribou) were calculated based on uptake from soil, water and vegetation into animal tissue. Similarly, benthic invertebrate tissue concentrations were calculated based on uptake from sediment. These calculations are based on uptake factors for each metal and cyanide reported in peer-reviewed scientific literature.

More detailed descriptions of the sources of the data, the data, summary statistics and tissue calculations are presented in Appendix I.

4. DEFINITION OF REFERENCE

Reference concentrations are an important component of risk assessments. A reference concentration is the amount of a chemical found in an area that is similar to the study area but without the source being studied (in this case, tailings or effluent from the mine). In a risk assessment, reference concentrations are one of the screening tools used to evaluate the significance of concentrations of substances found in an area of interest. The use of reference concentrations as a screening tool is consistent with risk assessment protocols developed by Health Canada (2003).

Reference concentrations are required because some substances, particularly metals, are naturally occurring, especially in an area rich in mineral and gold deposits. Since metals are common and widespread, soil and water always contain some metals. Metals are a major component of the earth's crust; therefore, metals can be measured in all environmental samples (e.g., soil, sediment, water, and plants) no matter where the samples are taken from. Thus, comparisons between the study area concentrations and reference area concentrations were used to check whether or not metals measured in the study area are increased due to activities at the site.

Reference locations for each of the media required for the risk assessment are presented in Table 1.

Table 1
Reference Sample Locations for Each Media Used in the Risk Assessment

Media	Reference Location
water	South Bay
sediment	Shallow Bay
vegetation	near the esker borrow area
sand	near the esker borrow area

As part of the chemical screening step in the risk assessment, maximum metals concentrations measured in soil, sand, vegetation, water, and sediment from the TCA were compared with mean concentrations measured in each of the reference areas. Also, maximum concentrations of cyanide measured in the TCA were compared with mean concentrations measured in the reference area. If the study area concentrations were less than reference concentrations, the

chemical was screened out; that is, it was not considered a chemical of concern and not considered further in the risk assessment. In other words, if concentrations are lower in the study area than in the reference areas, the source of metals and cyanide in the study area is not from the mine. If the study area concentrations were greater than the reference values, the substance was carried forward to the next step of the screening process. The screening process used in the risk assessment is described in more detail in Appendix II, Section 3.

5. RISK ASSESSMENT APPROACH

This risk assessment was conducted according to established health risk assessment protocols endorsed by Health Canada, the Canadian Council of Ministers of the Environment, Alberta Environment (AENV) and the United States Environmental Protection Agency (Health Canada 1994, 2003; CCME 1996 a,b,c; AENV 2000; U.S. EPA 1998) and risk assessment principles outlined in a report to Health Canada (Health Canada [unpublished] 1995).

Standard risk assessment terminology used in these guidance documents has been modified in this report to convey the information in a less technical manner. Refer to Appendix II for more detailed technical information.

What is Risk Assessment?

Risk assessment is a standard procedure for answering three fundamental questions about an area:

- How safe is it? (Section 5.1)
- How sure are we? (Section 5.2)
- Is it acceptable? (Section 5.3)

These questions must be answered in the context of the overall risk management goal. The overall goal for the closure plan at the Lupin Gold Mine is "No significant risks to wildlife populations using the area as a source of food and water and no risks to individual humans that consume caribou meat".

5.1 How Safe Is It?

Risk assessment is a standard process used to characterize potential adverse health effects of human and wildlife exposures to potential environmental hazards (Paustenbach 2002). This is done by defining two components, *exposure* and *hazard*, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and,
- Hazard: the type of adverse health effect(s) that can occur as a result of exposure.

Exposure to metals and cyanide by wildlife that may inhabit areas near the mine and people that may consume caribou meat is estimated by determining the following:

- the concentrations of substances in soil, sediment, plants and water;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the mine or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with substances (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the mine site (i.e., days/year);
- typical soil, sand, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and,
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the hazard potential of substances is estimated by considering the following:

- determining whether the quantity of substances in soil, sediment and water exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each substance; and,
- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (called toxicity benchmarks).

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then mitigation measures that reduce exposure to substances from the tailings containment area may need to be examined.

5.1.1 Identifying Chemicals of Concern

The first step of the risk assessment was to identify chemicals that are of concern in the study area, as a result of tailings deposition. First, maximum concentrations of substances in soil,

vegetation, water and sediment measured in the study area were compared to mean reference concentrations. The assessment focussed on metals concentrations in soil, water, vegetation and sediment and cyanide in water and sediment. Chemical concentrations that were lower in the study area than reference concentrations were not considered further. Comparison of maximum concentrations from the Lupin site to average reference area concentrations is conservative, since such a comparison over-estimates the metal concentrations present throughout the Lupin site (since most concentrations would be less than maximum). It also does not account for the higher natural background metal concentrations since average reference concentrations were used.

Chemicals with concentrations that were greater in the study area than in reference areas were then compared to CCME Environmental Quality Guidelines for soil, water and sediment quality (guidelines are not available for vegetation quality). The published guidelines used in this assessment are conservative; that is, they err on the side of safety in order to ensure the protection of the health of the most susceptible individuals in a population under daily exposure conditions. Environmental quality guidelines are derived using data for the most sensitive test species and are derived to be protective of all receptors, 100% of the time (CCME 1999). Therefore, concentrations less than guidelines can be assumed to be safe. Substances that were present at concentrations less than these guidelines were not evaluated further in the risk assessment.

The final step in determining the list of chemicals of concern was to determine if the chemical is an essential nutrient (e.g., calcium). Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present at concentrations greater than reference values were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. Further details on the screening process are provided in Appendix II, Section 3. The COCs evaluated for wildlife health were also evaluated for human health, since the only exposure pathway evaluated for human health was meat ingestion. The following COCs were evaluated in the risk assessment:

- aluminum;
- arsenic;
- barium;
- boron;
- chromium;
- cobalt;
- copper;
- lead;
- manganese;
- molybdenum;

- nickel;
- selenium;
- silver;
- strontium;
- thallium;
- vanadium;
- zinc; and,
- cyanide.

5.1.2 Identifying Receptors

5.1.2.1 Wildlife Receptors

Receptors are humans or wildlife species chosen as representative species that receive exposure to the chemicals of concern. There are many species that could be present in the arctic environment. However, it is not practical to evaluate all species. Receptors that were selected for the risk assessment: are representative of the local ecosystem; have the greatest potential for exposure; play a key role in the food web; and have sufficient characterization data to facilitate calculations of exposure and health risks. The short-listed receptors are defined as resources or environmental features that include the following:

- are important to human populations (i.e., used as a food source);
- have economic and/or social value (i.e., animal that are trapped for furs, recreational value);
- have intrinsic ecological significance (i.e., endangered species, key species in the food web); and,
- serve as a baseline from which the impacts can be evaluated (CCME 1996a).

The receptor selection process is described in detail in Appendix II, Section 4.1.1. The following receptors were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);
- fox (*Vulpes vulpes*);
- wolves (*Canis lupus*);

- hare (*Lepus arcticus*);
- arctic ground squirrel (*Spermophilus parryii*);
- ptarmigan (*Lagopus lagopus*);
- rough legged hawk (*Buteo lagopus*);
- snipe (*Gallinago gallinago*); and,
- long-tailed duck (*Clangula hyemalis*).

5.1.2.2 Human Receptors

Humans are not expected to be directly exposed to metals and cyanide in the TCA at Lupin by incidental ingestion of tailings or via drinking effluent. Inhalation of dust containing wind-blown tailings was also eliminated as a pathway since dust deposition from the tailings occurs in a limited area immediately adjacent to the source tailings and still on mine property. Furthermore, exposed tailings will be covered with sand as part of the reclamation strategy, such that wind-blown tailings will not occur. The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. The Lupin mine site is not in close proximity to any communities (i.e., closest community is Bathurst Inlet, approximately 150 km northeast of Lupin). There are four families that live near the Lupin mine site. Two families currently live year-round approximately 10 km south of Lupin mine, while two families live 3 km away near the shore of Contwoyto Lake in the summer months. However, it is unlikely that these families will continue to live in these locations after closure of the mine as they rely on the mine for most of their provisions (pers. comm. M. Tansey). Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2, since a spillway will be constructed to prevent movement of fish into the ponds. Fish-bearing lakes outside of the TCA were not part of the scope of work for this risk assessment. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated for the human health risk assessment was ingestion of caribou, where caribou are assumed to have taken up metals and cyanide from drinking water, food, and incidental soil ingestion from the Lupin mine site. Concentrations of metals and cyanide in caribou meat were estimated using uptake factors from published literature (Appendix I).

Both a hypothetical adult and toddler were evaluated for exposure to metals via ingestion of caribou meat. Consistent with risk assessment guidance (Health Canada 2003), the toddler life

phase (i.e., seven months to four years) was chosen as the most susceptible child lifestage for evaluation of non-carcinogenic metals. The toddler phase is the most susceptible childhood phase due to their ratio of body size to ingestion rates compared to other life stages.

5.1.3 Identifying Exposure Pathways

Receptors may be exposed to substances from the Lupin mine via several pathways (Table 2).

Table 2
Ingestion Pathways Evaluated in the Risk Assessment

Receptor	Ingestion Pathways					
	Soil	Sediment	Water	Vegetation	Wild Game/ Prey	Benthic Invertebrate
People					√	
Caribou	√		√	√		
Muskox	√		√	√		
Grizzly bear	√		√	√	√	
Wolverine	√		√		√	
Fox	√		√		√	
Wolf	√		√		√	
Arctic hare	√		√	√		
Arctic ground squirrel	√		√	√		
Ptarmigan	√		√	√		
Rough-legged hawk	√		√		√	
Snipe		√	√			√
Long-tailed duck		√	√			√

Direct skin contact was not considered to be a significant exposure pathway for fur- or feather-bearing receptors since fur and feathers provide effective protection of skin. Water and soil on fur or feathers is more likely to be ingested during grooming than absorbed through the skin. Grooming was considered as part of the ingestion pathway. The details of the exposure pathway analysis are presented in Appendix II, Sections 4.1.2, and 5.1.2 for wildlife and humans, respectively.

5.1.4 Risk Assessment Endpoints

This step involves establishing assessment and measurement endpoints. An assessment endpoint is a general statement describing what is being protected. The measurement endpoint is the method for measuring whether the assessment endpoint is being achieved.

5.1.4.1 Assessment Endpoints

In human health risk assessment, protection of individual health is the assessment endpoint. This means that no one individual person may be exposed to concentrations of metals that may pose a health risk.

The risk management objective for the human health assessment endpoint is:

> *There will be no unacceptable risks to the health of individual children or adults consuming their entire daily meat intake from caribou that have been exposed to substances from the Lupin Mine.*

In ecological risk assessment, the overall goal is to ensure that the structure and function of the ecosystem is not changed to the point where populations and communities cannot be sustained and where human uses are curtailed. The assessment endpoints may be different depending on the type of species being evaluated. Listed species are typically protected at the individual level. Wolverine and grizzly bears are listed as "sensitive" (COSEWIC 2002; SARA 2002). Other wildlife are protected at the population level. Protection of the population means that the population of a species within an area of interest should not be affected; however, a small number of individual animals within the population may be affected.

The risk management objective for wildlife receptors that are not listed species for this risk assessment are:

> *There will be no unacceptable risks to the population of caribou, muskoxen, wolves, fox, hare, ground squirrel, hawk, snipe, long-tailed duck, and ptarmigan that may be exposed to metals and cyanide from the tailings containment area at the Lupin Gold Mine.*

The assessment endpoint corresponding to this objective is population persistence in the Contwoyto Lake area, where population persistence is defined as the continuing presence of viable populations with sustainable birth rate and death rate. Unacceptable risks to populations are defined as sufficient effects on individuals that the viability of the population declines due to increased death rate or decreased birth rate.

The risk management objective for listed wildlife receptors is:

> *There will be no unacceptable risks to individual wolverines and grizzly bears that may be exposed to metals and cyanide from the tailings containment area at the Lupin Gold Mine.*

The assessment endpoint corresponding to this objective is health of individual animals. Unacceptable risks to individuals are defined as risks of sub-lethal effects (such as slower growth or lower capacity to reproduce).

5.1.4.2 Measurement Endpoints

Human Receptors

The measurement endpoint for humans must be protective to ensure that there will not be unacceptable risks to individual children or adults consuming caribou that may have been exposed to substances from the Lupin mine. The primary measurement endpoint is the toxicity benchmark or toxicity reference value (TRV). TRVs are safe exposures below which there is minimal risk of adverse health effects. The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004), the Netherlands Institute of Public Health (RIVM 2001) and the U.S. EPA's Integrated Risk Information Service database (IRIS 2004). The ratio between estimated exposure to individuals and the TRV, called an Exposure Ratio (ER), should be less then the acceptable threshold value, 0.2. This acceptable threshold value is less than 1 to account for exposure to the COCs from other sources, which is the approach used by CCME (1999) and Health Canada (2003).

Wildlife Receptors

For wildlife receptors, two types of measurement endpoints are defined. Primary measurement endpoints assess risks to individual animals, in the same way that risks to individual human receptors are evaluated (as discussed above). However, in most cases for ecological receptors, it is more important to assess risks to the population, rather than to individual animals. In this case, secondary measurement endpoints are defined that evaluate risks to the population. However, if an ecological receptor has special status (i.e., listed as endangered, threatened or sensitive), risks to individual animals are evaluated (this is the case for wolverines and grizzly bears). Primary and secondary measurement endpoints for each of the ecological receptors are described in the sections below.

Primary Measurement Endpoints

In order to meet the assessment endpoint for wildlife ecological receptors, the primary measurement endpoint (or TRV) is the Lowest Observed Adverse Effect Level (LOAEL). As is done in the human health assessment, an ER is calculated for each exposure pathway, by calculating the ratio between estimated exposure and the toxicity benchmark. ERs values from each exposure pathway are added together to determine the total ER value. The acceptable ER value for risks to individual wildlife receptors is 1, since all of the exposure for wildlife is assumed to be from the tailings containment area at Lupin.

Secondary Measurement Endpoints

A secondary measurement endpoint has been defined for species where risks are predicted for individuals. The secondary measurement endpoint is that the number of individuals affected must be less than 20% of the probable population size (Suter et al. 1995). This threshold for effects on populations is based upon an understanding of the natural variability in the factors that control the sustainability of populations (e.g., birth rate and death rate). It is a very conservative benchmark, since the natural variability in birth and death rates is usually much higher than 20%. The number of individuals affected is estimated from the home range size of each of the receptors. Species with small home range sizes (e.g., arctic hare) may have more than one home range overlapping the area. In these cases, the total number of individuals relative to the probable population size is evaluated.

5.1.5 Estimating Exposure

5.1.5.1 Wildlife Health

The amount of exposure that receptors might receive from the study area was determined for all of the exposure pathways defined in Table 2, in Section 5.1.3. The amount of exposure depends on the concentrations in various media (e.g., maximum metal concentrations measured in soil, plant tissue, and water and calculated prey tissue concentrations), the amount of time an animal is in contact with these media and the rates at which the receptors take in food and soil. Some of these factors (e.g., water ingestion rates, food ingestion rates) are available from government agencies (i.e., U.S. EPA) while others required professional judgement (i.e., time in the area). Whenever there was uncertainty and in order to account for the variability in animals' habits, conservative assumptions were used to ensure that exposure would not be underestimated.

5.1.5.2 Human Health

The amount of exposure to metals that people would get from the study area was determined for the caribou meat ingestion pathway. The amount of exposure depends on the concentration of metals and cyanide in caribou meat resulting from caribou ingestion of vegetation, water and soil from the TCA, meat ingestion rates and the frequency of meat ingestion. Default food ingestion rates for aboriginal people were obtained from Health Canada (2003). It was assumed that people consumed caribou meat 365 days per year from caribou that have spent 37 days per year (i.e., 10% of the year) ingesting vegetation, water and soil from the Lupin Mine site.

The assumptions used in the wildlife and human risk assessment are presented in Table 3. These assumptions, together with maximum measured metal and cyanide concentrations and literature values for parameters such as ingestion rates, were used as input to exposure equations for humans and wildlife.

5.1.5.3 Conservative Assumptions Used in the Risk Assessment

The conservative assumptions used in the human and wildlife exposure assessments are presented in Table 3. Further details on methods to estimate exposure are presented in Appendix II, Section 4.2 and 5.2 for wildlife and humans, respectively.

Table 3
Conservative Assumptions Used in the Risk Assessment and the Reasons Why Assumptions Are Conservative

Assumption Used in the Risk Assessment	Reason Why Assumption Is Conservative
Wildlife consume 100% of their food (i.e., vegetation or prey) and water while in the vicinity of the tailings containment area	Animals will not be confined to the Lupin Mine but rather are free to get drinking water and food from throughout the their home range. The grasses might grow on the esker cover are not necessarily preferred vegetation types for wildlife. In addition, there are many sources of water in the vicinity of the mine so it is very unlikely that wildlife would consume all of their daily drinking water from Ponds 1 and 2.
Receptors are exposed to maximum concentrations in plants, soil and water.	Animals are not confined to areas with the maximum concentration. While in the vicinity of the Lupin Mine, animals are most likely to be exposed to a range of metals concentrations.
People consume their entire meat intake per year from caribou that have been exposed to metals and cyanide from the Lupin Gold Mine.	It is unlikely that all of the meat that people would consume would be from caribou that have been exposed to maximum concentrations of metals and cyanide from the Lupin mine site. The majority of the caribou hunted in Nunavut are unlikely to encounter the mine at all.
Benthic invertebrates inhabit Ponds 1 and 2.	Ponds 1 and 2 in the tailings containment area of the Lupin Gold Mine are not intended to be aquatic habitat. It is very unlikely that substantial numbers of invertebrates are present and the numbers that might be present are unlikely to fully support dietary needs of snipe and long-tailed duck.
Caribou spend 10% of the year (37 days) at the Lupin site.	Caribou are migratory animals that travel through the barrenlands to and from their calving grounds near Bathurst Inlet. It is very unlikely that caribou would spend as much as 10% of the year at the Lupin Mine Site because they are constantly moving with movement rates ranging from 2 to 23 km/day (Gunn et al. 2002).

5.1.6 Determining the Toxicity Benchmark

Toxicity assessment involves identification of the potentially toxic effects of substances, and determination of the amount of a substance that a receptor can be exposed to without experiencing unacceptable effects. The results of the toxicity assessment are expressed as the TRV, or toxicity benchmark. TRVs are safe exposures below which there is minimal risk of

adverse health effects. Further details on determining toxicity benchmarks for this risk assessment are presented in Appendix II, Section 4.4, and 5.4 for wildlife and humans, respectively.

5.1.6.1 Wildlife Toxicity Benchmarks

TRVs for the wildlife health assessment were obtained from Sample et al. (1996). These TRVs are based on laboratory toxicity studies. Ideally, toxicity test species should be the same species being evaluated in the risk assessment, but this is rarely possible. Usually, laboratory toxicity studies using rats, mice, mallard ducks or other captive species provide dose-response information that can be extrapolated to wildlife. The Lowest-Observed-Adverse-Effect Level (LOAEL) for sublethal effects was selected for each metal, where available. In studies where mortality was the endpoint or where a LOAEL was not identified, the No-Observed-Adverse-Effect Level (NOAEL) was selected. The LOAELs and NOAELs from laboratory studies were extrapolated to TRVs for wildlife species by incorporating differences in physiology between large and small animals using the methods provided by Sample and Arenal 1999 (see Appendix II).

5.1.6.2 Human Health Toxicity Benchmarks

The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004) and the U.S. EPA's Integrated Risk Information Service Database (IRIS 2004). The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented.

Animal studies provide dose-response information for non-carcinogenic chemicals that can be extrapolated to humans by applying safety factors. In most cases safety factors of 100 to 1,000 are applied to a laboratory derived No-Observed-Adverse-Effect Level (NOAEL; the highest concentration in a toxicity test where no chronic health effects were observed or measured) to account for interspecies extrapolation and protection of the most susceptible in a population (i.e., children and elderly). Therefore, TRVs have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

For carcinogenic chemicals, dose-response information from laboratory studies is used to define cancer risk estimates to humans. Data from toxicity tests are used to determine the potential increase in cancer risk as a result of exposure to a cancer-causing substance (e.g., arsenic) called a slope factor (Health Canada 2003). The slope factor is used to calculate the cancer risk per 100,000 people due to exposure to cancer-causing substances. A cancer risk of 1 in 100,000 is considered to be "essentially negligible" by Health Canada (2003). The Canadian lifetime probability of developing cancer due to such as genetics, family history, diet, lifestyle and environmental pollutants is 4 in 10 or 40,000 in 100,000 (Health Canada 2003).

5.1.7 Risk Characterization

Risk estimates were calculated as the exposure ratio (ER), which is a ratio of the estimated exposure of metals and cyanide to the toxicity benchmarks, as follows:

$$ER = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

The resulting ER must be interpreted according to the assessment endpoints as described above.

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects; rather that there is a potential risk. Further consideration may be necessary to reduce uncertainty in the risk assessment, especially if the ERs are only slightly greater than 1, since making risk management decisions based on slight exceedances may result in unnecessary remediation action. If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur.

In some cases, it is necessary to reduce the acceptable ER value since other sources of exposure need to be considered. For example, since the earth's crust is made up of metals, they are all around us. They are in the food we eat, the air we breathe and the water we drink. Therefore, the ER calculated from exposure in the study area must be adjusted to consider exposure from other

sources. For this assessment the acceptable risk threshold for the human health risk assessment was an ER of 0.2 because it is assumed that people are exposed to metals from multiple sources.

For wildlife, the acceptable risk threshold is an ER of 1 since the risk assessment conservatively assumed wildlife obtained all of their food, water and soil from the Lupin Gold Mine. No other significant exposure sources would occur while wildlife are in the vicinity of the mine site.

5.2 How Sure Are We?

5.2.1 Applying Layers of Safety

In this risk assessment, exposures and benchmarks were estimated from available information about how exposure might take place and the potential health effects that could result. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human and wildlife health will still be protected. Every effort was made to ensure that assumptions were specific to the Lupin Gold Mine.

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. This assumption accounts for the potential variability in concentrations in soil, sand, sediment, water and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the mine site were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (i.e., 365 days per year) from caribou that were exposed to maximum concentrations from the mine site for 37 days per year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals from the study area is uncertain. To add a layer of safety, for human health risk assessments it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower). This large margin of

safety ensures that doses less than the toxicity benchmarks are safe and that exposure slightly greater than the benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that risks due to exposure to metals and cyanide from the mine site have not been underestimated.

5.3 Is It Acceptable?

5.3.1 Acceptability of Guidelines and Toxicity Benchmarks

The risk assessment approach, guidelines and toxicity benchmarks used in this risk assessment have been determined by regulatory agencies to be acceptable based on a combination of scientific information and public acceptability. Science provides the understanding of the consequences of exposure. Public opinion has determined the level of protection that must be built into the guidelines and toxicity benchmarks.

6. RISK ASSESSMENT RESULTS

6.1 Wildlife Health Risk Assessment Results

ERs for wildlife receptors for all COCs are presented in Figure 4. ERs were less than 1 for caribou, grizzly bears, wolverines, foxes, wolves and arctic hare for all COCs. Therefore, no risks to individual animals or populations of these receptors are expected.

ERs were also less than 1 for exposure to barium, boron, chromium, copper, lead, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, and vanadium for all receptors. Therefore, no risks to individual animals or populations are expected for exposure to these metals for all receptors.

ERs for maximum concentrations of aluminum, arsenic, cobalt, zinc and cyanide were greater than 1 from some receptors. These results are described in more detail below. The results are presented and discussed in terms of risks to individual animals. This represents the primary measurement endpoint. If risks to individuals were predicted, then risks to populations were discussed in terms of the secondary measurement endpoint (i.e., potential to affect birth or death rate by greater than 20%).

Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations

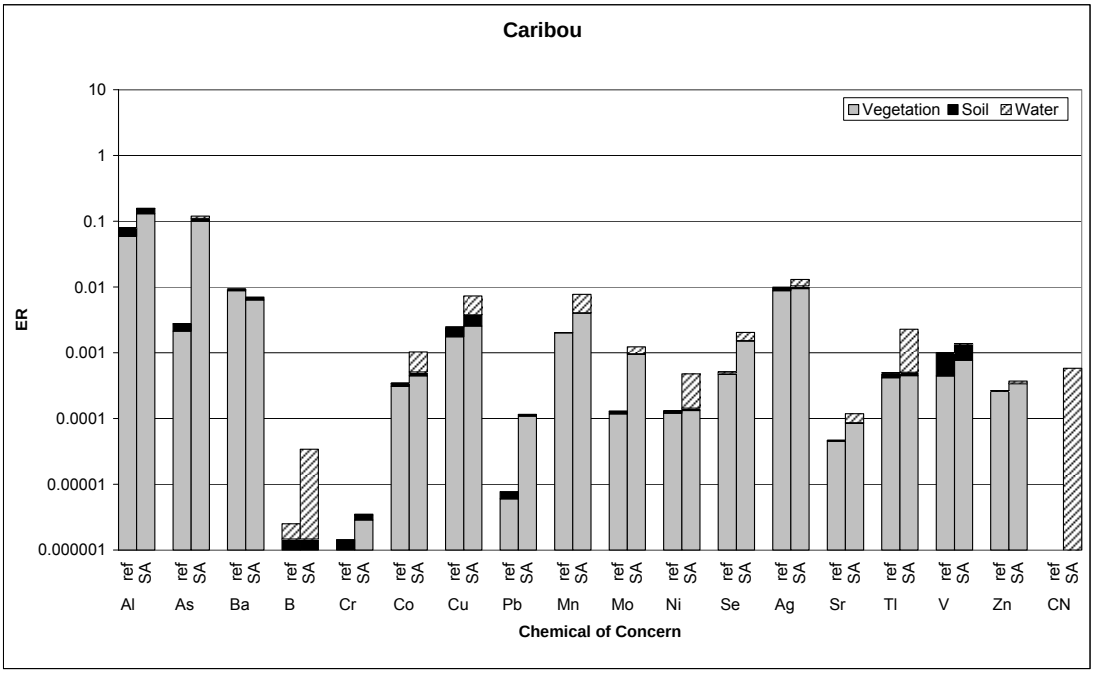
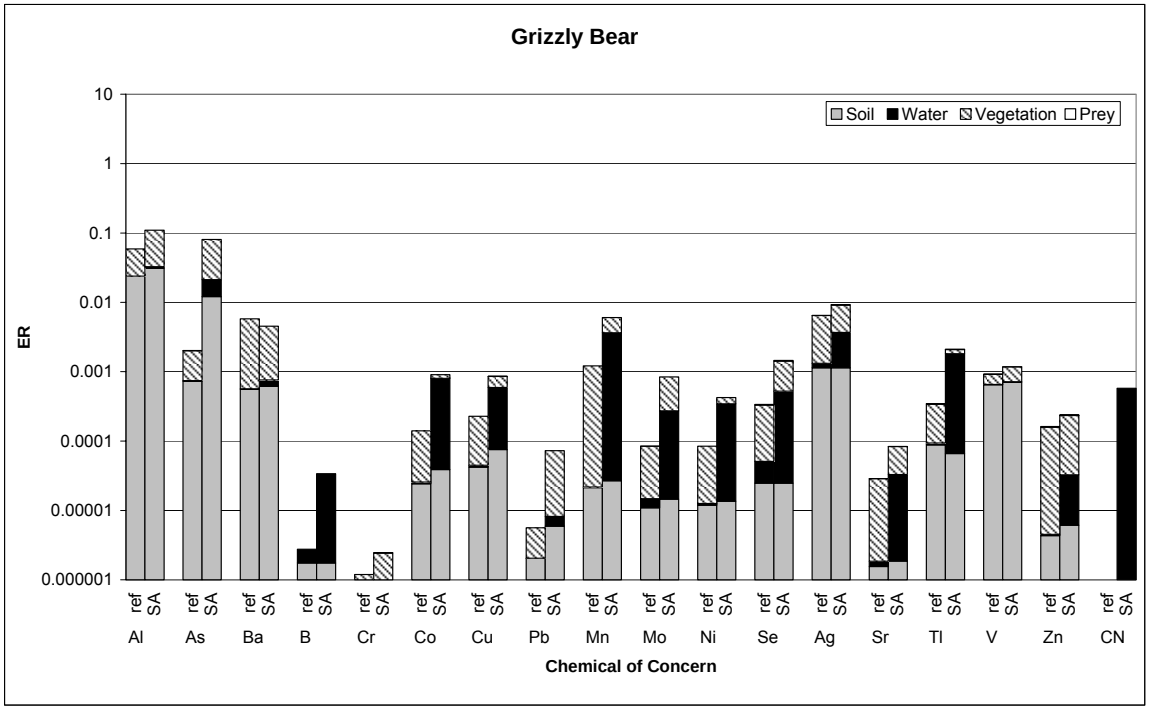


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



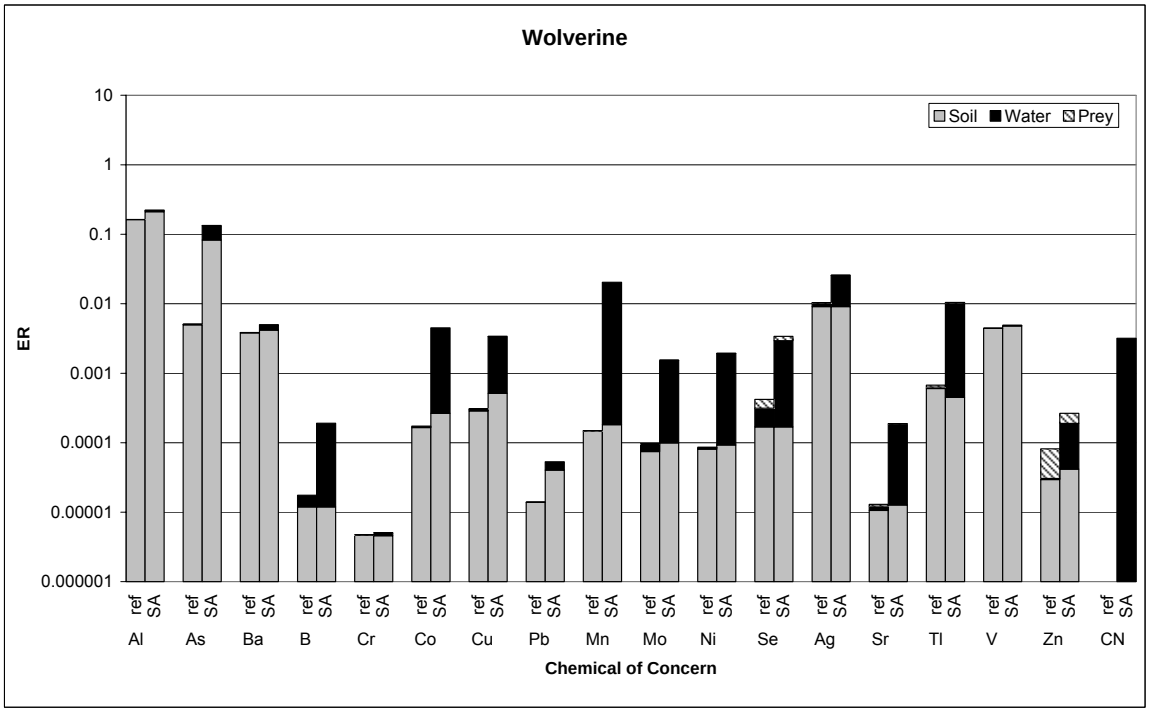
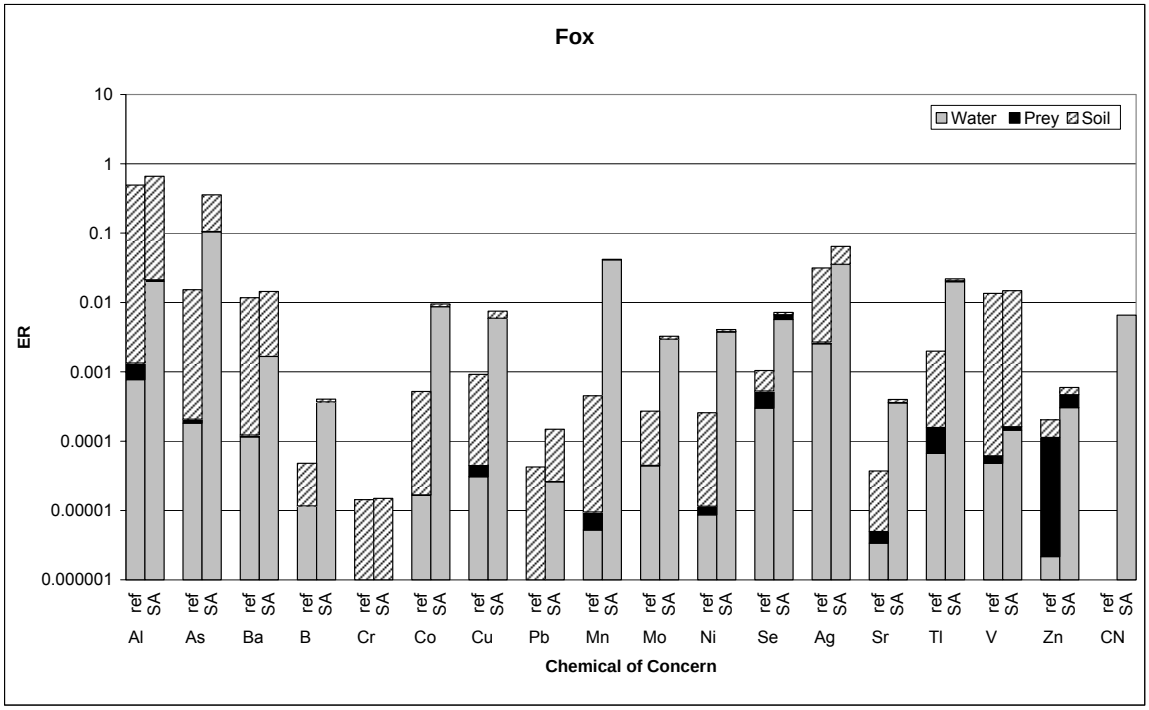


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



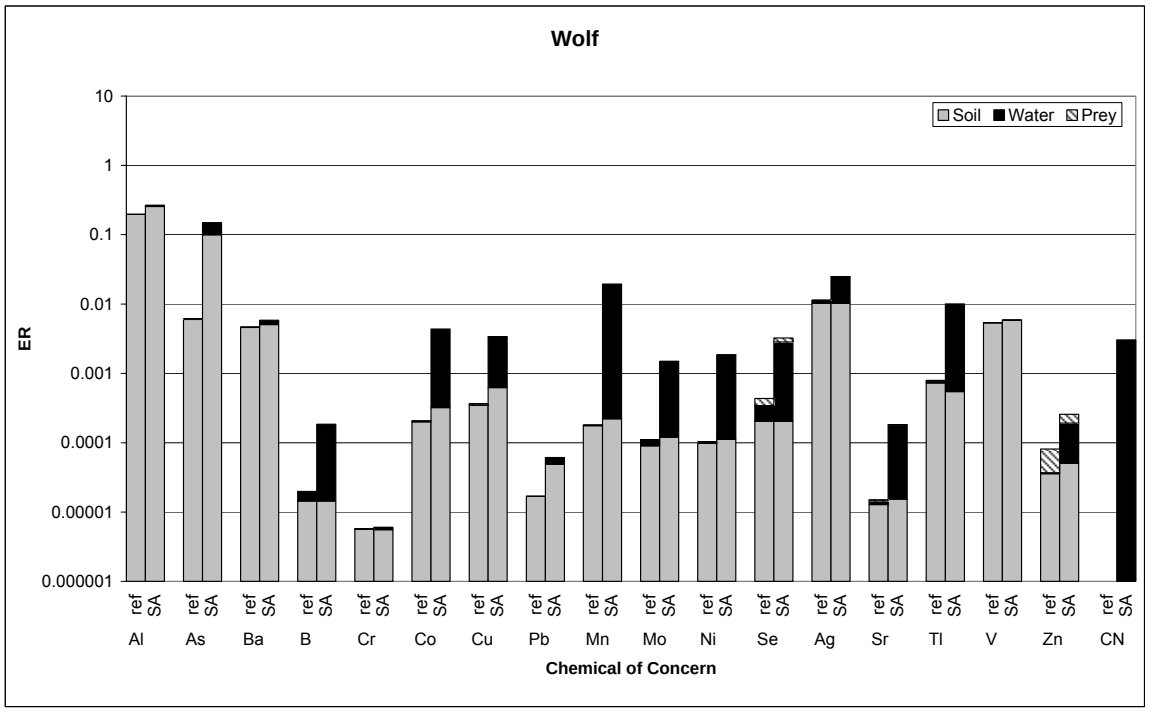
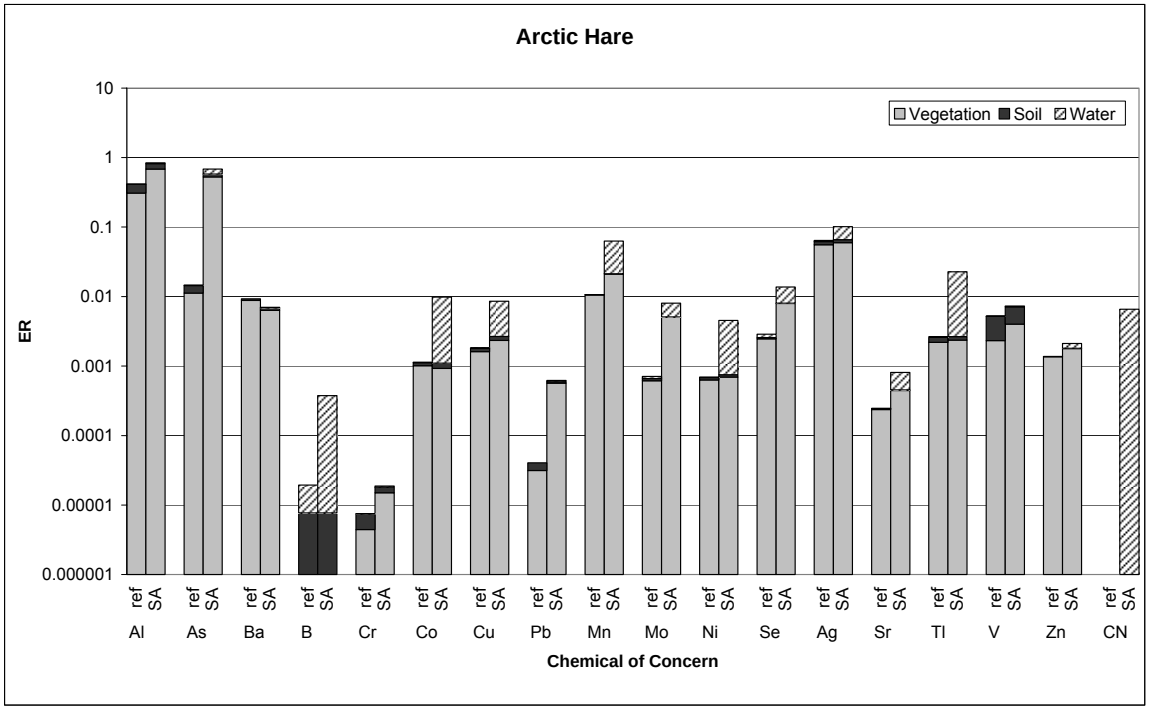


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



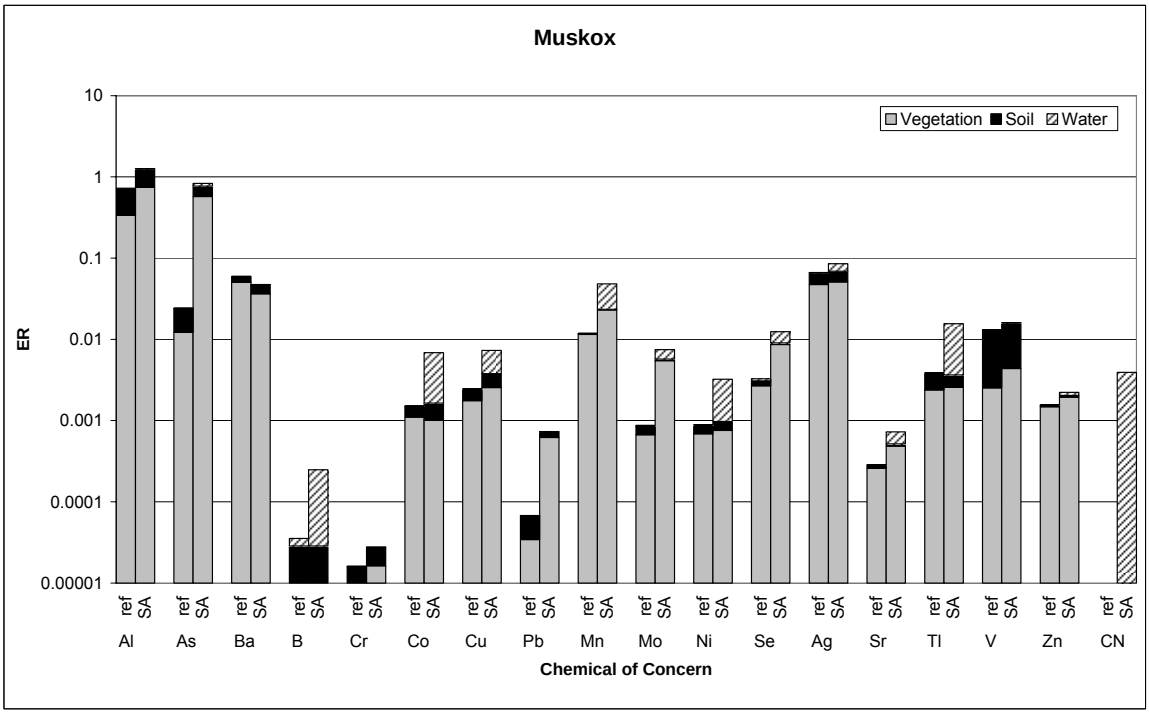
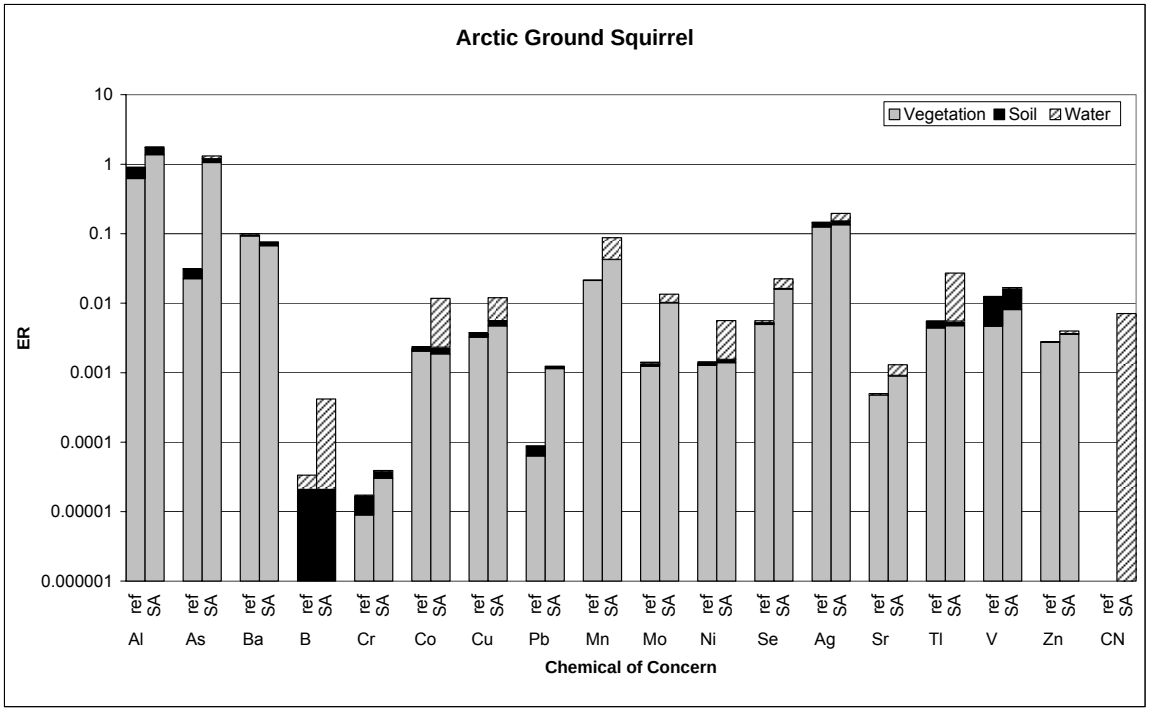


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



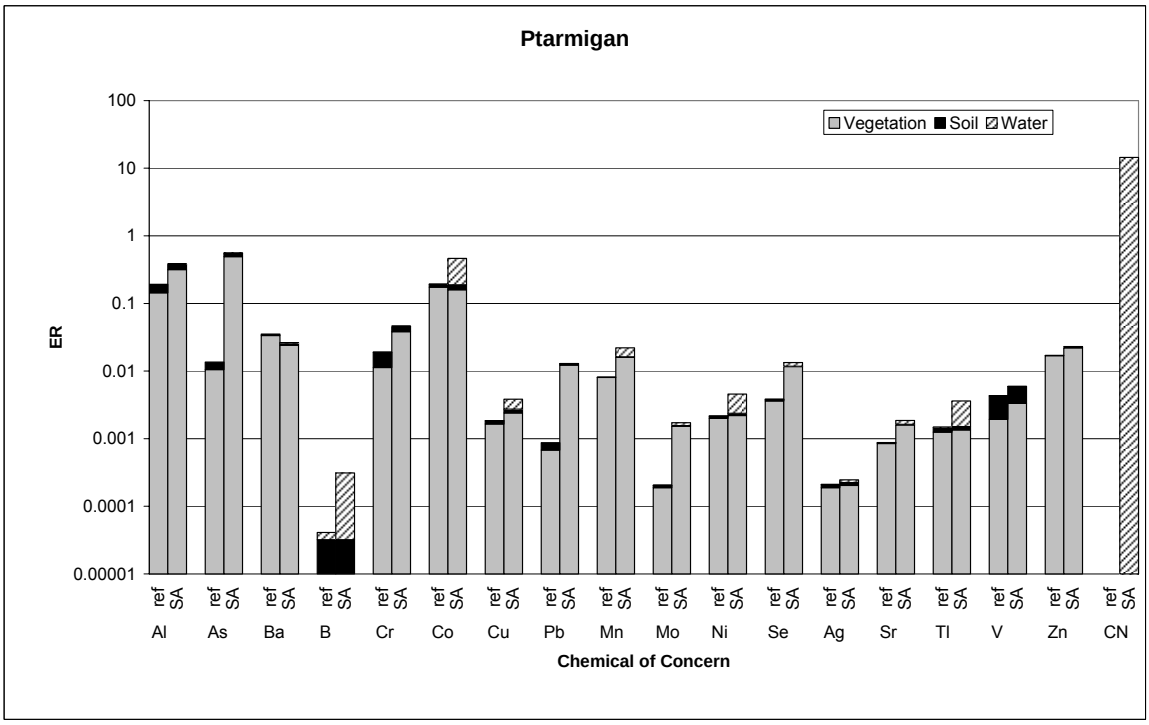
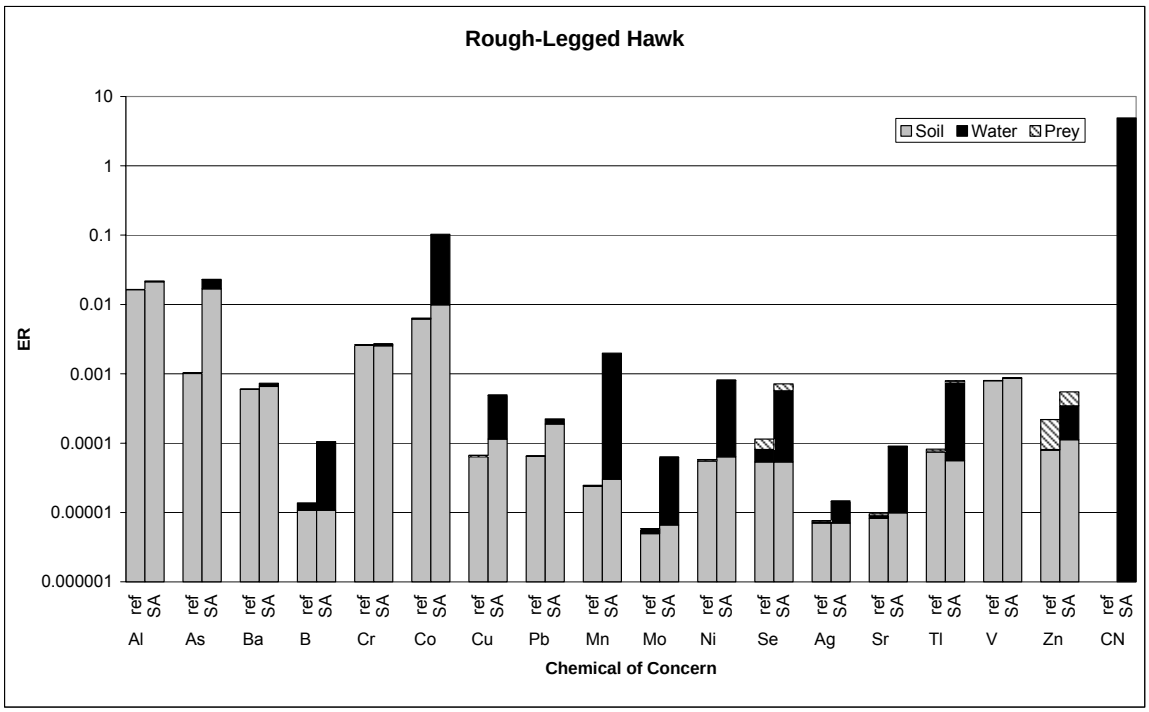


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



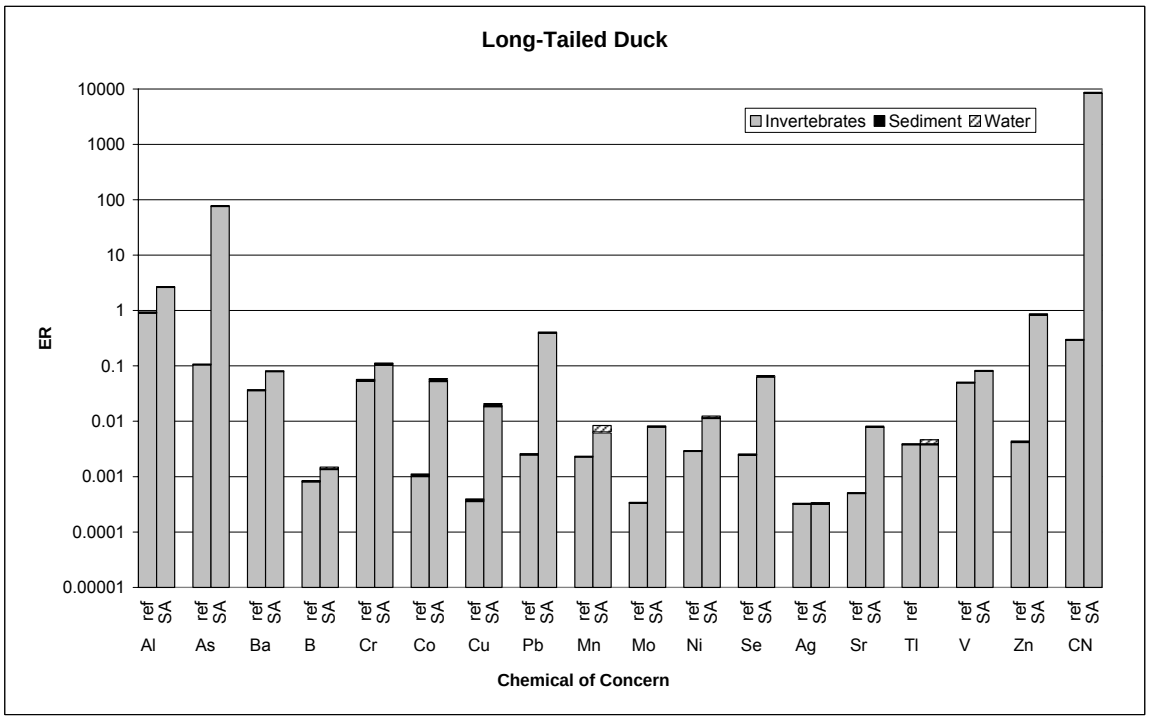
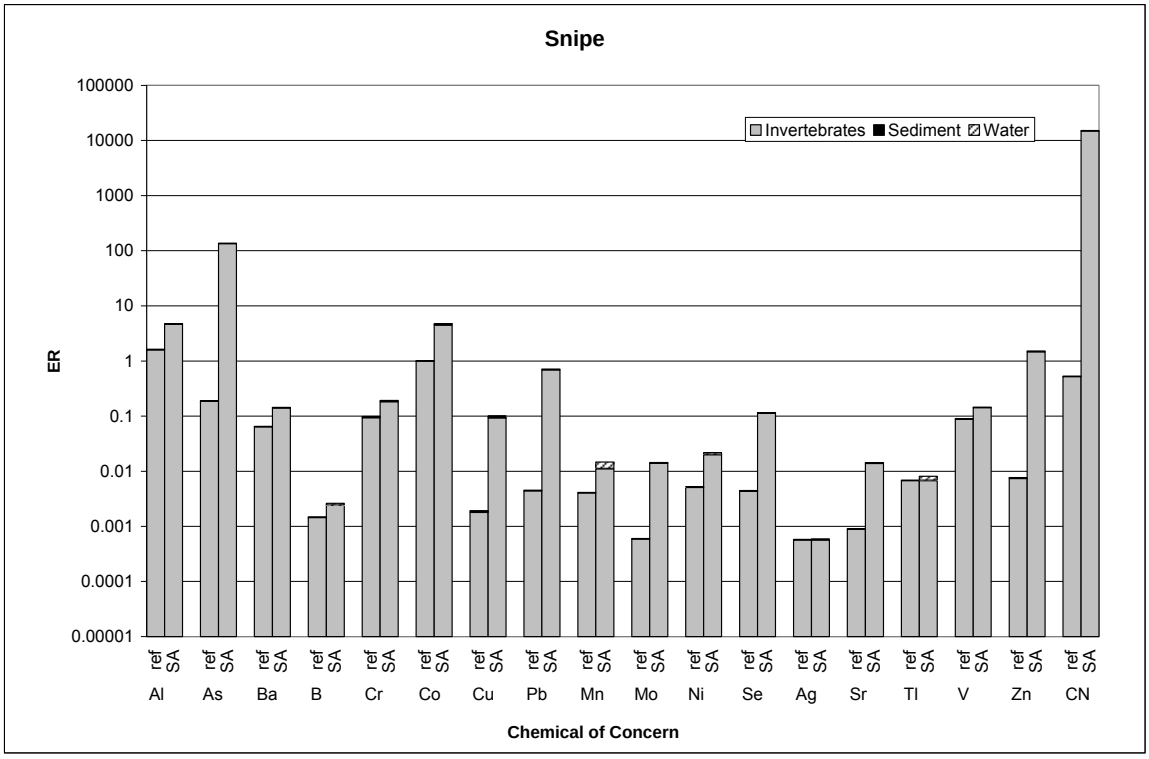


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



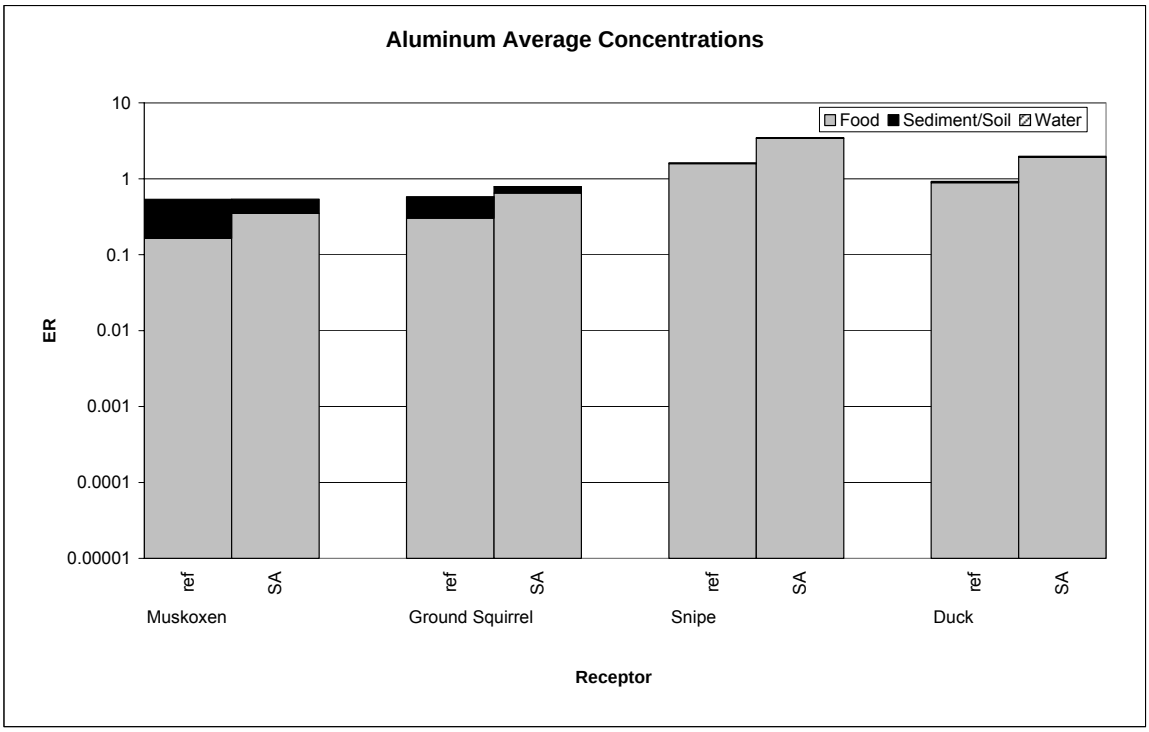
ref = reference area
SA = study area
Al = aluminum
As = arsenic
Ba = barium
B = boron
Cr = chromium
Co = cobalt
Cu = copper
Pb = lead
Mn = manganese
Mo = molybdenum
Ni = nickel
Se = selenium
Ag = silver
Sr = strontium
Tl = thallium
V = vanadium
Zn = zinc
CN = cyanide

6.1.1 Aluminum

ERs were marginally greater than 1 in the study area for muskox, arctic ground squirrel, snipe and long-tailed duck based on maximum concentrations. ERs in the study area were only slightly higher than ERs calculated for exposure to maximum concentrations of aluminum in the reference area (Figure 4). The main exposure pathway contributing to ERs greater than 1 is vegetation ingestion for muskox and arctic squirrel, and benthic invertebrate ingestion for snipe and long-tailed duck.

For comparison, ERs for muskox, arctic ground squirrel, snipe and long-tailed duck were calculated using average concentrations of aluminum measured in samples from the study area and reference area. ERs were less than 1 for muskox and arctic ground squirrel and ERs for the study area and reference area are very similar (Figure 5). ERs are marginally greater than 1 for snipe and long-tailed duck based on average concentrations of aluminum. The predominant exposure pathway is invertebrate ingestion. Invertebrate concentrations of aluminum were estimated from literature uptake factors. However, aluminum is one of the most common elements of the earth's crust and is often at relatively high concentrations in sediments and soils. Most naturally occurring aluminum compounds are insoluble and not available for uptake in invertebrates and subsequently wildlife. Therefore, it is likely that aluminum concentrations were substantially overestimated.

Figure 5
ERs for Muskoxen, Arctic Ground Squirrel, Snipe and Long-Tailed Duck Based on Average Concentrations of Aluminum



Aluminum is not likely to cause adverse health effects for any individual wildlife receptor for the following reasons:

- the differences between the study area and reference area ERs are small; therefore, measured concentrations are likely naturally occurring;
- it was assumed that 100% of aluminum measured in sediment was 100% available for uptake to invertebrates and birds; and,
- ERs are only marginally greater than 1 for maximum exposure by muskox and arctic ground squirrel and less than 1 for average exposure. ERs are only marginally greater than 1 for maximum and average exposure by snipe and long-tailed duck.

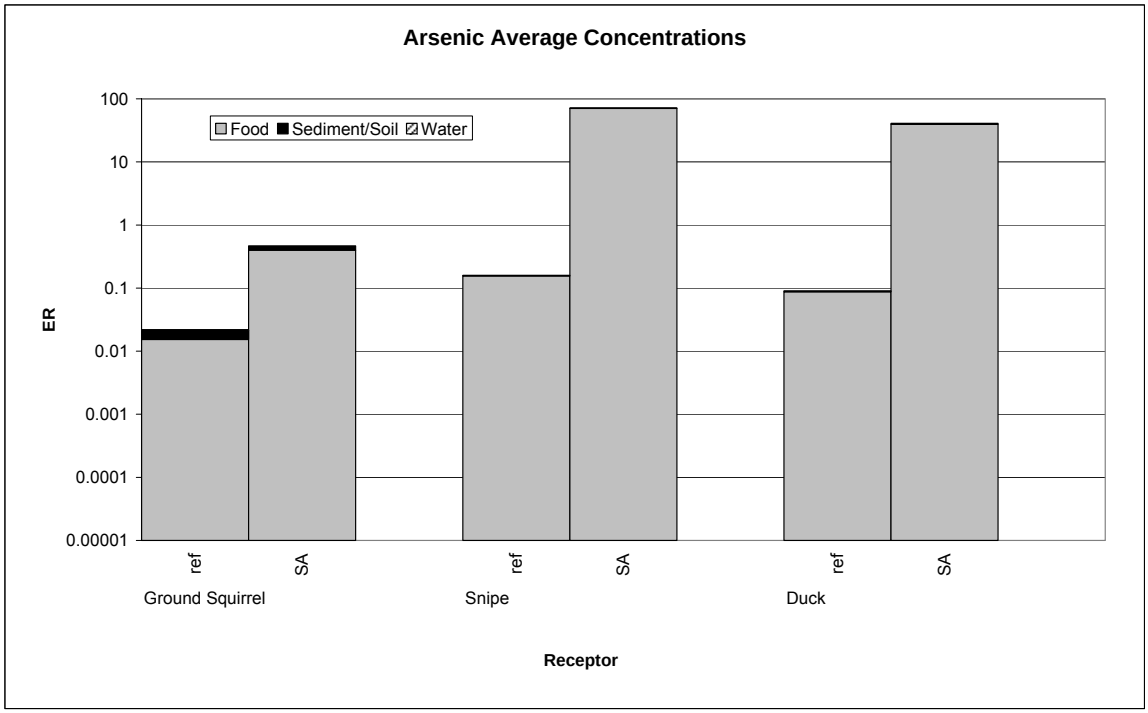
6.1.2 Arsenic

ERs estimated for maximum arsenic exposure were greater than 1 for arctic ground squirrel, snipe and long-tailed duck for exposure in the study area (Figure 4). ERs for arctic ground squirrel were only marginally greater than 1 (i.e., 1.1); therefore, risks to arctic ground squirrels are not expected to occur due to the conservative assumptions used in the risk assessment (e.g., exposure to maximum concentrations every day).

ERs for long-tailed duck and snipe exposure to arsenic were much greater than 1 (Figure 4). The predominant exposure pathway was invertebrate ingestion. Benthic invertebrate arsenic concentrations were estimated based on literature uptake values, which may have resulted in an overestimate of exposure. It is also not known whether substantial numbers of invertebrates inhabit the ponds on site. It is likely that invertebrate abundance is not sufficient to fully support the dietary needs of long-tailed ducks and snipe.

For comparison purposes, ERs for arctic ground squirrel, snipe and long-tailed duck were calculated using average concentrations of arsenic measured in samples from the study area and reference area. Based on average concentrations, ERs were less than 1 for arctic ground squirrel but remained greater than 1 for snipe and long-tailed duck (Figure 6).

Figure 6
ERs for Arctic Ground Squirrel, Snipe and Long-Tailed Duck Based on Average Concentrations of Arsenic

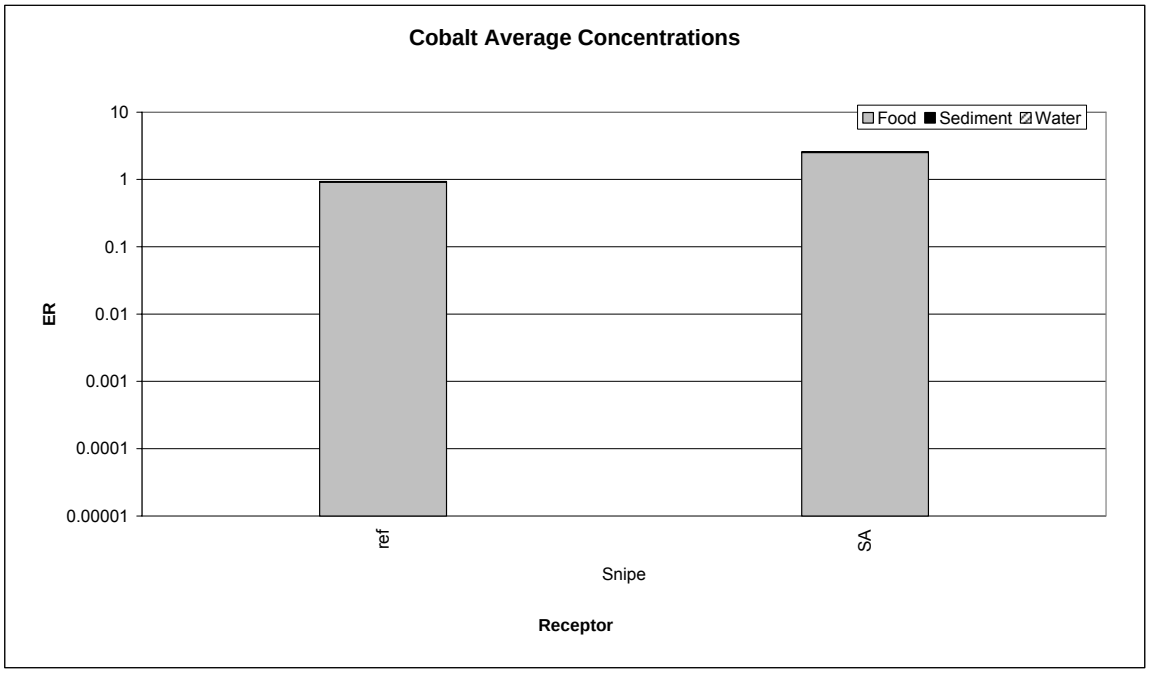


6.1.3 Cobalt

ERs were greater than 1 for snipe exposure to cobalt and benthic invertebrate ingestion was the predominant exposure pathway (Figure 4). Literature values for uptake were used to estimate benthic invertebrate concentrations from sediment data and as described above, this may have resulted in an overestimate of concentrations.

For comparison purposes, ERs for snipe were calculated using average concentrations of cobalt measured in samples from the study area and reference area. The ER based on average cobalt concentrations was marginally greater than 1 in the study area, but the majority of the exposure is expected to be due to background concentrations since the difference between ERs in the study area and reference area are minimal (Figure 7). Because of the conservative assumptions used in the risk assessment and minimal difference between the study and reference areas, adverse health effects are not expected for snipe exposure to cobalt.

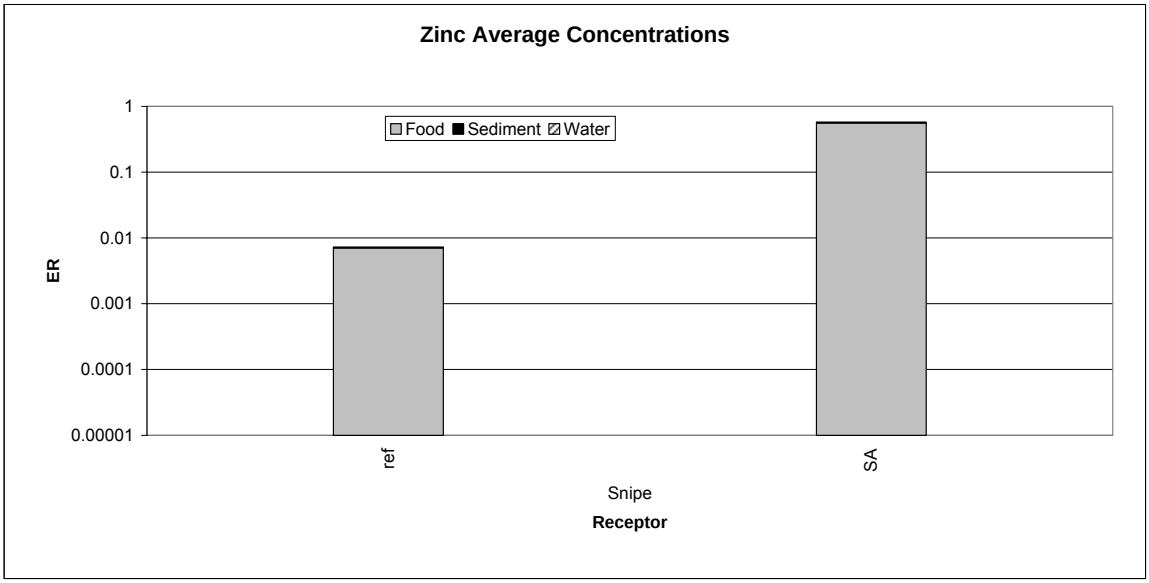
Figure 7
ERs for Snipe Based on Average Concentrations of Cobalt



6.1.4 Zinc

Exposure for snipe to maximum concentrations of zinc was only marginally greater than 1 in the study area (i.e., 1.5). The predominant exposure pathway is benthic invertebrate ingestion, which as described above is based on estimated benthic invertebrate concentrations using literature values. ERs calculated using average zinc concentrations were less than 1 (Figure 8). It is unlikely that adverse health effects would be caused by exposure to zinc because ERs were only marginally greater than 1 for maximum concentrations and were less than 1 based on average concentrations.

Figure 8
ERs for Snipe Based on Average Concentrations of Zinc

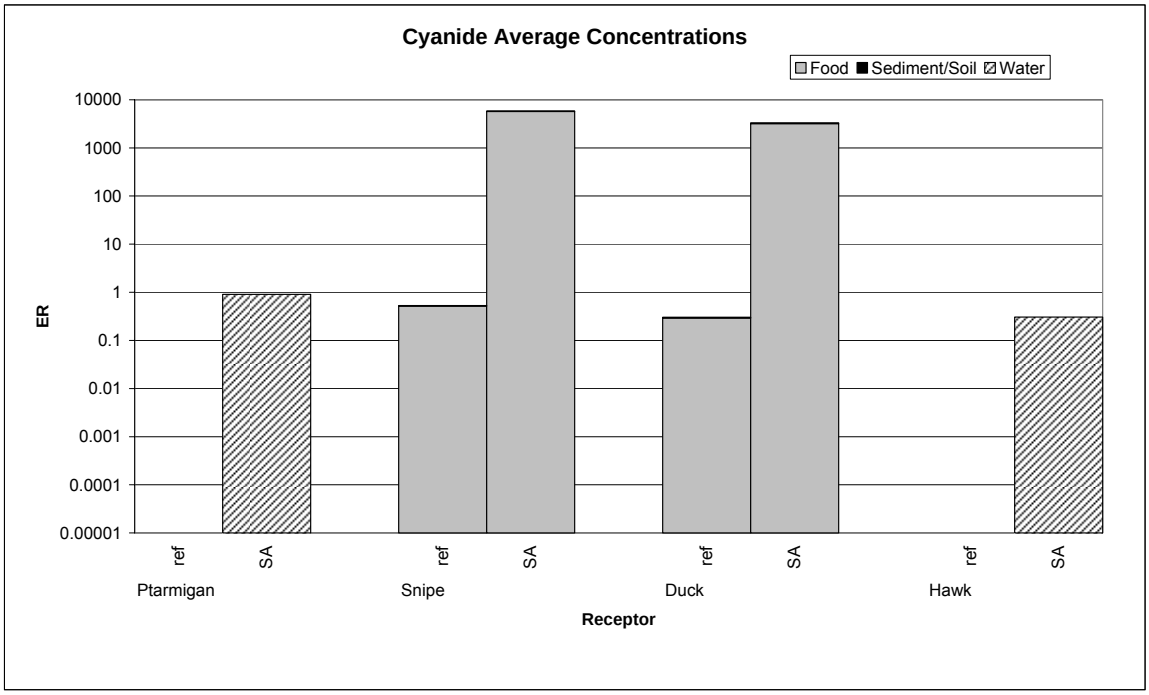


6.1.5 Cyanide

Estimated exposures to cyanide resulted in ERs much greater than 1 for long-tailed duck and snipe, and ERs slightly greater than 1 for ptarmigan and rough-legged hawk (Figure 4). The predominant exposure pathway is invertebrate ingestion; however, ERs for the sediment ingestion and water ingestion pathways were also much greater than 1 for long-tailed duck and snipe. Water ingestion is the predominant pathway for ptarmigan and rough-legged hawk.

ERs were also calculated based on average cyanide concentrations for long-tailed duck, snipe, ptarmigan and rough-legged hawk. ERs were less than 1 for ptarmigan and rough-legged hawk, but were greater than 1 for long-tailed duck and snipe (Figure 9).

Figure 9
ERs for Ptarmigan, Hawk, Snipe and Long-Tailed Duck Based on Average Concentrations of Cyanide



6.2 Risks to Wildlife Receptor Populations

The risks to wildlife receptors calculated from both maximum media concentrations and average media concentrations are presented in Table 4.

Table 4
Summary of Risks to Shorebirds and Waterfowl based on Maximum and Average Concentrations in the Study Area

Receptor	Contaminant of Concern	Total ER	
		Maximum Concentrations	Average Concentrations
Snipe	Arsenic	138	72
	Cyanide	15,173	5,822
Duck	Arsenic	78	41
	Cyanide	8,639	3,315

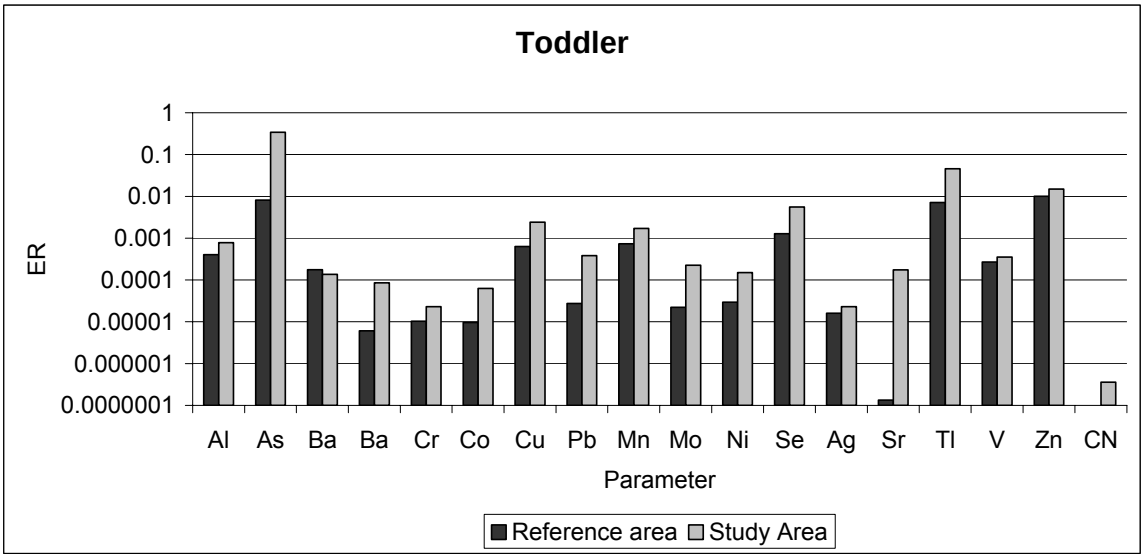
Population-level risks for migratory animals such as snipe and long-tailed duck would require a sufficient number of individuals to either have lower survivorship or lower reproductive capability due to exposure to the Lupin site to cause a decline in abundance and population persistence. The Lupin area is on the path of a major bird migratory route; therefore, many individuals may have short-duration exposure to the site. However, it is likely that very few individuals or breeding pairs would spend the entire breeding season at the site. Therefore, it is unlikely that sufficient numbers of individuals would be affected to pose a risk to populations.

6.3 Human Health Risk Assessment Results

ERs were less than 0.2 for all COCs for both toddler and adult ingestion of caribou meat, except for arsenic. ERs for maximum exposure to arsenic (non-carcinogenic effects) were marginally greater than 0.2 (i.e., 0.3 for both toddlers and adults) (Figure 10). Since arsenic is a carcinogen, a lifetime cancer risk due to arsenic exposure was also calculated. The lifetime cancer risk due to maximum concentrations of arsenic due to ingestion of caribou is 14 in 100,000. These calculations were based on maximum arsenic exposure in water, soil and vegetation by caribou and ingestion of these caribou by people everyday for a lifetime. This is a highly improbable scenario.

The cancer risks calculated for the reference areas and Study Area were compared with cancer risks calculated for the Canadian Drinking Water Quality Guideline and lifetime probability of getting cancer from all sources (such as, family history, genetics, lifestyle) (Figure 11). The lifetime probability of getting cancer from all sources is 40,000 in 100,000 (Health Canada 2003a). Since arsenic is naturally occurring, background water sources (surface water and groundwater) typically have concentrations of arsenic that have a greater than 1 in 100,000 cancer risk. Health Canada accepted a cancer risk for arsenic of 147 in 100,000 in the derivation of the drinking water quality guideline (Health Canada 2003b). The cancer risk estimated in the study area of 14 in 100,000 would not be considered measurable, and would be considered insignificant compared to the cancer risk associated with the Canadian Drinking Water Quality Guideline (Health Canada 2003b) and the cancer incidence from all causes in Canada (Health Canada 2003a).

Figure 10
ERs for Toddler and Adult Based on Maximum Arsenic Concentrations



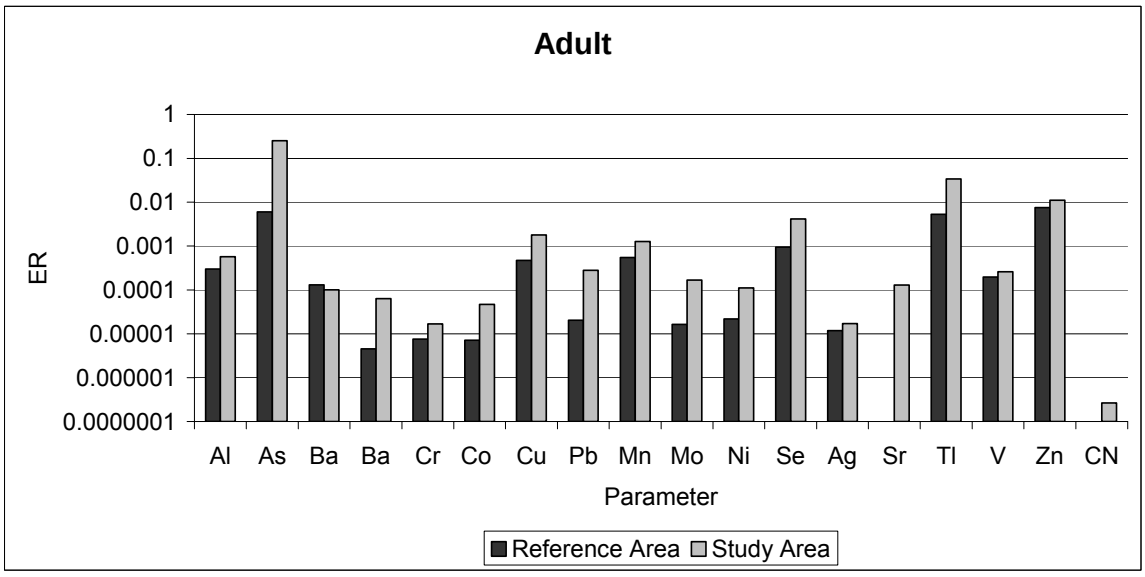
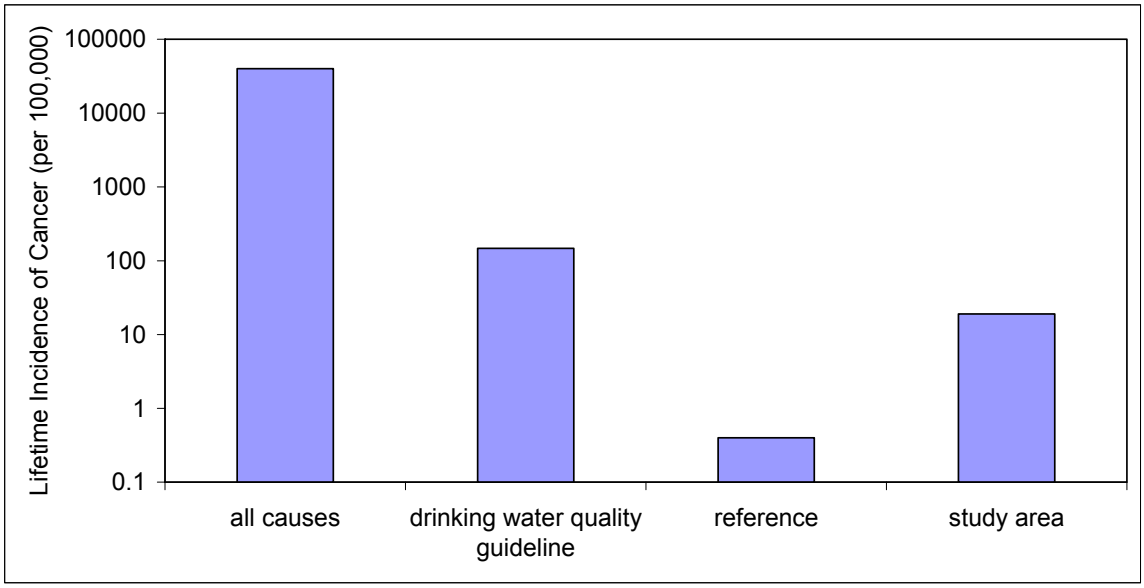


Figure 11
Lifetime Cancer Risks Due to All Causes, Drinking Water Quality Guideline and Maximum Arsenic Exposure in the Study Area and Reference Area



6.4 Uncertainty (How Sure Are We?)

There are several sources of uncertainty in the wildlife and human health risk assessment that may have resulted in an overestimate of potential risks.

- Amount of time spent by animals (particularly birds and caribou) in the vicinity of the TCA;
- Presence of adequate numbers of benthic invertebrates in the TCA to support shorebird and waterfowl diets;
- Availability for uptake and speciation (which affects toxicity) of metals and cyanide;
- Invertebrate uptake of metals and cyanide from sediment;
- Contribution of wind-blown tailings to vegetation metal concentrations versus direct uptake from soil (current plant concentrations may overestimate uptake from soil once all tailings are covered);
- Uptake of arsenic in caribou tissues;
- Frequency that people would consume caribou that have spent considerable of time at the Lupin TCA;

- Understanding of toxicity potential for wildlife (since toxicity benchmarks were based on a limited number of studies using laboratory animals such as rats and mice).

In addition to these areas of uncertainty, the characterization of risks to populations of receptors with predicted ERs greater than 1 (snipe and long-tailed duck) is uncertain because:

- The number of birds spending the entire breeding season in the area is unknown;
- Estimates of the total population of birds that may use the Lupin region either as a stop-over or for breeding is unknown;
- Quantitative estimates of the amount of change in survivorship or reproduction required to pose a risk to population persistence were not part of the scope of work for this screening-level assessment.

7. CONCLUSIONS

7.1 Human Health

For the human health risk assessment, for all of the metals evaluated in the assessment, estimated exposure was less than the toxicity benchmarks, with the exception of arsenic. It is very unlikely that the scenario used to estimate human exposure to arsenic via caribou ingestion would be realized. In addition, potential ERs of 0.3 for non-carcinogenic effects and 14 in 100,000 for carcinogenic effects are only slightly above 0.2 and 1 in 100,000; the levels for which no effects are expected. It is very unlikely that health effects would be observed based on these assumptions. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the study area.

7.2 Wildlife Health

Based on the results of this preliminary risk assessment, there is a potential for risk to individual shorebirds and waterfowl due to arsenic and cyanide exposure. Risks are not expected due to any other COCs or for any other receptors. Conservative assumptions and many layers of safety were applied to the wildlife health risk assessment. This means that there is a high degree of certainty that risks have not been underestimated. As stated in Section 6.3, there are several assumptions that were made in the risk assessment that might have lead to an overestimation of risks for shorebirds and waterfowl. Furthermore, risks to populations of shorebirds and waterfowl are unlikely. However, the characterization of risks to populations is uncertain.

7.3 What Does This Mean for the Lupin Closure Plan?

The closure plan for the Lupin TCA includes two major features; covering exposed tailings with 1 m of esker sand and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2.

No wildlife or human health risks are expected due to placement of 1 m of esker sand over exposed tailings.

The exposure pathways related to covering exposed tailings with esker sand are direct soil ingestion and ingestion of plants growing on the tailings areas. This risk assessment shows that risks from sand-covered tailings are acceptable, both for humans and wildlife. Furthermore, exposure via water from within the capped tailings will not be a concern. This is because, based on the results of the engineering feasibility of covering exposed tailings with esker sand, it is not expected that excessive water will seep into the ponds. Nor is it expected that water will move upward into the root zone of plants growing at the surface of the esker sand (Golder 2004). Therefore, water quality is not expected to worsen in the future.

Risks to individual shorebirds and waterfowl were predicted due primarily to exposure to arsenic and cyanide in invertebrates living in Ponds 1 and 2. This leads to the risk management questions:

- Should ponds 1 and 2 remain as features in the reclaimed landscape? and,
- If ponds 1 and 2 remain, should measures be taken to reduce exposure to arsenic and cyanide via invertebrates in contact with sediments?

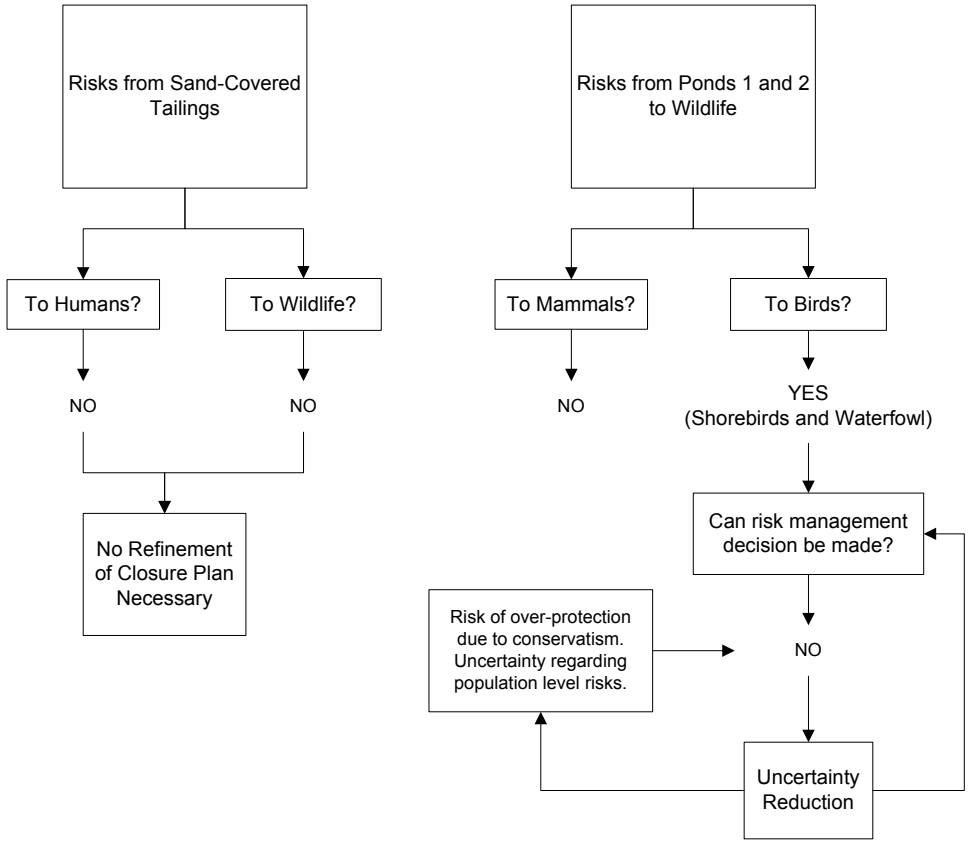
These two questions cannot be answered with confidence because of the uncertainties in the risk assessment. The risks are very likely to be greatly over-estimated. Therefore, it would not be advisable to proceed to risk management since there may be a large mis-match between the cost of remediation and the actual risk reduction achieved. Therefore, it is recommended that uncertainties in the assessment of risk to waterfowl and shorebirds be reduced. The following two steps should be considered as preliminary steps to reduce uncertainty:

(1) Sensitivity analysis of the exposure model to reveal which parameters “drive” the risk estimates; and,
(2) Collection of information from the Canadian Wildlife Service and other sources regarding migratory bird populations to better estimate the time that birds may actually spend during the breeding season in the area.

Completion of steps (1) and (2), will allow a re-examination of the level of conservatism in the exposure models, and will also allow a more confident characterization of risks to populations. If the combination of confirmation of highly-conservative risks to individuals plus a more confident prediction of no risks to populations results in a conclusion that risk management is not required, then no further work will be necessary. However, if risks to populations cannot be ruled out and/or if regulatory acceptance of risks to individuals (despite the lack of risks to populations) is not forthcoming, then proceeding with further reduction of uncertainty may be necessary. Further reduction of uncertainty would involve proceeding with additional data collection.

Results of this assessment can be illustrated by the following flow-chart (Figure 12).

Figure 12
Summary of Risk Assessment Results and Recommendations

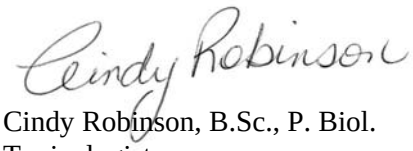


8. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

GOLDER ASSOCIATES LTD.

Report prepared by:



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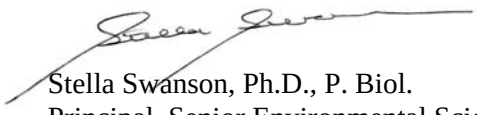

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9. REFERENCES

AENV (Alberta Environment). 2000. Policy for Management of Risks at Contaminated Sites in Alberta. AENV, Edmonton, AB.

AQUAMIN (Assessment of the Aquatic Effects of Mining in Canada). 1996. Supporting Document II: Appalachian Region. Case Studies Volume 1, Nanisivik and Lupin Mines. Prepared by AQUAMIN working group, Ottawa, ON. 56 p.

CCME (Canadian Council of Ministers of the Environment). 1996a. A Framework for Ecological Risk Assessment: General Guidance. National Contaminated Sites Remediation Program. CCME. Winnipeg, Manitoba. March 1996.

CCME (Canadian Council of Ministers of the Environment). 1996b. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. CCME-EPC-101E.

CCME (Canadian Council of Ministers of the Environment). 1996c. Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada. National Contaminated Sites Remediation Program. CCME. Winnipeg, Manitoba.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. Updated 2003. Winnipeg, CCME-1299.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2002. Endangered Species in Canada: 2001 List. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

EBM (Echo Bay Mines Ltd). 2001. Lupin Operation General Information. 21 p.

EBM (Echo Bay Mines Ltd.). 2000. 2000 Annual Report: Lupin Gold Mine for Nunavut Water Board.

EBM (Echo Bay Mines Ltd.). 2001. 2001 Annual Report: Lupin Gold Mine for Nunavut Water Board.

EBM (Echo Bay Mines Ltd.). 2003. 2003 Annual Report: Lupin Gold Mine for Nunavut Water Board.

EVS Environmental Consultants. 1996. Field Evaluation Aquatic Effects Monitoring – 1996 Survey: Final Report: Lupin Mine Site, Northwest Territories. Prepared for Aquatic Effects Technology Evaluation Program, Natural Resources Canada, CANMET (Canada Centre for Mineral and Energy Technology), Ottawa, Ontario. 60 pp + 6 app.

Golder (Golder Associates Ltd.). 2003. Final Report on Lupin Gold Mine Environmental Effects Monitoring Program: Historical Information Report. Submitted to: Reclamation/Projects Manager, Lupin, Kinross Gold Corporation. Edmonton, Alberta.

Golder (Golder Associates Ltd.) 2004. Draft Report on Studies Related to Water Licence Requirements and in Support of Reclamation Planning. Submitted to: Kinross Gold Corporation. Calgary, Alberta.

Gunn, A., J. Dragon and J. Boulanger. 2002. Seasonal Movements of Satellite-Collared Caribou from the Bathurst Herd. Final report to the West Kitikmeot Slave Study Society. Yellowknife, NT.

Health Canada. 1994. Canadian Environmental Protection Act: Human Health Risk Assessment for Priority Substances. Health Canada, Ottawa, ON.

Health Canada. 1995 (unpublished). Human Health Risk Assessment of Chemicals from Contaminated Sites: Volumes I and II. Health Canada, Ottawa ON.

Health Canada. 2003. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Screening Level Risk Assessment (SLRA). Version 1.1. Health Canada, Ottawa ON.

IRIS (Integrated Research Information System). 2004. U.S. Environmental Protection Agency, Cincinnati, OH. Available on the internet at: http://www.epa.gov/iris/ Accessed October 2004

Klohn-Leonoff. 1992. Acid Rock Drainage Study: Lupin Mine NWT Final Report.

Klohn-Crippen. 1995. Tailings Reclamation Test Cover Program: 1994 Report of Activities.

Paustenbach, D.J. (Editor). 2002. Human and Ecological Risk Assessment: Theory and Practice. John Wiley and Sons, Inc., New York.

RIVM (National Institute of Public Health and the Environment). 2001. Re-evaluation of Human-Toxicological Maximum Permissible Risk Levels. RIVM report 711701 025.

R.L.&L. Environmental Services Ltd. and Department of Fisheries and Oceans. 1991. Fisheries Investigations at the Lupin Gold Mine, Contwoyto Lake, NWT, 1990. Prepared for Echo Bay Mines Ltd., Edmonton, AB. R.L.&L. Report No. 275: 59 p + 2 app.

R.L.&L. Environmental Services Ltd. 1995. 1993 Fish Tissue Metals Analysis in Contwoyto Lake, N.W.T. Prepared for Echo Bay Mines Ltd., Edmonton, Alberta. R.L.&L. Report No. 385F: 33 p + 4 app.

R.L.&L. Environmental Services Ltd. 1996. Application of Selected Monitoring Methods to the Assessment of Impacts on Contwoyto Lake from Lupin Gold Mine Effluent. Phase 3 – Long Term Assessment Final Report.

SARA (Species At Risk Act). 2002. Species at Risk Act. Assented 12 December 2002, c.29.

Sample, B.E. and C.A. Arenal. 1999. Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data. Bull. Environ. Contam. Toxicol.; 62: 653-663.

Sample, B.E., D.M. Opresko and G.W. Suter II. 1996. Toxicological Benchmark for Wildlife: 1996 Revision. ES/ER/TM-86/R3.

Suter, G. W., B.W. Cornaby, C. T. Hadden, R. N. Hull, M. Stack and F. A. Zafran. 1995. An Approach for Balancing Health and Ecological Risks at Hazardous Waste Sites. Risk Analysis; 15(2): 221-231.

TERA (Toxicology Excellence for Risk Assessment). 2004. Available on the internet at: http://www.tera.org/ Accessed October 2004.

U.S. EPA. (United States Environmental Protection Agency). 1998. Guidelines for Ecological Risk Assessment. Washington, D.C. EPA/630/R-95/002F.

APPENDIX I

DATA USED IN RISK ASSESSMENT

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I DATA USED IN THE RISK ASSESSMENT

I.1 Introduction

Chemical data have been obtained for water and sediment samples, collected from the Lupin Mine Site receiving water bodies directly outside of the study area and from reference areas used in previous studies undertaken by Kinross Gold Corporation (Kinross). In addition, soil, sediment and vegetation samples were collected from the study area and from reference locations for the purposes of this assessment. These data were reviewed and evaluated in the risk assessment and are summarized in this appendix.

The risk assessment required information on metal concentrations in the following parts of the food chain:

- reference water, soil, sand, sediment and native plant species;
- sediment from ponds within the study area and the immediate receiving environment;
- soil from areas impacted by wind-blown tailings, and esker sand covering tailings containment cells;
- plants from areas impacted by wind-blown tailings and from the esker sand cover;
- water within the study area (pond 1, pond 2, cells 1, cell 4) and receiving environment;
- lake trout muscle and liver tissue from the study area (calculated), and receiving environment (calculated); and
- caribou meat tissue (calculated based on uptake from food, water, and soil).

I.2 Soil

In August, 2004, environmental technicians from Kinross collected soil samples from three locations:

- esker borrow area (reference location) approximately 3 km south-east of the Study Area;
- cell 1 esker sand covering; and
- an area potentially impacted by wind-blown tailings.

Soil concentrations used in the risk assessment are presented in Tables I-1 and I-2, for the reference areas and the Study Area, respectively.

Table I-1
Soil Concentrations from Samples Collected from the Reference Area (Esker Borrow Area)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)								
		27-Aug-04		29-Aug-04				Minimum	Maximum	Mean[(a)]
		EB 5-1	EB 5-2	EB 5-3	EB 5-4	EB 5-5	EB 5-6			
Aluminum	50	4,640	4,860	4,550	4,810	4,250	4,800	4,250	4,860	4,652
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	5.9	4.4	7.8	6.9	9.7	6.5	4.4	9.7	6.9
Barium	0.5	30.1	35.3	25.7	29.4	27.7	34.8	25.7	35.3	30.5
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	2	<2	<2	2	<2	<2	<2	<2	2	<2
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	18.4	20.9	18.8	18.3	17.6	23.0	17.6	23.0	19.5
Cobalt	0.1	3.0	3.5	2.2	2.9	2.1	3.2	2.1	3.5	2.8
Copper	0.5	8.2	7.1	5.2	7.6	5.9	8.3	5.2	8.3	7.1
Iron	200	7,000	7,900	6,800	7,500	5,800	7,900	5,800	7,900	7,150
Lead	0.5	1.4	1.3	1.8	1.3	2.0	1.4	1.3	2.0	1.5
Manganese	1	67	74	57	73	49	70	49	74	65
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.3	0.2
Nickel	0.5	9.9	11.6	7.8	10.1	7.5	11.4	7.5	11.6	9.7
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	4	4	4	5	5	3	3	5	4
Thallium	0.05	0.05	0.07	0.05	0.06	0.05	0.08	0.05	0.08	0.06
Tin	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Titanium	1	284	343	386	277	334	334	277	386	326
Uranium	0.05	0.48	0.44	0.46	0.43	0.65	0.58	0.43	0.65	0.51
Vanadium	0.2	13.5	15.4	16.4	13.0	12.9	14.8	12.9	16.4	14.3
Zinc	5	16	17	14	17	14	17	14	17	16

(a) Calculations were based on half detection limits for parameters that were less than analytical detection limits.

Table I-2
Soil Concentrations from Samples Collected from the Study Area (Cell 1 and Wind Blown Tailings Area)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)													
		Cell 1						Wind-Blown Tailings Area							
		27-Aug-04						27-Aug-04	29-Aug-04	30-Aug-04					
		Cell 1-5-1	Cell 1-5-2	Cell 1-5-3	Cell 1-5-4	Cell 1-5-5	Cell 1-5-6	WT 5-1	WT 5-2	WT 5-3	WT 5-4	WT 5-5	Minimum	Maximum	Mean[a]
Aluminum	50 - 100	50	50	50	50	50	50	4,380	4,950	5,750	4,330	6,310	<100	6,310	2,365
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	144.0	34.0	20.2	28.8	43.4	21.0	50.1	142.0	40.0	161.0	118.0	20.2	161.0	73.0
Barium	0.5	29.5	38.1	37.3	38.8	30.2	33.0	30.7	24.9	21.8	20.4	19.3	19.3	38.8	29.5
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	1 - 2	2	2	1	2	1	2	1	1	1	1	1	1	2	1
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	18.6	22.0	21.6	17.7	22.6	19.7	18.5	19.0	21.7	13.5	16.9	13.5	22.6	19.3
Cobalt	0.1	2.9	5.6	3.8	3.5	3.1	3.1	2.8	2.9	4.3	2.1	3.3	2.1	5.6	3.4
Copper	0.5	8.5	10.5	9.4	7.4	7.1	7.2	10.6	8.5	14.2	9.5	14.9	7.1	14.9	9.8
Iron	200	8,900	9,100	9,700	7,600	8,500	8,400	7,100	10,600	9,300	7,600	12,000	7,100	12,000	8,982
Lead	0.5	3.9	2.2	1.8	2.5	2.7	2.4	3.7	4.2	3.8	5.8	4.3	1.8	5.8	3.4
Manganese	1	63	93	90	87	74	73	63	71	70	57	80	57	93	75
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	0.11	<0.05
Molybdenum	0.1	0.2	0.3	0.1	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.4	0.1	0.4	0.3
Nickel	0.5	9.6	11.6	12.6	9.0	10.3	9.6	10.3	9.7	13.3	7.7	9.4	7.7	13.3	10.3
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1 - 2	<2	<2	<2	<2	<2	<2	6	4	6	6	6	<2	6	3
Thallium	0.05	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	0.06	<0.05	<0.05	<0.05	0.05	<0.05	0.06	<0.05
Tin	0.05 - 2	0.54	0.62	0.46	0.56	0.70	0.73	1	1	1	1	1	0.46	1.0	0.8
Titanium	1	6	5	5	7	5	5	335	377	420	306	378	5	420	168
Uranium	0.05	0.05	0.08	0.08	0.025	0.06	0.06	0.78	0.64	1.07	0.80	0.96	0.03	1.07	0.42
Vanadium	0.2	15.4	17.4	17.8	14.9	16.8	17.0	13.0	16.5	16.4	12.5	14.6	12.5	17.8	15.7
Zinc	5	17	19	22	24	18	18	16	18	19	13	17	13	24	18

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

(b) Not analyzed.

I.3 Sediment

In August 2004, environmental technicians from Kinross collected sediment samples from Pond 1 and Pond 2 (study area), Boomerang Lake (receiving environment), and Shallow Bay (reference location).

Sediment concentrations used in the risk assessment are presented in Tables I-3, I-4, and I-5 for the reference area, study area, and receiving environment, respectively.

Table I-3
Sediment Concentrations from Samples Collected from the Reference Area (Shallow Bay)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)				
		29-Aug-04		Minimum	Maximum	Mean[(a)]
		Ref-sed 1	Ref-sed 2			
Aluminum	50	5,810	5,880	5,810	5,880	5,845
Antimony	0.1	<0.1	<0.1	<.01	<0.1	<0.1
Arsenic	0.1	22.1	14.9	14.9	22.1	18.5
Barium	0.5	45.6	46.9	45.6	46.9	46.3
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	2	3	3	3	3	3
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	22.7	23.9	22.7	23.9	23.3
Cobalt	0.1	5.3	6.3	5.3	6.3	5.8
Copper	0.5	8.7	8.1	8.1	8.7	8.4
Iron	200	12,900	10,700	10,700	12,900	11,800
Lead	0.5	2.2	2.4	2.2	2.4	2.3
Manganese	1	135	139	135	139	137
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	0.1	0.4	0.3	0.3	0.4	0.4
Nickel	0.5	11.5	13.2	11.5	13.2	12.4
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	5	6	5	6	6
Thallium	0.05	0.09	0.08	0.08	0.09	0.09
Tin	2	<2	<2	<2	<2	<2
Titanium	1	476	481	476	481	479
Uranium	0.05	0.78	0.88	0.78	0.88	0.83
Vanadium	0.2	19.5	20.2	19.5	20.2	19.9
Zinc	5	28	31	28	31	30
Cyanide	0.1	0.3	0.3	0.3	0.3	0.3

[(a)] Calculations based on half detection limits for parameters that were less than analytical detection limits.

Table I-4
Sediment Concentrations from Samples Collected from the Study Area (Pond 1 and Pond 2)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)									
		Pond 1						Pond 2			
		28-Aug-04						28-Aug-04			
		P1-sed 1	P1-sed 2	P1-sed 3	P1-sed 4	P1-sed 5	P1-sed 6	P2-sed2	Minimum	Maximum	Mean[(a)]
Aluminum	50	8,840	17,100	6,120	17,000	16,600	15,000	7,170	6,120	17,100	12,547
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1
Arsenic	0.1	3,840	10,100	2,240	9,560	16,000	14,800	1,870	1,870	16,000	8,344
Barium	0.5	59.2	102	41.3	93.3	103	79.9	36.2	36.2	103.0	73.6
Beryllium	0.2	0.3	0.4	0.2	0.5	0.4	0.4	0.3	0.2	0.5	0.4
Boron	2	3	5	3	4	5	4	2	2	5	4
Cadmium	0.1	0.2	0.4	0.1	0.2	0.4	0.3	0.2	0.1	0.4	0.3
Chromium	0.2	28.1	44.5	20.9	46.7	42.3	43.1	22.9	20.9	46.7	35.5
Cobalt	0.1	11.4	15.8	8.9	15.4	17.1	14.5	28.5	8.9	28.5	15.9
Copper	0.5	331	387	234	444	414	451	210	210	451	353
Iron	200	36,500	92,300	24,100	94,900	100,000	117,000	28,600	24,100	117,000	70,486
Lead	0.5	60.2	235	33.8	287	377	214	46	33.8	377.0	179.0
Manganese	1	126	245	90	188	270	204	382	90	382	215
Mercury	0.05	0.13	<0.05	0.08	<0.05	0.05	0.06	0.11	<0.05	0.13	0.07
Molybdenum	0.1	2.2	2.5	1.7	9.5	4.9	4.2	7.7	1.7	9.5	4.7
Nickel	0.5	48.1	51.4	40.1	49	52	51.3	31	31.0	52.0	46.1
Selenium	0.2	1	2	0.5	1.4	2.6	2.1	0.8	0.5	2.6	1.5
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	33	82	24	70	94	81	19	19	94	58
Thallium	0.05	0.09	0.07	0.07	0.07	0.07	0.07	0.09	0.07	0.09	0.08
Tin	2	<2	2	<2	2	2	3	<2	<2	3	<2
Titanium	1	324	404	299	409	383	318	323	299	409	351
Uranium	0.05	1.12	1.1	0.98	1.25	1.57	1.2	1.41	0.98	1.57	1.23
Vanadium	0.2	19.1	31.1	14.9	32.8	29.9	26.6	17.1	14.9	32.8	24.5
Zinc	5	536	5,190	338	1,820	6,140	1,930	472	338	6,140	2,347
Cyanide	0.1	635	5,500	717	3,660	8,580	3,050	914	635	8,580	3,294

[(a)] Calculations were based on half the detection limit for values that were less than analytical detection limits.

Table I-5
Sediment Concentrations from Samples Collected from Boomerang Lake

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)					
		28-Aug-04			Minimum	Maximum	Mean[(a)]
		B-sed 1	B-sed 2-1	B-sed 2-2			
Aluminum	50	6,390	10,700	14,600	6,390	14,600	10,563
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	71.6	539	6,590	71.6	6,590	2,400
Barium	0.5	43.7	61	72.1	43.7	72.1	58.9
Beryllium	0.2	<0.2	0.6	0.6	<0.2	0.6	0.4
Boron	2	2	6	9	2	9	6
Cadmium	0.1	<0.1	0.4	0.4	<0.1	0.4	0.3
Chromium	0.2	24.5	40.8	41.3	24.5	41.3	35.5
Cobalt	0.1	6.2	27.9	19.7	6.2	27.9	17.9
Copper	0.5	12.9	83.8	298.0	12.9	298.0	131.6
Iron	200	11,400	34,500	73,300	11,400	73,300	39,733
Lead	0.5	3.1	15.1	107	3.1	107.0	41.7
Manganese	1	107	213	283	107	283	201
Mercury	0.05	<0.05	0.07	0.28	0.07	0.28	0.18
Molybdenum	0.1	0.5	1.4	8.8	0.5	8.8	3.6
Nickel	0.5	15.2	64.6	57.3	15.2	64.6	45.7
Selenium	0.2	<0.2	0.6	1.3	<0.2	1.3	0.7
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	4	15	48	4	48	22
Thallium	0.05	0.11	0.14	0.09	0.09	0.14	0.11
Tin	2	<2	<2	2	<2	2	<2
Titanium	1	357	520	376	357	520	418
Uranium	0.05	0.65	1.97	2.01	0.65	2.01	1.54
Vanadium	0.2	20.4	30.4	29.5	20.4	30.4	26.8
Zinc	5	30	185	1,340	30	1,340	518
Cyanide	0.1	24.4	34.7	0.6	0.6	34.7	19.9

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

I.4 Vegetation

In August 2004, environmental technicians from Kinross collected vegetation samples from cell 1 and areas potentially impacted by wind-blown tailings (study area), and the Esker Borrow Area (reference area). Vegetation collected from the esker-Borrow area included birch species (*Betula sp*.), crowberry (*Empertrum nigrum*), bearberry (*Arctostaphylos uva-ursi*) and native grasses. A variety of grasses were collected from cell 1 and areas potentially impacted by wind-blown tailings.

Vegetation concentrations used in the risk assessment are presented in Table I-6 and Table I-7, for the reference area and study area, respectively.

Table I-6
Metal Concentrations in Vegetation Collected from the Esker Borrow Area
(Reference Area)

Parameter	Detection Limit	Concentration (mg/kg - Dry Weight)							
		27-Aug-04		29-Aug-04			Minimum	Maximum	Mean[a]
		EB-1	EB-2	EB-3	EB-4	EB-5			
% Moisture	0.1	52	53	51	60	57	51	60	55
Aluminum	4	633	326	345	59	179	59	633	308
Antimony	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	0.2	1.5	0.7	1.2	0.7	1	0.7	1.5	1.0
Barium	0.08	29.4	3.92	13.2	9.4	10.1	3.92	29.4	13.20
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NC[c]	NC[c]	NC[c]
Cadmium	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chromium	0.2	1.5	0.9	0.8	0.6	0.9	0.6	1.5	0.9
Cobalt	0.08	0.93	1.47	0.48	0.32	0.25	0.25	1.47	0.69
Copper	0.08	3.19	3.2	2.1	2.1	3.08	2.1	3.2	2.73
Iron	2	293	176	162	45	104	45	293	156
Lead	0.04	0.31	0.12	0.2	0.04	0.1	0.04	0.31	0.15
Manganese	0.04	113	310	119	369	271	113	369	236
Mercury	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Molybdenum	0.04	<0.04	<0.04	0.07	0.17	0.11	<0.04	0.17	0.08
Nickel	0.08	4.44	5.19	6.22	4.81	3.33	3.33	6.22	4.80
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Strontium	0.04	7.66	2.73	6.73	3.13	3.91	2.73	7.66	4.83
Thallium	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tin	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Titanium	0.05	18.2	10.6	10.6	2.13	4.3	2.13	18.2	9.17
Uranium	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NC[c]	NC[c]	NC[c]
Vanadium	0.08	0.59	0.35	0.28	0.11	0.18	0.11	0.59	0.30
Zinc	0.2	53.5	26.9	29.2	19.7	19.5	19.5	53.5	29.8

[a]Calculations were based on half the detection limit for values that were below analytical detection limits.
[b]Data not analyzed.
[c]Not calculated.

Table I-7
Metal Concentrations in Vegetation Collected from the Study Area (Cell 1 and Wind-blown Tailings Area)

Parameter	Detection Limit	Concentration (mg/kg Dry Weight)												
		27-Aug-04						29-Aug-04	30-Aug-04			Minimum	Maximum	Mean[a]
		cell 1-1	cell 1-2	cell 1-3	cell 1-4	cell 1-5	WT-1	WT-2	WT-3	WT-4	WT-5			
% Moisture	0.1	58	44	61	50	51	49	49	53	48	53	44	61	51.6
Aluminum	4	1300	1170	488	298	654	717	798	385	427	360	298	1300	660
Antimony	0.04	<0.04	0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	0.05	<0.04
Arsenic	0.2	15.9	52.7	14.9	10.8	17.9	11.5	65.4	15.9	32.1	28.7	10.8	65.4	26.6
Barium	0.08	13.8	12	6.27	6.62	15.9	19.7	11	9.3	13.7	16.6	6.27	19.7	12.49
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NC[c]	NC[c]	NC[c]
Cadmium	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chromium	0.2	3.7	4.7	1.6	1	1.7	2.8	3.3	1	1.2	1.1	1	4.7	2.2
Cobalt	0.08	0.51	0.81	0.44	0.42	0.26	1.11	0.94	1.25	1.13	1.18	0.26	1.25	0.81
Copper	0.08	3.49	4.32	3	1.9	2.63	3.35	3.89	2.67	3.63	2.83	1.9	4.32	3.17
Iron	2	813	1470	534	400	662	577	1840	576	1080	685	400	1840	864
Lead	0.04	0.68	2.36	0.69	0.89	0.77	1.37	5.21	1.56	2.7	2.02	0.68	5.21	1.83
Manganese	0.04	252	395	688	345	217	243	118	186	176	135	118	688	276
Mercury	0.01	0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.02	<0.01
Molybdenum	0.04	0.28	1.29	0.53	0.14	0.1	0.12	0.07	0.05	0.07	<0.04	0.05	1.29	0.29
Nickel	0.08	4.65	5.89	2.27	1.49	1.69	5.36	6.35	4.07	4.43	4.07	1.49	6.35	4.03
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	0.3	<0.2
Silver	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Strontium	0.04	10.8	13.4	6.93	4.08	7.6	10.3	11.2	6.29	11.3	8.19	4.08	13.4	9.01
Thallium	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tin	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Titanium	0.05	31.9	27.6	13.1	10.1	23.2	22.9	22.6	10.2	10.7	9.93	9.93	31.9	18.22
Uranium	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NC[c]	NC[c]	NC[c]
Vanadium	0.08	0.95	0.93	0.39	0.31	0.57	0.71	0.81	0.35	0.4	0.32	0.31	0.95	0.57
Zinc	0.2	27.3	25.4	19.4	17.2	28.7	52.2	63.7	46.2	65.2	55.1	17.2	65.2	40.0

[a] Calculations based on half the detection limit for values that were below analytical detection limits.
[b] Data not analyzed.
[c] Not calculated.

Metal concentrations in plant tissue were provided in dry weight (mg/kg). Concentrations were converted to wet weight for use in exposure estimate calculations. Plant tissue in dry weight was converted to wet weight according to the following equation:

Concentration in wet weight = concentration in dry weight x (1- % moisture),
where % moisture was measured for each sample.

Vegetation concentrations (mg/kg wet weight) used in the risk assessment are presented in Table I-8.

Table I-8
Calculated Wet Weight Concentrations of Metals in Vegetation Collected from the Reference Area (Esker Borrow Area) and Study Area (Cell 1 and Wind-blown Tailings Area)[a]

Parameter[b]	Reference Vegetation			Study Area Vegetation		
	Maximum Dry Weight (mg/kg)	Moisture (%)	Wet Weight (mg/kg) (calculated)	Maximum Dry Weight (mg/kg)	Moisture (%)	Wet Weight (mg/kg) (calculated)
Aluminum	633	0.55	285	1300	0.516	629
Antimony	<0.02	0.55	<0.02	0.05	0.516	0.02
Arsenic	1.5	0.55	0.7	65.4	0.516	31.7
Barium	29.4	0.55	13.2	19.7	0.516	9.5
Beryllium	<0.2	0.55	<0.2	<0.2	0.516	<0.2
Cadmium	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Chromium	1.5	0.55	0.7	4.7	0.516	2.3
Cobalt	1.47	0.55	0.66	1.25	0.516	0.61
Copper	3.2	0.55	1.4	4.32	0.516	2.09
Iron	293	0.55	132	1840	0.516	891
Lead	0.31	0.55	0.14	5.21	0.516	2.52
Manganese	369	0.55	166	688	0.516	333
Mercury	0.02	0.55	0.01	0.02	0.516	0.01
Molybdenum	0.17	0.55	0.08	1.29	0.516	0.62
Nickel	6.22	0.55	2.799	6.35	0.516	3.07
Selenium	<0.2	0.55	<0.2	0.3	0.516	0.1
Silver	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Strontium	7.66	0.55	3.45	13.4	0.516	6.5
Thallium	<0.04	0.55	<0.04	<0.04	0.516	<0.04
Tin	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Titanium	18.2	0.55	8.2	31.9	0.516	15.4
Vanadium	0.59	0.55	0.27	0.95	0.516	0.46
Zinc	53.5	0.55	24.1	65.2	0.516	31.6

[a]Calculations based on half the detection limit for values that were below analytical detection limits.
[b]Boron and Uranium wet weight concentration not calculated because vegetation concentrations not measured.

I.5 Surface Water

Surface water data were obtained from water quality monitoring programs undertaken by Kinross at the Lupin Mine site from 1990 to 2004. Water quality data were collected from pond 1, pond 2, cell 1, cell 4, the receiving environment (Boomerang Lake, Long Lake, Test Lake, Norma Lake, Lori Lake, Dam 1A Lake, Dam 1a Siphon, Seep Creek, Inner Sun Bay, Outer Sun Bay), and reference locations in South Bay. These data were provided by Kinross, but have not been reported in other publications.

Water quality data collected by Kinross for the reference area are presented in Table I-9. Water quality data collected by Kinross for the study area (Pond 1, Pond 2, Cell 1, and Cell 4) are presented in Table I-10, I-11, and Table I-12. A descriptive summary of water quality data in the study areas is presented in Table I-12. Water quality data collected by Kinross for the receiving environment are presented in Table I-13.

Table I-9
Water Concentrations of Samples Collected from the Reference Area (South Bay)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)								
		1996						Minimum	Maximum	Mean[(a)]
		Lu-R1-1	Lu-R1-2	Lu-R1-3	Lu-R1-4	Lu-R1-5	Lu-R1-6			
Aluminum	0.01	0.12	0.13	0.12	0.12	0.12	0.10	0.10	0.13	0.12
Antimony	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Arsenic	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002
Barium	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.006	<0.005	0.006	<0.005
Beryllium	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	0.005	0.011	0.006	0.006	<0.005	0.005	0.009	<0.005	0.011	0.007
Cadmium	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	0.001	0.001	0.001	0.001	0.001	<0.001	0.002	<0.001	0.002	0.001
Copper	0.002	0.005	0.002	0.003	<0.002	<0.002	<0.002	<0.002	0.005	0.002
Iron	0.02	0.17	0.16	0.17	0.16	0.16	0.15	0.15	0.17	0.16
Lead	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	0.002	0.009	0.008	0.009	0.008	0.008	0.015	0.008	0.015	0.010
Molybdenum	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel	0.002	0.006	0.006	0.006	0.005	0.004	0.007	0.004	0.007	0.006
Selenium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver	0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Strontium	0.005	0.008	0.008	0.008	0.007	0.007	0.009	0.007	0.009	0.008
Thallium	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tin	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Zinc	0.002	<0.002	0.004	0.007	0.002	0.003	0.003	<0.002	0.007	0.003

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

Table I-10
Water Concentrations of Samples Collected from Pond 1

Parameter	Detection Limit (mg/L)	Concentration (mg/L)														
		07-Jul-98	05-Oct-98	23-Aug-98	28-Mar-99	25-Jul-99	06-Sep-99	02-Mar-00	25-Apr-00	21-Jul-00	09-Nov-00	12-Apr-01	04-Aug-01		01-Sep-01	
		P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-103	P1-104	P1-103	P1-104
Aluminum	0.005 - 0.009	0.073	0.223	0.081	0.091	0.123	0.184	0.023	0.081	0.065	0.070	0.052	0.078	0.093	0.094	0.098
Antimony	0.0002 - 0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Arsenic	0.0002 - 0.01	0.34	0.30	0.28	0.24	0.10	0.09	0.05	0.04	0.02	0.10	0.11	0.04	0.05	0.13	0.12
Barium	0.0002 - 0.001	0.0122	0.0143	0.0143	0.0182	0.0138	0.0134	0.0194	0.0257	0.0098	0.0164	0.0187	0.0109	0.0120	0.0119	0.0119
Beryllium	0.0001 - 0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Boron	0.002	0.115	0.139	0.130	0.170	0.087	0.089	0.118	0.137	0.057	0.084	0.138	0.064	0.066	0.089	0.087
Cadmium	0.00001 - 0.0006	<0.0005	<0.0005	0.0008	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Chromium	0.0005 - 0.0009	0.0010	<0.0008	0.0010	<0.0008	<0.0008	0.0228	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009
Cobalt	0.0008	0.0414	0.0506	0.0452	0.0649	0.0421	0.0451	0.0653	0.0693	0.0288	0.0411	0.0493	0.0312	0.0342	0.0391	0.0380
Copper	0.001	0.044	0.065	0.040	0.068	0.029	0.030	0.038	0.038	0.017	0.068	0.066	0.027	0.026	0.139	0.135
Iron	0.003 - 0.1	0.305	1.250	0.201	0.846	0.495	1.580	0.615	0.450	0.219	0.437	0.340	0.489	0.547	0.592	0.624
Lead	0.0001 - 0.002	0.003	<0.002	<0.002	<0.002	<0.002	0.021	0.004	0.004	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese	0.0002 - 0.005	0.3270	0.4910	0.4310	0.6780	0.4570	0.4870	0.7640	0.8200	0.3510	0.5460	0.6840	0.3860	0.4260	0.3950	0.3910
Molybdenum	0.001	0.034	0.034	0.031	0.039	0.023	0.020	0.020	0.021	0.008	0.020	0.025	0.010	0.013	0.020	0.019
Nickel	0.0005 - 0.001	0.094	0.111	0.097	0.140	0.096	0.116	0.137	0.148	0.066	0.104	0.122	0.073	0.080	0.106	0.104
Selenium	0.0002 - 0.004	0.007	0.005	<0.004	<0.004	<0.004	<0.004	0.019	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001
Strontium	0.0001 - 0.001	0.2130	0.2580	0.2270	0.3440	0.2070	0.2050	0.2890	0.3020	0.1410	0.3470	0.4650	0.2140	0.2330	0.3030	0.2970
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	0.005	<0.004	0.005	0.008	0.01	<0.004	<0.004	<0.004	<0.004	<0.004	0.005	0.005
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.005	0.005	<0.003	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	0.0004	<0.0004	<0.0004	0.0611	<0.0004	<0.0004	0.0012	<0.0004	<0.0004	<0.0004	0.0016	<0.0004	<0.0004
Uranium	0.0005	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.0007 - 0.001	0.0512	0.1250	0.0702	0.1720	0.1080	0.1360	0.2300	0.2410	0.0989	0.1090	0.1230	0.0770	0.0847	0.0956	0.0970
Cyanide	0.001 - 0.002	NA[(a)]	0.022	0.021	0.045	NA[(a)]	0.020	NA[(a)]	NA[(a)]	0.058	1.030	0.288	NA[(a)]	0.183	NA[(a)]	1.870

Table I-10
Water Concentrations of Samples Collected from Pond 1 (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)															
		03-Feb-02	04-Feb-02	12-Apr-02	05-Jul-02		16-Jul-02			24-Jul-02			08-Aug-02	22-Apr-03	02-Aug-03	12-Oct-03	13-Jul-04
		P1-104	P1-104T	P1-104	P1-104	P1-104b	P1-104a	P1-104b	P1-104c	P1-104a	P1-104b	P1-104c	P1-104a	P1-104	P1-104	P1-104	P1-104
Aluminum	0.005 - 0.009	0.083	0.076	0.087	0.057	0.067	0.046	0.045	0.046	0.044	0.045	0.048	0.044	0.060	0.068	0.079	0.065
Antimony	0.0002 - 0.006	<0.006	<0.006	<0.005	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0007	0.0004	0.0003	0.0003
Arsenic	0.0002 - 0.01	0.10	0.09	0.11	0.0932	0.1000	0.0933	0.0939	0.0928	0.0891	0.0896	0.0921	0.0851	0.1610	0.0734	0.0583	0.0726
Barium	0.0002 - 0.001	0.0156	0.0149	0.0180	0.0140	0.0150	0.0130	0.0130	0.013	0.013	0.013	0.013	0.014	0.021	0.011	0.015	0.012
Beryllium	0.0001 - 0.0006	<0.0006	<0.0006	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	0.002	0.100	0.101	0.175	0.077	0.083	0.084	0.083	0.083	0.081	0.082	0.082	0.083	0.179	0.088	0.102	0.076
Cadmium	0.00001 - 0.0006	<0.0006	<0.0006	<0.0005	0.00004	0.00007	0.00005	0.00005	0.00004	0.00005	0.00005	0.00005	0.00006	0.00007	0.00007	0.00014	0.00015
Chromium	0.0005 - 0.0009	<0.0009	<0.0009	<0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	0.0006	<0.0005	<0.0005
Cobalt	0.0008	0.0473	0.0453	0.0476	0.0314	0.0339	0.0343	0.0347	0.0342	0.0340	0.0341	0.0339	0.0361	0.0730	0.0415	0.0504	0.0351
Copper	0.001	0.051	0.045	0.045	0.030	0.032	0.028	0.028	0.028	0.025	0.025	0.026	0.026	0.083	0.043	0.027	0.150
Iron	0.003 - 0.1	0.342	0.292	0.316	0.326	0.295	0.267	0.272	0.269	0.224	0.245	0.280	0.393	0.4	0.4	0.3	0.5
Lead	0.0001 - 0.002	<0.002	<0.002	0.005	0.0026	0.0033	0.0018	0.0018	0.0018	0.0017	0.0016	0.0019	0.0069	0.0040	0.0010	0.0006	0.0007
Manganese	0.0002 - 0.005	0.5310	0.5030	0.5500	0.3360	0.3540	0.3640	0.4090	0.3630	0.3610	0.3660	0.3680	0.3750	0.6110	0.3540	0.4540	0.2770
Molybdenum	0.001	0.026	0.025	0.028	0.023	0.025	0.023	0.023	0.023	0.023	0.022	0.023	0.024	0.055	0.027	0.028	0.025
Nickel	0.0005 - 0.001	0.117	0.106	0.123	0.0672	0.0713	0.0680	0.0668	0.0664	0.0702	0.0692	0.0704	0.0790	0.1340	0.0825	0.0978	0.0847
Selenium	0.0002 - 0.004	<0.0002	0.0006	<0.0002	0.0004	0.0006	0.0003	0.0003	<0.0002	<0.0002	<0.0002	0.0003	0.0006	0.0008	0.0003	0.0006	0.0003
Silver	0.0001 - 0.001	<0.001	<0.001	0.001	0.0021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001
Strontium	0.0001 - 0.001	0.3880	0.3800	0.4180	0.3030	0.3310	0.323	0.323	0.323	0.325	0.318	0.326	0.334	0.547	0.286	0.339	0.490
Thallium	0.00005 - 0.004	<0.004	<0.004	0.004	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	<0.001	<0.001	<0.001	<0.001
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	<0.0004	0.004	0.0045	0.0046	0.0045	0.0046	0.0046	0.0046	0.0045	0.0044	0.0089	0.0044	0.0061	0.0046
Uranium	0.0005	NA[a]	NA[a]	NA[a]	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Zinc	0.0007 - 0.001	0.0917	0.0559	0.0839	0.0510	0.0630	0.052	0.052	0.057	0.050	0.052	0.056	0.093	0.096	0.047	0.064	0.284
Cyanide	0.001 - 0.002	0.680	NA[a]	0.270	0.390	0.270	0.024	0.022	0.022	0.022	0.022	0.022	0.022	1.700	0.036	0.026	0.720

[a] Not Analyzed.

Table I-11
Water Concentrations of Samples Collected from Pond 2

Parameter	Detection Limit (mg/L)	Concentration (mg/L)																							
		14-Apr-98	07-Jul-98	05-Oct-98	23-Aug-98	28-Mar-99		25-Jul-99	06-Sep-99	02-Mar-00		25-Apr-00	07-Jul-00	09-Nov-00	12-Apr-01		04-Aug-01		01-Sep-01		03-Feb-02	04-Feb-02	12-Apr-02	
		P2-102	P2-102	P2-102	P2-102	P2-102	P2-106	P2-102	P2-102	P2-102	P2-107	P2-107	P2-102	P2-102	P2-102	P2-107	P2-102	P2-107	P2-102	P2-107	P2-102	P2-102T	P2-102	P2-106
Aluminum	0.005 - 0.009	1.140	0.101	0.489	0.346	1.070	1.150	0.469	0.112	0.531	0.629	0.925	0.125	0.216	0.932	0.501	0.050	0.059	0.089	0.073	0.304	0.255	0.381	0.353
Antimony	0.0002 - 0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.005	<0.005
Arsenic	0.0002 - 0.01	0.04	0.02	0.03	0.04	0.02	0.05	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	0.02
Barium	0.0002 - 0.001	0.0304	0.0162	0.0189	0.0181	0.0257	0.0252	0.0172	0.0152	0.0226	0.0230	0.0433	0.0159	0.0200	0.0231	0.0217	0.0148	0.0147	0.0153	0.0143	0.0200	0.0189	0.0227	0.0229
Beryllium	0.0001 - 0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0005	<0.0005
Boron	0.002	0.348	0.156	0.171	0.168	0.239	0.231	0.131	0.121	0.165	0.173	0.199	0.136	0.121	0.195	0.179	0.115	0.114	0.116	0.108	0.146	0.137	0.209	0.206
Cadmium	0.00001 - 0.0006	0.0017	<0.0005	0.0022	0.0010	0.0007	0.0010	<0.0005	<0.0005	<0.0006	<0.0006	0.0007	<0.0006	0.0006	0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0005	<0.0005
Chromium	0.0005 - 0.0009	0.0093	0.0011	0.0016	0.0020	0.0009	0.0012	<0.0008	<0.0008	<0.0008	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0008	<0.0008
Cobalt	0.0008	0.1500	0.0658	0.0708	0.0650	0.1180	0.1100	0.0744	0.0682	0.1030	0.1020	0.1110	0.0659	0.0777	0.1130	0.1000	0.0654	0.0656	0.0648	0.0637	0.0853	0.0758	0.0887	0.0825
Copper	0.001	0.092	0.011	0.040	0.018	0.054	0.056	0.026	0.005	0.027	0.030	0.030	0.007	0.023	0.023	0.021	0.010	0.010	0.010	0.009	0.019	0.017	0.024	0.024
Iron	0.003 - 0.1	0.619	0.162	0.353	0.188	0.559	0.703	0.479	0.131	0.066	0.125	0.187	0.077	0.168	0.248	0.316	0.151	0.182	0.245	0.205	0.161	0.114	0.146	0.141
Lead	0.0001 - 0.002	0.007	<0.002	0.002	<0.002	<0.002	0.004	<0.002	0.006	0.004	<0.002	0.003	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Manganese	0.0002 - 0.005	2.95	1.26	1.32	1.25	2.37	2.18	1.49	1.27	1.99	1.9800	2.1600	1.32	1.60	2.49	2.15	1.37	1.37	1.32	1.29	1.74	1.61	1.89	1.77
Molybdenum	0.001	0.001	0.001	0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.003
Nickel	0.0005 - 0.001	0.234	0.103	0.121	0.110	0.183	0.177	0.121	0.111	0.167	0.165	0.177	0.110	0.128	0.179	0.160	0.109	0.108	0.109	0.107	0.144	0.131	0.163	0.155
Selenium	0.0002 - 0.004	<0.003	<0.004	0.012	<0.004	<0.004	<0.004	<0.004	0.007	0.013	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.010	0.019	0.007	0.006	<0.0002	<0.0002	<0.0002	0.0006
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Strontium	0.0001 - 0.001	0.448	0.309	0.320	0.307	0.461	0.454	0.278	0.264	0.374	0.371	0.387	0.282	0.286	0.394	0.380	0.249	0.248	0.256	0.253	0.342	0.322	0.362	0.344
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	<0.004	0.008	<0.004	<0.004	0.005	<0.004	<0.004	0.015	<0.004	<0.004	0.006	0.005	<0.004	<0.004	<0.004	0.007	<0.004	<0.004	0.007	0.008
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	0.0004 - 0.0005	0.0006	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	0.0009	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Uranium	0.0005	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Zinc	0.0007 - 0.001	0.532	0.225	0.291	0.239	0.50	0.475	0.318	0.278	0.449	0.454	0.049	0.245	0.326	0.496	0.427	0.248	0.248	0.243	0.238	0.353	0.253	0.378	0.352
Cyanide	0.001 - 0.002	0.006	NA[(a)]	0.061	0.031	0.052	0.037	NA[(a)]	0.028	NA[(a)]	NA[(a)]	NA[(a)]	0.014	0.012	0.006	0.012	0.173	0.187	0.087	NA[(a)]	0.058	NA[(a)]	0.018	0.018

Table I-11
Water Concentrations of Samples Collected from Pond 2 (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)																							
		05-Jul-02						08-Jul-02	16-Jul-02									22-Apr-03		02-Aug-03	12-Oct-03			13-Jul-04		
		P2-102	P2-102b	P2-106	P2-106b	P2-107	P2-107b	P2-102a	P2-102a	P2-102b	P2-102c	P2-106a	P2-106b	P2-106c	P2-107a	P2-107b	P2-107c	P2-102	P2-107	P2-102	P2-102	P2-105	P2-106	P2-106	P2-102	P2-105
Aluminum	0.005 - 0.009	0.073	0.070	0.078	0.082	0.070	0.072	0.074	0.051	0.050	0.059	0.054	0.057	0.055	0.051	0.052	0.052	1.020	0.430	0.059	0.114	0.117	0.115	0.080	0.073	0.120
Antimony	0.0002 - 0.006	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Arsenic	0.0002 - 0.01	0.0076	0.0074	0.0084	0.008	0.0078	0.0082	0.0072	0.0074	0.0073	0.0074	0.0073	0.0074	0.0079	0.0075	0.0078	0.0083	0.0341	0.0295	0.0415	0.0619	0.0625	0.0543	0.0131	0.0136	0.0312
Barium	0.0002 - 0.001	0.019	0.018	0.019	0.016	0.019	0.016	0.021	0.015	0.016	0.015	0.015	0.015	0.015	0.015	0.016	0.015	0.031	0.026	0.016	0.019	0.019	0.018	0.014	0.014	0.014
Beryllium	0.0001 - 0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	0.002	0.096	0.100	0.095	0.096	0.099	0.098	0.090	0.099	0.100	0.098	0.101	0.100	0.100	0.102	0.098	0.100	0.204	0.186	0.094	0.109	0.112	0.110	0.074	0.080	0.078
Cadmium	0.00001 - 0.0006	0.00022	0.00021	0.00021	0.00023	0.00021	0.00021	0.00019	0.00020	0.00021	0.00023	0.00020	0.00019	0.00021	0.00018	0.00023	0.00021	0.00053	0.00033	0.00023	0.00019	0.00019	0.00019	0.00019	0.00022	0.00017
Chromium	0.0005 - 0.0009	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt	0.0008	0.0569	0.0551	0.0550	0.0530	0.0562	0.0530	0.0520	0.0559	0.0571	0.0569	0.0565	0.0568	0.0568	0.0566	0.0570	0.0568	0.1280	0.0988	0.0449	0.0499	0.0502	0.0483	0.0449	0.0447	0.0439
Copper	0.001	0.008	0.008	0.007	0.007	0.008	0.008	0.008	0.010	0.007	0.008	0.010	0.008	0.009	0.008	0.007	0.009	0.029	0.019	0.004	0.007	0.006	0.005	0.028	0.027	0.050
Iron	0.003 - 0.1	0.009	0.051	0.059	0.060	0.077	0.094	0.056	0.299	0.123	0.101	0.204	0.159	0.109	0.113	0.132	0.123	0.4	0.4	0.2	0.4	0.4	0.4	0.1	0.1	0.4
Lead	0.0001 - 0.002	0.0004	0.0005	0.0005	0.0006	0.0006	0.0006	0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0005	0.0036	0.0027	0.0009	0.0010	0.0009	0.0008	0.0002	0.0002	0.0005
Manganese	0.0002 - 0.005	1.08	1.05	1.03	1.02	1.08	1.06	1.16	1.11	1.11	1.12	1.11	1.09	1.09	1.10	1.11	1.10	2.74	2.01	1.09	1.12	1.12	1.11	0.929	0.910	0.806
Molybdenum	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.003	0.002	0.004	0.004	0.003	0.005	0.005	0.009
Nickel	0.0005 - 0.001	0.0884	0.0843	0.0860	0.1010	0.0868	0.0818	0.0838	0.0806	0.0801	0.0795	0.0791	0.0797	0.0793	0.0811	0.0788	0.0807	0.2070	0.1550	0.0764	0.0907	0.0931	0.0909	0.0809	0.0809	0.0829
Selenium	0.0002 - 0.004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.0002	0.0003	<0.0002	<0.0002	<0.0002	0.0002	0.0004	0.0005	<0.0002	<0.0002	0.0003
Silver	0.0001 - 0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001
Strontium	0.0001 - 0.001	0.2900	0.2790	0.2790	0.2680	0.2860	0.2720	0.2630	0.275	0.274	0.276	0.277	0.281	0.281	0.277	0.281	0.274	0.538	0.454	0.248	0.289	0.308	0.300	0.275	0.284	0.337
Thallium	0.00005 - 0.004	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Tin	0.001 - 0.003	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	0.0004 - 0.0005	0.0040	0.0038	0.0040	0.0039	0.0039	0.0040	0.0034	0.0041	0.0042	0.0043	0.0041	0.0041	0.0040	0.0043	0.0046	0.0044	0.0096	0.0075	0.0048	0.0057	0.0058	0.0056	0.0046	0.0044	0.0063
Uranium	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
Zinc	0.0007 - 0.001	0.2030	0.1960	0.1960	0.1880	0.2000	0.1900	0.2030	0.1950	0.1950	0.198	0.196	0.197	0.198	0.199	0.204	0.208	0.560	0.397	0.153	0.178	0.187	0.175	0.184	0.186	0.204
Cyanide	0.001 - 0.002	0.078	0.082	0.082	0.090	0.084	0.092	0.084	<0.002	<0.002	<0.002	0.092	0.090	0.090	0.012	0.012	0.006	0.012	0.010	0.044	0.018	0.022	0.018	NA[a]	0.250	0.440

[a] Not Analyzed.

Table I-12
Water Concentrations of Samples Collected from Cell 1 and Cell 4

Parameter	Detection Limit (mg/L)	Concentration (mg/L)										
		23-Aug-98			01-Sep-01	07-Jul-02		03-Aug-02		02-Aug-03	13-Jul-04	
		Cell 4	Cell 4 u/s	Cell 4	Cell 4	cell 1 (ground)	cell 1 (surface)	cell 1-4	cell 1-5	Cell 4	Cell 1 pond	Cell 4 u/s
Aluminum	0.005 - 0.009	0.151	0.158	0.027	NA[(a)]	0.120	3.400	0.811	1.290	0.083	NA[(a)]	NA[(a)]
Antimony	0.0002 - 0.006	<0.005	<0.006	<0.006	NA[(a)]	<0.0002	<0.0002	0.0019	0.0004	0.0008	NA[(a)]	NA[(a)]
Arsenic	0.0002 - 0.01	1.15	0.40	0.17	NA[(a)]	0.0082	0.0549	0.0084	0.0121	0.4340	NA[(a)]	NA[(a)]
Barium	0.0002 - 0.001	0.0113	0.0131	0.0128	NA[(a)]	0.0870	0.0250	0.0220	0.0210	0.0160	NA[(a)]	NA[(a)]
Beryllium	0.0001 - 0.0006	<0.0005	<0.0006	<0.0006	NA[(a)]	<0.0001	0.0007	0.0006	0.0009	<0.0001	NA[(a)]	NA[(a)]
Boron	0.002	0.169	0.142	0.229	NA[(a)]	0.021	0.013	0.169	0.065	0.165	NA[(a)]	NA[(a)]
Cadmium	0.00001 - 0.0006	<0.0005	<0.0006	<0.0006	NA[(a)]	0.00012	0.00058	0.00296	0.00719	0.00004	NA[(a)]	NA[(a)]
Chromium	0.0005 - 0.0009	0.0010	<0.0009	<0.0009	NA[(a)]	0.0011	0.0007	<0.0005	<0.0005	0.0008	NA[(a)]	NA[(a)]
Cobalt	0.0008	0.0401	0.0454	0.0469	NA[(a)]	0.0396	0.0888	0.4600	1.0400	0.0514	NA[(a)]	NA[(a)]
Copper	0.001	0.346	0.389	0.227	NA[(a)]	0.019	0.051	0.167	0.206	0.961	NA[(a)]	NA[(a)]
Iron	0.003 - 0.1	1.010	0.776	3.400	NA[(a)]	1.500	2.310	0.129	0.007	0.4	NA[(a)]	NA[(a)]
Lead	0.0001 - 0.002	0.004	0.004	<0.002	NA[(a)]	0.0016	0.0014	0.0097	0.0124	0.0014	NA[(a)]	NA[(a)]
Manganese	0.0002 - 0.005	0.1170	5.4100	5.8900	NA[(a)]	1.1800	1.3700	5.5300	13.5000	0.1530	NA[(a)]	NA[(a)]
Molybdenum	0.001	0.058	0.041	0.027	NA[(a)]	<0.001	<0.001	0.002	<0.001	0.067	NA[(a)]	NA[(a)]
Nickel	0.0005 - 0.001	0.161	0.168	0.158	NA[(a)]	0.0047	0.1780	1.1500	3.0600	0.1950	NA[(a)]	NA[(a)]
Selenium	0.0002 - 0.004	<0.004	<0.004	0.007	NA[(a)]	<0.0002	0.0004	0.0015	0.0013	0.0022	NA[(a)]	NA[(a)]
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	NA[(a)]	0.0001	<0.0001	<0.0001	<0.0001	0.0013	NA[(a)]	NA[(a)]
Strontium	0.0001 - 0.001	0.3420	0.4630	0.4590	NA[(a)]	0.0550	0.2000	0.5160	0.9470	0.7400	NA[(a)]	NA[(a)]
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	NA[(a)]	0.00009	0.00012	0.00014	0.00043	<0.00005	NA[(a)]	NA[(a)]
Tin	0.001 - 0.003	<0.003	<0.003	0.004	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.001	NA[(a)]	NA[(a)]
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	0.0318	NA[(a)]	0.0025	0.0041	0.0075	0.0111	0.0070	NA[(a)]	NA[(a)]
Uranium	0.0005	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.0005	0.0014	<0.0005	0.0015	0.0009	NA[(a)]	NA[(a)]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	NA[(a)]	0.001	<0.0001	<0.0001	<0.0001	<0.0001	NA[(a)]	NA[(a)]
Zinc	0.0007 - 0.001	0.1600	0.1360	0.0947	NA[(a)]	0.0240	0.1680	0.437	0.692	0.983	NA[(a)]	NA[(a)]
Cyanide	0.001 - 0.002	NA[(a)]	NA[(a)]	NA[(a)]	4.500	NA[(a)]	NA[(a)]	0.028	0.002	3.000	0.004	1.800

(a) Not Analyzed.

Table I-13
Descriptive Summary of Water Concentrations of Samples Collected from the Study Area (Pond 1, Pond 2, Cell 1 and Cell 4)

Parameter	Minimum	Maximum	Mean[(a)]
Aluminum	0.023	3.4	0.25
Antimony	0.0003	0.002	0.0005
Arsenic	0.0072	1.15	0.09
Barium	0.0098	0.087	0.018
Beryllium	<0.0001	0.0009	0.0002
Boron	0.013	0.348	0.122
Cadmium	0.00004	0.0072	0.0005
Chromium	<0.0005	0.0228	0.0008
Cobalt	0.029	1.04	0.076
Copper	0.004	0.961	0.055
Iron	0.007	3.4	0.4
Lead	0.0002	0.021	0.002
Manganese	0.117	13.5	1.34
Molybdenum	<0.001	0.067	0.012
Nickel	0.0047	3.06	0.156
Selenium	<0.0002	0.019	0.002
Silver	<0.0001	0.002	0.0004
Strontium	0.055	0.947	0.330
Thallium	<0.00005	0.015	0.002
Tin	<0.001	0.005	0.002
Titanium	<0.0004	0.061	0.0037
Uranium	<0.0005	0.0015	<0.0005
Vanadium	<0.0001	0.003	0.0004
Zinc	0.024	0.98	0.22
Cyanide	<0.002	4.5	0.28

(a) Calculations were based on half the detection limit for values that were less than analytical detection limits.

Table I-14
Water Concentrations of Samples Collected from the Receiving Environment

Parameter	Detection Limit (mg/L)	Concentration (mg/L)															
		07-Jul-00		18-Jul-00		08-Jul-01						03-Aug-01		16-Jul-02	17-Jul-02	24-Jul-02	25-Jul-02
		Long Lake	Test Lake	Dam 1a Siphon		Lori Lake	Boomerang Lake	Dam 1a Lake	Dam 2 Lake	Seep Creek	Inner Sun Bay	Outer Sun Bay		Dam 1a Siphon	Dam 1a Siphon	Dam 1a Siphon	Dam 1a Siphon
		SB2	SB5	925-10a	925-10b	WQ4	B-WQ5	WQ6	WQ7	WQ8	WQ9	925-25	925-99	925-10	925-10	925-10	925-10
Aluminum	0.005 - 0.009	0.063	0.085	NA[b]	NA[b]	0.079	0.048	0.042	0.203	0.064	0.064	0.018	0.019	NA[b]	NA[b]	NA[b]	NA[b]
Antimony	0.0002 - 0.006	<0.006	<0.006	NA[b]	NA[b]	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	NA[b]	NA[b]	NA[b]	NA[b]
Arsenic	0.0002 - 0.01	0.03	0.005	NA[b]	NA[b]	0.03	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.0075	0.0087	0.0073	0.0078
Barium	0.0002 - 0.001	0.0066	0.0042	NA[b]	NA[b]	0.0059	0.0113	0.0067	0.0184	0.0039	0.0056	0.0024	0.0024	NA[b]	NA[b]	NA[b]	NA[b]
Beryllium	0.0001 - 0.0006	<0.0006	<0.0006	NA[b]	NA[b]	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	NA[b]	NA[b]	NA[b]	NA[b]
Boron	0.002	0.017	<0.002	NA[b]	NA[b]	<0.002	<0.002	0.003	0.007	<0.002	<0.002	<0.002	0.003	NA[b]	NA[b]	NA[b]	NA[b]
Cadmium	0.00001 - 0.0006	<0.0006	<0.0006	NA[b]	NA[b]	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	NA[b]	NA[b]	NA[b]	NA[b]
Chromium	0.0005 - 0.0009	0.0011	<0.0009	NA[b]	NA[b]	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	NA[b]	NA[b]	NA[b]	NA[b]
Cobalt	0.0008	0.0012	0.0008	NA[b]	NA[b]	<0.0008	0.0044	0.0011	0.0277	<0.0008	0.0009	<0.0008	<0.0008	NA[b]	NA[b]	NA[b]	NA[b]
Copper	0.001	0.003	0.002	NA[b]	0.006	0.003	0.002	<0.001	0.008	<0.001	0.001	0.001	0.001	0.007	0.014	0.007	0.007
Iron	0.003 - 0.1	0.075	0.423	NA[b]	NA[b]	0.183	0.227	0.164	0.121	0.149	0.147	0.035	0.025	NA[b]	NA[b]	NA[b]	NA[b]
Lead	0.0001 - 0.002	0.003	<0.002	NA[b]	NA[b]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA[b]	NA[b]	NA[b]	NA[b]
Manganese	0.0002 - 0.005	0.0104	0.0056	NA[b]	NA[b]	0.0040	0.1400	0.0180	0.5150	0.0044	0.0080	0.0052	0.0052	NA[b]	NA[b]	NA[b]	NA[b]
Molybdenum	0.001	0.001	<0.001	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Nickel	0.0005 - 0.001	0.015	0.007	NA[b]	NA[b]	0.005	0.01	0.004	0.147	0.001	0.003	0.001	0.001	NA[b]	NA[b]	NA[b]	NA[b]
Selenium	0.0002 - 0.004	<0.004	0.006	NA[b]	NA[b]	<0.004	0.007	<0.004	<0.004	0.008	<0.004	<0.004	<0.004	NA[b]	NA[b]	NA[b]	NA[b]
Silver	0.0001 - 0.001	<0.001	<0.001	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Strontium	0.0001 - 0.001	0.0169	0.0094	NA[b]	NA[b]	0.0188	0.0290	0.0182	0.0426	0.0124	0.0087	0.0056	0.0056	NA[b]	NA[b]	NA[b]	NA[b]
Thallium	0.00005 - 0.004	<0.004	<0.004	NA[b]	NA[b]	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	NA[b]	NA[b]	NA[b]	NA[b]
Tin	0.001 - 0.003	<0.003	<0.003	NA[b]	NA[b]	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	NA[b]	NA[b]	NA[b]	NA[b]
Titanium	0.0004 - 0.0005	0.0008	0.0008	NA[b]	NA[b]	0.0043	<0.0004	0.0037	0.0034	0.0036	0.0034	<0.0004	<0.0004	NA[b]	NA[b]	NA[b]	NA[b]
Uranium	0.0005	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
Vanadium	0.0001 - 0.001	0.002	0.002	NA[b]	NA[b]	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Zinc	0.0007 - 0.001	0.0196	0.0033	NA[b]	0.2430	0.0056	0.0057	0.0029	0.0610	0.0016	0.0047	0.0023	0.0031	0.1940	0.2060	0.1940	0.2010
Cyanide	0.001 - 0.002	0.001	0.001	0.014	0.016	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	0.001	0.003	<0.002	0.006	0.104	0.096

Table I-14
Water Concentrations of Samples Collected from the Receiving Environment (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)											
		03-Aug-02				07-Aug-02	08-Aug-02	12-Oct-03		13-Jul-04			
		Dam 1a Siphon	Norma Lake	Boomerang Lake	Dam 2 Lake	Dam 1a Siphon	Dam 1a Siphon	Boomerang Lake	Dam 2 Lake	Dam 1a Siphon	Minimum	Maximum	Mean[a]
		925-10	WQ1	B-WQ5	WQ7	925-10	925-10	B-WQ5	WQ7	925-10			
Aluminum	0.005 - 0.009	NA[b]	0.011	0.018	0.124	NA[b]	NA[b]	0.06	0.385	0.223	0.011	0.385	0.092
Antimony	0.0002 - 0.006	NA[b]	<0.0002	<0.0002	<0.0002	NA[b]	NA[b]	<0.0002	<0.0002	<0.0002	<0.0002	<0.006	<0.006
Arsenic	0.0002 - 0.01	0.0099	0.0179	0.0045	0.0036	0.0132	0.0123	0.0071	0.0017	0.0072	0.0017	0.03	0.01
Barium	0.0002 - 0.001	NA[b]	0.0050	0.0080	0.019	NA[b]	NA[b]	0.008	0.020	0.024	0.0024	0.0240	0.0094
Beryllium	0.0001 - 0.0006	NA[b]	<0.0001	<0.0001	0.0002	NA[b]	NA[b]	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0002
Boron	0.002	NA[b]	0.003	0.006	0.008	NA[b]	NA[b]	0.0040	0.010	0.009	<0.002	0.017	0.005
Cadmium	0.00001 - 0.0006	NA[b]	<0.00001	<0.00001	0.00013	NA[b]	NA[b]	0.00006	0.00023	0.00025	<0.00001	0.0003	0.0002
Chromium	0.0005 - 0.0009	NA[b]	<0.0005	<0.0005	<0.0005	NA[b]	NA[b]	<0.0005	<0.0005	<0.0005	<0.0005	0.0011	<0.0005
Cobalt	0.0008	NA[b]	0.0001	0.0005	0.0167	NA[b]	NA[b]	0.0018	0.0407	0.046	0.0001	0.0460	0.0111
Copper	0.001	0.006	0.001	0.002	0.008	0.006	0.007	0.003	0.016	0.009	0.001	0.016	0.005
Iron	0.003 - 0.1	NA[b]	0.030	0.083	0.034	NA[b]	NA[b]	0.1	<0.1	0.7	0.025	0.7	0.2
Lead	0.0001 - 0.002	NA[b]	<0.0001	<0.0001	<0.0001	NA[b]	NA[b]	0.0009	0.0002	0.0002	<0.0001	0.003	0.001
Manganese	0.0002 - 0.005	NA[b]	0.0022	0.0146	0.3090	NA[b]	NA[b]	0.016	0.412	0.566	0.0022	0.5660	0.1207
Molybdenum	0.001	NA[b]	<0.001	<0.001	<0.001	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Nickel	0.0005 - 0.001	NA[b]	0.0069	0.0034	0.126	NA[b]	NA[b]	0.0076	0.205	0.0867	0.0010	0.205	0.037
Selenium	0.0002 - 0.004	NA[b]	<0.0002	<0.0002	<0.0002	NA[b]	NA[b]	<0.0002	<0.0002	<0.0002	<0.0002	0.008	0.002
Silver	0.0001 - 0.001	NA[b]	<0.0001	<0.0001	<0.0001	NA[b]	NA[b]	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001
Strontium	0.0001 - 0.001	NA[b]	0.0110	0.0330	0.0430	NA[b]	NA[b]	0.039	0.0570	0.0730	0.0056	0.0730	0.0272
Thallium	0.00005 - 0.004	NA[b]	<0.00005	<0.00005	<0.00005	NA[b]	NA[b]	<0.00005	<0.00005	<0.00005	<0.00005	<0.004	<0.004
Tin	0.001 - 0.003	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	<0.003	<0.003
Titanium	0.0004 - 0.0005	NA[b]	<0.0005	0.0008	0.0008	NA[b]	NA[b]	0.0026	0.0014	0.0015	<0.0004	0.0043	0.0018
Uranium	0.0005	NA[b]	<0.0005	<0.0005	<0.0005	NA[b]	NA[b]	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	NA[b]	<0.0001	<0.0001	<0.0001	NA[b]	NA[b]	0.0001	<0.0001	<0.0001	<0.0001	0.002	0.0007
Zinc	0.0007 - 0.001	0.2000	0.005	0.004	0.054	0.201	0.247	0.006	0.087	0.283	0.0016	0.283	0.090
Cyanide	0.001 - 0.002	0.060	<0.002	<0.002	<0.002	0.092	0.092	0.001	0.002	NA[b]	<0.002	0.104	0.027

(a) Calculations based on half the detection limit for values that were less than analytical detection limits.

(b) Not analyzed.

I.6 Caribou Tissue Concentrations

Caribou tissue concentrations (i.e., caribou meat) were calculated based on uptake of chemicals from soil, water and vegetation into animal tissue. Empirical data on concentrations of metals in meat from caribou were not available for the Lupin mine area; therefore, meat tissue concentrations were calculated from soil, vegetation and water data. These calculations are based on metal-specific biotransfer factors (BTF) for beef obtained from an on-line database (RAIS 2004), which were corrected to account for the differences in lipid content for beef and caribou. Meat concentrations were calculated using exposure equations presented in Table I-15.

Table I-15
Meat Uptake Equations

Total Uptake from soil, food, and water (C_{meat}) = $C_{meatsoil}$ + $C_{meatvegetation}$ + $C_{meatwater}$	
Pathway	**Equation and Equation Parameters**
soil ingestion	$C_{meatsoil}$ = BTF x C_{soil} x IR_{soil} x fw x LCF
	BTF = Biotransfer Factor (day/kg) IR_{soil} = soil ingestion rate for caribou (0.03 kg/day) (Beyer et al. 1996) C_{soil} = maximum concentration in Study Area soil (mg/kg) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)
vegetation ingestion	$C_{meatvegetation}$ = BTF x $C_{vegetation}$ x $IR_{vegetation}$ x fw x LCF
	BTF = Biotransfer Factor (day/kg) $IR_{vegetation}$ = vegetation ingestion rate for caribou (1.6 kg/day) (U.S. EPA 1993) $C_{vegetation}$ = maximum concentration in Study Area vegetation (mg/kg) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)
water ingestion	$C_{meatwater}$ = BTF x C_{water} x IR_{water} x fw X LCF
	BTF = Biotransfer Factor (day/kg) IR_{water} = water ingestion rate for caribou (6.7 L/day) (U.S. EPA 1993) C_{water} = maximum concentration in Study Area water (mg/L) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)

Predicted caribou meat metal concentrations for the study area are presented in Tables I-16, I-17, and Table I-18 for soil, vegetation, and water ingestion, respectively. Total predicted caribou meat metal concentrations from ingestion of all media are presented in Table I-19.

Table I-16
Caribou Meat Concentrations Based on Soil Ingestion

Parameter[a]	BTF (day/kg)[b]	Soil Concentration (mg/kg)	Soil Ingestion Rate (kg/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)[c]
Aluminum	0.0015	6310	0.05	1	3.36	22.55	0.15	0.07
Antimony	0.00004	0.05	0.05	1	3.36	22.55	0.15	0.00000001
Arsenic	0.0020	161	0.05	1	3.36	22.55	0.15	0.002
Barium	0.00020	38.8	0.05	1	3.36	22.55	0.15	0.00006
Boron	0.00080	2	0.05	1	3.36	22.55	0.15	0.00001
Cadmium	0.00040	<0.1	0.05	1	3.36	22.55	0.15	0.00000015
Chromium	0.0090	22.6	0.05	1	3.36	22.55	0.15	0.0015
Cobalt	0.00010	5.6	0.05	1	3.36	22.55	0.15	0.000004
Copper	0.0090	14.9	0.05	1	3.36	22.55	0.15	0.0010
Lead	0.00040	5.8	0.05	1	3.36	22.55	0.15	0.00002
Manganese	0.00050	93	0.05	1	3.36	22.55	0.15	0.0003
Mercury	0.010	0.11	0.05	1	3.36	22.55	0.15	0.000008
Molybdenum	0.0010	0.4	0.05	1	3.36	22.55	0.15	0.000003
Nickel	0.0050	13.3	0.05	1	3.36	22.55	0.15	0.0005
Selenium	0.10	<0.2	0.05	1	3.36	22.55	0.15	0.00007
Silver	0.0030	<0.2	0.05	1	3.36	22.55	0.15	0.000002
Strontium	0.0080	6	0.05	1	3.36	22.55	0.15	0.0004
Thallium	0.040	0.06	0.05	1	3.36	22.55	0.15	0.00002
Vanadium	0.0025	17.8	0.05	1	3.36	22.55	0.15	0.0003
Zinc	0.10	24	0.05	1	3.36	22.55	0.15	0.02

[a] Meat concentration of cyanide not calculated, because cyanide is not expected in soil.
[b] RAIS 2004.
[c] Calculations were based on half detection limits for values that were less than analytical detection limits.

Table I-17
Caribou Meat Concentrations Based on Vegetation Ingestion

Parameter[b]	BTF (d/kg)[a]	Vegetation Concentration (mg/kg)	Vegetation Ingestion Rate (kg/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)[c]
Aluminum	0.0015	629	1.6	1	3.36	22.55	0.15	0.2
Antimony	0.00004	0.024	1.6	1	3.36	22.55	0.15	0.0000002
Arsenic	0.0020	31.7	1.6	1	3.36	22.55	0.15	0.02
Barium	0.00020	9.5	1.6	1	3.36	22.55	0.15	0.0005
Cadmium	0.00040	<0.08	1.6	1	3.36	22.55	0.15	0.000002
Chromium	0.0090	2.3	1.6	1	3.36	22.55	0.15	0.005
Cobalt	0.00010	0.61	1.6	1	3.36	22.55	0.15	0.00001
Copper	0.0090	2.09	1.6	1	3.36	22.55	0.15	0.004
Lead	0.00040	2.52	1.6	1	3.36	22.55	0.15	0.0002
Manganese	0.00050	333	1.6	1	3.36	22.55	0.15	0.04
Mercury	0.010	0.01	1.6	1	3.36	22.55	0.15	0.00002
Molybdenum	0.0010	0.62	1.6	1	3.36	22.55	0.15	0.0001
Nickel	0.0050	3.07	1.6	1	3.36	22.55	0.15	0.004
Selenium	0.10	0.1	1.6	1	3.36	22.55	0.15	0.003
Silver	0.0030	<0.08	1.6	1	3.36	22.55	0.15	0.00001
Strontium	0.0080	6.5	1.6	1	3.36	22.55	0.15	0.01
Thallium	0.040	<0.04	1.6	1	3.36	22.55	0.15	0.00009
Vanadium	0.0025	0.46	1.6	1	3.36	22.55	0.15	0.0003
Zinc	0.10	31.56	1.6	1	3.36	22.55	0.15	0.8

[a] RAIS 2004.
[b] Boron and cyanide meat concentration from vegetation ingestion not calculated because not analyzed in vegetation.
[c] Calculations based on half the detection limit for values below analytical detection limits.

Table I-18
Caribou Meat Concentrations Based on Water Ingestion

Parameter	BTF (d/kg)[a]	Water Concentration (mg/L)	Water Ingestion Rate (L/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)
Aluminum	0.0015	3.4	6.7	1	3.36	22.55	0.15	0.005
Antimony	0.00004	0.0019	6.7	1	3.36	22.55	0.15	0.00000008
Arsenic	0.0020	1.15	6.7	1	3.36	22.55	0.15	0.002
Barium	0.00020	0.087	6.7	1	3.36	22.55	0.15	0.00002
Boron	0.00080	0.348	6.7	1	3.36	22.55	0.15	0.0003
Cadmium	0.00040	0.0072	6.7	1	3.36	22.55	0.15	0.000003
Chromium	0.0090	0.0228	6.7	1	3.36	22.55	0.15	0.0002
Cobalt	0.00010	1.04	6.7	1	3.36	22.55	0.15	0.0001
Copper	0.0090	0.961	6.7	1	3.36	22.55	0.15	0.009
Lead	0.00040	0.021	6.7	1	3.36	22.55	0.15	0.00001
Manganese	0.00050	13.5	6.7	1	3.36	22.55	0.15	0.007
Mercury	0.010	NA[b]	6.7	1	3.36	22.55	0.15	NC[c]
Molybdenum	0.0010	0.067	6.7	1	3.36	22.55	0.15	0.0001
Nickel	0.0050	3.06	6.7	1	3.36	22.55	0.15	0.02
Selenium	0.10	0.019	6.7	1	3.36	22.55	0.15	0.002
Silver	0.0030	0.0021	6.7	1	3.36	22.55	0.15	0.00001
Strontium	0.0080	0.947	6.7	1	3.36	22.55	0.15	0.008
Thallium	0.040	0.015	6.7	1	3.36	22.55	0.15	0.0006
Vanadium	0.0025	0.003	6.7	1	3.36	22.55	0.15	0.00001
Zinc	0.10	0.983	6.7	1	3.36	22.55	0.15	0.10
Cyanide	0.00000031	4.5	6.7	1	3.36	22.55	0.15	0.000001

[a]RAIS 2004.
[b]Not analyzed.
[c]Not calculated because mercury not analyzed in water.

Table I-19
Total Caribou Meat Concentrations

Parameter	Meat Concentration (mg/kg) (calculated)			
	Soil	Water	Vegetation	Total
Aluminum	0.07	0.005	0.2	0.3
Antimony	0.00000001	0.00000008	0.0000002	0.0000003
Arsenic	0.002	0.002	0.02	0.02
Barium	0.00006	0.00002	0.0005	0.0005
Boron	0.00001	0.0003	NC[(a)]	0.0003[(b)]
Cadmium	0.0000001	0.000003	0.000002	0.000005
Chromium	0.002	0.0002	0.005	0.007
Cobalt	0.000004	0.0001	0.00001	0.0001
Copper	0.001	0.009	0.004	0.01
Lead	0.00002	0.000008	0.0002	0.0003
Manganese	0.0003	0.007	0.04	0.05
Mercury	0.000008	NC[(a)]	0.00002	0.00003[(c)]
Molybdenum	0.000003	0.00007	0.0001	0.0002
Nickel	0.0005	0.02	0.004	0.02
Selenium	0.00007	0.002	0.003	0.005
Silver	0.000002	0.000006	0.00001	0.00002
Strontium	0.0004	0.008	0.01	0.02
Thallium	0.00002	0.0006	0.00009	0.0007
Vanadium	0.0003	0.000007	0.0003	0.0006
Zinc	0.02	0.10	0.8	0.9
Cyanide	NC[(a)]	0.000001	NC[(a)]	0.000001[(d)]

[(a)] Not calculated because media concentration not available.
[(b)] Based on soil and water ingestion only; vegetation concentration not available.
[(c)] Based on soil and vegetation ingestion only; water concentration not available.
[(d)] Based on water ingestion only; soil and vegetation concentrations not available.

I.7 Benthic Invertebrate Concentrations

Body burdens of metals in benthic invertebrates have not previously been reported for receiving environment water bodies or the study area at the Lupin mine site. However, wild waterfowl have been observed using these water bodies as feeding areas. Therefore, it was necessary to estimate the concentrations of metals in invertebrates from these areas, as they would provide a major food source for waterfowl.

Site-specific bioconcentration factors (BCFs) could not be calculated for the Lupin mine site because reference data were not available for benthic invertebrate metal concentrations. Thus, literature-based BCFs (U.S. EPA 1999) were used for calculation of predicted invertebrate whole-

body concentrations in the study area and receiving environment. In cases where a literature-based BCF was not available, a conservative BCF of 1 was used as an alternative. Sediment to benthic invertebrate BCFs for each parameter were used to calculate predicted invertebrate whole-body concentrations for the study area (Pond 1 and Pond 2) and receiving environment (Boomerang Lake) based on the equation:

Predicted Benthic Invertebrate Whole Body Concentration (mg/kg) =
BCF (L/kg) x Maximum Sediment Concentration (mg/L)

Sediment data used to calculate invertebrate tissue metal concentrations for the study area and receiving environment are shown in Table I-4 and Table I-5, respectively. Predicted invertebrate whole-body metal concentrations are presented in Table I-20.

Table I-20
Predicted Invertebrate Whole-Body Metal Concentration in the Study Area and in the Receiving Environment[(a)]

Parameter	BCF[(b)]	Study Area		Receiving Environment	
		Maximum Sediment Concentration (mg/kg)	Invertebrate Concentration (mg/kg) (calculated)	Maximum Sediment Concentration (mg/kg)	Invertebrate Concentration (mg/kg) (calculated)
Aluminum	0.90	17100	15390	14600	13140
Arsenic	0.90	16000	14400	6590.0	5931
Barium	0.90	103	92.7	72.1	64.89
Boron	1	5	5	9	9
Chromium	0.39	46.7	18.213	41.3	16.107
Cobalt	1	28.5	28.5	27.9	27.9
Copper	0.30	451	135.3	298.0	89.4
Lead	0.63	377	237.51	107.0	67.41
Manganese	1	382	382	283	283
Mercury	0.068	0.13	0.00884	0.28	0.01904
Molybdenum	1	9.5	9.5	8.8	8.8
Nickel	0.90	52	46.8	64.6	58.14
Selenium	0.90	2.6	2.34	1.3	1.17
Silver	0.90	<0.2	0.09	<0.2	0.09
Strontium	1	94	94	48	48
Thallium	0.90	0.09	0.081	0.14	0.126
Vanadium	1	32.8	32.8	30.4	30.4
Zinc	0.57	6140	3499.8	1340	763.8
Cyanide	0.90	8580	7722	34.7	31.23

[(a)] Mean concentrations were used; calculations were based on half detection limits for values that were below analytical detection limits.
[(b)] U.S. EPA 1999. If no BCF was available, a conservative value of 1 was used.

I.8 References

RAIS (Risk Assessment Information System). 2004. Available On-line at http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801. Accessed in September, 2004.

U.S. EPA (United States Environmental Protection Agency). 1993. Wildlife Exposure Factors Handbook. Volume I of II. EPA/600/R-93/187a.

U.S. EPA (United States Environmental Protection Agency). 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Volume 3A and 3B. EPA530-D-99-001C.

APPENDIX II

RISK ASSESSMENT APPROACH

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1. INTRODUCTION

Appendix II presents the detailed methods used for the human and wildlife risk assessments.

1.1 Risk Assessment Guidance

In Canada and the United States, risk assessment has been accepted by various levels of federal and regional governments as a valid method to guide risk management decisions. The risk assessment methodology for this assessment is based on the following provincial and federal guidance documents:

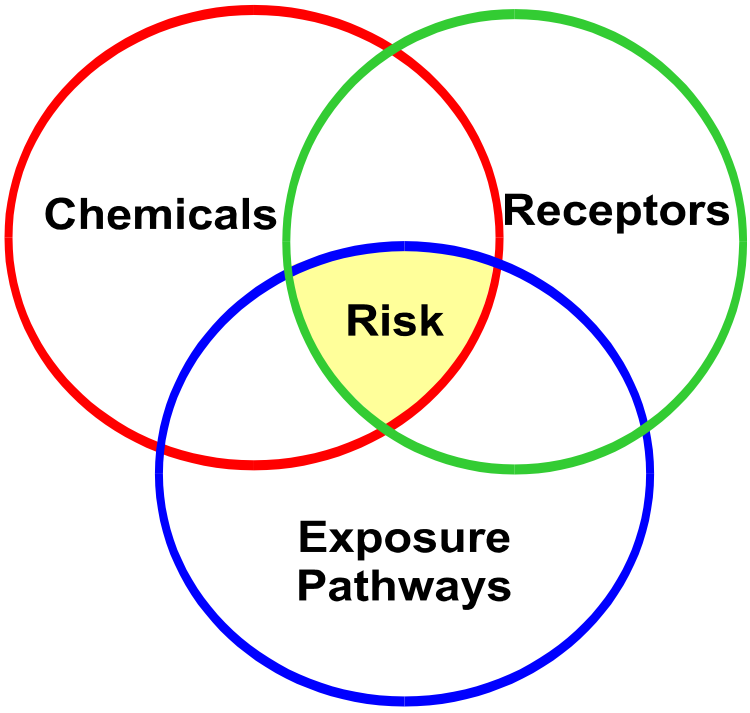
- CCME. A Framework for Ecological Risk Assessment. General Guidance. (1996).
- Health Canada. Federal Contaminated Site Risk Assessment in Canada. Version 1.1. (2003).
- Health Canada. Human Health Risk Assessment for Priority Substances. (1994).
- Health Canada. Human Health Risk Assessment of Chemicals from Contaminated Sites. Prepared by Golder Associates Ltd. and Cantox Inc. (not published 1995).
- United States Environmental Protection Agency (U.S. EPA). Guidelines for Ecological Risk Assessment (U.S. EPA 1998).

2. RISK ASSESSMENT APPROACH

2.1 Risk Assessment Framework

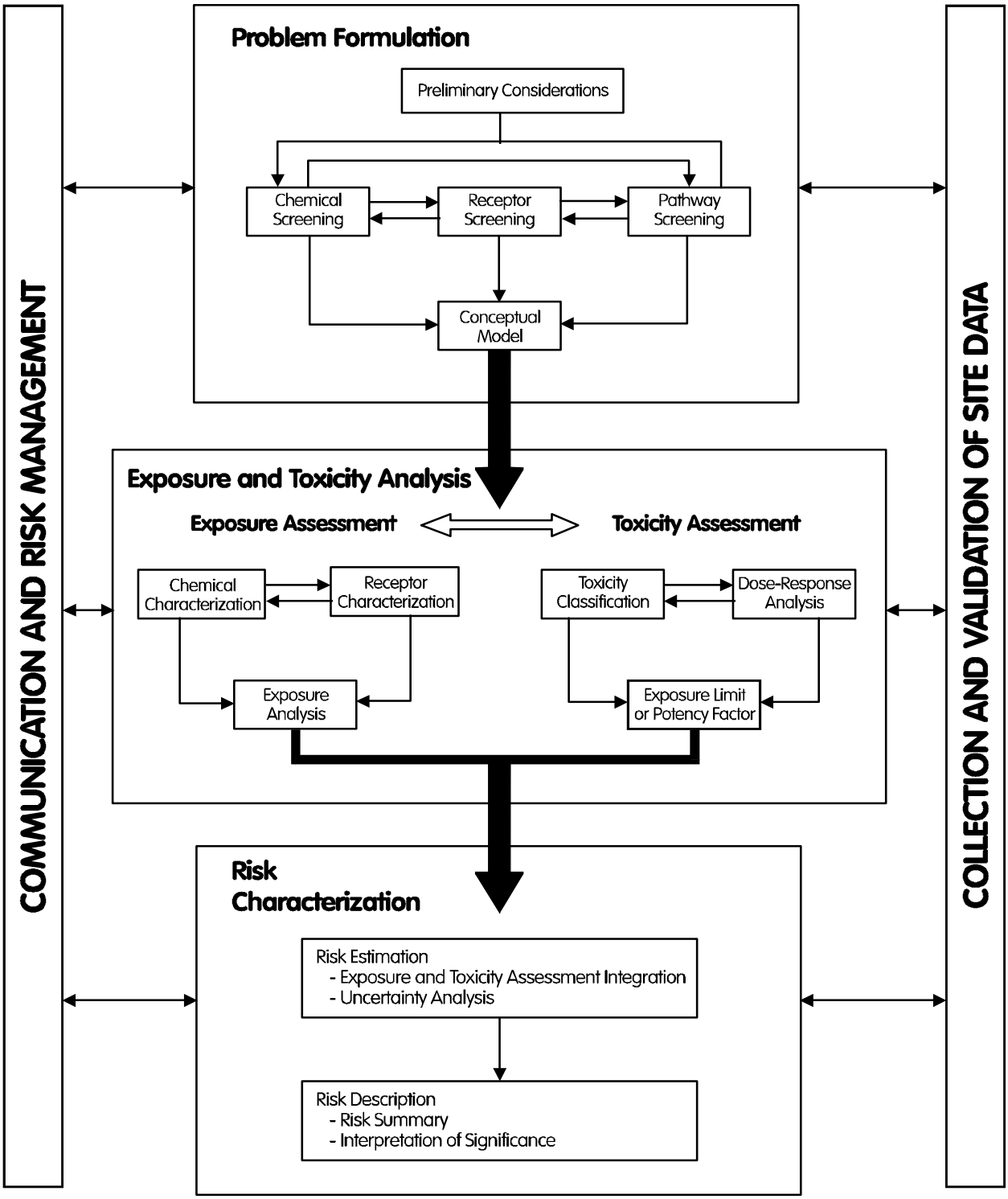
The potential for a risk to arise from exposure to chemicals is predicated on the co-existence of three elements including: i) chemicals must be present; ii) receptors (i.e., people or animals) must be present; and iii) exposure pathways must exist between the source of the chemicals and the receptors (Figure II-1). In the absence of any one of the three elements outlined in Figure II-1, risks cannot occur. The presence of all three elements, however, does not necessarily indicate an unacceptable risk. In such situations, risk assessment involves addressing both the magnitude and uncertainty associated with potential health risks.

Figure II-1
Three Elements of Risk



This risk assessment followed a widely recognized framework, as illustrated in Figure II-2 (Health Canada [unpublished] 1995). The framework progresses from a qualitative initial phase (Problem Formulation) through Exposure and Toxicity Analysis, and culminates in quantitative Risk Characterization.

Figure II-2
Risk Assessment Framework



Source: Health Canada [unpublished] 1995.

2.1.1 Problem Formulation

The objective of the problem formulation stage is to develop a focused understanding of how the closure plan for the Lupin Mine might affect the health of ecological receptors that spend time near the mine site and the health of people that may consume game (i.e., caribou) that have been exposed to metals from the mine site. This is achieved by the following:

- considering the attributes of the Lupin mine site;
- identifying the ecological receptors that are expected to access the area;
- focusing on the metals that may be hazardous; and
- identifying the plausible exposure pathways between metals and receptors.

The problem formulation helps to focus the risk assessment on the substances, receptors and exposure pathways of greatest concern (i.e., metals with the greatest toxic potential; receptors with the greatest likelihood of being exposed; and exposure pathways that account for the majority of exposure to metals). If unacceptable health risks are not predicted for these, it is unlikely that there will be unacceptable health risks for other metals, receptors or exposure pathways.

The three main components of problem formulation are:

1. Receptor screening: The objective of the receptor screening process is to select a representative set of receptors that may be exposed to metals in soil, water and food from the Lupin mine site. For the human health risk assessment, a toddler is typically evaluated as the most susceptible receptor. For the ecological risk assessment, representative receptors are those that would be most exposed and/or susceptible, that play a key role in the ecological food web and that have sufficient characterization data to facilitate calculations of exposure and health risks. Species lists compiled by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002; SARA 2002) were also consulted to determine whether any local species have been designated as sensitive or threatened.

2. Chemical screening: The objective of chemical screening is to focus on the chemicals of greatest concern. Only metals and cyanide were evaluated because other potential chemicals of concern (e.g., organic compounds) are not associated with mine tailings.

Substances were not evaluated in the risk assessment if concentrations in the study area were equivalent to or less than reference concentrations; if concentrations from the mine site were less than applicable guidelines/criteria; and/or the substances were identified as essential nutrients or were fundamentally not toxic. The remaining substances, which have the potential to contribute to increased health risks, were evaluated in the risk assessment.

3. Exposure pathway screening: The objective of exposure pathway screening is to determine all of the potential routes by which ecological receptors and people could be exposed to metals in soil, sediment, water and food from the Lupin mine site. A list of plausible exposure pathways was developed. The list was then evaluated to determine whether each pathway would be operable for each receptor. For example, the soil ingestion exposure pathway is operable for all ecological receptors, but vegetation ingestion is only operable for wildlife species that are herbivorous or omnivorous.

2.1.2 Exposure Assessment

Exposure assessment is the process of estimating the exposure of a substance to a human or ecological receptor under a given exposure scenario. An exposure assessment is conducted for each chemical of concern identified in the problem formulation. For humans and wildlife, exposure is determined as a dose. This value is called the estimated daily intake (EDI) and is typically expressed as mg of a chemical per kg of body weight per day (mg/kg-day). The EDI is calculated from site-specific concentrations of metals in soil/sediment, water and food (vegetation for herbivorous wildlife receptors and caribou meat for people and carnivorous wildlife), the amount of time a receptor spends near the mine site and receptor-specific parameters, such as body weight, ingestion rates and dietary preferences.

2.1.3 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of chemicals and determination of the amount of chemicals that a receptor can be exposed to without experiencing unacceptable effects. This value is called the toxicity reference value (TRV) or toxicity benchmark. For humans and wildlife, the TRV is expressed as mg of a chemical per kg of body weight per day (mg/kg-day) and is referred to as the tolerable daily intake (TDI). The toxicity

assessment provides the basis for evaluating what is an acceptable exposure and what level of exposure may adversely affect human and ecological health.

2.1.4 Risk Characterization

In the risk characterization step, information from the exposure and toxicity assessments are combined to determine if a potential risk exists. Risks may be estimated qualitatively based on scientific judgement for a screening level risk assessment, or quantitatively using exposure ratios for a more detailed risk assessment (CCME 1996). Exposure ratios (ERs) for chemicals of concern are calculated as the ratio of the estimated exposure (based on the exposure assessment) to the TRV (based on the toxicity assessment), according to the following equations:

Humans and Wildlife: ER = estimated exposure ÷ TRV; based on dose or daily intake.

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects but that further consideration is necessary. If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur.

It is important to note that ER values greater than 1 do not necessarily indicate that health effects will occur because of the layers of safety incorporated into the assessment. Thus, when an ER is greater than 1, it is important to consider the conservative assumptions upon which the assessment is based in combination with the degree of exceedence when determining the magnitude of risk.

2.2 Structure of the Appendix

The remainder of this appendix describes the methods and assumptions used in the risk assessment. The first step in the Problem Formulation, chemical screening, is presented in Section 3. The remainder of the appendix presents the rest of the steps in the assessments for wildlife health (Section 4) and human health (Section 5). These steps include receptor and exposure pathway screening, exposure assessment, toxicity assessment and risk characterization.

3. CHEMICAL SCREENING FOR WILDLIFE AND HUMAN HEALTH RISK ASSESSMENTS

The wildlife health risk assessment focused on substances that have been identified as chemicals of concern in water, soil, sediment, and vegetation from the Lupin mine. A chemical screening process was used to identify chemicals of concern for all receptors. Concentrations of substances (presented in Appendix I) in water, sediments, soil, and vegetation were used for the chemical screening process. The chemical screening process is presented in Figure II-3, and described below. The chemicals of concern identified for the human health risk assessment were the same as the chemicals identified for the wildlife risk assessment, because the only applicable human health exposure pathway is the consumption of game meat (e.g., caribou).

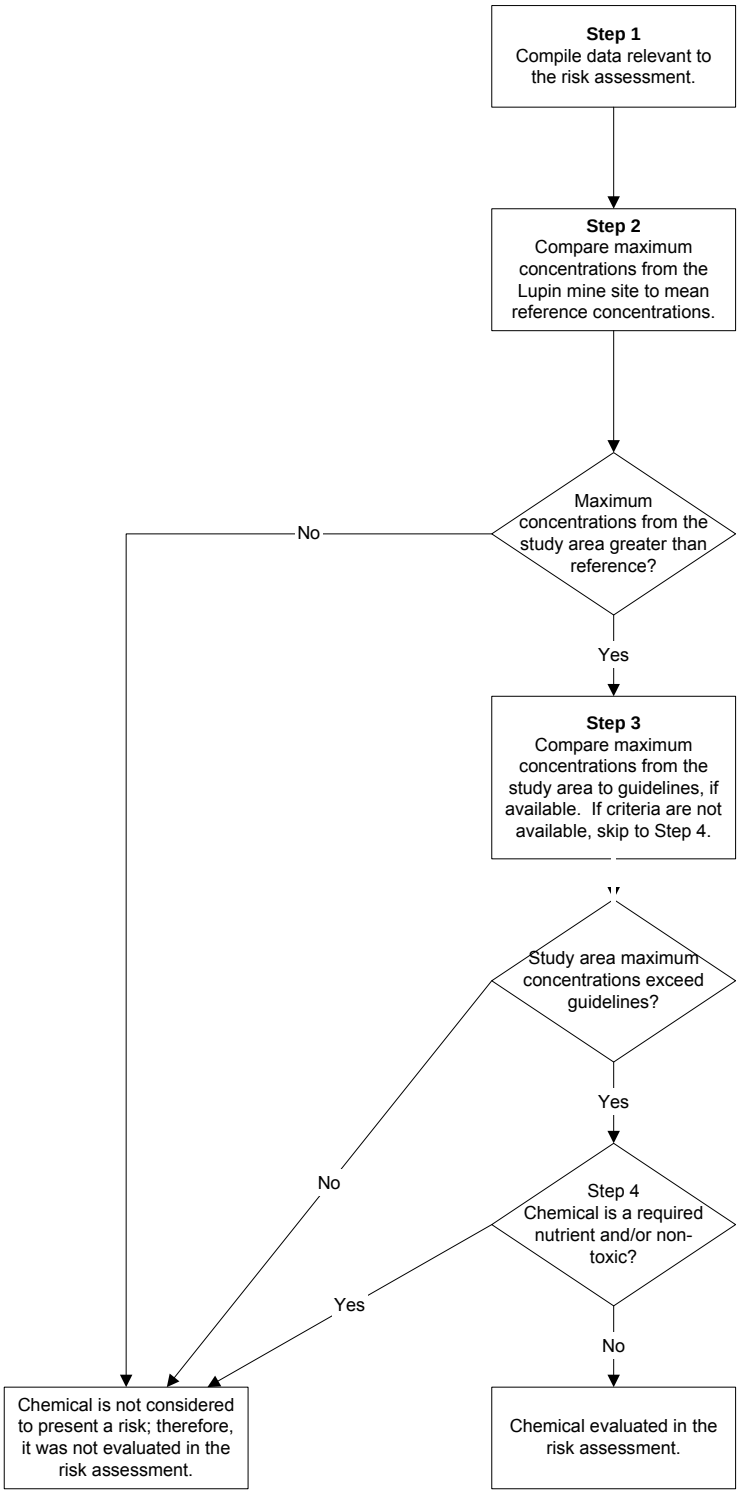
Step 1: Compile Relevant Data

Data used in the screening process are presented in Appendix I. Water, soil, sediment, and vegetation data used in the screening process of the risk assessment are presented in Appendix I, Sections 1.5, 1.2, 1.3, and 1.4, respectively.

Step 2: Comparison to Concentrations in the Reference Area

In Step 2 of the chemical screening process, maximum concentrations measured in the study area were compared with average concentrations measured in the reference area. The purpose of this step of the risk assessment is to identify metals that are present at greater concentrations in the study area than are typically present in the environment. Parameters that were present in the study area at concentrations that are greater than in the reference area are carried forward to the next step of the risk assessment.

Figure II-3
Chemical Screening Process



Step 3: Comparison to Guidelines

Step 3 of the screening process compares maximum concentrations in the study area with applicable regulatory guidelines for water, soil, and sediment. The guidelines used for screening process are presented in Table II-1. Parameters that do not exceed the guidelines were not evaluated further. The CCME guidelines are derived using a conservative risk-based approach; therefore, concentrations that are less than the guidelines are considered to be safe for wildlife (CCME 1999).

Table II-1
Guidelines Used for the Screening Step of the Wildlife and Human Health Risk Assessments

Media	Wildlife Health [(a)]
Water	Canadian Water Quality Guideline for the Protection of Agricultural Uses (CCME 1999)
Soil	Canadian Soil Quality Guidelines for Agricultural Uses (CCME 1999)
Sediment	Canadian Soil Quality Guidelines for Agricultural Uses (CCME 1999)

[(a)] Chemicals of concern identified for wildlife health were also used for the human health assessment because caribou meat ingestion was the only pathway evaluated for human health.

Step 4: Essential Nutrients and Fundamentally Non-toxic Substances

Two substances, tin and titanium, were considered fundamentally non-toxic to wildlife and human health based on their inert nature, as discussed below.

Tin

Tin is present in the earth's crust at concentrations up to 3 mg/kg (Toxnet 2004). Tin is poorly absorbed following oral exposure. Less than 5% of ingested tin is absorbed into the bloodstream (Hiles 1974; ATSDR 1992). Chronic health effects due to exposure to tin at environmental concentrations are not likely to occur due to poor absorption and lack of toxicity. Following absorption, most tin is excreted by the body since it has poor ability to bind to tissues (Hiles 1974). Therefore, since tin is poorly absorbed and does not cause health effects at environmental

concentrations, it was considered fundamentally non-toxic and was not evaluated further in the human and wildlife health risk assessments.

Titanium

Titanium is the ninth most abundant element in the earth's crust and is widely distributed. It is commonly used in industry because of its corrosion-resistant and toxicologically inert properties (WHO 1982; TOXNET 2004). Titanium is commonly used in the cosmetic industry and is used in the construction of surgical implants (WHO 1982). Chronic toxicity studies reviewed by the World Health Organization (WHO 1982) indicate that long term exposure to titanium does not result in adverse health effects. Two long-term studies of rats exposed to titanium in drinking water showed no differences in survival or microscopic cellular changes between exposed and control animals (WHO 1982). Occupational exposures to titanium dusts indicate that no health effects are associated with titanium inhalation exposure (WHO 1982; TOXNET 2004). Due to the lack of toxicity associated with titanium exposure and the general acceptance of its inert properties, titanium was considered fundamentally non-toxic and was not evaluated further in the human and wildlife health risk assessments.

The chemical screening (steps 2 through 4) for the Lupin mine site is presented below. The screening process focused on each media separately, for the human health and wildlife health risk assessments.

3.1 Water

3.1.1 Step 2: Comparison to Water Concentrations in the Reference Area

Maximum concentrations measured in the study area were compared with average concentrations measured in the reference area (South Bay). If concentrations from the study area were greater than concentrations from the reference area, these parameters were carried forward to Step 3 of the chemical screening process. Comparisons are presented in Table II-2.

Table II-2
Comparison of Metal Concentration in Water from the Study Area (Pond 1, Pond 2, Cell 1, and Cell 4) to Concentrations in the Reference Area (South Bay)

Parameter	Concentration (mg/L)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	0.118	3.4
Antimony	<0.002	0.0019
Arsenic	<0.002	1.2
Barium	<0.005	0.09
Beryllium	<0.005	0.0009
Boron	0.007	0.4
Cadmium	<0.0005	0.007
Chromium	<0.002	0.02
Cobalt	0.0011	1.04
Copper	0.002	0.96
Iron	0.16	3.4
Lead	<0.0001	0.02
Manganese	0.0095	13.5
Molybdenum	<0.002	0.07
Nickel	0.006	3.1
Selenium	<0.002	0.02
Silver	<0.0003	0.002
Strontium	0.008	0.9
Thallium	<0.0001	0.02
Tin	<0.002	0.005
Titanium	<0.002	0.06
Uranium	<0.0001	0.002
Vanadium	<0.002	0.003
Zinc	0.0033	0.98
Cyanide	Not Analyzed in Water	4.5

Note: Shading indicates concentration is greater than in the reference area.

3.1.2 Steps 3 and 4: Comparison to Water Quality Guidelines and Identification of Non-toxic Substances

The next step in the screening process compared parameters retained from Step 2 to applicable regulatory criteria (Table II-1). There are no water quality guidelines for the protection of wildlife; therefore, CCME water quality guidelines for the protection of agricultural uses (livestock) were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies

(CCME 1999). If the maximum concentration for a parameter from the study area exceeded regulatory criteria, then the parameter was carried forward to Step 4 of the screening process. In addition, if regulatory criteria were not available, metals from Step 3 were retained and evaluated in Step 4 of the screening process. In step 4, metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment.

Maximum water concentrations in the study area compared with regulatory guidelines, and those metals identified as non-toxic for wildlife (and human) health are presented in Table II-3.

Table II-3
Water Concentrations from the Study Area (Pond 1, Pond 2, Cell 1, and Cell 4) compared with Canadian Water Quality Guidelines for the Protection of Agricultural Land Uses

Parameter	Concentration (mg/L)		Evaluation for the Risk Assessment
	CWQG for the Protection of Agricultural Water Uses[a]	Study Area Maximum	
Aluminum	5	3.4	Less than guideline; Not evaluated
Arsenic	0.025	1.2	Exceeds guideline; Evaluated
Barium	No guideline	0.09	No guideline; Evaluated
Boron	5	0.3	Less than guideline; Not evaluated
Cadmium	0.08	0.007	Less than guideline; Not evaluated
Chromium	0.05[b]	0.02	Less than guideline; Not evaluated
Cobalt	1	1.04	Exceeds guideline; Evaluated
Copper	0.5	0.96	Exceeds guideline; Evaluated
Iron	No guideline	3.4	Non-toxic; Not evaluated
Lead	0.1	0.02	Less than guideline; Not evaluated
Manganese	No guideline	13.5	No guideline; Evaluated
Molybdenum	0.5	0.07	Less than guideline; Not evaluated
Nickel	1	3.1	Exceeds guideline; Evaluated
Selenium	0.050	0.02	Less than guideline; Not evaluated
Silver	No guideline	0.002	No guideline; Evaluated
Strontium	No guideline	0.9	No guideline; Evaluated
Thallium	No guideline	0.015	No guideline; Evaluated
Tin	No guideline	0.005	Non-toxic; Not evaluated
Titanium	No guideline	0.06	Non-toxic; Not evaluated
Uranium	0.2	0.002	Less than guideline; Not evaluated
Vanadium	0.1	0.003	Less than guideline; Not evaluated
Zinc	50	0.98	Less than guideline; Not evaluated
Cyanide	No guideline	4.5	No guideline; Evaluated

[a] CCME Agricultural Use Guidelines (CCME 1999).
[b] Interim guideline.
Note: Shading indicates concentration is greater than guideline or no guideline available and the substance was evaluated because the metal has the potential to cause health effects.

3.1.3 Chemicals of Concern in Water

Metals that are present in water from the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients were evaluated in the risk assessment. The chemicals of concern identified in water and evaluated in the risk assessment are presented in Table II-4.

Table II-4
Parameters Identified as Chemicals of Concern in Water

Parameter	Wildlife (and Human) Health Risk Assessment
Arsenic	√
Barium	√
Cobalt	√
Copper	√
Manganese	√
Nickel	√
Silver	√
Strontium	√
Thallium	√
Cyanide	√

3.2 Soil

3.2.1 Step 2: Comparison to Soil Concentrations in the Reference Area

Maximum metals concentrations measured in soil covering cell 1 and soil from areas expected to be impacted by wind blown tailings were compared with average metal concentrations measured in the reference area (esker borrow area). Parameters measured in the study area that were present at concentrations that were greater than the reference area were carried forward to Step 3 of the chemical screening process (Table II-5).

Table II-5
Comparison of Metal Concentration in Soil from the Study Area to Concentrations in the Reference Area

Parameter	Concentration (mg/kg)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	4,652	6,310
Antimony	<0.1	<0.1
Arsenic	6.9	161
Barium	30.5	38.8
Beryllium	<0.2	<0.2
Boron	<2	2
Cadmium	<0.1	<0.1
Chromium	19.5	22.6
Cobalt	2.8	5.6
Copper	7.1	14.9
Iron	7,150	12,000
Lead	1.5	5.8
Manganese	65	93
Mercury	<0.05	0.11
Molybdenum	0.2	0.4
Nickel	9.7	13.3
Selenium	<0.2	<0.2
Silver	<0.2	<0.2
Strontium	4	6
Thallium	0.06	0.06
Tin	<2	1
Titanium	326	420
Uranium	0.51	1.07
Vanadium	14.3	17.8
Zinc	16	24

Note: Shading indicates concentration is greater than reference area concentration.

3.2.2 Steps 3 and 4: Comparison to Soil Quality Guidelines and Non-toxic Substances

The next step in the screening process compared metals in soil retained from Step 2 to applicable regulatory criteria (Table II-1). There are no soil quality guidelines for the protection of wildlife; therefore, CCME soil quality guidelines for the protection of agricultural uses (livestock) were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies (CCME 1999). For some parameters, no Canadian soil quality guideline was available, so

the Canadian interim soil remediation criteria (CCME 1999) were used. Parameters that had concentrations in the study area that were greater than regulatory guidelines were retained and evaluated in the risk assessment. Parameters for which guidelines were not available were evaluated for their potential to cause health effects and those that were deemed to be essential nutrients or non-toxic (described in Section 3.0) were not evaluated further in the risk assessment.

Maximum soil concentrations in the study area compared with regulatory guidelines and identification of essential nutrients are presented in Table II-6.

Table II-6
Soil Concentrations from the Study Area (cell 1 and wind blown tailings area) Compared with Canadian Soil Quality Guidelines for Agricultural Land Uses

Parameter	Concentration (mg/kg)		Evaluation for the Risk Assessment
	CSQG for Agricultural Use[(a)]	Study Area Maximum Concentration	
Aluminum	No guideline	6,310	No guideline; Evaluated
Arsenic	12	161	Exceeds guideline; Evaluated
Barium	750[(b)]	38.8	Less than guideline; Not evaluated
Boron	No guideline	2	No guideline; Evaluated
Chromium	64	22.6	Less than guideline; Not evaluated
Cobalt	40[(b)]	5.6	Less than guideline; Not evaluated
Copper	63	14.9	Less than guideline; Not evaluated
Iron	No guideline	12,000	Non-toxic; Not evaluated
Lead	70	5.8	Less than guideline; Not evaluated
Manganese	No guideline	93	Exceeds guideline; Evaluated
Mercury	6.6	0.11	Less than guideline; Not evaluated
Molybdenum	5.0	0.4	Less than guideline; Not evaluated
Nickel	50	13.3	Less than guideline; Not evaluated
Strontium	No guideline	6	No Guideline; Evaluated
Titanium	No guideline	420	Non-toxic; Not evaluated
Uranium	10	1.07	Less than guideline; Not evaluated
Vanadium	130	17.8	Less than guideline; Not evaluated
Zinc	200	24	Less than guideline; Not evaluated

(a) CCME Soil Quality Guidelines for Agricultural Land Use (CCME 1999).
(b) CCME Interim Soil Remediation Criteria (CCME 1999).
Note: Shading indicates concentration is greater than guideline, no guideline is available, and evaluated in the risk assessment because of the potential to cause health effects.

3.2.3 Chemicals of Concern in Soil

Metals that are present in soil from the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients were evaluated in the risk assessment. The following chemicals of concern were identified for the soil pathway and evaluated in the wildlife (and human) heath risk assessments are:

- Aluminum;
- arsenic;
- boron;
- manganese; and,
- strontium.

3.3 Sediment

3.3.1 Step 2: Comparison to Sediment Concentrations in the Reference Area

Metals concentrations measured in sediment collected from the study area were compared with metal concentrations measured in the reference area. For each metal, the maximum concentration from the study area (pond 1 and pond 2) was compared to the average reference concentration (Shallow Bay). Parameters that were in the study area at concentrations that were greater than concentrations from the reference area, were carried forward to Step 3 of the chemical screening process (Table II-7).

Table II-7
Sediment Concentrations from the Study Area (pond 1 and pond 2) Compared with Concentrations in the Reference Area (Shallow Bay)

Parameter	Concentration (mg/kg)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	5,845	17,100
Antimony	<0.1	0.1
Arsenic	18.5	16,000
Barium	46.25	103
Beryllium	<0.2	0.5
Boron	3	5
Cadmium	<0.1	0.4
Chromium	23.3	46.7
Cobalt	5.8	28.5
Copper	8.4	451
Iron	11,800	117,000
Lead	2.3	377
Manganese	137	382
Mercury	<0.05	0.13
Molybdenum	0.35	9.5
Nickel	12.35	52
Selenium	<0.2	2.6
Silver	<0.2	<0.2
Strontium	5.5	94
Thallium	0.09	0.09
Tin	<2	3
Titanium	479	409
Uranium	0.83	1.57
Vanadium	19.85	32.8
Zinc	29.5	6,140
Cyanide	0.3	8,580

Note: Shading indicates concentration is greater than reference area concentration.

3.3.2 Steps 3 and 4: Comparison to Sediment Quality Guidelines and Non-toxic Substances

The next step in the screening process compared metals in sediment retained from Step 2 to applicable regulatory criteria (Table II-1). There are no sediment quality guidelines for the protection of wildlife (shorebirds and waterfowl); therefore, CCME soil quality guidelines for the protection of agricultural uses were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider

mammalian and avian toxicity studies (CCME 1999). The Canadian Interim Soil Remediation Criteria (CCME 1999) were used if a CCME guideline was not available. Parameters with concentrations in the study area that exceeded regulatory guidelines were evaluated in the risk assessment. If a regulatory guideline was not available the substance was evaluated for potential to cause health effects. Metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment.

Maximum sediment concentrations in the study area compared with regulatory guidelines and identification of non-toxic substances are presented in Table II-8 for wildlife.

Table II-8
Sediment Concentrations from the Study Area (pond 1 and pond 2) Compared with Canadian Soil Quality Guidelines for Agricultural Land Uses

Parameter	Concentration (mg/kg)		Evaluation for Risk Assessment
	CSQG for Agricultural Use[a]	Study Area Maximum Concentration	
Aluminum	No guideline	17,100	No guideline; Evaluated
Antimony	13[b]	0.1	Less than guideline; Not evaluated
Arsenic	12	16,000	Exceeds guideline; Evaluated
Barium	750[b]	103	Less than guideline; Not evaluated
Beryllium	1.2[b]	0.5	Less than guideline; Not evaluated
Boron	1.5[b]	5	Exceeds guideline; Evaluated
Cadmium	1.4	0.4	Less than guideline; Not evaluated
Chromium	64	46.7	Less than guideline; Not evaluated
Cobalt	40[b]	28.5	Less than guideline; Not evaluated
Copper	63	451	Exceeds guideline; Evaluated
Iron	No guideline	117,000	Non-toxic; Not evaluated
Lead	70	377	Exceeds guideline; Evaluated
Manganese	No guideline	382	No guideline; Evaluated
Mercury	6.6	0.13	Less than guideline; Not evaluated
Molybdenum	5.0	9.5	Exceeds guideline; Evaluated
Nickel	50	52	Exceeds guideline; Evaluated
Selenium	1	2.6	Exceeds guideline; Evaluated
Strontium	No guideline	94	No guideline; Evaluated
Tin	No guideline	3	Non-toxic; Not evaluated
Uranium	10	1.57	Less than guideline; Not evaluated
Vanadium	130	32.8	Less than guideline; Not evaluated
Zinc	200	6,140	Exceeds guideline; Evaluated
Cyanide	0.9	8,580	Exceeds guideline; Evaluated

[a] CCME Soil Quality Guidelines for Agricultural Land Use (CCME 1999).
[b] CCME Interim Soil Remediation Criteria (CCME 1999).
Note: Shading indicates concentration is greater than guideline or no guideline is available and the parameter was evaluated in the risk assessment due to the potential to cause health effects.

3.3.3 Chemicals of Concern in Sediment

Metals that are present in sediment in the study area at concentrations greater than measured in the reference area, that exceed applicable regulatory guidelines or for which no guidelines are available, and metals that were not essential nutrients were evaluated in the wildlife health risk assessment. The chemicals of concern identified in sediment and evaluated in the risk assessment are presented in Table II-9.

Table II-9
Parameters Identified as Chemicals of Concern in Sediment

Parameter	Wildlife Health Risk Assessment
Aluminum	√
Arsenic	√
Boron	√
Copper	√
Lead	√
Manganese	√
Molybdenum	√
Nickel	√
Selenium	√
Strontium	√
Zinc	√
Cyanide	√

3.4 Vegetation

3.4.1 Step 2: Comparison to Concentrations in Vegetation from the Reference Area

Metals concentrations measured in vegetation collected from the study area were compared with metal concentrations measured in the reference area. For each metal, the maximum concentration from the study area (cell 1 cover and wind blown tailings area) was compared to the mean reference concentrations (esker borrow area). If metal concentrations from the study area were greater than concentrations from the reference site, these metals were carried forward to Step 3 of the chemical screening process. Comparisons are presented in Table II-10.

Table II-10
Maximum Concentrations of Parameters in Vegetation from the Study Area (pond 1 and pond 2) Compared with Average Concentrations in the Reference Area (esker borrow area)

Parameter	Concentration (mg/kg) (Wet Weight)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	139	629
Antimony	<0.04	0.02
Arsenic	0.5	31.7
Barium	5.94	9.53
Beryllium	<0.2	<0.2
Cadmium	<0.08	<0.08
Chromium	0.4	2.3
Cobalt	0.31	0.61
Copper	1.23	2.09
Iron	70	891
Lead	0.07	2.52
Manganese	106	333
Mercury	<0.01	<0.01
Molybdenum	0.04	0.62
Nickel	2.16	3.07
Selenium	<0.2	<0.2
Silver	<0.08	<0.08
Strontium	2.17	6.49
Thallium	<0.04	<0.04
Tin	<0.08	<0.08
Titanium	4.12	15.44
Vanadium	0.14	0.46
Zinc	13.4	31.6

Note: Shading indicates that concentration in the study area is greater than in the reference area.

3.4.2 Steps 3 and 4: Comparison to Guidelines and Non-toxic Substances

There are no guidelines available for acceptable concentrations of metals in vegetation for human or wildlife health. Therefore, all metal concentrations that were higher in the study area than reference area were carried forward to step 4 of the screening process. In step 4, metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment. The substances that were considered non-toxic for vegetation and not evaluated for vegetation were tin and titanium.

3.4.3 Chemicals of Concern in Vegetation

Metals that were present in vegetation from the study area in concentrations greater than in the reference locations, for which no guidelines are available, and were not essential nutrients were evaluated in the human and wildlife health risk assessments. The chemicals of concern identified in vegetation and evaluated in the risk assessment are:

- aluminum
- arsenic
- barium
- chromium
- cobalt
- copper
- lead
- manganese
- molybdenum
- nickel
- strontium
- vanadium
- zinc

3.5 Final List of Chemicals of Concern

Parameters that are present in the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients or essentially non-toxic were evaluated in the risk assessment. The final chemicals of concern for the wildlife (and human) health risk assessments are presented in Table II-11. Although a metal may have only been identified as a chemical of concern in one media (water, soil, sediment, or vegetation), it was evaluated in all media in the risk assessment to determine total exposure.

Table II-11
Metals Evaluated in the Wildlife (and Human) Health Risk Assessment

Parameter	Water	Soil	Sediment	Vegetation
Aluminum		√	√	√
Arsenic	√	√	√	√
Barium	√			√
Boron		√	√	
Chromium				√
Cobalt	√			√
Copper	√		√	√
Lead			√	√
Manganese	√	√	√	√
Molybdenum			√	√
Nickel	√		√	√
Selenium			√	
Silver	√			
Strontium	√	√	√	√
Thallium	√			
Vanadium				√
Zinc			√	√
Cyanide	√		√	

4. WILDLIFE HEALTH RISK ASSESSMENT

4.1 Problem Formulation

4.1.1 Ecological Receptor Screening

There are many wildlife species that could be present in the tundra environment in the vicinity of the Lupin mine site. However, it is not practical to evaluate all species. Receptors selected for the risk assessment were considered to be representative of the local ecosystem. Representative receptors are those that have the greatest potential for exposure, that play a key role in the food web, and that have sufficient characterization data to facilitate calculations of exposure and health risks. Receptors were also selected to include animals that are considered to be vulnerable by COSEWIC (2002) and SARA (2002). According to CCME (1996), species identified as endangered, threatened or of special concern should be considered in the risk assessment. The short-listed wildlife receptors are defined as resources or environmental features with the following characteristics:

- are important to human populations (i.e., used as a food source);
- have economic and/or social value (i.e., animals that are trapped for furs, recreational value);
- have intrinsic ecological significance (i.e., endangered species, key species in the food web); and
- serve as a baseline from which the impacts can be evaluated (CCME 1996).

The risk assessment focused on birds and mammals that are herbivorous or that prey on herbivores in the vicinity of the Lupin mine site. Selection rationale for the wildlife receptors within the bird and mammal groups is presented in Table II-12.

Table II-12
Valued Ecosystem Components Evaluated in the Risk Assessment

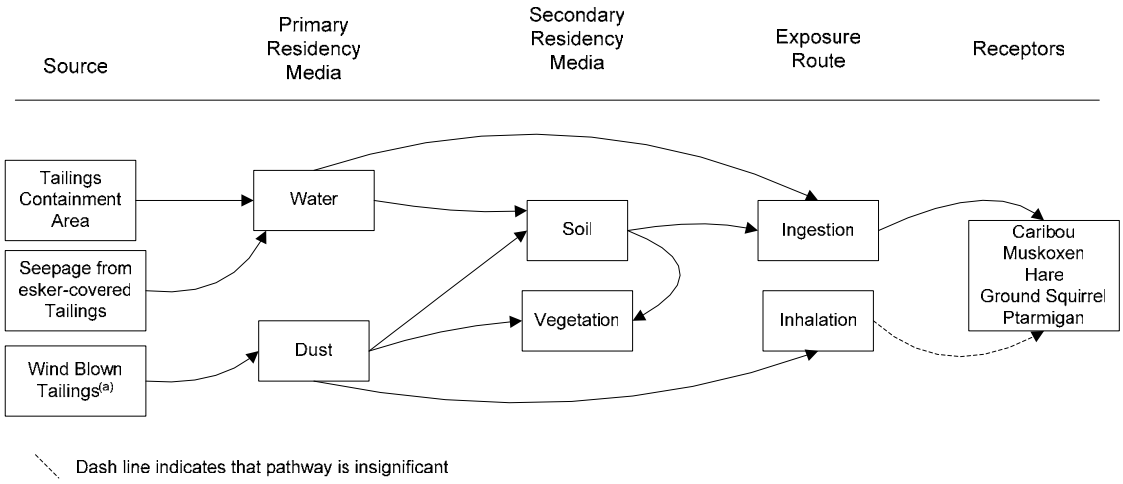
Classification	Common Name	Scientific Name	Rationale
Large Carnivorous/ Omnivorous Mammal	Grizzly Bear	*Ursus arctos horribilis*	The grizzly bear is a socially important species and represents an omnivorous receptor. Grizzly bear may feed on vegetation and prey that have been exposed to metals from the Lupin mine site. Grizzly bears are listed as species of special concern by COSEWIC. Therefore, Grizzly bears were evaluated in the risk assessment.
	Wolf	*Canis lupus*	The wolf is a primary predator of caribou and is considered to be one of the species at the top of the food chain. Wolves have been observed near the Lupin mine site. Therefore, due to their position in the food web and their presence near the mine, wolves were evaluated in the risk assessment.
Small carnivore	Wolverine	*Gulo gulo*	The wolverine is a carnivore. It is primarily a scavenger rather than a hunter and is usually dependent on other carnivores, such as wolves, to kill the animals for it to eat. Some individual wolverines can become good hunters and can kill young and adult ungulates, such as caribou, if the prey is in poor physical condition or if the wolverine has manoeuvred it into a disadvantaged position. Wolverines are listed as species of special concern by COSEWIC. Therefore, due to its COSEWIC classification and position in the food chain, wolverines were evaluated in the risk assessment.
	Fox	*Vulpes vulpes*	Foxes (both red and arctic) are primary predators of arctic ground squirrels and arctic hare. They have a relatively small home range and could spend a considerable amount of time in the vicinity of the Lupin mine site. Although Arctic or Red fox are not listed by COSEWIC, their role in the food chain is important. Thus, the fox was evaluated in the risk assessment.
Large Herbivores	Caribou	*Rangifer tarandus*	Caribou are an ecologically important species in the north. They are an important prey item for wolves and grizzlies and are an important food item for people. Thousands of caribou can pass through or near the Lupin mine while travelling to and from their calving grounds. Due to their importance as a food item for both people and wildlife, caribou were evaluated in the risk assessmen.
	Muskoxen	*Ovibos moschatus*	Muskoxen are arctic dwelling animals with relatively small home ranges. Muskoxen are slow-moving animals that must dig through snow to consume vegetation. They are also important prey items for wolves. Muskoxen have been observed occasionally near Lupin. Therefore, muskoxen were evaluated in the risk assessment.
Small Herbivores	Arctic hare	*Lepus arcticus*	Arctic hare are important prey items for carnivorous wildlife such as wolves and grizzly bears. Therefore, hare were evaluated in the risk assessment to represent all small herbivores in the study area.
	Arctic ground squirrel	*Spermophilus parryii*	Arctic ground squirrels are small herbivores and are important prey items for carnivores such as foxes. Ground squirrels are also trapped by local Inuit residents. Therefore, ground squirrels were evaluated in the risk assessment to represent small herbivores in the area.
Birds	Ptarmigan	*Lagopus lagopus*	Ptarmigan are important prey items for carnivorous wildlife such as wolves. In addition, they are one of few species of birds that have a small home range. Therefore, ptarmigan were evaluated in the risk assessment to represent small avian herbivores in the study area.
	Rough legged hawk	*Buteo lagopus*	Raptors and birds of prey are socially important species. Furthermore, their food source includes rodents such as the arctic ground squirrel. Several species of hawks have been observed surrounding the Lupin mine site. Therefore, the rough-legged hawk was evaluated as representative of raptors.
	Snipe	*Gallinago gallinago*	The snipe is a common shorebird in northern regions. Shorebirds consume sediment-dwelling invertebrates, so were chosen to represent this part of the food chain.
	Duck	*Clangula hyemalis*	The long-tailed duck is a common seabird that breeds in the area of the Lupin mine. During the breeding season, long-tailed ducks ingest aquatic and benthic invertebrates and sediments when foraging for food. Therefore, the long-tailed duck was chosen to represent waterfowl that might choose to forage for food on the Lupin mine site.

4.1.2 Wildlife Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors and are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The results of the exposure pathway screening are summarized in the Conceptual Exposure Model, which details the source of the metal, the release mechanisms, environmental transport and residency media, exposure routes and receptors. The conceptual exposure models for herbivores, grizzly bears, carnivores, and waterfowl are presented in Figures II-4, II-5, II-6, and II-7, respectively.

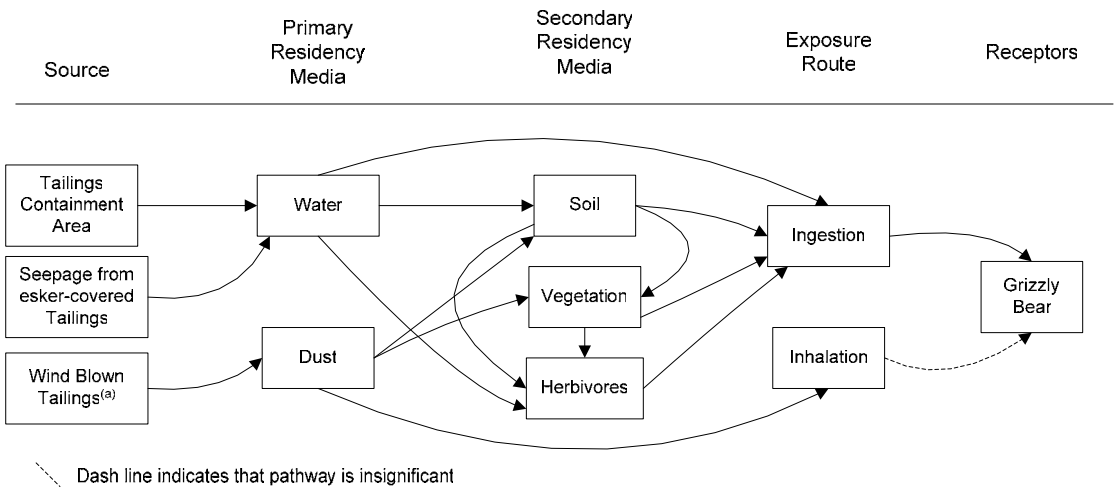
Wildlife Receptors may be exposed to metals through direct and indirect pathways. Direct pathways are those in which the receptor comes into direct contact with the source of metals and include soil and water ingestion. Indirect exposure pathways are those in which the exposure results from a secondary source (i.e., food chain). Ingestion of vegetation and prey would be examples of indirect exposure pathways.

Figure II-4
Herbivore Exposure Pathway



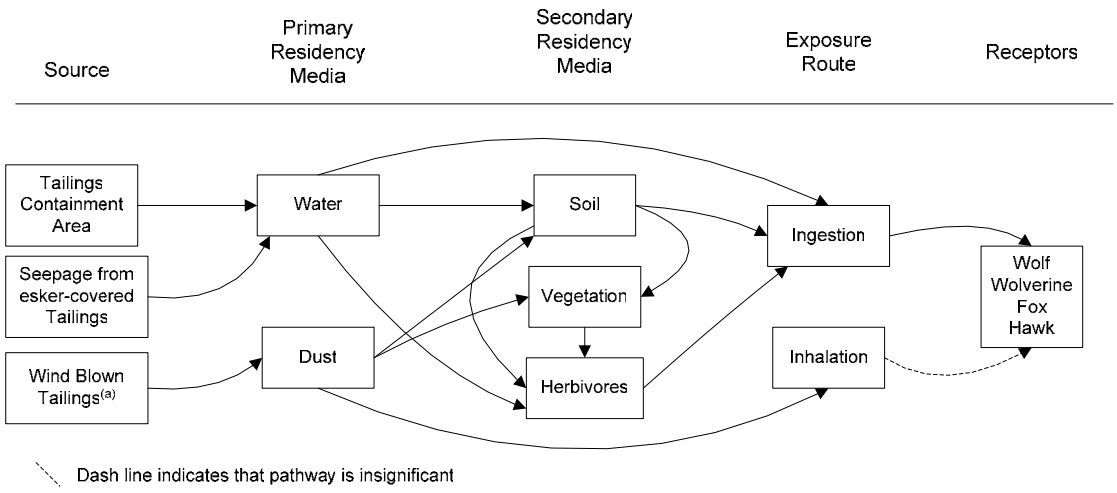
(a)Exposed tailings will be covered as part of closure plan.

Figure II-5
Grizzly Bear Exposure Pathway



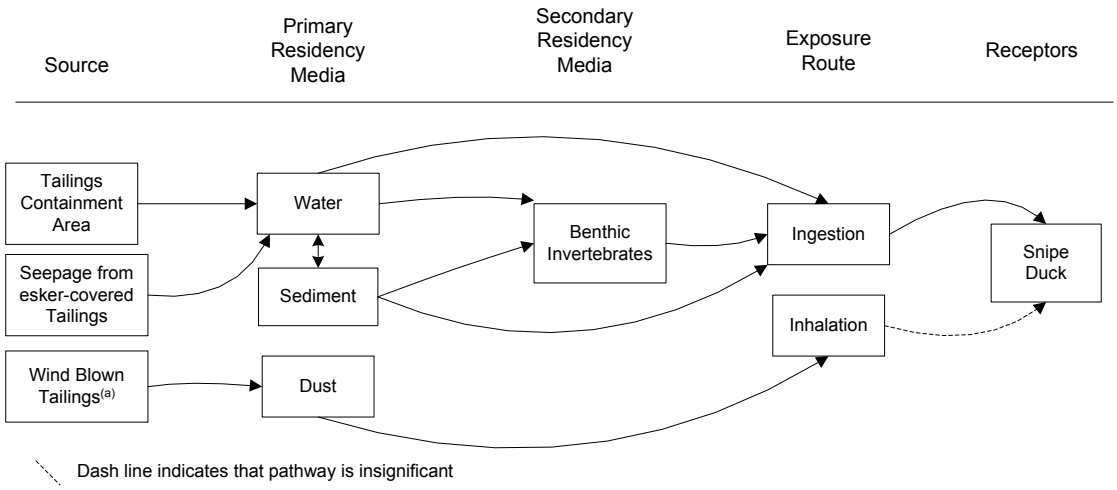
(a)Exposed tailings will be covered as part of closure plan.

Figure II-6
Carnivore Exposure Pathway



(a)Exposed tailings will be covered as part of closure plan.

Figure II-7
Waterfowl and Shorebird Exposure Pathway



(a)Exposed tailings will be covered as part of closure plan.

Dietary assumptions and exposure pathways for each receptor are presented in Table II-13 and described in the following paragraphs.

Table II-13
Dietary Preferences of the Wildlife Receptors

Species	Diet Preference[(a)]	Soil/Sediment Ingestion	Water Ingestion
Caribou	100% vegetation	Soil	Evaluated for all VECs
Muskoxen	100% vegetation	Soil	
Grizzly Bear	50% vegetation 50% caribou[(b)]	Soil	
Wolf	100% mammal	Soil	
Fox	100% mammal	Soil	
Wolverine	100% mammal	Soil	
Arctic Ground Squirrel	100% vegetation	Soil	
Hare	100% vegetation	Soil	
Ptarmigan	100% vegetation	Soil	
Hawk	100% mammal	Soil	
Duck	100% invertebrates	Sediment	
Snipe	100% invertebrates	Sediment	

(a) CWS 2003.
(b) Gau and Case 1998.

Ingestion of Soil

All wildlife may ingest soil either inadvertently when ingesting vegetation or grooming or purposely (Beyer et al. 1994). There are two sources of metals in soil; wind blown tailings dust and seepage upwards to esker sand from the reclaimed tailings areas. Direct ingestion of exposed tailings was not evaluated in the risk assessment because exposed tailings will be covered in the near future. Ingestion of soil was evaluated for all receptors in the risk assessment.

Ingestion of Sediment

Wildlife that are commonly found in an aquatic habitat may ingest sediment, similar to those that ingest soil while feeding, grooming, or purposely. Both waterfowl and shorebirds may ingest sediment by this pathway. Therefore, sediment ingestion was evaluated for both the duck and the Snipe.

Ingestion of Vegetation

Vegetation may take up metals from soil. Grasses growing on soil at the Lupin mine site are assumed to be consumed by all herbivorous wildlife. The pathway of vegetation ingestion was evaluated for ground squirrel, hare, ptarmigan, caribou, muskoxen and grizzly bears.

Ingestion of Water

There will be standing water in the holding ponds on the Lupin mine site area. All wildlife may use this water as a drinking water source while in the vicinity of the Lupin mine site. Therefore, ingestion of water was evaluated for all receptors in the risk assessment.

Ingestion of Invertebrates

Benthic or aquatic invertebrates take up substances from sediment. Therefore, wildlife such as ducks and snipe, may be exposed to chemicals of concern by eating invertebrates. It was assumed that the diet of waterfowl and shorebirds was composed of 100% invertebrates. Therefore, ingestion of invertebrates was evaluated for the duck and the snipe in the risk assessment.

Ingestion of Mammalian Prey

Predatory animals will consume herbivores that have consumed water, soil and vegetation from the Lupin mine site. Since herbivorous prey species may accumulate metals into their tissue, predatory animals may subsequently be exposed to metals. Therefore, the pathway of prey ingestion was evaluated for grizzly bears, wolves, foxes, wolverine, and hawks.

Inhalation of Air

The air inhalation pathway was not evaluated because none of the metals are volatile chemicals and because inhalation of airborne particles that may be composed of metals is an insignificant pathway when compared to the soil, food and water ingestion pathways.

4.2 Exposure Assessment

4.2.1 Spatial and Temporal Boundaries

The footprint of the Lupin mine is 10.4 km^2 and the tailings containment area itself is 7.8 km^2. Animals with relatively small home ranges (i.e., arctic hare, arctic ground squirrel and fox) were assumed to obtain 100% of their food and water from the vicinity of the Lupin tailings containment area. Although the arctic ground squirrel hibernates for 5 months per year, it was assumed that 100% its food and water is from the Lupin mine site during its 210-day active period (7 months). For animals that are migratory or have large home ranges, the area of the Lupin mine site is not enough area to fulfil all of the basic needs (such as food and shelter). Therefore, estimates of exposure time were based on reports on wildlife movement, literature descriptions of home ranges and communication with wildlife biologists.

4.2.2 Grizzly Bear

Studies of collared grizzly bears near an active diamond mine indicated that one bear spent 10% of its active, non-hibernating season (approximately six months extending from May to October) within 1 km of the mine (R. Gau, RWED, personal communication,). Assuming that the Lupin mine would be more attractive to a grizzly bear once it has closed and human activity is absent it was assumed for the purposes of the risk assessment that a grizzly bear spent 10% of its six active

months per year at the Lupin mine, or approximately 18 days. This is considered to be a conservative estimate, as the Lupin mine represents approximately 0.005% of the home range of an adult female grizzly bear (estimated at 2,074 km^2, McLoughlin et al. 1999).

4.2.3 Wolf

Barren-ground wolves of the central Canadian arctic rely heavily on Bathurst caribou, and their seasonal movements reflect this. Studies of wolves preying on Bathurst caribou indicate that wolves select den sites that are in an optimal position to encounter caribou returning from the calving ground when the nutritional demands of their pups is the greatest (Heard and Williams 1992). Barren-ground wolves generally spend the summer north of the treeline, and during this time show territorial behaviour, centred on the pack's den. During the winter, these wolves follow the caribou herds and do not exhibit territorial behaviour (Walton et al. 2001). Although their winter range (November to April) may overlap with the Lupin mine (Cluff 2001), the much larger size of the winter range (approximately 45,000 km^2 for males in the winter versus 2,000 km^2 for males in the summer, Walton et al. 2001) and the nomadic behaviour of wolves during the winter indicate that it is unlikely for a wolf to remain in contact with the Lupin mine for any length of time during the winter.

During the summer, males have a slightly larger home range than females (approximately 2,000 km^2 versus 1,100 km^2) (Walton et al. 2001). Summer denning extends from approximately May to October. Wolf movements during this time can be described as being concentrated in an area around the den (approximately 400 km^2, D. Cluff, RWED personal communication,) with occasional long-distance caribou hunting excursions during June and July if necessary.

For the purposes of the risk assessment, it was assumed that a pack of wolves denned within the footprint of the Lupin mine site for the summer season (May to October), that the individual from this pack did not leave the mine footprint during these six months. Although wolves rely on hunting excursions away from the den to provide enough food at the den, it was assumed that caribou (and other prey items) were readily available near the Lupin mine and hunting excursions were not necessary. Assuming that the Lupin mine attracts caribou and that the wolf's diet was supplemented by other species present at the mine site (such as arctic hare and arctic ground squirrel) it was conservatively assumed that the wolf obtained 50% of its food from the Lupin mine.

4.2.4 Wolverine

Wolverine, members of the weasel family, are small carnivores and frequent scavengers. Studies of wolverine in the Slave Geological Province identified caribou, muskox, arctic ground squirrel, microtines (lemmings and voles) and ptarmigan as the principal prey of the wolverine in this area (Mulders 2000).

The home range of adult female wolverine in the Slave Geological Province was estimated by Mulders (2000) at 126 km^2. The footprint of the Lupin mine represents approximately 0.08% of this home range. Unlike other carnivores, wolverine do not hibernate or migrate; thus, wolverine are likely to be present around the Lupin mine for a greater portion of the year. Like a grizzly bear, a wolverine obtains all of its food from within a distinct territory. Therefore, it was conservatively assumed that a wolverine would spend 50% of its time (183 days) at the Lupin mine.

4.2.5 Bathurst Caribou

Satellite telemetry data for 31 female caribou from the Bathurst herd were used to develop seasonal ranges of the herd (Gunn et al. 2002). Movements tracked from April 1996 to December 2001 were used to estimate the amount of time the Bathurst herd seasonal range could overlap with the Lupin mine. This data showed that the Lupin mine is located within the seasonal home range of the Bathurst herd during the summer, fall, rut and spring migration, for a total of approximately 187 days per year. Straight-line movement rates, compiled using the same satellite collar data by week by Gunn et al. (2002) indicate that caribou are constantly moving. Daily movement rates range from approximately 2 to 23 km/day (averaged by week). This suggests that the actual time that caribou would be present at the Lupin mine would be much less.

Use of mine sites by caribou was documented at the Lupin mine (Muller and Gunn 1996; Gunn 1998). These studies indicated that caribou will use disturbed areas and structures at an active mine (including tailings ponds, roads, airstrips, and buildings) for shade, to avoid mosquitoes, and to avoid predators. Based on these factors, a conservative estimate of 10% of the year (approximately 37 days) was used in the risk assessment to represent the time spent by caribou at the Lupin mine site.

4.2.6 Muskox

Muskox are not known to migrate; however, small seasonal movements have been documented (Gunn and Fournier 2000). Little research has been conducted on the home range or movement patterns of muskox in Canada, and no surveys have been conducted to document muskox numbers near the Lupin mine. It is expected that muskox will recolonize their former ranges, which may include the Lupin mine area (Fournier and Gunn 1998).

Assuming that muskox in the Contwoyto area do not migrate, a muskox may spend a considerable amount of the year at the Lupin mine. For the purposes of the risk assessment, it was assumed that a muskox may be present at the Lupin mine for 8 months, or 240 days. This is a substantial overestimate since although muskox are sedentary, their forage area is likely to be greater than mine site area.

4.2.7 Birds

Baseline data for the Diavik Diamond Mine Project, collected from 1995 to 1997, was used to estimate the amount of time that birds would spend in the vicinity of the Lupin mine (DDMI 1998). The Diavik mine, located on an island in Lac de Gras, is approximately 140 km to the south of the Lupin mine.

Baseline reports from the Diavik project were reviewed to identify the dates of earliest occurrence and latest occurrence (regardless of year) for each of the receptor bird species. These dates were used to determine the maximum number of days each species may be in the region of the Lupin mine. Since the Lupin mine is north of the Diavik mine, migratory birds probably spend less time in the Lupin area than suggested by the Diavik data. The time span between the observation of the earliest spring arrival and last fall departure were used as a conservative estimate of the exposure time of each species, except for ptarmigan, which were assumed to be at the site all year (Table II-14, DDMI 1998). Though many willow ptarmigan return south of the treeline for the winter months (Godfrey 1986), some stay above the treeline for the entire winter. Therefore, for the purposes of the risk assessment, it was assumed that willow ptarmigan could be get 100% of their food and water from the vicinity of the Lupin mine.

Table II-14
Estimated Residency Period of Bird Species at the Lupin Mine, Based on Studies at Lac de Gras, 1995 to 1997 (DDMI 1998)

Bird Species	First Occurrence (year observed)	Last Occurrence (year observed)	Maximum Number of Days Present
Willow ptarmigan	26 April (1996)	At least 29 October[a]	219[b]
Rough-legged hawk	5 May (1997)	17 October (1996)	166
Wilson's Snipe	31 May (1996)	3 September (1995)	96
Long-tailed duck	22 May (1997)	24 October (1996)	156

[a] Willow ptarmigan were still present in the study area when field studies were completed.
[b] Based on an estimated presence in the area until 30 November.

4.2.8 Summary

The estimated exposure time for the wildlife receptors is summarized in Table II-15. These estimates are not intended to be a precise representation of each species' behaviour near the mine; rather they are intended to represent a worst-case scenario. Due to the small size of the Lupin mine (10.4 km^2) relative to the home range of some barren-ground species, it is very unlikely that animals would spend a significant period of time in the vicinity of the Lupin mine.

Table II-15
Estimated Maximum Exposure Time for Wildlife Receptors

Species	Estimated Exposure (days)	Percent of Year at the Lupin Mine Site
Grizzly bear	18	10
Wolf	90	50
Wolverine	164	50
Red fox	365	100
Caribou	37	10
Muskox	240	66
Arctic hare	365	100
Arctic ground squirrel	210	100
Willow ptarmigan	365	100
Rough-legged hawk	166	45
Wilson's Snipe	96	26
Long-tailed duck	156	43

4.2.9 Exposure Estimate Equations

Exposure estimate equations used for the wildlife health exposure assessments are presented in Table II-16. Exposure was calculated based on maximum metal concentrations in soil, sediment, water and food.

Table II-16
Wildlife Exposure Equations

Pathway	Equation and Equation Parameters
Soil/Sediment ingestion	$EDI_{soil} = \frac{IR \times C_{soil} \times ET}{BW}$
	EDI_{soil} = exposure due to ingestion of soil (mg metal/kg body weight - day) IR = ingestion rate (kg/day) C_{soil} = metal concentration in soil (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Vegetation ingestion	$EDI_{veg} = \frac{IR \times C_{veg} \times ET}{BW}$
	EDI_{veg} = exposure due to ingestion of vegetation (mg metal/kg body weight - day) IR = ingestion rate from LLCF in wet weight (kg/day) C_{veg} = metal concentration in vegetation in wet weight (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Prey/invertebrate ingestion	$EDI_{prey} = \frac{IR_{prey} \times C_{prey} \times ET}{BW}$
	EDI_{prey} = exposure due to ingestion of prey (mg metal/kg body weight-day) IR_{prey} = food ingestion rate (kg/day) C_{prey} = concentration in prey (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Water ingestion	$EDI_{water} = \frac{IR_{water} \times C_{water} \times ET}{BW}$
	EDI_{water} = exposure due to ingestion of water (mg metal/kg body weight-day) IR_{water} = water ingestion rate (L/day) C_{water} = concentration in water (mg/L) ET = exposure time (days/year) BW = receptor body weight (kg)

4.2.10 Wildlife Exposure Parameters

Details on the body weights, food, water, sediment, and soil ingestion rates, dietary compositions and time spent near the Lupin mine site for wildlife receptors are presented in Table II-17.

Table II-17
Wildlife Parameters Used in the Risk Assessment

Receptor	Body weight (kg)	Food Ingestion rate (kg/day)[a]	Water Ingestion Rate (L/day)[a]	Soil Ingestion Rate[b]
Muskoxen	280[c]	5.3	15.8	0.4[g]
Caribou	108[c]	2.6	6.7	0.05[h]
Grizzly bears	139[d]	4.0	8.4	0.08[h]
Wolverine	10[d]	0.5	0.8	0.009[h]
Fox	5.0[e]	0.3	0.4	0.007[i]
Wolves	34[c]	1.3	2.4	0.04[i]
Hare	4.81[d]	0.1	0.4	0.001[h]
Arctic ground squirrel	0.750[d]	0.03	0.08	0.0007[j]
Ptarmigan	0.559[f]	0.04	0.04	0.0008[h]
Rough legged hawk	0.956[f]	0.06	0.06	0.001[h]
Snipe	0.1220[f]	0.015	0.014	0.0003[h]
Duck	0.873[f]	0.05	0.05	0.002[k]

[a] U.S. EPA 1993.
[b] Sediment ingestion rate for snipe and duck.
[c] Silva and Downing 1995; RWED 2004.
[d] Silva and Downing 1995.
[e] RWED 2004.
[f] Dunning 1993.
[g] Assumed 6.8% of food ingestion; surrogate bison; Beyer et al. 1994.
[h] Assumed 2% of food ingestion; Beyer et al. 1994.
[i] Assumed 2.8% of food ingestion; surrogate red fox; Beyer et al. 1994.
[j] Assumed 2.7% of food ingestion; surrogate white-tailed prairie dog; Beyer et al. 1994.
[k] Assumed 3.3% of food ingestion; surrogate mallard; Beyer et al. 1994.

4.3 Bioavailability

Bioavailability (also referred to as absorption efficiency) is a measure of the amount of a chemical that is absorbed and retained within the body. Consideration of bioavailability may be important under the following circumstances (Health Canada 1995; U.S. EPA 1989):

- if the medium of exposure is different than the medium on which the TRV is based (e.g., exposure is from soil, but the TRV is based on exposure from water);
- if the route of exposure is different than the routes of exposure in the study used to derive the TRV (e.g., oral route of exposure, but based on an inhalation study); and
- the TRV derived by the regulatory agency has been adjusted for bioavailability.

In the wildlife health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body), and the toxicity reference value was based on the same route of exposure as that being evaluated and/or because bioavailability rates were not available. The lack of adjustment for bioavailability may introduce additional conservatism if the form of the metal administered in laboratory toxicity tests is more soluble than the form of the metal in soil, plants and caribou meat. For example, metals are often introduced to water or food as metal salts during laboratory tests. Metal salts are more readily taken up into the body once administered. Therefore, a given concentration of metal salts may cause effects at lower thresholds than would have occurred had the metals been administered in more environmentally-realistic forms such as a mixture of salts, metal-organic complexes, and particulates.

4.4 Toxicity Assessment

Toxicity Reference Values (TRV) (or toxicity benchmarks) used in the wildlife health assessment are based on laboratory toxicity studies. Toxicity test species should ideally be the same species being evaluated in the risk assessment, but this is rarely possible. Most often, toxicity studies are conducted with rats and mice. Laboratory toxicity studies conducted using rats, mice, mallard ducks or other captive species provide dose-response information that can be extrapolated to wildlife. TRVs for the wildlife health assessment were obtained from Sample et al. (1996), unless otherwise noted. The Low-Observed-Adverse-Effect Level (LOAEL) for sublethal effects was selected for each metal, where available. The LOAELs from laboratory studies were extrapolated, incorporating differences in physiology between large and small animals according to the allometric method described in Sample and Arenal (1999). If a LOAEL was not available or inappropriate (i.e., based on mortality), a No-Observed-Adverse-Effect-Level (NOAEL) was used. The allometric method is based on the observation that many biological properties vary with body weight (Sample and Arenal 1999).

The equation used to calculate a TRV specific for mammals is based on the allometric scaling from toxicity laboratory studies is as follows:

$$A_w = A_t (BW_t/BW_w)^{1-0.94}$$

Where:

A_w = toxicity value for mammals

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for mammals

A similar scaling process was done for birds. The equation used to calculate a TRV specific for birds is based on the allometric scaling from toxicity laboratory studies is as follows:

$$A_w = A_t (BW_t/BW_w)^{1-1.2}$$

Where:

A_w = toxicity value for birds

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for birds

The mammalian and avian wildlife TRVs used in the wildlife health risk assessment are presented in Table II-18 and II-19, respectively.

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Muskoxen							
Aluminum	mouse	0.03	reproduction	19.3	280	11.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	280	0.73	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	280	3.5	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	280	63	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	280	1,833	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	280	8	NAS 1980
Copper	mink	1	reproduction	15.1	280	10.8	Sample et al. 1996
Lead	rat	0.35	reproduction	80	280	54	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Manganese	rat	0.35	reproduction	284	280	190	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	280	1.5	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	280	54	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	280	0.22	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	280	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	280	176	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	280	0.05	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	280	1.4	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	280	214	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	280	45.3	Sample et al. 1996
Caribou							
Aluminum	mouse	0.03	reproduction	19.3	108	11.8	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	108	0.77	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	108	3.7	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	108	66	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	108	1,941	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	108	8	NAS 1980
Copper	mink	1	reproduction	15.1	108	11.4	Sample et al. 1996
Lead	rat	0.35	reproduction	80	108	57	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	108	201	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	108	1.6	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	108	57	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	108	0.23	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	108	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	108	186	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	108	0.053	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	108	1.5	Sample et al. 1997
Zinc	rat	0.35	reproduction	320	108	227	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	108	48.0	Sample et al. 1996
Grizzly Bear							
Aluminum	mouse	0.03	reproduction	19.3	139	11.6	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	139	0.76	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	139	3.6	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	139	65	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	139	1,911	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	139	8	NAS 1980

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Copper	mink	1	reproduction	15.1	139	11.3	Sample et al. 1996
Lead	rat	0.35	reproduction	80	139	56	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	139	198	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	139	1.6	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	139	56	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	139	0.23	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	139	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	139	184	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	139	0.052	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	139	1.4	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	139	223	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	139	47.3	Sample et al. 1996
Wolverine							
Aluminum	mouse	0.03	reproduction	19.3	10	13.6	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	10	0.89	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	10	4.2	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	10	77	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	10	2,237	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	10	10	NAS 1980
Copper	mink	1	reproduction	15.1	10	13.2	Sample et al. 1996
Lead	rat	0.35	reproduction	80	10	65	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	10	232	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	10	1.8	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	10	65	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	10	0.27	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	10	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	10	215	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	10	0.061	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	10	1.7	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	10	262	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	10	55.3	Sample et al. 1996
Fox							
Aluminum	mouse	0.03	reproduction	19.3	5.0	14.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	5.0	0.93	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	5.0	4.4	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	5.0	80	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	5.0	2,333	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	5.0	10	NAS 1980
Copper	mink	1	reproduction	15.1	5.0	13.7	Sample et al. 1996
Lead	rat	0.35	reproduction	80	5.0	68	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	5.0	242	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	5.0	1.9	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	5.0	68	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	5.0	0.28	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	5.0	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	5.0	224	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	5.0	0.06	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	5.0	1.8	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	5.0	273	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	5.0	57.7	Sample et al. 1996
Wolf							
Aluminum	mouse	0.03	reproduction	19.3	34	12.7	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	34	0.83	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	34	3.9	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	34	71	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	34	2,079	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	34	9	NAS 1980
Copper	mink	1	reproduction	15.1	34	12.2	Sample et al. 1996
Lead	rat	0.35	reproduction	80	34	61	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	34	216	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	34	1.7	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	34	61	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	34	0.25	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	34	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	34	200	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	34	0.056	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	34	1.6	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	34	243	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	34	51.4	Sample et al. 1996
Hare							
Aluminum	mouse	0.03	reproduction	19.3	4.81	14.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	4.81	0.93	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Barium	rat	0.435	growth, hypertension	5.1	4.81	4.4	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	4.81	80	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	4.81	2,339	Sample et al. 1997
Cobalt	pig	225	clinical effects	8	4.81	10	NAS 1980
Copper	mink	1	reproduction	15.1	4.81	13.8	Sample et al. 1996
Lead	rat	0.35	reproduction	80	4.81	68	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	4.81	243	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	4.81	1.9	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	4.81	68	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	4.81	0.28	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	4.81	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	4.81	225	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	4.81	0.063	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	4.81	1.8	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	4.81	273	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	4.81	57.8	Sample et al. 1996
Arctic Ground Squirrel							
Aluminum	mouse	0.03	reproduction	19.3	0.750	15.9	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	0.750	1.0	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	0.750	4.9	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	0.750	89	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	0.750	2,615	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	0.750	11	NAS 1980
Copper	mink	1	reproduction	15.1	0.750	15.4	Sample et al. 1996
Lead	rat	0.35	reproduction	80	0.750	76	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	0.750	271	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	0.750	2.1	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	0.750	76	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	0.750	0.32	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	0.750	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	0.750	251	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	0.750	0.07	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	0.750	1.97	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	0.750	306	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	0.750	64.7	Sample et al. 1996

[(a)]Values is a NOAEL; no LOAEL value available.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Ptarmigan							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	0.559	141.8	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	0.559	4.57	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	0.559	28.2	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.559	89	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.559	4.3	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	0.559	0.27	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.559	62	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.559	14.7	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	0.559	1,472	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.559	29	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.559	100	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.559	0.9	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.559	6.8	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.559	290	NAS 1980.
Thallium	European starling	0.0823[(c)]	mortality	0.35[(b)]	0.559	0.51	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[(a)]	0.559	9.83	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.559	102.2	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[(a)]	0.559	0.022	Ma and Pritsos 1997.
Hawk							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	0.956	157.8	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	0.956	5.09	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	0.956	31.4	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.956	99.1	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.956	4.7	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	0.956	0.30	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.956	69	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.956	16.4	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	0.956	1,639	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.956	32.3	Sample et al. 1996.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.956	111.4	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.956	1.0	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.956	7.6	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.956	323	NAS 1980.
Thallium	European starling	0.0823[(c)]	mortality	0.35[(b)]	0.956	0.57	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[(a)]	0.956	10.95	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.956	113.8	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[(a)]	0.956	0.025	Ma and Pritsos 1997.
Snipe							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	0.1220	104.6	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	0.1220	3.37	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	0.1220	20.8	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.1220	65.7	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.1220	3.1	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	0.1220	0.20	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.1220	46	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.1220	10.84	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	0.1220	1,086	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.1220	21.4	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.1220	73.8	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.1220	0.7	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.1220	5.0	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.1220	214	NAS 1980.
Thallium	European starling	0.0823[(c)]	mortality	0.35[(b)]	0.1220	0.38	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[(a)]	0.1220	7.25	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.1220	75.4	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[(a)]	0.1220	0.016	Ma and Pritsos 1997.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Duck							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	5.847	226.7	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	5.847	7.32	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	5.847	45.2	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	5.847	142.4	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	5.847	6.8	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	5.847	0.43	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	5.847	100	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	5.847	23.5	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	5.847	2,354	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	5.847	46.3	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	5.847	160	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	5.847	1.4	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	5.847	10.9	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	5.847	464	NAS 1980.
Thallium	European starling	0.0823[(c)]	mortality	0.35[(b)]	5.847	0.82	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[(a)]	5.847	15.73	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	5.847	163.4	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[(a)]	5.847	0.036	Ma and Pritsos 1997.

(a) Value is a NOAEL; no LOAEL was available.
(b) Value is a NOAEL; LOAEL was not used because it was based on mortality.
(c) Dunning 1993.

4.4.1.1 Toxicity Profiles for Mammals

Aluminum

No specific data were identified regarding the oral toxicity of aluminum to mammalian wildlife. A LOAEL of 19.3 mg/kg-day was reported for effects on reproduction (i.e., number of litters, number of offspring and growth of generations) in laboratory mice that were exposed to

19.3 mg/kg-day of aluminum chloride in drinking water for three generations (Ondreicka et al. 1966 in Sample et al. 1996). There were no effects of number of offspring per litter or litter numbers, but the growth of the 2nd and 3rd generations was significantly reduced. Exposure was considered to be chronic because it occurred for longer than one year and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-18).

Arsenic

No specific data were identified regarding the oral toxicity of arsenic to mammalian wildlife. A LOAEL of 1.26 mg/kg-day was reported for effects on reproduction (i.e., litter size) in laboratory mice that were exposed to arsenite in their drinking water for three generations (Schroeder and Mitchner 1971 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than one year and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-19).

Barium

No specific data were identified regarding the oral toxicity of barium to mammalian wildlife. A NOAEL of 5.06 mg/kg-day was reported from reported for growth and hypertension in laboratory rats that were exposed to barium chloride by oral gavage for 16 months (Perry et al. 1983 in Sample et al. 1996). Since significance of hypertension in wild populations is unclear, the maximum dose that did not affect growth, food, or water consumption was considered a chronic NOAEL. For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Boron

No specific data were identified regarding the oral toxicity of boron to mammalian wildlife. A LOAEL of 93.6 mg/kg-day and a NOAEL of 28 mg/kg-day were reported for reproductive effects (i.e., sterility) in laboratory rats that were exposed to boric acid or borax in the diet for three generations (Weir and Fisher 1972 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than one year and throughout a critical lifestage (i.e.,

during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Chromium

A NOAEL of 2,737 mg/kg-day was reported for effects on reproduction and longevity of rats that were exposed to trivalent chromium in the diet for 90 days and 2 years (Ivankovic and Preussman 1975 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Cobalt

A NOAEL of 200 mg/kg cobalt in the diet and a LOAEL of 400 mg/kg cobalt in the diet was observed for effects on behaviour and neurological endpoints (e.g., anorexia, stiff legs, incoordination and muscular tremors) in pigs (Huck and Clawson 1976 in NAS 1980). The length of the study was not reported. Considering an average body weight and food ingestion rate for pigs of 225 kg and 4.5 kg/day (U.S. EPA 1988), the LOAEL and NOAEL were converted to a LOAEL of 8 mg/kg-day and a NOAEL of 4 mg/kg-day. For this assessment, the chronic LOAEL for pigs was used to estimate TRVs for mammalian wildlife (Table II-18).

Copper

No specific data were identified regarding the oral toxicity of copper to mammalian wildlife. A LOAEL of 15.14 mg/kg-day and a NOAEL of 11.7 mg/kg-day were reported for effects on reproduction (kit survivorship) in laboratory minks. The minks were exposed to 11.71, 15.14, 21.99, and 35.69 mg/kg-day of copper sulfate in their diet for 357 days (Aulerich et al. 1982 in Sample et al. 1996). Ingestion of 15.14, 21.99, and 35.69 mg/kg-day increased mink mortality, and ingestion of 11.71 mg/kg-day increased kit survivorship. Exposure was considered to be chronic because it was approximately one year in duration and occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mink was used to estimate TRVs for mammalian wildlife (Table II-19).

Lead

No specific data were identified regarding the oral toxicity of lead to mammalian wildlife. A LOAEL of 80 mg/kg-day and a NOAEL of 8 mg/kg-day were reported for effects on reproduction (i.e., number of pregnancies and number of live births) in laboratory rats. The rats were exposed to 0.8, 4, 8, 80, and 160 mg/kg-day of lead acetate in their diet for three generations (Azar et al. 1973 in Sample et al., 1996). Lead exposures of 80 and 160 mg/kg-day resulted in reduced offspring weights and produced kidney damage in young. Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than one year. For this assessment, the chronic LOAEL for rats was used to estimate TRVs mammalian wildlife (Table II-18).

Manganese

No specific data were identified regarding the oral toxicity of manganese to mammalian wildlife. A LOAEL of 284 mg/kg-day and a NOAEL of 88 mg/kg-day were reported for reproductive effects (i.e., pregnancy percentage and fertility) in laboratory rats that were exposed to manganese oxide in the diet for 224 days (Laskey et al. 1982 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., gestation). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Molybdenum

A LOAEL of 2.6 mg/kg-day was reported for reproductive effects (i.e., reduced reproductive success, high incidence of runts) in laboratory mice that were exposed to molybdate in their drinking water for three generations (Schroeder and Mitchener 1971 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than one year and occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-18).

Nickel

A LOAEL of 80 mg/kg-day and a NOAEL of 40 mg/kg-day were reported for effects on reproduction (i.e., reduced offspring body weights) in laboratory rats that were exposed to nickel

sulfate in their diet for three generations (Ambrose et al. 1976 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than one year. For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Selenium

No specific data were identified regarding the oral toxicity of selenium to mammalian wildlife. A LOAEL of 0.33 mg/kg-day and a NOAEL of 0.2 mg/kg-day were reported for reproductive effects (i.e., decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to potassium selenate in their diet for one year, through two generations (Rosenfeld and Beath 1954 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Silver

No specific data were identified regarding the oral toxicity of silver to mammalian wildlife. Therefore, the wildlife TRV was based on the NOAEL for argyria (bluish-grey discoloration of the skin) in humans (also the human health TRV; described in Section 5.4.3). Since the significance of argyria in wildlife is unclear, and the TRV incorporates uncertainty due to sensitive sub-populations, the human TRV was applied directly to wildlife for this assessment (Table II-18).

Strontium

A NOAEL of 263 mg/kg-day was reported for effects on growth (i.e., body weight and bone changes) in laboratory rats that were exposed to strontium chloride in drinking water for 3 years (Skoryna 1981 in Sample et al., 1996). A LOAEL was not reported for this study. Exposure was considered chronic because it occurred for longer than one year. For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Thallium

No specific data were identified regarding the oral toxicity of thallium to mammalian wildlife. A LOAEL of 0.74 mg/kg-day was reported for effects on reproduction (i.e., male testicular function) in laboratory rats that were exposed to thallium sulfate in their drinking water for 60 days (Formigli et al. 1986 in Sample et al. 1996). Exposure was considered to be subchronic because its duration was only 60 days. An uncertainty factor of 10 was applied to the LOAEL for subchronic to chronic extrapolation, for a chronic LOAEL of 0.074 mg/kg-day. For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Vanadium

No specific data were identified regarding on the oral toxicity of vanadium to mammalian wildlife. A LOAEL of 2.1 mg/kg-day was reported for reproductive effects (i.e., decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to sodium metavanadate by oral intubaton for 60 days prior to gestation, during gestation, delivery and lactation (Domingo et al. 1986 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during gestation, delivery and lactation). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Zinc

No specific data were identified regarding the oral toxicity of zinc to mammalian wildlife. A LOAEL of 320 mg/kg-day and a NOAEL of 160 mg/kg-day were reported for reproductive effects (i.e., fetal resorption and reduced fetal growth rates) in laboratory rats that were exposed to 160 and 320 mg/kg-day of zinc oxide in the diet during days one through 16 of gestation (Schlicker and Cox 1968 in Sample et al. 1996). Increased rates of fetal resorption and reduced fetal growth rates were observed at 320 mg/kg-day. Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Cyanide

No specific data were identified regarding the oral toxicity of cyanide to mammalian wildlife. A NOAEL of 68.7 mg/kg-day was reported for reproductive effects (offspring growth and food consumption) during gestation and lactation in rats exposed to potassium cyanide in the diet (Tewe and Maner 1981 in Sample et al. 1996). Exposure was considered to be chronic because it occurred throughout a critical lifestage (i.e., reproduction). For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

4.4.1.2 Toxicity Profiles for Avian Wildlife

Aluminum

No specific data were identified regarding the oral toxicity of aluminum to avian wildlife. A NOAEL of 109.7 mg/kg-day was reported for effects on reproduction for ringed doves that were exposed to aluminum sulfate in the diet for four months (Carriere et al. 1986 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than ten weeks and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic NOAEL for doves was used to estimate TRVs for avian wildlife (Table II-19).

Arsenic

No specific data were identified regarding the oral toxicity of arsenic to avian wildlife. A LOAEL of 12.8 mg/kg-/day and a NOAEL of 5.14 mg/kg-day were reported for effects on mortality for mallards that were exposed to sodium arsenite in the diet for 128 days (USFWS 1964 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than ten weeks. For this assessment, the chronic NOAEL for mallard ducks was used to estimate receptor-specific TRVs for avian wildlife (Table II-19).

Barium

No specific data were identified regarding the oral toxicity of barium to avian wildlife. A LOAEL of 416.53 mg/kg-day and a NOAEL of 208.26 mg/kg-day was reported for effects on mortality for day-old chicks that were exposed to barium hydroxide in the diet for four weeks (Johnson et al. 1960 in Sample et al. 1996). An uncertainty factor of 10 was applied to the LOAEL and the NOAEL to

extrapolate from subchronic to chronic exposure resulting in a chronic LOAEL of 41.7 mg/kg-day and a chronic NOAEL of 20.83 mg/kg-day. For this assessment, the chronic NOAEL for chicks was used to estimate TRVs for avian wildlife (Table II-19).

Boron

No specific data were identified regarding the oral toxicity of boron to avian wildlife. A LOAEL of 100 mg/kg-day and a NOAEL of 28.8 mg/kg-day were reported for reproductive effects (i.e., reduced egg fertility and duckling growth and increased embryo and duckling mortality) in mallard ducks exposed to boric acid in the diet for 3 weeks prior to, during and 3 weeks post reproduction (Smith and Anders 1989 in Sample et al. 1996). Exposure was considered to be chronic because it occurred throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Chromium

A LOAEL of 5 mg/kg-day and a NOAEL of 1 mg/kg-day were reported for effects on reproduction for black ducks exposed to trivalent chromium in the diet for ten months (Haseltine et al. 1985 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than ten weeks. For this assessment, the chronic LOAEL for black ducks was used to estimate TRVs for avian wildlife (Table II-19).

Cobalt

A NOAEL of 4.7 mg/kg of cobalt in the diet was reported for chickens for emaciation and mortality (Turk and Kratzer 1960 in NAS 1980). Considering an average body weight and food ingestion rate for chickens of 1.5 kg and 0.106 kg/day (U.S. EPA 1988), the NOAEL was converted to 0.33 mg/kg-day. For this assessment, the chronic NOAEL for chickens was used to estimate TRVs for avian wildlife (Table II-19).

Copper

No specific data were identified regarding the oral toxicity of copper to avian wildlife. A LOAEL of 61.7 mg/kg-/day and a NOAEL of 47 mg/kg-day were reported for effects on growth

and mortality for day-old chicks exposed to copper oxide in the diet for ten weeks (Mehring et al. 1960 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for 10 weeks. For this assessment, the chronic LOAEL for chicks was used to estimate TRVs for avian wildlife (Table II-19).

Lead

No specific data were identified regarding the oral toxicity of lead to avian wildlife. A NOAEL of 1.13 mg/kg-day and a LOAEL of 11.3 mg/kg-day were reported for effects on reproduction (hatching success) in Japanese quail exposed to lead acetate for 12 weeks in the diet (Edens et al. 1976 in Sample et al. 1996). Exposure was considered to be chronic because it occurred over 12 weeks and throughout a critical life stage. For this assessment, the chronic LOAEL for Japanese quail was used to estimate TRVs for avian wildlife (Table II-19).

Manganese

A NOAEL of 977 mg/kg-day was reported for growth and aggressive behaviour effects in male Japanese quail exposed to manganese oxide in their diet for 75 days (Laskey and Edens 1985 in Sample et al. 1996). A LOAEL was not observed during this study. Exposure was considered to be chronic because its duration was 75 days. For this assessment, the chronic NOAEL for Japanese quail was used to estimate the TRVs for avian wildlife (Table II-19).

Molybdenum

A LOAEL of 35.3 mg/kg-day and a NOAEL of 3.5 mg/kg-day were reported for effects on reproduction for chickens exposed to sodium molybdenum in their diet for 21 days during reproduction (Lepore and Miller 1965 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for chickens was used to estimate TRVs for avian wildlife (Table II-19).

Nickel

A LOAEL of 107 mg/kg-day and a NOAEL of 77.4 mg/kg-day were reported for effects on mortality, growth and behaviour for mallards that were exposed to nickel sulfate in their diet for

90 days during reproduction (Cain and Pafford 1981 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than 10 weeks (i.e., 90 days). For this assessment, the chronic LOAEL for mallards was used to estimate TRVs for avian wildlife (Table II-19).

Selenium

No specific data were identified regarding the oral toxicity of selenium to avian wildlife. A LOAEL of 1.0 mg/kg-day and a NOAEL of 0.5 mg/kg-day were reported for effects on reproduction of mallard ducks exposed to sodium selenite in the diet for 78 days (Heinz et al. 1987 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., reproduction) and for greater than ten weeks. For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Silver

A NOAEL of 22.2 mg/kg-day (300 ppm) and a LOAEL of 66.6 mg/kg-day were reported for effects on growth and blood in commercial turkey poults exposed to silver acetate in the diet for four weeks (Jensen et al., 1974). Exposure was considered sub-chronic, so an uncertainty factor of 10 was applied to the NOAEL and LOAEL to derive a chronic NOAEL of 2.2 mg/kg-day, and a chronic LOAEL of 6.66 mg/kg-day. For this assessment, the chronic LOAEL for turkeys was used to estimate TRVs for avian wildlife (Table II-19).

Strontium

A LOAEL of 50,000 mg/kg-day and a NOAEL of 30,000 mg/kg in the diet were reported for effects on egg production, egg weight and body weight for mature hens exposed to strontium carbonate in the diet for 4 weeks (Dobrenz et al. 1969 in NAS 1980). The NOAEL and LOAEL were adjusted to account for body weight and food ingestion rate of 1.5 kg and 0.106 kg/d (U.S. EPA 1988), respectively. An uncertainty factor of 10 was applied to extrapolate from subchronic to chronic exposure. Exposure was considered to be sub-chronic because it occurred for only 4 weeks. The resulting LOAEL and NOAEL are 353 mg/kg-day and 212 mg/kg-day, respectively. For this assessment, the chronic LOAEL for hens was used to estimate TRVs for avian wildlife (Table II-19).

Thallium

No specific data were identified regarding the oral toxicity of thallium to avian wildlife. The dose causing 50% mortality amongst starlings (LD50) was 35 mg/kg-day (U.S. EPA 1999). No information regarding exposure doses was provided. An uncertainty factor of 100 was applied to account for using an acute study (i.e., to determine a chronic NOAEL). Therefore, the chronic NOAEL was 0.35 mg/kg-day. For this assessment, the chronic NOAEL for starlings was used to estimate TRVs for avian wildlife (Table II-19).

Vanadium

No specific data were identified regarding the oral toxicity of vanadium to avian wildlife. A NOAEL of 11.4 mg/kg-day was reported for effects on mortality, body weight, and blood chemistry of mallards that were exposed to vanadyl sulfate in the diet for 12 weeks (White and Dieter 1978 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for more than 10 weeks. A LOAEL was not identified in the literature reviewed. For this assessment, the chronic NOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Zinc

No specific data were identified regarding the oral toxicity of zinc to avian wildlife. A LOAEL of 131 mg/kg-day and a NOAEL of 14.5 mg/kg-day were reported for reproductive effects in white leghorn hens that were exposed to zinc sulphate in the diet for 44 weeks (Stahl et al. 1990 in Sample et al. 1996). Exposure was considered to be chronic because it was for greater than 10 weeks and it occurred during a critical lifestage (i.e., reproduction). For this assessment, the chronic LOAEL for white leghorn hens was used to estimate TRVs for avian wildlife (Table II-19).

Cyanide

A NOAEL of 2.0 mg/kg-day for decreased adenosine triphosphate (ATP) production in heart tissue was observed in mallard ducks exposed to potassium cyanide (duration was reported as acute, but specific time period not reported) (Ma and Pritsos 1997). The LOAEL for the same study was 0.25 mg/kg-day for decreased ATP production in liver and brain tissue. No NOAEL was reported for ATP production in liver and brain tissue. An uncertainty factor of 10 was

applied to the LOAEL to account for acute exposure (for derivation of a chronic LOAEL). For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

4.5 Risk Characterization

Risk estimates or Exposure Ratios (ERs) were calculated as the ratio of the estimated exposure to the TRV, as follows:

$$\text{Risk Estimate} = \frac{\text{Estimated Exposure}}{\text{TRV}}$$

For wildlife, the acceptable risk threshold is an ER of 1, since the risk assessment evaluated exposure from all sources (i.e., food, water and soil or sediment ingestion) from the Lupin mine site. ERs were calculated individually for exposure from soil or sediment, water and food.

Calculated ER values for mammals in the reference area and study area from exposure to soil, water, and food (vegetation, and caribou meat) are shown in Tables II-20, II-21, II-22, and II-23, respectively.

The ERs from each exposure route were summed to calculate the total ER for mammals exposed to metals from the study area (Table II-24).

Calculated ER values for avian wildlife in the study area from exposure to soil (or sediment), water, and food (vegetation, caribou meat, or invertebrates) are shown in Tables II-25, II-26, and II-27, respectively.

The ERs from each exposure route were summed to calculate the total ER for avian wildlife exposed to metals from the study area (Table II-28).

Table II-20
Mammalian ER Values for Exposure to Metals in Soil from the Reference Area and Study Area

Parameter[(a)]	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.5	0.4	0.03	0.02	0.03	0.02	0.2	0.2	0.6	0.5	0.3	0.2	0.1	0.1	0.4	0.3
Arsenic	0.2	0.01	0.01	0.0006	0.01	0.0007	0.08	0.005	0.3	0.02	0.1	0.006	0.05	0.003	0.1	0.009
Barium	0.01	0.009	0.0005	0.0005	0.0006	0.0006	0.004	0.004	0.01	0.01	0.005	0.005	0.003	0.002	0.007	0.007
Boron	0.00003	0.00003	0.000001	0.000001	0.000002	0.000002	0.00001	0.00001	0.00004	0.00004	0.00001	0.00001	0.000008	0.000008	0.00002	0.00002
Chromium	0.00001	0.00001	0.0000006	0.000001	0.0000007	0.0000007	0.000005	0.000005	0.00001	0.00001	0.000006	0.000006	0.000003	0.000003	0.000008	0.000008
Cobalt	0.0006	0.0004	0.00003	0.00002	0.00004	0.00002	0.0003	0.0002	0.0008	0.0005	0.0003	0.0002	0.0002	0.0001	0.0005	0.0003
Copper	0.001	0.0007	0.00006	0.00004	0.00008	0.00004	0.0005	0.0003	0.002	0.0009	0.0006	0.0003	0.0003	0.0002	0.0009	0.0005
Lead	0.0001	0.00003	0.000005	0.000002	0.000006	0.000002	0.00004	0.00001	0.0001	0.00004	0.00005	0.00002	0.00003	0.000009	0.00007	0.00002
Manganese	0.0004	0.0003	0.00002	0.00002	0.00003	0.00002	0.0002	0.0001	0.0006	0.0004	0.0002	0.0002	0.0001	0.00009	0.0003	0.0003
Molybdenum	0.0002	0.0002	0.00001	0.000009	0.00001	0.00001	0.0001	0.00007	0.0003	0.0002	0.0001	0.00009	0.00006	0.00005	0.0002	0.0001
Nickel	0.0002	0.0002	0.00001	0.00001	0.00001	0.00001	0.00009	0.00008	0.0003	0.0002	0.0001	0.0001	0.00006	0.00005	0.0002	0.0001
Selenium	0.0004	0.0004	0.00002	0.00002	0.00002	0.00002	0.0002	0.0002	0.0005	0.0005	0.0002	0.0002	0.0001	0.0001	0.0003	0.0003
Silver	0.02	0.02	0.001	0.00098	0.001	0.001	0.009	0.009	0.03	0.03	0.01	0.0103	0.006	0.006	0.02	0.02
Strontium	0.00003	0.00003	0.000002	0.000001	0.000002	0.000002	0.00001	0.00001	0.00004	0.00003	0.00002	0.00001	0.000008	0.000007	0.00002	0.00002
Thallium	0.001	0.001	0.00006	0.00007	0.00007	0.00009	0.0005	0.0006	0.001	0.002	0.0005	0.0007	0.0003	0.0004	0.0008	0.001
Vanadium	0.01	0.01	0.0006	0.0005	0.0007	0.0006	0.005	0.004	0.01	0.01	0.006	0.005	0.003	0.003	0.008	0.008
Zinc	0.0001	0.00007	0.000005	0.000004	0.000006	0.000004	0.00004	0.00003	0.0001	0.00009	0.00005	0.00004	0.00003	0.00002	0.00007	0.00005

[(a)]Cyanide was not measured in soil.

Table II-21
Mammalian ER Values for Exposure to Metals in Water from the Reference Area

Parameter	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.01	0.0005	0.002	0.00007	0.002	0.00007	0.01	0.0004	0.02	0.0008	0.009	0.0004	0.02	0.0008	0.02	0.0008
Arsenic	0.06	0.0001	0.009	0.00002	0.009	0.00002	0.05	0.00009	0.1	0.0002	0.05	0.00008	0.1	0.0002	0.1	0.0002
Barium	0.001	0.00007	0.0001	0.00001	0.0001	0.00001	0.0008	0.00006	0.002	0.0001	0.0008	0.00005	0.002	0.0001	0.002	0.0001
Boron	0.0002	0.000007	0.00003	0.000001	0.00003	0.000001	0.0002	0.000006	0.0004	0.00001	0.0002	0.000005	0.0004	0.00001	0.0004	0.00001
Chromium	0.0000005	0.00000002	0.00000007	0.000000003	0.00000007	0.000000003	0.0000004	0.00000002	0.0000008	0.00000004	0.0000004	0.00000002	0.0000008	0.00000004	0.0000009	0.00000004
Cobalt	0.005	0.00001	0.0008	0.000001	0.0008	0.000001	0.004	0.000008	0.009	0.00002	0.004	0.000008	0.009	0.00002	0.009	0.00002
Copper	0.004	0.00002	0.0005	0.000003	0.0005	0.000003	0.003	0.00001	0.006	0.00003	0.003	0.00001	0.006	0.00003	0.006	0.00003
Lead	0.00002	0.00000004	0.000002	0.000000005	0.000002	0.000000005	0.00001	0.00000003	0.00003	0.00000006	0.00001	0.00000003	0.00003	0.00000006	0.00003	0.00000007
Manganese	0.02	0.000003	0.004	0.0000005	0.004	0.0000005	0.02	0.000003	0.04	0.000005	0.02	0.000002	0.04	0.000005	0.04	0.000006
Molybdenum	0.002	0.00003	0.0003	0.000004	0.0003	0.000004	0.001	0.00002	0.003	0.00004	0.001	0.00002	0.003	0.00004	0.003	0.00005
Nickel	0.002	0.000005	0.0003	0.0000008	0.0003	0.0000008	0.002	0.000004	0.004	0.000009	0.002	0.000004	0.004	0.000009	0.004	0.000009
Selenium	0.003	0.0002	0.0005	0.00003	0.0005	0.00003	0.003	0.0001	0.006	0.0003	0.003	0.0001	0.006	0.0003	0.006	0.0003
Silver	0.02	0.001	0.003	0.0002	0.003	0.0002	0.02	0.001	0.04	0.003	0.01	0.001	0.04	0.003	0.04	0.003
Strontium	0.0002	0.000002	0.00003	0.0000003	0.00003	0.0000003	0.0002	0.000002	0.0004	0.000003	0.0002	0.000002	0.0004	0.000003	0.0004	0.000004
Thallium	0.01	0.00004	0.002	0.000006	0.002	0.000006	0.01	0.00003	0.02	0.00007	0.009	0.00003	0.02	0.00007	0.02	0.00007
Vanadium	0.00009	0.00003	0.00001	0.000004	0.00001	0.000004	0.00007	0.00002	0.0001	0.00005	0.00007	0.00002	0.0001	0.00005	0.0002	0.00005
Zinc	0.0002	0.000001	0.00003	0.0000002	0.00003	0.0000002	0.0001	0.0000009	0.0003	0.000002	0.0001	0.000001	0.0003	0.000002	0.0003	0.000002
Cyanide	0.004	NA	0.0006	NA	0.0006	NA	0.003	NA	0.007	NA	0.003	NA	0.007	NA	0.007	NA

NA = Data not available; cyanide concentration not measured in reference area.

Table II-22
Mammalian ER Values for Exposure to Metals in Vegetation from the Study Area and Reference Area

Parameter[a]	Muskoxen		Caribou		Grizzly Bear		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.7	0.3	0.1	0.06	0.08	0.03	0.7	0.3	1	0.6
Arsenic	0.6	0.01	0.1	0.002	0.06	0.001	0.5	0.01	1	0.02
Barium	0.04	0.05	0.006	0.009	0.004	0.005	0.03	0.05	0.07	0.09
Chromium	0.00002	0.000005	0.000003	0.0000008	0.000002	0.0000005	0.00002	0.000004	0.00003	0.000009
Cobalt	0.001	0.001	0.0002	0.0002	0.0001	0.0001	0.0009	0.001	0.002	0.002
Copper	0.003	0.002	0.0004	0.0003	0.0003	0.0002	0.002	0.002	0.005	0.003
Lead	0.0006	0.00003	0.0001	0.000006	0.00006	0.000004	0.0006	0.00003	0.001	0.00006
Manganese	0.02	0.01	0.004	0.002	0.002	0.001	0.02	0.01	0.04	0.02
Molybdenum	0.005	0.0007	0.001	0.0001	0.0006	0.00007	0.005	0.0006	0.01	0.001
Nickel	0.0008	0.0007	0.0001	0.0001	0.00008	0.00007	0.0007	0.0006	0.001	0.001
Selenium	0.009	0.003	0.002	0.0005	0.0009	0.0003	0.008	0.002	0.02	0.005
Silver	0.05	0.05	0.009	0.009	0.006	0.005	0.06	0.06	0.1	0.1
Strontium	0.0005	0.0003	0.00008	0.00005	0.00005	0.00003	0.0004	0.0002	0.0009	0.0005
Thallium	0.003	0.002	0.0004	0.0004	0.0003	0.0002	0.002	0.002	0.005	0.004
Vanadium	0.004	0.003	0.0008	0.0004	0.0005	0.0003	0.004	0.002	0.008	0.005
Zinc	0.002	0.001	0.0003	0.0003	0.0002	0.0002	0.002	0.001	0.004	0.003

[a]Cyanide and boron not measured in vegetation.

Table II-23
Mammalian ER Values for Exposure to Metals in Caribou Meat from the Study Area Reference Area

Parameter	Grizzly Bear		Wolverine		Fox		Wolves	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.00004	0.00002	0.0005	0.0003	0.001	0.0006	0.0004	0.0002
Arsenic	0.00004	0.0000009	0.0005	0.00001	0.001	0.00003	0.0004	0.00001
Barium	0.0000002	0.0000003	0.000003	0.000004	0.000006	0.000008	0.000002	0.000003
Boron	0.000000006	0.0000000005	0.00000009	0.000000006	0.0000002	0.00000001	0.00000007	0.000000005
Chromium	0.000000005	0.000000002	0.00000007	0.00000003	0.0000001	0.00000007	0.00000006	0.00000003
Cobalt	0.00000002	0.000000003	0.0000003	0.00000004	0.0000006	0.0000001	0.0000003	0.00000004
Copper	0.000002	0.0000005	0.00002	0.000006	0.00005	0.00001	0.00002	0.000006
Lead	0.000000007	0.0000000005	0.00000009	0.000000007	0.0000002	0.00000001	0.00000008	0.000000006
Manganese	0.0000003	0.0000001	0.000005	0.000002	0.00001	0.000004	0.000004	0.000002
Molybdenum	0.0000002	0.00000002	0.000003	0.0000003	0.000006	0.0000006	0.000002	0.0000002
Nickel	0.0000005	0.0000001	0.000007	0.000001	0.00001	0.000003	0.000006	0.000001
Selenium	0.00003	0.000008	0.0005	0.0001	0.001	0.0002	0.0004	0.00009
Silver	0.000006	0.000004	0.0001	0.00007	0.0002	0.0002	0.00008	0.00006
Strontium	0.0000002	0.00000005	0.000002	0.0000007	0.000005	0.000002	0.000002	0.0000006
Thallium	0.00002	0.000003	0.0003	0.00004	0.0006	0.00009	0.0002	0.00004
Vanadium	0.0000006	0.0000005	0.000008	0.000006	0.00002	0.00001	0.000007	0.000005
Zinc	0.000006	0.000004	0.00008	0.00005	0.0002	0.0001	0.00007	0.00004

Table II-24
Total Mammalian ER Values for Exposure to Metals from all Media in the Study Area and Reference Area

Parameter	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	1	0.7	0.2	0.08	0.1	0.06	0.2	0.2	0.7	0.5	0.3	0.2	0.8	0.4	2	0.9
Arsenic	0.8	0.02	0.1	0.003	0.08	0.002	0.1	0.005	0.4	0.02	0.1	0.006	0.7	0.01	1	0.03
Barium	0.05	0.06	0.007	0.009	0.005	0.006	0.005	0.004	0.01	0.01	0.006	0.005	0.04	0.05	0.08	0.1
Boron	0.0002	0.00004	0.00003	0.000002	0.00003	0.000003	0.0002	0.00002	0.0004	0.00005	0.0002	0.00002	0.0004	0.00002	0.0004	0.00003
Chromium	0.00003	0.00002	0.000003	0.000001	0.000002	0.000001	0.000005	0.000005	0.00001	0.00001	0.000006	0.000006	0.00002	0.000008	0.00004	0.00002
Cobalt	0.007	0.002	0.001	0.0002	0.0009	0.0001	0.005	0.0002	0.01	0.0005	0.004	0.0002	0.01	0.001	0.01	0.002
Copper	0.007	0.002	0.001	0.0003	0.0009	0.0002	0.003	0.0003	0.008	0.0009	0.003	0.0004	0.009	0.002	0.01	0.004
Lead	0.0007	0.00007	0.0001	0.000008	0.00007	0.000006	0.00005	0.00001	0.0001	0.00004	0.00006	0.00002	0.0006	0.00004	0.001	0.00009
Manganese	0.05	0.01	0.008	0.002	0.006	0.001	0.02	0.0002	0.04	0.0005	0.02	0.0002	0.06	0.01	0.09	0.02
Molybdenum	0.007	0.0009	0.001	0.0001	0.0008	0.00008	0.002	0.0001	0.003	0.0003	0.001	0.0001	0.008	0.0007	0.01	0.001
Nickel	0.003	0.0009	0.0005	0.0001	0.0004	0.00008	0.002	0.00009	0.004	0.0003	0.002	0.0001	0.005	0.0007	0.006	0.001
Selenium	0.01	0.003	0.002	0.0005	0.001	0.0003	0.003	0.0004	0.007	0.001	0.003	0.0004	0.01	0.003	0.02	0.006
Silver	0.09	0.07	0.01	0.01	0.009	0.006	0.03	0.01	0.06	0.03	0.02	0.01	0.1	0.06	0.2	0.1
Strontium	0.0007	0.0003	0.0001	0.00005	0.00008	0.00003	0.0002	0.00001	0.0004	0.00004	0.0002	0.00002	0.0008	0.0002	0.001	0.0005
Thallium	0.02	0.004	0.002	0.0005	0.002	0.0003	0.01	0.0007	0.02	0.002	0.01	0.0008	0.02	0.003	0.03	0.006
Vanadium	0.02	0.01	0.001	0.001	0.001	0.0009	0.005	0.004	0.01	0.01	0.006	0.005	0.007	0.005	0.02	0.01
Zinc	0.002	0.002	0.0004	0.0003	0.0002	0.0002	0.0003	0.00008	0.0006	0.0002	0.0003	0.00008	0.002	0.001	0.004	0.003
Cyanide	0.004	NA	0.0006	NA	0.0006	NA	0.003	NA	0.007	NA	0.003	NA	0.007	NA	0.007	NA

NA = cyanide concentrations not measured in the reference area.

Table II-25
Avian ER Values for Exposure to Metals from Soil or Sediment in the Study Area and Reference Area

Parameter	Ptarmigan (soil)		Hawk (soil)		Snipe (sediment)		Duck (sediment)	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.06	0.05	0.02	0.02	0.1	0.04	0.1	0.03
Arsenic	0.05	0.003	0.02	0.001	3	0.004	3	0.004
Barium	0.002	0.002	0.0007	0.0006	0.003	0.001	0.003	0.001
Boron	0.00003	0.00003	0.00001	0.00001	0.00005	0.00003	0.00004	0.00003
Chromium	0.008	0.008	0.003	0.003	0.009	0.005	0.009	0.004
Cobalt	0.03	0.02	0.01	0.006	0.09	0.02	0.08	0.02
Copper	0.0003	0.0002	0.0001	0.00006	0.006	0.0001	0.006	0.0001
Lead	0.0006	0.0002	0.0002	0.00007	0.02	0.0001	0.02	0.0001
Manganese	0.00009	0.00007	0.00003	0.00002	0.0002	0.00008	0.0002	0.00007
Molybdenum	0.00002	0.00001	0.000007	0.000005	0.0003	0.00001	0.0003	0.00001
Nickel	0.0002	0.0002	0.00006	0.00006	0.0004	0.0001	0.0004	0.0001
Selenium	0.0002	0.0002	0.00005	0.00005	0.002	0.0001	0.002	0.00009
Silver	0.00002	0.00002	0.000007	0.000007	0.00001	0.00001	0.00001	0.00001
Strontium	0.00003	0.00002	0.00001	0.000008	0.0003	0.00002	0.0003	0.00002
Thallium	0.0002	0.0002	0.00006	0.00007	0.0001	0.0001	0.0001	0.0001
Vanadium	0.003	0.002	0.0009	0.0008	0.003	0.002	0.003	0.002
Zinc	0.0003	0.0002	0.0001	0.00008	0.05	0.0003	0.05	0.0002
Cyanide	NA	NA	NA	NA	330	0.01	305	0.01

NA = Cyanide not measured in soil.

Table II-26
Avian ER Values for Exposure to Metals from Water in the Study Area and Reference Area

Parameter	Ptarmigan		Hawk		Snipe		Duck	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.002	0.00007	0.0006	0.00002	0.001	0.00004	0.0006	0.00002
Arsenic	0.02	0.00003	0.006	0.00001	0.01	0.00002	0.006	0.00001
Barium	0.0002	0.00002	0.00007	0.000005	0.0001	0.000009	0.00007	0.000005
Boron	0.0003	0.000009	0.00009	0.000003	0.0002	0.000005	0.00009	0.000003
Chromium	0.0004	0.00002	0.0001	0.000006	0.0002	0.00001	0.0001	0.000006
Cobalt	0.3	0.0005	0.09	0.0002	0.2	0.0003	0.09	0.0002
Copper	0.001	0.000006	0.0004	0.000002	0.0006	0.000003	0.0004	0.000002
Lead	0.0001	0.0000002	0.00003	0.00000008	0.00006	0.0000001	0.00003	0.00000008
Manganese	0.006	0.0000007	0.002	0.0000002	0.003	0.0000004	0.002	0.0000002
Molybdenum	0.0002	0.000002	0.00006	0.0000008	0.0001	0.000001	0.00006	0.0000008
Nickel	0.002	0.000005	0.0007	0.000002	0.001	0.000003	0.0007	0.000002
Selenium	0.002	0.00008	0.0005	0.00003	0.0009	0.00005	0.0005	0.00003
Silver	0.00002	0.000002	0.000007	0.0000005	0.00001	0.0000009	0.000007	0.0000005
Strontium	0.0002	0.000002	0.00008	0.0000008	0.0001	0.000001	0.00008	0.0000008
Thallium	0.002	0.000007	0.0007	0.000002	0.001	0.000004	0.0007	0.000002
Vanadium	0.00002	0.000007	0.000007	0.000002	0.00001	0.000004	0.000007	0.000002
Zinc	0.0007	0.000005	0.0002	0.000002	0.0004	0.000003	0.0002	0.000002
Cyanide	14	NA	5	NA	8	NA	5	NA

NA = Cyanide concentrations not measured in water from the reference area.

Table II-27
Avian ER Values for Exposure to Metals from Food (vegetation, prey, or invertebrates) in the Study Area and Reference Area

Parameter	Ptarmigan (vegetation)		Hawk (prey)		Snipe (invertebrates)		Duck (invertebrates)	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.3	0.1	0.00005	0.00003	5	2	3	0.9
Arsenic	0.5	0.01	0.0001	0.000002	135	0.2	76	0.1
Barium	0.02	0.03	0.0000004	0.0000006	0.1	0.06	0.08	0.04
Boron	NA	NA	0.00000008	0.000000006	0.002	0.001	0.001	0.0008
Chromium	0.04	0.01	0.00004	0.00002	0.2	0.09	0.1	0.05
Cobalt	0.2	0.2	0.00001	0.000002	4	1	3	0.6
Copper	0.002	0.002	0.000005	0.000001	0.09	0.002	0.05	0.001
Lead	0.01	0.0007	0.0000004	0.00000003	0.7	0.004	0.4	0.002
Manganese	0.02	0.008	0.0000008	0.0000003	0.01	0.004	0.006	0.002
Molybdenum	0.002	0.0002	0.0000002	0.00000002	0.01	0.0006	0.008	0.0003
Nickel	0.002	0.002	0.000005	0.0000009	0.02	0.005	0.01	0.003
Selenium	0.01	0.004	0.0001	0.00003	0.1	0.004	0.06	0.002
Silver	0.0002	0.0002	0.00000008	0.00000005	0.0006	0.0006	0.0003	0.0003
Strontium	0.002	0.0008	0.000002	0.0000006	0.01	0.0009	0.008	0.0005
Thallium	0.001	0.001	0.00003	0.000005	0.007	0.007	0.004	0.004
Vanadium	0.003	0.002	0.000001	0.000001	0.1	0.09	0.08	0.05
Zinc	0.02	0.02	0.0002	0.0001	1	0.007	0.8	0.004
Cyanide	NA	NA	0.000001	NA	14,835	0.5	8,328	0.3

NA = Data not available.

Table II-28
Total Avian ER Values for Exposure to Metals from all Media in the Study Area and Reference Area

Parameter	Ptarmigan		Hawk		Snipe		Duck	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.4	0.2	0.02	0.02	5	2	3	0.9
Arsenic	0.6	0.01	0.02	0.001	138	0.2	78	0.1
Barium	0.03	0.04	0.0007	0.0006	0.1	0.07	0.08	0.04
Boron	0.0003	0.00004	0.0001	0.00001	0.003	0.001	0.001	0.0008
Chromium	0.05	0.02	0.003	0.003	0.2	0.1	0.1	0.06
Cobalt	0.5	0.2	0.1	0.006	5	1	3	0.6
Copper	0.004	0.002	0.0005	0.00007	0.1	0.002	0.06	0.001
Lead	0.01	0.0009	0.0002	0.00007	0.7	0.005	0.4	0.003
Manganese	0.02	0.008	0.002	0.00002	0.01	0.004	0.008	0.002
Molybdenum	0.002	0.0002	0.00006	0.000006	0.01	0.0006	0.008	0.0003
Nickel	0.005	0.002	0.0008	0.00006	0.02	0.005	0.01	0.003
Selenium	0.01	0.004	0.0007	0.0001	0.1	0.004	0.07	0.003
Silver	0.0002	0.0002	0.00001	0.000008	0.0006	0.0006	0.0003	0.0003
Strontium	0.002	0.0009	0.00009	0.00001	0.01	0.0009	0.008	0.0005
Thallium	0.004	0.001	0.0008	0.00008	0.008	0.007	0.005	0.004
Vanadium	0.006	0.004	0.0009	0.0008	0.1	0.09	0.08	0.05
Zinc	0.02	0.02	0.0005	0.0002	2	0.008	0.9	0.004
Cyanide	14	NA	5	NA	15173	0.5	8639	0.3

NA = Data not available.

ERs based on maximum media concentrations were greater than 1 for aluminum, arsenic, cobalt, zinc, and cyanide for some VECs at the Lupin mine site. Therefore, for these selected chemicals of concern and receptors, ERs were also calculated based on average media concentrations for comparative purposes. ERs calculated from average concentrations for aluminum, arsenic, cobalt, zinc and cyanide are presented in Tables II-29, II-30, II-31, II-32, and II-33, respectively.

Table II-29
ERs for Aluminum based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Soil/Sediment[a]		Water		Food[b]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Muskoxen	0.2	0.4	0.0009	0.0004	0.4	0.2	0.5	0.5
Ground Squirrel	0.1	0.3	0.002	0.0008	0.6	0.3	0.8	0.6
Snipe	0.08	0.04	0.00007	0.00003	3	2	3	2
Duck	0.07	0.03	0.00004	0.00002	2	0.9	2	0.9

[a] Soil ingestion is applicable to muskoxen and ground squirrel; Sediment ingestion is applicable to snipe and duck.
[b] Muskoxen and ground squirrel food is based on vegetation ingestion; Snipe and duck food is based on invertebrate ingestion.

Table II-30
ERs for Arsenic based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Soil/Sediment[a]		Water		Food[b]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Ground Squirrel	0.07	0.006	0.00005	0.0001	0.4	0.02	0.5	0.02
Snipe	2	0.003	0.000004	0.000009	70	0.2	72	0.2
Duck	1	0.003	0.000003	0.000005	39	0.09	41	0.09

[a] Soil ingestion is applicable to ground squirrel; Sediment ingestion is applicable to snipe and duck.
[b] Ground squirrel food is based on vegetation ingestion; Snipe and duck food is based on invertebrate ingestion.

Table II-31
ERs for Cobalt based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Sediment		Water		Invertebrate Ingestion		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Snipe	0.05	0.02	0.01	0.0002	3	0.9	3	0.9

NA = Not applicable.

Table II-32
ERs for Zinc based on Average Media Concentrations in the Study Area and Reference Area for the Common Snipe

Receptor	Sediment		Water		Invertebrate Ingestion		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Snipe	0.02	0.0002	0.00009	0.000001	0.6	0.007	0.6	0.007

Table II-33
ERs for Cyanide based on Average Media Concentrations in the Study Area and Reference Area for Various VECs

Receptor	Soil/Sediment[(a)]		Water		Food[(b)]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Ptarmigan	NA	NA	0.9	NA	NA	NA	0.9	NA
Hawk	NA	NA	0.3	NA	0.00000009	NA	0.3	NA
Snipe	127	0.01	0.5	0	5695	0.5	5822	0.5
Duck	117	0.01	0.3	0.0	3197	0.3	3315	0.3

[(a)] Soil ingestion is applicable to ptarmigan; Sediment ingestion is applicable to snipe and duck.
[(b)] Ptarmigan food is based on vegetation ingestion; Hawk food is based on caribou ingestion; Snipe and duck food is based on invertebrate ingestion.
NA = cyanide not analyzed in these media.

5. HUMAN HEALTH RISK ASSESSMENT

5.1 Problem Formulation

5.1.1 Human Receptor Screening

Consistent with risk assessment guidance (Health Canada 2003), the toddler life phase (i.e., seven months to four years) was chosen as the most susceptible child lifestage for evaluation of non-carcinogenic metals. The toddler phase is the most susceptible childhood phase due to their smaller body size to ingestion rate ratio. Therefore, the risk assessment estimated exposures that a hypothetical child may have after ingesting meat tissue from caribou that are exposed to metals from the Lupin mine site. A hypothetical adult receptor was also evaluated for exposure to metals in caribou meat since adults eat greater amounts of meat for a longer period of time.

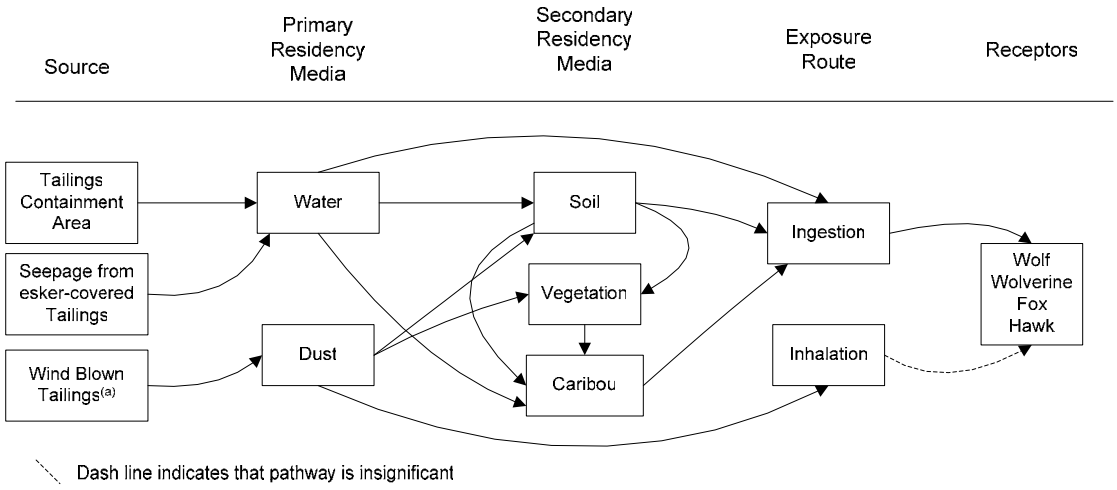
5.1.2 Human Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors. They are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The purpose of the exposure pathway screening process is to determine the ways in which people may come into contact with metals from the Lupin mine site.

The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. The Lupin mine site is not in close proximity to any communities (i.e., closest community is Bathurst Inlet, approximately 150 km northeast of Lupin). Although four families currently live in the region of Lupin mine, close to Contwoyto Lake (2 families only in the summer months), knowledge of the presence of the mine will prevent people from spending much time in the area, and these families are likely to leave after mine closure, as most of their provisions are acquired from the mine. Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2 since a spillway will be constructed to prevent movement of fish into the ponds. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated from the human health

risk assessment was ingestion of caribou, which have taken up metals from drinking water, food, and incidental soil ingestion from the Lupin mine site.

Figure II-8
Human Exposure Pathways



(a)Exposed tailings will be covered as part of closure plan.

5.2 Exposure Assessment

5.2.1 Spatial and Temporal Boundaries

It was assumed that people would eat caribou that have been exposed to metals from the Lupin mine site every day for their entire lives. This is a very conservative assumption since not all caribou would pass through the Lupin gold mine or spend significant periods of time near the study area.

5.2.2 Exposure Estimate Equations

The exposure estimate equation used for meat ingestion in the human health exposure assessment is presented in Table II-34. Meat tissue concentrations were calculated using bioconcentration factors from water, soil and food ingestion to meat tissue. The concentrations and calculations are presented in Appendix I. Although humans may consume other meat tissue such as

muskoxen, the concentration in meat tissue in other organisms would be similar to caribou because the meat concentration is based on metal-specific bioconcentration factors.

Table II-34
Exposure Equations

Pathway	Equation and Equation Parameters
Meat ingestion	$EDI_{meat} = \frac{IR \times C_{meat}}{BW}$
	EDI_{meat} = exposure due to ingestion of meat (mg metal/kg body weight-day) IR = ingestion rate (kg/day) C_{meat} = metal concentration in caribou meat (mg/kg) BW = receptor body weight (kg)

5.2.3 Human Exposure Parameters

Details on the body weights and food ingestion rates for humans are presented in Table II-35.

Table II-35
Exposure Parameters Used in the Human Health Risk Assessment

Age class	Body weight (kg)	Wild Game (Caribou) Ingestion (kg/day)	Reference
0-6 months (infant)	8.2	0	Health Canada 2003
7 months to 4 years (toddler)	16.5	0.085	Health Canada 2003
5-11 years (child)	32.9	0.125	Health Canada 2003
12-19 years (teen)	59.7	0.175	Health Canada 2003
20+ years (adult)	70.7	0.270	Health Canada 2003

5.3 Bioavailability

As described in Section 4.3, bioavailability is typically not adjusted in a risk assessment unless one of the following occurs:

- if the medium of exposure is different than the medium on which the toxicity reference value is based (e.g., exposure is from soil, but the toxicity reference value is based on exposure from water);

- if the route of exposure is different than the route of exposures in the study used to derive the toxicity reference value (e.g., oral route of exposure, but based on an inhalation study); and
- the toxicity reference value derived by the regulatory agency has been adjusted for bioavailability.

In the human health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body) and because bioavailability information was not available. However, bioavailability was incorporated into the exposure assessment for nickel because the nickel TRV is based on exposure through drinking water (Health Canada 2003), a very soluble and bioavailable form of nickel, whereas the form of nickel in food is much less bioavailable (ATSDR 1997). In humans, ingested nickel is poorly absorbed. In a study reviewed in ATSDR (1997), nickel administered in drinking water was absorbed much more readily than when administered in food (27% absorption in water versus 0.7% absorption in food). For the purpose of this assessment, bioavailability of via food ingestion was assumed to be 3% relative to bioavailability via water ingestion (ATSDR 1997).

5.4 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of metals and determination of the amount of metals that can be taken into the body without experiencing adverse health effects. The toxicity assessment provides the basis for determining an acceptable exposure and what level of exposure may adversely affect people's health. The toxicity assessment is based on chronic exposure and not acute exposure.

5.4.1 Metals That do Not Cause Cancer

For most metals, there is a threshold exposure level below which no adverse health effects occur. Above the threshold level, adverse health effects begin to occur and increase in severity with increasing exposure to the substance. The non-carcinogenic metals evaluated in this risk assessment (all but arsenic) exhibit this type of threshold-response relationship.

5.4.2 Metals That Can Cause Cancer

Carcinogenic metals, in theory, do not exhibit threshold-response behaviour. Rather, even at low doses, there is some risk of genetic damage; although nature provides ways of repairing this to some extent.

To evaluate the acceptability of environmental exposures to carcinogenic metals such as arsenic, regulatory agencies have declared that a safe dose is one that has a probability of less than 1 chance in 100,000 chances of developing cancer. This level of risk is much lower than the risk of developing cancer from other sources, such as genetics, family history, diet (risk level of 1 in 4; Health Canada 2003) and some voluntary practices such as smoking (risk level of 1 in 20). A risk level of 1 in 100,000 ensures that exposure to environmental chemicals does not significantly increase the risk of people developing cancer.

5.4.3 Toxicity Reference Values

Toxicity reference values (TRVs) are safe exposures below which there is minimal risk of adverse health effects. The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004), the U.S. EPA's Integrated Risk Information Service Database (IRIS 2004), the Agency for Toxic Substances and Disease Registry (2004), and the Netherlands National Institute of Public Health and the Environment (RIVM 2001). The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented.

Animal studies provide dose-response information that can be extrapolated to humans by applying safety factors. In most cases safety factors of 100 to 1,000 are applied to laboratory derived No-Observed-Adverse-Effect Level (NOAEL; the highest concentration in a toxicity test where no chronic health effects were observed or measured) to account for interspecies extrapolation and protection of the most susceptible in a population (i.e., children and elderly). Therefore, TRVs have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

The TRVs used in this assessment are presented as reference doses (RfDs) for non-carcinogenic chemicals and slope factors for carcinogenic chemicals (i.e., arsenic). The RfD is defined as the amount of metal per unit body weight that can be taken into the body each day with no risk of adverse health effects. The slope factor is derived from dose-response relationships from epidemiological or animal toxicity studies that measured the relationship between exposure to substances and incidence of cancer. The RfDs and slope factor chosen for the human health risk assessment from available sources, the rationale for the selection, and a brief summary of the toxicity studies on which they were based is presented in Table II-36.

5.5 Risk Characterization

In the risk characterization step, ERs were calculated as the ratio of the estimated exposure to the toxicity benchmark value, according to the following equation:

ER = estimated exposure ÷ toxicity benchmark value

For non-carcinogenic chemicals, an ER value of less than 0.2 (considered to be the appropriate threshold for this assessment) represents exposure that does not pose a significant health risk to receptors (Health Canada 2003). As stated in Section 2.1.4, an ER value of 0.2 is considered appropriate because only one exposure pathway was evaluated for human health.

When the ER is greater than 0.2, the scenarios pose a potential concern and require further scrutiny. It is important to note that ER values greater than 0.2 do not necessarily indicate that adverse health effects will occur due to the layers of safety employed in their estimation (e.g., the toxicity reference values are protective of human health).

5.5.1 Results

ERs for the human health risk assessment are presented in Tables II-43 and II-44. ERs are based on caribou meat ingestion only, as other pathways of exposure were not evaluated for human health. ER values for non-carcinogenic metals for toddlers and adults exposed to caribou meat from the study area are presented in Table II-37. Estimated cancer incidence due to arsenic exposure via ingestion of caribou is presented in Table II-38, along with cancer incidence associated with drinking water quality guidelines for arsenic and background cancer rate.

Table II-36
Reference Doses Used for the Human Health Risk Assessment

Parameter	Reference Dose (mg/kg-day)				Rationale
	Health Canada	U.S. EPA IRIS	ATSDR	RIVM	
Aluminum	1.0	none	2.0	none	The ATSDR RfD was based on the NOAEL for neurotoxicity in a study of mice exposed to aluminum lactate in the diet. An uncertainty factor of 30 was applied to the NOAEL; 3 for extrapolation from animals to humans and 10 for human variability. The Health Canada RfD is based on operational guidance values for water treatment plants using aluminum-based coagulants. The ATSDR RfD was used in the risk assessment because it is based on a health-related outcome.
Arsenic (carcinogenic)[a]	2.8	1.5	none	none	Health Canada and IRIS derived slope factors based on the same epidemiological studies conducted for a population in Taiwan. The slope factor from Health Canada is more conservative because it was computed directly from the dose-response curve within the experimental range, whereas the IRIS slope factor was calculated from the upper 95% confidence limit on the low-dose extrapolation (TERA 2004). The Health Canada slope factor was used because the approach used to calculate the slope factor is based on the dose-response curve.
Arsenic (non-carcinogenic)	none	0.0003	0.0003	0.001	Both IRIS and ATSDR based the non-carcinogenic RfD for arsenic on the NOAEL for hyperpigmentation and keratosis in an epidemiological study for a population in Taiwan. An uncertainty factor of 3 was applied to the NOAEL for database deficiencies. The RIVM RfD is based on NOAELs from a group of human epidemiological studies. The composite NOAEL for dermal effects chosen by RIVM is higher than that noted in the Taiwanese population cited by IRIS and ATSDR. However, RIVM does not provide a substantial argument for choosing a higher NOAEL value to base the RfD. Therefore, the RfD from IRIS and ATSDR was used for the risk assessment.
Barium	0.02	0.07	none	0.02	Health Canada, IRIS, and RIVM based the RfD on the NOAEL for any effect in an epidemiological study of cardiovascular disease in humans. IRIS applied an uncertainty factor of 3 to the NOAEL for database deficiencies and human variability. Health Canada and RIVM applied an uncertainty factor of 10 to account for human variability. The Health Canada and RIVM RfD was used based on the more conservative uncertainty factor.
Boron	0.0175	0.2	none	none	The Health Canada RfD was based on the NOAEL for testicular atrophy and spermatogenesis in a two year study of dogs exposed to borax (boric acid) in the diet. An uncertainty factor of 500 was applied to the NOAEL; 10 for extrapolation from animals to humans, 10 for sensitive individuals, and 5 for limitations in the study (small number of experimental animals exposed for a small portion of their life span). The IRIS RfD was based on the benchmark dose for decreasing fetal weight calculated from two studies of rats exposed to boric acid in the diet. A data-derived uncertainty factor of 66 was applied to the benchmark dose; 3.3 for rat to human toxicokinetic variability, 2 for human toxicokinetic variability, 3.16 for rat to human toxicodynamic variability, and 3.16 for human toxicodynamic variability. The Health Canada RfD was used for the risk assessment because it was based on a clearly defined NOAEL and uncertainty factors.
Chromium (total)	0.001	1.5	0.003	5.0	The Health Canada RfD is based on the NOAEL for health effects from a variety of sources cited in the Guidelines for Canadian Drinking Water Quality, including studies of hexavalent chromium. The IRIS RfD is based on the NOAEL for any effects from a study of rats exposed to chromic oxide in the diet. An uncertainty factor of 1000 was applied to the NOAEL; 10 for extrapolation from animals to humans, 10 for human variability, and 10 for deficiencies in the database. The ATSDR RfD is based on the upper range of the NRC estimated safe and adequate daily dietary intake, and is adopted as a provisional guidance only. The RIVM RfD is based on the assumption that the toxicity of insoluble chromium is approximately 1000 times less than the toxicity of soluble forms. The IRIS RfD was used for this risk assessment because it is based on the appropriate form of the compound.
Cobalt	none	none	0.01	0.0014	The ATSDR RfD was based on a LOAEL for increased erythrocyte levels in a human epidemiological study. An uncertainty factor of 100 was applied to the LOAEL; 10 for use of a LOAEL, and 10 for human variability. The RIVM RfD is based on the LOAEL for cardiomyopathy from a different human epidemiological study. This effect was noticed in a small population, and may have been confounded by alcohol intake. An uncertainty factor of 30 was applied to the LOAEL; 10 for use of LOAEL and 3 for human variability. The ATSDR RfD was used for the risk assessment because the uncertainty in the RIVM study population (alcohol consumption) was not accounted for.
Copper	0.03	none	0.02	0.14	The RfD from Health Canada and RIVM is based on copper's function as an essential nutrient. Both agencies have used their country's recommended daily intake as the RfD. ATSDR established a minimal risk level on gastrointestinal effects in women given copper sulfate in drinking water for two weeks. The NOAEL was less than the recommended daily intake. An RfD cannot be lower than the levels required for essentiality; therefore, the RfD from Health Canada was used in the risk assessment, as it is specific to a safe level for the Canadian population.
Lead	0.0036	none	none	0.0036	The Health Canada and RIVM RfD is based on the provisional tolerable weekly intake of lead derived by the FAO/WHO. The RfD from Health Canada and RIVM was used in the risk assessment.

Parameter	Reference Dose (mg/kg-day)				Rationale
	Health Canada	U.S. EPA IRIS	ATSDR	RIVM	
Manganese	none	0.14	0.07	none	IRIS derived an RfD based on the NOAEL for CNS effects from several large epidemiological investigations of humans exposed to manganese in food. The ATSDR RfD is based on the upper range of the estimated safe and adequate daily dietary intake for manganese. The IRIS RfD was used for the risk assessment because it represents concentrations of manganese that have been measured in food and found to cause no health effects in humans.
Molybdenum	none	0.005	none	0.01	The IRIS RfD was based on the LOAEL for increased uric acid levels in a human lifetime dietary exposure study. An uncertainty factor of 30 was applied to the LOAEL; 3 for protection of sensitive individuals, and 10 for use of a LOAEL rather than an NOAEL. The RIVM RfD is based on the NOAEL for renal toxicity in rats exposed to molybdenum. An uncertainty factor of 100 was applied to the NOAEL; 10 for extrapolation from animals to humans, and 10 for human variability. The RfD from IRIS was used for the risk assessment because it was derived based on data for a human exposure study.
Nickel, soluble salts	0.0013	0.02	none	0.05	The IRIS and RIVM RfD was based on the NOAEL for decreased body and organ weights from a study of rats exposed to nickel in the diet. IRIS applied an uncertainty factor of 300; 10 for animal to human extrapolation, 10 to protect sensitive populations, and 3 for the inadequacies of the reproductive studies. RIVM applied an uncertainty factor of 100 to the NOAEL. Health Canada based the RfD on the LOAEL for pup mortality in a study of rats exposed to nickel chloride in drinking water. An uncertainty factor of 1000 was applied to the LOAEL; 10 for extrapolation from animals to humans, 10 for human variability, and 10 for use of a LOAEL rather than a NOAEL. The Health Canada RfD was used for the risk assessment because it was based on exposure that occurred during the reproductive phase. Since reproduction is a sensitive life stage, the Health Canada value was the preferred RfD for the risk assessment.
Selenium	none	0.005	0.005	none	The IRIS and ATSDR RfD was based on the NOAEL for clinical selenosis in a human epidemiological study. An uncertainty factor of 3 was applied to the NOAEL to account for sensitive individuals. The RfD from IRIS and ATSDR was used for the risk assessment.
Silver	none	0.005	none	none	The U.S. EPA RfD was based on the LOAEL for argyria (bluish-grey discoloration of the skin) in humans exposed to silver by intravenous injection of silver arsphenamine over a 2 to 9.75 year period. An uncertainty factor of 3 was applied to the LOAEL to account for use of a LOAEL rather than a NOAEL. The U.S. EPA RfD was used in the risk assessment.
Strontium	none	0.6	none	none	The U.S. EPA RfD was based on the NOAEL for bone demineralization and cartilage defects in rats exposed to strontium carbonate for 3 years. An uncertainty factor of 300 was applied to the NOAEL; 10 for animal to human extrapolation, 10 for database deficiencies, and 3 for sensitive populations. The U.S. EPA RfD was used in the risk assessment.
Thallium	none	0.00008	none	none	The U.S. EPA RfD was based on the NOAEL for increasing blood chemistry parameters in rats exposed to thallium chloride in the diet for 90 days. An uncertainty factor of 3000 was applied to the NOAEL; 10 for use of a sub-chronic study, 10 for extrapolation from animals to humans, 10 for human sensitivity, and 3 for lack of reproductive and chronic toxicity data.
Vanadium	none	0.009	0.003	none	The IRIS RfD is based on a NOAEL for decreased hair cysteine in rats exposed to vanadium pentoxide in the diet. An uncertainty factor of 100 was applied to the NOAEL; 10 for extrapolation from animals to humans and 10 to protect sensitive individuals. The ATSDR RfD is based on a dose-related trend for mild histological renal effects and increased plasma urea in rats exposed to sodium metavanadate in the diet. No dose-related responses were reported. An uncertainty factor of 100 was applied to account for human variability and extrapolation from animals to humans. The IRIS RfD was used for the risk assessment because it was based on an observed NOAEL, and the ATSDR RfD was not based on a clear dose level.
Zinc	none	0.3	0.3	0.5	IRIS, ATSDR, and RIVM based the RfD on a LOAEL for enzyme concentration from a human diet supplement study. IRIS and ATSDR applied an uncertainty factor of 3 to the LOAEL for use of a LOAEL and to account for sensitive individuals. RIVM applied an uncertainty factor of 2 to the LOAEL to account for use of the LOAEL, rather than a NOAEL. The IRIS and ATSDR RfD was used in the risk assessment because of the additional safety factor to account for sensitive sub-populations.
Cyanide	0.02	0.02	none	0.05	The Health Canada, U.S. EPA, and RIVM based the RfD on the NOAEL for weight loss and myelin degeneration in rats exposed to food fumigated with hydrogen cyanide. Health Canada and RIVM applied an uncertainty factor of 500 to the NOAEL; 10 for extrapolation from animals to humans, 10 for sensitive human individuals, and 5 for exposure in food rather than water or air (more bioavailable exposure routes for cyanide). RIVM chose a different NOAEL for increased blood thiocyanate levels. An uncertainty factor of 100 was applied to this NOAEL; 10 for extrapolation from animals to humans and 10 for sensitive human individuals. The Health Canada and U.S. EPA RfD was used for the risk assessment because a clearly defined NOAEL was used.

[(a)]Slope factor $(mg/kg\text{-}day)^{-1}$

Table II-37
Human Health ER Values for Non-carcinogenic Metals in Caribou Meat from the Study Area and Reference Area

Parameter	Study Area		Reference Area	
	Toddler	Adult	Toddler	Adult
Aluminum	0.0008	0.0006	0.0004	0.0003
Arsenic	0.3	0.3	0.008	0.006
Barium	0.0001	0.0001	0.0002	0.0001
Boron	0.00009	0.00006	0.000006	0.000005
Chromium	0.00002	0.00002	0.00001	0.000008
Cobalt	0.00006	0.00005	0.00001	0.000007
Copper	0.002	0.002	0.0006	0.0005
Lead	0.0004	0.0003	0.00003	0.00002
Manganese	0.002	0.001	0.0007	0.0005
Molybdenum	0.0002	0.0002	0.00002	0.00002
Nickel	0.0002	0.0001	0.00003	0.00002
Selenium	0.006	0.004	0.001	0.001
Silver	0.00002	0.00002	0.00002	0.00001
Strontium	0.0002	0.0001	0.0000001	0.0000001
Thallium	0.05	0.03	0.007	0.005
Vanadium	0.0004	0.0003	0.0003	0.0002
Zinc	0.01	0.01	0.01	0.007
Cyanide	0.0000004	0.0000003	NA	NA

NA = Concentrations not available for the reference area.

Table II-38
Estimated Cancer Incidence due to Exposure to Arsenic in Caribou Meat

Exposure Pathway	Reference Area	Study Area
Caribou Meat Ingestion	0.4 in 100,000	19 in 100,000
Cancer incidence based on Canadian drinking water quality guideline[a]	147 in 100,000	
Cancer incidence from all causes[b]	40,000 in 100,000	

[a] Health Canada 2003.

6. REFERENCES

AENV (Alberta Environment). 2000. Policy for Management of Risks at Contaminated Sites in Alberta. AENV, Edmonton, AB.

ATSDR (Agency for Toxic Substances and Disease Registry). 1992. Toxicological Profiles: Tin. CRC Press Inc., Atlanta.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Toxicological Profiles: Nickel. CRC Press Inc., Atlanta.

ATSDR (Agency for Toxic Substances and Disease Registry). 2004. Toxicological Profiles Available on-line at http://www.atsdr.cdc.gov/toxpro2.html#-A. Accessed in October 2004.

Beyer, N. W., E. E. Connor and S. Gerould. 1994. Estimates of Soil Ingestion by Wildlife. J. of Wildlife Management; 58(2):376-382.

CCME (Canadian Council of Ministers of the Environment). 1996. A Framework for Ecological Risk Assessment: General Guidance. National Contaminated Sites Remediation Program. CCME. Winnipeg, Manitoba. March 1996.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines Updated 2003. Winnipeg, CCME.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2002. Endangered Species in Canada: 2001 List. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON.

Cluff, D.C, M. Musiani, P. Paquet and C. Gates. 2001. Wolf Notes. No. 6. Published by the Department of Resources, Wildlife and Economic Development. Yellowknife, NT.

Cluff, D. Regional Biologist, Resources Wildlife and Economic Development. Personal communication. 3 November 2004.

CWS (Canadian Wildlife Service). 2003. Available on the internet at: http://www.cws-scf.ec.gc.ca/hww-fap/index_e.cfm. Accessed October 2003.

DDMI (Diavik Diamond Mines Inc.) 1998. Wildlife Baseline Report, Diavik Diamonds Project, Lac de Gras, NWT. July 1998. Prepared by Penner and Associates Ltd. for Diavik Diamond Mines Inc. Yellowknife, NT.

Dunning, J.B. Jr. 1993. CRC Handbook of Avian Body Masses. CRC Press, Inc. Boca Raton, Florida.

Fournier, B. and A. Gunn. 1998. Muskox numbers and distribution in the Northwest Territories, 1997. File Report No. 121. Department of Resources, Wildlife and Economic Development. Yellowknife, NT.

Gau, R. Regional Biologist, Resources, Wildlife and Economic Development. Personal Communication. 20 October 2004.

Gau, R. J. and R. Case. 1998. Grizzly Bear (*Ursus arctos*) Studies in the Northwest Territories: Final Report to the West Kitikmeot/Slave Study Component No. 1, Nutritional Ecology. University of Saskatchewan, Saskatoon, Saskatchewan.

Godfrey, W.E. 1986. The Birds of Canada. Revised Edition. Published by the National Museum of Canada. Ottawa, ON.

Gunn, A. 1998. Summer Behaviour of Bathurst Caribou Near Mine Sites and Response of Caribou to Fencing and Plastic Deflector. Report submitted to the West Kitikmeot Slave Study Society. Yellowknife, NT.

Gunn, A. and B. Fournier. 2000. Calf Survival and Seasonal Migrations of a Mainland Muskox Population. File Report 124. Department of Resources, Wildlife and Economic Development. Yellowknife, NT.

Gunn, A., J. Dragon and J. Boulanger. 2002. Seasonal movements of satellite-collared caribou from the Bathurst herd. Final report to the West Kitikmeot Slave Study Society. Yellowknife, NT.

Health Canada. 1994. Canadian Environmental Protection Act: Human Health Risk Assessment for Priority Substances. Health Canada, Ottawa, ON.

Health Canada. 1995 (unpublished). Human Health Risk Assessment of Chemicals from Contaminated Sites: Volumes I and II. Health Canada, Ottawa ON.

Health Canada. 2003. Federal Contaminated Site Risk Assessment in Canada. Part I: Guidance on Human Health Screening Level Risk Assessment (SLRA). Version 1.1. Health Canada, Ottawa ON.

Heard, D.C. and T.M. Williams. 1992. Distribution of Wolf Dens on Migratory Caribou Ranges in the Northwest Territories, Canada. Canadian Journal of Zoology 70:1504-1510

Hiles, R.A. 1974. Absorption, Distribution, and Excretion of Inorganic Tin in Rats. Toxicology and Applied Pharmacology. 27:366-379.

IRIS (Integrated Research Information System). 2004. U.S. Environmental Protection Agency, Cincinnati, OH. Available on the internet at: http://www.epa.gov/iris/ Accessed October 2004.

Jensen, L.S., R.P Peterson, and L. Falen. 1974. Inducement of Enlarged Hearts and Muscular Dystrophy in Turkey Poults with Dietary Silver. Poultry Science. 53:57-64.

Ma, J. and C.A. Pritsos. 1997. Tissue-specific Bioenergetic Effects and Increased Enzymatic Activities Following Acute Sublethal Peroral Exposure to Cyanide in the Mallard Duck. Toxicology and Applied Pharmacology. 142:297-302.

McLoughlin, P.D., R.L. Case, R.J. Gau, S.H. Ferguson, and F. Messier. 1999. Annual and Seasonal Movement Patterns of Barren-Ground Grizzly Bears in the Central Northwest Territories. Ursus 11:79-86.

Mueller, F.P. and A. Gunn. 1996. Caribou Behaviour in the Vicinity of the Lupin Gold Mine, Northwest Territories 1993. Manuscript Report 31. Department of Resources, Wildlife and Economic Development. Yellowknife, NT.

Mulders, R. 2000. Wolverine Ecology, Distribution and Productivity in the Slave Geological Province. Final Report to the West Kitikmeot / Slave Study Society. Yellowknife, NT.

NAS (National Academy of Sciences). 1980. Mineral Tolerance of Domestic Animals. National Academy Press, Washington, D.C.

RIVM (National Institute of Public Health and the Environment). 2001. Re-evaluation of human-toxicological maximum permissible risk levels. RIVM report 711701 025.

RWED (Resources, Wildlife and Economic Development). 2004. Government of the Northwest Territories. Available on the Internet at http://www.gov.nt.ca/RWED/index.html. Accessed October 2004.

Sample, B.E. and C.A. Arenal. 1999. Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data. Bull. Environ. Contam. Toxicol.; 62: 653-663.

Sample, B.E., D.M. Opresko and G.W. Suter II. 1996. Toxicological Benchmark for Wildlife: 1996 Revision. ES/ER/TM-86/R3.

SARA (Species At Risk Act). 2002. Species at Risk Act. Assented 12 December 2002, c.29.

Silva, M. and J.A. Downing. 1995. CRC Handbook of Mammalian Body Masses. CRC Press Inc. Boca Raton, Florida.

TERA (Toxicology Excellence for Risk Assessment). 2004. Available on the internet at www.tera.org. Accessed in October, 2004.

TOXNET (ToxicologyNetwork). 2003. Available on the internet at: http://toxnet.nlm.nih.gov. Accessed in November, 2003.

U.S. EPA. (United States Environmental Protection Agency). 1988. Recommendations for and Documentation of Biological Values for Use in Risk Assessment. Environmental Criteria and Assessment Office, Cincinnati, OH. EPA/600/6-87/008

U.S. EPA (United States Environmental Protection Agency). 1989. Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response. December 1989. U.S. EPA-540/1-89/002.

U.S. EPA. (United States Environmental Protection Agency). 1993. Wildlife Exposure Factors Handbook. Volume I of II. EPA600/R-93/187.

U.S. EPA. (United States Environmental Protection Agency). 1998. Guidelines for Ecological Risk Assessment. Washington, D.C. EPA/630/R-95/002F.

U.S. EPA (United States Environmental Protection Agency). 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Volume 3A and 3B. EPA530-D-99-001C.

Walton, L.R., H.D. Cluff, P.C. Paquet and M.A. Ramsay. 2001. Movement Patterns of Barren-Ground Wolves in the Central Canadian Arctic. Journal of Mammology 82:867-876.

WHO (World Health Organization). 1982. International Programme on Chemical Safety. Environmental Health Criteria 24. Titanium. World Health Organization. Geneva, 1982.

APPENDIX V

EEM REPORT

FINAL REPORT

LUPIN GOLD MINE
ENVIRONMENTAL EFFECTS MONITORING
CYCLE 1 INTERPRETATIVE REPORT

Submitted to:
Kinross Gold Corporation
9818 International Airport
Edmonton, Alberta
T5J 2T2

Attention: Mr. C. Michael Tansey
Prepared by :
Golder Associates Ltd.

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June 2006
05-1373-019

EXECUTIVE SUMMARY

Under the Metal Mining Effluent Regulations (MMER), Kinross Gold Corporation (Kinross) was required to submit either an Environmental Effects Monitoring (EEM) biological historical information report or an EEM biological monitoring study for the Lupin Mine. A historical information report was submitted in 2003 (Golder 2003), and, according to the regulations, a subsequent biological monitoring study report must be submitted no later than 42 months after the day on which the mine became subject to the EEM requirements (i.e., 6 June 2006). Kinross carried out data collections for their MMER EEM biological monitoring program in 2005, which are presented in this Cycle 1 Interpretive Report.

The goal of the biological monitoring study was to investigate the effects, if any, of mine effluent on the receiving environment. Lupin Mine conducted a benthic invertebrate community (BIC) survey and a fish population survey. Fish tissues were collected and archived for copper analysis, if required. The results from the monitoring studies will direct the mine as to the type and frequency of follow-up investigations as outlined by the environmental effects monitoring guidance document (EC 2002).

The program was based on a control/impact study design. The exposure area encompassed portions of the Seep Creek system (Dam 1a Lake, Seep Creek, and Seep Creek Ponds 1 & 2). The reference area included Fingers Lake and Fingers Creek. The timing of the biological monitoring study was scheduled to coincide with effluent discharge; however, effluent discharge was terminated on 11 August 2005 due to low effluent pH.

The mill at the Lupin Mine has one final effluent discharge point (Nunavut Water Licence Surveillance Network Point [SNP] 925-10). Treated effluent is released into the environment at one of three headwater systems to Seep Creek (Dam 1a Lake). The treated effluent passes downstream through the Seep Creek system for approximately 6.5 km. Seep Creek empties into Unnamed Lake, which is a small embayment south of Inner Sun Bay. Inner and Outer Sun bays are embayments to the West Arm of Contwoyto Lake. Inner and Outer Sun bays are separated by a narrow (approximately 25 m wide) and short (approximately 250 m long) channel. Mixing occurs in this area, primarily due to flows from Concession Creek, and the effluent plume appears to disperse into Outer Sun Bay of Contwoyto Lake.

Plume delineation modelling indicated that, under worst-case scenarios, 1% plume concentrations can extend for approximately 1600 m into Outer Sun Bay (as measured from the lake-ward side of the narrows between Inner and Outer Sun bays).

During periods of extremely low flows, treated effluent concentrations at the mouth of Seep Creek can be close to 100%. Though effluent was not being discharged during the 2005 biological monitoring study, effluent concentration was approximately 87% at 250 m downstream of the final discharge point (FDP).

Fingers Lake is located approximately 2 km east of the tailings containment area (TCA). The lake is drained by one outlet stream, Fingers Creek, which flows approximately 3 km north-east before emptying into Contwoyto Lake. Finger Lake and Fingers Creek are not impacted by mine effluent or tailings. In late summer 2005, the conductivity in Fingers Lake was 14.8 µS/cm and in Fingers Creek it was 15.3 µS/cm.

Field conductivity measurements were higher in the exposure area than in the reference area. The measured pH values were slightly below the Canadian Water Quality Guidelines (CWQG; CCME 2005), but were typical of the Nunavut barrenlands waterbodies (RCPL and RL&L 1985).

In general, water quality and sediment quality variables were elevated in the exposure area relative to the reference area. Aluminum, arsenic, cadmium, copper, lead, nickel and zinc exceeded the CWQG in the exposure water quality samples. Water quality guidelines were not exceeded in the reference area. Arsenic and chromium exceeded the Interim Sediment Quality Guidelines (ISQG; CCME 2005) in the exposure area sediment samples. In the reference area, arsenic was the only variable that exceeded the ISQG.

Based on the BIC survey data, mine effluent significantly affected patterns of diversity (Simpson's Diversity Index [SDI]) and evenness of the BIC within the aquatic receiving environment (Seep Creek Ponds 1 & 2) relative to the reference area (Fingers Lake). The mine effluent did not significantly affect invertebrate density, family richness or the Bray-Curtis Index (BCI). The data had sufficient power, greater than 90%, to detect a change of plus or minus two standard deviations (±2SD) compared to the reference mean.

The fish study focused on juvenile (age 1) Arctic grayling as the target species. Arctic grayling are common to both the exposure and reference areas of the Lupin Mine EEM biological monitoring studies. This species also is commonly fished and consumed by local residents and mine personnel. Insufficient numbers of a second fish species, preferentially small-bodied, were captured in the reference area, thus ninespine stickleback data from the exposure area are included as background data for potential comparisons in future monitoring reports.

In total, 52 Arctic grayling and one ninespine stickleback were captured in the reference area, and 86 Arctic grayling and 99 ninespine stickleback were captured in the exposure

area. Overall, Catch-per-unit-effort (CPUE) was higher in the exposure area than in the reference area.

The state of general health (i.e., occurrence of abnormalities and parasites) of Arctic grayling was similar between the Fingers Lake system (reference) and the Seep Creek system (exposure). Most of the Arctic grayling and ninespine stickleback did not have any recordable abnormalities. Parasite infestations were recorded for approximately 20% of the sacrificed ninespine stickleback.

Based on information collected in the fish survey, Arctic grayling in the exposure area have been negatively impacted by mine effluent. Arctic grayling were heavier, longer and in better condition in the reference area. Liver weight relative to carcass weight was similar between reference and exposure fish, although liver weight relative to fork length was significantly greater in the reference area than in the exposure area. Power analysis indicated that there was sufficient sample size to detect a change of 10% in length, 20% in weight, 5% in condition and 10% in relative liver weight in Arctic grayling, with 90% power.

Laboratory assessments determined that mine effluent collected from station SNP925-10, did not have sublethal or acute effects on a fish species (fathead minnow). Effluent was not acutely toxic to a zooplankton species (*Ceriodaphnia dubia*), although reproductive inhibition was observed. Reproductive and growth inhibition was observed for an aquatic plant (*Lemna minor*). Growth was also inhibited for an algal species (*Selenastrum capricornutum*). Based on the plume delineation model, the potential zone of sublethal effects could extend from the final discharge point downstream as far as Outer Sun Bay of Contwoyto Lake.

The results of the Cycle 1 EEM monitoring program indicate that the BIC and fish population have been impacted by mine effluent; therefore, Lupin mine is required to continue the next phase of the EEM program, Periodic Monitoring – Surveillance, within three years.

TABLE OF ACRONYMS AND UNITS

ANCOVA	Analysis of covariance	TOC	Total organic carbon
ANOVA	Analysis of variance	TSS	Total suspended solids
AO	Authorizing Officer	UTM	Universal Transverse Mercator
ARC	Alberta Research Council	α	Alpha
BCI	Bray-Curtis index	β	Beta
BIC	Benthic invertebrate community	%	percent
CPUE	Catch-per-unit-effort	µg/L	micrograms per litre
CWQG	Canadian water quality guidelines	µm	micrometres
DO	Dissolved oxygen	µS/cm	microSeimens per centimetre
EBM	Echo Bay Mines	ºC	degrees Celsius
EC	Environment Canada	Bq/L	Becquerels per litre
EEM	Environmental effects monitoring	cm	centimetres
ETL	Enviro-Test Laboratories Ltd.	g	grams
FDP	Final discharge point	h	hours
Golder	Golder Associates Ltd.	ha	hectares
GLM	General linear model	Hz	hertz
GPS	Global positioning system	km	kilometres
ISQG	Interim sediment quality guidelines	km^2	square kilometres
Kinross	Kinross Gold Corporation	L	litre
MDL	Method detection limit	m/s	metres per second
MMER	Metal mining effluent regulations	m^2	square metres
QA/QC	Quality assurance/quality control	m^3	cubic metres
NWB	Nunavut Water Board	m^3/d	cubic metres per day
SD	Standard deviation	m^3/s	cubic metres per second
SDI	Simpson's diversity index	mg/kg	milligrams per kilogram
SE	Standard error	mg/L	milligrams per litre
SNP	Surveillance Network Point	mm	millimetres
SSD	Statistically significant difference	ms	milliseconds
TAP	Technical Advisory Panel	NTU	Nephelometric Turbidity Units
TCA	Tailings containment area	s	Seconds
TGD	Technical guidance document	V	volts

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1.0 INTRODUCTION

The Metal Mining Effluent Regulations (MMER) of the *Fisheries Act*, promulgated in June 2002, stipulates conditions under which owners/operators of metal mines may deposit or discharge effluent to the aquatic environment (GC 2002). The regulations apply to all operating metal mines in Canada, and impose limits on release of cyanide, metals, radium-226, suspended solids, and prohibit the discharge of effluent that is acutely lethal to fish. Schedule 5 of the MMER requires that all mines subject to the regulations develop and implement an environmental effects monitoring (EEM) program to assess the effects of metal mining effluent on fish, fish habitat, and the use of fisheries resources. Where there is no pre-existing biological data, the first study design must be submitted within 12 months of a mine becoming subject to the regulations. Where there is pre-existing biological data the first Study Design must be submitted with 24 months. In the latter scenario, the mine must prepare a report that summarizes the biological monitoring studies and supporting documentation within 12 months of becoming subject to the regulations.

The Lupin Mine, owned and operated by Kinross Gold Corporation (Kinross), is subject to the MMER. Consequently, Kinross is required to conduct biological monitoring studies in the aquatic receiving environment for its operations. Because numerous studies have been conducted since initial environmental assessments in the late 1970s and early 1980s, Kinross submitted a summary of historical biological monitoring data in December 2003 in compliance with the MMER. In December 2004, the Fish Study Design for Lupin Mine's Cycle 1 EEM program was submitted to Environment Canada (EC), as required under the MMER. Recommended changes to the Cycle 1 study design were reviewed during a meeting with EC's Technical Advisory Panel (TAP), Kinross, and Golder Associates Ltd. (Golder) in April 2005, and a revised field survey and study design was approved by the TAP in August 2005. Following approval of the Cycle 1 study design by the TAP, Kinross contracted Golder to conduct a comprehensive aquatic monitoring program during the summer of 2005. Study components included a sentinel fish survey, a benthic invertebrate community survey, water quality and sediment quality monitoring, and sublethal toxicity testing. The present report summarizes results of the Cycle 1 biological monitoring program, water quality monitoring, sediment quality monitoring and sublethal toxicity testing in fulfilment of the MMER requirements.

2.0 SITE CHARACTERIZATION

This section provides an updated summary of the site characterization that is provided in the Lupin gold mine EEM study design (Golder 2004).

2.1 General Mine Site Description

The Lupin Mine is located on the west shore of Contwoyto Lake, Nunavut, approximately 300 km south-east of Kugluktuk and 80 km south of the Arctic Circle (65°46' N, 111°15' W) (Figure 2.1). Between April and late December each year, the only access to Lupin is by air, and from January to March the mine can also be accessed from Yellowknife via an ice road.

Mine site construction started in August 1980 and was completed in March 1982, when pre-production commissioning began. The mine operated continuously from 1982 to January 1998, when operations were suspended and the mine was placed in care and maintenance status due to low gold prices. Production resumed in April 2000. Following Echo Bay Mine's merger with Kinross in 2003, the mine was re-closed and placed under care and maintenance while undergoing feasibility studies to re-commence operations. Lupin Mine re-started operations during March 2004. In February 2005, the mine returned to care and maintenance.

The Lupin Mine included underground mining and production systems, as well as an ore handling system. Mining and processing equipment was designed to handle up to 2300 tonnes per day. During the mine's most recent operational period, processing rates were approximately 1200 tonnes of ore per day. Since the start of production in 1982, the Lupin Mine produced over 100 million grams of gold.

Other than transportation requirements for materials and supplies necessary to sustain the workforce and operations, the Lupin site is completely self-contained. It is comprised of two principal clusters of buildings: the residential complex, which consists of accommodations, a kitchen and recreation center; and the industrial complex, which houses the mine, mill, powerhouse, maintenance facility, warehouse and offices. Ancillary features include a sewage lagoon immediately to the south of the industrial complex, a 1.9 km long airstrip, and a tailings containment area (TCA) located approximately 7 km south of the mine (Figure 2.1).

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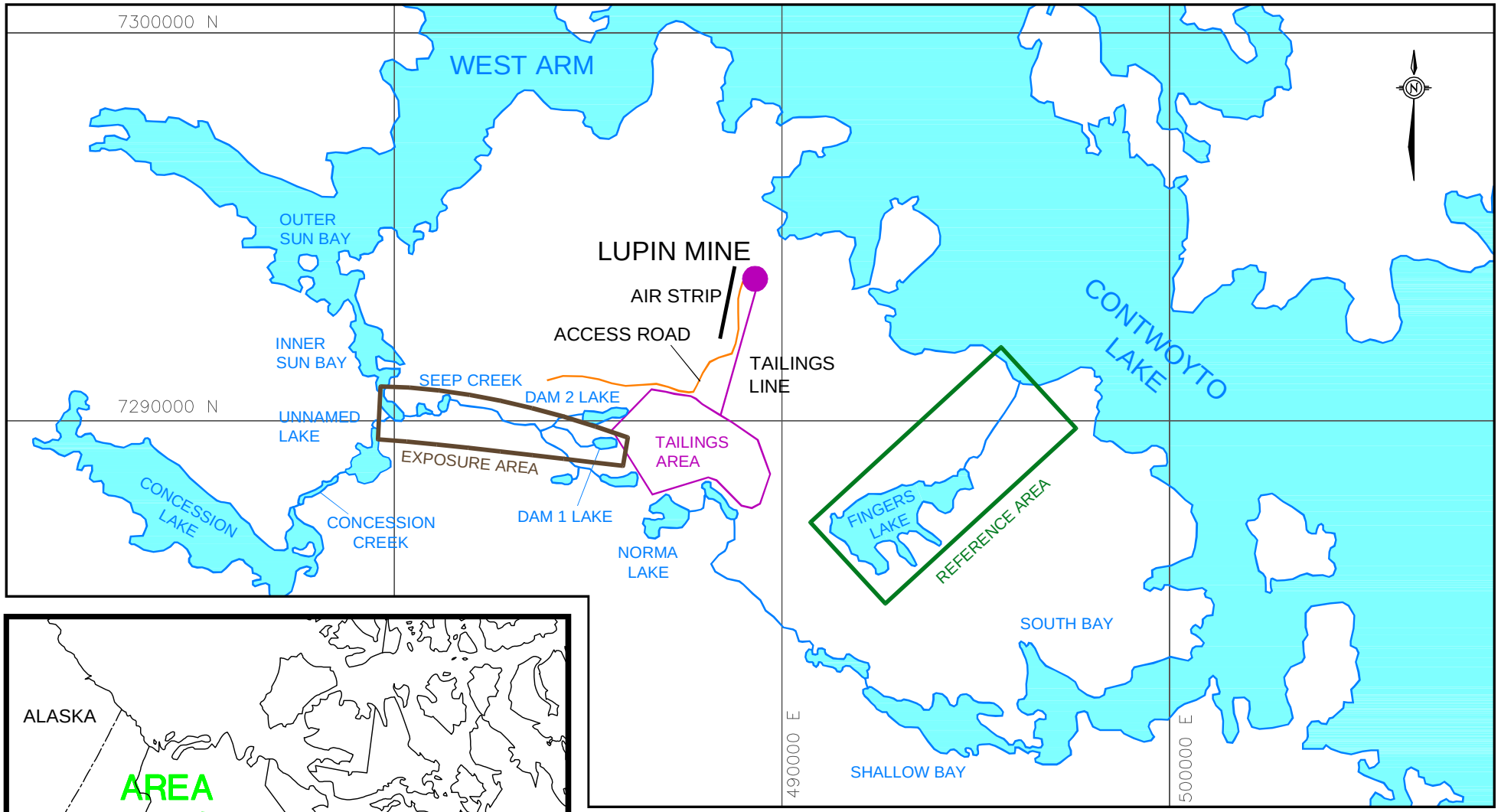

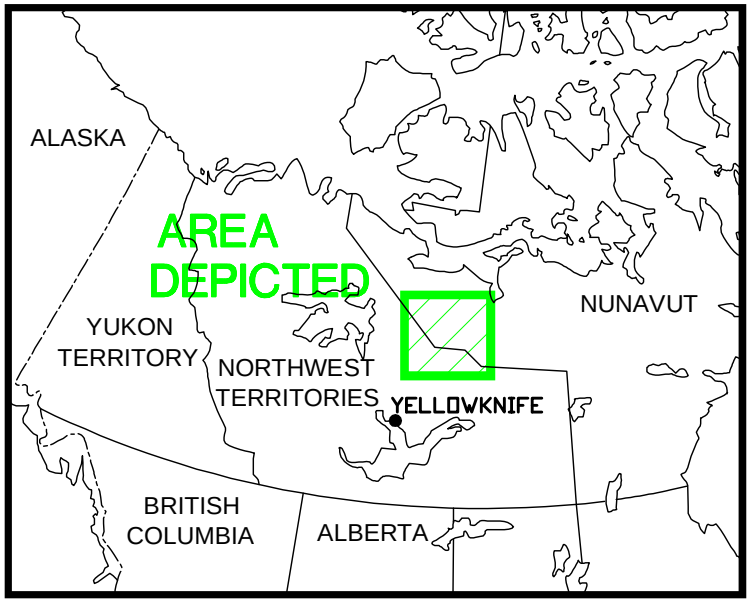

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PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Lupin Mine Location Plan

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730630
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
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Figure: 2.1

2.2 Environment Laws and Regulations

The territorial and federal laws that apply to the operations of the Lupin Mine, and are applicable to effluent and environmental monitoring, are summarized below.

The Nunavut Water Board (NWB), which operates under regulations in the *Nunavut Land Claims Agreement,* governs the use of water and the deposition of waste in the Lupine Mine's area. Kinross holds a water license with criteria for limiting the amount of water drawn from Contwoyto Lake, and discharge of deleterious substances and other water quality constituents under these regulations from the NWB. Kinross also has an Emergency Spill Response and Contingency Plan developed under these regulations. Some of the conditions in the NWB license comply with the *Northwest Territories Waters Act*.

The federal *Territorial Lands Act*, and Land Use Regulations pertaining to the *Act*, applies to Crown lands in the Northwest Territories and Nunavut. The Lupin Mine received a Land Use Permit with conditions related to waste disposal under these regulations.

The federal *Fisheries Act* is applicable to effluent discharges from the Lupin Mine. The main objective of the *Fisheries Act* is to conserve and protect fish and fish habitat from harm caused by physical alteration or pollution. The MMER, administered within the *Fisheries Act*, restricts the release of deleterious substances to maximum discharge concentrations, regulates the requirements for release of non-acutely lethal effluent, and through the EEM program, assess the effectiveness of these limits with regards to environmental protection.

2.3 Local Environment

2.3.1 Climate

Climate in this region (Environment Canada Station 23026HN, Lupin A) is classified as semi-arid subArctic, with a mean daily temperature of -11.1°C and an average annual precipitation of 299 mm (Canadian Climate Normals 1961-2000). Average temperature for the months May through September is 4.6°C (Canadian Climate Normals 1961-2000). Precipitation is heaviest in the months of June through September. Snowfall can occur during any month, although heaviest snowfalls generally occur in October. The average total annual snowfall is 138.1 cm (Canadian Climate Normals 1961-2000). The project area is subject to frequent strong winds from the northwest (Beak Consultants Ltd. and Mary Collins Consultants Ltd. 1980; Geocon Ltd. 1980).

2.3.2 Geology and Topography

The Lupin Mine is located in the tundra zone of the Canadian Shield, the geological core of the continent that occupies almost half of Canada's surface. The mine is located within the Slave province of the Shield, a province that features intrusive igneous material, such as granite (Natural Resources Canada 2003). Terrain in the vicinity of the mine is generally low and undulating, ranging between 450 and 530 m elevation. Numerous shallow lakes and streams occur in depressions throughout the area (Beak Consultants Ltd. and Mary Collins Consultants Ltd. 1980; Geocon Ltd. 1980).

2.3.3 Vegetation

The Lupin Mine is located in the subArctic tundra vegetation zone, an area characterized by continuous permafrost and typical "barren ground" vegetation of moss, lichens, heather, and dwarf shrub communities. These types of vegetation are predominant on the more well-drained areas, whereas grasses and sedges are dominant in the wet ground adjacent to stream courses and around the perimeters of lakes. Dwarf willow shrubs up to 1 m high occur adjacent to some stream courses (RCPL and RL&L 1985).

2.3.4 Hydrology

Contwoyto Lake is the major waterbody in the region, with a surface area of approximately 95 900 hectares (ha) and a drainage area of 8000 km^2 (Roberge et al. 1986). Contwoyto Lake has two outlets – the Burnside River, which flows from the northwest end of the lake towards Bathurst Inlet, and the Back River at the southeast end of the lake, which flows into Pellatt Lake (Roberge et al. 1986). The main body of Contwoyto Lake lies to the east and south of the mine site (Figure 2.1). To the north of the mine, a portion of the lake (known as the West Arm) extends to the west and south, terminating in a narrow bay (Sun Bay), which lies directly west of the mine site (Moore 1978; Roberge et al. 1986).

Seep Creek is a small stream (approximately 6.5 km in length) that flows in a westerly direction into Inner Sun Bay of Contwoyto Lake (Figure 2.1). The Seep Creek watershed includes three lakes (colloquially known as Dam 2 Lake, Dam 1a Lake and Unnamed Lake), three headwater streams, two ponds (Seep Creek Ponds 1&2), and two embayment areas (Inner and Outer Sun bays). Dam 2 Lake is a small lake (maximum depth of 7 m), bordered on the north by a gravel pit and on the east by the TCA. Dam 1a Lake is a small lake (maximum depth of less than 1 m) that is located to the south of Dam 2 Lake. This waterbody freezes to the bottom in winter. A southern branch of Seep Creek, originating from Dam 1a Lake, enters Seep Creek approximately 2 km downstream of Dam 2 Lake.

A third branch of the creek arises to the south of Dam 1a Lake and joins the mainstem about 400 m downstream of the confluence of Dam 2 Lake and Dam 1a Lake branches.

2.4 Description of Production Processes

The ore body at the Lupin Mine extends from the surface to about 2000 m below the surface. Gold is found primarily within a sulphide rich iron formation. The gold is fine grained (generally less than 100 µm in diameter) and is associated mainly with pyrrhotite and arsenopyrite. Lupin Mine uses cyanidation processing to leach gold into solution. A detailed description of the underground mining and milling techniques used at the Lupin Mine is provided in Golder (2003) and Echo Bay Mines Ltd. (2001).

2.5 Environmental Protection Practices

A waste management program for the handling, disposal and tracking of contaminated and non-contaminated waste generated by the Lupin Mine has been established, which complies with applicable federal and territorial laws and regulations. While the storage and disposal of non-contaminated waste does occur at the Lupin Mine, the value of the 4Rs system (reduce, reuse, recycle, and recover) is recognized and actively promoted. Following is a summary of the waste management program as it relates to wastewater management.

2.5.1 Waste Rock

While the Lupin Mine was in operation, waste rock was used as roadbed material, in dams, in the airstrip, or as backfill. During the past few years, very little development waste has been produced in the underground operation; as a result, a surface waste stockpile no longer exists.

2.5.2 Management of Mine Water

Relative to most underground mining operations, Lupin is a dry mine, having an average water inflow of between 45 and 95 L per minute. Most of this water seeps into workings below the permafrost level (500 m below surface). The main de-watering system consists of four main sumps located at the 250, 650, 890, and 1105 m shaft stations. The discharge line is 15.24 cm diameter, and is located in the shaft. The mine discharge water is pumped to the TCA via the mill.

Both drill water and potable water is supplied to the mine via separate pipelines located in the shaft. A brine line services the upper levels, in permafrost. A 3% to 6% brine solution

(by weight) is mixed in tanks on the surface and fed to upper level sumps when needed. Also located in the shaft is a 3.81 cm fuel line, which allows diesel fuel to be sent to a main storage facility on the 890 m level.

2.5.3 Management of Tailings

Originally, all waste was to be contained within the TCA. As mine capacity increased, it became necessary to expand the TCA and discharge effluent. Effluent discharge commenced on 5 September 1985. Effluent was discharged in mid summer, generally beginning on 15 July and continued for periods that extended into early September. The maximum rate of effluent discharge, as per the Nunavut Water Board water licence, has been 60 000 to 70 000 m^3/d (AQUAMIN 1996; EVS 1996). Since the initial discharge in 1985, effluent is discharged into Seep Creek, which empties into an unnamed lake. Unnamed Lake drains into Contwoyto Lake at the south end of Inner Sun Bay (Figure 2.1).

The tailings management process at Lupin is as follows:

- The tailings slurry is pumped from the mill to one of two solids retention cells (Cell 3 or Cell 5) in the TCA, where the solids settle. For the past six years, Cell 5 has been used for winter deposition and Cell 3 for summer deposition (Figure 2.2).

- Each spring, usually beginning in late June, the build-up of meltwater and tailings water is decanted from Cells 5 and 3 into Cell 4. Cell 4 has not been used for solids deposition, and functions as a primary polishing pond. Water is held in this cell for a one-year period, where cyanide undergoes natural degradation due to exposure to sunlight, air, and agitation by wind.

- The following year, water is released from Cell 4, through a gated culvert, into Pond 1, where it is held for a one-year period, before being siphoned into Pond 2 where it is held for another year. If necessary, the water can be treated with ferric-sulphate during the siphoning process to precipitate arsenic in Pond 2.

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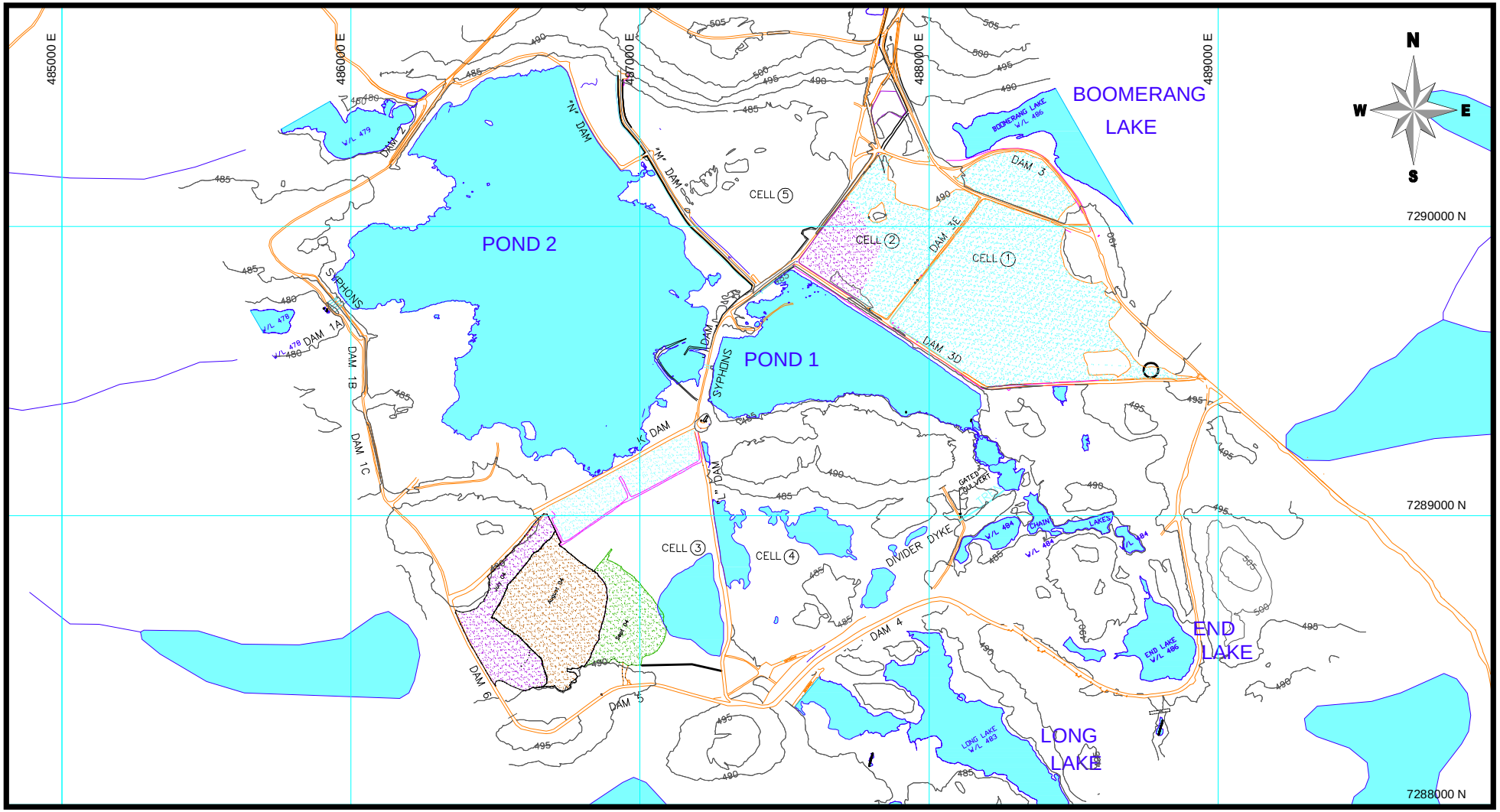

LEGEND

Esker covered tailings

PROJECT

Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE

Lupin Tailings Containment Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730631
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Figure: 2.2

- Historically, water was retained only for a 2-year period, and arsenic levels were still high in Pond 1. An arsenic treatment plant was built between Pond 1 and Pond 2, so that the water could be injected with ferric sulphate solution as it was being siphoned between the two ponds. Since 2000, water has been retained for a three year period (one year in Cell 4, one year in Pond 1, and one year in Pond 2). The extra year of water retention before going into Pond 2 has resulted in naturally lowering the arsenic levels, thus negating the use the treatment plant. Periodically, treatments of ferric sulphate (two tonne batches) are placed into Pond #1 to control arsenic concentrations.

- Depending on the water level and water quality in Pond 2, water can be released to the environment after 15 July of any year (as per Nunavut Water Board water licence). Water quality is monitored on a daily basis during discharge to ensure that discharge criteria are not exceeded.

Reclamation activities have been ongoing at the Lupin Mine since 1988. Between 1988 and 2005, Cell 1, Cell 2, Cell 3 and Cell 5 have been covered with esker sand to prevent access to surface tailings by wildlife in the area. Water from Cell 3 was pumped into Cell 4 prior to covering with esker sand, and water from Cell 4 will be released to Pond 1 after a suitable retention period.

2.5.4 Sewage Disposal

Sewage and domestic grey water is pumped to the Sewage Lake Disposal System for natural degradation. The system features two small unnamed lakes located to the south of the mine and empty via an unnamed creek into Contwoyto Lake (Echo Bay Mines Ltd. 1994).

2.5.5 Historical Effluent and Water Quality Monitoring

Kinross identified one final discharge point to Environment Canada in 2003. Plans, specifications, operation, and maintenance information were provided in accordance with Section 9 of the MMER (GC 2002). The final discharge point is regularly monitored under licensing agreement with the Nunavut Water Board (SNP 925-10), along with downstream receiving environment sampling locations. Effluent is siphoned from TCA Pond 2 into Dam 1a Lake, a headwater tributary of Seep Creek (Figures 2.1 and 2.2). A brief description of the final discharge water quantity, quality, and plume delineation is provided below.

2.5.6 Effluent Monitoring

Discharge at SNP 925-10 is monitored regularly (65°43'43.8" N, 111°18'23.3" W), with annual quality reports submitted to the NWB. Total annual discharge between 1994 and 2005 ranged from 0 m^3 to 3 102 895 m^3 (Table 2.1).

Table 2.1. Total annual discharge volumes from Lupin Mine TCA (SNP 925-10), 1994 to 2005

Year	Annual Total (m^3)	Discharge Period
1994	863 868	15 - 29 Jul
1995	938 715	15 Jul – 2 Aug
1996	1 139 233	15 Jul – 7 Aug
1997	2 892 289	15 Jul – 1 Sep
1998	0	n/a
1999	0	n/a
2000	2 701 360	15 Jul – 2 Sep
2001	0	n/a
2002	3 102 895	15 Jul – 7 Sep
2003	0	n/a
2004	0	n/a
2005	1 682 135	15 Jul – 11 Aug

Note: n/a = not applicable

Water quality at SNP 925-10 is monitored for a variety of constituents at varying frequencies (Table 2.2). Constituents listed in Schedule 4 of the MMER (GC 2002), with the exception of radium-226, are routinely measured at SNP 925-10. The maximum concentrations discharged from SNP 925-10 during 2000, 2002 and 2005 (Table 2.3) are below authorized limits (GC 2002).

Table 2.2. Monitoring and sampling frequencies of TCA effluent at SNP 925-10

Constituents	Frequency
pH, Conductivity, Temperature, Total Suspended Solids, Arsenic, Cyanide, Copper, Zinc, Volume	Daily (grab)
Cadmium, Lead, Nickel, Alkalinity, Ammonia, Hardness	Weekly (grab)
24 Metals (Total), ICPMS (inductive coupled plasma mass spectrometer)	First discharge day and monthly thereafter (grab)
Static Pass/Fail Bioassay for Both Rainbow Trout and *Daphnia* Species (per Environment Canada's Environmental Protection Series Biological Test Methods)	Twice per year (grab)

Table 2.3. Maximum concentrations of MMER deleterious substances at the Lupin Mine (SNP 925-10)

Constituent	Units	2000	2002	2005	Maximum Authorized Concentration in a Grab Sample[a]
Arsenic	mg/L	0.0133	0.0800	0.0146	1.00
Copper	mg/L	0.011	0.034	0.015	0.60
Cyanide	mg/L	0.032	0.144	0.040	2.00
Lead	mg/L	<0.0020	0.0006	0.0050	0.40
Nickel	mg/L	0.1210	0.0893	0.0955	1.00
Zinc	mg/L	0.303	0.247	0.251	1.00
Radium-226	Bq/L	n/a	n/a	0.006	1.11
TSS	mg/L	2	5	<2	30.00

Note: [a] GC (2002) ; TSS = Total Suspended Solids; n/a = not available

Several metals and other constituents were measured as part of the routine water quality monitoring program at SNP 925-10 (Table 2.4). Metal concentrations and levels of conventional constituents, such as conductivity, pH and total suspended solids (TSS), have been remained at consistent concentrations. Arsenic, for example, remained below 0.015 mg/L, and conductivity ranged from 847 to 906 µS/cm.

Table 2.4. Water quality of Lupin Mine TCA effluent at SNP 925-10

Constituent	Units	2000				2002		2005
		15-Jul	16-Jul	21-Aug	02-Sep	15-Jul	12-Aug	27-Jul
Conventional								
Field Temperature	°C	n/a	14.4	12.3	6.2	14.7	15.9	n/a
pH	units	6.95	7.00	7.05	6.53	7.01	6.95	6.39
Conductivity	µS/cm	869	887	n/a	906	858	855	847
Total Suspended Solids	mg/L	1	1	1	1	<1	<1	<2
Total Alkalinity (as $CaCO_3$)	mg/L	10	11	7	<5	20	10	<5
Total Hardness (as $CaCO_3$)	mg/L	227	227	244	239	245	218	216
Inorganic Non-metallic								
Ammonium-N	mg/L	4.57	4.00	3.91	3.07	1.08	1.36	1.88
Cyanide	mg/L	0.016	0.016	0.014	0.016	0.004	0.078	0.040
Major Ions								
Calcium (dissolved)	mg/L	78.7	78.9	n/a	n/a	84.7	75.1	74.2
Magnesium (dissolved)	mg/L	7.49	7.37	n/a	n/a	8.03	7.41	7.50
Hydroxide	mg/L	<5	<5	n/a	n/a	<5	<5	<5
Carbonate	mg/L	<6	<6	n/a	n/a	<6	12	<6
Bicarbonate	mg/L	13	14	n/a	n/a	24	<5	<5
Metals (Total)								
Aluminum	mg/L	0.063	0.056	0.090	0.096	0.055	0.080	0.128
Antimony	mg/L	<0.006	<0.006	<0.006	<0.006	<0.002	0.005	<0.0002
Arsenic	mg/L	<0.01	<0.01	<0.01	0.01	0.0149	0.0108	0.0146
Barium	mg/L	0.0142	0.015	0.0158	0.0162	0.016	0.017	0.016
Beryllium	mg/L	<0.0006	<0.0006	<0.0006	<0.0006	<0.0001	<0.0001	<0.0001
Bismuth	mg/L	<0.008	<0.008	<0.008	<0.006	<0.0005	<0.0005	<0.0005
Boron	mg/L	0.126	0.134	0.116	0.099	0.098	0.106	0.087
Cadmium	mg/L	<0.0006	<0.0006	<0.0006	<0.0006	0.0002	0.0002	0.0001
Calcium	mg/L	78.1	82.1	77.6	81.0	71.6	76.8	n/a
Chromium	mg/L	<0.0009	<0.0009	<0.0009	<0.0009	0.0007	<0.0005	<0.0005
Cobalt	mg/L	0.0626	0.0658	0.0654	0.0684	0.0559	0.0566	0.0496
Copper	mg/L	0.003	0.005	0.007	0.011	0.012	0.006	0.015
Iron	mg/L	0.068	0.075	0.227	0.250	0.980	0.267	0.200
Lead	mg/L	<0.002	<0.002	<0.002	<0.002	0.0005	0.0004	0.0005
Lithium	mg/L	0.018	0.019	0.018	0.019	0.018	0.019	0.030
Magnesium	mg/L	7.31	7.67	7.55	8.23	7.10	7.66	n/a
Manganese	mg/L	1.26	1.32	1.30	1.36	1.10	1.14	0.005
Molybdenum	mg/L	0.001	<0.001	<0.001	0.002	0.002	0.003	0.002
Nickel	mg/L	0.103	0.110	0.107	0.111	0.0807	0.0838	0.0955
Phosphorus	mg/L	0.04	<0.03	<0.03	<0.03	n/a	n/a	n/a

Note: n/a = not available

2.6 Water Quality Monitoring

Water quality is routinely monitored at several locations in the exposure area downstream of the final discharge point (Figure 2.3). The conductivity was 11 µS/cm at the mouth of Concession Creek (SNP 925-21), which does not receive effluent from Lupin Mine. Concentrations of several constituents decreased with increasing distance from the mouth of Seep Creek. In 2005, mean conductivity was 519 µS/cm at the mouth of Seep Creek (SNP 925-20), 240 µS/cm at the centre of Inner Sun Bay (SNP 925-22), 129 µS/cm at the Sun Bay narrows (SNP 925-24), and 76 µS/cm in Outer Sun Bay (SNP 925-25). Nickel, zinc, hardness, and ammonium exhibited similar data trends of decreasing concentrations with increasing distance from the final discharge point (FDP) (Table 2.5 to 2.7).

2.7 Delineation of Effluent Plume

The MMER requires an estimate of the effluent concentration at 250 m downstream of the FDP. A description of the extent of effluent contact with the surrounding water environment, to a concentration level of 1% of discharged effluent, is also required.

The common method used to estimate the effluent concentration at 250 m from the FDP is to compare the effluent conductivity to the field conductivity at a point 250 m from the FDP while the Mine is discharging effluent. The mine terminated effluent discharge on 11 August 2005; therefore, effluent was not being discharged during the EEM sampling program. Although effluent was not being discharged, the laboratory conductivity measurement was 738 µS/cm 250 m from the FDP, in Dam 1a Lake, on 21 August 2005. The effluent conductivity on 27 July 2005 was 847 µS/cm. In 1985, RL&L and DFO (1991) estimated that up to 90% of the flow in Seep Creek was due to effluent discharge into the stream system. Mine effluent discharged from the TCA is the main source of water into Dam 1a Lake; therefore, we cautiously estimate the effluent concentration to be 87% in Dam 1a Lake, 250 m from the FDP.

Effluent mixing in the exposure zone was described in Golder (2004) using dilution and dispersion modeling of the effluent stream into Outer Sun Bay. The model predicted that a 1% effluent concentration would extend 850 to 1200 m from the mouth of the narrows into Outer Sun Bay under average effluent discharge and ambient current velocity (average conditions). At maximum effluent discharge and high ambient current velocity (worst case conditions), the model predicted that the 1% effluent concentration would extend up to 1630 m from the mouth of the narrows into Outer Sun Bay (Figure 2.4).

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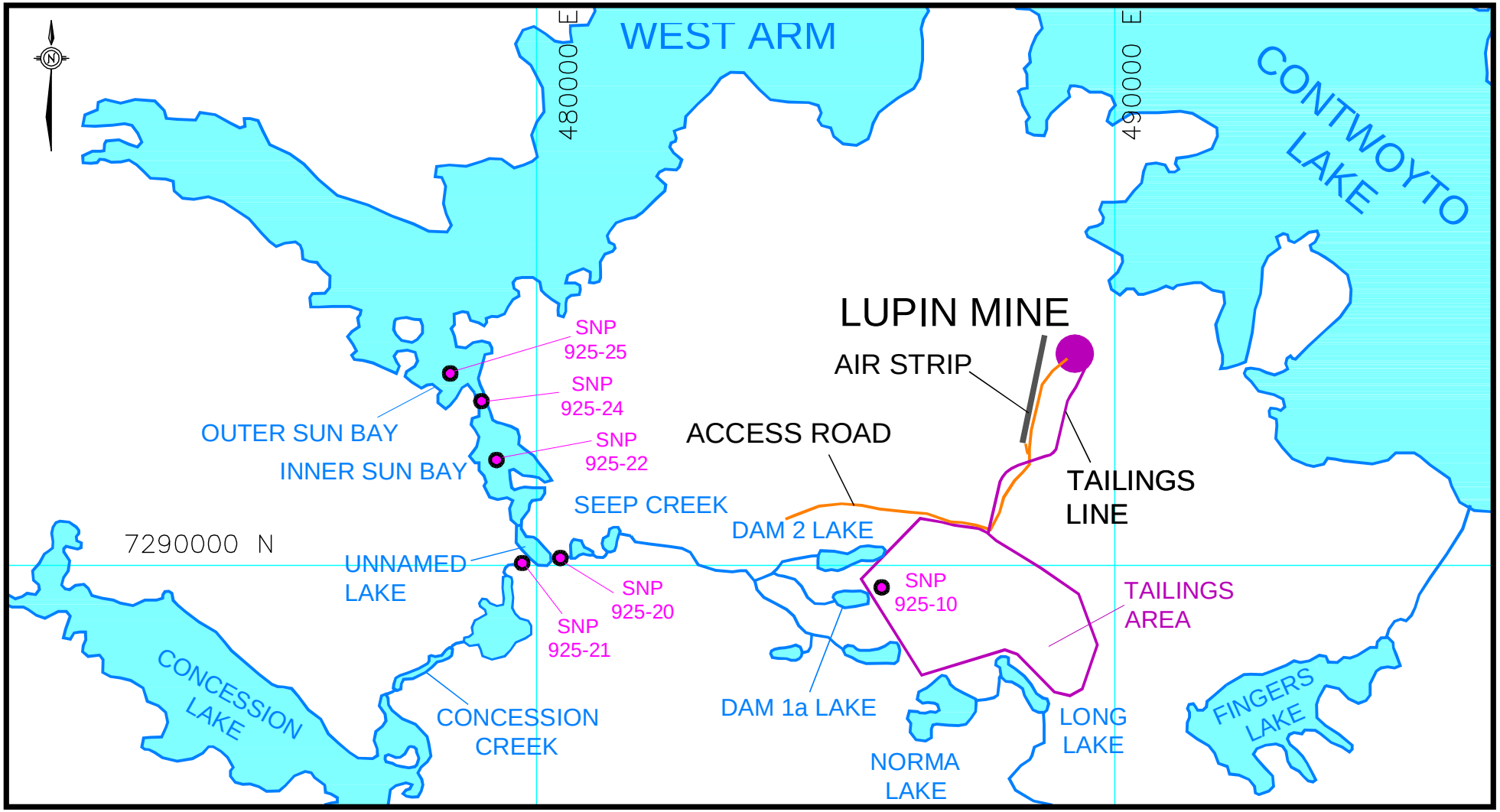

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Scale KM

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Exposure Area
Water Quality Monitoring Stations

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730632
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 2.3

Table 2.5. Summary of water quality monitoring data downstream of the Lupin Mine effluent discharge location

Constituent[a]	Mouth of Seep Cr. (SNP 925-20)									Mouth of Concession Cr. (SNP 925-21)								
	2000			2002			2005			2000			2002			2005		
	n	Mean[c]	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
pH (units)	7	6.03	0.25	7	6.48	0.15	6	5.70	0.45	7	6.43	0.32	7	6.28	0.41	6	6.67	0.14
Conductivity (□S/cm)	3	887	37	7	748	114	6	519	279	3	14	6	7	12	1	6	11	1
TSS[b]	7	0.53	0.17	7	0.93	0.73	5	<2	0	7	0.96	1.35	7	<1	0	5	<2	0
Total Arsenic	7	0.0024	0.0006	7	0.0036	0.0006	6	0.0032	0.0013	7	0.0004	0.0003	7	0.0011	0.0017	6	0.0007	0.0002
Total Cyanide	7	0.007	0.004	7	0.015	0.014	6	0.016	0.008	7	<0.002	0	7	0.003	0.004	6	0.002	0
Total Cadmium	7	<0.0006	0	7	0.00017	0.00003	6	0.00017	0.00010	7	<0.0006	0	7	<0.00001	0	6	<0.00001	0
Total Copper	7	0.005	0.002	7	0.004	0.002	6	0.005	0.002	7	0.001	0.001	7	0.001	0.001	6	<0.001	0
Total Lead	7	<0.002	0	7	0.0002	0.0002	6	0.0001	0.0001	7	0.001	0.001	7	0.0001	0.0001	6	0.0001	0
Total Nickel	7	0.115	0.009	7	0.0755	0.0084	6	0.0762	0.0411	7	0.008	0.018	7	0.0006	0.0003	6	0.0006	0.0001
Total Zinc	7	0.228	0.026	7	0.146	0.017	6	0.159	0.091	7	0.008	0.01	7	0.003	0.003	6	0.002	0.001
Total Alkalinity (as $CaCO_3$)	7	<5	0	7	7.4	9.2	6	<5	0	7	<5	0	7	<5	0	6	6	1
Hardness (as $CaCO_3$)	7	231	9.1	7	199	34.3	6	135	75.4	7	4	0.6	7	5	0.3	6	3	1.4
Ammonium	7	2.72	0.48	7	0.72	0.31	6	0.64	0.47	7	0.32	0.16	7	0.03	0.02	6	<0.05	0

Note: [a] Concentration units are mg/L, unless otherwise listed; [b] Total suspended solids; [c] where a portion of the results were below the method detection limits, half of this limit was used to calculate means; SD=standard deviation; 2005 water quality data is presented in Appendix B

Table 2.6. Summary of water quality monitoring data downstream of the Lupin Mine effluent discharge location

Constituent[a]	Centre of Inner Sun Bay (SNP 925-22)									Sun Bay Narrows (SNP 925-24)								
	2000			2002			2005			2000			2002			2005		
	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
pH (units)	7	6.33	0.33	7	6.37	0.09	17	6.36	0.27	7	6.47	0.29	7	6.36	0.29	7	6.47	0.18
Conductivity (□S/cm)	3	296	130	7	336	88.5	17	240	155	3	78.4	48.5	7	267	114	7	129	101
TSS[b]	7	0.47	0.2	7	<1	0	17	<2	0	7	0.37	0.3	7	<1	0	6	<2	0
Total Arsenic	7	0.001	0.0004	7	0.014	0.0003	17	0.0017	0.0006	7	0.0007	0.0005	7	0.0011	0.0002	7	0.0012	0.0003
Total Cyanide	7	0.007	0.01	7	0.007	0.004	17	0.010	0.008	7	0.006	0.012	7	0.004	0.002	7	0.006	0.003
Total Cadmium	7	<0.0006	0	7	0.00006	0.00002	17	0.00017	0.00019	7	<0.0006	0	7	0.00003	0.00002	7	0.00005	0.00002
Total Copper	7	0.002	0.001	7	0.003	0.004	17	0.002	0.001	7	0.002	0.002	7	0.002	0.001	7	0.001	0.001
Total Lead	7	<0.002	0	7	0.0002	0.0002	17	0.0004	0.0003	7	<0.002	0	7	0.0002	0.0003	7	0.0005	0.0003
Total Nickel	7	0.041	0.016	7	0.027	0.007	17	0.029	0.020	7	0.012	0.011	7	0.0163	0.0073	7	0.0130	0.0108
Total Zinc	7	0.08	0.034	7	0.054	0.017	17	0.070	0.055	7	0.025	0.022	7	0.038	0.014	7	0.029	0.023
Total Alkalinity (as $CaCO_3$)	7	<5	0	7	<5	0	17	<5	0	7	<5	0	7	<5	0	7	<5	0
Hardness (as $CaCO_3$)	7	88	25	7	82.7	21.9	17	57.8	38.4	7	31.2	22.6	7	64.3	26.4	7	31.1	23.5
Ammonium	7	1.06	0.28	7	0.24	0.12	17	0.40	0.14	7	0.57	0.28	7	0.15	0.1	7	0.17	0.09

Note: [a] Concentration units are mg/L, unless otherwise listed; [b] Total suspended solids; [c] where a portion of the results were below the method detection limits, half of this limit was used to calculate means; SD=standard deviation; 2005 water quality data is presented in Appendix B

Table 2.7. Summary of water quality monitoring data downstream of the Lupin Mine effluent discharge location

Constituent[a]	Outer Sun Bay (SNP 925-25)								
	2000			2002			2005		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
pH (units)	7	6.51	0.28	7	6.39	0.35	7	6.63	0.13
Conductivity (□S/cm)	3	25.3	19.8	7	40.7	25.7	7	76	81
TSS[b]	7	0.46	0.27	7	0.8	0.6	6	<2	0
Total Arsenic	7	0.0012	0.0021	7	0.0006	0.0001	7	0.0013	0.0002
Total Cyanide	7	0.001	0.001	7	0.002	0.001	7	0.005	0.007
Total Cadmium	7	<0.0006	0	7	<0.00001	0	7	0.00003	0
Total Copper	7	0.001	0.001	7	0.002	0.002	7	0.001	0.001
Total Lead	7	<0.002	0	7	0.0002	0.0004	7	0.0007	0.0005
Total Nickel	7	0.002	0.001	7	0.0026	0.0016	7	0.0039	0.0036
Total Zinc	7	0.009	0.004	7	0.007	0.004	7	0.012	0.007
Total Alkalinity (as $CaCO_3$)	7	<5	0	7	<5	0	7	<5	0
Hardness (as $CaCO_3$)	7	6.63	3.86	7	9.97	5.52	7	20.6	25.2
Ammonium	7	0.28	0.16	7	0.04	0.02	7	<0.05	0

Note: [a] Concentration units are mg/L, unless otherwise listed; [b] Total suspended solids; [c] where a portion of the results were below the method detection limits, half of this limit was used to calculate means; SD=standard deviation; 2005 water quality data is presented in Appendix B

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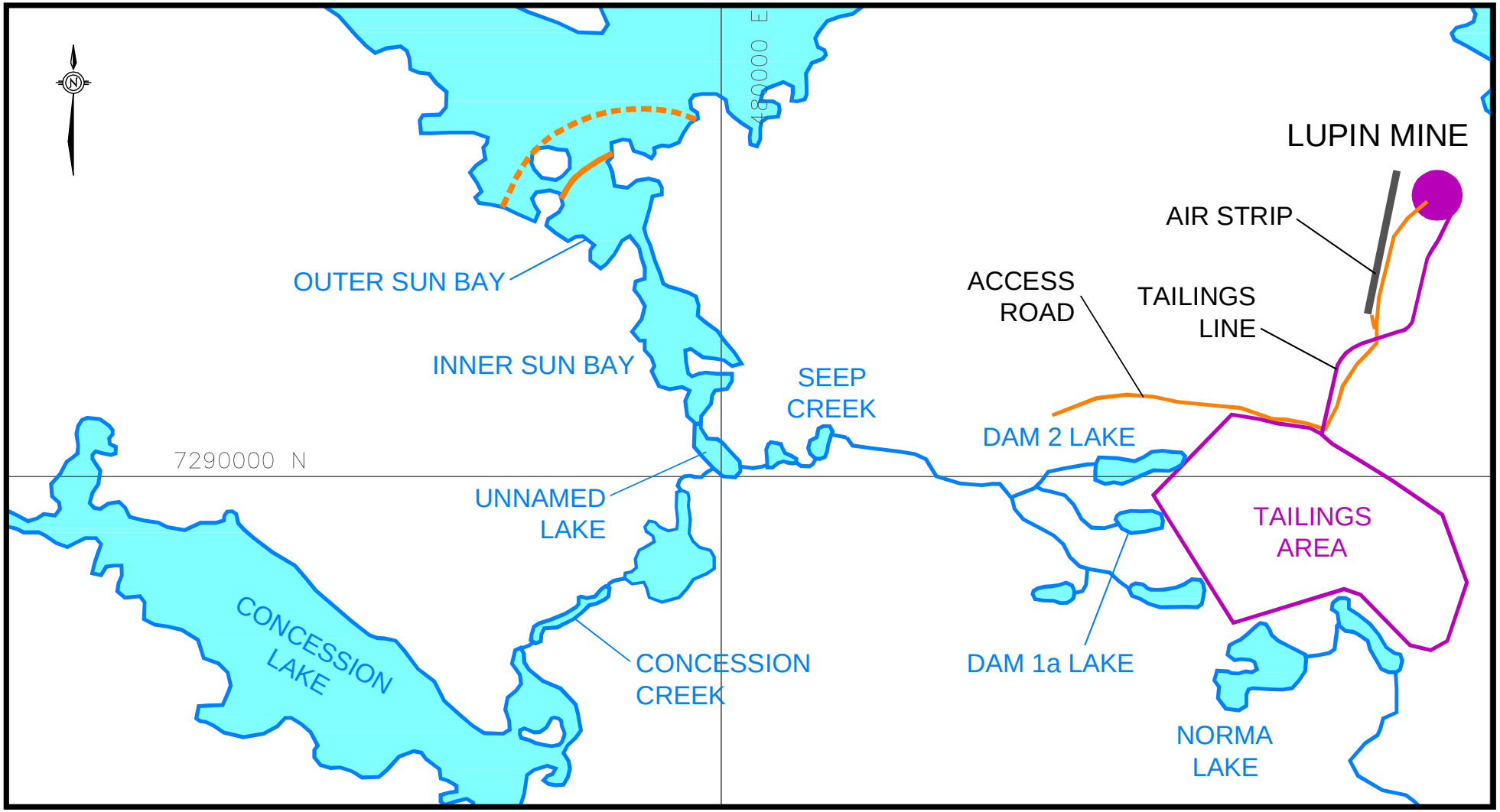

LEGEND

- Average conditions (1% concentration)
- Worst case conditions (1% concentration)

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SCALE KM

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Dispersion of Effluent Plume

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730633
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 2.4

Water quality is monitored in Outer Sun Bay (SNP 925-25), approximately 500 m from the mouth of the narrows. Based on monitoring data in 2000 and 2002, effluent concentrations of 1.3 to 3.4% were present in the bay. These values are consistent with the results of the dilution and dispersion analysis, and indicate that there is sufficient mixing in Outer Sun Bay.

2.8 Exposure and Reference Area Characterization

2.8.1 Seep Creek and Seep Creek Ponds – Exposure Area

Aquatic habitat in the receiving environment downstream of the tailings area (Figures 2.1 and 2.3) is comprised of three shallow lakes (Dam 2 Lake, Dam 1a Lake, and Unnamed Lake), two streams (Seep Creek and Concession Creek), two shallow ponds, and two embayment areas of Contwoyto Lake (Inner and Outer Sun bays). With the exception of Dam 2 Lake, all of the small lakes and ponds freeze to the bottom in winter. Much of Inner Sun Bay also freezes to the bottom. Due to low winter flows, both Seep Creek and Concession Creek freeze to the bottom in winter. As a consequence, over-wintering habitat for fish is limited primarily to Outer Sun Bay and the main body of Contwoyto Lake (RCPL and RL&L 1985).

Seep Creek is approximately 6.5 km in length, flowing from its source in Dam 2 Lake and Dam 1a Lake (via separate branches which join about 2 km downstream) to Unnamed Lake (Figures 2.1 and 2.3). The stream channel in upper Seep Creek is generally poorly defined, often flowing through marshy areas, or between large boulders or through bedrock fractures. This section of the creek generally was less than 0.5 m in depth and less than 2 m wide. The dominant substrate type is boulders, although localized areas of cobble and gravel are present. Lower Seep Creek (i.e., the 400 m section upstream of Unnamed Lake) is characterized by a well developed channel varying in width from 1 to 4 m, although during freshet, maximum wetted width was about 20 m. The dominant substrate type is boulder, with localized areas of cobble and gravel (RCPL and RL&L 1985).

Two ponds are located near the downstream end of Seep Creek. The maximum depths of these ponds are approximately 1.5 m; the surface area of the upstream-most pond (Pond 1) was 3 ha, and the surface area of the downstream-most pond (Pond 2) was 2 ha.

Lake trout, Arctic grayling, cisco, round whitefish, ninespine stickleback and slimy sculpin have been documented in Seep Creek (RCPL and RL&L 1985). RL&L and DFO (1991) indicated that fish use the stream for spawning, feeding and juvenile rearing in the early part of the open water season. The majority of the fish were moving downstream

when captured in 1990. RL&L and DFO (1991) suggested that this was in response to decreasing water levels as snowmelt run-off subsided. RCPL and RL&L (1985) documented Arctic grayling spawning in Seep Creek in 1983 and 1984.

2.8.2 Fingers Creek and Fingers Lake – Reference Area

Fingers Creek flows for approximately 3 km between Fingers Lake and Contwoyto Lake (Figure 2.1). The upstream end of the channel was braided and contained substrate composed primarily of silt and boulders, with some cobble. The stream channel widened to approximately two to three metres in the mid-section of the stream. The substrate consisted of cobble, gravel, and silt, with limited boulders also present. The downstream end of the creek featured a narrow channel, approximately 1.0 m wide, with substrate dominated by cobble and boulders. The upstream section was primarily shallow flat habitat, whereas the midstream and downstream sections were primarily shallow run habitat. The average depth was 0.5 m through the upstream and midstream sections, and approximately 0.3 m in the downstream section. Approximately 20% of the entire creek, and 40% of the midstream section, contained aquatic vegetation and periphytic algae. The banks were vegetated and stable, and were composed primarily of fines.

Fingers Lake has a maximum depth of 6 m and a surface area of 370 ha (Moore 1978). Fingers Lake is a clearwater lake with little aquatic vegetation, except in the deposition areas. The lake is shallower toward the north-east end of the lake, and the substrate is primarily cobble and boulders extending from the north-east shore to approximately 400 m into the lake. There is a boat dock on the south-west end of the lake. The north, east and west shores had steep drop-offs and boulders near shore. The south shore of the lake has a gradual slope, and there are four narrow shallow bays on the south-east side of the lake that are primarily depositional habitat.

Moore (1978) encountered lake trout and Arctic char in Fingers Lake. Fish capture data has not been collected for Fingers Creek.

3.0 STUDY DESIGN

This section provides a brief overview of the Lupin EEM Study Design, as well as the required components of the First Biological Monitoring Study. In addition, the information in this section includes any deviations in the approved study design (Golder 2004 and 2005). Each component and deviation of the First EEM Study Design was approved by either the TAP, prior to the start of the 2005 sampling program, or the Authorization Officer (AO) during the 2005 sampling program (Appendix A).

3.1 Components of the Biological Monitoring Study

The objective of the MMER EEM biological monitoring program is to determine whether mine effluent is having a significant impact on fish, fish habitat or the use of fisheries resources. Depending on effluent conditions, there are two possible components of the EEM Biological Monitoring Program:

- a benthic invertebrate community survey; and,
- a fish survey, consisting of a fish population study and a fish tissue study.

According to the MMER EEM requirements, Kinross was required to complete a benthic invertebrate study and a fish population study because the mine effluent concentration in the exposure area was greater than 1% within 250 m of the FDP. Kinross was not required to complete a mercury study for fish tissues because the concentration of mercury in the TCA and discharged effluent was below the MMER limit of 0.10 µg/L (Appendix B). The TAP requested that liver and muscle tissues from Arctic grayling be collected for possible copper analysis, pending the results of the fish population survey (Appendix A).

3.1.1 Benthic Invertebrate Community Survey

The biological monitoring component of the MMER EEM program requires an evaluation of the effects of mine effluent on fish habitat, which is determined by examining the BIC structure. The information collected as part of this study included benthic invertebrate taxonomic enumeration, sediment particle size, water quality, and limnology.

Sampling was completed in the exposure (Seep Creek Ponds) and reference (Fingers Lake) areas. The original study design proposed the use of Concession Lake as the reference area, however, appropriate habitat within Concession Lake could not be identified; therefore Fingers Lake was sampled. The survey investigated whether the

mine effluent affected the BIC, using several community descriptors (density and richness) and indexes (Simpson's Diversity Index [SDI], Evenness, and Bray-Curtis Index [BCI]). Detailed methods are provided in Section 5.0 of this report.

Supporting environmental variables, including sediment quality from BIC stations and water quality from BIC and fish survey stations, were measured within the exposure and reference areas. Detailed sampling methods and results are presented in Section 4.0 of this report.

3.1.2 Fish Survey

The fish survey is a requirement of the MMER EEM program. Fish were collected from an exposure area (Seep Creek and Dam 1a Lake) and a reference area (Fingers Creek). The survey investigated whether the mine effluent affected the fish population, using several descriptors (age distribution, energy use and energy storage).

Juvenile Arctic grayling (*Thymalus arcticus*) and slimy sculpin (*Cottus cognatus*) were selected as the primary target sentinel species for a lethal sampling program. Ninespine stickleback (*Pungitius pungitius*) were to be a contingent target species under a non-lethal sampling program. However, in consultation with the AO, the fish study design was modified during the field survey to focus on juvenile Arctic grayling due to the low numbers of slimy sculpin and ninespine stickleback in the catch. The AO requested that 100 ninespine stickleback from the exposure area be measured for length and weight, and a sub-sample of 30 fish be examined for parasites. Due to the small size of fish collected in the sampling program, liver tissues were small and difficult to collect. In consultation with the AO, liver tissues were composited into approximately 2.0 g samples, and whole carcasses were preserved for future copper analysis. Detailed methods and results are provided in Section 6.0 of this report.

4.0 WATER QUALITY AND SEDIMENT QUALITY SURVEY

The goal of the EEM water quality and sediment quality survey was to generate supporting environmental data to aid in the interpretation of results of the biological monitoring survey, as well as provide a basis upon which chemical habitat within the study areas can be compared (EC 2002).

Water quality monitoring was conducted concurrently with fish and invertebrate surveys to monitor variables specified in Schedule 4 of the MMER (GC 2002). The Seep Creek and associated Dam 1a Lake and Ponds served as the exposure sites (Figure 4.1; Table 4.1) whereas Fingers Lake and Fingers Creek served as the reference sites (Figure 4.2; Table 4.2). *In situ* field measurements were conducted at each sampling location in the exposure area, and in Fingers Creek. Field measurements were not taken at the BIC stations in the reference area due to equipment malfunction. One composite sample for laboratory analyses was collected from each of the BIC survey reference and exposure areas. For the fish survey, one additional grab sample from Fingers Creek, and one grab sample from Dam 1a Lake were collected for laboratory analyses.

Physical and chemical information acquired from the sediment samples was also used to help characterize the benthic invertebrate habitat and identify potential confounding factors. Sampling was conducted at the benthic invertebrate sampling stations (Figures 4.1 and 4.2; Tables 4.1 and 4.2), concurrently with the BIC survey during the late summer of 2005.

4.1 Methods

4.1.1 Water Quality

4.1.1.1 Field Sampling and Measurements

Water samples in the reference and exposure areas were collected according to the methods outlined in the MMER technical guidance document (TGD) (EC 2002).

Grab water samples were collected at each BIC sampling site in the exposure and reference areas, approximately 0.2 – 0.5 m below the water surface. The grab samples were combined to form composite samples for the Seep Creek Ponds, and for Fingers Lake. A single grab sample was collected in each of the fish survey exposure (Dam 1a Lake, Site SCD1) and reference areas (Fingers Creek, Site FC2). The analytical laboratories provided pre-washed and sterilized sample bottles. When required, the appropriate preservatives were added in the field, and all samples were kept cool on ice until delivered to the analytical laboratory.

The following variables were measured in the field:

- water temperature;
- dissolved oxygen (DO);
- pH;
- conductivity;
- turbidity; and,
- air temperature.

Temperature, DO, and pH were measured with an Oakton™ 300 series meter, and conductivity with an Oakton™ TDS Testr 3. Air temperature was measured with a hand-held alcohol thermometer, and turbidity was measured with a LaMotte 2020 turbidity meter. In addition, all sampling sites were geo-referenced as Universal Transverse Mercator (UTM) and longitude-latitude coordinates with a hand-held GARMIN™ model 12 global positioning system (GPS) unit.

4.1.1.2 Laboratory Analysis

Major ions and total and dissolved metals were analysed by the Alberta Research Council (ARC) Laboratory in Vegreville. All other variables were analysed by Enviro-Test Laboratories (ETL) in Edmonton.

Water samples were analysed for the following variables:

- deleterious substances listed in Schedule 4 of the MMER (i.e., arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids, and radium-226);
- nutrients and carbon (i.e., ammonia, nitrite and nitrate, total phosphorus, total organic carbon, and dissolved organic carbon);
- physical characteristics (i.e., pH, conductivity, alkalinity and total hardness, total and dissolved metals); and,
- major ions (i.e., chloride, calcium, magnesium, potassium, sodium, sulphate).

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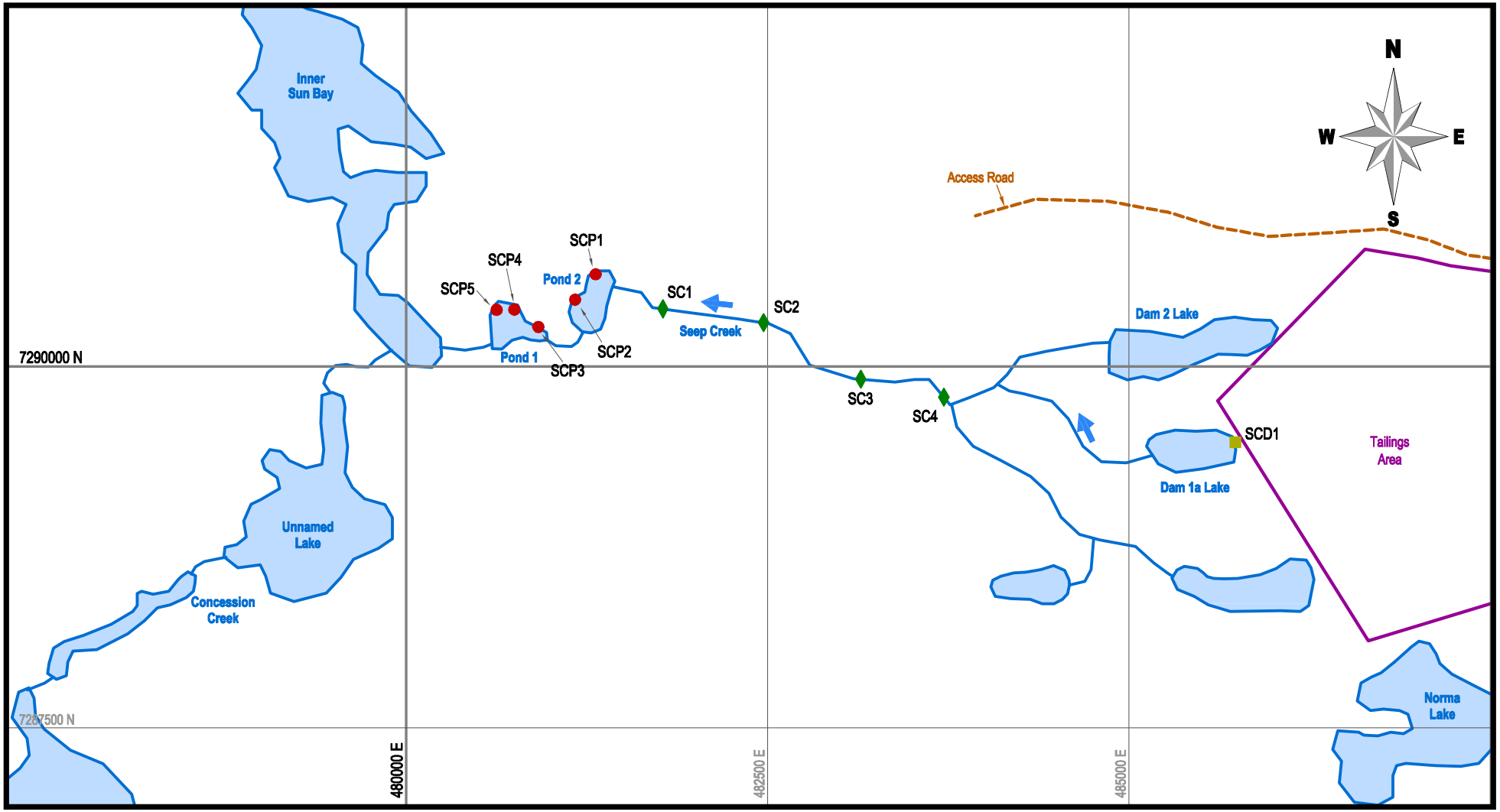

LEGEND

- Direction of flow
- Watercourse
- Water quality, field limnology, sediment
- Water quality, field limnology
- Field limnology

800 0 800
Scale Metres

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE
Water Quality, Field Limnology and Sediment in the Exposure Area Locations

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730634
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CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 4.1

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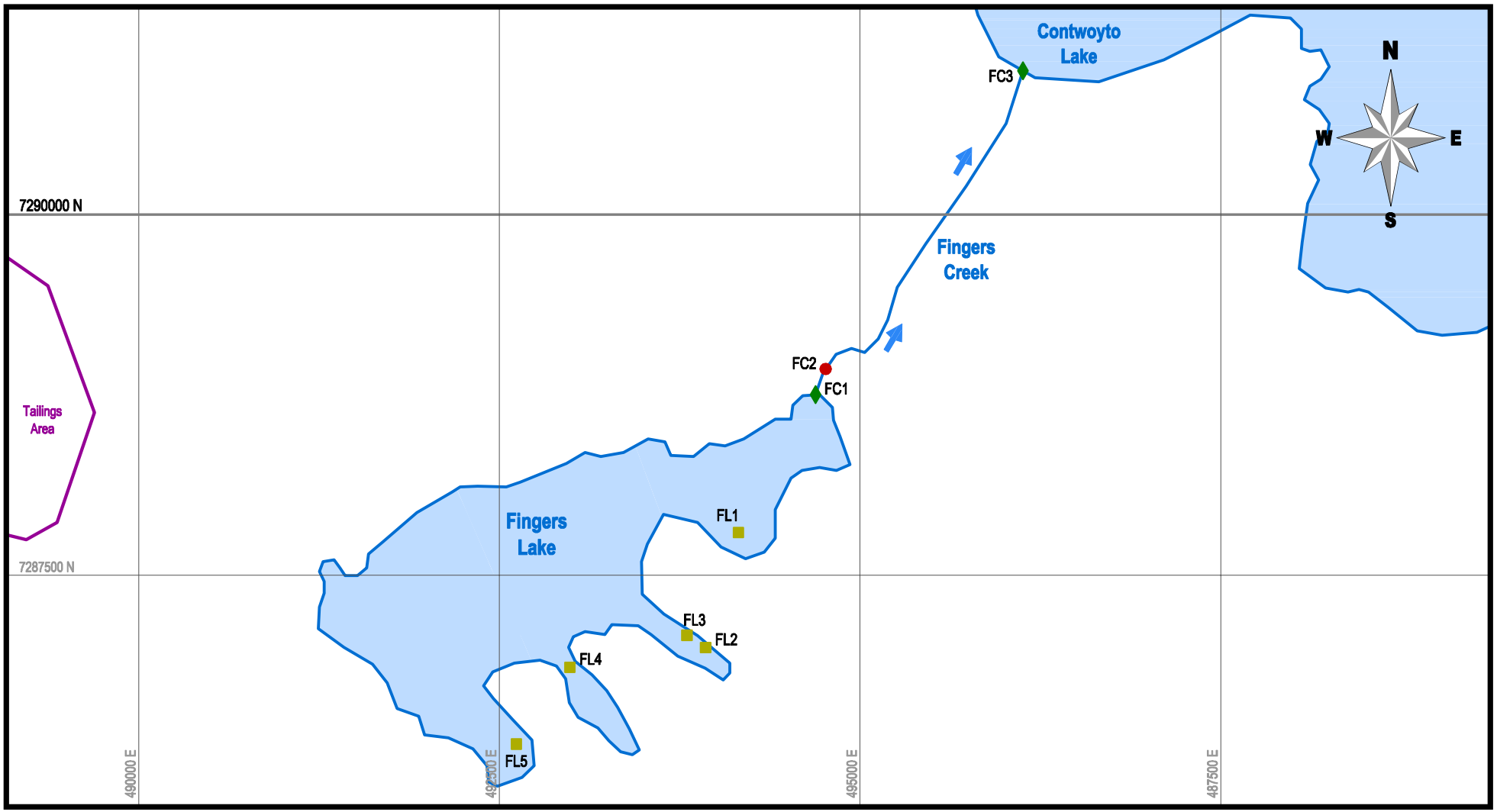

LEGEND

- Direction of flow
- Watercourse
- Water quality, field limnology
- Water quality, sediment
- Field limnology

800 0 800
Scale Metres

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Water Quality, Field Limnology and Sediment in the Reference Area Locations

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730634
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
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CHECK					
REVIEW					

Figure: 4.2

Table 4.1. Water quality sampling locations

Sample Type	Area	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
				Easting	Northing		
Fish Survey Limnology	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	485788	7289683	65° 41' 42.60" N	111° 18' 35.39" W
		Seep Creek 1 (SC1)	19-Aug-05	481435	7290663	65° 41' 13.42" N	111° 24' 17.57" W
		Seep Creek 1 (SC1)	22-Aug-05	481424	7290658	65° 44' 13.27" N	111° 24' 18.43" W
		Seep Creek 2 (SC2)	20-Aug-05	483174	7289998	65° 43' 52.32" N	111° 22' 00.70" W
		Seep Creek 3 (SC3)	25-Aug-05	483986	7289971	65° 43' 51.56" N	111° 20' 56.36" W
		Seep Creek 4 (SC4)	02-Sep-05	483917	7289948	65° 43' 50.88" N	111° 21' 02.34" W
	Reference	Fingers Creek, near mouth to Contwoyto Lake (FC3)	03-Sep-05	496327	7290999	65° 44' 26.16" N	111° 04' 48.36" W
		Fingers Creek (FC2)	27-Aug-05	494609	7288868	65° 43' 48.72" N	111° 06' 08.64" W
		Fingers Creek, at outlet to Fingers Lake (FC1)	05-Sep-05	494623	7288989	65° 43' 21.44" N	111° 07' 01.92" W
Invertebrate Survey Limnology	**Exposure**	Seep Creek Pond 2 (SCP1)	24-Aug-05	480913	7290274	65° 44' 00.78" N	111° 24' 58.28" W
		Seep Creek Pond 2 (SCP2)	05-Sep-05	480595	7290520	65° 44' 08.67" N	111° 25' 23.41" W
		Seep Creek Pond 1 (SCP3)	22-Aug-05	481268	7290730	65° 44' 15.58" N	111° 24' 30.71" W
		Seep Creek Pond 1 (SCP4)	24-Aug-05	481268	7290730	65° 44' 04.63" N	111° 25' 11.35" W
		Seep Creek Pond 1 (SCP5)	06-Sep-05	481252	7290713	65° 44' 15.04" N	111° 24' 31.90" W
Laboratory Water Quality Samples	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	485788	7289683	65° 41' 42.60" N	111° 18' 35.39" W
		Seep Creek Ponds composite	06-Sep-05	n/a	n/a	n/a	n/a
	Reference	Fingers Creek (FC2)	27-Aug-05	494609	7288868	65° 43' 48.72" N	111° 06' 08.64" W
		Fingers Lake composite	05-Sep-05	n/a	n/a	n/a	n/a

Notes: n/a=not applicable

Table 4.2. Sediment sampling locations

Sample Type	Area	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
				Easting	Northing		
Sediment Quality Samples	**Exposure**	Seep Creek Pond 1 (SCP3)	24-Aug-05	480913	7290274	65° 44' 15.58" N	111° 24' 30.71" W
		Seep Creek Pond 1 (SCP4)	24-Aug-05	480748	7290394	65° 44' 04.63" N	111° 25' 11.35" W
		Seep Creek Pond 1 (SCP5)	24-Aug-05	480595	7290520	65° 44' 15.04" N	111° 24' 31.90" W
		Seep Creek Pond 2 (SCP1)	24-Aug-05	481252	7290713	65° 44' 00.78" N	111° 24' 58.28" W
		Seep Creek Pond 2 (SCP2)	24-Aug-05	481109	7290489	65° 44' 08.67" N	111° 25' 23.41" W
	Reference	Fingers Lake (FL1)	01-Sep-05	492619	7286326	65° 41' 54.98" N	111° 09' 38.63" W
		Fingers Lake (FL2)	01-Sep-05	492927	7287021	65° 42' 17.46" N	111° 09' 14.62" W
		Fingers Lake (FL3)	01-Sep-05	493930	7286995	65° 42' 16.69" N	111° 07' 55.67" W
		Fingers Lake (FL4)	01-Sep-05	494157	7287794	65° 42' 42.51" N	111° 07' 38.29" W
		Fingers Lake (FL5)	01-Sep-05	493801	7287081	65° 42' 19.46" N	111° 08' 06.10" W

4.1.1.3 Quality Assurance and Quality Control

Quality assurance for the water sampling program included the use of field and trip blanks that were analysed identical to test samples. These blanks are used to detect potential sample contamination during collection, shipping, and analysis. Field blank samples were prepared during field sampling by filling a set of sample bottles with deionized water and adding appropriate preservatives, as done for test samples. A trip blank is an analyte-free sample (usually containing deionized water), supplied by the laboratory in the same type of container as for field samples, that is transported to field sampling sites and returned to the laboratory unopened.

Field equipment were calibrated frequently, and all samples were collected by experienced personnel following standard protocols. Concentrations of water quality variables were considered significant in blanks if they were greater than five times the corresponding method detection limit (MDL).

4.1.2 Sediment Quality

Sediment samples were collected concurrently with the BIC samples. All sediment samples were collected at a water depth ranging between 0.5 to 1.0 m. Five sub samples were collected at each of the five BIC replicate stations using a core sampler (diameter 67 mm). At each replicate station, the five subsamples were combined into a single composite sample. The sample represented the top 4 cm of sediment at each BIC replicate station. These samples were submitted to Enviro-Test Laboratories for a metal scan, total organic carbon (TOC), content, and particle size determination to the following classification:

- gravel (2 to 16 mm);
- course sand (0.2 to 2 mm);
- fine sand (0.062 to 0.2 mm);
- silt (0.0039 to 0.062 mm); and,
- clay (<0.0039 mm).

Samples were stored in sterile sediment polyethylene bags, double bagged and double labeled with waterproof ink, then frozen for shipment to Enviro-Test Laboratories.

4.2 Results

4.2.1 Water Quality

4.2.1.1 Field Measurements

Overall, water depth and flow rates were low at the reference (Fingers Creek) and exposure creek (Seep Creek) sampling sites (Table 4.3). Mean depth at the exposure creek station ranged from 0.10 to 0.20 m with current velocities of 0.10 to 0.20 m/s and discharge rates of 0.03 to 0.20 m^3/s. Mean depth was 0.10 m at the reference creek station with a current velocity 0.09 m/s and a discharge rate of 0.01 m^3/s. Wetted channel width was greater at exposure sites than at the reference sites. For lentic sites, water depths were slightly lower in the exposure area (Dam 1a Lake and Seep Creek Ponds 1&2) than in the reference area (Fingers Lake) (Table 4.3).

Table 4.3. Summary of physical characteristics of sampling sites

Area	Station	Wetted Width (m)	Bankfull Width (m)	Water Depth (m)		Velocity (m/s)		Discharge (m^3/s)
				Mean (±SD)	Range	Mean (±SD)	Range	
Exposure	Dam 1a Lake (SCD1)	n/a	n/a	0.50 ± 0.09	0.4 - 0.62	n/a	n/a	n/a
	Seep Creek (SC1)	4	4	0.10 ± 0.09	0.0 - 0.21	0.20 ± 0.16	0.0 - 0.47	0.1
	Seep Creek (SC2)	4.4	7.2	0.10 ± 0.09	0.0 - 0.28	0.06 ± 0.09	0.0 - 0.25	0.04
	Seep Creek (SC3)	3	4.7	0.20 ± 0.11	0.0 - 0.32	0.03 ± 0.03	0.0 - 0.08	0.03
	Seep Creek (SC4)	3	4.5	n/a	n/a	n/a	n/a	n/a
	Seep Creek Ponds 1&2[1]	n/a	n/a	0.39 ± 0.13	0.28 - 0.62	n/a	n/a	n/a
Reference	Fingers Creek (FC2)	0.97	1.25	0.10 ± 0.05	0.0 - 0.13	0.09 ± 0.14	0.0 - 0.39	0.01
	Fingers Lake[1]	n/a	n/a	0.94 ± 0.21	0.8 - 1.30	n/a	n/a	n/a

Note: n/a = not applicable; [1] Mean of five sampling stations (see Figures 4.1 and 4.2).

Air temperature during the survey period ranged from 2 to 18°C. Water temperatures ranged from 4.7 to 13.6°C at the exposure stations and from 7.7 to 13.4°C at the reference stations (Appendix C). All DO concentrations were well above the Canadian Water Quality Guideline (CWQG) minimum concentration of 6.5 mg/L for the protection of aquatic life (CCME 2005).

Conductivity at exposure stations varied considerably, but was much higher than at the reference stations (Table 4.4). Similarly, turbidity varied among stations, but was lower in the reference area than in the exposure area. Water pH was slightly acidic both in the exposure and reference areas, and ranged from 5.3 to 5.9. These pH values were non-

compliant with the CWQG, but were typical of the range of pH values in Nunavut barrenlands waterbodies reported by RCPL and RL&L (1985).

Due to equipment malfunction, field limnology measurements are not available for Fingers Lake. Although slightly higher than field values, laboratory-determined pH and conductivity were similar between lake and creek samples in the reference area, and the exposure station nearest to the FDP (Dam 1a Lake) had higher conductivity and lower pH than the exposure stations farther downstream from the FPD (Seep Creek Ponds) (Appendix C).

4.2.1.2 Laboratory Analysis

Generally, concentrations of most water quality variables were higher in the exposure area than in the reference area (Appendix C). Within the exposure area, concentrations were typically higher at the sampling station nearest to the final discharge point (i.e., Dam 1a Lake) than at stations farther downstream (i.e., Seep Creek Ponds 1&2) (Appendix C).

Nitrate and ammonia concentrations were elevated in the exposure area nearest the FDP (Dam 1a Lake), and total phosphorus and nitrite were below the MDL in all samples (Appendix C). Nitrate concentrations were 5.7 mg/L in Dam 1a Lake, and declined to 0.4 mg/L in Seep Creek Ponds 1 & 2. In the reference area, nitrate was equal to, or below, the MDL (0.1 mg/L). Ammonia concentrations were 0.51 mg/L in Dam 1a Lake, and were below the MDL (less than 0.05 mg/L) in all other samples.

In the exposure stations and Fingers Creek, pH was below the CWQG (Appendix C). Concentrations of aluminum, arsenic, cadmium, copper, lead, nickel, and zinc in the exposure area were above the CWQG. All metal concentrations in the reference area were compliant with the CWQG (Appendix C). For most of these metals, the dissolved component (soluble form) accounted for greater than 70% of the total concentrations. Aluminum and arsenic concentrations exceeded the guidelines in the exposure station nearest the FDP, whereas lead was elevated in the exposure station furthest from the FDP (Table 4.5).

Table 4.4. Field-measured water quality variables

Survey	Area	Sampling Station	Date	Temperature (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Turbidity (NTU)
Fish Population	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	4.7	12.3	5.3	740	0.9
		Seep Creek 1 (SC1)	19-Aug-05	11	n/a	5.6	126	n/a
			22-Aug-05	10.8	n/a	n/a	n/a	0.6
		Seep Creek 2 (SC2)	20-Aug-05	n/a	n/a	n/a	n/a	n/a
		Seep Creek 3 (SC3)	25-Aug-05	9.8	11	5.6	130	0.56
		Seep Creek 4 (SC4)	02-Sep-05	8.4	11.4	5.3	120	n/a
	Reference	Fingers Creek (FC3)	03-Sep-05	7.7	10.6	5.3	120	n/a
		Fingers Creek (FC2)	27-Aug-05	13.4	10.3	5.7	10	n/a
		Fingers Creek (FC1)[1]	05-Sep-05	8.1	10.6	5.9	10	0.54
Benthic Invertebrate Community	**Exposure**	Seep Creek Pond 2 (SCP1)	24-Aug-05	12	n/a	5.8	200	0.91
		Seep Creek Pond 2 (SCP2)	05-Sep-05	13.6	11.7	5.7	130	2.36
		Seep Creek Pond 1 (SCP3)	22-Aug-05	10.8	n/a	5.9	110	n/a
		Seep Creek Pond 1 (SCP4)	24-Aug-05	n/a	n/a	n/a	n/a	1.46
		Seep Creek Pond 1 (SCP5)	06-Sep-05	12.1	11.2	5.9	90	n/a
		Seep Creek Ponds composite	06-Sep-05	n/a	n/a	n/a	n/a	2.36
	Reference	Fingers Lake composite[2]	05-Sep-05	n/a	n/a	n/a	n/a	0.67

Note: n/a = not available;[1] Data for this station used as surrogate for Fingers Lake sampling stations; [2] Composite sample from five sampling stations.

Table 4.5. Total and dissolved concentrations of water quality constituents that exceed CWQG in the exposure area

Variable	Unit	MDL	CWQG	Dam 1a Lake		Seep Creek Ponds 1&2	
				Total	Dissolved	Total	Dissolved
Aluminum	µg/L	2	100	**110**	92.1	72.4	33.6
Arsenic	µg/L	0.04	5	**6.8**	3.78	2.93	2.1
Cadmium	µg/L	0.006	0.017	**0.411**	0.373	**0.0913**	0.0783
Copper	µg/L	0.1	2	**13.1**	12.2	**6.53**	5.15
Lead	µg/L	0.006	1	0.115	0.057	**1.39**	0.638
Nickel	µg/L	0.06	25	**133**	123	**28.4**	26.5
Zinc	µg/L	0.2	30	**314**	303	**40.4**	39.5

MDL = method detection limit; Concentrations of total metals above CWQG are bold and shaded.

4.2.1.3 Quality Assurance and Quality Control

Except for conductivity, constituents analysed in both field and trip blanks were below the quality criterion of five times the MDL. Thus it appears that contaminants were not introduced into samples during field sampling, shipping, or analysis (Appendix C).

Although conductivity values were higher than five times the MDL (0.2 µS/cm), the similarity between the field and trip blank values indicate that any potential contamination may be related to the deionized water supplied by ETL. Nonetheless, the elevated conductivity values should have negligible effect on the results, given the high field-measured values.

The pH in both blank samples differed from the expected 6.9 to 7.1 (range provided by ETL Lab), but this variation may be an artifact of analytical procedure, because the holding time for this variable was exceeded.

4.2.2 Sediment Quality

4.2.2.1 Particle Size and Total Organic Carbon

Particle size composition was uniform across the five reference stations. The particle size of sediment samples collected within the exposure area varied among stations, and generally had higher silt content compared to the reference samples. The texture of the exposure sediment samples ranged from silt to sandy loam. Reference sediment samples were composed primarily of sand (92.4 to 99.1%), with lesser contributions of silt and clay. Silt composition within the reference samples ranges from 0.7 to 6.7%, as compared

to silt composition in exposure samples, which ranged from 9.7 to 78.6% silt (Table 4.6; Appendix D).

TOC within the study area was low. TOC values within the exposure area ranged from 0.4% to 4.3% and were higher than the reference area (less than 0.1% to 0.4%) (Table 4.6; Appendix D).

Table 4.6. Physical and chemical characteristics of bottom sediments at benthic invertebrate replicate stations

Treatment	Station	Particle Size					TOC (%)
		Clay (%)	Silt (%)	Fine Sand (%)	Coarse Sand (%)	Gravel (%)	
Exposure	SCP1	5.5	78.6	7.3	8.6	0	2.6
	SCP2	1.8	61	29.6	7.6	0	0.5
	SCP3	4.6	48.6	4.6	42.2	0	4.3
	SCP4	0.8	22.7	52.4	24.1	0	0.4
	SCP5	1.2	9.7	49.9	39.2	0	0.4
	Mean	**2.8**	**44.1**	**28.8**	**24.3**	**0**	**1.6**
Reference	FL1	0.4	0.7	36.8	62.1	0	0.1
	FL2	1	4	45	50	0	0.2
	FL3	1	6.1	43.7	49.2	0	0.3
	FL4	0	0.9	45.4	53.7	0	<0.1
	FL5	0.9	6.7	34.4	58	0	0.4
	Mean	**0.7**	**3.7**	**41.1**	**54.6**	**0**	**0.2**

Note: TOC = total organic carbon

4.2.2.2 Metal Analysis

In general, metal concentrations were elevated within the exposure area as compared to the reference area. Sediments collected within the exposure area had elevated levels of arsenic, barium, cobalt, chromium, copper, nickel, vanadium, and zinc relative to the reference area. Arsenic and chromium concentrations exceeded the ISQG for the protection of aquatic life at a number of sample stations. Arsenic concentrations were above the ISQG (5.9 mg/kg) at all exposure stations, as well as one station within the reference area (Table 4.1; Appendix D). Arsenic concentrations at stations within the exposure area ranged from 9.6 mg/kg to 45.6 mg/kg. Chromium concentrations were above the ISQG sediment guidelines (37.3 mg/kg) for two stations within the exposure area. Exposure Stations SCP1 and SCP3 had chromium values of 64.9 and 57.5 mg/kg, respectively. The arsenic concentration at FL1, within the reference area, was slightly higher than the ISQG, with a value of 7.0 mg/kg (Table 4.7; Appendix D).

Table 4.7. Sediment Quality Metal Concentrations Exceeding ISQG

Variable	Unit	MDL	ISQG	Area	Station	Concentration
Arsenic	mg/kg	0.2	5.9	Reference	FL1	7.0
				Exposure	SCP1	45.6
					SCP2	17.6
					SCP3	38.9
					SCP4	9.6
					SCP5	18.3
Chromium	mg/kg	0.5	37.3	Exposure	SCP1	64.9
					SCP3	57.5

Note: MDL=method detection limit; ISQG=Interim Sediment Quality Guideline (CCME 2005)

4.3 Summary

Generally, the physical environment was similar in the exposure and reference areas. Seep Creek and Fingers Creek were shallow, with low flow. Fingers Lake was deeper than Dam 1a Lake and Seep Creek Ponds 1 & 2.

The pH was slightly acidic in both reference and exposure stations. Conductivity was higher in the exposure area than in the reference area, and decreased with distance from the FDP.

Nitrate was elevated in the exposure area, with a higher concentration near the FDP (Dam 1a Lake) than farther downstream (Seep Creek ponds). Ammonia was slightly elevated in Dam 1a Lake. Total phosphorus and nitrite were at or below the MDL in all samples.

In general, water quality variables were elevated in the exposure area relative to the reference area. Aluminum, arsenic, cadmium, copper, lead, nickel and zinc exceeded the CWQG in the exposure water quality samples.

Sediment samples were collected from the benthic invertebrate sample stations in depositional habitats. Exposure sediments were composed of sand and silt, whereas reference sediments consisted of mainly sand, with little silt or clay.

Sediment quality variables were elevated in the exposure area relative to the reference area. Sediment arsenic concentrations in the exposure area, and one reference sample exceeded the ISQG for the protection of aquatic life. Chromium exceeded the ISQG in two exposure sediment samples.

5.0 BENTHIC INVERTEBRATE COMMUNITY SURVEY

The BIC in Fingers Lake (reference area) and Seep Creek Ponds 1 & 2 (exposure areas) were surveyed in 2005 to meet MMER EEM requirements. The objective of the BIC survey was to provide sufficient data to determine whether the Mine effluent has had a significant negative effect on the BIC within the aquatic receiving environment. Supporting environmental variables (limnology, water quality, and sediment) were collected at each replicate station.

5.1 Methods

5.1.1 Field Methods

5.1.1.1 Benthic Invertebrate Community

Benthic invertebrate sampling occurred concurrently with the sediment quality survey on 24 August and 1 September 2005. Sampling station suitability was verified before samples were collected by checking water depth and substrate characteristics. Attempts were made to standardize physical habitat between stations to the maximum extent possible. Due to the boulder substrate and lack of suitable depositional material within the originally identified reference area (Concession Creek and Concession Lake), Fingers Lake was selected as an alternate reference area.

As outlined in the TAP approved study design, both the exposure and reference areas contained five replicate stations in depositional habitats (Table 5.1). Replicate stations were spaced approximately 100 m apart (Figures 5.1 and 5.2). At each replicate station, five benthic sub-samples were collected from within a 100 m^2 area. Benthic sub-samples were collected using an Ekman grab, with an area of 0.0232 m^2, following procedures outlined in the EEM guidance document (EC 2002). These five sub-samples were combined into a single composite sample for a total sample area of 0.116 m^2. All benthic samples were collected at a water depth ranging between 0.3 to 1.3 m. Benthic samples were sieved in the field using a 243 µm mesh sieve bag, and preserved with 10% buffered formalin in one litre Nalgene containers. Samples were shipped in sealed coolers, to the Edmonton Golder office, then to J. Fedoruk & Associates Environmental Consultants of Redwater, Alberta, for enumeration and taxonomic identification.

Table 5.1. Benthic sampling station locations

Treatment	Sampling Station	Date	UTM (Zone 12W NAD 83)		Latitude	Longitude
			Easting	Northing		
Exposure	Seep Creek Pond 1 (SCP3)	24-Aug-05	480913	7290274	65° 44' 15.58" N	111° 24' 30.71" W
	Seep Creek Pond 1 (SCP4)	24-Aug-05	480748	7290394	65° 44' 04.63" N	111° 25' 11.35" W
	Seep Creek Pond 1 (SCP5)	24-Aug-05	480595	7290520	65° 44' 15.04" N	111° 24' 31.90" W
	Seep Creek Pond 2 (SCP1)	24-Aug-05	481252	7290713	65° 44' 00.78" N	111° 24' 58.28" W
	Seep Creek Pond 2 (SCP2)	24-Aug-05	481109	7290489	65° 44' 08.67" N	111° 25' 23.41" W
Reference	Fingers Lake (FL1)	01-Sep-05	492619	7286326	65° 41' 54.98" N	111° 09' 38.63" W
	Fingers Lake (FL2)	01-Sep-05	492927	7287021	65° 42' 17.46" N	111° 09' 14.62" W
	Fingers Lake (FL3)	01-Sep-05	493930	7286995	65° 42' 16.69" N	111° 07' 55.67" W
	Fingers Lake (FL4)	01-Sep-05	494157	7287794	65° 42' 42.51" N	111° 07' 38.29" W
	Fingers Lake (FL5)	01-Sep-05	493801	7287081	65° 42' 19.46" N	111° 08' 06.10" W

5.1.1.2 Supporting Environmental Variables

Limnology and Water Quality

Field water quality parameters were measured within the exposure area (Seep Creek Ponds 1 & 2), but not within the reference area (Fingers Lake) due to equipment malfunction.

Water samples in the reference and exposure areas were collected according to the methods outlined in the MMER TGD (EC 2002). Samples were analysed for metals, deleterious substances, major ions, and nutrients. Detailed methods and results are provided in Section 4.0 of this report. A summary of the results is provided below to provide information regarding the supporting environmental variables associated with the BIC habitat.

Sediment

Sediment samples were collected concurrently with the BIC samples. One sediment sample, composed of five subsamples, was collected at each replicate station using a core sampler (diameter 67 mm) for metal analysis, TOC content, and particle size determination. Detailed methods and results are provided in Section 4.0 of this report. A summary of the results is provided below to provide information regarding the supporting environmental variables associated with the BIC habitat.

5.1.1.3 Field QA/QC

Specific work instructions outlining each field task in detail were provided to field personnel by the task manager prior to the field program. Samples were collected by experienced personnel, and were collected, labelled, preserved, and shipped according to EC (2002). Detailed field notes were recorded in waterproof field notebooks and on pre-printed waterproof field data sheets. Sample jars were labelled in waterproof ink, and a second waterproof label was inserted into each jar. Data collected during the field survey underwent a variety of individual quality assurance checks. Field data sheets were checked at the end of each day for completeness and accuracy. Chain-of-Custody forms were used to track sample shipment from the field, to the Edmonton Golder office, and finally to the taxonomist.

5.1.2 Laboratory Analyses

5.1.2.1 Benthic Invertebrate Community

Due to large sample size and large amounts of organic debris, two composite BIC samples (FL3 and SCP5) were divided into 1.0 mm, 500 µm and 250 µm fractions, which were all sub-sampled using standard taxonomic methods. The remaining composite BIC samples were divided into coarse (500 µm) and fine (250 µm) fractions. The coarse fraction was sorted and fine fractions were sub-sampled as outlined in the MMER TGD (EC 2002).

Invertebrates were identified to the lowest practical taxonomic level (typically to the family level), using current literature and nomenclature. Organisms that could not be identified to the desired level (e.g., immature or damaged specimens) were reported as a separate category, at the lowest level of taxonomic resolution possible, typically family. Organisms that required detailed microscopic examination for identification (e.g., Chironomidae and Oligochaeta) were mounted on microscope slides using an appropriate mounting medium (i.e., Hoyers'). The most common taxa were distinguishable based on gross morphology, and required only a few mounts (5 to 10) as checks. All rare or less commonly occurring taxa were mounted for identification. A reference collection was prepared, consisting of several representative specimens from each taxon.

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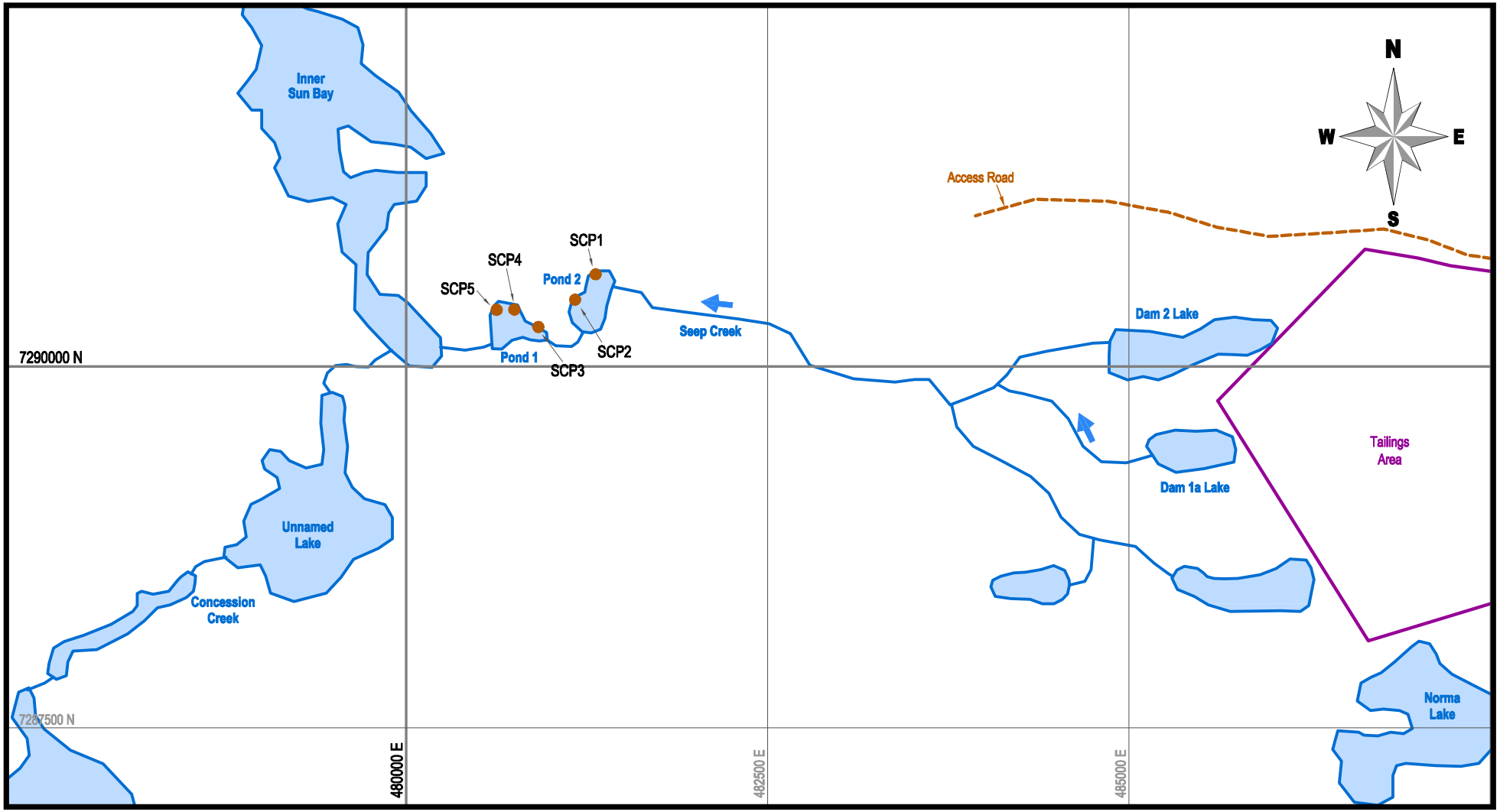


LEGEND

- Direction of flow
- Watercourse
- Benthic invertetrate community sampling station

800 0 800

Scale Metres

PROJECT

Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE

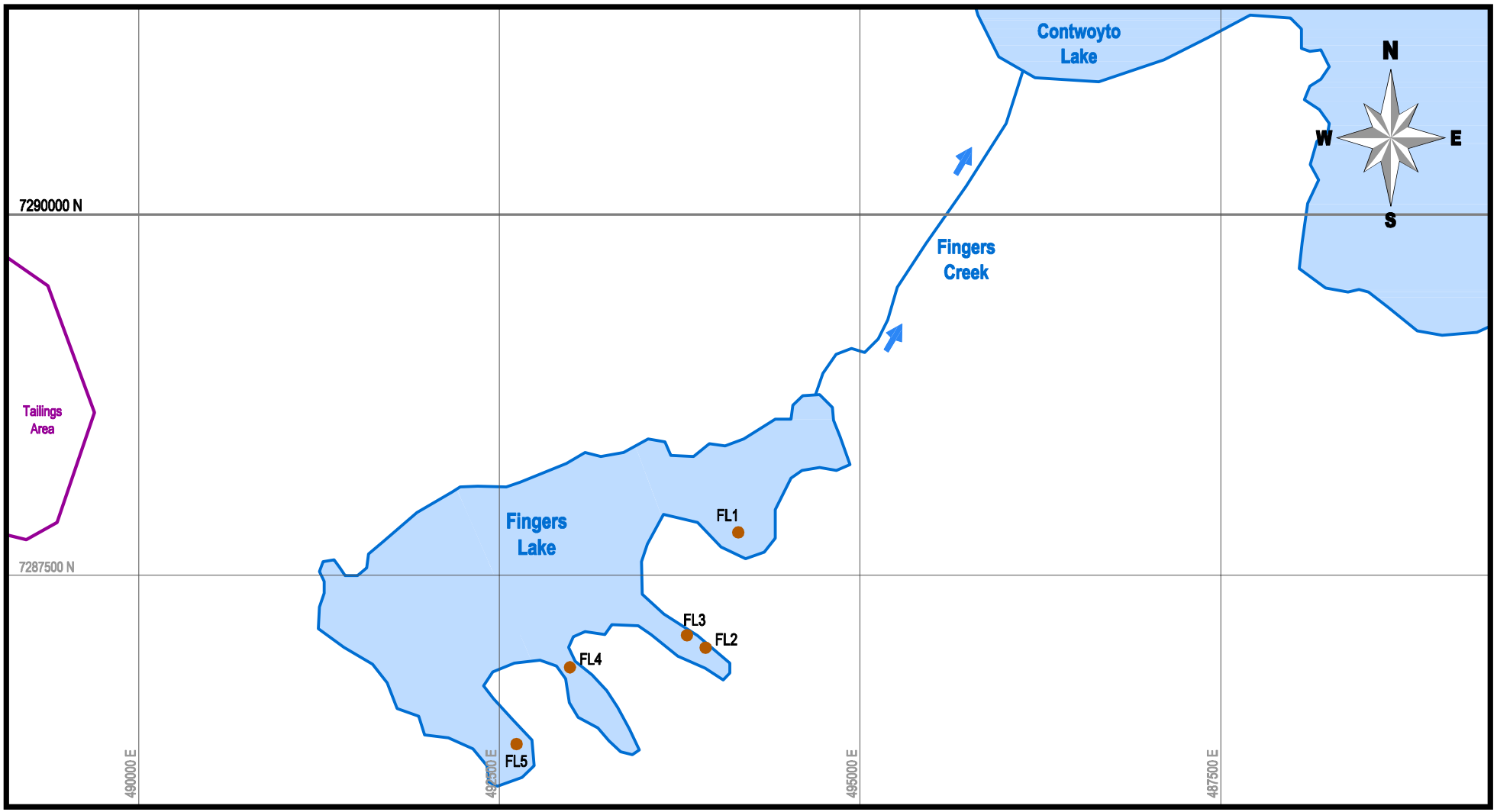
Benthic Invertetrate Community Sampling Stations in the Exposure Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730636
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 5.1

Drawing path and name: R:\CAD\2005\1370-Edmonton\1373-ES\05-1373-019\5.2 - 1730637 benthicSamples.dwg Jun. 2, 2006 (4:37 PM)



LEGEND

- Direction of flow
- Watercourse
- Benthic invertetrate community sampling station

800 0 800
Scale Metres

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Benthic Invertetrate Community Sampling Stations in the Reference Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730637
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 5.2

5.1.2.2 Benthic Invertebrate Taxonomist QA/QC

QA/QC for laboratory work consisted of verifying invertebrate removal efficiency and taxonomic identification. Identification of specimens was conducted by one person (Joanna Fedoruk). As part of standard quality control measurements, one sample (10% of all samples) was re-sorted. A removal efficiency of greater than 90% was considered acceptable. QA/QC results are presented and discussed in Appendix E.

5.1.3 Data Analysis

5.1.3.1 Data Entry and Screening

Taxonomic data were received from the taxonomist in both electronic format and hard copy. A quality control check was completed between the hard copy and the electronic data to verify no transcription errors. Supporting invertebrate community survey data from the field were added to the electronic taxonomy data, and the complete dataset was imported into the Golder Associates electronic database. All non-benthic organisms were removed from the dataset and recorded for future reference. Data from the 500 µm fraction were used in all analyses. Raw data for the 250 µm fraction are provided in Appendix E.

Data were entered into an Excel spreadsheet, and results were converted to individuals per square metre area. Converted results were used for the calculation of the following community descriptors and biotic indices at the family level:

- total invertebrate density;
- taxon richness;
- Simpson's Diversity Index (SDI);
- Bray-Curtis Index (BCI);
- evenness;
- taxon density;
- taxon proportion; and,
- taxon presence/absence.

Calculations of the community descriptors and biotic indices were based on the formulas provided in the MMER TGD (EC 2002).

Density was calculated as the number of organisms per square metre.

Richness is the total number of taxonomic groups within a station, at the family level. Richness provides an indication of the diversity of benthic invertebrates in an area; a higher richness value usually indicates a more healthy and balanced community.

Evenness is a measure of the relative abundance of the different species making up the richness of an area.

SDI measures the proportional distribution of organisms in the community, given that not all organisms have the same success in the environment, since certain conditions may favour or affect one organism over another. SDI values range between 0 and 1, where lower values indicate a community dominated by fewer taxonomic groups (less diverse); these are often referred to as stressed communities, which may be caused by natural and/or anthropogenic conditions. High values indicate a community consisting of more taxa that are more evenly distributed among the taxonomic groups.

The above indices are measures of total density and taxon richness, but do not take into account any quantitative information on the types of organisms present. Therefore, the ***BCI***, which is a dissimilarity index, was calculated to compare entire communities among sampling areas. The BCI summarizes the overall difference in community structure between the reference and exposure stations. BCI values range between 0 and 1, where lower values indicate that the community in the exposure area is similar to the reference community.

5.1.3.2 Statistical Analyses

An effect on the BIC was determined if there were statistical differences in any of the following endpoints:

- total invertebrate density;
- family richness;
- BCI;
- SDI; and
- evenness

The following descriptors were calculated, and are included as supporting variables (i.e., they are not statistically analyzed to determine “effects”):

- major family density;
- family proportion; and,
- family presence/absence.

Summary statistics for each descriptor (i.e., arithmetic mean, median, minimum, maximum, standard deviation, standard error, and sample size) were calculated and summarized by area.

Statistical analyses were conducted on total density, richness, and index data calculated for each replicate station. With the exception of the raw total invertebrate density data, the data met the assumptions of normality and equality of variances. Total invertebrate density was log-transformed to meet the assumptions for statistical analyses.

A two-sample *t*-test was used to determine whether there was a statistically significant difference in density and richness between the two sampling areas (α=0.1). A Mann-Whitney *U* test was used to determine whether there was a statistically significant difference in the derived endpoints (evenness, BCI and SDI). As stated in the study design, non-parametric analyses are more appropriate for derived variables due to the unusual statistical properties of these types of variables (Golder 2004). Statistical tests were run using PC-Ord™ version 4.0 and SSPS™ version 14.0 software packages.

Power Analysis

Retrospective power analysis was conducted for each invertebrate community variable with the statistical software package SYSTAT version 11.0. To estimate power, effect size was set to ±2SD and sample size (i.e., number of stations per area) was set to five, corresponding to the number of stations sampled per area during this study. Power was estimated for both α and β set at 0.05 and 0.1.

5.1.3.3 Data QA/QC

Data entered into the Golder Associates database underwent a 10% check for accuracy by a second person not involved in the initial entry process. All tables and data sets generated by the database underwent an additional 10% QA/QC screening.

5.2 Results

5.2.1 Supporting Environmental Variables

Limnology and Water Quality

Limnology variables were measured in the exposure and reference exposure areas. The pH values in the exposure and reference areas were non-compliant with the CWQG, but were typical of the range of pH values in Nunavut barrenlands waterbodies reported by RCPL and RL&L (1985). The laboratory measured pH in the exposure area (6.1) was

lower than the reference area (6.5). Conductivity in the exposure sample (141 µS/cm) was higher than in the reference sample (14.8 µS/cm) (Table 4.4).

Nitrate concentrations were higher within the Seep Creek Ponds than in Fingers Lake. Ammonia, nitrite and total phosphorus concentrations were at or below the detection limit for both reference and exposure areas (Appendix C).

In general, metal concentrations were elevated in the BIC exposure area compared to the reference area. Metal concentrations did not exceed the CWQG in the reference area. In the BIC exposure area, cadmium, copper, lead, nickel and zinc concentrations exceeded the CWQG for the protection of aquatic life (Appendix C).

Sediment Quality Monitoring

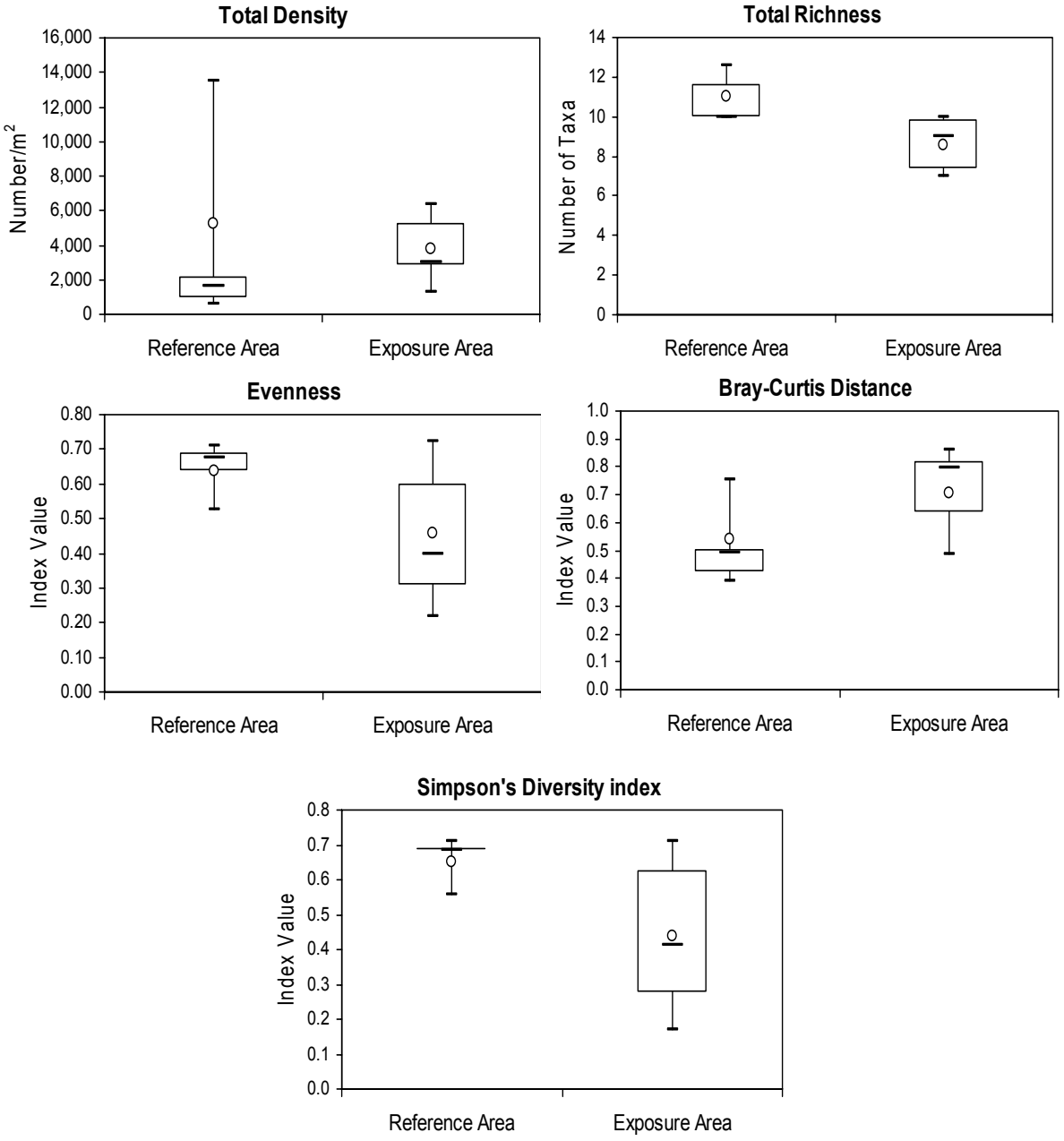
The texture of the exposure sediment samples ranged from silt to sandy loam. Reference sediment samples were composed primarily of sand, with lesser contributions of silt and clay. The particle size composition within the reference area generally had lower silt content compared to the exposure samples (Table 4.5; Appendix D). TOC values within the exposure area (mean of 1.6%) were higher than the reference area (mean of 0.3%).

In general, sediment metal concentrations were elevated within the exposure area as compared to the reference area. Arsenic concentrations were above the ISQG (5.9 mg/kg) at all exposure stations (range from 9.6 to 45.6 mg/kg), as well as one station within the reference area (7.0 mg/kg). Chromium concentrations were above the ISQG sediment guidelines (37.3 mg/kg) for two stations within the exposure area (64.9 and 57.5 mg/kg) (Table 4.6; Appendix D).

5.2.2 Data Screening

Results of taxonomic identification and enumeration are summarized as station means and standard deviations (Appendix E). Data screening, using box and whisker plots for total invertebrate density, family richness, evenness, SDI and BCI, identified potential outliers at some of the stations; however, data checks confirmed the validity of the data and thus no data were removed (Figure 5.3). The following results are based on mean values calculated for each of the five replicate stations in each area.

Figure 5.3. Box plots of benthic invertebrate effect endpoints



Box plot range: 30th and 70th percentiles
Error bar range: 10th and 90th percentiles
Open circles: means
Horizontal bars: medians

5.2.3 Statistical Analyses

5.2.3.1 Density

Mean total invertebrate density was higher in the reference area compared to the mean value from the exposure area (5107 and 3710 organisms/m^2, respectively) (Table 5.2; Figure 5.4). Mean density did not differ significantly between the two areas (*t*-test, $P>0.1$; Table 5.3).

5.2.3.2 Richness

Richness was similar between areas, ranging from three to six families in the exposure area and three to nine families in the reference area (Table 5.2; Figure 5.5). Richness was not significantly different between areas (*t*-test, $P>0.1$; Table 5.3).

5.2.3.3 Evenness

Evenness was lower in the exposure area (0.170) as compared to the reference area (0.308) (Table 5.2; Figure 5.6). The Mann-Whitney *U* test indicated that the difference between areas was significant at $\alpha = 0.1$, but non-significant at $\alpha = 0.05$ (Table 5.3).

5.2.3.4 Simpson's Diversity Index

The mean SDI value was lower in the exposure area (0.104) as compared to the reference area (0.226). The variation in the SDI among exposure stations was smaller than the variation among reference stations (Table 5.2; Figure 5.7). The difference in the mean SDI between areas was significant (Mann-Whitney *U* test, $P<0.05$; Table 5.3).

5.2.3.5 Bray-Curtis Index

The mean BCI for the reference area provided an indication of background variability within the reference area, since each station was compared to the median of the reference stations. The reference area displayed considerable variation in BCI values compared to the exposure area (Table 5.2; Figure 5.8). The BCI values were not significantly different between the exposure and reference areas (Mann-Whitney *U* test, $P>0.1$; Table 5.3).

Table 5.2. Summary statistics for invertebrate community variables for the exposure and reference areas

Endpoints	Seep Creek Ponds 1 & 2 (Exposure)						Fingers Lake (Reference)					
	Mean	Median	SD	SE	Min	Max	Mean	Median	SD	SE	Min	Max
Total Invertebrate Density (orgs/m^2)	3710	3045	2507.3	1121	387	6604	5107	1634	8612.5	3851.6	430	20459
Richness[a]	5	5	1.1	0.5	3	6	5	5	2.3	1	3	9
Evenness	0.17	0.191	0.087	0.019	0.064	0.291	0.308	0.344	0.102	0.023	0.158	0.422
SDI	0.104	0.086	0.069	0.015	0.032	0.21	0.226	0.238	0.101	0.023	0.097	0.323
BCI	0.498	0.593	0.155	0.069	0.307	0.64	0.417	0.351	0.315	0.141	0.069	0.867
Ceratopogonidae Density (orgs/m^2)	96	0	215.4	96.3	0	482	2	0	3.8	1.7	0	9
Chironomidae Density (orgs/m^2)	3478	2839	2307.2	1031.8	370	5847	4747	1419	8227.3	3679.4	353	19427
Enchytraeidae Density (orgs/m^2)	14	0	30.8	13.8	0	69	138	9	249	111.4	0	576
Lumbriculidae Density (orgs/m^2)	62	43	68.1	30.5	0	172	46	26	48.5	21.7	0	120

Note: [a]Family level richness; SD = standard deviation; SE = standard error; Min = minimum; Max = Maximum; samples size was five for all endpoints; orgs/m^2=organisms per square metre

Figure 5.4. Benthic invertebrate densities of major invertebrate families at each replicate station

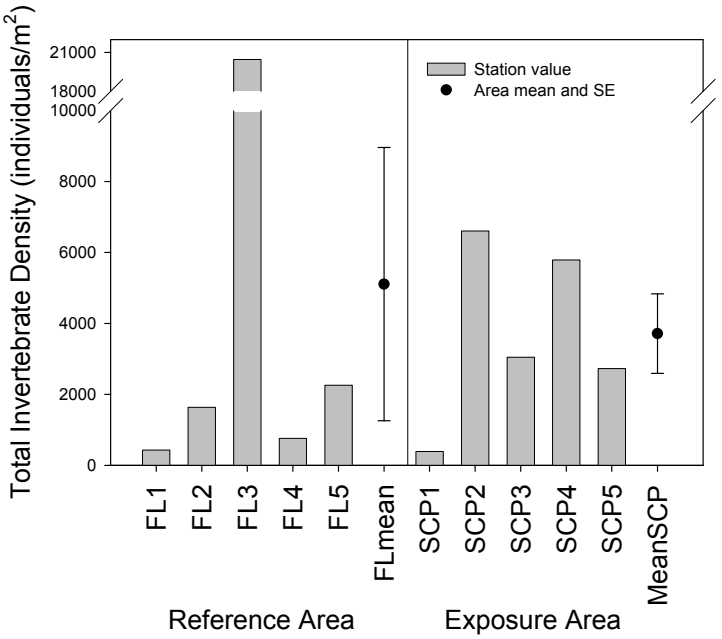


Figure 5.5. Benthic invertebrate richness of invertebrate families at each replicate station

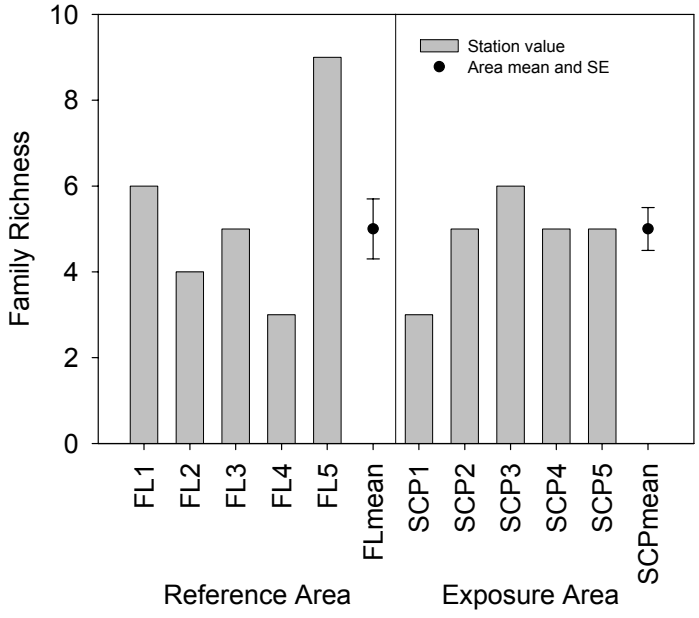


Figure 5.6. Evenness indices at each replicate station

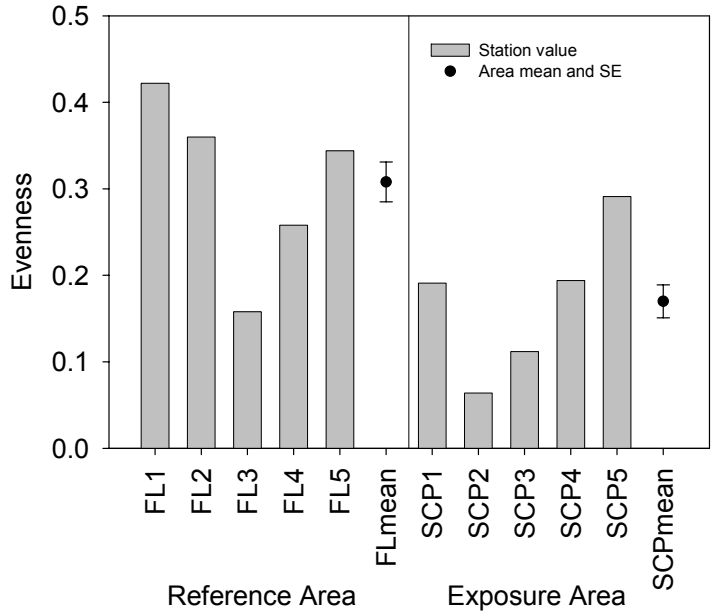


Figure 5.7. Simpson's diversity indices at each replicate station

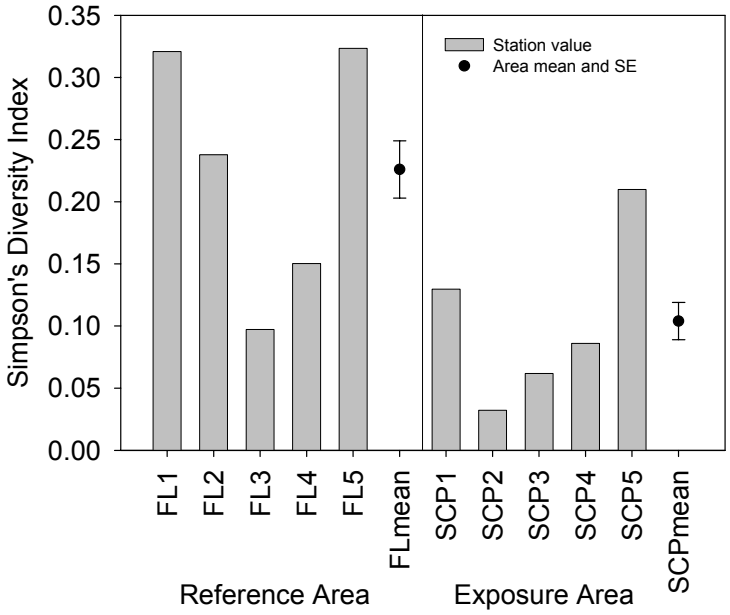
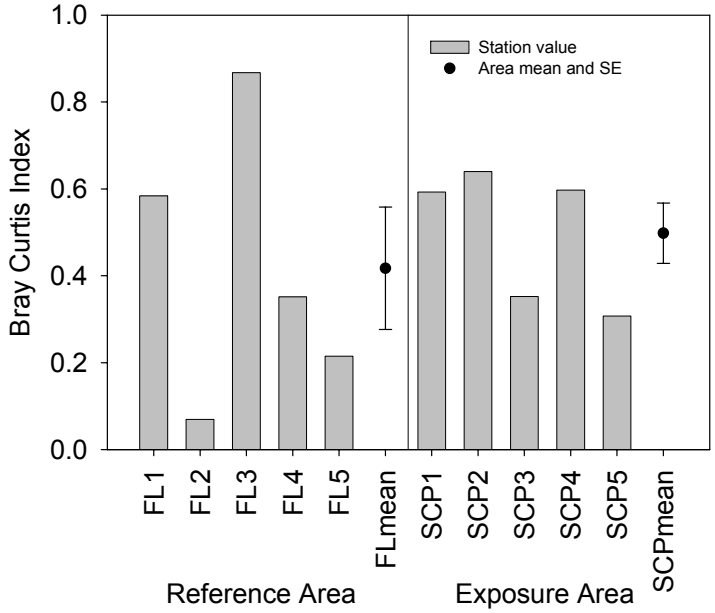


Figure 5.8. Bray-Curtis indices at each replicate station



5.2.3.6 Power Analysis

Power of the statistical tests comparing invertebrate community variables between the two sampling areas ranged from 0.93 to 0.99 for α=0.1, and 0.85 to 0.96 for α=0.05 (Table 5.3). These results suggest that the statistical tests met or exceeded the recommended EEM guideline of 90% power. To increase the power to 95%, seven replicates per area would be required.

Table 5.3. Statistical results summary for invertebrate community endpoints

Endpoint	*P*	Significant Difference Between Areas[a]	Estimated Power for T-test	
			α=β=0.1	α=β=0.05
Total Invertebrate Density	0.709	No	0.95	0.88
Family Richness	0.467	No	0.98	0.95
Simpson Diversity Index	0.047	Yes	0.96	0.91
Evenness Index	0.076	Yes	0.99	0.96
Bray-Curtis Index	0.347	No	0.93	0.85

Note: [a] Significant at $P \leq 0.1$

5.2.4 Community Analysis

5.2.4.1 Family Presence/Absence

In total, 10 benthic invertebrate families were encountered in the exposure area, whereas 11benthic invertebrate families were encountered in the reference area (Table 5.4). Families Aeolosomatidae and Heptageniidae were observed in the exposure area, but were not observed in the reference area. Ostracoda, and the families Sphaeriidae and Limnephilidae, were collected in the reference area, but not in the exposure area.

Table 5.4. Presence/Absence of each invertebrate family in the reference and exposure areas

Major Taxon	Family (Subfamily/Tribe)	Reference Area	Exposure Area
Oligochaeta	Aeolosomatidae		✓
	Enchytraeidae	✓	✓
	Lumbriculidae	✓	✓
Acari	Hydrachnidia	✓	✓
Pelecypoda	Sphaeriidae	✓	
Ostracoda	-	✓	
Ephemeroptera	Heptageniidae		✓
Tricoptera	Leptoceridae	✓	✓
	Limnephilidae	✓	
Diptera	Chironomidae	✓	✓
	**Chironomini	✓	✓
	**Tanytarsini	✓	✓
	*Orthocladiinae	✓	✓
	*Tanypodinae	✓	✓
	Ceratopogonidae	✓	✓
	Empididae	✓	✓
	Tipulidae	✓	✓

Note: ✓ = family present; * = Subfamily; ** = Tribe

5.2.4.2 Percent Composition

Community composition was summarized based on five groups: Chironomidae, Ceratopogonidae, Enchytraeidae, Lumbriculidae and others, representing the remaining groups (Figure 5.9). Both the reference and exposure stations were dominated by dipterans, primarily Chironomidae. The mean proportion of Chironomidae in the reference and exposure areas was 91% and 93%, respectively. None of the remaining 19 groups comprised more than 2% of the total density. The remaining groups varied in presence and proportion across all stations, with Enchytraeidae being the second most

abundant group (1.7% of total density). There were no significant differences in family density detected between exposure and reference areas (Table 5.5)

Figure 5.9. Percent composition of major invertebrate families at each replicate station

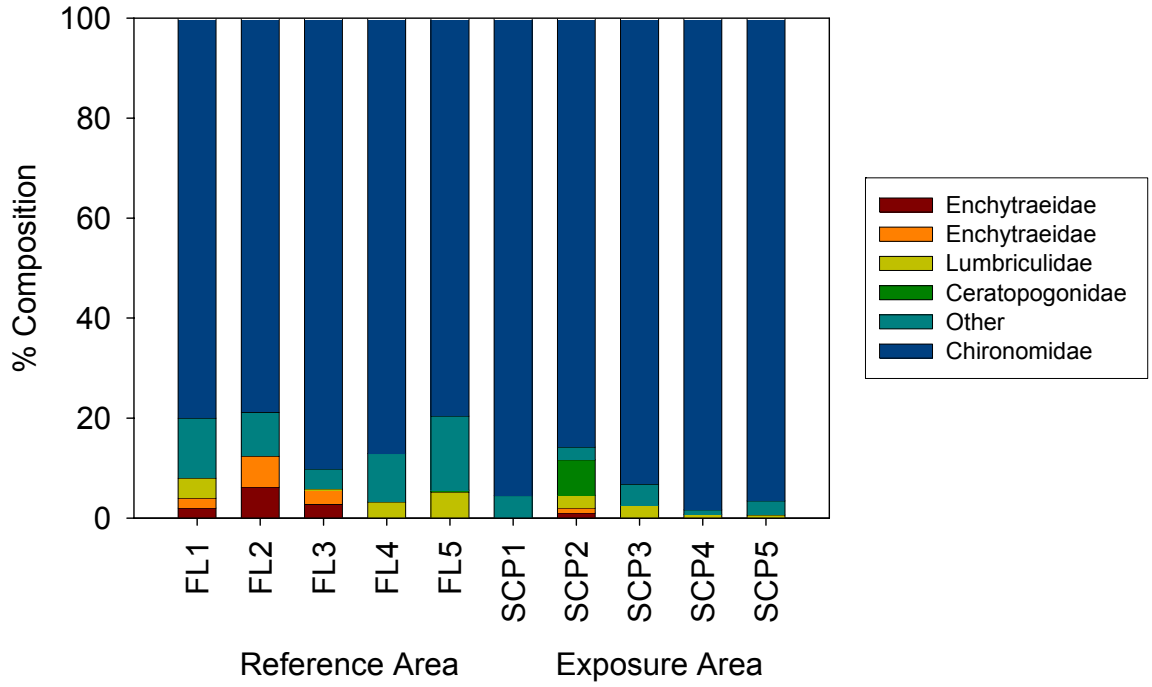


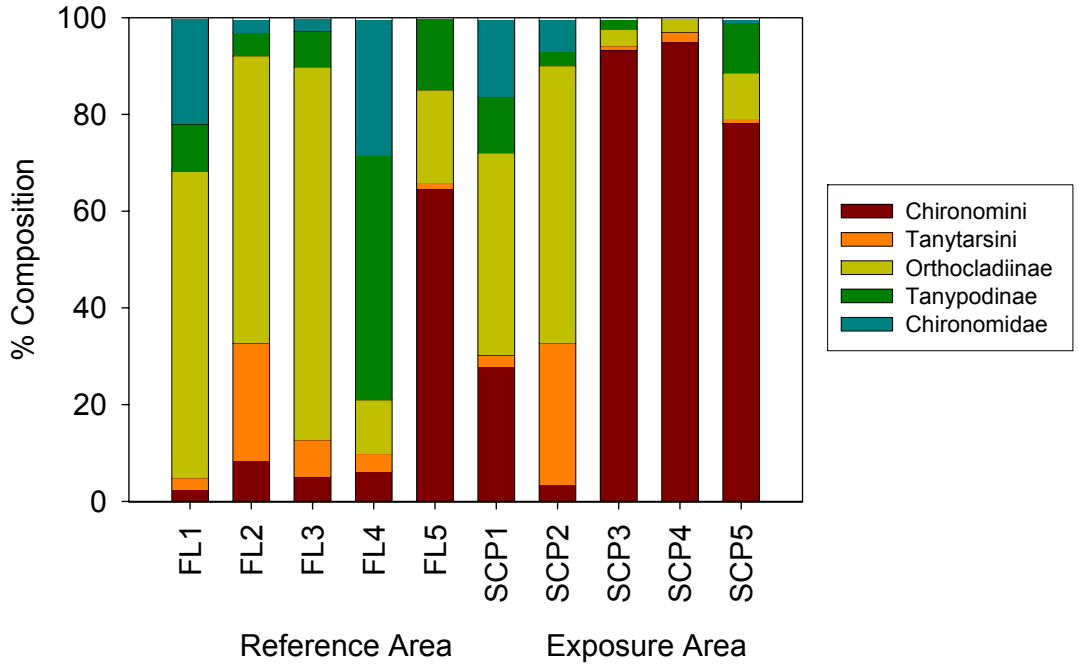
Table 5.5. Summary of Statistical Analyses for Benthic Invertebrate Families Surveyed

Endpoint	*P*	Significant Difference Between Areas[a]
Total Invertebrate Density	0.709	No
Chironomidae Density	0.649	No
Ceratopogonidae Density	0.568	No
Enchytraeidae Density	0.270	No
Lumbriculidae Density	0.878	No

Note: [a] Significant at $P \leq 0.1$

Individuals from the Chironomidae family were identified to subfamily or tribe, where possible. Four main subfamily/tribes were noted: Chironomini, Tanytasini, Orthocladinae, and Tanypodinae. The percentage of each subfamily/tribe varied among stations and between treatment areas (Figure 5.10).

Figure 5.10. Percent composition of chironomidae subfamilies and tribes at each replicate station



Families making up greater than 1% of the total abundance were analyzed statistically. These families included Chironomidae, Ceratopogonidae, Enchytraeidae, and Lumbriculidae. Mean density was not significantly different between areas for any of the surveyed families (*t*-test, $P<0.1$; Table 5.5).

5.3 Summary

Limnological field measurements (i.e., pH, conductivity, turbidity) were only recorded within the exposure area (Seep Creek Ponds 1 & 2). Due to the absence of the reference area field water quality, comparison betweens treatments were not possible; however, laboratory measured pH was lower in the exposure area than the reference area. Laboratory conductivity was higher in the exposure sample than in the reference sample (Table 4.3).

Nitrate concentration was slightly higher in the BIC exposure area than in the reference area. With the exception of selenium and mercury, concentrations of total metals tended to be higher in the exposure area compared to the reference area. In the BIC exposure area, cadmium, copper, lead, nickel and zinc concentrations exceeded the CWQG for the protection of aquatic life.

The substrate of the exposure area was composed primarily of silt and sand, whereas the substrate of the reference area was composed primarily of sand. Relative to the reference station, substrate particle size was more variable within the exposure area, with higher silt contributions. The higher TOC observed in the exposure stations may be linked to differences in basin morphologies (i.e., fingers Lake is larger than the Seep Creek Ponds).

Sediments collected within the exposure area had elevated metal concentrations compared to the reference area. Arsenic concentrations were above the ISQG at all exposure stations, as well as at Station FL1 within the reference area. Chromium concentrations were above the ISQG sediment guidelines for two stations within the exposure area.

Although BIC density was greater in the reference area than in the exposure area, differences were not statistically significant. Family richness was similar in both areas, and was not significantly different. BCI was more variable in the reference area, but was not significantly different from the exposure area. SDI and evenness were significantly lower in the exposure area than the reference area. The differences in SDI and evenness may be linked to the elevated arsenic and chromium concentrations in the exposure area sediments, and the elevated metal concentrations in the water column of the exposure area.

Based on the information collected during the BIC survey, mine effluent has had a low impact on the BIC within the aquatic receiving environment (Seep Creek Ponds 1 & 2) relative to the reference area (Fingers Lake). The mine did not significantly affect invertebrate density, family richness or BCI, but did significantly affect SDI and evenness.

6.0 FISH SURVEY

6.1 Survey Objectives

The fish community in Fingers Creek and Fingers Lake (reference area) and the Seep Creek system (exposure area) were surveyed in 2005 to meet MMER EEM requirements. The objective of the EEM fish population survey was to determine if mine effluent discharged into the aquatic environment had a significant effect on the growth, reproduction, survival, condition or usability of fish relative to fish populations in a reference area. Supporting environmental variables (limnology and water quality) were collected in each area.

6.2 Methods

As part of the revised TAP-approved study design, juvenile Arctic grayling (*Thymalus arcticus*) and slimy sculpin (*Cottus cognatus*) were selected as the primary target sentinel species for a lethal sampling program. Ninespine stickleback (*Pungitius pungitius*) was to be a contingent target species, under a non-lethal sampling program. Target sample sizes for each area were 40 juvenile Arctic grayling, and 60 slimy sculpin (20 adult males, 20 adult females, and 20 juveniles).

The field sampling schedule included a two-day reconnaissance survey in each of the reference and exposure areas to assess the presence of fish and spawning condition. However, seven days (including the two-day reconnaissance) of intensive fishing efforts in each of the study areas resulted in the capture of only two slimy sculpin from the reference area and none in the exposure area. Similarly, although several ninespine sticklebacks were captured in the exposure area, only one was captured in the reference area. Thus, due to the low numbers of slimy sculpin and ninespine stickleback, the fish study design was modified during the field survey, in consultation with the AO, to focus the EEM study on juvenile (age 1 or younger) Arctic grayling. Carcass and liver tissue from these juvenile Arctic grayling were frozen for copper analysis. In addition, ninespine stickleback from the exposure area were measured for length and weight, and a sub-sample was examined for parasites, as directed by the AO.

6.2.1 Field Methods

6.2.1.1 Fish Collection

Fish sampling was conducted in the Fingers Creek system (reference) and (Seep Creek system (exposure) from 19 August to 4 September 2005, using a variety of gear types

(Tables 6.1 and 6.2; Figures 6.1 and 6.2). To maximize fish capture, fish sampling was conducted in different habitat types and at different times of the day.

Table 6.1. Gill net, hoop net and fyke net locations

Method	Treatment	Station	UTM (Zone 12W NAD 83)		Latitude	Longitude
			easting	northing		
Gill net	Exposure	C1	479104	7292537	65° 45' 13.45" N	111° 27' 21.64" W
		SCD1	485723	7289663	65° 43' 41.95" N	111° 18' 40.50" W
		SCD1	485903	7289729	65° 43' 44.08" N	111° 18' 26.42" W
		SCD1	485716	7289665	65° 43' 41.99" N	111° 18' 41.04" W
		SCD1	485632	7289683	65° 43' 42.56" N	111° 18' 47.66" W
		SCP2	481268	7290730	65° 44' 15.58" N	111° 24' 30.71" W
	Reference	FL1	494153	7288557	65° 43' 07.14" N	111° 07' 38.71" W
Fyke net	Exposure	SC3	484061	7289912	65° 43' 49.69" N	111° 20' 51.11" W
Hoop net	Reference	FC3	494622	7288989	65° 43' 21.14" N	111° 07' 01.92" W

The fishing gear consisted of five minnow traps, two fyke nets, one hoop net, a set of six 1.8 × 15 m gill nets of different mesh sizes (19, 25, 38, 50, 64, and 76 mm stretch mesh), and a Smith-Root Type XII POW (Programmable Output Waveform) backpack electrofisher (settings of 400-500 V, 50 Hz, and 6 ms). Gill nets were set for 4 to 12 h periods, whereas minnow traps, hoop, and fyke nets were set for a minimum of 24 h. The following information was recorded for each sampling station:

- date and time set and retrieved (traps and gill nets);
- whether the trap was baited or unbaited;
- mesh and panel size (gill nets);
- date and time started and ended (electrofishing);
- electrofisher setting;
- the number and species of fish captured;
- water depth; and,
- UTM coordinates.

6.2.1.2 Field Data Collection

Length (fork length for Arctic grayling and total length for ninespine stickleback) and weight were recorded for all sentinel and non-target fish. Length was measured using a measuring board, marked by metric graduations with an accuracy of 1 mm. Total body weight was measured using an Acculab® VIC-123 electronic scale with an accuracy of 0.001 g.

Table 6.2. Backpack electrofishing and baited minnow trap locations

Method	Treatment	Station	UTM (Zone 12W NAD 83)							
			Start point		End point		Start point		End point	
			easting	northing	easting	northing	Latitude	Longitude	Latitude	Longitude
Backpack electrofishing	Exposure	SC2	483135	7289994	483325	7289999	65° 43' 52.18" N	111° 22' 03.83" W	65° 43' 52.32" N	111° 22' 00.70" W
		SC1	481838	7290521	481654	7290539	65° 44' 08.95" N	111° 23' 45.82" W	65° 44' 09.46" N	111° 24' 00.32" W
		SC4	483918	7289949	483592	7289894	65° 43' 50.84" N	111° 21' 02.34" W	65° 43' 49.01" N	111° 21' 27.86" W
	Reference	FC3	494608	7288867	494617	7288953	65° 43' 17.22" N	111° 07' 03.00" W	65° 43' 19.96" N	111° 07' 02.42" W
		FC3	494680	7289068	494681	7289068	65° 43' 23.70" N	111° 06' 57.42" W	65° 43' 23.70" N	111° 06' 57.35" W
		FC3	496327	7290999	496123	7290579	65° 44' 12.59" N	111° 05' 04.31" W	65° 44' 26.16" N	111° 04' 48.36" W
		FC3	495303	7289841	494619	7288840	65° 43' 16.36" N	111° 07' 02.17" W	65° 43' 48.72" N	111° 06' 08.64" W
Baited minnow trap	Exposure	SCD1	485594	7289539	n/a	n/a	65° 43' 37.90" N	111° 18' 50.60" W	n/a	n/a
		SCD1	485685	7289495	n/a	n/a	65° 43' 36.50" N	111° 18' 43.44" W	n/a	n/a
		SCD1	485730	7289436	n/a	n/a	65° 43' 34.60" N	111° 18' 39.89" W	n/a	n/a
		SCD1	485689	7289366	n/a	n/a	65° 43' 32.33" N	111° 18' 43.08" W	n/a	n/a
		SCD1	485603	7289325	n/a	n/a	65° 43' 30.99" N	111° 18' 49.81" W	n/a	n/a
		SC1	481432	7290659	n/a	n/a	65° 44' 13.31" N	111° 24' 11.66" W	n/a	n/a
		SC1	481510	7290643	n/a	n/a	65° 44' 12.80" N	111° 24' 17.86" W	n/a	n/a
		SC1	481570	7290632	n/a	n/a	65° 44' 12.48" N	111° 24' 06.95" W	n/a	n/a
		SC1	481618	7290570	n/a	n/a	65° 44' 10.46" N	111° 24' 03.13" W	n/a	n/a
		SC1	481704	7290530	n/a	n/a	65° 44' 09.17" N	111° 23' 56.40" W	n/a	n/a
	Reference	FL2	492298	7286271	n/a	n/a	65° 41' 53.16" N	111° 10' 03.83" W	n/a	n/a
		FL2	492321	7286266	n/a	n/a	65° 41' 53.02" N	111° 10' 01.96" W	n/a	n/a
		FL2	492332	7286225	n/a	n/a	65° 41' 51.72" N	111° 10' 01.06" W	n/a	n/a
		FL2	492349	7286217	n/a	n/a	65° 41' 51.47" N	111° 09' 59.72" W	n/a	n/a
		FC3	494616	7288879	n/a	n/a	65° 43' 17.58" N	111° 07' 02.46" W	n/a	n/a

Notes: n/a=not applicable

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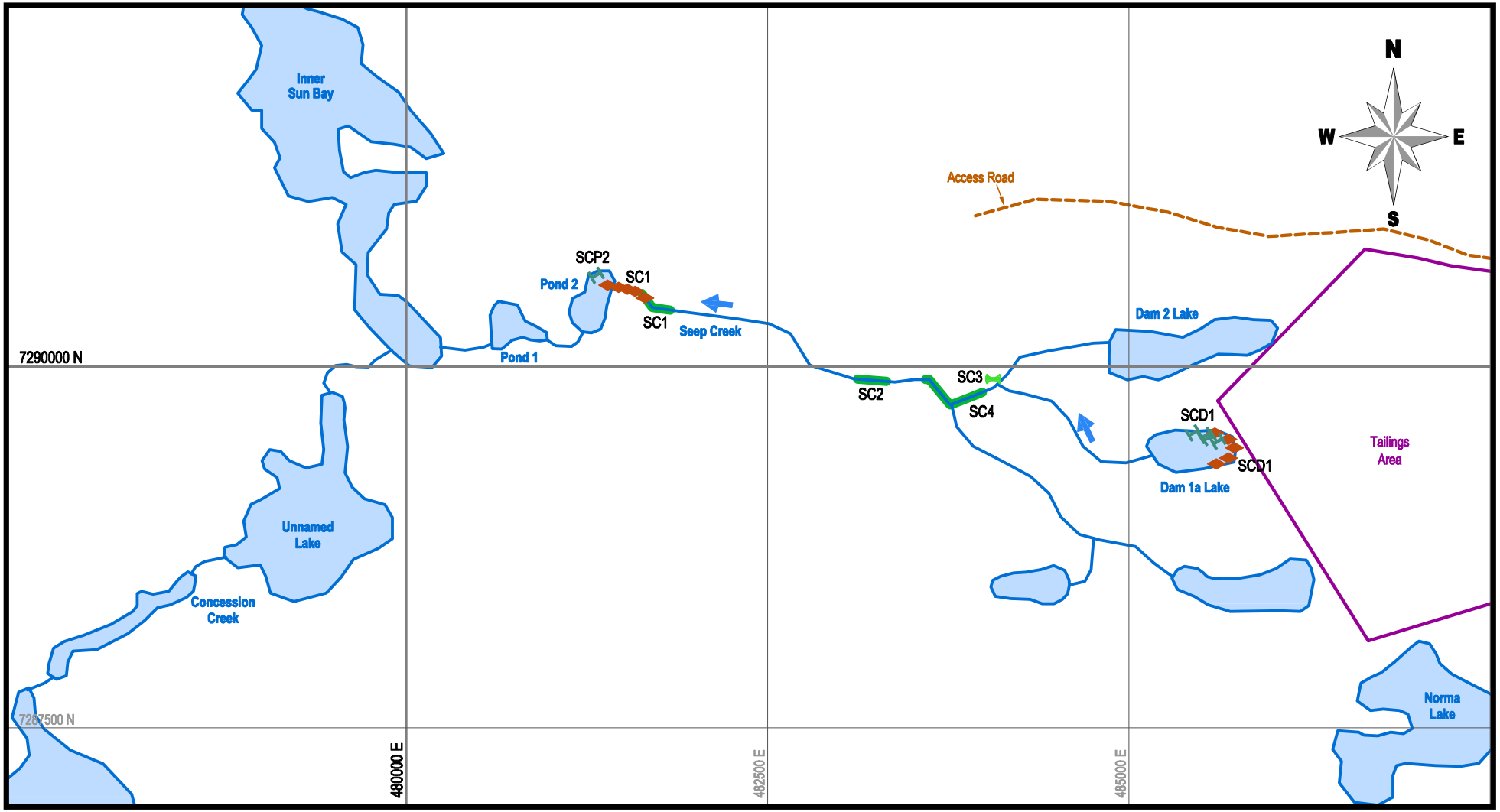


LEGEND

- Direction of flow
- Watercourse
- Backpack electrofishing
- Baited Minnow trap
- Gill net
- Fyke net

800 0 800

Scale Metres

PROJECT

Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report,
Lupin Gold Mine

TITLE

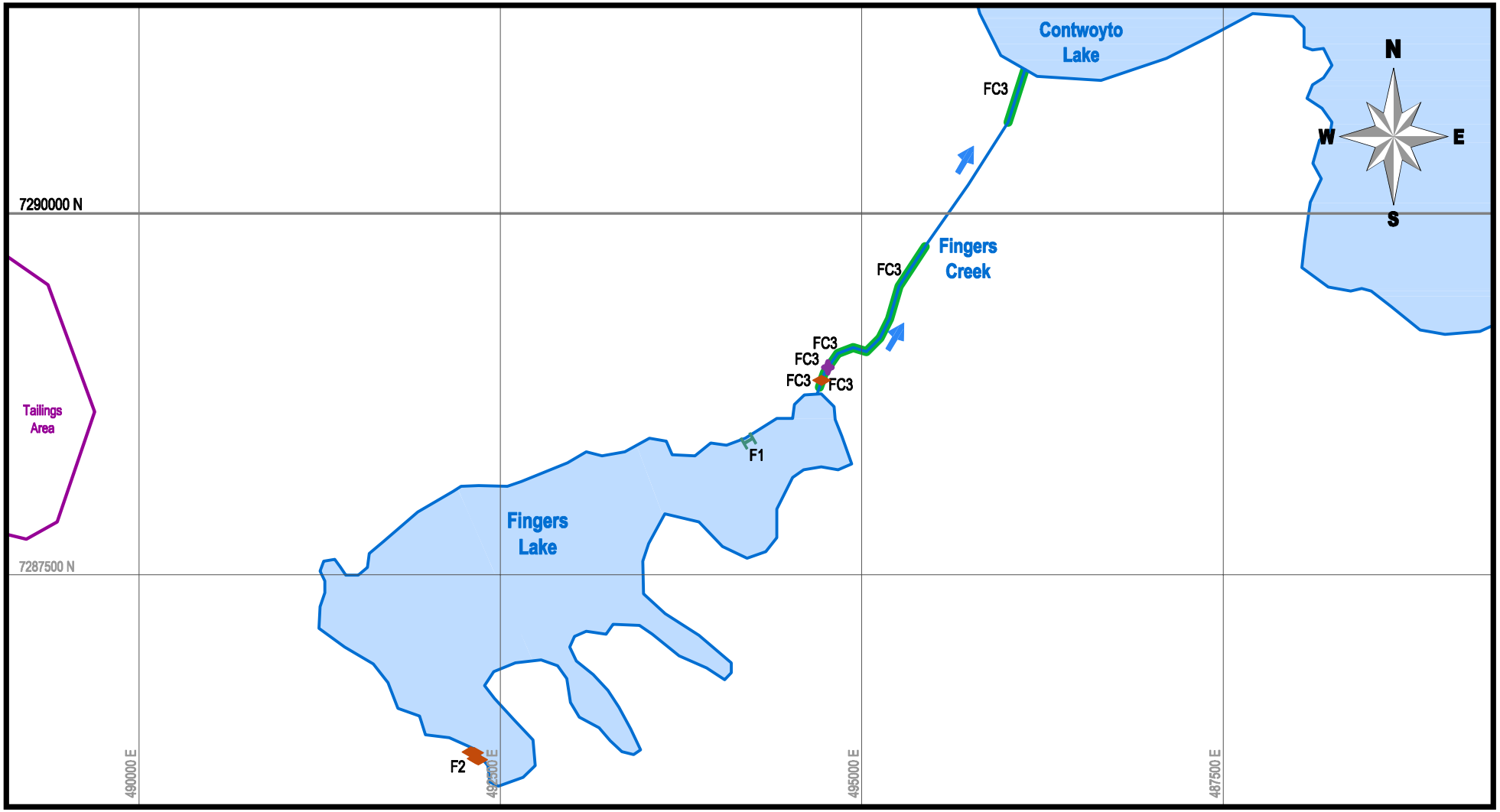
Fish Sampling Locations in the Exposure Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730638
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 6.1

Drawing path and name: R:\CAD\2005\1370-Edmonton\1373-ES\05-1373-019\6.2 - 1730639 fishSamples.dwg Jun. 2, 2006 (2:49 PM)



LEGEND

- Direction of flow
- Watercourse
- Backpack electrofishing
- Baited Minnow trap
- Gill net
- Hoop net

800 0 800
Scale Metres

PROJECT
Kinross Gold Corporation
Environmental Effects Monitoring Interpretive Report, Lupin Gold Mine

TITLE
Fish Sampling Locations in the Reference Area

Golder Associates
Edmonton, Alberta

PROJECT No.		05-1373-019	FILE No.		1730639
DESIGN	AH	23/05/06	SCALE	As shown	REV. 0
CADD	RW	23/05/06			
CHECK					
REVIEW					

Figure: 6.2

Scales were collected from Arctic grayling for fish ageing. Ageing structures from Arctic grayling were removed in the field and placed into individual sealed envelopes with the appropriate information for identification (i.e., fish number, area, length, weight).

6.2.1.3 Supporting Environmental Variables

Field water quality parameters were measured at each sampling station within the exposure area (Seep Creek and Dam 1a Lake) and the reference area (Fingers Creek and Fingers Lake). One water quality grab sample was collected from Fingers Creek and one in Dam 1a Lake. A composite water quality sample was collected from Fingers Lake and one from the Seep Creek ponds.

Water samples in the exposure and reference areas were collected according to the methods outlined in the MMER TGD (EC 2002). Samples were analysed for metals, deleterious substances, major ions and nutrients. Detailed methods and results are provided in section 4.0 of this report. A summary of the results is provided in section 6.0 to provide information regarding the water quality associated with the fish habitat.

6.2.2 Laboratory Measurements

6.2.2.1 External Examination

An external examination was conducted on all sentinel fish sampled during the fish survey. Detailed observations were made on any features of the fish that did not appear normal (i.e., wounds, tumors, parasites, fin fraying, gill parasites or lesions). External examinations were completed following the recommendations outlined in the MMER TGD (EC 2002).

6.2.2.2 Internal Examination

A complete internal health examination was conducted on all collected Arctic grayling, following the recommendations outlined in the MMER TGD (EC 2002). Thirty ninespine stickleback were examined for internal abnormalities and parasites. The internal examination included the following:

- sex;
- life stage;
- internal pathology;
- liver weight;
- stomach contents; and,
- state-of-maturity.

In both species, all organ systems were examined for the presence of any abnormalities, such as tumors, necrosis, or parasites. The livers were carefully excised from the intestines. Liver weight was determined using an Acculab® VIC-123 electronic scale with an accuracy of 0.001g. Stomach fullness was noted, along with a general description of gut contents. When possible, maturity and sex were recorded for Arctic grayling. Gonad weight was not recorded due to the focus on juvenile Arctic grayling for the EEM study.

6.2.2.3 Fish Tissue Collection

The TAP requested that the Mine conduct copper analysis for muscle fillets and liver tissues as part of the fish survey if significant results were found in the effect endpoints. Due to the small size of the juvenile Arctic grayling captured in the fish survey, muscle fillets could not be removed without contamination of the sample. In consultation with the AO, whole carcasses (head removed) were preserved for copper analysis. In total, 35 carcasses were preserved from the reference area and 40 from the exposure area.

A minimum 2.0 g sample is required for liver tissue analysis. To meet this requirement, liver tissues were combined into composite samples. The number of individual liver tissues required to meet the required 2.0 g sample weight varied in each composite sample (Appendix F). Two composite samples were collected in the exposure area, and three composite samples were collected in the reference area. The small sample size would likely preclude statistical analyses of liver tissue copper concentration.

Liver tissues and carcasses of Arctic grayling were frozen separately. These samples were placed in long-term storage (-20^{o}C) at the Alberta Research Council Laboratory pending copper analysis as directed by the TAP. The results of the tissue analysis will be reported separately when the data are available.

6.2.2.4 Quality Assurance/Quality Control

Specific work instructions outlining the fish survey tasks in detail were provided to field personnel by the task manager prior to the field program. Samples were collected by experienced personnel, and were labeled, preserved, and shipped to the Edmonton Golder office. Detailed field notes were recorded on pre-printed waterproof field data sheets.

Data collected during the fish survey underwent a variety of individual quality assurance checks. Field data sheets were checked at the end of each day for completeness and accuracy. Data entered into Golder Associates database underwent a 10% check for accuracy by a second person not involved in the initial entry process. All tables and data sets generated by the database underwent a 10% check for completeness and accuracy.

6.2.3 Laboratory

6.2.3.1 Fish Ageing

Ages of the Arctic grayling collected during the fish survey were determined following the methods outlined in Mackay et al. (1990). Scales were viewed using a compound microscope, and annuli were counted on the distal side from the focus to the edge of the dorsal tip. QA/QC results are presented in Appendix F.

6.2.3.2 Quality Assurance/Quality Control Procedures

A proportion (10%) of the age data was randomly selected and re-analyzed by Golder Associates personel in Edmonton. A greater than 10% difference would have resulted in all of the scale samples being reanalyzed. Age of all selected samples were consistent with the original ageing.

6.2.4 Data Analysis

Catch-per-unit-effort (CPUE) was calculated for each species captured, and was summarized by area and sampling method to document the effort expended in collecting the required number of fish. This calculation also provided a measure of relative abundance among sampling areas by standardizing the catch data for the exposure and reference areas.

The biological variables that were analyzed in the summary and/or statistical analyses included the following:

- physical abnormalities (e.g., tumors, lesions, obvious parasites);
- total body weight (g);
- fork length (mm);
- age (years); and,
- liver weight (g).

Summary statistics for each biological variable (i.e., sample size, arithmetic mean, median, minimum, maximum, standard deviation, and standard error) were calculated for mature fish, and summarized by area, and species. The biological variables were used to estimate energy storage and energy use in fish populations from the reference and exposure areas.

Age determinations indicated that all juvenile Arctic graylings captured from the exposure area were age 1 or young-of-the-year, whereas the catch in the reference area consisted of both ages 1 and 2 fish, as well as a few young-of-the-year. Because some of the endpoints, such as length-weight relationships and condition factor, vary with fish size and age, only fish of the same age and within similar size ranges (age 1 fish) were used for comparisons between the reference and exposure areas. Survival and size-at-age, which are EEM effect endpoints, could not be examined for the Lupin EEM study due to the limited age range.

Energy Use is a measure of the ability of the fish population to utilize resources in their environment to grow and reproduce. It is also a measure of hindrances that can deter fish from growing and reproducing normally and successfully (EC 2002, Gray et al. 2002).

Energy Storage is a measure of the current condition of the fish population. A healthy fish will demonstrate a greater body weight to length ratio. Stressors from the environment, whether they are natural or anthropogenic, can affect the condition of fish populations (EC 2002, Gray et al. 2002).

Two types of analyses were conducted on the data: effect analyses and supporting analyses (Table 6.3). An effect is defined as a statistically significant difference between fish population measurements taken in an exposure and reference area (EC 2002). Effect analyses are used to determine effects on the fish population. Supporting analyses are used for informational purposes only, and a significant difference between exposure and reference areas are not necessarily used to designate an effect (EC 2002).

The magnitude of the effect was calculated as the percent difference between the reference and exposure area means according to the following equation:

$$[(\text{exposure mean} - \text{reference mean})/ \text{reference mean}] \times 100$$

For ANCOVA analyses, the adjusted least squares means were used in the magnitude calculations.

Table 6.3. Response endpoint variables and statistical procedures used for identifying differences between reference and exposure areas

Type of Response	Endpoint	Dependent Variable (Y)	Covariate (X)	Statistical Procedure	Endpoint - Effect or Support Analysis[a]
Energy Storage	Condition	Body weight	Length	ANCOVA	Effect
	Relative liver weight	Liver weight	Carcass weight	ANCOVA	Effect
		Liver weight	Length	ANCOVA	Support
Energy Use	Total body weight	n/a	n/a	t-test	Support
	Length	n/a	n/a	t-test	Support

Notes: n/a = not applicable; [a] Indicates how statistical results will be interpreted

The study design consisted of only two areas, one reference and one exposure area; therefore, the two-sample *t*-test for comparing length and weight between areas was used. Statistical analyses were conducted with SYSTAT 11.0.

A general linear model (GLM) followed by an ANCOVA were used to assess the remaining endpoints, including condition and liver weight. Data were $\log_{10}$-transformed prior to ANCOVA analysis to ensure normality and allow comparison of regression lines (slope and intercept). GLM was used to test for homogeneity of slopes between the dependent variable and covariate for each area (i.e., test for significant area covariate interaction). ANCOVA was performed when the GLM did not produce a significant interaction between areas and the covariate (i.e., homogeneity of slopes was not violated). The ANCOVA was used to test for differences in intercepts, which is the effect of area on the dependent variable, using Type III sum of squares. If a significant difference in intercepts had been found, adjusted least squares means and standard error for each area were compared, and the level of significance, direction and magnitude were reported.

Power Analysis

Retrospective power analysis was conducted with the SYSTAT 11.0. Power was estimated for a range of effect sizes using a sample size (i.e., number of fish per area) corresponding to the minimum number of fish used in the statistical analysis of the fish data. Power was estimated for α and β equal at 0.05 and 0.1.

6.3 Results

6.3.1 Supporting Environmental variables

Water pH was slightly acidic in Fingers Creek (5.3 to 5.9) and the Seep Creek system (5.3 to 5.6; Table 4.3). These pH values were non-compliant with the CWQG, but were typical of the range of pH values in Nunavut barrenlands waterbodies reported by RCPL and RL&L (1985). Field conductivity was lower in Fingers Creek (10 to 120 µS/cm) than in the Seep Creek system (90 to 740 µS/cm).

Nitrate and ammonia concentrations were slightly elevated within the exposure area relative to the reference area. Nitrite and total phosphorus concentrations were at or below the MDL for both the reference and exposure areas (Appendix C). In general, metal concentrations were elevated in the exposure area compared to the reference area, and were higher in the stations nearest to the FDP than those farther downstream. In the exposure area, aluminum, arsenic, cadmium, copper, lead, nickel and zinc concentrations exceeded the CWQG for the protection of aquatic life (Appendix C).

6.3.2 Fish Catch data

Fish sampling was conducted in a variety of habitat types in both the reference and exposure areas. Except for gill net locations at Inner Sun Bay of Contwoyto Lake (exposure area) and Fingers Lake (reference), which were in deeper water (3 m), the majority of sampling stations were in shallow water that could be waded (0.3-0.6 m).

In total, 71 fish, representing six species, were captured in the reference area, and 188 fish, representing four species, were captured in the exposure area (Table 6.4; Appendix F). Within the reference area, backpack electrofishing was conducted for a total of 5044 s (1.4 h), the hoop net was set for 189.4 h, baited minnow traps were set for a total of 759.7 h, and gill nets were set for a total of 4.0 h. Within the exposure area, backpack electrofishing was conducted for 2935 s (0.82 h), fyke nets were set for a total of 90.9 h, baited minnow traps were set for a total of 588.6 h and gill nets were set for a total of 102.4 h.

The majority of the Arctic grayling in the reference area were captured by backpack electrofishing (49 fish). Despite considerable effort, only one ninespine stickleback and no slimy sculpin were captured in the reference area (Table 6.4). In the exposure area, similar numbers of Arctic grayling were captured using backpack electrofishing (36 fish) and gill nets (45 fish). Most of the ninespine stickleback were captured in baited minnow traps (Table 6.4).

Table 6.4. Summary of fish catch, 2005 Lupin mine EEM program

Method	Location	Effort	Species	Number of Fish Captured	CPUE
Gill Net		***hours***			***fish/h***
	Fingers Lake (FL1)	4.00	Lake Trout	1	0.25
			Round Whitefish	10	2.50
	Total	**4.00**		**11**	**2.75**
	Seep Creek (SCD1)	96.50	Arctic grayling	45	0.47
	Seep Creek Pond (SCP2)	2.40	no catch	0	0.00
	Inner Sun Bay (C1)	3.50	Arctic char	1	0.29
			Lake Trout	2	0.57
	Total	**102.40**		**48**	**0.47**
Baited Minnow Trap		***hours***			***fish/h***
	Fingers Lake (FL2)	759.70	Ninespine stickleback	1	0.001
			slimy sculpin	1	0.001
	Total	**759.70**		**2**	**0.003**
	Seep Creek (SCD1)	215.80	Ninespine stickleback	70	0.32
	Seep Creek (SC1)	372.80	Ninespine stickleback	20	0.05
	Total	**588.60**		**90**	**0.15**
Hoop Net		***hours***			***fish/h***
	Fingers Creek (FC3)	189.40	Arctic grayling	3	0.02
			Burbot	1	0.01
	Total	**189.40**		**4**	**0.02**
Fyke Net		***hours***			***fish/h***
	Seep Creek (SC3)	90.90	Arctic grayling	5	0.06
			Ninespine stickleback	8	0.09
	Total	**90.90**		**13**	**0.14**
Backpack electrofishing		***seconds***			***fish/100s***
	Fingers Creek (FC3)	5044	Arctic grayling	49	0.97
			Burbot	3	0.06
			Lake Trout	1	0.02
			slimy sculpin	1	0.02
	Total	**5044**		**54**	**1.07**
	Seep Creek (SC1)	904	Arctic grayling	15	1.66
			Ninespine stickleback	1	0.11
	Seep Creek (SC2)	1252	Arctic grayling	15	1.20
	Seep Creek (SC4)	779	Arctic grayling	6	0.77
	Total	**2935**		**37**	**1.26**

Note: individual dates and set times are presented in Appendix F

6.3.3 Fish Health Results

In total, 52 Arctic grayling and one ninespine stickleback were captured in the reference area, and 86 Arctic grayling and 99 ninespine stickleback were captured in the exposure area. Internal and external examinations were conducted for 78 Arctic grayling and 30 ninespine stickleback.

6.3.3.1 Arctic Grayling

Preliminary examinations of Arctic grayling data indicated that there were no significant differences in length or weight between sexes, therefore data were pooled across sexes for all analyses.

6.3.3.1.1 General Health

In total, 36 Arctic grayling from the reference area and 42 Arctic grayling from the exposure area were sacrificed. External and internal health examinations were conducted on each of these fish. The majority of the fish from both areas did not have any recordable abnormalities; however, one fish from the exposure area had severe fin erosion, and one fish from the exposure area had abnormal liver texture.

6.3.3.1.2 Summary Statistics

Summary statistics were calculated for fork length, weight, liver weight, and carcass weight for each area (Table 6.5). Only fish that were included in the statistical assessment of energy storage and energy use were included (i.e., age 1 fish only).

Table 6.5. Summary statistics for age 1 Arctic grayling

Area	Variable	*n*	Median	Mean	SD	SE	Minimum	Maximum
Exposure	Fork length (mm)	51	101	103	9.29	1.3	86	122
	Total weight (g)	47	10.43	11.3	3.25	0.47	7.06	19.62
	Carcass weight (g)	37	7.37	8.15	2.54	0.42	4.89	13.37
	Liver weight (g)	37	0.12	0.12	0.04	0.01	0.05	0.2
Reference	Fork length (mm)	31	111	110	3.28	0.48	92	123
	Total weight (g)	31	17.34	16.39	3.53	0.64	8.2	22.88
	Carcass weight (g)	29	13.23	13.12	3.15	0.59	6.69	18.87
	Liver weight (g)	29	0.17	0.16	0.04	0.01	0.09	0.24

Note: *n*=sample size; SD=standard deviation; SE=standard error

6.3.3.1.3 Energy Use

Total body weight and length of age 1 Arctic grayling were statistically different between the two study areas (*t*-test, $P<0.1$; Table 6.6). Age 1 Arctic grayling weighed 31.0% more and were 6.8% longer in the reference than in the exposure area (Table 6.6; Figure 6.3).

Table 6.6. Summary of statistical analyses for Arctic grayling

Type of Response	Endpoint	Endpoint Effect or Support Analysis	Primary Analysis				
			Interaction Statistic *P*	Intercept Statistic *P*	SSD	Direction of Difference	Magnitude of Difference (%)
Energy Use	Total Body Weight	Support	n/a	<0.0001	yes	ref<exp	31.0
	Length	Support	n/a	0.0004	yes	ref<exp	7.0
Energy Storage	Condition	Effect	0.30	<0.0001	yes	ref<exp	7.5
	Relative liver weight (liver weight-at-carcass weight)	Effect	0.14	0.29	no		
	Relative liver weight (liver weight-at-fork length)	Support	0.84	0.01	yes	ref<exp	9.5

Note: SSD=statistically significant difference; statistical significance assessed at $P \leq 0.1$

6.3.3.1.4 Energy Storage

Condition of age 1 Arctic grayling, as determined by comparing the length-weight relationships, was significantly different between the exposure and reference areas (Table 6.5; Figure 6.4). The interaction term was not significant, indicating that the slopes were similar between reference and exposure areas; however, the intercept was significantly higher in the reference area than in the exposure area. This indicated that, for a given length, fish from the reference area were heavier than those from the exposure area. The condition of age 1 Arctic grayling was 7.5% higher in reference fish than exposure fish (Table 6.5). The linear length-weight relationships were described by the following equations, where W is total body weight in grams and L is fork length in millimetres:

Reference area: $\text{Log}_{10}\ W = -4.99\ \text{Log}_{10}\ L + 3.03;\ r^2 = 0.88;\ n = 29$

Exposure area: $\text{Log}_{10}\ W = -4.26\ \text{Log}_{10}\ L + 2.64;\ r^2 = 0.77;\ n = 48$

The slope and intercept for the relationship of liver weight-at-carcass weight were not significantly different ($P>0.01$) between reference and exposure areas (Table 6.5, Figure 6.5). The linear liver weight-at-carcass weight relationships were described by the following equations, where Liver is liver weight in grams and Carcass is carcass weight in grams:

Reference area: $\text{Log}_{10}\ \text{Liver} = -1.51\ \text{Log}_{10}\ \text{Carcass} + 0.65;\ r^2 = 0.53;\ n = 29$

Exposure area: $\text{Log}_{10}\ \text{Liver} = -1.75\ \text{Log}_{10}\ \text{Carcass} + 0.91;\ r^2 = 0.61;\ n = 37$

Figure 6.3. Length-frequency distribution for age 1 Arctic grayling in the exposure and reference areas

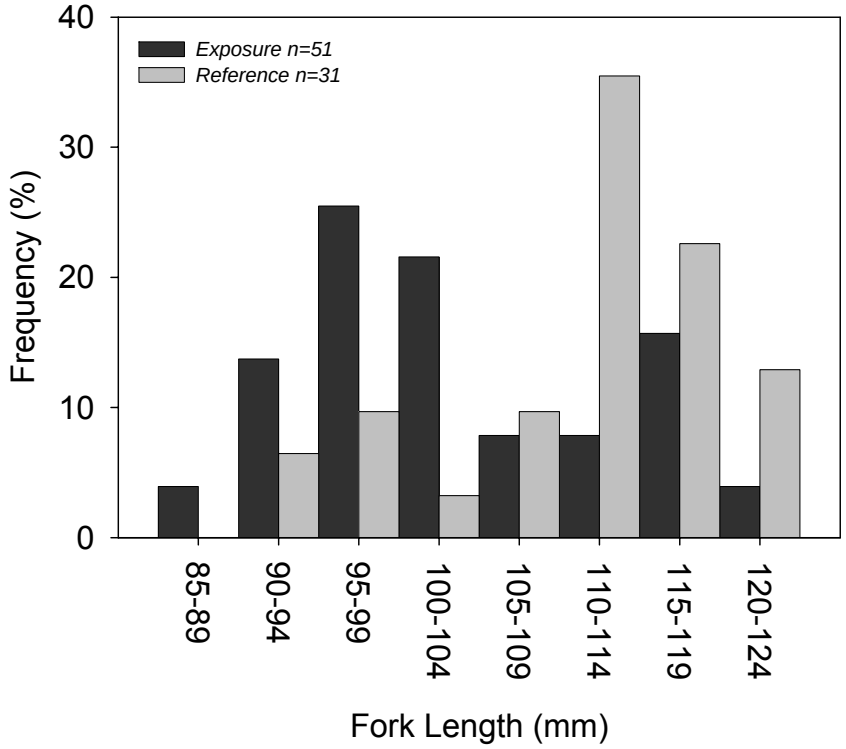
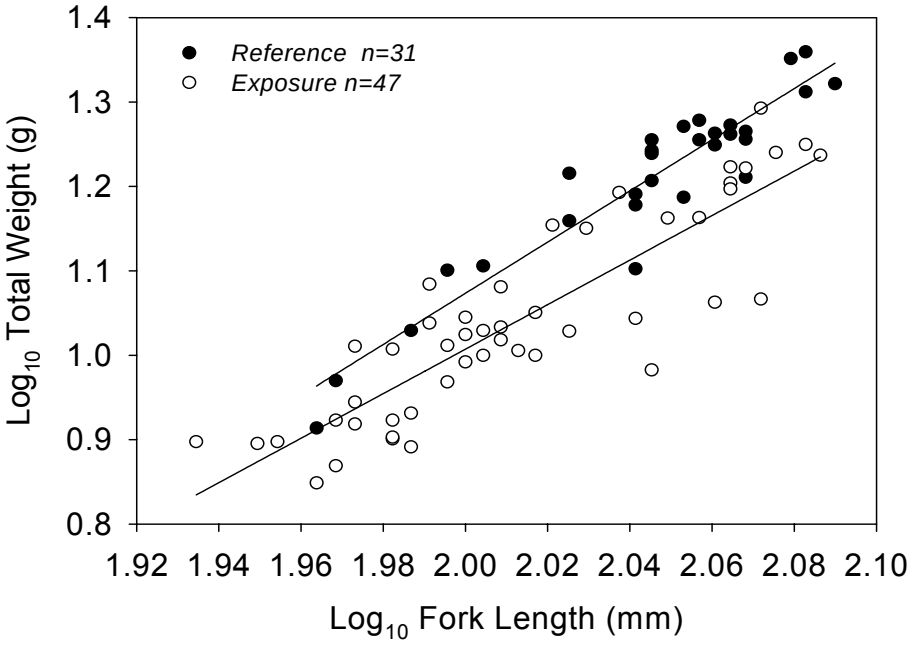


Figure 6.4. Relationship of Artic grayling total weight to fork length (condition)



The interaction term was not significant (P>0.1)for the GLM of liver weight-at-fork length, indicating that the slope of the regressions were similar between reference and exposure areas; however, the intercept was significantly higher in the reference area than in the exposure area (Table 6.5; Figure 6.6). The covariate was significant, though the r^2 values were very low, which suggests that the relationships between liver weight and fork length were weak. For a given length, fish from the reference area have 9.5% larger livers than those from the exposure area. The linear liver weight-at-length relationships were described by the following equations, where Liver is liver weight in grams and Length is fork length in millimetres:

Reference area: Log_{10} Liver = -5.30 Log_{10} Length + 2.20; $r^2 = 0.48$; $n = 29$

Exposure area: Log_{10} Liver = -5.04 Log_{10} Length + 2.03; $r^2 = 0.26$; $n = 37$

Figure 6.5. Relationship of Arctic grayling liver weight-at-carcass weight

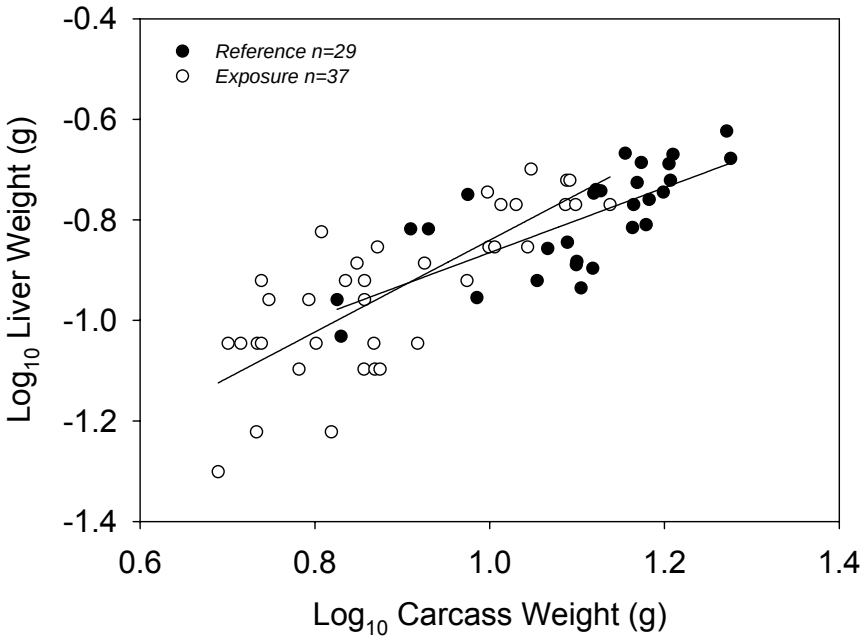
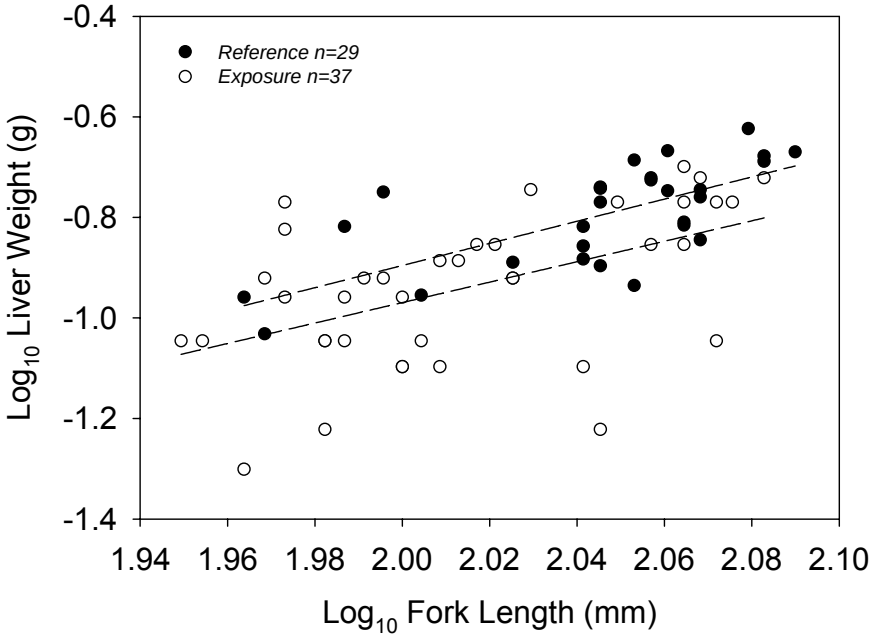


Figure 6.6. Relationship of Artic grayling liver weight-at-fork length



Note: dashed lines are used to represent weak regression relationships

6.3.3.1.5 Power Analysis

Currently, the MMER EEM program does not specify a critical effect size for fish endpoints (EC 2002); thus, the power of this study and the sample size required to detect a range of effect sizes was calculated for α and β equal at 0.05 and 0.10. The data in this study had sufficient power (greater than 90%) to detect a change of 10% in length, 20% in weight, 5% in condition and 10% in relative liver weight (Table 6.7).

6.3.3.2 Ninespine Stickleback

Despite considerable effort, only one ninespine stickleback was captured in the reference area. In total, 99 ninespine stickleback were captured in the exposure area. The lengths and weights were recorded for all captured fish, and internal and external examinations were conducted on the first 30 captured fish to assess abnormalities and parasite load. Though statistical analyses could not be conducted, data for the exposure area are presented here as background data for possible comparison in future monitoring programs.

Table 6.7. Power analysis for Arctic grayling.

Endpoint	Critical Effect Size	Estimated Power		Required *n* for desired power	
		α=β=0.1	α=β=0.05	1-β=0.9	1-β=0.95
Length	5%	0.7280	0.6105	52	79
	10%	0.9941	0.9979	14	21
	15%	1.0	1.0	7	10
Weight	5%	0.1971	0.1183	446	676
	10%	0.4539	0.3302	112	170
	15%	0.7408	0.6254	51	77
	20%	0.9206	0.8598	29	44
	25%	0.9851	0.9670	19	29
	30%	0.9983	0.9953	14	20
	35%	1.0	1.0	10	15
Condition	5%	1.0	1.0	11	13
Liver (at carcass weight)	5%	0.6450	0.5197	58	86
	10%	0.9950	0.9881	15	22
	15%	1.0000	1.0000	7	10

Note*: n*=sample size per area; critical effect size is a percentage of the reference mean; 1-β = power

6.3.3.2.1 General Health

The majority of the 30 sacrificed fish did not have any recordable abnormalities. Of the abnormalities that were recorded, one fish had severe skin aberrations, one fish had a small lesion on the opercule, one fish had a cream coloured liver, one had cysts on the liver, and low parasite loads were recorded in six fish.

6.3.3.2.2 Summary Statistics

Summary statistics were calculated for fork length, weight, liver weight and carcass weight for the exposure area (Table 6.8).

Table 6.8. Summary statistics for ninespine stickleback captured in the exposure area

Variable	*n*	Median	Mean	SD	SE	Minimum	Maximum
Total length (mm)	99	55	56	5.184	0.521	43	74
Total weight (g)	99	1.02	1.08	0.326	0.033	0.65	2.72
Carcass weight (g)	17	0.04	0.04	0.043	0.011	0.02	0.20
Liver weight (g)	17	0.52	0.60	0.238	0.060	0.34	1.23

Note: *n*=sample size; SD=standard deviation; SE=standard error

6.3.3.2.3 Energy Use and Energy Storage

The mean length (total length) of ninespine stickleback in the exposure area was 56 mm (range 43 to 74 mm), and the mean weight was 1.08 g (range 0.65 to 2.72 g). The length-frequency distribution shows that 86% of ninespine stickleback were between 50 and 64 mm (Figure 6.7).

The condition of ninespine stickleback in the exposure area was assessed using linear regression analysis on log_{10}-transformed length and weight data (Figure 6.8). Three outliers were removed from the regression analysis due to errors in data recording. The length-weight relationship was described by the following equation, where W is total body weight in grams and L is total length in millimetres:

$$Log_{10}\ W = -4.17\ Log_{10}\ L + 2.40;\ r^2 = 0.80;\ n = 96$$

Relative liver weight was also assessed using linear regression analysis on the log_{10}-transformed data. There was no relationship found between liver weight and carcass weight (r^2=0.003) or liver weight and total length (r^2=0.008).

Figure 6.7. Length-frequency distribution of ninespine stickleback in the exposure area.

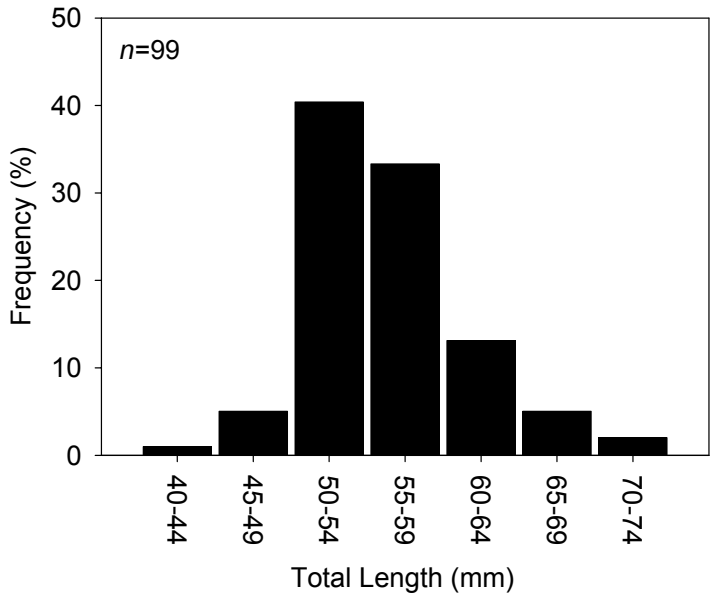
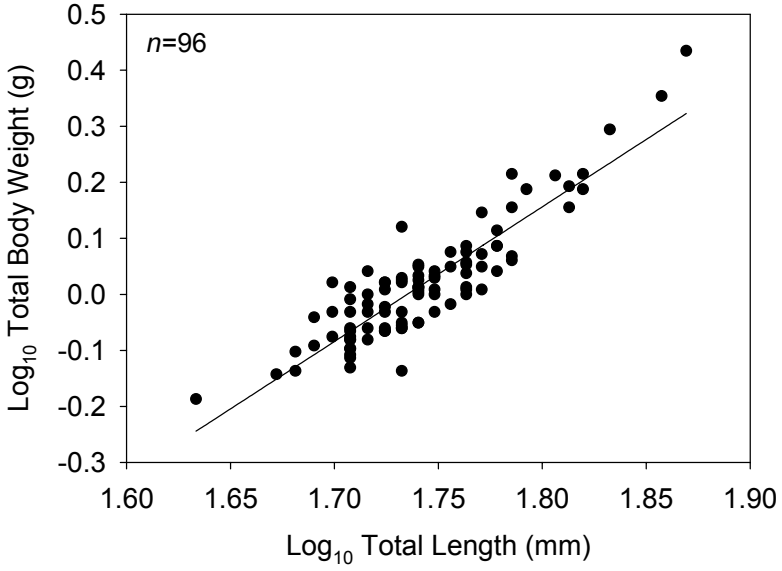


Figure 6.8. Relationship of ninespine stickleback total weight to total length (condition) in the exposure area



6.4 Summary

Fish were collected from a variety of habitats, including streams, lakes and ponds, in an attempt to increase fish capture. Conductivity was higher in the exposure area, which suggested the presence of mine effluent. Nitrate and ammonia were elevated in the exposure area, particularly in the stations nearest to the FDP. In the exposure area, aluminum, arsenic, cadmium, copper, lead, nickel and zinc concentrations exceeded the CWQG for the protection of aquatic life.

Overall, the state of general health (i.e., occurrence of abnormalities and parasites) of Arctic grayling was similar between the Fingers Lake system (reference) and the Seep Creek system (exposure).

Age 1 Arctic grayling were 31.0% heavier and 6.8% longer , on average, in the reference area than in the exposure. Condition was 7.5% greater in the reference fish than in exposure fish. Liver weight-at-carcass weight was not statistically different between reference and exposure fish. Although not considered an effect endpoint, the liver weight-at-fork length was 9.5% lower in exposure fish than in reference fish. Increased liver weight for fish exposed to metal pollution has been observed in field studies (Orlando et al. 1999); however, liver weight may decrease in response to exposure to specific metals.

For example, Norris et al. (2000) and Ricard et al. (1998) reported that long-term exposure to cadmium resulted in decreased liver weight and activity.

Power analysis indicated that there was sufficient sample size to detect a change of 10% in length, 20% in weight, 5% in condition and 10% in relative liver weight for Arctic grayling, with 90% power.

Although similar numbers of Arctic grayling in the exposure area were captured by backpack electrofishing and gill nets, all of the Arctic grayling in the reference area were captured by backpack electrofishing. Gill nets tend to be more selective than electrofishing, and are generally more effective at capturing smaller individuals (Hubert 1996). In contrast, electrofishing is generally more effective at capturing larger individuals (Reynolds 1996). Thus, the differences between exposure and reference areas may have been influenced by gear selectivity.

Of the ninespine stickleback that were examined for abnormalities and parasites, 13% had recordable abnormalities and 20% had parasites.

7.0 SUBLETHAL TOXICITY TESTING

Under the MMER regulations, sublethal toxicity tests on the final effluent must be conducted by the Mine twice each calendar year for the first three years; thereafter, the frequency may be reduced to once per calendar year. The purpose of sublethal toxicity testing is to determine if mine effluent may affect fish, invertebrates, and aquatic plants.

Sublethal toxicity test results can be used to estimate the potential for exposure area impacts (EC 2002). The regulations stipulate that if the sublethal toxicity results show an IC_{25} result of less than 30% concentration of effluent, the mine should calculate the geographic extent of the response in the exposure area and identify the zone where the concentration of effluent is comparable to the IC_{25} result. The IC_{25} is the effluent concentration where a 25% inhibition is observed in the exposed test organisms.

Sublethal toxicity test results can also be used to measure changes in effluent quality over time as a result of changes in water treatment, surface water management, acid rock drainage mitigation measures or mine process changes.

7.1 Methods

7.1.1 Field

Grab samples were collected by Mine staff from the final discharge point (SNP 925-10) in July and August of 2005. These samples were shipped to HydroQual Laboratories Ltd. in Calgary, Alberta, for toxicity testing.

7.1.2 Laboratory

The following toxicity tests were performed by HydroQual on each of the effluent samples collected in July and August according to established protocols:

- 7 day *Ceriodaphnia dubia* survival and reproduction (EC 1992a).
- 7 day Fathead minnow (*Pimephales promelas*) survival and growth (EC 1992b).
- 72 hour algal growth inhibition (*Selenastrum capricornutum*; EC 1992c).
- 7 day *Lemna minor* growth (EC 1999).

7.1.3 Data Analysis

The laboratory testing methods and QA/QC procedures are presented in the detailed reports from HydroQual in Appendix B.

7.2 Results

7.2.1 Survival and Growth Tests for the Fathead Minnow

Undiluted mine effluent was not acutely toxic to fathead minnows in either of the two samples tested (Table 7.1). Similarily, sublethal effects (growth) were not observed for the undiluted effluent samples.

Table 7.1. Acute and sublethal toxicity test results for fathead minnows (*Pimephales promelas)*

Date	Laboratory	Survival (LC_{50})	Growth (EC_{25} or IC_{25})
27-Jul-05	HydroQual	>100%	>100%
30-Aug-05	HydroQual	>100%	>100%

LC_{50} = lethal concentration at 50%; EC_{25} = effect concentration at 25%; IC_{25} =inhibition concentration at 25%

7.2.2 Survival and Reproduction of *Ceriodaphnia dubia*

Undiluted effluent was not acutely toxic to *Ceriodaphnia dubia* (Table 7.2). Reproductive impairment (IC_{25}) was observed at effluent concentrations ranging from 4.1% to 15%.

Table 7.2. Acute and sublethal toxicity test results for the water flea (*Ceriodaphnia dubia*)

	Laboratory	Survival (LC_{50})	Reproduction (EC_{25} or IC_{25})	EC_{25} or IC_{25} Lower	EC_{25} or IC_{25} Upper
27-July-05	HydroQual	>100%	>100%	n/a	n/a
30-Aug-05	HydroQual	>100%	12%	4.1%	15%

Notes: n/a=not applicable

7.2.3 Growth Inhibition Test for *Selanstrum capricornutum*

Undiluted effluent affected the growth of *Selanstrum capricornutum*. In July and August 2005, effluent concentrations of 17% and 27%, respectively, were found to inhibit growth in 25% of the test population (Table 7.3).

Table 7.3. Sublethal toxicity test results for *Selanstrum capricornutum*

Date	Laboratory	Growth (EC_{25} or IC_{25})	EC_{25} or IC_{25} Lower	EC_{25} or IC_{25} Upper
27-Jul-05	HydroQual	17%	15%	19%
30-Aug-05	HydroQual	27%	22%	32%

7.2.4 Growth and Reproduction of *Lemna minor*

Undiluted effluent collected from the mine in July and August 2005 demonstrated sublethal toxicity to *Lemna minor* (Table 7.4). The tests showed growth inhibition occurring at 10% (July) and 51% (August). Reproductive impairment was observed at effluent concentrations of <6.1% (July) and 7.8% (August).

Table 7.4. Sublethal toxicity test results for *Lemna minor*

Date	Laboratory	Growth (EC_{25} or IC_{25})	EC_{25} or IC_{25} Lower	EC_{25} or IC_{25} Upper	Reproduction (EC_{25} or IC_{25})	EC_{25} or IC_{25} Lower	EC_{25} or IC_{25} Upper
27-Jul-05	HydroQual	10%	3.5%	71%	<6.1	n/a	n/a
30-Aug-05	HydroQual	51%	n/a	n/a	7.8%	1.5%	12%

Notes: n/a=not applicable

7.3 Summary

While the biological surveys provide the direct measurement of ecological effects (if any), toxicity tests serve as a useful tool for predicting potential biological effects. However, predicting ecological significances in the field of a potential sub-lethal effect zone from single-species laboratory tests is difficult, at best, given the tools currently available under the EEM program. Laboratory measurements of physical, chemical, or biological properties of a substance or mixture cannot predict its exact behaviour in the

more variable and complicated environment found in nature. Translating potential (laboratory) into actual (field) toxicity requires consideration of the environmental factors that influence the expression of toxicity in the field. These confounding factors include:

- the nature of the toxicant;
- the chemical and physical environment,
- the timing and duration of exposure;
- the transport and fate mechanisms; and,
- the similarity of the test organisms to the organisms in the field.

All of these factors must be considered when toxicity data are used to estimate potential effect zones. Caution must be exercised when trying to extrapolate results from the laboratory to the receiving environment.

Sublethal and acute effects of mine effluent were not detected for fathead minnow. Effluent was not acutely toxic to *Ceriodaphnia dubia*, although reproductive inhibition was recorded at 12% effluent in August 2005. *Selenastrum capricornutum* growth was inhibited in effluent concentrations greater that 17%, and *Lemna minor* growth and reproduction were inhibited at concentrations greater than 10% and 6.1%, respectively.

The plume delineation modeling results (Section 2.7; Golder 2004) estimate that the 1% effluent zone could extend up to 1630 m into Outer Sun Bay. At the narrows between Inner and Outer Sun bays, the estimated effluent concentration ranged from 5.9 to 33%, depending on the stream and effluent flows. The sublethal toxicity test results indicate that biological effects may be detected at effluent concentrations as low as 6.1%. Based on the effluent plume model results and the sublethal toxicity results, the potential zone of biological effects could extend from the final discharge point downstream to the narrows, or Outer Sun Bay of Contwoyto Lake under worst case effluent mixing scenarios.

8.0 SYNOPSIS

The overall objective of the MMER EEM biological monitoring program was to assess whether or not the effluent from Lupin Mine had a negative effect on the aquatic receiving environment. The biological monitoring survey included a benthic invertebrate survey and fish survey. Fish tissue analysis was not conducted, but samples have been archived for examination if required by Environment Canada.

Effluent was discharged between 15 July and 11 August 2005. Effluent quality did not exceed the maximum allowable concentrations for deleterious substances as listed under the MMER. Effluent was not acutely lethal to fathead minnows or *Ceriodaphnia dubia*. Sublethal effects on growth and reproduction were recorded for *Ceriodaphnia dubia, Selenastrum capricornutum,* and *Lemna minor* in effluent concentrations ranging from less than 6.1% to 51%. Based on these effluent concentrations and the plume delineation model, the potential zone of biological effects could extend from the FDP as far as Outer Sun Bay.

Water quality variables were generally elevated in the exposure area relative to the reference area. Aluminum, arsenic, cadmium, copper, lead, nickel and zinc exceeded the CWQG in the exposure area.

Sediment quality variables were also elevated in the exposure area relative to the reference area. Arsenic exceeded the ISQG in the exposure area and in one reference sample. Chromium exceeded the ISQG in two of the five exposure area samples.

Benthic invertebrate communities in the exposure area have been negatively affected by Mine effluent. Statistically significant differences between the reference and exposure areas were not detected for total invertebrate density, family richness, or BCI. SDI and evenness were significantly lower in the exposure area than in the reference area. These impacts may be related to the elevated arsenic and chromium concentrations, which exceeded the ISQG for the protection of aquatic life, or the elevated metal concentrations in the water column, including several metals that exceeded CWQG for the protection of aquatic life.

Arctic grayling in the exposure area have been negatively impacted by Mine effluent. The general health (i.e., abnormalities and parasites) were similar between reference and exposure areas; however, Arctic grayling were heavier, longer and in better condition in the reference area compared to the exposure area. Liver weight relative to carcass weight was not significantly different between reference and exposure fish. Although not

considered an effect endpoint, liver weight relative to fork length was greater in reference fish than in exposure fish. Decreased liver weight may be related to exposure to elevated concentrations of specific metals, such as cadmium (Norris et al. 2000; Ricard et al. 1998).

Results of the present study indicated that the benthic invertebrate community and the fish population have been affected by mine effluent. Therefore, Lupin Mine is required to continue with the subsequent phase of EEM, Periodic Monitoring – Surveillance.

9.0 RECOMMENDATIONS FOR SUBSEQUENT BIOLOGICAL MONITORING

Based on the results obtained from the Initial EEM Biological Monitoring program, the MMGD (EC 2002) suggests the appropriate subsequent EEM study would be a Periodic Monitoring – Surveillance study. Table 9.1 outlines the schedule of the second EEM program at Lupin mine.

Table 9.1. Schedule of the second Lupin EEM program

Component	Execution/Submission Date
EEM Study Design	6 months prior to the biological monitoring field program (2008)
Field program	Late Summer 2008
Second Interpretive Report	06-Jun-09

In addition to the information included in the First EEM Study Design, the second study design will include a summary of the results from the First EEM Biological Monitoring Program. Fingers Creek has provided appropriate data for use as a reference comparison and should remain as the reference area for the second EEM program.

Although adequate biological information was collected in the Initial EEM Biological Monitoring Program to determine if there was an effect, it is recommended that the following changes be made to the EEM study design:

- standardize fishing gear use between reference and exposure areas to eliminate the potential confounding influence of differential size-selectivity between gear types;
- increase efforts to capture ninespine stickleback in the reference area;
- sample fish when the Mine is discharging effluent into the exposure area if possible; and,
- sample the BIC when the Mine is discharging effluent into the aquatic receiving environment, if possible.

10.0 REFERENCES

Assessment of the Aquatic Effects of Mining in Canada (AQUAMIN). 1996. Supporting Document II: Appalachian Region. Case studies Volume 1, Nanisivik and Lupin Mines. Prepared by AQUAMIN Working Group 5, AQUAMIN Secretariat for the AQUAMIN Steering Group, Ottawa, Ontario. 56 p.

Beak Consultants Ltd. and Mary Collins Consultants Ltd. 1980. Initial environmental evaluation for the Lupin gold project, Contwoyto Lake, N.W.T. Prepared for Echo Bay Mines Ltd.

Canadian Climate Normals – 1961 to 2000. Computer file provided by Atmospheric Environment Service, Ottawa, Ontario. Internet web site: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html

Canadian Council of Ministers of the Environment (CCME). 1999 (with 2005 updates). Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Ministers of the Environment. Water Quality Objectives Division, Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa, Ontario. 365 p. + 21 app.

Echo Bay Mines Ltd. 1994. A submission to the Northwest Territories Water Board in support of an application for water licence renewal. Water Licence No. N712-0925. 44 p. + app.

Echo Bay Mines Ltd. 2001. Lupin operation general information. 21 p.

Environment Canada (EC). 1992a (amended 1997). Test of reproduction and survival using the cladoceran *Ceriodaphnia dubia*. Ottawa, Ontario. Report EPS 1/RM/21.

Environment Canada (EC). 1992b (amended 1997). Test of larval growth and survival using fathead minnow. Ottawa, Ontario. Report EPS 1/RM/22.

Environment Canada (EC). 1992c (amended 1997). Growth inhibition test using the freshwater alga *Selenastrum capricornutum*. Ottawa, Ontario. Report EPS 1/RM/25.

Environment Canada (EC). 1999. Test for measuring the inhibition of growth using the freshwater macrophyte, *Lemna minor*. Ottawa, Ontario. Report EPS 1/RM/37.

Environment Canada (EC). 2002. Metal mining guidance document for aquatic environmental effects monitoring. EEM/2002. Ottawa, Ontario. June 2002.

EVS Environmental Consultants (EVS). 1996. 1996 field evaluation aquatic effects monitoring– 1996 survey: Final report, Lupin Mine Site, Northwest Territories. Prepared for Aquatic Effects Technology Evaluation Program, Natural Resources Canada, CANMET (Canada Centre for Mineral and Energy Technology), Ottawa, Ontario. 60 p. +6 app.

Geocon (1975) Ltd. (Geocon) 1980. Geotechnical study of proposed tailings pond, Lupin project, Contwoyto Lake, N.W.T. Prepared for Echo Bay Mines Ltd., Project A1207. Golder Associates Ltd. (Golder). 2003. Lupin Gold Mine environmental effects monitoring program historical information report. Prepared for Kinross Gold Corporation, Edmonton, Alberta. Golder Report No. 03-1370-049. 39 p. + 18 app.

Golder Associates Ltd. (Golder). 2004. Lupin gold mine environmental effects monitoring study design. Prepared for Kinross Gold Corporation, Edmonton, Alberta. Golder Report No. 04-1373-046. 75 p. + 4 app.

Golder Associates Ltd. (Golder). 2005. Addendum report: Changes to the initial environmental effects monitoring study design for the Lupin mine. Prepared for Kinross Gold Corporation, Edmonton, Alberta. Golder Report No. 05-1373-019. 20 p.

Government of Canada (GC). 2002. Fisheries Act: Metal Mining Effluent Regulations. 6 June, 2002. Canada Gazette. Part II. Vol. 136, No. 13

Gray, M.L., A.R., Curry, and K.R. Munkittrick. 2002. Non-lethal sampling methods for assessing environmental impacts using a small-bodied sentinel fish species. Water Quality Research Journal of Canada 37 :195-211.

Hubert, A.W. 1996. Passive capture techniques. Pages 157 – 181 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques. Second edition. American Fisheries Society, Bethesda, Maryland, USA.

MacKay, W.C., G.R. Ash, and H.J. Norris (eds.). 1990. Fish ageing methods for Alberta. RL&L Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and the University of Alberta, Edmonton. 113 p.

Moore, J.W. 1978. Biological and water quality surveys at potential mines in the Northwest Territories. II Inco Gold Property, Contwoyto Lake. Environment Canada, Environmental Protection Services, Northwest Region. Manuscript Report NW – 7806. 39 p.

Natural Resources Canada. 2003. The atlas of Canada. Internet web site: http://atlas.gc.ca/site/english/maps/environment/geology/geologicalprovinces/1

Norris, D.O., J.M. Camp, T.A. Maldonado, and J.D. Woodling. 2000. Some aspects of hepatic function in feral brown trout, Salmo trutta, living in metal contaminated water. Comparative Biochemistry and Physiology C: Toxicology and Pharmacology 127: 71-78.

Orlando, E.F., N.D. Denslow, L.C. Folmar, and L.J. Guillette Jr. 1999. A comparison of reproductive physiology of largemouth bass, Micropterus salmoides, collected from the Escambia and Blackwater rivers in Florida. Environmental Health Perspectives 107: 199-204.

Reid Crowther & Partners Ltd. and RL&L Environmental Services Ltd. (RCPL and RL&L). 1985. Report on aquatic studies program. Prepared for Echo Bay Mines Ltd., Lupin Mine. 86 p. + 5 app.

Reynolds, J.B. 1996. Electrofishing. Pages 221 – 253 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques. Second edition. American Fisheries Society, Bethesda, Maryland, USA.

Ricard, A.C., C. Daniel, P. Anderson, and A. Hontela. 1998. Effects of Subchronic Exposure to Cadmium Chloride on Endocrine and Metabolic Functions in Rainbow Trout, Oncorhynchus mykiss. Archives of Environmental Contamination and Toxicology 34: 377-381.

RL&L Environmental Services Ltd. and Department of Fisheries and Oceans (RL&L and DFO). 1991. Fisheries investigations at the Lupin Gold Mine, Contwoyto Lake, NWT, 1990. Prepared for Echo Bay Mines Ltd., Edmonton, AB. RL&L Report No. 275: 59 p. + 2 app.

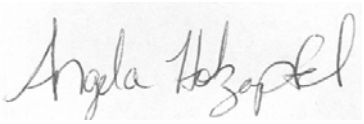
Roberge, M.M., L. Dahlke, and J.B. Dunn. 1986. Biological investigation of Contwoyto Lake, Northwest Territories, 1981-82. Canadian Data Report of Fisheries and Aquatic Sciences 605: iv + 29 p.

11.0 CLOSURE

This report was prepared by Golder Associates Ltd. (Golder) on behalf of Kinross Gold Corporation. We trust that the information provided meets the requirements of the MMER submission for the Lupin Mine. Should there be any further requirements or clarification, please do not hesitate to contact the undersigned individuals.

GOLDER ASSOCIATES LTD.

Report prepared by:



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Principal

Appendix A

Supporting Documentation

Environment Canada Environnement Canada

Prairie & Northern Region
Environmental Protection Branch
Environment Canada
Twin Atria #2, Room 200
4999-98th Avenue
Edmonton, AB T6B 2X3

File number: 7834-3-37/E77-1

August 11 2005

Michael Tansey
Reclamation Manager
Kinross Gold Corporation, Lupin Operations
9818 Edmonton International Airport
Edmonton, Alberta
T5J 2T2

FAX: (204) 890-8814

Dear Mr. Tansey:

Re: The Lupin Gold Mine Initial Monitoring EEM Study Design

This letter is to advise you that I accept the Initial Monitoring EEM Study Design for the Lupin Gold mine. This acceptance is based on the Technical Advisory Panel's (TAP) review of "Lupin Gold Mine Environmental Effects Monitoring Study Design", received December 6, 2004, the final April 18 2005 TAP Mine meeting minutes, and the August 2 2005 electronic submission entitled 'Addendum Report: Changes to the Initial Environmental Effects Monitoring Study Design for the Lupin Mine'.

Please note that the TAP accepts the mercury results of the pre-decant sample from Pond #2 and will not require that samples be collected for fish tissue mercury analysis during this EEM biological monitoring study. Fish tissue samples will be archived for possible copper analysis however, as outlined in the addendum. Also note that the TAP had requested water samples be collected near the beginning and the end of the decant period (Item #13).

It is my understanding that the mine will remain in contact with the TAP during reconnaissance and field work, and that the TAP will be consulted on field decisions involving sentinel species, sample size, and other EEM endpoints.

If you have any questions please do not hesitate to contact the EEM Coordinator for your facility, (Email: paula.siwik@ec.gc.ca, Tel: 780-951-8824, Fax: 780-495-2758).

EcoLogo® Paper / Papier Eco-Logo®

Sincerely,

Peter Blackall, P. Eng
Regional Director of Environmental Protection
MMER Authorization Officer

cc Paula Siwik, Environment Canada
Chuck Brumwell, Environment Canada
Ken Russell, Environment Canada

MEETING MINUTES

MMER ENVIRONMENTAL EFFECTS MONITORING
STUDY DESIGN MEETING
Lupin Gold Mine

Monday April 18 2005
12:30 p.m. to 4:00 p.m.

Attendees:

Mike Tansey	Lupin Gold Mine
Rick Schryer	Golder Associates
Gary Ash	Golder Associates
Mark Dunnigan	Golder Associates
Chris Baron	Fisheries and Oceans Canada
Steve Harbicht	Environment Canada
Anne Wilson	Environment Canada
David Hohnstein	Nunavut Water Board
Paula Siwik	Environment Canada

1. **Introductions**
2. **Adult fish survey**

Paula began by outlining the TAP's preferences. They included: 1- a 2 day reconnaissance to assess a) the presence of fish, b) the spawning condition and c) the presence of parasites in the ninespine stickleback population, 2- the use of juvenile arctic grayling and ninespine stickleback as sentinel species in lethal surveys, 3- a progression downstream in the Seep Creek system if species/populations higher in Seep Creek were not adequate, 4- July 15 as an acceptable start date, 5- other reference areas should be investigated due to the possible influence of wind blown tailings on the Norma system (recommended Fingers) and 6 – that copper concentrations be determined in the viscera or liver of the juvenile arctic grayling.

a. Sentinel species selection and timing

There was some discussion about past sampling techniques and the results of the ninespine stickleback survey at the Miramar CON site. The result was a decision to a) delay the adult fish survey until August (fish and benthic surveys done at the same time) and b) attempt to use sculpin as a sentinel species. Sample sizes were 20 adult males, 20 adult females and 20 immature fish per area for the sculpin and 40 immature fish per area for the arctic grayling. The TAP agreed that a non-lethal ninespine stickleback survey with a subsample sacrificed for ageing and to determine the presence of parasites be the backup plan.

The TAP had expressed the desire to have water quality data collected near the beginning of decant. Originally, this would not have been an issue with the proposed temporal separation of the fish and benthic surveys. Anne inquired as to whether Pond 2 was well mixed and David replied that it was, that Pond 2 was relatively shallow, and that the siphons draw off the top 3 m. The facility agreed to sample water quality in the proposed biological

reference and exposure areas soon after commencing decant to address the TAP's concern.

b. Copper and mercury

Paula explained that the TAP agreed mercury need not be sampled in fish tissue provided the mercury concentration in the effluent sample to be collected from Pond #2 pre decant was ‹ 0.1 µg/l. If the effluent sample has a mercury concentration > 0.1 µg/l, it was suggested that non-lethal tissue sampling be considered (guidance to be available soon).

The group did not reach resolution on the issue of copper analysis. Sufficient tissue for 12 copper samples per area will be collected and archived during the adult fish survey. The preferred tissue is arctic grayling liver. If grayling are not found in the study areas, liver or viscera from other sentinel species should be collected. Further discussion on this topic will take place.

c. Reference area

The rationale for locating a new reference area was outlined. There is a road to Fingers Lake and the creek can be accessed by boat. Reconnaissance will be done to determine if sufficient numbers of the appropriate species reside in that system. Paula advised the mine that the absence of fish in an area where they should be present is considered an effect in the metal mining EEM program. Therefore the reference area must be sampled even if insufficient numbers of fish are caught in the exposure area.

3. Benthic Invertebrate Survey

Paula outlined the TAP's suggestions. They included: 1- using Seep Creek as the exposure area, 2- to sample during decant even if it means compromising a bit on timing, 3- focus on depositional habitat, 4- collect sediment samples for metals analysis in addition to TOC and PSA, 5- use cores instead of an Eckman to collect sediment samples, 6 – include both the 243 and 500 µm fraction in the Interpretative Report and 5 – increase the number of benthic subsamples from 3 to 5.

a. Sieve size and sub samples

It was agreed that the number of subsamples would be increased from 3 to 5 per station. There was some discussion about the 500 vs. the 243 µm fraction. Paula explained that future program decisions would likely be made at the 500 µm level and analysis should be done on that fraction. It was decided that the data for both the 500 and 243 µm fraction would be included in the Interpretative Report but that analysis would be done on the 500 µm fraction.

b. Sampling areas

As the TAP recommended sampling depositional areas, it was suggested that the small unnamed lakes along Seep Creek might be the most suitable sampling areas. The TAP agreed that they should be looked at. In terms of reference areas, the decision was to explore the area downstream of Concession Lake to see if the habitat and flow were similar. Other options, including some small lakes in the Fingers system, were discussed as back up.

c. Sediment sampling

Sediment will be collected using a core sampler at each benthic invertebrate station and analyzed for PSA, TOC and metals. As outlined in the review comments, the TAP recommended collecting the upper 4 cm for analysis.

4. Effluent and Water Quality

Paula reminded everyone to ensure that labs use the appropriate detection limits when analyzing effluent and water quality samples, and that water sampling must be done in both the fish and benthic exposure and reference areas. The comments were noted. Mike asked about suitable sampling stations for the routine effluent and water quality sampling. Paula stated that the exposure station should be close to the point of discharge but far enough downstream to allow for some dilution. David suggested the station at the narrows be the exposure station and the one at Concession Creek act as a reference station.

5. Additional Items

a) Paula will be the EEM contact during the field surveys and will supply the consultants and facility with contact information
b) Paula will make arrangements with Mike for a visit to the site during field work.
c) Some of the TAP comments were discussed and an addendum will be submitted. The highlights of that conversation include: 1- lake seiche effects were not included in the model, 2- an estimate of the plume at 250 m will be done in the field, 3- any tissue metal data will continue to be reported in dry weight but the moisture content of the sample will also be presented and 4 – the consultants will verify the volume of sediment required for analysis.
d) Lupin is considering their options and may decide to submit a letter requesting Recognized Close Mine status. ***ACTION ITEM: Paula will review recent decisions regarding the timing of this request and provide that information to Mike.***

Appendix B

Effluent and Water Quality Monitoring Data

KINROSS
Gold Corporation

LUPIN NU

Lupin Operation
9818 Edmonton International Airport
Edmonton, AB T5J 2T2 Canada

Telephone: (780) 890-8797
Fax: (780) 890-8814
email: mike.tansey@kinross.com

March 24, 2006

Ms. Paula Siwik
Regional EEM Coordinator
Toxic Substances Division
Environmental Protection Branch
Room 200, 4999-98 Ave. NW
Edmonton Alberta T6B 2X3

Dear Paula:

RE: Kinross Gold Corporation, Lupin Operations, Contwoyto Lake, NU; 2005 EEM Reporting Requirements.

With regard to the reporting requirements of Part 1, Paragraph 8 of the MMER, please accept this report of our annual effluent and water quality monitoring for 2005.

Discharge took place at the Lupin Discharge Syphons for a period of 27 days between July 15 and August 11, 2005. A total of 1,682,135 cubic metres of effluent was discharged into Seep Creek during this period. As the discharge period was less than one month duration, only one sample date is presented.

Tailings discharge effluent was sampled for Effluent Characterization on July 27, 2005, as was the sample for Sublethal Toxicity testing. These samples were taken at the point of discharge of the Lupin discharge siphons, designated as sample point 925-10. The location of the sample point in latitude and longitude is given in the sample summary report for 925-10.

Water Quality Monitoring samples were taken on July 19, 2005, in the exposure area downstream from the point of entry of the effluent into the environment (designated as sample point 925-24) and at the related reference area (designated as sample point 925-21). The locations of the sample points in latitude and longitude are given in the sample summary reports for 925-24 and 925-21.

Laboratory QA/QC data for the samples is attached.

Should you have any questions or comments regarding the above information and this report submission, please feel free to contact the undersigned at one of the numbers listed above.

Yours truly,

Michael Tansey
Reclamation Manager, Lupin

cc: Mark Ioli, Kinross

Facility Name Kinross Gold Corporation - Lupin Operations (Contwoyto Lake)
FDP Name Lupin Discharge Syphons
Discharge Locn Name SNP 925-10
FDP Location **Lat** 65 deg 43 min 43.8 sec N **Long** 111 deg 18 min 23.3 sec W
Outlet of Dam 1A syphons.
Sample location at point of discharge

EFFLUENT CHARACTERIZATION

Sample Date July 27, 2005
Discharge Volume 68,812 cubic metres

Parameter	units	Concentration	Mass Loading	units
Hardness	mg/l	216		
Alkalinity	mg/l	< 5		
Aluminum	mg/l	0.128		
Cadmium	mg/l	0.00010		
Iron	mg/l	0.2		
Mercury	ug/l	< 0.02		
Molybdenum	mg/l	0.002		
Ammonia	mg/l	1.88		
Nitrate	mg/l	7.45		
Arsenic	mg/l	0.0146	1.00	kg
Copper	mg/l	0.015	1.03	kg
Cyanide	mg/l	0.040	2.75	kg
Lead	mg/l	0.0005	0.03	kg
Nickel	mg/l	0.0955	6.57	kg
Zinc	mg/l	0.251	17.27	kg
TSS	mg/l	< 2	137.62	kg
Radium 226	Bq/l	0.006	412,872.00	Bq
Effluent Notes		Sample 51080		
Sublethal Toxicity Test		Sample 51081		

NOTE 925-10 is the only Final Discharge Point from the Lupin tails containment area
Effluent was discharged for a total of 27 days, from July 15, 2005 to August 11, 2005
The only sublethal toxicity sample taken while discharge was occurring was taken on July 27

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

	NWL Number	398142-13	398142-14	398142-15	
	Sample Date	Jul 26, 2005	Jul 27, 2005	Jul 27, 2005	
	Sample Description	925-25 / 51078	925-14 / 51079	925-10 / 51080	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Inorganic Nonmetallic Parameters						
Ammonium - N		mg/L	<0.05	<0.05	1.88	0.05
Kjeldahl Nitrogen	Total	mg/L	-	0.53	-	0.05
Phosphorus	Total	mg/L	-	<0.1	-	0.1
Orthophosphate-P	Dissolved	mg/L	-	0.02	-	0.01
Cyanide	Strong Acid Dissociable	mg/L	0.002	-	0.040	0.002
Metals Total						
Iron	Total	mg/L	<0.1	0.3	0.2	0.1
Manganese	Total	mg/L	0.008	0.072	0.984	0.005
Silicon	Total	mg/L	0.11	0.25	1.86	0.05
Sulfur	Total	mg/L	1.9	22.4	95.5	0.3
Mercury	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Mercury	Total	ug/L	-	-	<0.02	0.02
Aluminum	Total	mg/L	0.026	0.049	0.128	0.005
Antimony	Total	mg/L	0.0016	0.001	<0.0002	0.0002
Arsenic	Total	mg/L	0.0015	0.0139	0.0146	0.0002
Barium	Total	mg/L	0.003	0.019	0.016	0.001
Beryllium	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Bismuth	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Boron	Total	mg/L	0.004	0.037	0.087	0.002
Cadmium	Total	mg/L	0.00003	<0.00001	0.00010	0.00001
Chromium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Cobalt	Total	mg/L	0.0004	0.0038	0.0496	0.0001
Copper	Total	mg/L	0.002	0.004	0.015	0.001
Lead	Total	mg/L	0.0009	0.0003	0.0005	0.0001
Lithium	Total	mg/L	0.002	0.236	0.030	0.001
Molybdenum	Total	mg/L	<0.001	0.002	0.002	0.001
Nickel	Total	mg/L	0.0022	0.0122	0.0955	0.0005
Selenium	Total	mg/L	<0.0002	<0.0002	<0.0002	0.0002
Silver	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Strontium	Total	mg/L	0.009	1.18	0.304	0.001
Thallium	Total	mg/L	<0.00005	<0.00005	<0.00005	0.00005
Tin	Total	mg/L	<0.001	<0.001	<0.001	0.001
Titanium	Total	mg/L	0.0008	0.0018	0.0045	0.0005
Uranium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Vanadium	Total	mg/L	<0.0001	0.0002	0.0001	0.0001

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Analytical Report

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **398142**
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
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	NWL Number	398142-13	398142-14	398142-15	
	Sample Date	Jul 26, 2005	Jul 27, 2005	Jul 27, 2005	
	Sample Description	925-25 / 51078	925-14 / 51079	925-10 / 51080	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Total - Continued						
Zinc	Total	mg/L	0.015	0.009	0.251	0.001
Physical and Aggregate Properties						
Temperature of observed pH		°C	21.7	22.0	22.4	
Solids	Total Suspended	mg/L	<2	<2	<2	1
Routine Water						
pH	@ 25 °C	pH	-	7.43	-	
pH			6.67	7.62	6.39	
Electrical Conductivity		µS/cm at 25 C	25	845	847	1
Calcium	Dissolved	mg/L	1.7	69.0	74.2	0.2
Magnesium	Dissolved	mg/L	0.6	7.4	7.5	0.1
Sodium	Dissolved	mg/L	1.6	79.8	85.4	0.4
Potassium	Dissolved	mg/L	<0.4	5.6	7.3	0.4
Iron	Dissolved	mg/L	0.01	0.23	<0.01	0.01
Manganese	Dissolved	mg/L	0.008	0.067	0.991	0.005
Chloride	Dissolved	mg/L	1.0	202	57.8	0.4
Nitrate - N		mg/L	0.10	1.23	7.45	0.01
Nitrite - N		mg/L	<0.005	<0.005	0.056	0.005
Nitrate and Nitrite - N		mg/L	0.10	1.23	7.50	0.02
Sulfate (SO4)	Dissolved	mg/L	5.9	73.3	303	0.9
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	<5	28	<5	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	<5	23	<5	5
Total Dissolved Solids	Calculated	mg/L	11	451	537	1
Hardness	Dissolved as CaCO3	mg/L	7	203	216	
Ionic Balance	Dissolved	%	100	99	99	

SRC Group: 2005-4060

SRC ANALYTICAL
422 Downey Road
Saskatoon, Saskatchewan S7N 4N1
(306) 933-6932 1-800-240-8808

Aug-12-2005

Norwest Labs
7217 Roper Road
Edmonton, Alberta T6B 3J4
Attn: Client Services

Date Samples Received: Jul-29-2005 Client P.O.:

SAMPLE CLIENT DESCRIPTION
16737 LOT# 398142-15 *WATER*

ANALYTE	UNITS	16737
RADIO CHEMISTRY		
Radium-226	Bq/L	0.006

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Aggregate Organic Constituents

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Biochemical Oxygen Demand	mg/L	<4	0	-4	4	✓
Material Used:	BOD - Blank					
Date Acquired:	Jul 29, 2005					
Acquired By:	Zahra Momen					

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Biochemical Oxygen Demand	mg/L	<4	<4	30	8	✓
Material Used:	Surrey - Int. Duplicate 1					
Date Acquired:	Jul 29, 2005					
Acquired By:	Zahra Momen					

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Biochemical Oxygen Demand	mg/L	144	167	116	218	✓
Material Used:	BOD - G/GA					
Date Acquired:	Jul 29, 2005					
Acquired By:	Zahra Momen					

NORWEST LABS

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Location: Nunavut
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P.O.:
Acct. Code:

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Inorganic Nonmetallic Parameters

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Ammonium - N	mg/L	<0.05	0.00	-0.08	0.08	✓
Kjeldahl Nitrogen	mg/L	<0.05	0.00	-0.05	0.05	✓
Phosphorus	mg/L	<0.1	0.0	-0.1	0.1	✓
Orthophosphate-P	mg/L	<0.01	0.00	-0.05	0.05	✓
Cyanide	mg/L	<0.001	0.000	-0.001	0.001	✓
Material Used:	Edmonton Method Blank					
Date Acquired:	Aug 08, 2005					
Acquired By:	Gordon Grensmann					

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Ammonium - N	mg/L	<0.05	<0.05	9.99	0.10	✓
Phosphorus	mg/L	2.1	2.2	10.0	0.2	✓
Orthophosphate-P	mg/L	0.93	0.89	9.99	0.05	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 29, 2005					
Acquired By:	Andrew Jong					

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Ammonium - N	mg/L	3.00	2.99	2.59	3.39	✓
Kjeldahl Nitrogen	mg/L	14.8	15.25	11.65	18.85	✓
Phosphorus	mg/L	8.0	8.0	7.2	8.8	✓
Cyanide	mg/L	0.077	0.077	0.067	0.087	✓
Material Used:	Water High					
Date Acquired:	Aug 08, 2005					
Acquired By:	Gordon Grensmann					
Ammonium - N	mg/L	0.80	0.79	0.66	0.91	✓
Kjeldahl Nitrogen	mg/L	3.33	3.00	2.41	3.59	✓
Phosphorus	mg/L	2.1	2.0	1.8	2.2	✓
Orthophosphate-P	mg/L	0.41	0.41	0.36	0.47	✓
Cyanide	mg/L	0.015	0.016	0.013	0.018	✓
Material Used:	Water Low					
Date Acquired:	Aug 08, 2005					
Acquired By:	Gordon Grensmann					
Orthophosphate-P	mg/L	0.07	0.08	0.07	0.09	✓
Material Used:	Water Trace					
Date Acquired:	Jul 29, 2005					
Acquired By:	Andrew Jong					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
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Metals Dissolved

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Sulfur	mg/L	<0.3	0.0	-0.3	0.3	✓
Material Used:	Edmonton Method Blank					
Date Acquired:	Jul 29, 2005					
Acquired By:	To Thong					

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Sulfur	mg/L	16.5	16.4	10.0	0.1	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 29, 2005					
Acquired By:	To Thong					

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Sulfur	mg/L	48.0	50.0	45.0	55.0	✓
Material Used:	Metals High					
Date Acquired:	Jul 29, 2005					
Acquired By:	To Thong					
Sulfur	mg/L	1	1.0	0.9	1.2	✓
Material Used:	Metals Low					
Date Acquired:	Jul 29, 2005					
Acquired By:	To Thong					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
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Metals Total

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	<0.1	0.0	0.0	0.0	✓
Manganese	mg/L	<0.005	0.000	-0.001	0.001	✓
Silicon	mg/L	<0.05	0.02	-0.04	0.09	✓
Sulfur	mg/L	<0.3	0.0	-0.3	0.3	✓
Mercury	mg/L	<0.0001	0.0000	0.0000	0.0000	✓
Aluminum	ug/L	<5	0	-5	5	✓
Antimony	ug/L	<0.2	0.0	-0.2	0.2	✓
Arsenic	ug/L	<0.2	0.0	-0.2	0.2	✓
Barium	ug/L	<1	0	-1	1	✓
Beryllium	ug/L	<0.1	0.0	-0.1	0.1	✓
Bismuth	ug/L	<0.5	0.0	-0.5	0.5	✓
Boron	ug/L	<2	0	-2	2	✓
Cadmium	ug/L	<0.01	0.00	-0.01	0.01	✓
Chromium	ug/L	<0.5	0.0	-0.5	0.5	✓
Cobalt	ug/L	<0.1	0.0	-0.1	0.1	✓
Copper	ug/L	<1	0	-1	1	✓
Lead	ug/L	<0.1	0.0	-0.1	0.1	✓
Lithium	ug/L	<1	0	-1	1	✓
Molybdenum	ug/L	<1	0	-1	1	✓
Nickel	ug/L	<0.5	0.0	-0.5	0.5	✓
Selenium	ug/L	<0.2	0.0	-0.2	0.2	✓
Silver	ug/L	<0.1	0.0	-0.1	0.1	✓
Strontium	ug/L	<1	0	-1	1	✓
Thallium	ug/L	<0.05	0.00	-0.05	0.05	✓
Tin	ug/L	<1	0	-1	1	✓
Titanium	ug/L	<0.5	0.0	-0.5	0.5	✓
Uranium	ug/L	<0.5	0.0	-0.5	0.5	✓
Vanadium	ug/L	<0.1	0.0	-0.1	0.1	✓
Zinc	ug/L	<1	0	-1	1	✓
Material Used:	Edmonton Method Blank					
Date Acquired:	Aug 03, 2005					
Acquired By:	Linda Li					
Mercury	ug/L	<0.02	0.000	-20.010	20.010	✓
Material Used:	Metals Blank - water - total					
Date Acquired:	Aug 08, 2005					
Acquired By:	Kelly Restiaux					

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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
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Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Metals Total (Continued...)

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Iron	mg/L	0.1	0.1	15.0	0.2	✓
Manganese	mg/L	0.991	0.968	15.000	0.010	✓
Silicon	mg/L	1.86	1.81	15.00	0.10	✓
Sulfur	mg/L	97.3	94.8	15.0	0.1	✓
Mercury	mg/L	<0.0001	<0.0001	9.9900	0.0003	✓
Aluminum	ug/L	49	49	15	11	✓
Antimony	ug/L	1	1.1	15.0	0.4	✓
Arsenic	ug/L	4.3	4.3	15.0	0.4	✓
Barium	ug/L	2	2	15	2	✓
Beryllium	ug/L	<0.1	<0.1	15.0	0.2	✓
Bismuth	ug/L	<0.6	<0.6	15.0	1.1	✓
Boron	ug/L	86	86	15	4	✓
Cadmium	ug/L	<0.01	<0.01	15.00	0.02	✓
Chromium	ug/L	408	425	15.0	1.1	✓
Cobalt	ug/L	3.8	4.0	15.0	0.2	✓
Copper	ug/L	544	569	15	2	✓
Lead	ug/L	0.3	0.3	15.0	0.2	✓
Lithium	ug/L	95	95	15	2	✓
Molybdenum	ug/L	5	5	15	2	✓
Nickel	ug/L	29.4	30.2	15.0	1.1	✓
Selenium	ug/L	<0.2	<0.2	15.0	0.4	✓
Silver	ug/L	<0.1	<0.1	15.0	0.2	✓
Strontium	ug/L	1180	1190	15	2	✓
Thallium	ug/L	0.60	0.64	15.00	0.11	✓
Tin	ug/L	<1	<1	15	2	✓
Titanium	ug/L	13.6	12.8	15.0	1.1	✓
Uranium	ug/L	<0.6	<0.6	15.0	1.1	✓
Vanadium	ug/L	0.2	0.2	15.0	0.2	✓
Zinc	ug/L	9	10	15	2	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Aug 03, 2005					
Acquired By:	Linda Li					
Mercury	ug/L	<0.02	<0.02	30.000	0.050	✓
Material Used:	Metals Int. Duplicate - water tot					
Date Acquired:	Aug 08, 2005					
Acquired By:	Kelly Restiaux					

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Fax: (780) 438-0396

Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
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Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	2.0	2.0	1.8	2.2	✓
Manganese	mg/L	0.485	0.500	0.450	0.550	✓
Silicon	mg/L	4.97	5.00	4.50	5.50	✓
Sulfur	mg/L	9.8	10.0	9.0	11.0	✓
Mercury	mg/L	0.0008	0.0008	0.0007	0.0010	✓
Aluminum	ug/L	307	322	273	371	✓
Antimony	ug/L	12.0	11.5	10.2	12.8	✓
Arsenic	ug/L	11.9	11.5	10.3	12.7	✓
Barium	ug/L	62	61	52	69	✓
Beryllium	ug/L	6.0	5.9	4.9	7.0	✓
Bismuth	ug/L	32.0	30.2	26.0	34.4	✓
Boron	ug/L	127	125	102	148	✓
Cadmium	ug/L	0.60	0.63	0.47	0.78	✓
Chromium	ug/L	31.3	31.8	27.5	36.2	✓
Cobalt	ug/L	6.8	6.4	5.4	7.5	✓
Copper	ug/L	63	63	55	70	✓
Lead	ug/L	6.8	6.2	5.4	7.0	✓
Lithium	ug/L	62	65	53	76	✓
Molybdenum	ug/L	62	61	53	69	✓
Nickel	ug/L	30.8	31.4	27.0	35.8	✓
Selenium	ug/L	11.2	11.0	9.7	12.3	✓
Silver	ug/L	6.2	6.2	5.5	7.0	✓
Strontium	ug/L	68	64	55	72	✓
Thallium	ug/L	3.46	3.14	2.56	3.72	✓
Tin	ug/L	59	59	52	66	✓
Titanium	ug/L	35.8	31.5	27.0	36.0	✓
Uranium	ug/L	32.7	30.8	26.9	34.7	✓
Vanadium	ug/L	6.3	6.5	5.4	7.6	✓
Zinc	ug/L	63	59	49	69	✓
Material Used:	Edmonton Digestion Check					
Date Acquired:	Aug 03, 2005					
Acquired By:	Linda Li					
Iron	mg/L	9.8	10.0	9.0	11.0	✓
Manganese	mg/L	2.37	2.500	2.250	2.750	✓
Silicon	mg/L	24.3	25.00	22.50	27.50	✓
Sulfur	mg/L	48.6	50.0	45.0	55.0	✓
Mercury	mg/L	0.0031	0.0031	0.0027	0.0035	✓
Material Used:	Metals High					
Date Acquired:	Jul 29, 2005					
Acquired By:	To Thong					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	0.2	0.2	0.2	0.2	✓
Manganese	mg/L	0.052	0.050	0.045	0.055	✓
Silicon	mg/L	0.53	0.50	0.45	0.55	✓
Sulfur	mg/L	1.0	1.0	0.9	1.2	✓
Mercury	mg/L	0.0008	0.0008	-0.0016	0.0032	✓
Aluminum	ug/L	963	1000	850	1150	✓
Antimony	ug/L	40.0	40.0	34.0	46.0	✓
Arsenic	ug/L	40.1	40.0	34.0	46.0	✓
Barium	ug/L	193	200	170	230	✓
Beryllium	ug/L	20.6	20.0	17.0	23.0	✓
Bismuth	ug/L	98.4	100.0	85.0	115.0	✓
Boron	ug/L	403	400	340	460	✓
Cadmium	ug/L	2.09	2.00	1.70	2.30	✓
Chromium	ug/L	95.8	100.0	85.0	115.0	✓
Cobalt	ug/L	19.8	20.0	17.0	23.0	✓
Copper	ug/L	189	200	170	230	✓
Lead	ug/L	20.6	20.0	17.0	23.0	✓
Lithium	ug/L	202	200	170	230	✓
Molybdenum	ug/L	188	200	170	230	✓
Nickel	ug/L	96.9	100.0	85.0	115.0	✓
Selenium	ug/L	39.7	40.0	34.0	46.0	✓
Silver	ug/L	20.8	20.0	17.0	23.0	✓
Strontium	ug/L	191	200	170	230	✓
Thallium	ug/L	10.4	10.00	8.50	11.50	✓
Tin	ug/L	183	200	170	230	✓
Titanium	ug/L	97.6	100.0	85.0	115.0	✓
Uranium	ug/L	98.1	100.0	85.0	115.0	✓
Vanadium	ug/L	18.3	20.0	17.0	23.0	✓
Zinc	ug/L	197	200	170	230	✓

Material Used: Metals Low
Date Acquired: Aug 03, 2005
Acquired By: Linda Li

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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Aluminum	ug/L	54	50	43	58	✓
Antimony	ug/L	2.2	2.0	1.7	2.3	✓
Arsenic	ug/L	2.1	2.0	1.7	2.3	✓
Barium	ug/L	11	10	9	12	✓
Beryllium	ug/L	1.1	1.0	0.9	1.2	✓
Bismuth	ug/L	5.2	5.0	4.3	5.8	✓
Boron	ug/L	22	20	17	23	✓
Cadmium	ug/L	0.11	0.10	0.09	0.12	✓
Chromium	ug/L	5.2	5.0	4.3	5.8	✓
Cobalt	ug/L	1.0	1.0	0.9	1.2	✓
Copper	ug/L	10	10	9	12	✓
Lead	ug/L	1.1	1.0	0.9	1.2	✓
Lithium	ug/L	9	10	9	12	✓
Molybdenum	ug/L	10	10	9	12	✓
Nickel	ug/L	5.2	5.0	4.3	5.8	✓
Selenium	ug/L	2.1	2.0	1.7	2.3	✓
Silver	ug/L	1.0	1.0	0.9	1.2	✓
Strontium	ug/L	10	10	9	12	✓
Thallium	ug/L	0.54	0.50	0.43	0.58	✓
Tin	ug/L	9	10	9	12	✓
Titanium	ug/L	5.2	5.0	4.3	5.8	✓
Uranium	ug/L	5.4	5.0	4.3	5.8	✓
Vanadium	ug/L	1.1	1.0	0.9	1.2	✓
Zinc	ug/L	10	10	9	12	✓
Material Used:	Metals Trace					
Date Acquired:	Aug 03, 2005					
Acquired By:	Linda Li					
Mercury	ug/L	13	14.000	11.000	17.000	✓
Material Used:	S0102 - Hg					
Date Acquired:	Aug 08, 2005					
Acquired By:	Kelly Restiaux					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Physical and Aggregate Properties

Certified Reference Material		Units	Measured	Target	Lower Limit	Upper Limit	Passed QC
Solids		mg/L	394	500	260	440	✓
Material Used:	S2016 - Solid						
Date Acquired:	Aug 02, 2005						
Acquired By:	Vanessa Li						
Solids		mg/L	<2	0	-1	1	✓
Material Used:	Surrey Blank 2						
Date Acquired:	Aug 02, 2005						
Acquired By:	Vanessa Li						

Replicates		Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Solids		mg/L	43	45	10	15	✓
Material Used:	Edmonton Duplicate						
Date Acquired:	Jul 29, 2005						
Acquired By:	Christina Onyskiw						
Solids		mg/L	8	7	30	5	✓
Material Used:	Surrey - Int. Duplicate 1						
Date Acquired:	Aug 02, 2005						
Acquired By:	Vanessa Li						

Control Sample		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Solids		mg/L	200	200	180	220	✓
Material Used:	Water High						
Date Acquired:	Jul 29, 2005						
Acquired By:	Christina Onyskiw						
Solids		mg/L	20	20	18	22	✓
Material Used:	Water Low						
Date Acquired:	Jul 29, 2005						
Acquired By:	Christina Onyskiw						

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T5J 2T2
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Project
ID:
Name: Lupin Mine
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P.O.:
Acct. Code:

NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
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Routine Water

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Calcium	mg/L	<0.2	0.0	-0.2	0.2	✓
Magnesium	mg/L	<0.1	0.0	-0.1	0.1	✓
Sodium	mg/L	<0.4	0.0	-0.4	0.4	✓
Potassium	mg/L	<0.4	0.0	-0.4	0.4	✓
Iron	mg/L	<0.01	0.00	-0.01	0.01	✓
Manganese	mg/L	<0.005	0.000	-0.005	0.005	✓
Chloride	mg/L	<0.4	0.0	-0.5	0.5	✓
Nitrate - N	mg/L	<0.01	0.00	-0.01	0.01	✓
Nitrite - N	mg/L	<0.005	0.000	-0.005	0.005	✓

Material Used: Edmonton Method Blank
Date Acquired: Jul 29, 2005
Acquired By: Marc Dzura

Calibration Check	Units	Measured	Target	% Recovery	Criteria (%)	Passed QC
pH	pH	8.0	8.00	100.50	98.50-101.50	✓

Material Used: s2013 - pH
Date Acquired: Jul 29, 2005
Acquired By: Zahra Momen

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
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NWL Lot ID: 398142
Control Number:
Date Received: Jul 28, 2005
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Routine Water (Continued...)

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
pH		8.22	8.18	9.99	0.10	✓
Electrical Conductivity	dS/m at 25 C	0.839	0.840	9.990	0.002	✓
Calcium	mg/L	2310	2310	10.0	0.6	✓
Magnesium	mg/L	40	40	10.0	0.7	✓
Sodium	mg/L	13.2	13.0	10.0	1.2	✓
Potassium	mg/L	160	160	10.0	1.2	✓
Iron	mg/L	0.02	0.02	9.99	0.05	✓
Manganese	mg/L	0.073	0.074	9.990	0.010	✓
Chloride	mg/L	83.8	83.4	10.0	0.5	✓
Nitrate - N	mg/L	7.27	7.35	9.99	0.01	✓
Nitrite - N	mg/L	0.054	0.055	9.990	0.010	✓
Hydroxide	mg/L	<5	<5	10		✓
Carbonate	mg/L	8	8	10		✓
Bicarbonate	mg/L	150	149	10		✓
P-Alkalinity	mg/L	<5	<5	10	5	✓
T-Alkalinity	mg/L	6	6	10	5	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 29, 2005					
Acquired By:	Annya Hundal					
pH	pH	7.43	7.50	0.00	0.10	✓
Material Used:	Surrey - Int. Duplicate 1					
Date Acquired:	Jul 29, 2005					
Acquired By:	Zahra Momen					

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Quality Control

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9818 International Airport
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T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
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NWL Lot ID: 398142
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Date Received: Jul 28, 2005
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Routine Water (Continued...)

Control Sample		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Chloride		mg/L	2070	2087.0	1875.2	2298.8	✓
Material Used:	Chloride High						
Date Acquired:	Jul 29, 2005						
Acquired By:	Andrew Jong						
Calcium		mg/L	234	250.0	225.0	275.0	✓
Magnesium		mg/L	94.6	100.0	90.0	110.0	✓
Sodium		mg/L	240	250.0	225.0	275.0	✓
Potassium		mg/L	243	250.0	225.0	275.0	✓
Iron		mg/L	9.75	10.00	9.01	10.99	✓
Manganese		mg/L	2.32	2.500	2.260	2.740	✓
Material Used:	Metals High						
Date Acquired:	Jul 29, 2005						
Acquired By:	To Thong						
Calcium		mg/L	5.0	5.0	4.5	5.5	✓
Magnesium		mg/L	2.1	2.0	1.8	2.2	✓
Sodium		mg/L	4.8	5.0	4.5	5.5	✓
Potassium		mg/L	4.7	5.0	4.5	5.5	✓
Iron		mg/L	0.21	0.20	0.18	0.22	✓
Manganese		mg/L	0.049	0.050	0.045	0.055	✓
Material Used:	Metals Low						
Date Acquired:	Jul 29, 2005						
Acquired By:	To Thong						
pH			9.21	9.23	9.11	9.35	✓
Electrical Conductivity		dS/m at 25 C	2.78	2.730	2.611	2.849	✓
Chloride		mg/L	80.9	81.0	76.4	85.6	✓
Nitrate - N		mg/L	10.2	10.00	9.61	10.39	✓
Nitrite - N		mg/L	10.3	10.000	9.562	10.438	✓
P-Alkalinity		mg/L	492	507	415	599	✓
T-Alkalinity		mg/L	994	1009	969	1049	✓
Material Used:	Water High						
Date Acquired:	Jul 29, 2005						
Acquired By:	Annva Hundal						

NORWEST LABS

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Quality Control

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9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
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NWL Lot ID: **398142**
Control Number:
Date Received: Jul 28, 2005
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Routine Water (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
pH		6.90	6.90	6.83	6.97	✓
Electrical Conductivity	dS/m at 25 C	0.080	0.076	0.070	0.081	✓
Chloride	mg/L	14.5	14.9	13.2	16.6	✓
Nitrate - N	mg/L	0.52	0.50	0.44	0.56	✓
Nitrite - N	mg/L	0.521	0.495	0.437	0.553	✓
P-Alkalinity	mg/L	57	54	20	88	✓
T-Alkalinity	mg/L	136	127	118	136	✓

Material Used: Water Low
Date Acquired: Jul 29, 2005
Acquired By: Annva Hundal

Norwest Labs
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Methodology and Notes

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
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NWL Lot ID: **398142**
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

Method of Analysis:

MethodName	Reference		Method	Date Analysis Started	Location
Alkalinity, pH, and EC in water	APHA	*	Conductivity - Laboratory Method, 2510 B	29-Jul-05	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Electrometric Method, 4500-H+ B	29-Jul-05	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Titration Method, 2320 B	29-Jul-05	Norwest Labs Edmonton
Ammonium-N in Water	APHA	*	Automated Phenate Method, 4500-NH3 G	2-Aug-05	Norwest Labs Edmonton
Anions (Routine) by Ion Chromatography	APHA	*	Ion Chromatography with Chemical Suppression of Eluent Cond., 4110 B	2-Aug-05	Norwest Labs Edmonton
BOD in water (surrey)	APHA	*	5 Day, 5210 B	29-Jul-05	Norwest Labs Surrey
Chloride in Water	APHA	*	Automated Ferricyanide Method, 4500-Cl- E	29-Jul-05	Norwest Labs Edmonton
Coliforms - Membrane Filtration	APHA		Fecal Coliform Membrane Filter Procedure, 9222 D	29-Jul-05	Norwest Labs Calgary
Cyanide (Strong Acid Dissociable) in water	APHA	*	Total Cyanide after Distillation, 4500-CN- C	8-Aug-05	Norwest Labs Edmonton
Kjeldahl Nitrogen & Phosphorus (Total) in Water	Alberta Research Council	*	Nitrogen, Total Kjeldahl, 07021 626	29-Jul-05	Norwest Labs Edmonton
Kjeldahl Nitrogen & Phosphorus (Total) in Water	APHA	*	Automated Ascorbic Acid Reduction Method, 4500-P F	29-Jul-05	Norwest Labs Edmonton
Mercury (Total) in water	MDMES	*	Determination of Mercury in Water by Cold Vapor Atomic Absor, 245.1	29-Jul-05	Norwest Labs Edmonton
Mercury Low Level (Total) in water	APHA	*	Cold Vapour Atomic Absorption Spectrometric Method, 3112 B	9-Aug-05	Norwest Labs Surrey
Metals ICP-MS (Total) in water	US EPA	*	Determination of Trace Elements in Waters and Wastes by ICP-MS, 200.8	29-Jul-05	Norwest Labs Edmonton
Metals Trace (Dissolved) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	29-Jul-05	Norwest Labs Edmonton
Metals Trace (Total) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	29-Jul-05	Norwest Labs Edmonton
Orthophosphate-P in Water	APHA	*	Automated Ascorbic Acid Reduction Method, 4500-P F	29-Jul-05	Norwest Labs Edmonton
pH in water (Surrey)	APHA	*	Electrometric Method, 4500-H+ B	29-Jul-05	Norwest Labs Surrey
Solids Suspended (Total, Fixed and Volatile)	APHA	*	Total Suspended Solids Dried at 103-105'C, 2540 D	29-Jul-05	Norwest Labs Edmonton
Solids Suspended (Total, Fixed and Volatile)	APHA	*	Total Suspended Solids Dried at 103-105'C, 2540 D	2-Aug-05	Norwest Labs Surrey

Please direct any inquiries regarding this report to our Client Services group.
Results relate only to samples as submitted

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Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Methodology and Notes

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **398142**
Control Number:
Date Received: Jul 28, 2005
Date Reported: Aug 09, 2005
Report Number: 727534

* Norwest method(s) is based on reference method

References:

Alberta Research Council	Methods Manual for Chemical Analysis of Water and Wastes
APHA	Standard Methods for the Examination of Water and Wastewater
MDMES	Mthds for the Determination of Metals in Enviromental Smpls
US EPA	US Environmental Protection Agency Test Methods

Comments:

Called Wayne from Kinross in regards to the last sample not being sent in, I just left a message on machine. The sample missing was 51081. This sample will not be added to the lot.

Sample 4 Insufficient sample was provided for TSS for samples 2 and 4 through 15 to reach lower detection limit of 1 mg/l.

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Tel (403) 253-7121 / Fax (403) 252-9363 www.hydroqual.ca

Test Report

Client:	NOR239	Sample:	20051122

Client

Client: Norwest Labs
Address: 7217 Roper Road
City: Edmonton
Country: Canada
Billing: Lot # 398418
Tel: 780-438-5522

Operation: Edmonton
Prov./State: Alberta
Postal/ZIP Code: T6B 3J4
Contact: Linda LeGroix/ Darlene Lintott
Fax: 780-438-0396

Sample

type: water method: grab
collected: 2005/07/27 at not given by not given
shipped: 2005/07/27 by First Air/Air Canada
received: 2005/07/29 at 1100 by L.Fantin
signed-in: 2005/07/29 at 1100 by L.Fantin
container: 12 x 10L containers - containers composited and split for testing
seals present: no initials on seals no sample condition good
storage: 4 ± 2°C in darkness initial temperature (°C) 23
Samples are disposed following Supporting Work Instruction 4.3.1.4.3

Physical and Chemical Measurements at Sample Receipt

lab code	-1
client code	398418

water/effluent/pore water

pH	7.1
EC (uS/cm)	868
DO (mg/L)	7.3
temp (°C)	22
alkalinity	not done
hardness	157
NH4 (mg/L)	not done
TRC (mg/L)	not done
colour	clear
odour	odourless

soil/sediment

moisture (%)	na
sand:silt:clay	na
TOC (%)	na

Test Log

type	TR-S	DA-S	LM-D	AG-D	CD-D	FM-D
number	20053127	20053126	20053129	20053130	20053128	20053131
started	2005/07/29	2005/07/29	2005/07/30	2005/07/29	2005/07/29	2005/07/29
ended	2005/08/02	2005/07/31	2005/08/06	2005/08/01	2005/08/05	2005/08/05
reported	2005/08/15	2005/08/15	2005/08/15	2005/08/15	2005/08/15	2005/08/15
faxed	2005/08/03	2005/08/01	na	na	na	na

Notes: D, definitive; S, single treatment; EC, electrical conductivity; DO, dissolved oxygen; TRC, total residual chlorine; TOC, total organic carbon; na, not applicable

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Test Report

Client: NOR239	Sample: 20051122	Test: 20053126

Method *Daphnia* 48h Static Acute Test (undiluted sample plus a control) (HQ 4.4.3.1)
Reference: Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to *Daphnia magna*, 1990. Environ. Can., EPS 1/RM/14. (amended 1996 and 2000)

Client: Norwest Labs Operation: Edmonton

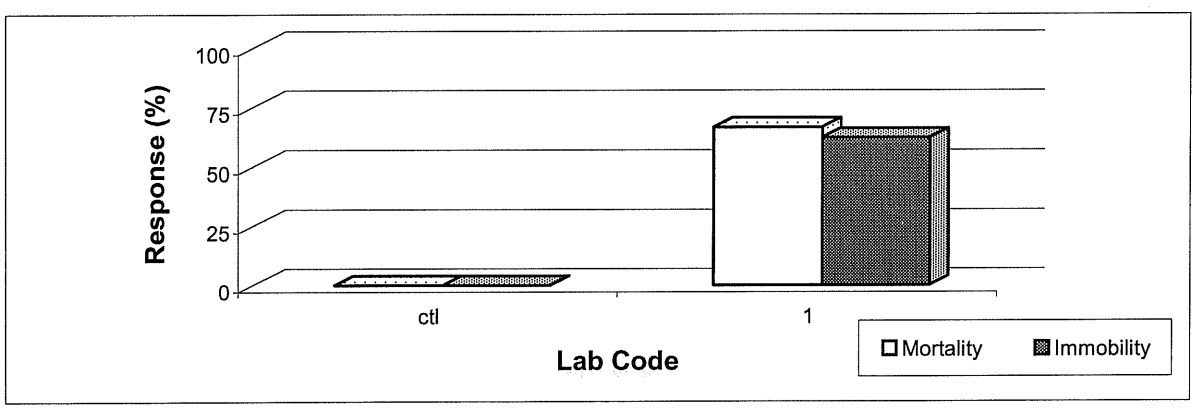
Sample:
description: 398418, location 925-10
collected: 2005/07/27 at not given by not given
received: 2005/07/29 at 1100 by L.Fantin

Test:
started: 2005/07/29 at 1300 by L. Fantin
ended: 2005/07/31 at 1050 by K. de Windt
reported: 2005/08/15 by G. Diaz

Result:

Lab Code	Client Code	Mortality (%) mean	sd	cv(%)	Immobility (%) mean	sd	cv(%)	Comment
ctl	lab control	0	0	0	0	0	0	
1	398418	67	15	23	62	21	33	toxic as tested

Notes: sd, sample standard deviation; cv, coefficient of variance
Mortality is calculated as percent of total daphnids per treatment at test initiation
Immobility is calculated as percent of live daphnids on day 2



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Test Report

Test Data

Client:	NOR239	Sample:	20051122	Test:	20053126

Day	Time	Technician	Comment/Observation
0	1300	L. Fantin	Test *Daphnia* appear normal.
1	1300	K. de Windt	Test *Daphnia* appear normal.
2	1050	K. de Windt	Test *Daphnia* appear normal.

lab code	ctl			1		
replicate	a	b	c	a	b	c
day	**pH (units)**					
0	8.4	8.4	8.4	7.3	7.3	7.3
2	8.4	8.5	8.5	7.3	7.3	7.4
	EC (uS/cm)					
0	423	423	423	902	902	902
2	417	401	398	880	891	886
	DO (mg/L)					
0	8.1	8.1	8.1	7.9	7.9	7.9
2	7.8	7.9	7.8	7.6	7.7	7.7
	Temperature (°C)					
0	19	19	19	21	21	21
2	19	20	20	20	20	20
	Number Alive (F, floating; I, immobile; B, stuck on bubble; D, caught in debris)					
1	10	10	10	10(3I)	10(1D,5I)	12(1I)
2	10	10	10	2(2I)	3 (2I)	5(1I)

Notes: EC, electrical conductivity; DO, dissolved oxygen; nd, not done; na, not applicable

Comments:

Organism: <24 h old *Daphnia magna;* in-house culture; mortality 7 days before test (%): 13
Culture's time to first brood (d): 9 Brood size (neonates per brood): 26
Adjustments prior to testing: pH: none hardness (mg CaCO3/L): none
The duration of pre-aeration, at a rate of 37.5 ± 12.5 mL/min·L^{-1}, was (min): 0
The hardness of the lab dilution water was (mg $CaCO_3$/L): 161
The test was conducted in 385 mL plastic vessels containing 150 mL of test solution and ten daphnids (loading density of 15 mL per daphnid or neonate).
One of the 100% test vessels was loaded with 12 neonates.

The test data and results are verified correct. K. Steele

Authorized by K.Steele, B.Sc., Quality Assurance Officer

Our liability is limited to the cost of the test requested on the sample as received. No liability in whole or in part is assumed for the collection, handling or transport of the sample, application or interpretation of the test data or results in part or in whole.

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Test Report

Client: NOR239	Sample: 20051122	Test: 20053127

Method Trout 96h Static Acute Test (undiluted sample plus a control) (HQ 4.4.4.1)
Reference: Biological Test method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout, 1990. Environ. Can., EPS 1/RM/13. (amended 1996 and 2000)

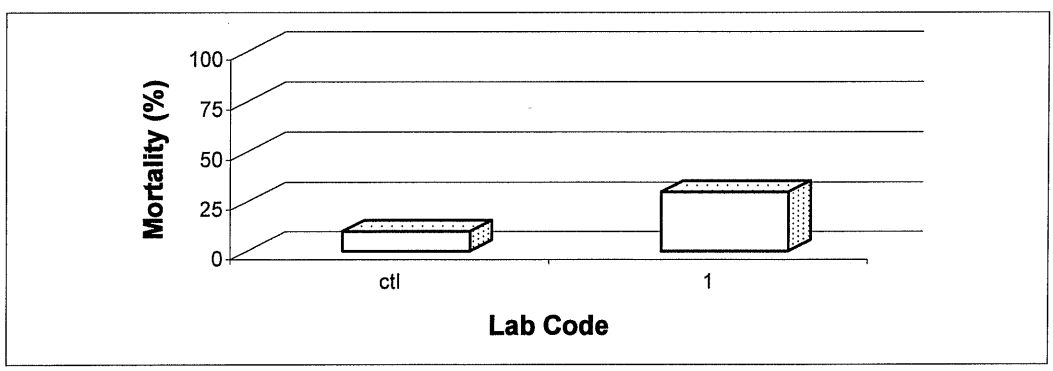
Client: Norwest Labs Operation: Edmonton

Sample:
description: 398418, location 925-10
collected: 2005/07/27 at not given by not given
received: 2005/07/29 at 1100 by L.Fantin

Test:
started: 2005/07/29 at 1600 by L.Fantin/A.Corbett
ended: 2005/08/02 at 1600 by L.Fantin/A.Corbett
reported: 2005/08/15 by G. Diaz

Result:

Lab Code	Client Code	Mortality (%)	Comment
ctl	lab control	10	
1	398418	30	not toxic as tested



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Test Report

Test Data

Client:	NOR239	Sample:	20051122	Test:	20053127

Day	Time	Technician	Comment/Observation
0	1600	L.Fantin/A.Corbett	test fish loaded at 1600 h
1	1330	K.Steele/M.Luong	all test fish appear normal
2	1030	K. de Windt/M.Luong	all test fish appear normal
3	1415	K.Steele/M.Luong	all test fish appear normal
4	1600	L.Fantin/A.Corbett	all test fish appear normal

Preaeration (6.5 mL/min/L)	0.5	1.0	1.5	2 (h)
DO (mg/L)	8.5			

lab code	ctl	1						

day								
	pH (units)							
0	8.0	6.8						
1	8.4	7.0						
2	8.4	7.4						
3	8.4	7.1						
4	8.3	7.3						
	EC (uS/cm)							
0	415	938						
1	395	877						
2	391	882						
3	401	885						
4	380	884						
	DO (mg/L)							
0	8.5	8.5						
1	8.3	8.4						
2	8.4	8.2						
3	8.4	8.6						
4	8.5	8.7						
	Temperature (°C)							
0	16	16						
1	16	16						
2	16	16						
3	16	16						
4	16	16						
	Number Alive							
0	10	10						
1	10	8						
2	10	8						
3	10	7						
4	9	7						
	Mortality (%)							
	10	30						

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Test Report

Test Data

Client:	NOR239	Sample:	20051122	Test:	20053127

Control Fish	Length (cm)	Weight (g)
1	3.1	0.2
2	3.6	0.3
3	3.5	0.4
4	3.2	0.2
5	3.2	0.2
6	3.2	0.2
7	3.4	0.3
8	3.3	0.2
9	3.2	0.2
10	3.6	0.3
average	3.3	0.3
sd	0.2	0.1
cv(%)	5.5	22.7

Lab Code	Group Weight (g)
ctl	2.7
1	2.8

Ammonium (mg NH_4^+-N/L) initial	final
0.2	0.6
2.5	2.7

Test Information

Organism: *Oncorhynchus mykiss* from Trout Lodge Inc.
Age and condition: The fish were held 14 days before testing (batch 20050714TR).

Conditions

The test volume was: 20 (L)
The test was conducted in 22 L plastic pails with polyethylene liners.
One replicate per treatment.
Ten fish per replicate with a loading density of: 0.1 (g/L)
Stock mortality 7 days prior to testing: 0.1 (%)
All treatments aerated at: 6.5 (±1 mL/min/L)
The sample was not pH adjusted.

Comments

none

The test data and results are verified correct.

Authorized by K.Steele, B.Sc., Quality Assurance Officer

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Test Report

Client:	NOR239	Sample:	20051122	Test:	20053128

Method: *Ceriodaphnia* Survival and Reproduction Test (five treatments plus a control) (HQ 4.4.3.2)
reference: Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*, 1992. Environ.Can., EPS 1/RM/21. (amended November, 1997)

Client: Norwest Labs Operation: Edmonton

Sample:
description: 398418, location 925-10
collected: 2005/07/27 at not given by not given
received: 2005/07/29 at 1100 by L.Fantin

Test:
started: 2005/07/29 at 1200 by B. Denny
ended: 2005/08/05 at 1200 by B. Denny
reported: 2005/08/15 by G.Diaz

Result:

	Endpoint	Value	Confidence Limits	Units	Method Calculated
Acute:	LC25	>100		%	estimated
(mortality)	LC50	>100		%	estimated
	NOEC	100		%	estimated
	LOEC	> 100		%	estimated
	MSD	could not be calculated		ceriodaphnid	
Chronic:	IC25	>100		%	estimated
(fecundity)	IC50	>100		%	estimated
	NOEC	100		%	estimated
	LOEC	>100		%	estimated
	MSD	could not be calculated		young	

Notes: LCx & ICx, concentrations lethal or inhibitory to 'x' percent of the test population; NOEC & LOEC, no and lowest observed effect concentrations; fecundity, reproduction as the number of young produced

Comments: The test results are plotted on page 2 of the report.
No unusual behaviour, appearance, or treatment of the test organisms was noted prior to or during the conduct of the test. All test organisms came from a brood source that are all the same age.
The numbers in bold print under the "Biology (#, young produced . . .) section refers to the number of young the test organism had the day it died.
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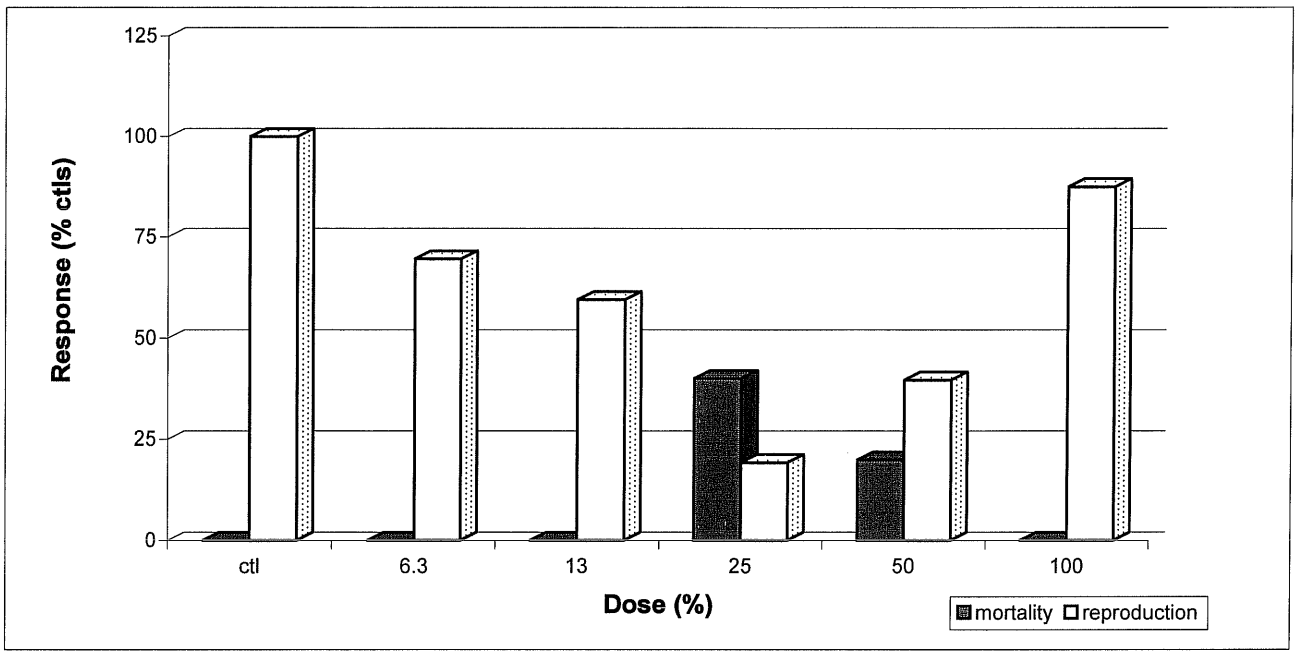
Test Report

Client:	NOR239	Sample:	20051122	Test:	20053128



Test Design

Organism: *Ceriodaphnia dubia* Source: in-house cultures Age: <24 h; released within 12 h
The number of young produced by each brood organism in the last complete brood before use was 7
No ephippia were noted in the cultures 7 days before test initiation. Culture mortality wa 0%
during this period and the mean number of surviving young per adult was 15
The dilution water was a mixture of moderately hard reconstituted water and Bow River Water (50:50).
Chemicals added to dilution water: 0.96 g $NaHCO_3$, 0.60 g $CaSO_4$, 0.60 g $MgSO_4$, 0.04 g KCl per 20L
The tests were conducted in 30 mL plastic vessels containing 15 mL of solution (2cm depth).
The test organisms were fed daily a mixture of fermented trout chow, yeast, alfalfa powder, and the green alga *Raphidocelis subcapitata*. food expiration: 2005/07/30, 2005/08/14

Sample Information

The test was conducted with three subsamples. Samples a, b, and c were for days 0 to 2, 3 to 4, and 5 to 7.
The sample was not aerated, filtered or pH adjusted prior to testing or during testing.
The dissolved oxygen concentration (mg/L) was 7.1 The sample pH was 7.0

Test Log

Date	Day	Time	Technicians	Comments
2005/07/29	0	1200	B. Denny	Test *Ceriodaphnia* appear normal.
2005/07/30	1	1230	K. de Windt	Test *Ceriodaphnia* appear normal.
2005/07/31	2	0915	K. de Windt	Test *Ceriodaphnia* appear normal.
2005/08/01	3	1130	K. de Windt	Test *Ceriodaphnia* appear normal.
2005/08/02	4	1145	B. Denny	Test *Ceriodaphnia* appear normal.
2005/08/03	5	1045	B. Denny	Test *Ceriodaphnia* appear normal.
2005/08/04	6	1115	B. Denny	Test *Ceriodaphnia* appear normal.
2005/08/05	7	1200	B. Denny	Test *Ceriodaphnia* appear normal.

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Test Report

Test Data

Client: NOR239	Sample: 20051122	Test: 20053128

Chemistry

New Solutions

Dose (%) / day	ctl	6.3	13	25	50	100	
pH (units)							
0	8.3	8.3	8.3	8.2	8.0	7.0	
1	8.5	8.5	8.5	8.4	8.2	7.5	
2	8.4	8.4	8.3	8.3	8.1	7.7	
3	8.4	8.4	8.3	8.2	8.1	7.1	
4	8.4	8.4	8.3	8.3	8.1	7.3	
5	8.3	8.3	8.3	8.2	8.0	7.2	
6	8.3	8.3	8.3	8.2	8.0	7.3	
7							
8							
conductance (uS/cm)							
0	378	397	429	497	628	877	
1	367	381	408	476	605	840	
2	371	385	415	480	613	858	
3	365	384	416	477	597	857	
4	353	379	410	479	603	851	
5	364	397	420	491	620	863	
6	382	407	430	496	630	880	
7							
8							
dissolved oxygen (mg/L)							
0	7.1	7.1	7.1	7.1	7.1	7.1	
1	6.8	6.9	7.0	7.0	7.1	7.1	
2	7.1	7.1	7.1	7.1	7.1	7.1	
3	7.3	7.3	7.3	7.2	7.3	7.4	
4	7.0	7.0	7.0	7.0	7.0	7.0	
5	7.3	7.3	7.3	7.3	7.3	7.3	
6	7.4	7.3	7.3	7.3	7.3	7.3	
7							
8							
temperature (°C)							
0	25	25	25	25	25	25	
1	25	25	25	25	25	25	
2	25	25	25	25	25	25	
3	25	25	25	25	25	25	
4	25	25	25	25	25	25	
5	25	25	25	25	25	25	
6	25	25	25	25	25	25	
7							
8							

Old Solutions

ctl	6.3	13	25	50	100	
pH (units)						
8.4	8.4	8.3	8.2	8.1	7.4	
8.3	8.3	8.3	8.2	8.1	7.7	
8.3	8.2	8.2	8.2	8.1	7.4	
8.2	8.3	8.2	8.2	8.1	7.5	
8.3	8.2	8.2	8.2	8.1	7.3	
8.3	8.2	8.2	8.2	8.1	7.4	
8.3	8.2	8.2	8.2	8.0	7.5	
conductance (uS/cm)						
375	438	443	499	631	890	
368	415	432	494	634	886	
370	401	439	500	640	887	
364	393	423	489	635	885	
380	418	448	512	652	892	
377	412	435	508	655	900	
380	410	432	506	646	880	
dissolved oxygen (mg/L)						
6.5	6.6	6.5	6.4	6.6	6.5	
6.7	6.7	6.7	6.7	6.8	6.8	
6.9	6.9	6.9	7.0	7.0	7.0	
6.4	6.4	6.4	6.6	6.7	6.8	
6.9	6.9	6.9	6.9	6.9	6.9	
6.9	6.9	6.9	6.9	6.9	6.9	
6.8	6.8	6.8	6.8	6.8	6.8	
temperature (°C)						
25	25	25	25	25	25	
25	25	25	25	25	25	
25	25	25	25	25	25	
25	25	25	25	25	25	
25	25	25	25	25	25	
25	25	25	25	25	25	
24	24	24	24	24	24	

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Test Report

Test Data | Client: NOR239 | Sample: 20051122 | Test: 20053128

Biology (#, young produced; 0, no young; blank, dead)

Dose (%)	ctl	6.3	13	25	50	100		ctl	6.3	13	25	50	100	
replicate	day 1							day 5						
1	0	0	0	0	0	0		6	6	0			0	
2	0	0	0	0	0	0		7	6	6		2	5	
3	0	0	0	0	0	0		6	0	5	0	3	6	
4	0	0	0	0	0	0		0	0	6		3	7	
5	0	0	0	0	0	0		7	5	0	0	0	6	
6	0	0	0	0	0	0		0	0	0	0	2	0	
7	0	0	0	0	0	0		7	5	0	0	2	6	
8	0	0	0	0	0	0		6	5	6	3	0	0	
9	0	0	0	0	0	0		7	0	5		0	5	
10	0	0	0	0	0	0		0	6	0	0		6	
	day 2							day 6						
1	0	0	0		0	0		0	7	4			6	
2	0	0	0		0	0		0	0	0		5	7	
3	0	0	0	0	0	0		8	6	8	4	6	0	
4	0	0	0	0	0	0		8	7	7		5	8	
5	0	0	0	0	0	0		10	0	0	0	3	8	
6	0	0	0	0	0	0		6	6	6	4	0	6	
7	0	0	0	0	0	0		8	0	5	0	0	0	
8	0	0	0	0	0	0		9	0	0	0	0	0	
9	0	0	0	0	0	0		0	6	0		0	7	
10	0	0	0	0	0	0		7	0	0	3		0	
	day 3							day 7						
1	0	0	0			0		9	0	6			9	
2	0	0	0		0	0		9	8	8		0	9	
3	0	0	0	0	0	0		10	8	0	0	8	10	
4	0	0	0		0	1		9	9	0		9	0	
5	0	0	0	0	0	0		0	10	0	5	9	10	
6	0	0	0	0	0	0		8	0	8	6	6	9	
7	0	0	0	0	0	0		10	7	0	4	5	8	
8	0	0	0	0	0	0		9	8	8	5	6	9	
9	0	0	0		0	0		9	0	9		8	10	
10	0	0	0	0	0	0		0	9	9	6		10	
	day 4							day 8						
1	4	2	0			2								
2	4	3	2		0	0								
3	3	3	3	0	0	2								
4	3	3	3		0	0								
5	3	2	2	0	0	0								
6	3	0	0	0	0	2								
7	4	2	3	0	0	0								
8	3	2	2	0	0	3								
9	2	3	2		0	2								
10	3	0	0	0		2								

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Test Report

Summary Tables

Client: NOR239	Sample: 20051122	Test: 20053128

Biology

Mortality (%)

Dose (%) / day	ctl	6.3	13	25	50	100	
0	0	0	0	0	0	0	
1	0	0	0	0	0	0	
2	0	0	0	20	0	0	
3	0	0	0	40	10	0	
4	0	0	0	40	20	0	
5	0	0	0	40	20	0	
6	0	0	0	40	20	0	
7	0	0	0	40	20	0	
8							
totals	0	0	0	40	20	0	

Daily Young Production

ctl	6.3	13	25	50	100	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	0	
0	0	0	0	0	1	
32	20	17	0	0	13	
46	33	28	3	12	41	
56	32	30	11	19	42	
73	59	48	26	51	84	
207	144	123	40	82	181	

average young per adult

21	14	12	4	8	18	

young production as a percent of controls

100	70	59	19	40	87	

Total Young Produced by Each Adult

replicate						
1	19	15	10	0	0	17
2	20	17	16	0	7	21
3	27	17	16	4	17	18
4	20	19	16	0	17	16
5	20	17	2	5	12	24
6	17	6	14	10	8	17
7	29	14	8	4	7	14
8	27	15	16	8	6	12
9	18	9	16	0	8	24
10	10	15	9	9	0	18

Chemistry

New Solutions — Average Values

Dose (%)	ctl	6.25	12.5	25	50	100	
pH	8.4	8.4	8.3	8.3	8.1	7.3	
EC	369	390	418	485	614	861	
DO	7.1	7.1	7.2	7.1	7.2	7.2	
temp	25	25	25	25	25	25	

New Solutions — Variance (%)

pH	1	1	1	1	1	3	
EC	3	3	2	2	2	2	
DO	3	2	2	2	2	2	
temp	0	0	0	0	0	0	

Old Solutions — Average Values

ctl	6.25	12.5	25	50	100	
8.3	8.3	8.2	8.2	8.1	7.5	
373	412	436	501	642	889	
6.7	6.7	6.7	6.8	6.8	6.8	
25	25	25	25	25	25	

Old Solutions — Variance (%)

1	1	1	0	0	2	
2	3	2	2	1	1	
3	3	3	3	2	2	
2	2	2	2	2	2	

The test data and results are verified correct. K. Steele

Authorized by K.Steele, B.Sc., Quality Assurance Officer

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Test Report

Client: NOR239	Sample: 20051122	Test: 20053129

Method Reference: *Lemna* 7d Static Acute Test (five treatments plus a control) (HQ 4.4.2.3)
Biological Test Method: Test for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, Lemna minor, 1999. Environment Canada, EPS 1/RM/37.

Client: Norwest Labs Operation: Edmonton

Sample:
description: 398418, location 925-10
collected: 2005/07/27 at not given by not given
received: 2005/07/29 at 1100 by L.Fantin

Test:
started: 2005/07/30 at 1330 by K. de Windt
ended: 2005/08/06 at 1130 by B. Denny
reported: 2005/08/15 by G. Diaz

Result:

	Endpoint	Value	Confidence Limits		Units	Method Calculated
Chronic:	IC25	<6.1			%	Linear Interpolation
(frond #)	IC50	24	could not be calculated		%	Linear Interpolation
	NOEC	<6.1			%	Dunnett's
	LOEC	6.1			%	Dunnett's
	MSD	4.6			fronds	Dunnett's
Chronic:	IC25	10	3.5	71	%	Linear Interpolation
(biomass)	IC50	>97			%	Linear Interpolation
	NOEC	6.1			%	estimated
	LOEC	12			%	estimated
	MSD	could not be calculated			mg	estimated

Notes: ICx, concentrations lethal or inhibitory to 'x' percent of the test population; NOEC & LOEC, no and lowest observed effect concentrations; MSD, minimum significant difference

Comments:

No unusual behaviour or appearance or treatment of test organisms was noted prior to testing or during testing. There was not growth stimulation observed during the test. Only three replicates were weighted in the 49% concentration.

Our liability is limited to the cost of the test requested. No liability is assumed for the application and or interpretation of the test results.

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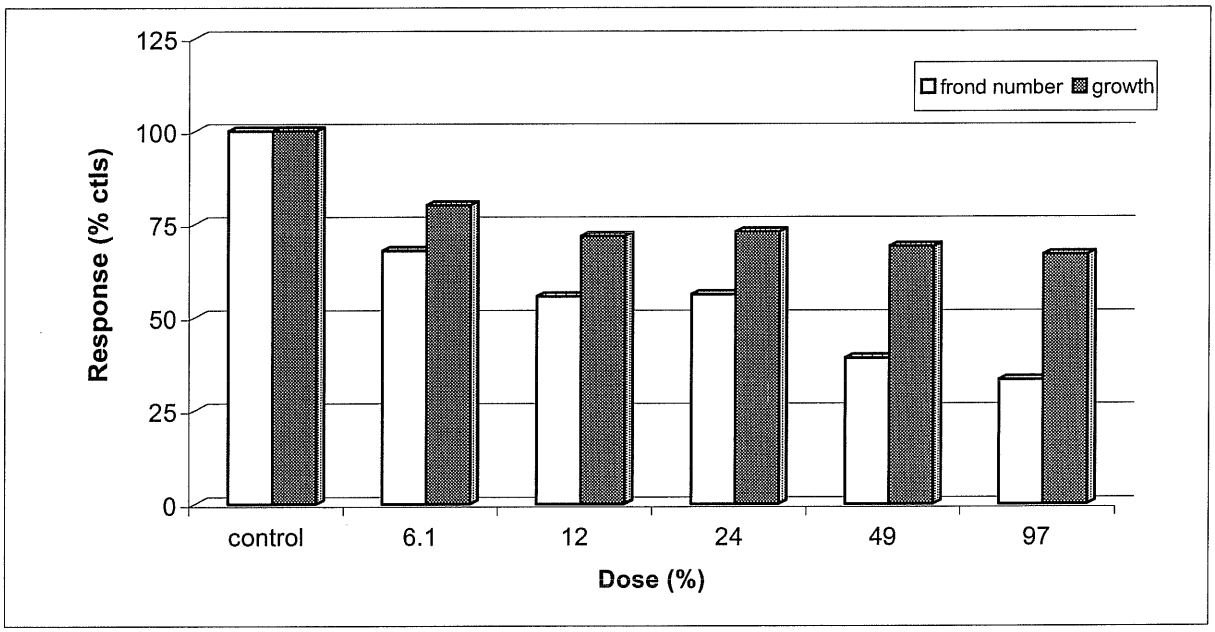
Test Report

Client: NOR239	Sample: 20051122	Test: 20053129



Test Information

Organism: The test organism was Lemna minor from in-house cultures. It was originally obtained from the University of Toronto Culture Collection (492). The fronds were acclimated in test media for 24 h prior to test initiation.The test culture was axenic prior to testing.
The fronds are 9 days old at test initiation.
The mean increase in frond number of culture over last 7 days: 25 fold increase: 8

Test Design: The test was a static test conducted in 200 mL polyethylene plastic containers with clear lids. The test volume was 150 mL. There were four replicates per treatment. The test was initiated with two 3 frond daughter plants per replicate.

Test Media: The test media was deionized water spiked with nutrients (Environment Canada EPS 1/RM/37, 1999). No other chemicals were added to the test media. The media aerated for two hours and pH adjusted to 8.3±0.1 with 6N HCl or NaOH. The test media was not filtered. The control and dilution water was test media.

					Temperature (°C)		
Date	Day	Time	Technicians	Rotate	Control	24%	97%
2005/07/30	0	1330	K. de Windt	na	25	25	25
2005/07/31	1	0850	M. Luong	yes	25	25	25
2005/08/01	2	0900	M. Luong	yes	25	25	25
2005/08/02	3	0900	C.A. Martens	yes	25	25	25
2005/08/03	4	0800	C.A. Martens	yes	25	25	25
2005/08/04	5	0830	C.A. Martens	yes	25	25	25
2005/08/05	6	0820	C.A. Martens	yes	25	25	25
2005/08/06	7	1130	B. Denny	na	24	24	24

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Test Report

Test Data

Client:	NOR239	Sample:	20051122	Test:	20053129

Biology

Frond Number

	replicate	Dose (%) control	6.1	12	24	49	97	
day 0	a	6	6	6	6	6	6	
	b	6	6	6	6	6	6	
	c	6	6	6	6	6	6	
	d	6	6	6	6	6	6	
day 7	a	51	34	31	26	25	16	
	b	54	36	27	31	16	19	
	c	48	30	28	29	20	16	
	d	52	39	28	29	19	17	
	average	51	35	29	29	20	17	
	sd	3	4	2	2	4	1	
	cv	5	11	6	7	19	8	
	% ctls	100	68	56	56	39	33	

Dry Weights (mg)

day 7	a	3.8	2.8	3.2	2.9	not done	3.0	
	b	4.2	3.5	2.6	2.7	2.6	2.3	
	c	3.9	2.9	3.2	3.4	3.1	2.6	
	d	4.1	3.7	2.6	2.8	2.6	2.9	
	average	4.0	3.2	2.9	2.9	2.8	2.7	
	sd	0.2	0.4	0.3	0.3	0.3	0.3	
	cv	5	13	11	11	12	11	
	%ctls	100	80	72	73	69	67	

Chemistry

day 0	pH	8.2	8.1	8.1	8.1	8.2	8.2	
	EC	951	908	945	10.5	1209	1556	
	DO	7.3	7.2	7.3	7.3	7.3	7.3	
	temp	23	23	23	23	23	23	
day 7	pH	8.4	8.8	8.8	9.0	8.9	8.8	
	EC	915	931	965	1076	1340	1624	
	DO	7.3	8.3	8.2	9	8.4	8.3	
	temp	24	24	24	24	24	24	

Notes: pH, units; EC, electrical conductance (uS/cm); DO, dissolved oxygen (mg/L); temp, temperature (°C); sd, standard deviation; cv, coefficient of variance; %ctls, percent of controls

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Test Report

Test Data

Client: NOR239	Sample: 20051122	Test: 20053129

Comments (day 7)

Dose	
control	light green, long roots
6.1	light green, long roots
12	light green, medium roots, slight gib, slight chl
24	light green, medium roots,slight chl
49	light green, short roots, slight chl
97	light green, short roots, slight chl

Notes: chl, chlorotic; nec, necrotic; asf, abnormally sized fronds; gib, gibbosity; cd, colony destroyed; rd, roots destroyed; lb, loss of bouyancy

Comments

The effluent was spiked with nutrients (Environment Canada EPS 1/RM/37, 1999).
The sample was not pH adjusted or filtered prior to testing.
The sample was pre-aerated for at least 20 minutes with oil free filtered compressed air from a 1 mL glass pipette attached to an air pump at a rate of 2-3 bubbles per second.
Date of effluent preparation: 2005/07/30

The light levels (lux) were measured at the sample surface, at three locations on the testing bench, during testing:

left: 4465 center: 4750 right: 4465

The mean number of fronds in the controls have increased b 9 fold.

The test data and results are verified correct. K. Steele

Authorized by K.Steele, B.Sc., Quality Assurance Officer

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Test Report

Client:	NOR239	Sample:	20051122	Test:	20053130

Method: 72h Algal Growth Inhibition Test (HQ 4.4.2.7)
reference: Biological Test Method: Growth Inhibition Test Using the Freshwater Alga *Selenastrum capricornutum*, 1992. Environment Canada, EPS 1/RM/25. (ammended November 1997)

Client: Norwest Labs Operation: Edmonton

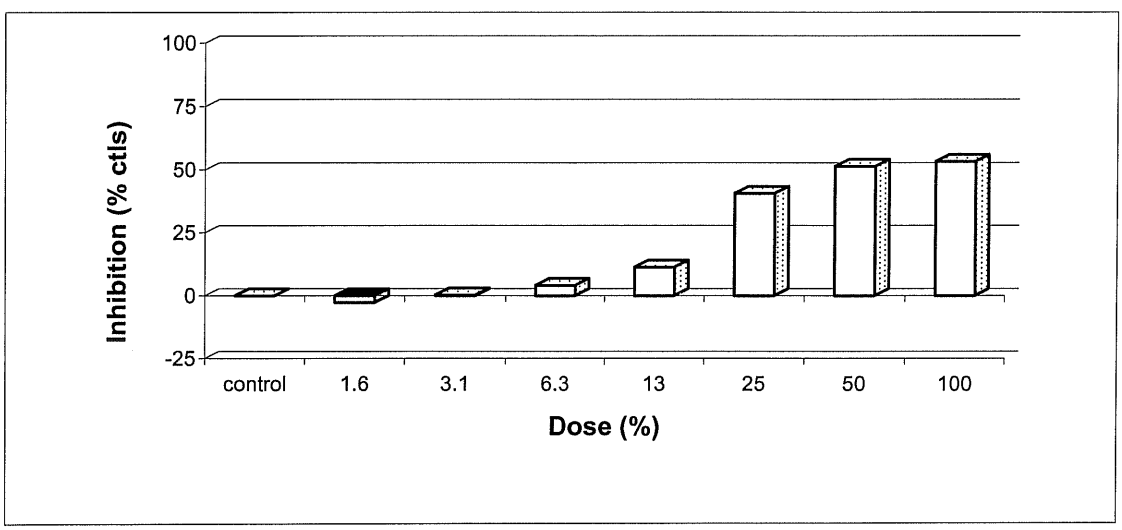
Sample:
description: 398418, location 925-10
collected: 2005/07/27 at not given by not given
received: 2005/07/29 at 1100 by L.Fantin

Test:
started: 2005/07/29 at 1430 by K. de Windt
ended: 2005/08/01 at 1315 by K. de Windt
reported: 2005/08/15 by G. Diaz

Result:

Endpoint	Value	Confidence Limits		Units	Method Calculated
IC25	17	15	19	%	Linear Interpolation
IC50	44	35	53	%	Linear Interpolation
NOEC	13			%	estimated
LOEC	25			%	estimated

Notes: ICx, concentrations inhibiting growth by 'x' percent relative to controls; NOEC & LOEC, no and lowest observed effect concentrations; MSD, minimum significant difference; cv, coefficient of variance (%); sd, standard deviation



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Test Report

Test Data

Client:	NOR239	Sample:	20051122	Test:	20053130

Sample Pretreatment:

pH adjustment	not required	preaeration	not required
turbidity	100 mL filtered through a 0.45um membrane filter		
other	sample spiked with nutrients as required by the method; no other chemicals added		

Final Cell Densities ($x10^3$ / mL)

Dose (%)	Plate a	Plate b	Plate c	Average	sd	cv (%)	Percent Controls	Inhibition (%)
control	461	438	427	442	17	4	100	0
1.6	479	450	434	454	23	5	103	-3
3.1	466	435	421	441	23	5	100	0
6.3	430	424	418	424	6	1	96	4
13	410	384	383	392	15	4	89	11
25	266	270	253	263	9	3	59	41
50	215	210	220	215	5	2	49	51
100	201	213	205	206	6	3	47	53

Note: The final cell densities for the controls are an average of 10 replicate well reading per plate. The final cell densities for each dose is an average of 5 replicate well readings per plate.

Comments

The test was conducted in 96 well microplates. Three replicate plates were run (a, b and c). On each plate 220 uL of sample was plated in 5 replicate wells per dose and 10 replicate wells per control.
The test species was *Raphidocelis subcapitata* (formerly *Selenastrum capricornutum*).
The test was started with 7 day old, exponentially growing cells from in-house cultures.
The plates were incubated under continuous light (4,000 lux).

Inoculum (cells/mL)	
a	10400
b	10600
c	11000
mean	10667
cv (%)	3

Daily Temperature	
0	25
1	25
2	25
3	25
mean	25
cv (%)	0

control pH: initial final
100% pH: initial

Dose (%)	Absorbance (430nm)	Direct Cell Counts (/0.5mL)
ctl-a	0.14	6850
12.5-a	0.12	5700
100-a	0.06	1100
ctl-b	0.13	5550
12.5-b	0.11	4750
100-b	0.06	1300
ctl-c	0.13	5100
12.5-c	0.11	4750
100-c	0.06	1350

Final cell densities were determined from the absorbance at 430 nm calibrated against cell counts.
The conversion factor for absorbance to cells per millilitre was 3398 with a cv of 34 %
Control growth was a 41 fold increase over the inoculum with a cv of 4 %
No significant stimulatory or inhibitory trends were detected by Mann-Kendall Trend analysis (p=0.05).

The test data and results are verified correct.

K. Steele

Authorized by K.Steele, B.Sc., Quality Assurance Officer

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Test Report

Client:	NOR239	Sample:	20051122	Test:	20053131

Method: 7 d Fathead Minnow Survival and Growth Test (five treatments plus a control) (HQ 4.4.4.6)
reference: Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnow, 1992. Environment Canada, EPS 1/RM/22. (ammended 1997)

Client: Norwest Labs Operation: Edmonton

Sample:

description:	398418, location 925-10				
collected:	2005/07/27	at	not given	by	not given
received:	2005/07/29	at	1100	by	L.Fantin

Test:

started:	2005/07/29	at	1330	by	A. Corbett
ended:	2005/08/05	at	1350	by	L. Fantin
reported:	2005/08/15			by	G. Diaz

Result:

	Endpoint	Value	Confidence Limits	Units	Method Calculated
Acute:	LC25	>100		%	estimated
(mortality)	LC50	>100		%	estimated
	NOEC	100		%	estimated
	LOEC	>100		%	estimated
	MSD	could not be calculated		fish	
Chronic:	IC25	>100		%	estimated
(growth)	IC50	>100		%	estimated
	NOEC	100		%	estimated
	LOEC	>100		%	estimated
	MSD	could not be calculated		mg	

Notes: LCx & ICx, concentrations lethal or inhibitory to 'x' percent of the test population; NOEC & LOEC, no and lowest observed effect concentrations

Comments: The EC guidance document on the importation of test organisms (1999) has been followed. No unusual behaviour or appearance or treatment of test organisms was noted prior to shipping, upon arrival or preceding the test. Test organisms were received in good condition, with inflated swim bladders. No acclimation of test organisms was required. The mortality of the test organisms was <2%upon arrival, and before test initiation.

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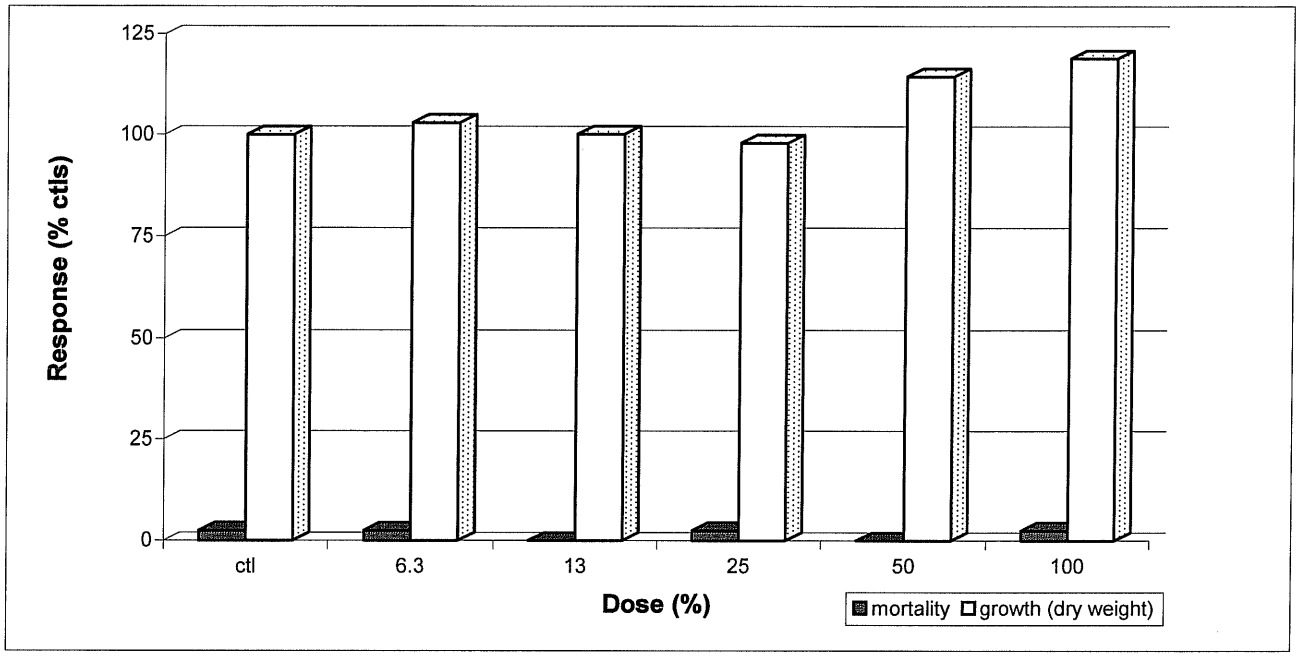
Test Report

Client:	NOR239	Sample:	20051122	Test:	20053131



Test Design

Organism: *Pimephales promelas* Source: Aquatox Inc. Age: < 24 hour post hatch
Breeding stock mortality was less than five percent during the week prior to test initiation.
The tests were conducted in 500 mL plastic vessels with 250 mL volumes (depth of 6.5 cm).
The sample was diluted with dechlorinated City of Calgary water acclimated to the test conditions.

Sample Information

The test was conducted with three samples. Samples a, b, and c were for days 0 to 2, 3 to 4, and 5 to 7.
The sample was not preaerated, filtered or pH adjusted prior to testing or during testing.
The dissolved oxygen concentration (mg/L) was 7.8 The sample pH was 7.2

Test Log

Date	Day	Time	Technicians	Comments
2005/07/29	0	1330	A. Corbett	Test organisms appear normal.
2005/07/30	1	1200	M. Luong	Test organisms appear normal.
2005/07/31	2	1230	M. Luong	Test organisms appear normal.
2005/08/01	3	1200	M. Luong	Test organisms appear normal.
2005/08/02	4	1350	A.Corbett	Test organisms appear normal.
2005/08/03	5	1330	A. Corbett	Test organisms appear normal.
2005/08/04	6	1400	L. Fantin	Test organisms appear normal.
2005/08/05	7	1350	L. Fantin	Test organisms appear normal.

The test data and results are verified correct. K. Steele

Authorized by K.Steele, B.Sc., Quality Assurance Officer

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Test Report

Test Data

Client: NOR239	Sample: 20051122	Test: 20053131

Chemistry

pH (units)

dose (%) / day	New Solutions ctl	6.3	13	25	50	100		Old Solutions ctl	6.3	13	25	50	100	
0	8.3	8.3	8.2	8.2	8.1	7.2								
1	8.4	8.3	8.3	8.2	8.1	7.4		8.4	8.4	8.4	8.3	8.3	7.6	
2	8.3	8.3	8.3	8.2	8.1	7.3		8.2	8.2	8.1	8.1	8.0	7.2	
3	8.3	8.3	8.3	8.2	8.1	7.3		8.2	8.2	8.1	8.1	7.9	7.3	
4	8.3	8.3	8.3	8.2	8.1	7.2		8.2	8.1	8.1	8.1	8.0	7.3	
5	8.3	8.3	8.3	8.2	8.1	7.3		8.2	8.1	8.1	8.0	8.0	7.4	
6	8.4	8.4	8.4	8.3	8.2	7.6		8.1	8.0	7.9	7.8	7.6	7.6	
7								8.2	8.1	8.1	8.1	7.9	7.7	
8														

conductance (uS/cm)

0	444	458	490	547	673	921								
1	409	421	455	520	634	870		398	408	429	483	593	845	
2	468	439	458	521	631	863		432	427	444	495	616	884	
3	400	417	450	505	623	852		410	415	462	515	601	887	
4	420	418	440	500	626	850		412	432	460	516	600	880	
5	418	418	423	500	620	852		420	455	480	486	550	910	
6	432	446	479	538	667	896		433	473	507	572	520	722	
7								457	465	501	555	693	934	
8														

dissolved oxygen (mg/L)

0	7.6	7.6	7.6	7.6	7.7	7.8								
1	7.6	7.7	7.7	7.7	7.7	7.7		7.3	7.3	7.3	7.4	7.5	7.5	
2	7.6	7.6	7.6	7.7	7.7	7.7		6.8	6.8	6.7	6.8	6.8	6.8	
3	7.4	7.4	7.5	7.5	7.6	7.7		6.8	6.8	6.8	6.8	6.8	6.8	
4	7.4	7.4	7.4	7.4	7.4	7.4		6.9	6.6	6.6	6.7	6.7	6.9	
5	7.4	7.3	7.3	7.3	7.6	7.3		6.8	6.8	6.8	6.7	6.4	6.5	
6	7.3	7.4	7.3	7.4	7.4	7.4		6.2	6.1	6.1	6.0	6.4	6.1	
7								6.6	6.7	6.7	6.7	6.7	6.8	
8														

temperature (°C)

0	25	25	25	25	25	25								
1	25	25	25	25	25	25		25	25	25	25	25	25	
2	25	25	25	25	25	25		25	25	25	25	25	25	
3	25	25	25	25	25	25		25	25	25	25	25	25	
4	25	25	25	25	25	25		25	25	25	25	25	25	
5	25	25	25	25	25	25		25	25	25	25	25	25	
6	25	25	25	25	25	25		25	25	25	25	25	25	
7								25	25	25	25	25	25	
8														

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Test Report

Test Data

Client: NOR239	Sample: 20051122	Test: 20053131

Biology (number alive)

dose (%)	ctl	6.3	13	25	50	100		ctl	6.3	13	25	50	100	
replicate	day 1							day 5						
a	10	10	10	10	10	10		10	10	10	10	10	10	
b	10	10	10	10	10	10		10	9	9	10	10	10	
c	10	10	10	10	10	10		10	10	10	10	10	9	
d	10	10	10	10	10	10		9	10	10	10	10	10	
	day 2							day 6						
a	10	10	10	10	10	10		10	10	10	10	10	10	
b	10	10	10	10	10	10		10	9	10	9	10	10	
c	10	10	10	10	10	9		10	10	10	10	10	9	
d	9	10	10	10	10	10		9	10	10	10	10	10	
	day 3							day 7						
a	10	10	10	10	10	10		10	10	10	10	10	10	
b	10	9	10	10	10	10		10	9	10	9	10	10	
c	10	10	10	10	10	9		10	10	10	10	10	9	
d	9	10	10	10	10	10		9	10	10	10	10	10	
	day 4							**dry weights (mg)**						
a	10	10	10	10	10	10		5.8	6.1	5.3	6.4	7.2	7.4	
b	10	9	10	10	10	10		5.6	5.6	6.1	5.3	7.1	8.1	
c	10	10	10	10	10	9		6.0	5.8	6.3	5.5	6.0	5.1	
d	9	10	10	10	10	10		5.4	6.0	5.8	5.2	6.5	6.8	

Summary Tables

Mortality (%)

a	0	0	0	0	0	0
b	0	10	0	10	0	0
c	0	0	0	0	0	10
d	10	0	0	0	0	0
mean	3	3	0	3	0	3
sd	5	5	0	5	0	5
cv(%)	200	200	0	200	0	200

Growth Data (mg per fish)

0.6	0.6	0.5	0.6	0.7	0.7	
0.6	0.6	0.6	0.6	0.7	0.8	
0.6	0.6	0.6	0.6	0.6	0.6	
0.6	0.6	0.6	0.5	0.6	0.7	
0.6	0.6	0.6	0.6	0.7	0.7	
0.0	0.0	0.0	0.1	0.1	0.1	
3	3	7	9	9	14	

Growth as a Percent of Controls

100	103	100	98	114	119

Chemistry

New Solutions

dose (%)	ctl	6.3	13	25	50	100	
Average Values							
pH	8.3	8.3	8.3	8.2	8.1	7.3	
EC	427	431	456	519	639	872	
DO	7.5	7.5	7.5	7.5	7.6	7.6	
temp	25	25	25	25	25	25	
Variance (%)							
pH	1	0	1	0	0	2	
EC	5	4	5	4	3	3	
DO	2	2	2	2	2	3	
temp	0	0	0	0	0	0	

Old Solutions

ctl	6.3	13	25	50	100	
Average Values						
8.2	8.2	8.1	8.1	8.0	7.4	
423	439	469	517	596	866	
6.8	6.7	6.7	6.7	6.8	6.8	
25	25	25	25	25	25	
Variance (%)						
1	2	2	2	3	3	
5	6	6	7	9	8	
5	5	5	6	5	6	
0	0	0	0	0	0	

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Quality Assurance Information

Test Method: *Daphnia* Static Acute Test (LC50, five or more treatments plus a control)
HydroQual Test Method Manual, section: 4.4.3.1

Reference: Biological Test Method: Reference Method for Determining the Acute Lethality of Effluents to *Daphnia magna,* 1990. Environment Canada, EPS 1/RM/14. including May 1996 and December 2000 ammendments.

Test Organism	
test species	*Daphnia magna*
culture source	in-house
original culture source	Environment Canada
days to first brood	9
mean brood size	26
ephippia in stock culture	no
age of test organisms	<24 hours old
culture mortality (%)	6.7

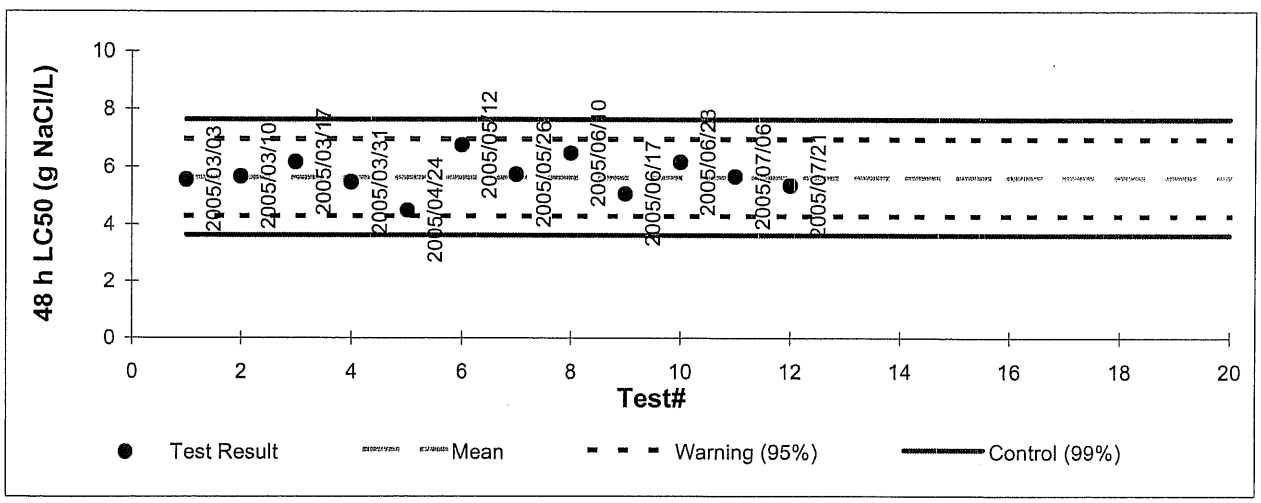
Test Design	
vol. of test vessel (mL)	500
toxicant	sodium chloride
test volume (mL)	150
replicates per treatment	1
neonates per replicate	10
volume per neonate (mL)	15
samples preaerated	no
hardness adjustment	no
temperature (°C)	20
photoperiod	16h light:8h dark
light level (water surface)	400-800 lux
control/dilution water	dechlorinated tap water

Quality Assurance Unit:
The test data and result are verified correct.

K. Steele 2005/07/25
Authorized by K. Steele

Warning Chart (mortality LC50 at 48 h)

Toxicant: Sodium Chloride (NaCl)
Current Test: **started :** 2005/07/19 **ended:** 2005/07/21
Result (48 h LC50): 5.4 (4.9-5.8) g NaCl/L 95% confidence limits are in brackets
Historical Mean: 5.6 **std. dev:** 0.7 **cv (%):** 12
Chart Limits: **warning:** 4.3 7.0 **control:** 3.6 7.6
95% , two standard deviations 99%, three standard deviations



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Quality Assurance Information

Test Method: Trout 96h Static Acute Test. (LC50, five or more treatments plus a control)
HydroQual Test Method Manual, section: 4.4.4.1

Reference: Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout, 1990. Environment Canada, EPS 1/RM/13. including May 1996 and December 2000 amendments.

Test Organism		Test Design	
test species	*Oncorhyncus mykiss*	**vol. of test vessel (L)**	22
culture source	Rainbow Springs Trout Farms	**test volume depth**	>15 cm
temperature (°C)	15 ± 1	**replicates per treatment**	1
dissolved oxygen	saturated	**fingerlings per replicate**	10
stock mortality (last 7d)	<2%	**loading (g fish/L)**	<0.5
batch number	20050714TR	**temperature (°C)**	15 ± 1
		photoperiod	16h light: 8h dark
		light level (water surface)	100-500 lux
		control/dilution water	dechlorinated tap water

Qualty Assurance Unit:
The test data and result are verified correct.

K. Steele 2005/08/12
Authorized by K. Steele

Warning Chart (mortality LC50 at 96 h)

Toxicant: Phenol (C_6H_5OH)

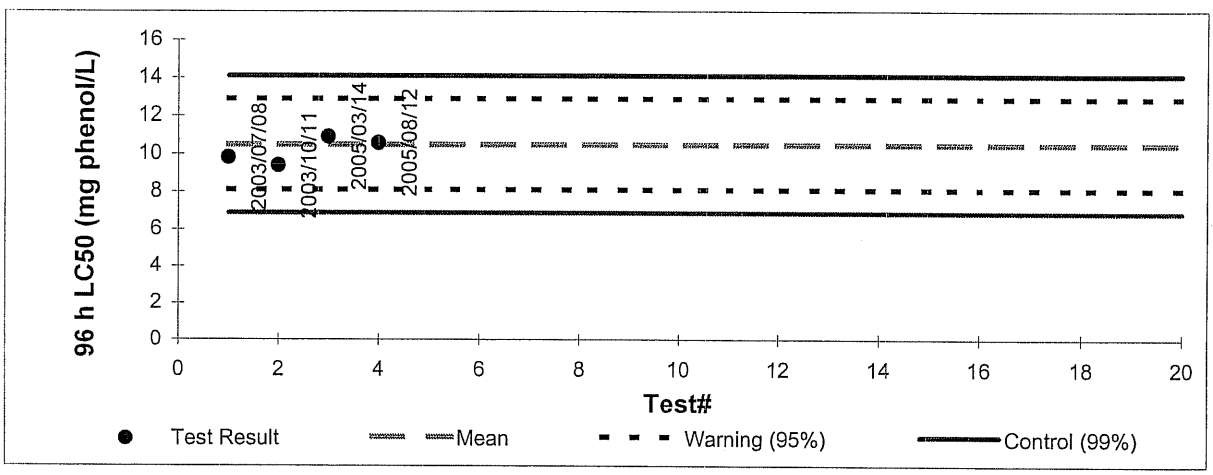
Current Test: **started:** 2005/08/08 **ended:** 2005/08/12

Result (96 h LC50): 10.6 (8.0-16.0) mg/L 95% confidence limits are in brackets

Historical Mean: 10.5 **std.dev:** 1.2 **CV(%):** 11

Chart Limits: **warning:** 8.1 12.9 **control:** 6.9 14.1

95% , two standard deviations 99%, three standard deviations



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Quality Assurance Information

Test Method: *Ceriodaphnia* Survival and Reproduction Test (5 treatments plus a control)
HydroQual Test Method Manual, section: 4.4.3.2

Reference: Biological Test Method: Test of Reproduction and Survival Using the Cladoceran *Ceriodaphnia dubia*, 1992. Environment Canada, EPS 1/RM/21 including November, 1997 amendments.

Test Organism

test species	*Ceriodaphnia dubia*
culture source	in-house
original culture source	Environment Canada
ephippia in stock culture	none
mortality in culture	2
culture fecundity	18(mean young/adult)
young produced in previous brood	7
food type	YAT:Algae
frequency of feeding	daily
condition prior to test initiation	normal
age of test organisms	<24 hours

*note: there are 2 subcultures within this culture source, separated by one week in age.

The test is set with organisms from one subculture. The number of young a culture has is monitored daily.
If young are not used that day, they are discarded, therefore organisms in tests are <24h.

Test Design

test type	static renewal
toxicant	sodium chloride (NaCl)
test vessel	30 mL plastic cup
test volume (mL)	15
replicates per treatment	10
organisms per replicate	1
feeding	daily
temperature (°C)	24-26
photoperiod	16 hours light: 8 hours dark
light level (surface)	100-600 lux
hardness adjustment	no

Control/Dilution Water

source	equal volumes of Bow River water and moderately hard reconstituted water (50:50)
pH (units)	8.1
conductance (uS/cm)	352
dissolved oxygen (mg/L)	7.1
NH_4^+ (mg/L)	<0.1
hardness (mg $CaCO_3$/L)	120
alkalinity (mg $CaCO_3$/L)	119
total residual chlorine (mg/L)	<0.01

moderately hard reconstituted water prepared as per EPS 1/RM/21

Quality Assurance Unit:
The test data and results are verified correct. 2005/07/25
Authorized by: K. Steele

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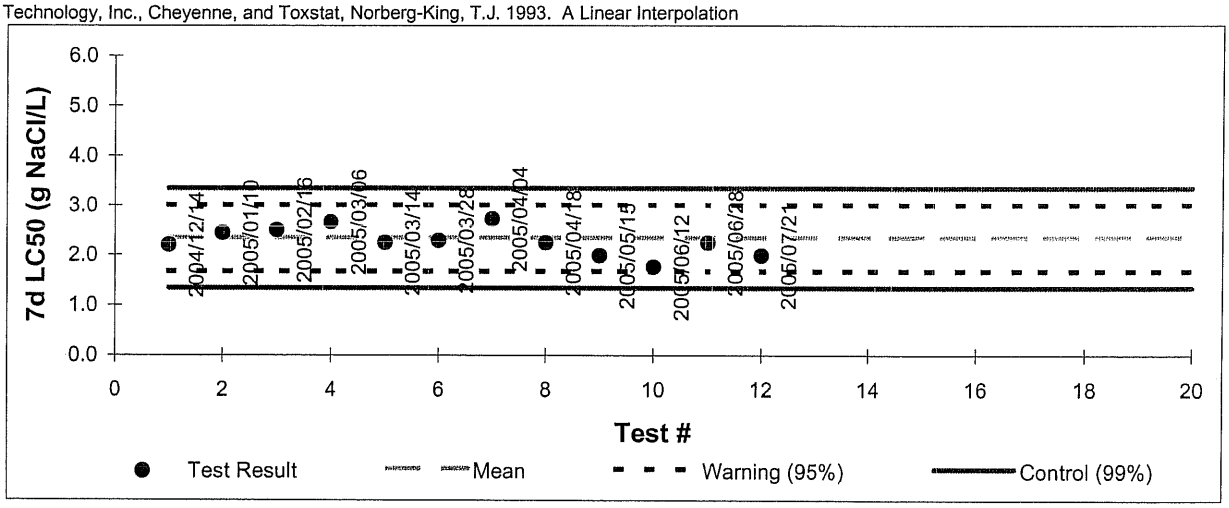
Quality Assurance Information

Ceriodaphnia dubia Warning Chart (Mortality: LC50 at 7 days)

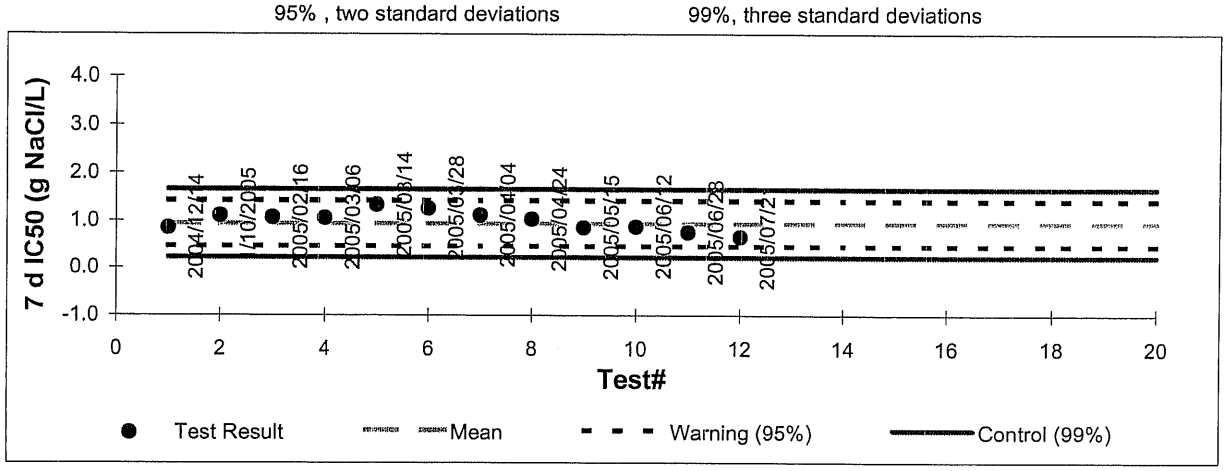
Toxicant:	Sodium Chloride (NaCl)					
Current Test:	**started:**	2005/07/15	**ended:**	2005/07/21		
Result (7 d LC50):	2.0	(0.8-2.5)	g NaCl/L	95% confidence limits are in brackets		
Historical Mean:	2.3	**std dev:**	0.3	**CV (%):**	14	
Chart Limits:	**warning:**	1.7	3.0	**control:**	1.3	3.3
	95% , two standard deviations			99%, three standard deviations		

Statistical analysis perfomed by ICPIN, West, Inc. and D. D. Gulley, 1994. Toxstat 3.4. Western Eco-Systems Technology, Inc., Cheyenne, and Toxstat, Norberg-King, T.J. 1993. A Linear Interpolation



Ceriodaphnia dubia Warning Chart (Reproduction: IC50 at 7 days)

Toxicant:	Sodium Chloride (NaCl)					
Current Test:	**started:**	2005/07/15	**ended:**	2005/07/21		
Result (7d IC50):	0.7	(0.4-0.8)	g NaCl/L	95% confidence limits are in brackets		
Historical Mean:	0.9	**std dev:**	0.2	**CV (%):**	26	
Chart Limits:	**warning:**	0.5	1.4	**control:**	0.2	1.7
	95% , two standard deviations			99%, three standard deviations		



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Reference Toxicant
Ceriodaphnia Culture Log

Adults live	7 d ago	day used
	42	41

day prior to use		row/replicate	1	2	3	4	5	6	7	8	9	10	11	12
			A2	A4	B1	B2	C2							
7	number of young													
	number of adults													
			A2	A4	B1	B2	C2							
6	number of young													
	number of adults													
			A2	A4	B1	B2	C2							
5	number of young													
	number of adults													
			A2	A4	B1	B2	C2							
4	number of young		8	7	10	12	0							
	number of adults		2	2	2	2	2							
			A2	A4	B1	B2	C2							
3	number of young		0	0	0	0	8							
	number of adults		2	2	2	2	2							
			A2	A4	B1	B2	C2							
2	number of young		12	14	12	18	12							
	number of adults		2	2	2	2	2							
			A2	A4	B1	B2	C2							
DAY USED	number of young		16	14	12	12	12							
2005/07/15	number of adults		2	2	2	2	2							
			A2	A4	B1	B2	C2							
totals			18	17.5	17	21	16							

number of young produced per organism in the last brood before use: 7

mean number of surviving young per adult over the last seven days: 18

culture mortality over the last seven days: 2

water type was equal mixture of moderately hard reconstituted water and Bow River Water (50:50)

less than 24 h organisms were used in the test with the reference toxicant

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Ceriodaphnia Culture Log

Adults live	7 d ago	day used
	42	42

Sample 20051122

day prior to use	row/replicate	#2 1	2	#3 3	4	5	6	7	8	9	10	11
		D1	E1	A1	B1	B2						
7	number of young											
	number of adults											
		D1	E1	A1	B1	B2						
6	number of young											
	number of adults											
		D1	E1	A1	B1	B2						
5	number of young											
	number of adults											
		D1	E1	A1	B1	B2						
4	number of young											
	number of adults											
		D1	E1	A1	B1	B2						
3	number of young	12	8	10	0	0						
	number of adults	2	2	2	2	2						
		D1	E1	A1	B1	B2						
2	number of young	12	8	12	13	12						
	number of adults	2	2	2	2	2						
		D1	E1	A1	B1	B2						
DAY USED 2005/07/29	number of young	13	14	14	12	13						
	number of adults	2	2	2	2	2						
		D1	E1	A1	B1	B2						
totals		19	15	18	13	13						

number of young produced per organism in the last brood before use: 7

mean number of surviving young per adult over the last seven days: 15

culture mortality over the last seven days: 0

water type was equal mixture of moderately hard reconstitued water and Bow River Water (50:50)

less than 24 h organisms were used in the test on the sample

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Quality Assurance Information

Test Method: 7 days Lemna Minor Survival and Growth Test (five treatments plus a control)
HydroQual Test Method Manual, section: 4.4.2.3

Reference: Biological Test Method: Test for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, *Lemna minor*, 1999. Environment Canada, EPS 1/RM/37.

Test Organism

test species	*Lemna minor*
culture source	in-house
original source	UTCC - 492
culture vessels	250 mL Erlenmeyer flask
water source	deionized water
growth medium	Hoagland's E+ medium
cultivation method	as per test conditons
temp of breeding aquaria	25 ± 2°C
organism age	7-10 days old acclimated to test media for 18 to 24 hours
mean increase in frond #	32
(fold increase)	11

Test Design

test type	static
toxicant	potassium chloride
water source	deionized reverse osmosis water with nutrients as per EPS 1/RM/37
test vessel	8 oz polystyrene cups
test volume (ml)	150
test cover	clear plastic lids
replicates per treatment	4
organisms per replicate	two 3 frond plants
temperature (°C)	25 ± 2°C
photoperiod	24 hours light
light level (surface)	4, 500 ± 300 lux
light source	cool white fluorescent
hardness adjustment	no

Control/Dilution Water

water source deionized reverse osmosis water and nutirents as per EPS 1/RM/37

Quality Assurance Unit:
The test data and result are verified correct.

Authorized by: K. Steele 2005/08/04

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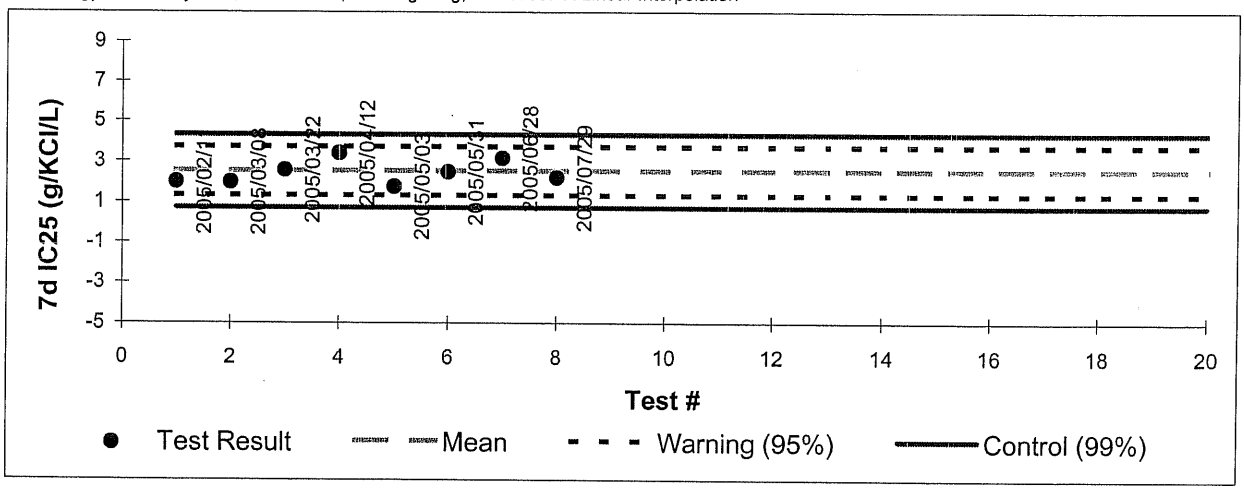
Quality Assurance Information

Lemna minor Warning Chart (Growth: frond number IC25 at 7 days)

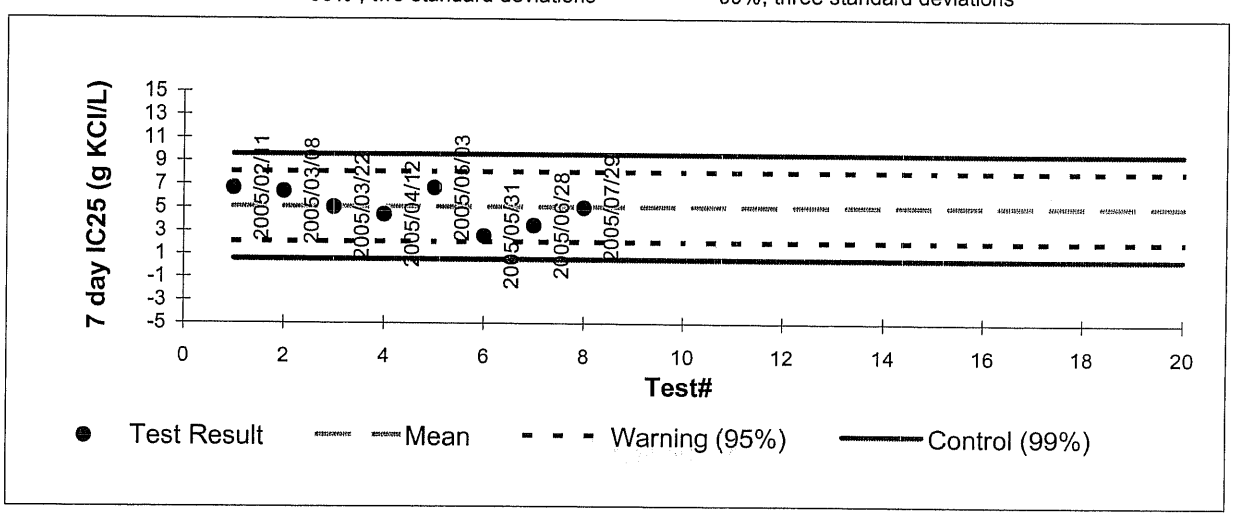
Toxicant:	potassium chloride (KCl)					
Current Test:	**started:**	2005/07/22	**ended:**	2005/07/29		
Result (7d IC25):	2.2	(1.5-3.0)	g KCl/L	95% confidence limits are in brackets		
Historical Mean:	2.5	**std dev:**	0.6	**CV (%):**	24	
Chart Limits:	**warning:**	1.3	3.7	**control:**	0.7	4.3
	95% , two standard deviations			99%, three standard deviations		

Statistical analysis perfomed by ICPIN, West, Inc. and D. D. Gulley, 1994. Toxstat 3.4. Western Eco-Systems Technology, Inc., Cheyenne, and Toxstat, Norberg-King, T.J. 1993. A Linear Interpolation



Lemna minor Warning Chart (Growth: biomass IC25 at 7 days)

Toxicant:	potassium chloride (KCl)					
Current Test:	**started:**	2005/07/22	**ended:**	2005/07/29		
Result (7d IC25):	5.0	(0.7-15.1)	g KCl/L	95% confidence limits are in brackets		
Historical Mean:	5.1	**std dev:**	1.5	**CV (%):**	30	
Chart Limits:	**warning:**	2.0	8.1	**control:**	0.5	9.6
	95% , two standard deviations			99%, three standard deviations		



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Quality Assurance Information

Test Method: 72 hours Algal Growth Inhibition Test (IC50, five or more treatments plus a control)
HydroQual Test Method Manual, section: 4.4.2.7

Reference: Biological Test Method: Growth Inhibition Test Using the Freshwater Alga *Selenastrum capricornutum*, 1992. Environment Canada, EPS 1/RM/25, with Nov., 1997 amendments

Test Organism		Test Design	
test species	*Raphidocelis subcapitata*	**test type**	static
(formerly)	*Selenastrum capricornutum* (strain LB37)	**toxicant**	zinc
		test vessel	96 well flat bottom microplate
original source	ATCC	**test volume (uL)**	220
culture vessels	2L Erlenmeyer flask	**no. of replicates**	3
water source	deionized water	**no. of replicate wells/treatment (per plate)**	5
growth medium	nutrient solution	**control**	10
cultivation method	batch as per test conditions	**mean temperature (°C)**	24 ± 2°C
culture condition at start of test	normal	**photoperiod**	continuous light
culture age	4-7 days	**light level**	4000 lux ± 10%
		contol/dilution water	deionized water and nutrients (prepared as per EPS1/RM/25)

Qualty Assurance Unit:
The test data and result are verified correct.

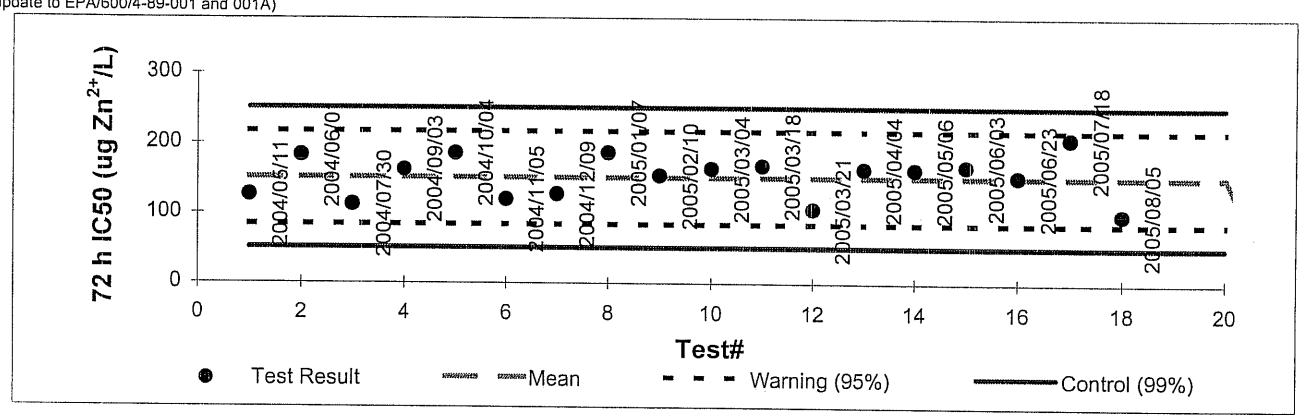
K. Steele 2005/08/11
Authorized by: K. Steele

Algae Warning Chart (growth IC50 at 72 hours)

Toxicant: Zinc ($ZnSO_4*7H_2O$)
Current Test: **started:** 2005/08/02 **ended:** 2005/08/05
Result (72 h IC50): 99 (85-108) ug Zn^{2+}/L 95% confidence limits are in brackets
Historical Mean: 151 **std.dev:** 33 **CV(%):** 22
Chart Limits: **warning:** 84 218 **control:** 51 251
95% , two standard deviations 99%, three standard deviations

Statistical analysis perfomed by ICPIN, West, Inc. and D. D. Gulley, 1994. Toxstat 3.4. Western Eco-Systems Technology, Inc., Cheyenne, and Toxstat, Norberg-King, T.J. 1993.

A Linear Interpolation. Method for Sublethal Toxicity: The Inhibition Concentration Approach (Ver. 2.0). National Effluent Toxicity Assessment Centre Technical Report 03-93. (update to EPA/600/4-89-001 and 001A)



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Quality Assurance Information

Test Method: 7 days Fathead minnow Survival and Growth Test (five treatments plus a control)

Reference: HydroQual Test Method Manual, section: 4.4.4.6
Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnow, 1992. Environment Canada, EPS 1/RM/22, with Nov. 1997 amendments.

Test Organism

test species	*Pimephales promelas*
culture source	Aquatic Biological Systems (Arkansas, USA)
temp of breeding aquaria	23 - 26 °C
food type	frozen brine shrimp
frequency of feeding	daily
breeding colony mortality	<5% (last 7 days)
age of test organisms	<24 hours
condition prior to test initiation	normal
batch number	20050729FM

Test Design

test type	static renewal
toxicant	sodium chloride
test vessel	polypropelyene cups, 11x9 cm
volume of test vessel	450
test volume (ml)	250
depth of test solution	>3 cm
replicates per treatment	4 replicates
organisms per replicate	10
feeding	twice daily
temperature (°C)	24-26
photoperiod	16 hours light: 8 hours dark
light level (surface)	100-500 lux

Control/Dilution Water

source	dechlorinated City of Calgary tap water no chemicals were added to the dilution water
pH (units)	7.2
conductance (uS/cm)	391
dissolved oxygen (mg/L)	7.3
NH_4^+ (mg/L)	<0.1
hardness (mg $CaCO_3$/L)	157
alkalinity (mg $CaCO_3$/L)	120
total residual chlorine (mg/L)	<0.01

Quality Assurance Unit:
The test data and results are verified correct.

Authorized by: K. Steele — as per 2005/08/16

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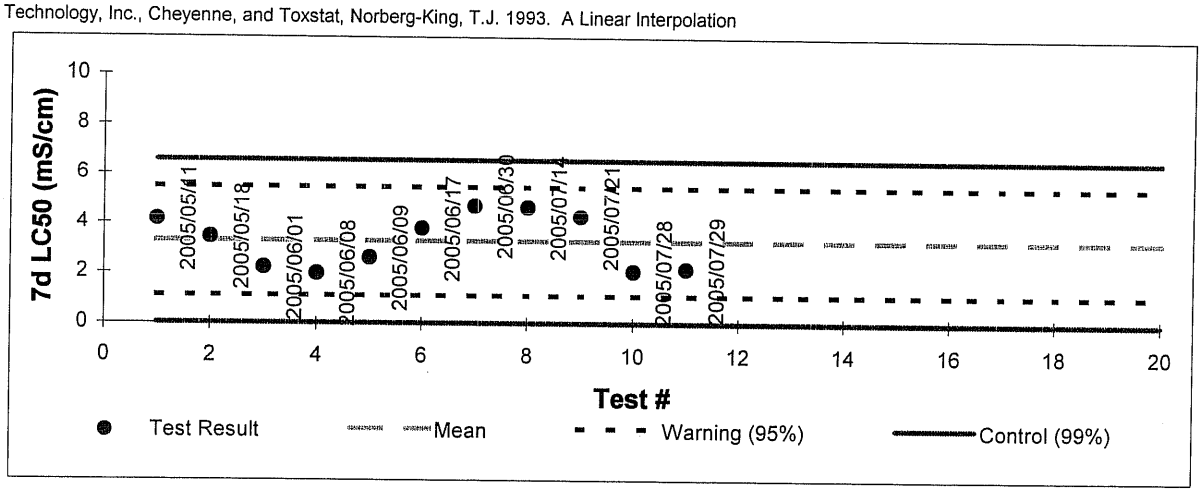
Quality Assurance Information

Fathead minnow Warning Chart (Mortality: LC50 at 7 days)

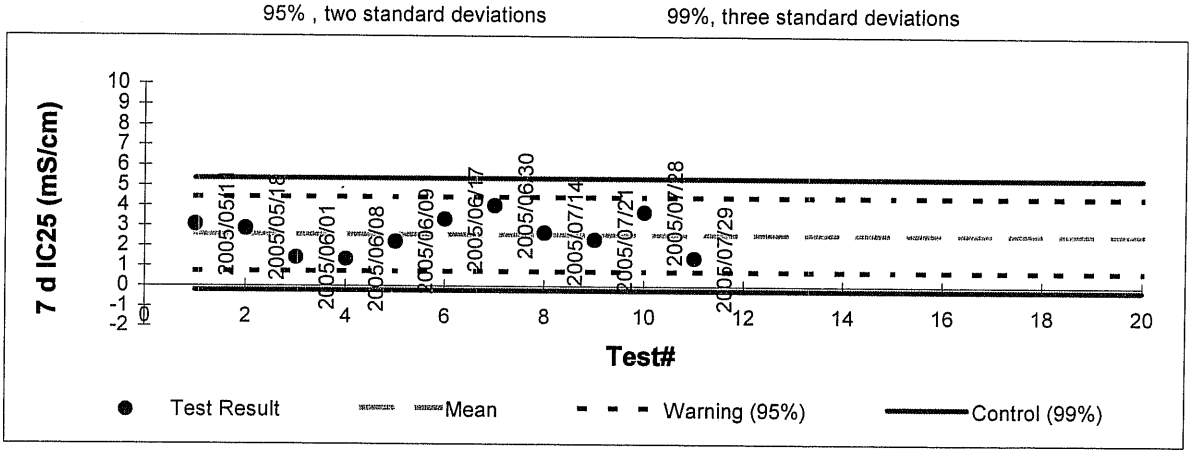
Toxicant:	Sodium Chloride (NaCl)					
Current Test:	**started:**	2005/07/29	**ended:**	2005/08/05		
Result (7 d LC50):	2.2	(2.0-2.5)	mS/cm	95% confidence limits are in brackets		
Historical Mean:	3.3	**std dev:**	1.1	**CV (%):**	33	
Chart Limits:	**warning:**	1.1	5.5	**control:**	0.0	6.6
	95% , two standard deviations			99%, three standard deviations		

Statistical analysis perfomed by ICPIN, West, Inc. and D. D. Gulley, 1994. Toxstat 3.4. Western Eco-Systems Technology, Inc., Cheyenne, and Toxstat, Norberg-King, T.J. 1993. A Linear Interpolation



Fathead minnow Warning Chart (Growth: IC25 at 7 days)

Toxicant:	Sodium Chloride (NaCl)					
Current Test:	**started:**	2005/07/29	**ended:**	2005/08/05		
Result (7d IC25):	1.4	(0.3-3.2)	mS/cm	95% confidence limits are in brackets		
Historical Mean:	2.6	**std dev:**	0.9	**CV (%):**	36	
Chart Limits:	**warning:**	0.7	4.4	**control:**	-0.2	5.4
	95% , two standard deviations			99%, three standard deviations		



AQUATOX, INC.

100 Springwood Drive #15
Hot Springs, Arkansas 71913
(501) 767-9120

TEST ORGANISM HISTORY

DATE SHIPPED 7-28-05 Hydroqual

SPECIES Pimephales promelas

QUANTITY SHIPPED 4000+

AGE/LIFE STAGE 48hrs 7/25 1500ct

BROODSTOCK SOURCE Anderson Hamsher

CULTURE WATER Groundwater

ALKALINITY (Mg/l as $CaCO_3$) =180

HARDNESS (Mg/l as $CaCO_3$)/Salinity (ppt) =160

FEEDING Artemia

COMMENTS PO# 2005-136

pH: 7.9, EC: 478, DO: 8.1, Temp: 23.2

Alk: 151, Hard: 137

PACKAGED BY

BILL HALL PRINTERS 3171

HydroQual Laboratories Ltd.
#3, 6125 12th Street SE Calgary, Alberta Canada T2H 2K1
Tel (403) 253-7121 Fax (403) 252-9363 www.hydroqual.ca

Test Summary

Client: NORWEST LABS Client #: NOR 839 Contact: Darlene Linfoot

Sample #: 20051182 Fax #: 780-438-0896 Date: 2005/08/05

Date Collected: 2005/07/27 Date Rec'd: 2005/07/29

HydroQual Contact: Ingrid Carleton-Dodds or Kim Steele

Description: lot#398418
Method: IR (9)
Test #: 20053187
Tester: AC
Started: 2005/07/29
Ended: 2005/08/02

Sample Strength %	Cumulative Mortality % 24 hrs	48 hrs	72 hrs	96 hrs	Endpoint/Comments
Control	0	0	0	10%	none
100%	20%	20%	30%	30%	

Description:
Method:
Test #:
Tester:
Started:
Ended:

Sample Strength %	Cumulative Mortality % 24 hrs	48 hrs	72 hrs	96 hrs	Endpoint/Comments
Control					

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HydroQual Laboratories Ltd.
#3, 6125 12th Street SE Calgary, Alberta Canada T2H 2K1
Tel (403) 253-7121 Fax (403) 252-9363 www.hydroqual.ca

Test Summary

Client: NORWEST Client #: NOR239 Contact: DARLENE LINTOTT

Sample #: 20051122 Fax #: 780-438-0396 Date: 2005/08/01

Date Collected: 2005/07/27 Date Rec'd: 2005/07/29

HydroQual Contact: Ingrid Carleton-Dodds or Kim Steele

Description: Lot#398418
Method: DA(S)
Test #: 20053126
Tester: LF
Started: 2005/07/29
Ended: 2005/07/31

Sample Strength %	Cumulative Mortality % 24 hrs	48 hrs	72 hrs	96 hrs	Endpoint/Comments
Control	0	0			
100%	0	70%			

Description:
Method:
Test #:
Tester:
Started:
Ended:

Sample Strength %	Cumulative Mortality % 24 hrs	48 hrs	72 hrs	96 hrs	Endpoint/Comments
Control					

The document(s) included in this transmission are intended only for the recipient(s) named above and contain privileged and confidential information. Any unauthorized disclosure, dissemination or copying of this transmission is strictly prohibited. If you have received this transmission in error, please immediately notify us by telephone and destroy the transmission. Thank you.

Facility Name Kinross Gold Corporation - Lupin Operations (Contwoyto Lake)
FDP Name Lupin Discharge Syphons
Reference Locn Name SNP 925-21
Location **Lat** 65 deg 43 min 52.1 sec N **Long** 111 deg 26 min 29.6 sec W
Midpoint of Concession Creek, 100m upstream from Unnamed Lake

WATER QUALITY MONITORING - REFERENCE LOCATION

Sample Date		July 19, 2005
pH		6.73
Hardness	mg/l	<0.9
Alkalinity	mg/l	<5
Aluminum	mg/l	0.022
Cadmium	mg/l	<0.00001
Iron	mg/l	<0.1
Mercury	ug/l	<0.02
Molybdenum	mg/l	<0.001
Ammonia	mg/l	<0.05
Nitrate	mg/l	<0.01
Arsenic	mg/l	0.0009
Copper	mg/l	<0.001
Cyanide	mg/l	0.002
Lead	mg/l	0.0001
Nickel	mg/l	<0.0005
Zinc	mg/l	0.002
TSS	mg/l	<3
Radium 226	Bq/l	<0.005
Effluent Notes		Sample 51058
Effluent flow	cu.m.	64,124

(at SNP 925-10 discharge point)

NOTE Effluent was discharged for a total of 27 days, from July 15, 2005 to August 11, 2005

Facility Name Kinross Gold Corporation - Lupin Operations (Contwoyto Lake)
FDP Name Lupin Discharge Syphons
Exposure Locn Name SNP 925-24
Location **Lat** 65 deg 45 min 28.1 sec N **Long** 111 deg 27 min 35.5 sec W
Midpoint of channel between Inner and Outer Sun Bay

WATER QUALITY MONITORING - EXPOSURE LOCATION

Sample Date		July 19, 2005	
pH		6.76	
Hardness	mg/l	3	
Alkalinity	mg/l	<5	
Aluminum	mg/l	0.026	
Cadmium	mg/l	<0.00001	
Iron	mg/l	<0.1	
Mercury	ug/l	<0.02	
Molybdenum	mg/l	<0.001	
Ammonia	mg/l	0.07	
Nitrate	mg/l	<0.01	
Arsenic	mg/l	0.001	
Copper	mg/l	<0.001	
Cyanide	mg/l	0.002	
Lead	mg/l	0.0001	
Nickel	mg/l	0.001	
Zinc	mg/l	0.004	
TSS	mg/l	3	
Radium 226	Bq/l	<0.005	
Effluent Notes		Sample 51062	
Effluent flow	cu.m.	64,124	(at SNP 925-10 discharge point)

NOTE Effluent was discharged for a total of 27 days, from July 15, 2005 to August 11, 2005

NORWEST LABS

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

	NWL Number	396502-13	396502-14	396502-15	
	Sample Date	Jul 19, 2005	Jul 19, 2005	Jul 19, 2005	
	Sample Description	925-20 / 51057	925-21 / 51058	925-22-1 / 51059	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Inorganic Nonmetallic Parameters						
Ammonium - N		mg/L	1.01	<0.05	0.32	0.05
Cyanide	Strong Acid Dissociable	mg/L	0.026	0.002	0.002	0.002
Metals Total						
Iron	Total	mg/L	0.1	<0.1	0.1	0.1
Manganese	Total	mg/L	0.856	0.008	0.024	0.005
Silicon	Total	mg/L	1.64	0.10	0.18	0.05
Sulfur	Total	mg/L	82.3	0.8	3.4	0.3
Mercury	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Mercury	Total	ug/L	-	<0.02	-	0.02
Aluminum	Total	mg/L	0.090	0.022	0.038	0.005
Antimony	Total	mg/L	<0.0002	<0.0002	<0.0002	0.0002
Arsenic	Total	mg/L	0.0039	0.0009	0.0018	0.0002
Barium	Total	mg/L	0.049	0.002	0.005	0.001
Beryllium	Total	mg/L	0.0001	<0.0001	<0.0001	0.0001
Bismuth	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Boron	Total	mg/L	0.077	0.002	0.004	0.002
Cadmium	Total	mg/L	0.00031	<0.00001	0.00002	0.00001
Chromium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Cobalt	Total	mg/L	0.0431	0.0002	0.0011	0.0001
Copper	Total	mg/L	0.003	<0.001	0.001	0.001
Lead	Total	mg/L	<0.0001	0.0001	0.0002	0.0001
Lithium	Total	mg/L	0.024	<0.001	0.002	0.001
Molybdenum	Total	mg/L	<0.001	<0.001	<0.001	0.001
Nickel	Total	mg/L	0.118	<0.0005	0.0036	0.0005
Selenium	Total	mg/L	<0.0002	<0.0002	<0.0002	0.0002
Silver	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Strontium	Total	mg/L	0.280	0.005	0.016	0.001
Thallium	Total	mg/L	<0.00005	<0.00005	<0.00005	0.00005
Tin	Total	mg/L	<0.001	<0.001	<0.001	0.001
Titanium	Total	mg/L	0.0042	<0.0005	0.0011	0.0005
Uranium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Vanadium	Total	mg/L	<0.0001	<0.0001	0.0001	0.0001
Zinc	Total	mg/L	0.221	0.002	0.006	0.001
Physical and Aggregate Properties						
Temperature of observed pH		°C	18.7	19.3	20.4	

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

	NWL Number	396502-13	396502-14	396502-15	
	Sample Date	Jul 19, 2005	Jul 19, 2005	Jul 19, 2005	
	Sample Description	925-20 / 51057	925-21 / 51058	925-22-1 / 51059	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Physical and Aggregate Properties - Continued						
Solids	Total Suspended	mg/L	<2	<3	5	1
Routine Water						
pH			5.76	6.73	6.73	
Electrical Conductivity		µS/cm at 25 C	720	11	41	1
Calcium	Dissolved	mg/L	67.0	<0.2	1.9	0.2
Magnesium	Dissolved	mg/L	8.2	0.1	0.7	0.1
Sodium	Dissolved	mg/L	78.8	0.5	2.9	0.4
Potassium	Dissolved	mg/L	6.5	<0.4	0.6	0.4
Iron	Dissolved	mg/L	0.05	0.03	0.04	0.01
Manganese	Dissolved	mg/L	0.900	<0.005	0.011	0.005
Chloride	Dissolved	mg/L	50.2	0.5	2.2	0.4
Nitrate - N		mg/L	6.38	<0.01	0.15	0.01
Nitrite - N		mg/L	<0.005	<0.005	<0.005	0.005
Nitrate and Nitrite - N		mg/L	6.38	<0.02	0.15	0.02
Sulfate (SO4)	Dissolved	mg/L	269	2	12	0.9
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	<5	<5	<5	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
Total Dissolved Solids	Calculated	mg/L	481	3	20	1
Hardness	Dissolved as CaCO3	mg/L	201	<0.9	8	
Ionic Balance	Dissolved	%	103	60	100	

NORWEST LABS

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

	NWL Number	396502-16	396502-17	396502-18	
	Sample Date	Jul 19, 2005	Jul 19, 2005	Jul 19, 2005	
	Sample Description	925-22-2 / 51060	925-22-3 / 51061	925-24 / 51062	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Inorganic Nonmetallic Parameters						
Ammonium - N		mg/L	<0.05	<0.05	0.07	0.05
Cyanide	Strong Acid Dissociable	mg/L	0.002	0.002	0.002	0.002
Metals Total						
Iron	Total	mg/L	0.1	0.1	<0.1	0.1
Manganese	Total	mg/L	0.021	0.020	0.006	0.005
Silicon	Total	mg/L	0.16	0.14	0.09	0.05
Sulfur	Total	mg/L	3.3	3.3	0.5	0.3
Mercury	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Mercury	Total	ug/L	-	-	<0.02	0.02
Aluminum	Total	mg/L	0.028	0.025	0.026	0.005
Antimony	Total	mg/L	<0.0002	<0.0002	<0.0002	0.0002
Arsenic	Total	mg/L	0.0016	0.0016	0.0010	0.0002
Barium	Total	mg/L	0.005	0.005	0.002	0.001
Beryllium	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Bismuth	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Boron	Total	mg/L	0.016	0.008	0.004	0.002
Cadmium	Total	mg/L	0.00001	<0.00001	<0.00001	0.00001
Chromium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Cobalt	Total	mg/L	0.001	0.0009	0.0002	0.0001
Copper	Total	mg/L	0.001	0.001	<0.001	0.001
Lead	Total	mg/L	0.0002	0.0001	0.0001	0.0001
Lithium	Total	mg/L	0.002	0.002	<0.001	0.001
Molybdenum	Total	mg/L	<0.001	<0.001	<0.001	0.001
Nickel	Total	mg/L	0.0040	0.0040	0.0010	0.0005
Selenium	Total	mg/L	<0.0002	<0.0002	<0.0002	0.0002
Silver	Total	mg/L	<0.0001	<0.0001	<0.0001	0.0001
Strontium	Total	mg/L	0.014	0.014	0.005	0.001
Thallium	Total	mg/L	<0.00005	<0.00005	<0.00005	0.00005
Tin	Total	mg/L	<0.001	<0.001	<0.001	0.001
Titanium	Total	mg/L	0.0006	<0.0005	<0.0005	0.0005
Uranium	Total	mg/L	<0.0005	<0.0005	<0.0005	0.0005
Vanadium	Total	mg/L	0.0001	0.0001	0.0001	0.0001
Zinc	Total	mg/L	0.006	0.006	0.004	0.001
Physical and Aggregate Properties						
Temperature of observed pH		°C	20.0	19.6	19.4	

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

	NWL Number	396502-16	396502-17	396502-18	
	Sample Date	Jul 19, 2005	Jul 19, 2005	Jul 19, 2005	
	Sample Description	925-22-2 / 51060	925-22-3 / 51061	925-24 / 51062	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Physical and Aggregate Properties - Continued						
Solids	Total Suspended	mg/L	3	<3	3	1
Routine Water						
pH			6.74	6.74	6.76	
Electrical Conductivity		µS/cm at 25 C	40	40	12	1
Calcium	Dissolved	mg/L	1.7	2.6	0.7	0.2
Magnesium	Dissolved	mg/L	0.7	0.9	0.4	0.1
Sodium	Dissolved	mg/L	2.7	2.5	<0.4	0.4
Potassium	Dissolved	mg/L	<0.4	<0.4	<0.4	0.4
Iron	Dissolved	mg/L	0.04	0.03	0.01	0.01
Manganese	Dissolved	mg/L	0.010	0.017	<0.005	0.005
Chloride	Dissolved	mg/L	2.1	1.8	0.8	0.4
Nitrate - N		mg/L	0.15	0.16	<0.01	0.01
Nitrite - N		mg/L	<0.005	<0.005	<0.005	0.005
Nitrate and Nitrite - N		mg/L	0.15	0.16	<0.02	0.02
Sulfate (SO4)	Dissolved	mg/L	12	11	2	0.9
Hydroxide		mg/L	<5	<5	<5	5
Carbonate		mg/L	<6	<6	<6	6
Bicarbonate		mg/L	<5	<5	<5	5
P-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
T-Alkalinity	as CaCO3	mg/L	<5	<5	<5	5
Total Dissolved Solids	Calculated	mg/L	19	19	4	1
Hardness	Dissolved as CaCO3	mg/L	7	10	3	
Ionic Balance	Dissolved	%	80	110	100	

SRC Group: 2005-3909

SRC ANALYTICAL

422 Downey Road
Saskatoon, Saskatchewan S7N 4N1
(306) 933-6932 1-800-240-8808

Norwest Labs
7217 Roper Road
Edmonton, Alberta T6B 3J4
Attn: Client Services

Aug-05-2005

Date Samples Received: Jul-22-2005 Client P.O.:

SAMPLE		CLIENT DESCRIPTION
16092	396502-1	*WATER*
16093	396502-14	*WATER*
16094	396502-18	*WATER*

ANALYTE	UNITS	16092	16093	16094
RADIO CHEMISTRY				
Radium-226	Bq/L	0.01	<0.005	<0.005

SAMPLE		CLIENT DESCRIPTION
16095	396502-21	*WATER*

ANALYTE	UNITS	16095
RADIO CHEMISTRY		
Radium-226	Bq/L	<0.005

"<": not detected at level stated above

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Inorganic Nonmetallic Parameters

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Ammonium - N	mg/L	<0.05	0.00	-0.08	0.08	✓
Cyanide	mg/L	<0.001	0.000	-0.001	0.001	✓
Material Used:	Edmonton Method Blank					
Date Acquired:	Jul 27, 2005					
Acquired By:	Gordon Grensmann					

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Ammonium - N	mg/L	126	130	9.99	0.10	✓
Cyanide	mg/L	0.002	0.002	9.990	0.002	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 27, 2005					
Acquired By:						

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Ammonium - N	mg/L	2.94	2.99	2.59	3.39	✓
Cyanide	mg/L	0.080	0.077	0.067	0.087	✓
Material Used:	Water High					
Date Acquired:	Jul 27, 2005					
Acquired By:	Gordon Grensmann					
Ammonium - N	mg/L	0.80	0.79	0.66	0.91	✓
Cyanide	mg/L	0.016	0.016	0.013	0.018	✓
Material Used:	Water Low					
Date Acquired:	Jul 27, 2005					
Acquired By:	Gordon Grensmann					

Norwest Labs
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Edmonton, AB. T6B 3J4
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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Dissolved

Blanks		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Sulfur		mg/L	<0.3	0.0	-0.3	0.3	✓
Material Used:	Edmonton Method Blank						
Date Acquired:	Jul 22, 2005						
Acquired By:	To Thong						

Replicates		Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Sulfur		mg/L	92	90	10.0	0.1	✓
Material Used:	Edmonton Duplicate						
Date Acquired:	Jul 22, 2005						
Acquired By:	To Thong						

Control Sample		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Sulfur		mg/L	49.7	50.0	45.0	55.0	✓
Material Used:	Metals High						
Date Acquired:	Jul 22, 2005						
Acquired By:	To Thong						
Sulfur		mg/L	1.1	1.0	0.9	1.2	✓
Material Used:	Metals Low						
Date Acquired:	Jul 22, 2005						
Acquired By:	To Thong						

Norwest Labs
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Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Total

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	<0.1	0.0	0.0	0.0	✓
Manganese	mg/L	<0.005	0.000	-0.001	0.001	✓
Silicon	mg/L	<0.05	0.02	-0.04	0.09	✓
Sulfur	mg/L	<0.3	0.0	-0.3	0.3	✓
Mercury	mg/L	0.0001	0.0000	0.0000	0.0000	✓
Aluminum	ug/L	<5	0	-5	5	✓
Antimony	ug/L	<0.2	0.0	-0.2	0.2	✓
Arsenic	ug/L	<0.2	0.0	-0.2	0.2	✓
Barium	ug/L	<1	0	-1	1	✓
Beryllium	ug/L	<0.1	0.0	-0.1	0.1	✓
Bismuth	ug/L	<0.5	0.0	-0.5	0.5	✓
Boron	ug/L	<2	0	-2	2	✓
Cadmium	ug/L	<0.01	0.00	-0.01	0.01	✓
Chromium	ug/L	<0.5	0.0	-0.5	0.5	✓
Cobalt	ug/L	<0.1	0.0	-0.1	0.1	✓
Copper	ug/L	<1	0	-1	1	✓
Lead	ug/L	<0.1	0.0	-0.1	0.1	✓
Lithium	ug/L	<1	0	-1	1	✓
Molybdenum	ug/L	<1	0	-1	1	✓
Nickel	ug/L	<0.5	0.0	-0.5	0.5	✓
Selenium	ug/L	<0.2	0.0	-0.2	0.2	✓
Silver	ug/L	<0.1	0.0	-0.1	0.1	✓
Strontium	ug/L	<1	0	-1	1	✓
Thallium	ug/L	<0.05	0.00	-0.05	0.05	✓
Tin	ug/L	<1	0	-1	1	✓
Titanium	ug/L	<0.5	0.0	-0.5	0.5	✓
Uranium	ug/L	<0.5	0.0	-0.5	0.5	✓
Vanadium	ug/L	<0.1	0.0	-0.1	0.1	✓
Zinc	ug/L	<1	0	-1	1	✓
Material Used:	Edmonton Method Blank					
Date Acquired:	Jul 22, 2005					
Acquired By:	Fernando Maglalang					
Mercury	ug/L	<0.02	0.000	0.000	0.000	✓
Material Used:	Metals Blank - water - total					
Date Acquired:	Jul 28, 2005					
Acquired By:	Marie England					

NORWEST LABS

Norwest Labs
7217 Roper Road NW
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Phone: (780) 438-5522
Fax: (780) 438-0396

Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Total (Continued...)

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Iron	mg/L	0.8	0.8	15.0	0.2	✓
Manganese	mg/L	0.980	0.975	15.000	0.010	✓
Silicon	mg/L	6.79	6.78	15.00	0.10	✓
Sulfur	mg/L	91.8	92.6	15.0	0.1	✓
Mercury	mg/L	0.0001	0.0002	9.9900	0.0003	✓
Aluminum	ug/L	48	48	15	11	✓
Antimony	ug/L	0.6	0.7	15.0	0.4	✓
Arsenic	ug/L	877	862	15.0	0.4	✓
Barium	ug/L	26	25	15	2	✓
Beryllium	ug/L	1.6	1.6	15.0	0.2	✓
Bismuth	ug/L	<0.5	<0.5	15.0	1.1	✓
Boron	ug/L	41	40	15	4	✓
Cadmium	ug/L	3.07	3.09	15.00	0.02	✓
Chromium	ug/L	67.2	67.6	15.0	1.1	✓
Cobalt	ug/L	762	754	15.0	0.2	✓
Copper	ug/L	221	220	15	2	✓
Lead	ug/L	33.8	33.0	15.0	0.2	✓
Lithium	ug/L	4	4	15	2	✓
Molybdenum	ug/L	1	1	15	2	✓
Nickel	ug/L	2090	2070	15.0	1.1	✓
Selenium	ug/L	1.2	1.4	15.0	0.4	✓
Silver	ug/L	0.2	0.2	15.0	0.2	✓
Strontium	ug/L	91	91	15	2	✓
Thallium	ug/L	0.35	0.35	15.00	0.11	✓
Tin	ug/L	<1	<1	15	2	✓
Titanium	ug/L	907	891	15.0	1.1	✓
Uranium	ug/L	5.8	5.8	15.0	1.1	✓
Vanadium	ug/L	44.2	44.4	15.0	0.2	✓
Zinc	ug/L	645	644	15	2	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 21, 2005					
Acquired By:	Fernando Maglalang					
Mercury	ug/L	<0.02	<0.02	30.000	0.050	✓
Material Used:	Metals Int. Duplicate - water tot					
Date Acquired:	Jul 28, 2005					
Acquired By:	Marie England					

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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	2.0	2.0	1.8	2.2	✓
Manganese	mg/L	0.490	0.500	0.450	0.550	✓
Silicon	mg/L	5.11	5.00	4.50	5.50	✓
Sulfur	mg/L	9.7	10.0	9.0	11.0	✓
Mercury	mg/L	0.0007	0.0008	0.0007	0.0010	✓
Aluminum	ug/L	314	322	273	371	✓
Antimony	ug/L	12.1	11.5	10.2	12.8	✓
Arsenic	ug/L	12.2	11.5	10.3	12.7	✓
Barium	ug/L	63	61	52	69	✓
Beryllium	ug/L	5.9	5.9	4.9	7.0	✓
Bismuth	ug/L	31.2	30.2	26.0	34.4	✓
Boron	ug/L	124	125	102	148	✓
Cadmium	ug/L	0.67	0.63	0.47	0.78	✓
Chromium	ug/L	32.3	31.8	27.5	36.2	✓
Cobalt	ug/L	6.6	6.4	5.4	7.5	✓
Copper	ug/L	62	63	55	70	✓
Lead	ug/L	6.6	6.2	5.4	7.0	✓
Lithium	ug/L	62	65	53	76	✓
Molybdenum	ug/L	62	61	53	69	✓
Nickel	ug/L	31.2	31.4	27.0	35.8	✓
Selenium	ug/L	11.8	11.0	9.7	12.3	✓
Silver	ug/L	6.5	6.2	5.5	7.0	✓
Strontium	ug/L	63	64	55	72	✓
Thallium	ug/L	3.14	3.14	2.56	3.72	✓
Tin	ug/L	60	59	52	66	✓
Titanium	ug/L	31.7	31.5	27.0	36.0	✓
Uranium	ug/L	31.2	30.8	26.9	34.7	✓
Vanadium	ug/L	6.6	6.5	5.4	7.6	✓
Zinc	ug/L	61	59	49	69	✓
Material Used:	Edmonton Digestion Check					
Date Acquired:	Jul 22, 2005					
Acquired By:	Fernando Maglalang					
Iron	mg/L	9.6	10.0	9.0	11.0	✓
Manganese	mg/L	2.32	2.500	2.250	2.750	✓
Silicon	mg/L	24.3	25.00	22.50	27.50	✓
Sulfur	mg/L	49.1	50.0	45.0	55.0	✓
Mercury	mg/L	0.0031	0.0031	0.0027	0.0035	✓
Material Used:	Metals High					
Date Acquired:	Jul 25, 2005					
Acquired By:	Nicole Sehn					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Iron	mg/L	0.2	0.2	0.2	0.2	✓
Manganese	mg/L	0.051	0.050	0.045	0.055	✓
Silicon	mg/L	0.53	0.50	0.45	0.55	✓
Sulfur	mg/L	0.9	1.0	0.9	1.2	✓
Mercury	mg/L	0.0008	0.0008	-0.0016	0.0032	✓
Aluminum	ug/L	1040	1000	850	1150	✓
Antimony	ug/L	40.3	40.0	34.0	46.0	✓
Arsenic	ug/L	42.5	40.0	34.0	46.0	✓
Barium	ug/L	200	200	170	230	✓
Beryllium	ug/L	19.3	20.0	17.0	23.0	✓
Bismuth	ug/L	97.9	100.0	85.0	115.0	✓
Boron	ug/L	389	400	340	460	✓
Cadmium	ug/L	2.07	2.00	1.70	2.30	✓
Chromium	ug/L	105	100.0	85.0	115.0	✓
Cobalt	ug/L	21.6	20.0	17.0	23.0	✓
Copper	ug/L	204	200	170	230	✓
Lead	ug/L	19.7	20.0	17.0	23.0	✓
Lithium	ug/L	182	200	170	230	✓
Molybdenum	ug/L	200	200	170	230	✓
Nickel	ug/L	104	100.0	85.0	115.0	✓
Selenium	ug/L	41.6	40.0	34.0	46.0	✓
Silver	ug/L	21.4	20.0	17.0	23.0	✓
Strontium	ug/L	203	200	170	230	✓
Thallium	ug/L	10.0	10.00	8.50	11.50	✓
Tin	ug/L	192	200	170	230	✓
Titanium	ug/L	103	100.0	85.0	115.0	✓
Uranium	ug/L	98.4	100.0	85.0	115.0	✓
Vanadium	ug/L	18.8	20.0	17.0	23.0	✓
Zinc	ug/L	211	200	170	230	✓

Material Used: Metals Low
Date Acquired: Jul 22, 2005
Acquired By: Fernando Maglalang

Norwest Labs
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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Metals Total (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Aluminum	ug/L	55	50	43	58	✓
Antimony	ug/L	2.1	2.0	1.7	2.3	✓
Arsenic	ug/L	2.0	2.0	1.7	2.3	✓
Barium	ug/L	10	10	9	12	✓
Beryllium	ug/L	1.0	1.0	0.9	1.2	✓
Bismuth	ug/L	4.9	5.0	4.3	5.8	✓
Boron	ug/L	20	20	17	23	✓
Cadmium	ug/L	0.11	0.10	0.09	0.12	✓
Chromium	ug/L	5.3	5.0	4.3	5.8	✓
Cobalt	ug/L	1.1	1.0	0.9	1.2	✓
Copper	ug/L	11	10	9	12	✓
Lead	ug/L	1	1.0	0.9	1.2	✓
Lithium	ug/L	10	10	9	12	✓
Molybdenum	ug/L	10	10	9	12	✓
Nickel	ug/L	5.0	5.0	4.3	5.8	✓
Selenium	ug/L	2.2	2.0	1.7	2.3	✓
Silver	ug/L	1	1.0	0.9	1.2	✓
Strontium	ug/L	10	10	9	12	✓
Thallium	ug/L	0.52	0.50	0.43	0.58	✓
Tin	ug/L	10	10	9	12	✓
Titanium	ug/L	5.2	5.0	4.3	5.8	✓
Uranium	ug/L	5.1	5.0	4.3	5.8	✓
Vanadium	ug/L	1.0	1.0	0.9	1.2	✓
Zinc	ug/L	10	10	9	12	✓
Material Used:	Metals Trace					
Date Acquired:	Jul 22, 2005					
Acquired By:	Fernando Maglalang					
Mercury	ug/L	0.58	14.000	11.000	17.000	✓
Material Used:	S0102 - Hg					
Date Acquired:	Jul 28, 2005					
Acquired By:						

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Physical and Aggregate Properties

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
Solids	mg/L	117	117	10	15	✓
Material Used:	Edmonton Duplicate					
Date Acquired:	Jul 22, 2005					
Acquired By:	Christina Onyskiw					

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Solids	mg/L	197	200	180	220	✓
Material Used:	Water High					
Date Acquired:	Jul 22, 2005					
Acquired By:	Christina Onyskiw					
Solids	mg/L	20	20	18	22	✓
Material Used:	Water Low					
Date Acquired:	Jul 22, 2005					
Acquired By:	Christina Onyskiw					

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Quality Control

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Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project
ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Routine Water

Blanks	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Calcium	mg/L	<0.2	0.0	-0.2	0.2	✓
Magnesium	mg/L	<0.1	0.0	-0.1	0.1	✓
Sodium	mg/L	<0.4	0.0	-0.4	0.4	✓
Potassium	mg/L	<0.4	0.0	-0.4	0.4	✓
Iron	mg/L	<0.01	0.00	-0.01	0.01	✓
Manganese	mg/L	<0.005	0.000	-0.005	0.005	✓
Chloride	mg/L	<0.4	0.0	-0.5	0.5	✓
Nitrate - N	mg/L	<0.01	0.00	-0.01	0.01	✓
Nitrite - N	mg/L	<0.005	0.000	-0.005	0.005	✓

Material Used: Edmonton Method Blank
Date Acquired: Jul 22, 2005
Acquired By: Marc Dzura

Replicates	Units	Replicate1	Replicate2	% RSD Criteria	Absolute Criteria	Passed QC
pH		8.10	8.10	9.99	0.10	✓
Electrical Conductivity	dS/m at 25 C	40.3	40.3	9.990	0.002	✓
Calcium	mg/L	72	70	10.0	0.6	✓
Magnesium	mg/L	20	19	10.0	0.7	✓
Sodium	mg/L	8	8	10.0	1.2	✓
Potassium	mg/L	<4	<4	10.0	1.2	✓
Iron	mg/L	0.08	0.07	9.99	0.05	✓
Manganese	mg/L	0.71	0.67	9.990	0.010	✓
Chloride	mg/L	7.4	7.4	10.0	0.5	✓
Nitrate - N	mg/L	204	203	9.99	0.01	✓
Nitrite - N	mg/L	<0.05	<0.05	9.990	0.010	✓
Hydroxide	mg/L	<5	<5	10		✓
Carbonate	mg/L	7	9	10		✓
Bicarbonate	mg/L	153	152	10		✓
P-Alkalinity	mg/L	<5	<5	10	5	✓
T-Alkalinity	mg/L	6	8	10	5	✓

Material Used: Edmonton Duplicate
Date Acquired: Jul 22, 2005
Acquired By: Annya Hundal

NORWEST LABS

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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 396502
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Routine Water (Continued...)

Control Sample		Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
Chloride		mg/L	2130	2087.0	1875.2	2298.8	✓
Material Used:	Chloride High						
Date Acquired:	Jul 22, 2005						
Acquired By:	Wilailuk Somiit						
Calcium		mg/L	241	250.0	225.0	275.0	✓
Magnesium		mg/L	96.4	100.0	90.0	110.0	✓
Sodium		mg/L	248	250.0	225.0	275.0	✓
Potassium		mg/L	247	250.0	225.0	275.0	✓
Iron		mg/L	9.32	10.00	9.01	10.99	✓
Manganese		mg/L	2.38	2.500	2.260	2.740	✓
Material Used:	Metals High						
Date Acquired:	Jul 22, 2005						
Acquired By:	To Thong						
Calcium		mg/L	5.2	5.0	4.5	5.5	✓
Magnesium		mg/L	2.1	2.0	1.8	2.2	✓
Sodium		mg/L	5.2	5.0	4.5	5.5	✓
Potassium		mg/L	4.8	5.0	4.5	5.5	✓
Iron		mg/L	0.21	0.20	0.18	0.22	✓
Manganese		mg/L	0.051	0.050	0.045	0.055	✓
Material Used:	Metals Low						
Date Acquired:	Jul 21, 2005						
Acquired By:	Nicole Sehn						
pH			9.24	9.23	9.11	9.35	✓
Electrical Conductivity		dS/m at 25 C	2.82	2.730	2.611	2.849	✓
Chloride		mg/L	81.6	81.0	76.4	85.6	✓
Nitrate - N		mg/L	10.3	10.00	9.61	10.39	✓
Nitrite - N		mg/L	10.4	10.000	9.562	10.438	✓
P-Alkalinity		mg/L	492	507	415	599	✓
T-Alkalinity		mg/L	999	1009	969	1049	✓
Material Used:	Water High						
Date Acquired:	Jul 22, 2005						
Acquired By:	Annva Hundal						

NORWEST LABS

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Quality Control

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Routine Water (Continued...)

Control Sample	Units	Measured	Mean	Lower Limit	Upper Limit	Passed QC
pH		6.93	6.90	6.83	6.97	✓
Electrical Conductivity	dS/m at 25 C	0.079	0.076	0.070	0.081	✓
Chloride	mg/L	14.6	14.9	13.2	16.6	✓
Nitrate - N	mg/L	0.52	0.50	0.44	0.56	✓
Nitrite - N	mg/L	0.515	0.495	0.437	0.553	✓
P-Alkalinity	mg/L	66	54	20	88	✓
T-Alkalinity	mg/L	132	127	118	136	✓

Material Used: Water Low
Date Acquired: Jul 22, 2005
Acquired By: Annva Hundal

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Methodology and Notes

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
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NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

Method of Analysis:

MethodName	Reference		Method	Date Analysis Started	Location
Alkalinity, pH, and EC in water	APHA	*	Conductivity - Laboratory Method, 2510 B	22-Jul-05	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Electrometric Method, 4500-H+ B	22-Jul-05	Norwest Labs Edmonton
Alkalinity, pH, and EC in water	APHA	*	Titration Method, 2320 B	22-Jul-05	Norwest Labs Edmonton
Ammonium-N in Water	APHA	*	Automated Phenate Method, 4500-NH3 G	27-Jul-05	Norwest Labs Edmonton
Anions (Routine) by Ion Chromatography	APHA	*	Ion Chromatography with Chemical Suppression of Eluent Cond., 4110 B	25-Jul-05	Norwest Labs Edmonton
Chloride in Water	APHA	*	Automated Ferricyanide Method, 4500-Cl- E	22-Jul-05	Norwest Labs Edmonton
Cyanide (Strong Acid Dissociable) in water	APHA	*	Total Cyanide after Distillation, 4500-CN-C	26-Jul-05	Norwest Labs Edmonton
Cyanide (Strong Acid Dissociable) in water	APHA	*	Total Cyanide after Distillation, 4500-CN-C	27-Jul-05	Norwest Labs Edmonton
Mercury (Total) in water	MDMES	*	Determination of Mercury in Water by Cold Vapor Atomic Absor, 245.1	25-Jul-05	Norwest Labs Edmonton
Mercury (Total) in water	MDMES	*	Determination of Mercury in Water by Cold Vapor Atomic Absor, 245.1	23-Jul-05	Norwest Labs Edmonton
Mercury Low Level (Total) in water	APHA	*	Cold Vapour Atomic Absorption Spectrometric Method, 3112 B	29-Jul-05	Norwest Labs Surrey
Metals ICP-MS (Total) in water	US EPA	*	Determination of Trace Elements in Waters and Wastes by ICP-MS, 200.8	22-Jul-05	Norwest Labs Edmonton
Metals Trace (Dissolved) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	22-Jul-05	Norwest Labs Edmonton
Metals Trace (Dissolved) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	22-Jul-05	Norwest Labs Edmonton
Metals Trace (Total) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	22-Jul-05	Norwest Labs Edmonton
Metals Trace (Total) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	22-Jul-05	Norwest Labs Edmonton
Solids Suspended (Total, Fixed and Volatile)	APHA	*	Total Suspended Solids Dried at 103-105'C, 2540 D	22-Jul-05	Norwest Labs Edmonton

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Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
Fax: (780) 438-0396

Methodology and Notes

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: Steve Schlesak
Company: Kinross Gold Corporation

Project ID:
Name: Lupin Mine
Location: Nunavut
LSD:
P.O.:
Acct. Code:

NWL Lot ID: **396502**
Control Number:
Date Received: Jul 21, 2005
Date Reported: Aug 02, 2005
Report Number: 724749

* Norwest method(s) is based on reference method

References:

APHA	Standard Methods for the Examination of Water and Wastewater
MDMES	Mthds for the Determination of Metals in Enviromental Smpls
US EPA	US Environmental Protection Agency Test Methods

Comments:

For samples 3, 4, 12, 13, 14, 17, and 21, insufficient sample was provided to reach lower TSS detection limit of 1 mg/l.
The ion balance was outside the acceptable range for sample 396502-7. All parameters used in the ion balance calculation have been confirmed.
The ion balance was outside the acceptable range for samples 396502-14 and 16. The ion balance can be variable in samples with TDS less than 100 mg/L.

Please direct any inquiries regarding this report to our Client Services group.
Results relate only to samples as submitted
The test report shall not be reproduced except in full, without the written approval of the laboratory

NORWEST LABS

Norwest Labs
7217 Roper Road NW
Edmonton, AB. T6B 3J4
Phone: (780) 438-5522
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Analytical Report

Bill to: Echo Bay Mines Ltd.
Report to: Echo Bay Mines Ltd.
9818 International Airport
Edmonton, AB, Canada
T5J 2T2
Attn: Michael Tansey
Sampled By: M. Tansey/B. Lowe
Company:

Project ID:
Name:
Location:
LSD:
P.O.:
Acct. Code:

NWL Lot ID: 392192
Control Number:
Date Received: Jun 30, 2005
Date Reported: Jul 07, 2005
Report Number: 716952

	NWL Number	392192-16	392192-19	392192-24	
	Sample Date	Jun 29, 2005	Jun 29, 2005	Jun 29, 2005	
	Sample Description	51024 / Station 102	51026 / Station 102	51031 / Lower sewage lagoon	
	Matrix	Water - General	Water - General	Water - General	
Analyte		**Units**	**Results**	**Results**	**Results**	**Detection Limit**
Metals Total						
Iron	Total	mg/L	0.2	-	0.4	0.1
Manganese	Total	mg/L	0.864	-	0.177	0.005
Silicon	Total	mg/L	1.60	-	0.41	0.05
Sulfur	Total	mg/L	82.8	-	16.0	0.3
Mercury	Total	mg/L	<0.0001	-	<0.0001	0.0001
Mercury	Total	ug/L	-	0.05	-	0.02
Aluminum	Total	mg/L	0.243	-	0.153	0.005
Antimony	Total	mg/L	0.0046	-	0.0004	0.0002
Arsenic	Total	mg/L	0.0185	-	0.0138	0.0002
Barium	Total	mg/L	0.014	-	0.014	0.001
Beryllium	Total	mg/L	<0.0001	-	<0.0001	0.0001
Bismuth	Total	mg/L	<0.0005	-	<0.0005	0.0005
Boron	Total	mg/L	0.075	-	0.026	0.002
Cadmium	Total	mg/L	0.00013	-	<0.00001	0.00001
Chromium	Total	mg/L	<0.0005	-	<0.0005	0.0005
Cobalt	Total	mg/L	0.0426	-	0.0068	0.0001
Copper	Total	mg/L	0.015	-	0.003	0.001
Lead	Total	mg/L	0.0019	-	0.0008	0.0001
Lithium	Total	mg/L	0.020	-	0.136	0.001
Molybdenum	Total	mg/L	0.001	-	0.001	0.001
Nickel	Total	mg/L	0.0820	-	0.0092	0.0005
Selenium	Total	mg/L	<0.0002	-	<0.0002	0.0002
Silver	Total	mg/L	<0.0001	-	<0.0001	0.0001
Strontium	Total	mg/L	0.250	-	0.744	0.001
Thallium	Total	mg/L	<0.00005	-	<0.00005	0.00005
Tin	Total	mg/L	<0.001	-	<0.001	0.001
Titanium	Total	mg/L	0.0039	-	0.0052	0.0005
Uranium	Total	mg/L	<0.0005	-	<0.0005	0.0005
Vanadium	Total	mg/L	<0.0001	-	0.0004	0.0001
Zinc	Total	mg/L	0.211	-	0.015	0.001

Appendix C

Water Quality Data and QA/QC Results

Table C.1. Water Quality Data for Exposure and Reference Sites

Parameter	Units	MDL	CWQG	Exposure		Reference	
				Dam 1a Lake	Seep Creek Pond 1&2	Fingers Lake	Fingers Creek
Nutrients							
Ammonia-N	mg/L	0.05	5.79	0.51	<0.05	<0.05	<0.05
Dissolved Organic Carbon	mg/L	1		2	6	3	<1
Phosphorus, Total	mg/L	0.02		<0.02	<0.02	0.02	<0.02
Total Organic Carbon	mg/L	1		2	6	3	3
Major Ions							
Nitrate+Nitrite-N	mg/L	0.1		5.7	0.4	0.1	<0.1
Nitrate-N	mg/L	0.1		5.7	0.4	0.1	<0.1
Nitrite-N	mg/L	0.05	0.06	<0.05	<0.05	<0.05	<0.05
Chloride (Cl)	mg/L	1		48	6	<1	<1
Iron (Fe)-Extractable	mg/L	0.06		<0.06	0.15	<0.06	0.14
Manganese(Mn)-Extractable	mg/L	0.02		1.24	0.09	<0.02	0.10
ICP Metals and SO_4 for Routine Water Analysis							
Calcium (Ca)	mg/L	0.5		61.5	10.2	1.1	1.6
Potassium (K)	mg/L	0.5		5.2	1.1	<0.5	0.6
Magnesium (Mg)	mg/L	0.1		7.9	2.7	0.6	0.7
Sodium (Na)	mg/L	1		69	10	1	1
Sulfate (SO_4)	mg/L	0.5		237	43.3	2.7	2.6
TDS and Hardness							
TDS (Calculated)	mg/L			454	75	6	7
Hardness (as $CaCO_3$)	mg/L			186	37	5	7
pH, Conductivity and Total Alkalinity							
pH		0.1	6.5-9.0	**5.8**	**6.1**	6.5	**6.3**
Conductivity (EC)	µS/cm	0.2		738	141	14.8	15.3
Bicarbonate (HCO_3)	mg/L	5		<5	<5	<5	<5
Carbonate (CO_3)	mg/L	5		<5	<5	<5	<5
Hydroxide (OH)	mg/L	5		<5	<5	<5	<5
Alkalinity, Total (as $CaCO_3$)	mg/L	5		<5	<5	<5	<5
Other							
Total Suspended Solids	mg/L	3		<3	<3	<3	<3
Cyanide, Total	mg/L	0.002		<0.002	<0.002	<0.002	<0.002
Radium-226	Bq/L	0.005		0.010	0.006	0.006	<0.005

MDL = Method Detection Limit; CWQG = Canadian Water Quality Guidelines for freshwater (CCME 2005); bold and highlighted values exceed, or fall outside the range of, CCME guideline values

Table C.2. Total Metal Data for Exposure and Reference Sites

Parameter	Units	MRV	MDL	CWQG	Exposure		Reference	
					Dam 1a Lake	Seep Creek Pond 1&2	Fingers Lake	Fingers Creek
Total Metals								
Aluminum (Al)	µg/L	0.50	2.00	100	**110**	72.4	16.4	10.3
Antimony (Sb)	µg/L	0.0005	0.0010		0.0389	0.0403	0.0106	0.0060
Arsenic (As)	µg/L	0.0020	0.0400	5	**6.80**	2.93	2.07	1.21
Barium (Ba)	µg/L	0.0040	0.1000		27.7	7.53	1.75	1.47
Beryllium (Be)	µg/L	0.0030	0.0100		0.141	0.0270	< 0.003	< 0.003
Bismuth (Bi)	µg/L	0.0010	0.0100		0.0015	0.0039	0.0017	< 0.001
Boron (B)	µg/L	0.050	0.800		63.5	9.59	1.45	< 0.05
Cadmium (Cd)	µg/L	0.0020	0.0060	0.017	**0.411**	**0.0913**	0.0089	< 0.002
Calcium (Ca)	mg/L	0.0040	0.1000		57.7	10.2	0.895	0.962
Chromium (Cr)	µg/L	0.030	0.300		< 0.03	0.379	0.0999	< 0.03
Cobalt (Co)	µg/L	0.0010	0.0100		42.1	5.50	0.0493	0.0691
Copper (Cu)	µg/L	0.050	0.100	2	**13.1**	**6.53**	0.562	0.390
Iron (Fe)	µg/L	2.0	4.0	300	30.2	171	30.2	18.1
Lead (Pb)	µg/L	0.0010	0.0060	1	0.115	**1.39**	0.279	0.0130
Lithium (Li)	µg/L	0.020	0.200		22.0	7.58	0.396	0.866
Magnesium (Mg)	mg/L	0.0001	0.0005		6.16	2.11	0.512	0.487
Manganese (Mn)	µg/L	0.0030	0.0300		1330	93.4	2.87	3.82
Mercury (Hg)	ng/L	0.0100	0.0500	100	0.0113	< 0.01	< 0.01	< 0.01
Molybdenum (Mo)	µg/L	0.0010	0.0080	73	0.236	0.166	0.0165	0.0084
Nickel (Ni)	µg/L	0.0050	0.0600	25	**133**	**28.4**	0.394	0.339
Phosphorus (P)	µg/L	0.80	5.00		9.88	14.5	38.2	10.7
Potassium (K)	µg/L	2.0	5.0		5260	1070	397	360
Selenium (Se)	µg/L	0.100	0.300	1	0.475	< 0.1	< 0.1	< 0.1
Silicon (Si)	mg/L	0.0100	0.8000		1.81	0.834	0.0923	0.0124
Silver (Ag)	µg/L	0.0005	0.0050	0.1	0.0023	0.0111	0.0033	0.0014
Sodium (Na)	µg/L	2.0	6.0		60700	8090	601	402
Strontium (Sr)	µg/L	0.0040	0.0080		244	43.3	4.89	5.30
Sulphur (S)	mg/L	0.20	0.60		95.5	15.7	1.29	< 0.2
Thallium (Tl)	µg/L	0.0003	0.0030		0.0145	0.0061	0.0011	0.0012
Thorium (Th)	µg/L	0.0003	0.0300		0.0066	0.0069	0.0011	0.0006
Tin (Sn)	µg/L	0.030	0.070		< 0.03	0.0323	< 0.03	< 0.03
Titanium (Ti)	µg/L	0.040	0.070		0.756	1.60	0.521	0.157
Uranium (U)	µg/L	0.0001	0.0030		0.0144	0.0247	0.0048	0.0047
Vanadium (V)	µg/L	0.0050	0.2000		< 0.005	0.0918	0.0533	< 0.005
Zinc (Zn)	µg/L	0.100	0.200	30	**314**	**40.4**	2.16	1.67

MRV = Minimum Reported Value; MDL = Method Detection Limit; CWQG = Canadian Water Quality Guidelines for freshwater (CCME 2005); Bold and shaded values exceed CWQG.

Table C.3. Dissolved Metal Data for Exposure and Reference Sites

Parameter	Units	MRV	MDL	Exposure		Reference	
				Dam 1a Lake	Seep Creek Pond 1&2	Fingers Lake	Fingers Creek
Dissolved Metals							
Aluminum (Al)	µg/L	0.20	2.00	92.1	33.6	2.03	3.37
Antimony (Sb)	µg/L	0.0005	0.0010	0.0342	0.0331	0.0104	0.0060
Arsenic (As)	µg/L	0.0020	0.0400	3.78	2.10	1.64	1.21
Barium (Ba)	µg/L	0.0040	0.1000	25.7	6.66	1.38	1.45
Beryllium (Be)	µg/L	0.0030	0.0100	0.106	0.0234	< 0.003	< 0.003
Bismuth (Bi)	µg/L	0.0010	0.0100	0.0014	0.0021	0.0016	< 0.001
Boron (B)	µg/L	0.030	0.800	59.6	8.34	0.492	< 0.03
Cadmium (Cd)	µg/L	0.0020	0.0060	0.373	0.0783	0.0066	< 0.002
Calcium (Ca)	mg/L	0.0040	0.1000	54.1	9.56	0.837	0.953
Chromium (Cr)	µg/L	0.030	0.300	< 0.03	0.200	0.0427	< 0.03
Cobalt (Co)	µg/L	0.0010	0.0100	38.7	5.20	0.0248	0.0396
Copper (Cu)	µg/L	0.050	0.100	12.2	5.15	0.557	0.363
Iron (Fe)	µg/L	2.0	4.0	< 2	55.6	< 2	< 2
Lead (Pb)	µg/L	0.0010	0.0060	0.0570	0.638	0.0930	0.0125
Lithium (Li)	µg/L	0.020	0.200	19.9	7.35	0.163	0.826
Magnesium (Mg)	mg/L	0.0001	0.0005	5.77	2.00	0.468	0.486
Manganese (Mn)	µg/L	0.0030	0.0300	1200	89.1	0.562	2.15
Mercury (Hg)	µg/L	0.0100	0.0500	0.0101	< 0.01	< 0.01	< 0.01
Molybdenum (Mo)	µg/L	0.0010	0.0080	0.217	0.161	0.0124	0.0081
Nickel (Ni)	µg/L	0.0050	0.0600	123	26.5	0.338	0.335
Phosphorus (P)	µg/L	0.80	5.00	7.46	9.49	24.6	10.5
Potassium (K)	µg/L	2.0	5.0	4890	1020	372	352
Selenium (Se)	µg/L	0.100	0.300	0.467	< 0.1	< 0.1	< 0.1
Silicon (Si)	mg/L	0.0100	0.8000	1.72	0.730	0.0606	0.0119
Silver (Ag)	µg/L	0.0005	0.0050	0.0009	0.0024	0.0008	0.0010
Sodium (Na)	µg/L	2.0	6.0	55700	7770	600	401
Strontium (Sr)	µg/L	0.0040	0.0080	234	42.7	4.54	5.20
Sulphur (S)	mg/L	0.20	0.60	90.4	15.0	1.29	< 0.2
Thallium (Tl)	µg/L	0.0003	0.0030	0.0144	0.0060	0.0011	0.0010
Thorium (Th)	µg/L	0.0003	0.0300	0.0065	0.0061	0.0011	0.0006
Tin (Sn)	µg/L	0.030	0.070	< 0.03	< 0.03	< 0.03	< 0.03
Titanium (Ti)	µg/L	0.040	0.070	0.537	0.405	0.0818	0.116
Uranium (U)	µg/L	0.0001	0.0030	0.0068	0.0178	0.0020	0.0023
Vanadium (V)	µg/L	0.0050	0.2000	< 0.005	0.0230	0.0293	< 0.005
Zinc (Zn)	µg/L	0.050	0.200	303	39.5	2.13	1.21
Total Chlorine (Cl)	mg/L	0.100	0.300	41.2	5.62	0.238	0.137
Dissolved Chlorine (Cl)	mg/L	0.100	0.300	39.4	5.60	0.237	0.132

MRV = Minimum Reported Value; MDL = Method Detection Limit

Table C.4. QA/QC Results

Parameter	Units	MDL	Field Blank	Trip Blank
Nutrients				
Ammonia-N	mg/L	0.05	<0.05	<0.05
Dissolved Organic Carbon	mg/L	1	<1	<1
Phosphorus, Total	mg/L	0.02	<0.02	<0.02
Total Organic Carbon	mg/L	1	<1	<1
Total Suspended Solids	mg/L	3	<3	<3
Major Ions				
Nitrate+Nitrite-N	mg/L	0.1	<0.1	<0.1
Nitrate-N	mg/L	0.1	<0.1	<0.1
Nitrite-N	mg/L	0.05	<0.05	<0.05
Chloride (Cl)	mg/L	1	<1	<1
Iron (Fe)-Extractable	mg/L	0.06	<0.06	<0.06
Manganese(Mn)-Extractable	mg/L	0.02	<0.02	<0.02
Calcium (Ca)	mg/L	0.5	<0.5	<0.5
Potassium (K)	mg/L	0.5	<0.5	<0.5
Magnesium (Mg)	mg/L	0.1	<0.1	<0.1
Sodium (Na)	mg/L	1	<1	<1
Sulphate (SO_4)	mg/L	0.5	<0.5	<0.5
Ion Balance Calculation				
Ion Balance	%		Low TDS	Low TDS
TDS (Calculated)	mg/L		<1	<1
Hardness (as $CaCO_3$)	mg/L		<1	<1
pH, Conductivity and Total Alkalinity				
pH	pH	0.1	5.7	8.4
Conductivity (EC)	µS/cm	0.2	**1.1**	**1.1**
Bicarbonate (HCO_3)	mg/L	5	<5	<5
Carbonate (CO_3)	mg/L	5	<5	<5
Hydroxide (OH)	mg/L	5	<5	<5
Alkalinity, Total (as $CaCO_3$)	mg/L	5	<5	<5
Other				
Cyanide, Total	mg/L	0.002	<0.002	<0.002
Radium-226	Bq/L	0.005	<0.005	<0.005

MDL = Method Detection Limit; Samples were analysed at the Enviro-Test Laboratories; Bold and shaded values are greater than five times greater than the MDL.

Appendix D

Sediment Quality and Particle Size Data

Table D.1. Sediment quality and particle size data from the BIC survey reference area

Parameter	Units	MDL	ISQG	Reference Sites (Fingers Lake)						
				Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Total Carbon by Combustion	%	0.1		0.2	0.2	0.4	<0.1	0.4	0.3	0.115
Inorganic Carbon	%	0.01		0.06	0.03	0.03	0.08	0.07	0.054	0.023
Total Organic Carbon	%	0.1		0.1	0.2	0.3	<0.1	0.4	0.25	0.129
Particle Size										
%Sand (0.2 - 2.0 mm)	%			62.10	50.00	49.20	53.7	58	54.6	5.453
% Gravel (>2.0 - 16.0 mm)	%			0	0	0	0	0	0	0.000
Sand (>0.05 mm)	%	1		97	90	86	98	82	90.6	6.914
Slit (0.002 - 0.05 mm)	%	1		2	8	12	2	16	8	6.164
Clay (<0.002 mm)	%	1		1	2	2	<1	2	1.75	0.500
Texture				Sand	Sand	Sand/ Loam	Sand	Loamy Sand		
Metals in Sediment										
Silver (Ag)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Arsenic (As)	mg/kg	0.2	5.9	**7**	3.9	4.1	2.9	3.1	4.2	1.646
Barium (Ba)	mg/kg	5		40	44	38	22	50	38.8	10.450
Beryllium (Be)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Cadmium (Cd)	mg/kg	0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Cobalt (Co)	mg/kg	1		3	4	3	3	5	3.6	0.894
Chromium (Cr)	mg/kg	0.5	37.3	19.8	20.8	18.2	10.2	24.8	18.76	5.369
Copper (Cu)	mg/kg	2	35.7	12	9	7	3	9	8	3.317
Mercury (Hg)	mg/kg	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Molybdenum (Mo)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Nickel (Ni)	mg/kg	2		11	13	9	8	14	11	2.550
Lead (Pb)	mg/kg	5	35	<5	<5	<5	<5	<5	<5	
Antimony (Sb)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Selenium (Se)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Tin (Sn)	mg/kg	5		<5	<5	<5	<5	<5	<5	
Thallium (Tl)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Uranium (U)	mg/kg	40		<40	<40	<40	<40	<40	<40	
Vanadium (V)	mg/kg	1		17	17	16	9	20	15.8	4.087
Zinc (Zn)	mg/kg	10	123	20	20	20	10	30	20	7.071

Notes: MDL=method detection limit; ISQG = Interim Sediment Quality Guideline for the protection of aquatic life (CCME 2005); bold and shaded values exceed ISQG

Table D.2. Sediment quality and particle size data from the BIC survey exposure area

Parameter	Units	MDL	ISQG	Exposure Sites (Seep Creek Pond 1 and Pond 2)						
				Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Total Carbon by Combustion	%	0.1		2.6	0.5	4.4	0.4	0.5	1.68	1.780
Inorganic Carbon	%	0.01		0.03	0.06	0.07	0.03	0.03	0.044	0.019
Total Organic Carbon	%	0.1		2.6	0.5	4.3	0.4	0.4	1.64	1.759
Particle Size										
%Sand (0.2 - 2.0 mm)	%			8.61	7.63	42.1	24.1	39.2	28.26	15.855
% Gravel (>2.0 - 16.0 mm)	%			0.0	0.0	0.0	0.0	0.1	0.025	0.050
Sand (>0.05 mm)	%	1		8	32	8	69	82	47.75	33.925
Slit (0.002 - 0.05 mm)	%	1		86	66	84	30	16	49	31.432
Clay (<0.002 mm)	%	1		6	2	8	1	2	3.25	3.202
Texture				Silt	Silt Loam	Silt	Sandy Loam	Loam		
Metals in Sediment										
Silver (Ag)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Arsenic (As)	mg/kg	0.2	5.9	**45.6**	**17.6**	**38.9**	**9.6**	**18.3**	26	15.406
Barium (Ba)	mg/kg	5		78	37	65	28	28	47.2	22.950
Beryllium (Be)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Cadmium (Cd)	mg/kg	0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Cobalt (Co)	mg/kg	1		20	9	21	9	10	13.8	6.140
Chromium (Cr)	mg/kg	0.5	37.3	**64.9**	27.9	**57.5**	14.7	15.1	36.02	23.736
Copper (Cu)	mg/kg	2	35.7	29	23	30	20	13	23	6.964
Mercury (Hg)	mg/kg	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Molybdenum (Mo)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Nickel (Ni)	mg/kg	2		46	26	48	22	16	31.6	14.519
Lead (Pb)	mg/kg	5	35	<5	<5	<5	<5	<5	<5	
Antimony (Sb)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Selenium (Se)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Tin (Sn)	mg/kg	5		<5	<5	<5	<5	<5	<5	
Thallium (Tl)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Uranium (U)	mg/kg	40		<40	<40	<40	<40	<40	<40	
Vanadium (V)	mg/kg	1		44	21	40	12	14	26.2	14.873
Zinc (Zn)	mg/kg	10	123	90	50	90	50	30	62	26.833

Notes: MDL=method detection limit; ISQG = Interim Sediment Quality Guideline for the protection of aquatic life (CCME 2005); bold and shaded values exceed ISQG

Table D.1. Sediment quality and particle size data from the BIC survey reference area

Parameter	Units	MDL	ISQG	Reference Sites (Fingers Lake)						
				Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Total Carbon by Combustion	%	0.1		0.2	0.2	0.4	<0.1	0.4	0.3	0.115
Inorganic Carbon	%	0.01		0.06	0.03	0.03	0.08	0.07	0.054	0.023
Total Organic Carbon	%	0.1		0.1	0.2	0.3	<0.1	0.4	0.25	0.129
Particle Size										
%Sand (0.2 - 2.0 mm)	%			62.10	50.00	49.20	53.7	58	54.6	5.453
% Gravel (>2.0 - 16.0 mm)	%			0	0	0	0	0	0	0.000
Sand (>0.05 mm)	%	1		97	90	86	98	82	90.6	6.914
Slit (0.002 - 0.05 mm)	%	1		2	8	12	2	16	8	6.164
Clay (<0.002 mm)	%	1		1	2	2	<1	2	1.75	0.500
Texture				Sand	Sand	Sand/ Loam	Sand	Loamy Sand		
Metals in Sediment										
Silver (Ag)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Arsenic (As)	mg/kg	0.2	5.9	**7**	3.9	4.1	2.9	3.1	4.2	1.646
Barium (Ba)	mg/kg	5		40	44	38	22	50	38.8	10.450
Beryllium (Be)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Cadmium (Cd)	mg/kg	0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Cobalt (Co)	mg/kg	1		3	4	3	3	5	3.6	0.894
Chromium (Cr)	mg/kg	0.5	37.3	19.8	20.8	18.2	10.2	24.8	18.76	5.369
Copper (Cu)	mg/kg	2	35.7	12	9	7	3	9	8	3.317
Mercury (Hg)	mg/kg	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Molybdenum (Mo)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Nickel (Ni)	mg/kg	2		11	13	9	8	14	11	2.550
Lead (Pb)	mg/kg	5	35	<5	<5	<5	<5	<5	<5	
Antimony (Sb)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Selenium (Se)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Tin (Sn)	mg/kg	5		<5	<5	<5	<5	<5	<5	
Thallium (Tl)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Uranium (U)	mg/kg	40		<40	<40	<40	<40	<40	<40	
Vanadium (V)	mg/kg	1		17	17	16	9	20	15.8	4.087
Zinc (Zn)	mg/kg	10	123	20	20	20	10	30	20	7.071

Notes: MDL=method detection limit; ISQG = Interim Sediment Quality Guideline for the protection of aquatic life (CCME 2005); bold and shaded values exceed ISQG

Table D.2. Sediment quality and particle size data from the BIC survey exposure area

Parameter	Units	MDL	ISQG	Exposure Sites (Seep Creek Pond 1 and Pond 2)						
				Site 1	Site 2	Site 3	Site 4	Site 5	Mean	SD
Total Carbon by Combustion	%	0.1		2.6	0.5	4.4	0.4	0.5	1.68	1.780
Inorganic Carbon	%	0.01		0.03	0.06	0.07	0.03	0.03	0.044	0.019
Total Organic Carbon	%	0.1		2.6	0.5	4.3	0.4	0.4	1.64	1.759
Particle Size										
%Sand (0.2 - 2.0 mm)	%			8.61	7.63	42.1	24.1	39.2	28.26	15.855
% Gravel (>2.0 - 16.0 mm)	%			0.0	0.0	0.0	0.0	0.1	0.025	0.050
Sand (>0.05 mm)	%	1		8	32	8	69	82	47.75	33.925
Slit (0.002 - 0.05 mm)	%	1		86	66	84	30	16	49	31.432
Clay (<0.002 mm)	%	1		6	2	8	1	2	3.25	3.202
Texture				Silt	Silt Loam	Silt	Sandy Loam	Loam		
Metals in Sediment										
Silver (Ag)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Arsenic (As)	mg/kg	0.2	5.9	**45.6**	**17.6**	**38.9**	**9.6**	**18.3**	26	15.406
Barium (Ba)	mg/kg	5		78	37	65	28	28	47.2	22.950
Beryllium (Be)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Cadmium (Cd)	mg/kg	0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Cobalt (Co)	mg/kg	1		20	9	21	9	10	13.8	6.140
Chromium (Cr)	mg/kg	0.5	37.3	**64.9**	27.9	**57.5**	14.7	15.1	36.02	23.736
Copper (Cu)	mg/kg	2	35.7	29	23	30	20	13	23	6.964
Mercury (Hg)	mg/kg	0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Molybdenum (Mo)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Nickel (Ni)	mg/kg	2		46	26	48	22	16	31.6	14.519
Lead (Pb)	mg/kg	5	35	<5	<5	<5	<5	<5	<5	
Antimony (Sb)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Selenium (Se)	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	
Tin (Sn)	mg/kg	5		<5	<5	<5	<5	<5	<5	
Thallium (Tl)	mg/kg	1		<1	<1	<1	<1	<1	<1	
Uranium (U)	mg/kg	40		<40	<40	<40	<40	<40	<40	
Vanadium (V)	mg/kg	1		44	21	40	12	14	26.2	14.873
Zinc (Zn)	mg/kg	10	123	90	50	90	50	30	62	26.833

Notes: MDL=method detection limit; ISQG = Interim Sediment Quality Guideline for the protection of aquatic life (CCME 2005); bold and shaded values exceed ISQG

Appendix E

Benthic Invertebrate Data and QA/QC Results

Table E.1. Raw benthic invertebrate community data for organisms retained on the 500 µm sieve

Major Group	Family (Subfamily/Tribe)	Genus/Species	Fingers Lake Reference Area (Individuals/m^2)					Pond 1 (Individuals/m^2)			Pond 2 (Individuals/m^2)	
			FL1	FL2	FL3	FL4	FL5	SCP3	SCP4	SCP5	SCP1	SCP2
Oligochaeta	Aeolosomatidae	-						1				
	Enchytraeidae	-	1	12	67					8		
	Lumbriculidae	-	2		8	3	14	2		20	9	5
	Naididae	-										
Acari	Eremaeidae	-										
	Hydrachnidia	-				1	6			4	8	1
Pelecypoda	Sphaeriidae	(i/d)					2					
		Pisidium	2				18					
Ostracoda	-	-			34		3					
Cladocera		(i/d)		2		2						
	Chydoridae	(i/d)			4							
	Daphnidae	(i/d)			7							
Copepoda		(i/d)										
	Calanoida	(i/d)		2		3						
	Cyclopoida	(i/d)			40		7	1		16		
Ephemeroptera	Heptageniidae	(i/d)									1	
Tricoptera	Leptoceridae	*Mystacides*			11							1
		Oecetis					1				3	
	Limnephilidae	(i/d)					1					
		Ecclisomyia		1								

Table E.1. Raw benthic invertebrate community data for organisms retained on the 500 µm sieve

Major Group	Family (Subfamily/Tribe)	Genus/Species	Fingers Lake Reference Area (Individuals/m^2)					Pond 1 (Individuals/m^2)			Pond 2 (Individuals/m^2)	
			FL1	FL2	FL3	FL4	FL5	SCP3	SCP4	SCP5	SCP1	SCP2
Diptera	Chironomidae pupae	-								4		
	Chironomidae	(i/d)	9	4	63	23		3	7	44		
	Chironominae	(i/d)		1								
	Chironomini	-	1	14	114	5	138	240	12	24	308	629
	Tanytarsini	-	1	40	173	3	3	3	1	200	3	13
	Orthocladiinae	-	26	98	1742	9	41	29	18	392	11	20
	Tanypodinae	-	4	8	167	41	32	32	5	20	8	
	Ceratopogonidae	(i/d)								12		
		Bezzia								44		
		Culicoides					1					
		Serromyia						1				
	Empididae	*(i/d)*	1									
		Chelifera	1	12			2	4	1		3	4
	Tipulidae	*(i/d)*						3				
		Dicranota	2			3						
		Tipula							1			
Total			**50**	**194**	**2428**	**93**	**269**	**319**	**45**	**788**	**354**	**673**

Notes: i/d = immature/damaged; Converted to individuals/m^2 by multiplying values by 8.6. Based on area of Ekman grab ($0.0232m^2$)×5 samples at each station

Table E.2. Benthic invertebrate community data summary for organisms retained on the 500 µm sieve

Major Group	Family (Subfamily/Tribe)	Fingers Lake Referance Area (Individuals/m^2)					Reference	Pond 1 (Individuals/m^2)			Pond 2 (Individuals/m^2)		Exposure
		FL1	FL2	FL3	FL4	FL5	Total	SCP3	SCP4	SCP5	SCP1	SCP2	Total
Oligochaeta	Aeolosomatidae							9	0	0	0	0	9
	Enchytraeidae	9	103	576	0	0	688	0	0	69	0	0	69
	Lumbriculidae	17	0	69	26	120	232	17	0	172	77	43	310
Acari	Hydrachnidia	0	0	0	9	52	60	0	0	34	69	9	112
Pelecypoda	Sphaeriidae	17	0	0	0	172	189						
Ostracoda		0	0	292	0	26	318						
Ephemeroptera	Heptageniidae							0	0	0	9	0	9
Tricoptera	Leptoceridae	0	0	95	0	9	103	0	0	0	26	9	34
	Limnephilidae	0	9	0	0	9	17						
Diptera	Chironomidae	353	1419	19427	697	1840	23736	2640	370	5847	2839	5693	17389
	Ceratopogoninae	0	0	0	0	9	9	0	0	482	0	0	482
	Empididae	17	103	0	0	17	138	34	9	0	26	34	103
	Tipulidae	17	0	0	26	0	43	26	9	0	0	0	34
Total (Individuals/m^2)		**430**	**1634**	**20459**	**757**	**2253**	**25533**	**2726**	**387**	**6604**	**3045**	**5788**	**18550**
	Mean	39	149	1860	69	205	5107	273	39	660	305	579	3710
	SD	104	423	5829	208	545	8613	832	116	1829	891	1797	2507
	SE	31	128	1758	63	164	2597	263	37	578	282	568	793
	Median	9	0	0	0	17	1634	4	0	17	17	4	3045
	Min	0	0	0	0	0	430	0	0	0	0	0	387
	Max	353	1419	19427	697	1840	20459	2640	370	5847	2839	5693	6604
Family Richness (Taxonomic Catergories)		**6**	**4**	**5**	**3**	**9**	**11**	**5**	**3**	**5**	**6**	**5**	**10**
% Dominant Family		82	87	95	92	82	93	97	96	89	93	98	94

Table E.3. Raw benthic invertebrate community data for organisms retained on the 250 µm sieve

Major Group	Family (Subfamily/Tribe)	Genus/Species	Fingers Lake Referance Area (Individuals/m^2)					Pond 1 (Individuals/m^2)			Pond 2 (Individuals/m^2)	
			FL1	FL2	FL3	FL4	FL5	SCP3	SCP4	SCP5	SCP1	SCP2
Oligochaeta	Aeolosomatidae	-	3					4				
	Enchytraeidae	-	3	216	52		4			40	40	56
	Lumbriculidae	-										
	Naididae	-	3	24	8							
Acari	Eremaeidae	-			4					16		
	Hydrachnidia	-	3				56					
Pelecypoda	Sphaeriidae	(i/d)										
		Pisidium										
Ostracoda	-	-		8	8	9		40	8	8	80	2
Cladocera		(i/d)				9						
	Chydoridae	(i/d)				9						
	Daphnidae	(i/d)			4							
Copepoda		(i/d)		8	20							
	Calanoida	(i/d)		8			16					
	Cyclopoida	(i/d)		8			72			4		
Ephemeroptera	Heptageniidae	(i/d)										
Tricoptera	Leptoceridae	*Mystacides*										
		Oecetis										
	Limnephilidae	(i/d)										
		Ecclisomyia										

Table E.3. Raw benthic invertebrate community data for organisms retained on the 250 µm sieve

Major Group	Family (Subfamily/Tribe)	Genus/Species	Fingers Lake Referance Area (Individuals/m^2)					Pond 1 (Individuals/m^2)			Pond 2 (Individuals/m^2)	
			FL1	FL2	FL3	FL4	FL5	SCP3	SCP4	SCP5	SCP1	SCP2
Diptera	Chironomidae pupae	-										
	Chironomidae	(i/d)	261	216	160	57	80	64	100	156	50	20
	Chironominae	(i/d)	3		8	568		44	20	4	90	
	Chironomini	-					20	224		8	1800	6
	Tanytarsini	-		16	8	22	64	16		16	80	10
	Orthocladiinae	-	41	280	52	110	112	140	24	116	1020	106
	Tanypodinae	-		8		13	8	4	4	4	40	
	Ceratopogoninae	(i/d)										
		Bezzia								4	20	
		Culicoides										
		Serromyia										
	Empididae	*(i/d)*					4					
		Chelifera		16		4						
	Tipulidae	*(i/d)*										
		Dicranota										
		Tipula										
Total			**316**	**808**	**324**	**801**	**436**	**536**	**156**	**376**	**3220**	**200**

Notes: i/d = immature/damaged; Converted to individuals/m^2 by multiplying values by 8.6. Based on area of Ekman grab ($0.0232m^2$)×5 samples at each station

Table E.4. QA/QC re-sort results

Major Group	Family (Subfamily/Tribe)	Genus/Species	Resorted Sample FL4
Oligochaeta	Aeolosomatidae	-	
	Enchytraeidae	-	
	Lumbriculidae	-	
	Naididae	-	
Acari	Eremaeidae	-	
	Hydrachnidia	-	
Pelecypoda	Sphaeriidae	(i/d)	
		Pisidium	
Ostracoda	-	-	
Cladocera		(i/d)	
	Chydoridae	(i/d)	
	Daphnidae	(i/d)	
Copepoda		(i/d)	
	Calanoida	(i/d)	
	Cyclopoida	(i/d)	
Ephemeroptera	Heptageniidae	(i/d)	
Tricoptera	Leptoceridae	*Mystacides*	
		Oecetis	
	Limnephilidae	(i/d)	
		Ecclisomyia	
Diptera	Chironomidae pupae	-	
	Chironomidae	(i/d)	
	Chironominae	(i/d)	
	Chironomini	-	
	Tanytarsini	-	
	Orthocladiinae	-	
	Tanypodinae	-	
	Ceratopogoninae	(i/d)	
		Bezzia	
		Culicoides	
		Serromyia	
	Empididae	*(i/d)*	
		Chelifera	
	Tipulidae	*(i/d)*	
		Dicranota	
		Tipula	
Total Number in Resorted Sample			0
Total Number in Original Sample			93
Sorting Efficiency (%)			100

Appendix F

Fish Survey Data

Table F.1. Raw Fish Capture Data

Watercourse	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SC1	1	BP	NNST	61	1.43			A	U	U	19-Aug-05	No external parasites, preserved
Seep Creek	SC1	2	BP	ARGR	48	0.8			J	IM	U	19-Aug-05	healthy, preserved
Seep Creek	SC1	3	BP	ARGR	46	0.6					U	19-Aug-05	No external parasites, preserved
Seep Creek	SC1	4	BP	ARGR	49	0.96			J	IM	U	19-Aug-05	healthy, preserved
Seep Creek	SC1	5	BP	ARGR	50	1			J	IM	U	19-Aug-05	burned, preserved
Seep Creek	SC1	6	BP	ARGR	45	0.9			J	IM	U	19-Aug-05	burned, preserved
Seep Creek	SC1	7	BP	ARGR	32	0.3			YOY	IM	U	19-Aug-05	burned, preserved
Seep Creek	SC1	8	BP	ARGR	105	10	0.52		J	IM	M	19-Aug-05	healthy,too small for collection
Seep Creek	SC1	9	BP	ARGR	104	10			J	IM		19-Aug-05	healthy, preserved
Seep Creek	SC1	10	BP	ARGR	44	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	11	BP	ARGR	45	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	12	BP	ARGR	48	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	13	BP	ARGR	42	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	14	BP	ARGR	45	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	15	BP	ARGR	48	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC1	16	BP	ARGR	49	<2			J	IM	U	19-Aug-05	healthy, released
Seep Creek	SC2	1	BP	ARGR	101	10			J	IM		20-Aug-05	
Seep Creek	SC2	2	BP	ARGR	96	8			J	IM		20-Aug-05	
Seep Creek	SC2	3	BP	ARGR	47	<2			J	IM		20-Aug-05	
Seep Creek	SC2	4	BP	ARGR	44	<2			J	IM		20-Aug-05	
Seep Creek	SC2	5	BP	ARGR	44	<2			J	IM		20-Aug-05	
Seep Creek	SC2	6	BP	ARGR	55	<2			J	IM		20-Aug-05	
Seep Creek	SC2	7	BP	ARGR	46	<2			J	IM		20-Aug-05	
Seep Creek	SC2	8	BP	ARGR	43	<2			J	IM		20-Aug-05	
Seep Creek	SC2	9	BP	ARGR	49	<2			J	IM		20-Aug-05	
Seep Creek	SC2	10	BP	ARGR	49	<2			J	IM		20-Aug-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SC2	11	BP	ARGR	50	<2			J	IM		20-Aug-05	
Seep Creek	SC2	12	BP	ARGR	45	<2			J	IM		20-Aug-05	
Seep Creek	SC2	13	BP	ARGR	47	<2			J	IM		20-Aug-05	
Seep Creek	SC2	14	BP	ARGR	48	<2			J	IM		20-Aug-05	
Seep Creek	SC2	15	BP	ARGR	49	<2			J	IM		20-Aug-05	
Seep Creek	SCD1	1	GN	ARGR	97				J	IM	U	21-Aug-05	
Seep Creek	SCD1	2	GN	ARGR	98				J	IM	U	21-Aug-05	
Seep Creek	SCD1	3	GN	ARGR	95				J	IM	U	21-Aug-05	
Seep Creek	SCD1	4	GN	ARGR	98				J	IM	U	21-Aug-05	
Seep Creek	SCD1	5	GN	ARGR	99	9.3			J	IM	F	21-Aug-05	
Seep Creek	SCD1	6	GN	ARGR	86	7.9			J	IM	U	21-Aug-05	
Seep Creek	SCD1	7	GN	ARGR	102	10.8			J	IM	F	21-Aug-05	
Seep Creek	SCD1	8	GN	ARGR	93	7.4			J	IM	M	21-Aug-05	
Seep Creek	SC1	18	MB	NNST	68	1.97			U	U	F	22-Aug-05	gonads must be inspected for maturity
Seep Creek	SC1	19	MB	NNST	64	1.63	0.03	1.23	U	U	F	22-Aug-05	
Seep Creek	SC1	20	MB	NNST	61	1.64	0.04	0.91	U	U	M	22-Aug-05	
Seep Creek	SC1	21	MB	NNST	59	1.4	0.04	0.83	U	U	U	22-Aug-05	
Seep Creek	SC1	22	MB	NNST	58	1.22	0.05	0.69	U	U	M	22-Aug-05	Lesion on opercle
Seep Creek	SC1	23	MB	NNST	53	0.86	0.2	0.45	J	IM	F	22-Aug-05	
Seep Creek	SC1	24	MB	NNST	50	0.93	0.02	0.45	J	IM	M	22-Aug-05	
Seep Creek	SC1	25	MB	NNST	49	0.91	0.02	0.39	J	IM	F	22-Aug-05	
Seep Creek	SC1	26	MB	NNST	51	0.77	0.02	0.38	U	U	U	22-Aug-05	preserved in formalin
Seep Creek	SC1	27	MB	NNST	47	0.72			U	U	U	22-Aug-05	
Seep Creek	SC1	28	MB	NNST	52	1.10	0.04	0.46	U	U	M	22-Aug-05	preserved in formalin
Seep Creek	SC1	29	MB	NNST	51	1.03			U	U	M	22-Aug-05	preserved in formalin, body degrading; no internal exam

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SC1	30	MB	NNST	51	0.83			U	U	M	22-Aug-05	
Seep Creek	SC1	31	MB	NNST	74	2.72			A	U	M	22-Aug-05	
Seep Creek	SC1	32	MB	NNST	66	1.64			U	U	M	22-Aug-05	
Seep Creek	SC1	33	MB	NNST	51	0.98			U	U	M	22-Aug-05	
Seep Creek	SC1	34	MB	NNST	59	1.12			U	U	M	22-Aug-05	
Seep Creek	SC1	35	MB	NNST	54	0.73			U	U	M	22-Aug-05	
Seep Creek	SC1	36	MB	NNST	51	0.80			U	U	M	22-Aug-05	
Seep Creek	SC1	37	MB	NNST	65	1.56			U	U	U	22-Aug-05	
Seep Creek	SC3	0	FN	ARGR	64	2.21						25-Aug-05	Healthy
Seep Creek	SC3	1	FN	ARGR	49	1.25						25-Aug-05	Healthy
Seep Creek	SC3	2	FN	ARGR	49	1.36						25-Aug-05	Healthy
Seep Creek	SC3	3	FN	ARGR	97	7.79	0.09	5.42		IM	F	25-Aug-05	
Seep Creek	SC3	4	FN	ARGR	97	8.54	0.11	5.59		IM	M	25-Aug-05	
Seep Creek	SC3	5	FN	NNST	65	1.43	0.03	0.75		MA	F	25-Aug-05	
Seep Creek	SC3	6	FN	NNST	53	1.02	0.03	0.44		IM	F	25-Aug-05	
Seep Creek	SC3	7	FN	NNST	55	1.06				IM	F	25-Aug-05	
Seep Creek	SC3	8	FN	NNST	53	0.95	0.02	0.55		IM	F	25-Aug-05	
Seep Creek	SC3	9	FN	NNST	57	1.19	0.04	0.48		IM	F	25-Aug-05	
Seep Creek	SC3	10	FN	NNST	58	1.13	0.04	0.67		IM	F	25-Aug-05	
Seep Creek	SC3	11	FN	NNST	43	0.65	0.04	0.63		IM	F	25-Aug-05	
Seep Creek	SC3	12	FN	NNST	51	0.78	0.04	0.34			U	25-Aug-05	fungal infection/skin aberrations
Seep Creek	C1	1	GN	ARCH	612	2260			U	U	U	25-Aug-05	given to local assistant
Seep Creek	C1	2	GN	LKTR	593	2175						25-Aug-05	given to local assistant
Seep Creek	C1	3	GN	LKTR	764	4610						25-Aug-05	given to local assistant
Seep Creek	SCD1	9	GN	ARGR	115	11.56		0.46	J	IM	M	27-Aug-05	
Seep Creek	SCD1	10	GN	ARGR	121	17.77	0.19	12.35	J	IM	M	28-Aug-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SC3	11	FN	NNST	43	0.65	0.04	0.63		IM	F	25-Aug-05	
Seep Creek	SC3	12	FN	NNST	51	0.78	0.04	0.34			U	25-Aug-05	
Seep Creek	C1	1	GN	ARCH	612	2260			U	U	U	25-Aug-05	given to local assistant
Seep Creek	C1	2	GN	LKTR	593	2175						25-Aug-05	given to local assistant
Seep Creek	C1	3	GN	LKTR	764	4610						25-Aug-05	given to local assistant
Seep Creek	SCD1	9	GN	ARGR	115	11.56		0.46	J	IM	M	27-Aug-05	
Seep Creek	SCD1	10	GN	ARGR	121	17.77	0.19	12.35	J	IM	M	28-Aug-05	
Seep Creek	SCD1	11	GN	ARGR	103	10.13	0.13	7.05	J	IM	M	28-Aug-05	
Seep Creek	SCD1	12	GN	ARGR	104	11.24	0.14	7.44	J	IM	M	28-Aug-05	
Seep Creek	SCD1	13	GN	ARGR	122	17.26			J	IM	F	28-Aug-05	
Seep Creek	SCD1	14	GN	ARGR	94	8.29	0.17		J	IM	F	28-Aug-05	
Seep Creek	SCD1	15	GN	ARGR	96	8.38	0.09	5.48	J	IM	F	28-Aug-05	
Seep Creek	SCD1	16	GN	ARGR	110	11.06	0.08	7.49	J	IM	F	28-Aug-05	
Seep Creek	SCD1	17	GN	ARGR	119	17.39	0.17	12.21	J	IM	F	28-Aug-05	
Seep Creek	SCD1	18	GN	ARGR	114	14.56	0.14	10.13	J	IM	M	28-Aug-05	
Seep Creek	SCD1	19	GN	ARGR	118	11.66	0.09	8.27	J	IM	M	28-Aug-05	
Seep Creek	SCD1	20	GN	ARGR	96	7.96	0.06	5.41	J	IM	M	28-Aug-05	
Seep Creek	SCD1	21	GN	ARGR	92	7.06	0.05	4.89	J	IM	M	28-Aug-05	
Seep Creek	SCD1	92	GN	ARGR	116	15.74	0.2	11.15	J	IM	M	02-Sep-05	
Seep Creek	SCD1	93	GN	ARGR	118	19.62	0.17	13.73	J	IM	M	02-Sep-05	
Seep Creek	SCD1	94	GN	ARGR	102	12.05	0.13	8.42	J	IM	M	02-Sep-05	
Seep Creek	SCD1	95	GN	ARGR	99	10.27	0.12	6.84	J	IM	U	02-Sep-05	
Seep Creek	SCD1	96	GN	ARGR	107	14.14	0.18	9.94	J	IM	M	02-Sep-05	
Seep Creek	SCD1	97	GN	ARGR	100	11.09	0.08	7.39	J	IM	U	02-Sep-05	
Seep Creek	SCD1	98	GN	ARGR	96	10.17	0.09	6.33	J	IM	F	02-Sep-05	
Seep Creek	SCD1	99	GN	ARGR	111	9.61	0.06	6.59	J	IM	U	02-Sep-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SC4	1	BP	ARGR	94	10.25	0.15	6.42	J	IM		02-Sep-05	
Seep Creek	SC4	2	BP	ARGR	61				YOY			02-Sep-05	released
Seep Creek	SC4	3	BP	ARGR	54				YOY			02-Sep-05	released
Seep Creek	SC4	4	BP	ARGR	57				YOY			02-Sep-05	released
Seep Creek	SC4	5	BP	ARGR	62				YOY			02-Sep-05	released
Seep Creek	SC4	6	BP	ARGR	55				YOY			02-Sep-05	released
Seep Creek	SC4		OB	ARGR					YOY			02-Sep-05	
Seep Creek	SC4		OB	ARGR					YOY			02-Sep-05	
Seep Creek	SC4		OB	ARGR					YOY			02-Sep-05	
Seep Creek	SC4		OB	NNST					J			02-Sep-05	
Seep Creek	SC4		OB	NNST					J			02-Sep-05	
Seep Creek	SCD1	100	GN	ARGR	100	9.82	0.08	6.05	J	IM	M	03-Sep-05	
Seep Creek	SCD1	101	GN	ARGR	112	14.54	0.17	10.30	J	IM	F	03-Sep-05	
Seep Creek	SCD1	102	GN	ARGR	116	16.00	0.17	10.72	J	IM	F	03-Sep-05	
Seep Creek	SCD1	103	GN	ARGR	152	18.91	0.2	13.35	J	IM	F	03-Sep-05	
Seep Creek	SCD1	104	GN	ARGR	117	16.67	0.19	12.25	J	IM	M	03-Sep-05	
Seep Creek	SCD1	105	GN	ARGR	90	7.90	0.09	5.19	J	IM	F	03-Sep-05	
Seep Creek	SCD1	106	GN	ARGR	116	16.72	0.14	11.05	J	IM	U	03-Sep-05	
Seep Creek	SCD1	107	GN	ARGR	94	8.80	0.11	6.21	J	IM	F	03-Sep-05	
Seep Creek	SCD1	108	GN	ARGR	101	10.70	0.09	7.37	J	IM	F	03-Sep-05	
Seep Creek	SCD1	109	GN	ARGR	100	10.58	0.11	7.19	J	IM	M	04-Sep-05	
Seep Creek	SCD1	110	GN	ARGR	106	10.68	0.12	9.42	J	IM	M	04-Sep-05	
Seep Creek	SCD1	111	GN	ARGR	102	10.43	0.08	7.18	J	IM	U	04-Sep-05	
Seep Creek	SCD1	112	GN	ARGR	89	7.86	0.09	5.02	J	IM	M	04-Sep-05	
Seep Creek	SCD1	113	GN	ARGR	98	10.92	0.12	7.19	J	IM	F	04-Sep-05	
Seep Creek	SCD1	114	GN	ARGR	105	14.26	0.14	9.98	J	IM	M	04-Sep-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SCD1	115	GN	ARGR	93	8.38	0.12	5.48	J	IM	F	04-Sep-05	
Seep Creek	SCD1	22	MB	NNST	58	1.00						04-Sep-05	
Seep Creek	SCD1	23	MB	NNST	55	1.03						04-Sep-05	
Seep Creek	SCD1	24	MB	NNST	55	1.01						04-Sep-05	
Seep Creek	SCD1	25	MB	NNST	56	0.93						04-Sep-05	
Seep Creek	SCD1	26	MB	NNST	52	1.00						04-Sep-05	
Seep Creek	SCD1	27	MB	NNST	50	1.05						04-Sep-05	
Seep Creek	SCD1	28	MB	NNST	49	0.81						04-Sep-05	
Seep Creek	SCD1	29	MB	NNST	52	0.83						04-Sep-05	
Seep Creek	SCD1	30	MB	NNST	54	0.88						04-Sep-05	
Seep Creek	SCD1	31	MB	NNST	56	1.07						04-Sep-05	
Seep Creek	SCD1	32	MB	NNST	56	1.10						04-Sep-05	
Seep Creek	SCD1	33	MB	NNST	57	1.12						04-Sep-05	
Seep Creek	SCD1	34	MB	NNST	56	1.02						04-Sep-05	
Seep Creek	SCD1	35	MB	NNST	51	0.93						04-Sep-05	
Seep Creek	SCD1	36	MB	NNST	66	1.54						04-Sep-05	
Seep Creek	SCD1	37	MB	NNST	60	2.09						04-Sep-05	
Seep Creek	SCD1	38	MB	NNST	53	1.05						04-Sep-05	
Seep Creek	SCD1	39	MB	NNST	55	1.03						04-Sep-05	
Seep Creek	SCD1	40	MB	NNST	54	1.07						04-Sep-05	
Seep Creek	SCD1	41	MB	NNST	57	0.96						04-Sep-05	
Seep Creek	SCD1	42	MB	NNST	54	1.05						04-Sep-05	
Seep Creek	SCD1	43	MB	NNST	54	1.32						04-Sep-05	
Seep Creek	SCD1	44	MB	NNST	51	0.74						04-Sep-05	
Seep Creek	SCD1	45	MB	NNST	61	1.17						04-Sep-05	
Seep Creek	SCD1	46	MB	NNST	55	1.03						04-Sep-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SCD1	47	MB	NNST	59	1.18						04-Sep-05	
Seep Creek	SCD1	48	MB	NNST	51	0.83						04-Sep-05	
Seep Creek	SCD1	49	MB	NNST	59	1.02						04-Sep-05	
Seep Creek	SCD1	50	MB	NNST	53	0.87						04-Sep-05	
Seep Creek	SCD1	51	MB	NNST	51	0.86						04-Sep-05	
Seep Creek	SCD1	52	MB	NNST	55	1.02						04-Sep-05	
Seep Creek	SCD1	53	MB	NNST	55	1.00						04-Sep-05	
Seep Creek	SCD1	54	MB	NNST	55	1.08						04-Sep-05	
Seep Creek	SCD1	55	MB	NNST	52	0.96						04-Sep-05	
Seep Creek	SCD1	56	MB	NNST	55	0.89						04-Sep-05	
Seep Creek	SCD1	57	MB	NNST	56	1.08						04-Sep-05	
Seep Creek	SCD1	58	MB	NNST	55	0.89						04-Sep-05	
Seep Creek	SCD1	59	MB	NNST	72	2.26						04-Sep-05	
Seep Creek	SCD1	60	MB	NNST	51	0.84						04-Sep-05	
Seep Creek	SCD1	61	MB	NNST	55	1.12						04-Sep-05	
Seep Creek	SCD1	62	MB	NNST	61	1.15						04-Sep-05	
Seep Creek	SCD1	63	MB	NNST	54	0.87						04-Sep-05	
Seep Creek	SCD1	64	MB	NNST	54	0.93						04-Sep-05	
Seep Creek	SCD1	65	MB	NNST	52	0.87						04-Sep-05	
Seep Creek	SCD1	66	MB	NNST	51	0.80						04-Sep-05	
Seep Creek	SCD1	67	MB	NNST	60	1.22						04-Sep-05	
Seep Creek	SCD1	68	MB	NNST	58	1.02						04-Sep-05	
Seep Creek	SCD1	69	MB	NNST	54	0.89						04-Sep-05	
Seep Creek	SCD1	70	MB	NNST	52	0.93						04-Sep-05	
Seep Creek	SCD1	71	MB	NNST	50	0.84						04-Sep-05	
Seep Creek	SCD1	72	MB	NNST	48	0.79						04-Sep-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Seep Creek	SCD1	73	MB	NNST	60	1.22						04-Sep-05	
Seep Creek	SCD1	74	MB	NNST	58	1.03						04-Sep-05	
Seep Creek	SCD1	75	MB	NNST	54	1.06						04-Sep-05	
Seep Creek	SCD1	76	MB	NNST	60	1.30						04-Sep-05	
Seep Creek	SCD1	77	MB	NNST	62	1.54						04-Sep-05	
Seep Creek	SCD1	78	MB	NNST	53	0.86						04-Sep-05	
Seep Creek	SCD1	79	MB	NNST	64	0.96						04-Sep-05	
Seep Creek	SCD1	80	MB	NNST	48	0.73						04-Sep-05	
Seep Creek	SCD1	81	MB	NNST	56	1.00						04-Sep-05	
Seep Creek	SCD1	82	MB	NNST	58	1.09						04-Sep-05	
Seep Creek	SCD1	83	MB	NNST	53	1.05						04-Sep-05	
Seep Creek	SCD1	84	MB	NNST	51	0.87						04-Sep-05	
Seep Creek	SCD1	85	MB	NNST	53	0.93						04-Sep-05	
Seep Creek	SCD1	86	MB	NNST	58	1.19						04-Sep-05	
Seep Creek	SCD1	87	MB	NNST	60	1.10						04-Sep-05	
Seep Creek	SCD1	88	MB	NNST	55	1.13						04-Sep-05	
Seep Creek	SCD1	89	MB	NNST	54	0.87						04-Sep-05	
Seep Creek	SCD1	90	MB	NNST	58	1.14						04-Sep-05	
Seep Creek	SCD1	91	MB	NNST	60	0.77						04-Sep-05	
Fingers Creek	F1	1	GN	RNWH	395	665						26-Aug-05	Ageing structures removed
Fingers Creek	F1	2	GN	RNWH	398	645						26-Aug-05	Ageing structures removed
Fingers Creek	F1	3	GN	RNWH	397	675						26-Aug-05	Ageing structures removed
Fingers Creek	F1	4	GN	RNWH	393	640						26-Aug-05	Ageing structures removed
Fingers Creek	F1	5	GN	RNWH	357	480						26-Aug-05	Ageing structures removed
Fingers Creek	F1	6	GN	RNWH	392	695						26-Aug-05	Ageing structures removed
Fingers Creek	F1	7	GN	RNWH	418	810						26-Aug-05	Ageing structures removed

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Fingers Creek	F1	8	GN	RNWH	413	745						26-Aug-05	Ageing structures removed
Fingers Creek	F1	9	GN	RNWH	414	755						26-Aug-05	Ageing structures removed
Fingers Creek	F1	10	GN	RNWH								26-Aug-05	individual released
Fingers Creek	F1	11	GN	LKTR								26-Aug-05	specimen released
Fingers Creek	FC3	5	BP	BURB								27-Aug-05	Mortality
Fingers Creek	FC3	6	BP	BURB								27-Aug-05	
Fingers Creek	FC3	7	BP	BURB								27-Aug-05	
Fingers Creek	FC3	8	BP	ARGR	63							31-Aug-05	Released
Fingers Creek	FC3	9	BP	ARGR	62							31-Aug-05	Released
Fingers Creek	FC3	10	BP	ARGR	61							31-Aug-05	Released
Fingers Creek	FC3	11	BP	ARGR	64							31-Aug-05	Released
Fingers Creek	FC3	12	BP	ARGR	61							31-Aug-05	Released
Fingers Creek	FC3	13	BP	ARGR	57							31-Aug-05	Released
Fingers Creek	FC3	14	BP	ARGR	56							31-Aug-05	Released
Fingers Creek	FC3	33	BP	ARGR	171	68.46	0.520	58.68	J	IM	M	31-Aug-05	
Fingers Creek	FC3	32	BP	ARGR	111	16.10	0.127	13.12	J	IM		31-Aug-05	
Fingers Creek	FC3	31	BP	ARGR	93	9.33	0.093	6.76	J	IM		31-Aug-05	
Fingers Creek	FC3	30	BP	ARGR	113	18.67	0.206	14.91	J	IM		31-Aug-05	
Fingers Creek	FC3	29	BP	ARGR	117	18.03	0.174	15.22	J	IM		31-Aug-05	
Fingers Creek	FC3	28	BP	ARGR	115	17.75	0.179	13.15	J	IM		31-Aug-05	
Fingers Creek	FC3	27	BP	ARGR	123	20.98	0.214	16.21	J	IM		31-Aug-05	
Fingers Creek	FC3	26	BP	ARGR	101	12.76	0.111	9.67	J	IM		31-Aug-05	
Fingers Creek	FC3	25	BP	ARGR	110	15.52	0.131	12.58	J	IM		31-Aug-05	
Fingers Creek	FC3	24	BP	ARGR	121	20.52	0.205	16.04	J	IM		31-Aug-05	
Fingers Creek	FC3	23	BP	ARGR	111	17.34	0.181	13.4	J	IM		31-Aug-05	
Fingers Creek	FC3	22	BP	ARGR	98	12.14			J	IM	F	31-Aug-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Fingers Creek	F2	1	MB	SLSC	60							01-Sep-05	released, trap at end of dock
Fingers Creek	F2	2	MB	NNST								01-Sep-05	Mortality, returned to lake
Fingers Creek	FC3	1	HN	ARGR					YOY			03-Sep-05	Mortality
Fingers Creek	FC3	2	HN	ARGR					YOY			03-Sep-05	Mortality
Fingers Creek	FC3	3	HN	ARGR					YOY			03-Sep-05	Mortality
Fingers Creek	FC3	4	HN	BURB	220							03-Sep-05	Released
Fingers Creek	FC3	15	BP	ARGR					YOY			03-Sep-05	Released
Fingers Creek	FC3	16	BP	ARGR					YOY			03-Sep-05	Released
Fingers Creek	FC3	17	BP	ARGR					YOY			03-Sep-05	Released
Fingers Creek	FC3	18	BP	ARGR					YOY			03-Sep-05	Released
Fingers Creek	FC3	19	BP	LKTR	119				J			03-Sep-05	Released
Fingers Creek	FC3	20	BP	SLSC	81				A			03-Sep-05	Released
Fingers Creek	FC3	21	BP	ARGR	57				YOY			03-Sep-05	Released
Fingers Creek	FC3	58	BP	ARGR	158	47.44	0.408	38.820	J	IM		03-Sep-05	
Fingers Creek	FC3	57	BP	ARGR	120	22.46	0.238	18.670	J	IM		03-Sep-05	
Fingers Creek	FC3	56	BP	ARGR	116	18.74	0.155	15.100	J	IM		03-Sep-05	
Fingers Creek	FC3	55	BP	ARGR	111	18.00	0.170	14.610	J	IM		03-Sep-05	
Fingers Creek	FC3	54	BP	ARGR	92	8.20	0.110	6.690	J	IM		03-Sep-05	
Fingers Creek	FC3	53	BP	ARGR	114	18.00	0.188	14.750	J	IM		03-Sep-05	
Fingers Creek	FC3	52	BP	ARGR	109	15.59			J	IM		03-Sep-05	
Fingers Creek	FC3	51	BP	ARGR	113	15.39	0.116	12.720	J	IM		03-Sep-05	
Fingers Creek	FC3	50	BP	ARGR	117	18.42	0.180	15.800	J	IM		03-Sep-05	
Fingers Creek	FC3	49	BP	ARGR	114	18.98	0.190	16.100	J	IM		03-Sep-05	
Fingers Creek	FC3	48	BP	ARGR	166	56.00	0.420	47.310	J	IM		03-Sep-05	
Fingers Creek	FC3	47	BP	ARGR	165	57.71	0.413	49.140	J	IM		03-Sep-05	
Fingers Creek	FC3	46	BP	ARGR	121	22.88	0.210	18.870	J	IM		03-Sep-05	

Table F.1. Raw Fish Capture Data (cont.)

Watercourse Name	Site ID	Specimen No.	Sample Method	Species	Length (mm)	Weight (g)	Liver Weight (g)	Carcass Weight (g)	Life Stage	Sex Mat	Gender	Date	Comment
Fingers Creek	FC3	45	BP	ARGR	115	18.33	0.215	14.29	J	IM		03-Sep-05	
Fingers Creek	FC3	44	BP	ARGR	110	12.66	0.152	8.51	J	IM		03-Sep-05	
Fingers Creek	FC3	43	BP	ARGR	97	10.7	0.152	8.12	J	IM		03-Sep-05	
Fingers Creek	FC3	42	BP	ARGR	99	12.61	0.178	9.44	J	IM		03-Sep-05	
Fingers Creek	FC3	41	BP	ARGR	169	64.77	0.504	54.24	J	IM		03-Sep-05	
Fingers Creek	FC3	40	BP	ARGR	161	54.08	0.509	45.03	J	IM		03-Sep-05	
Fingers Creek	FC3	39	BP	ARGR	110	15.07	0.139	11.65	J	IM		03-Sep-05	
Fingers Creek	FC3	38	BP	ARGR	116	18.28	0.153	14.57	J	IM		03-Sep-05	
Fingers Creek	FC3	37	BP	ARGR	117	16.25	0.143	12.27	J	IM		03-Sep-05	
Fingers Creek	FC3	36	BP	ARGR	106	16.43	0.129	12.56	J	IM		03-Sep-05	
Fingers Creek	FC3	35	BP	ARGR	106	14.43	0.12	11.33	J	IM		03-Sep-05	
Fingers Creek	FC3	34	BP	ARGR	111	17.48	0.182	13.23	J	IM		03-Sep-05	

Note: Length is fork length for ARGR, RNWH, LKTR, ARCH, BURB; Length is total length for NNST and SLSC

Codes:

Species:	ARGR	Arctic grayling	Sample Method:	BP	Backpack electrofishing	Life stage, maturity, gender:	A	Adult
	ARCH	Arctic char		FN	Fyke net		F	Female
	BURB	Burbot		GN	Gill net		IM	Immature
	LKTR	Lake trout		HN	Hoop net		J	Juvenile
	NNST	Ninespine stickleback		MB	Minnow trap, baited		M	Male
	RNWH	Round whitefish		OB	Observed		U	Unknown
	SLSC	Slimy sculpin					YOY	Young-of-year

Table F.2. Net and trap effort

Site	Method	Set	Set date	Set time	Pull date	Pull time	Effort (h)
D1AP	Gill Net	1	21-Aug-05	9:37	21-Aug-05	13:35	4.0
	Gill Net	2	27-Aug-05	8:20	27-Aug-05	15:35	7.3
	Gill Net	3	28-Aug-05	12:00	28-Aug-05	18:50	6.8
	Gill Net	5	28-Aug-05	12:10	28-Aug-05	19:00	6.8
	Gill Net	6	29-Aug-05	14:15	29-Aug-05	19:30	5.3
	Gill Net	7	01-Sep-05	19:40	02-Sep-05	14:30	18.8
	Gill Net	8	02-Sep-05	14:40	03-Sep-05	18:15	27.6
	Gill Net	9	03-Sep-05	18:30	04-Sep-05	14:30	20.0
D1AP	Baited Minnow Trap	1	02-Sep-05	19:00	04-Sep-05	14:10	43.2
	Baited Minnow Trap	2	02-Sep-05	19:02	04-Sep-05	14:12	43.2
	Baited Minnow Trap	3	02-Sep-05	19:04	04-Sep-05	14:14	43.2
	Baited Minnow Trap	4	02-Sep-05	19:06	04-Sep-05	14:16	43.2
	Baited Minnow Trap	5	02-Sep-05	19:08	04-Sep-05	14:18	43.2
FC1	Gill Net	1	26-Aug-05	10:30	26-Aug-05	14:30	4.0
FC2	Baited Minnow Trap	1	26-Aug-05	11:25	01-Sep-05	19:20	151.9
	Baited Minnow Trap	2	26-Aug-05	11:27	01-Sep-05	19:23	151.9
	Baited Minnow Trap	3	26-Aug-05	11:30	01-Sep-05	19:24	151.9
	Baited Minnow Trap	4	26-Aug-05	11:32	01-Sep-05	19:28	151.9
	Baited Minnow Trap	5	26-Aug-05	11:34	01-Sep-05	19:32	152.0
C1	Gill Net	1	25-Aug-05	10:30	25-Aug-05	14:00	3.5
FC3	Hoop Net	1	26-Aug-05	15:35	31-Aug-05	12:15	116.7
	Hoop Net	2	31-Aug-05	12:15	03-Sep-05	13:00	72.8
FC3	Baited Minnow Trap	1	04-Sep-05	18:00	05-Sep-05	8:30	14.5
	Baited Minnow Trap	2	04-Sep-05	18:00	05-Sep-05	8:34	14.6
	Baited Minnow Trap	3	04-Sep-05	18:00	05-Sep-05	8:36	14.6
	Baited Minnow Trap	4	04-Sep-05	18:00	05-Sep-05	8:40	14.7
SC1	Baited Minnow Trap	1	19-Aug-05	12:55	22-Aug-05	15:20	74.4
	Baited Minnow Trap	2	19-Aug-05	12:58	22-Aug-05	15:30	74.5
	Baited Minnow Trap	3	19-Aug-05	13:02	22-Aug-05	15:40	74.6
	Baited Minnow Trap	4	19-Aug-05	13:06	22-Aug-05	15:44	74.6
	Baited Minnow Trap	5	19-Aug-05	13:12	22-Aug-05	15:47	74.6
SC3	Fyke Net	1	21-Aug-05	15:50	25-Aug-05	10:45	90.9
SCP2	Gill Net	1	22-Aug-05	14:45	22-Aug-05	17:10	2.4

Table F.3. Backpack electrofishing effort

Site	Run	Date	Time	Effort (s)
FC3	1	27-Aug-05	11:30	222
	2	31-Aug-05	12:50	1747
	3	03-Sep-05	9:30	386
	4	03-Sep-05	12:30	2689
SC4	1	02-Sep-05	15:45	779
SC1	1	19-Aug-05	10:15	904
SC2	1	20-Aug-05	12:50	1252

Table F.4. Total number of fish liver tissues combined in fish tissue composite samples

Site	Sample Number	No. of Liver Tissues	Total Weight of Composite Sample (g)
Exposure	LUPO5UDIAPARGR001C	19	2.37
	LUPO5UDIAPARGR002C	17	2.08
Reference	LUPO5UF3ARGR001C	13	2.47
	LUPO5UF3ARGR002C	11	2.45
	LUPO5UF3ARGR003C	11	2.60

Table F.5. Arctic grayling ageing QA/QC results

Sample ID	Fork Length	Ageing Results	
		1st Read	2nd Read
FC3 - 27	123	1	1
FC3 - 33	171	2	2
FC3 - 36	106	1	1
FC3 - 46	121	1	1
FC3 - 48	166	2	2
FC3 - 54	92	1	1
FC3 - 58	158	2	2

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26 February 2007 **05-1373-019**

ENVIRONMENTAL PROTECTION OPERATIONS DIVISION

Prairie and Northern Region
Room 200, 4999 – 98 Avenue
Edmonton, Alberta T6B 2X3

ATTN: Shauna Sigurdson
Regional Director, Regional Authorization Officer

RE: ADDENDUM REPORT TO THE ENVIRONMENTAL EFFECTS MONITORING CYCLE 1 INTERPRETIVE REPORT FOR THE LUPIN MINE

Dear Ms. Sigurdson,

On 6 December 2006, Environment Canada's Technical Advisory Panel (TAP) provided review comments to the "Lupin Gold Mine Environmental Effects Monitoring Cycle 1 Interpretive Report". As requested by Environment Canada, responses to the comments are addressed in the present addendum report. TAP comments and questions are provided (*italics*) for each of the responses provided below.

General Comments

1. *Overall, this report is clear and well written. The information is nicely summarized in graphs, tables and text. The TAP also appreciates the QAQC information provided.*

The study was a collaborative effort among personnel from Golder Associates Ltd. (Golder) and Kinross Gold Corporation, Lupin Operations (Kinross). Golder and Kinross appreciate Environment Canada's expression of gratitude.

CANADA'S 50 BEST MANAGED PRIVATE COMPANIES

Site Characterization

2. *p. 2-18: it is noted that water quality data from 2000 and 2002 demonstrate that there is adequate mixing in Outer Sun Bay. Was any of the 2005 data considered in this evaluation? Based on Table 2.7, it appears that some of the water quality parameters have increased slightly at station 925-25 in Outer Sun Bay. Is this data still consistent with the dilution and dispersion model?*

The modelling was conducted in the fall of 2004, and would have only considered the 2000 and 2002 data (Golder 2004). The 2006 interpretive report only considered 2000 and 2002 data.

Dilution and dispersion modelling of the effluent into Outer Sun Bay was based on generalized flow and wind conditions, and assumptions about the geometry of the bay and narrows. For the month of July, regional hydrology indicated a combined discharge of approximately 11 m^3/s from Seep and Concession creeks. Combined with the effluent discharge, this would give effluent concentrations of 5.9 and 7.3% at the narrows under average and worst case conditions. Meteorological data indicated that the predominant July wind is from the east with a mean speed of 17 km/h and a 90^{th} percentile speed of 31 km/h. Using an assumption that current speed is 3% of wind speed (Dejiang Long, personal communication 2003, as cited in Golder 2003a), this would yield current speeds of 0.15 and 0.26 m/s in the bay for mean and worst case conditions.

When used as model parameters, these conditions produce an estimated effluent concentration, at Survey Network Point (SNP) 925-25, of approximately 1.6% for mean conditions and 2.1% with worst-case conditions. Stagnant wind conditions produced concentrations of 2.3 and 2.9% at SNP 925-25 for the mean and worst case discharges. Winds blowing into the bay would produce higher effluent concentrations, as wind induced lake currents would counteract the effluent plume velocity.

Based on available water quality data from 2005, it appears that concentrations higher than estimated by the model are present in Outer Sun Bay. The estimated effluent concentrations range from 0.0 % to greater than 100 % (Table 1). Dilution calculations are based on the mean of the samples, taken during the discharge period, for the Effluent and Outer Sun Bay. Consideration has been made for background concentrations of the constituents by subtracting the corresponding constituent level as sampled at Concession Creek (SNP 925-21

These data generally are consistent with the dilution model, except for the lead concentration, which appears to be anomalously high. Lower lead concentrations were observed at the Sun Bay Narrows (0.0005 mg/L; Table 2.6, Golder 2006). Runoff volumes in 2005 were lower than modelled, giving lower than expected effluent dilution, and consequently higher effluent concentrations. In 2005, mean effluent concentration in Sun Bay Narrows was 9.4 %. When the 2005 data are incorporated into the dispersion model, effluent concentrations accounted for approximately 2.0 to 5.4 % of the water in Outer Sun Bay (i.e., SNP 925-25). When the dry conditions of 2005 are taken into consideration and that the modelled 1% dispersion limits are up

to 1630 m beyond the SNP 925-25 sample site, the 2005 data are consistent with the dilution and dispersion model.

Table 1 Estimated effluent concentrations in Outer Sun Bay, 2005

Constituent	Units	Concentration (mean) at SNP 925-10 (effluent)	Concentration (mean) at SNP 925-25 (Outer Sun Bay)	Effluent Concentration (%)
Arsenic	mg/L	0.0097	0.0013	6.7
Conductivity	µS/cm	846	30	2.3
Copper	mg/L	0.016	0.001	0.0
Cyanide	mg/L	0.039	0.002	0.0
Lead	mg/L	0.0004	0.0006	141
Nickel	mg/L	0.0970	0.0026	2.2
Zinc	mg/L	0.257	0.011	3.5

Note: Means were calculated from data collected during the discharge period. SNP 925-10 *n=28* ; SNP 925-25 *n=4*.

Water Quality and Sediment Quality

3. *p. 4-10: Table 4-4 Conductivity measurements suggest that FC3 may be influenced by Contwoyto Lake. Please comment.*

A prominent sandbar divided Contwoyto Lake from Fingers Creek (FC3). Both ponded water and low velocities were observed at the downstream end of Fingers Creek, and water flow into Contwoyto Lake was limited to seepage through the sandbar. The elevated conductivity values observed at the downstream end of the creek was more likely a result of site-specific stream conditions rather than influence from Contwoyto Lake. Conductivity data were not collected from Contwoyto Lake at the time of the survey; however, past studies have generally reported conductivity values of less than or equal to 12 µS/cm (see data reports provided in Golder 2003b).

4. *p. 4-11: Table 4.5, it is noted that the Seep Creek Ponds composite sample had elevated lead concentration. None of the SNP samples from the exposure area demonstrated high lead concentrations. No explanation is given. Could this sample have been contaminated during mixing?*

To the best of our knowledge, the Seep Creek Ponds composite water sample was not contaminated during sampling. Standard water sampling techniques were used to fill the containers, and bottles were securely sealed for transport. Every effort was taken to prevent contamination.

5. *p. 4-11: In section 4.2.1.3., it is not clear whether the holding time for pH was exceeded for all of the samples or only the field and trip blanks.*

The recommended maximum holding time for samples undergoing pH analysis is 48 hours. Because of challenges associated with the remote field location and limitations on

shipping availability, the holding time was exceeded for all of the water samples shipped to the analytical laboratory. Field measurements for pH were also collected at most water quality sites to supplement the laboratory results.

6. *p. 4-12: Would the higher percentage of silt (greater surface area) in the reference sediments vs. the exposure sediments influence metal concentrations?*

The data indicate that silt composition and metal concentrations were higher in the exposure sediments compared to the reference sediments. In the response below, it is assumed that the TAP inadvertently reversed the sites and corresponding results in the question posed.

The higher percentage of silt in the exposure site could influence metal concentrations. In an aqueous environment, metals tend to sequester in the sediment layer. Smaller particles provide higher surface area, and thus a greater concentration of metals can bind to the sediment. Several articles in the primary literature have reported a positive relationship between metal concentrations and the proportion of fine particles in sediments (e.g., Moore et al. 1989; Axtmann and Luoma 1991; Filion and Morin 2000).

7. *p. 4-12: Is the difference in TOC statistically significant among areas?*

A single factor ANOVA (SPSS 2002) was used to determine if there was a difference in the amount of TOC between samples collected in the reference and exposure areas. Prior to conducting the ANOVA, data were arc-sine square-root transformed to normalize differences (Sokal and Rohlf 1995).

SPSS (2002) evaluates data for outliers. During the ANOVA computations, an outlier was detected. Based on Environment Canada's (2002) recommendation of using α=0.01, results indicated that mean TOC concentrations were significantly different for the entire dataset (P=0.058) and when the outlier was removed (P=0.086).

8. *p. 4-12: Please note that descriptive summary statistics are required for TOC and PSA (Schedule 5, section 16 of the Metal Mining Effluent Regulations) Mean and standard deviation are presented in Appendix D but median, standard error, minimum and maximum values are not presented.*

Summary statistics for sediment TOC and particle size are provided below (Table 2). Such data will be included in subsequent reports.

Table 2 Summary of sediment characteristics

Endpoints	Seep Creek Ponds 1 & 2 (Exposure)					
	Mean	Median	SD	SE	Min	Max
Total Organic Carbon (TOC %)	1.6	0.5	1.8	0.8	0.4	4.3
Particle Size Analysis (PSA)						
Clay (%)	2.8	1.8	2.1	1.0	0.8	5.5
Silt (%)	44.1	48.6	28.0	12.5	9.7	78.6
Fine Sand (%)	28.8	29.6	22.6	10.1	4.6	52.4
Coarse Sand (%)	24.3	24.1	16.3	7.31	7.6	42.2
Gravel (%)	0	0	0	0	0	0

Endpoints	Fingers Lake (Reference)					
	Mean	Median	SD	SE	Min	Max
Total Organic Carbon (TOC %)	0.2	0.2	0.13	0.058	<0.1	0.4
Particle Size Analysis (PSA)						
Clay (%)	0.7	0.9	0.44	0.20	0	1
Silt (%)	3.7	4.0	2.8	1.3	0.7	6.7
Fine Sand (%)	41.1	43.7	5.10	2.28	34.4	45.4
Coarse Sand (%)	54.6	53.7	5.45	2.44	49.2	62.1
Gravel (%)	0	0	0	0	0	0

Benthic Invertebrate Community Survey

9. *The facility should be commended for identifying invertebrates down to the lowest practical level and including the raw data at both the 500 and 250 µm size fractions.*

TAP comments will be passed on to the analytical laboratory. Thank you.

10. *Benthic density at FL3 is quite high and appears to be driven by Orthocladiinae (Table E1). The TAP recommends that the location of that site be discussed before the next biological field program.*

Golder and Kinross are open to discussion and will consider recommendations the TAP would like to provide.

11. *p. 4-9: Were any in situ measurements taken at the Fingers Lake benthic invertebrate sites? EC staff who visited this site during the field program noted that some Oakton pens were available as backup to the Oakton meter. Was station depth recorded?*

The only *in situ* measurement taken at Fingers Lake was a turbidity reading (0.67 NTU), which was measured from the composite water sample.

Depths measured at the time of sediment core collection can also be used for benthic samples. Benthic samples were collected at the same stations as the sediment cores. Multiple Ekman grabs were required for each benthic invertebrate sample. The boat was anchored at the designated waypoint, and multiple samples were collected from various locations around the boat. Since, depths around the boat had limited variability, the depths provided for sediment core collected are representative of the depths for benthic sampling. These depths were as follows: FL1=1.0 m; FL2=0.80 m; FL3=0.80 m; FL4=0.8 m; and, FL5=1.3 m.

Fish Survey

12. *The TAP appreciates the clear presentation of data and the effective use of graphs and tables.*

Comment noted. Thank you.

13. *As per the TAP request (email from P. Siwik, June 8, 2005), please analyse the archived fish liver for copper. If data on other elements are included in the analytical suite, please present that data as well.*

Copper analyses for fish liver tissues are provided below (Table 3). Due to small sample sizes, statistical analysis of the copper data were not carried out as suggested by Environment Canada (2002); however, the copper concentration is 72% higher in the exposure livers than in reference livers. Results of the complete metal scan are attached.

Table 3 Total copper in composite liver samples

Location	Sample Identifier	No. of Livers	Sample Weight (g)	Moisture (%)	Total Copper (µg/g)[a]
Exposure	LUPO5UDIAPARGR001C	19	2.37	78.1	29.2
	LUPO5UDIAPARGR002C	17	2.08	81.9	29.2
Reference	LUPO5UF3ARGR001C	13	2.47	79.8	8.16
	LUPO5UF3ARGR002C	11	2.45	81.2	8.27
	LUPO5UF3ARGR003C	11	2.60	83.3	8.01

[a] Dry weight.

14. *p. 6-8: While fish were aged, no statistical analysis of age or age frequency distribution was presented.*

A length frequency histogram for all captured Arctic grayling was created to assess age classes (Figure 1). Fish scales were used to age a subset of fish to verify the results of the length frequency distribution. The three data groups in Figure 1 corresponded to three age classes - YOY, age 1, and age 2.

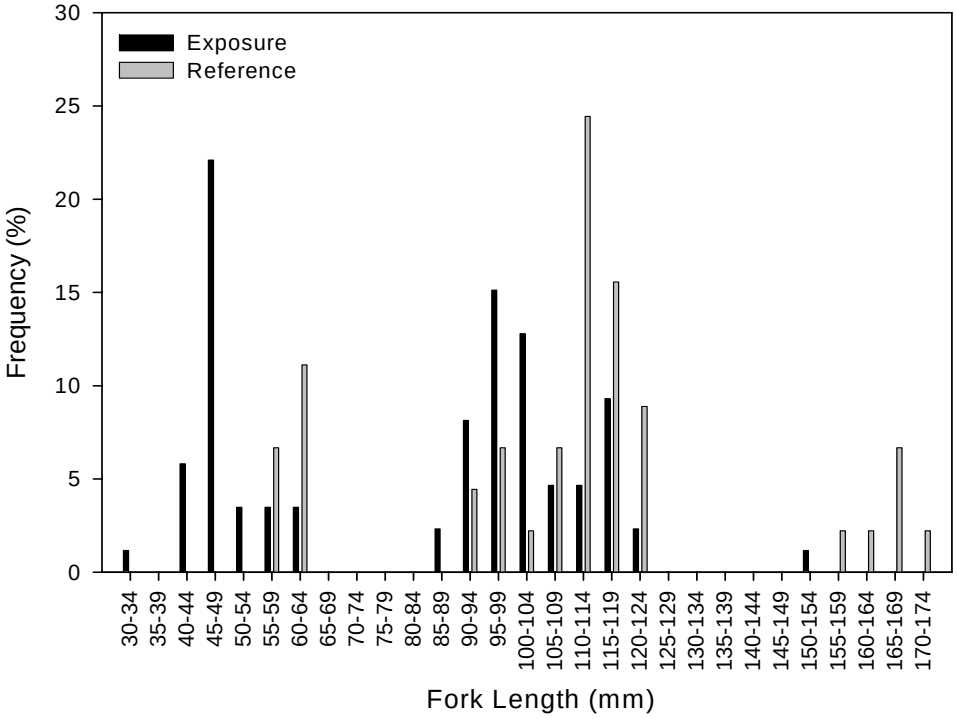

Figure 1 Length frequency distribution of Arctic Grayling

15. *A review of Appendix F indicates that there were not many YOY's caught in either Fingers or Seep Creek. Please confirm whether this is the reason why no separate analysis was done of the YOY data.*

A separate analysis was not conducted on the young of the year (YOY) Arctic grayling due to the limited number of YOY captured during the study. In total, 33 YOY were captured in Seep Creek (exposure) and eight YOY were captured in Fingers Creek (reference). For the same reason, data analyses also did not include age 2 fish. One age 2 fish was captured in the exposure area and six were captured in the reference area.

16. *Please include a summary of biological parameters for the YOY and age 2 fish collected in this survey.*

Data for YOY and age 2 Arctic grayling are provided below (Tables 4 and 5).

Table 4 Summary data for Arctic grayling YOY

Location	Variable	*n*	Median	Mean	SD	SE	Minimum	Maximum
Exposure	Fork length (mm)	34	48	49	6.1	1.0	32	64
	Total weight (g)	29	<2	<2	-	-	<2	2.2
Reference	Fork length (mm)	8	61	60	3.0	1.1	56	64

Table 5 Summary data for age 2 Arctic grayling

Location	Variable	*n*	Median	Mean	SD	SE	Minimum	Maximum
Exposure	Fork length (mm)	1	-	152	-	-	-	-
	Total weight (g)	1	-	18.9	-	-	-	-
	Carcass weight (g)	1	-	13.4	-	-	-	-
	Liver weight (g)	1	-	0.2	-	-	-	-
Reference	Fork length (mm)	6	166	165	4.86	1.98	158	171
	Total weight (g)	6	56.9	58.0	7.57	3.10	47.0	68.0
	Carcass weight (g)	6	48.2	48.9	6.98	2.85	38.8	58.7
	Liver weight (g)	6	0.5	0.5	0.05	0.02	0.4	0.5

17. *p. 6-12: While it may be generally true that electrofishing tends to select for larger individuals than gill nets, the raw data in this particular study does not support this statement. Based on a quick overview of the data from Seep Creek (no grayling were caught by a gill net in the reference area), it appears that the gill-netted grayling tended to be larger than those caught by electrofishing. This suggests that the difference between the exposure and reference areas might not have been significantly influenced by gear selectivity.*

It is agreed that the difference in Arctic grayling size between the exposure and reference areas is not likely to have been significantly influenced by gear selectivity. Gear selectivity was presented as a general acknowledgement that the use of different gear at different sample locations could influence sample results. However, it should also have been noted that the difference in gear selection was related to the difference in habitat type, which may influence sampling results. Backpack electrofishing was conducted in the exposure and reference creeks, and gill nets were set in the exposure ponds and the reference lake.

18. *p. 6-14: In Table 6.6, for all parameters, the direction of difference is listed as reference less than exposure, rather than exposure less than reference.*

Comment noted.

Sublethal Toxicity Testing

19. *p. 7-2: Please comment on the possible difference in chemical composition between July and August effluent.*

Kinross staff monitors effluent daily during the discharge period for pH, conductivity, temperature, total suspended solids, arsenic, cyanide, copper, and zinc. On 11 August 2005, effluent pH dropped below 6.0 (threshold for water licence) and discharge of mine effluent was terminated for the remainder of the year. The August sample that was submitted for sublethal toxicity testing was collected from tailings Pond 2 on 30 August. Kinross ceased ore processing in February 2005, and wastewater from mine clean-up activities in summer 2005 was held in a containment cell; therefore, there is no obvious explanation for the change in effluent water quality within tailings Pond 2.

Recommendations for Subsequent Biological Monitoring

20. *p. 9-1: TAP supports the recommendations made in this section and also suggests that a second fish reference site containing ninespine stickleback be considered in future studies.*

Golder and Kinross would be pleased to consider recommendations put forth by the TAP.

21. *During the next phase of biological monitoring, please confirm the estimate of effluent concentration at 250 m if possible.*

Effort will be made to meet this request during subsequent biological monitoring programs.

Minor Comments

22. *The MMGD state that field water quality measurements should be taken concurrently with the BIC and sediment sampling. It is understood that field water quality measurements could not be acquired in the reference area due to equipment malfunction, but there is no explanation given for the variation in dates between the BIC/sediment sampling and the field water quality measurements in the exposure area.*

The site names Seep Creek Pond 1 and Seep Creek Pond 2 and sampling stations were mislabelled for the water quality field measurements presented in Table 4.4 of the Environmental Effects Monitoring (EEM) interpretive report for the Lupin Mine. A revised Table is provided below (Table 6).

Table 6 Field-measured water quality variables (revised Table 4.4 of EEM report)

Survey	Location	Sampling Station	Date	Temperature (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Turbidity (NTU)
Fish Population	**Exposure**	Seep Creek Dam 1a Lake (SCD1)	29-Aug-05	4.7	12.3	5.3	740	0.9
		Seep Creek 1 (SC1)	19-Aug-05	11	n/a	5.6	126	n/a[a]
		Seep Creek 1 (SC1)	22-Aug-05	10.8	n/a	n/a	n/a	0.6
		Seep Creek 2 (SC2)	20-Aug-05	n/a	n/a	n/a	n/a	n/a
		Seep Creek 3 (SC3)	25-Aug-05	9.8	11	5.6	130	0.56
		Seep Creek 4 (SC4)	02-Sep-05	8.4	11.4	5.3	120	n/a
	Reference	Fingers Creek (FC3)	03-Sep-05	7.7	10.6	5.3	120	n/a
		Fingers Creek (FC2)	27-Aug-05	13.4	10.3	5.7	10	n/a
		Fingers Creek (FC1)[b]	05-Sep-05	8.1	10.6	5.9	10	0.54
Benthic Invertebrate Community	**Exposure**	Seep Creek Pond 1 (SCP3)	24-Aug-05	12	n/a	5.8	200	0.91
		Seep Creek Pond 1(SCP5)	05-Sep-05	13.6	11.7	5.7	130	n/a
		Seep Creek Pond 2 (~30m from SCP1)	22-Aug-05	10.8	n/a	5.9	110	n/a
		Seep Creek Pond 2 (SCP1)	24-Aug-05	n/a	n/a	n/a	n/a	1.46
		Seep Creek Pond 2 (SCP1)	06-Sep-05	12.1	11.2	5.9	90	n/a
		Seep Creek Ponds composite	05-Sep-05	n/a	n/a	n/a	n/a	2.36
	Reference	Fingers Lake composite[c]	05-Sep-05	n/a	n/a	n/a	n/a	0.67

[a] n/a = not available.
[b] Data for this station used as surrogate for Fingers Lake sampling stations.
[c] Composite sample from five sampling stations.

For Pond 1, water quality readings were collected on 24 August and 5 September. Benthic sampling occurred on 24 August, and sediment was collected on 5 September. For Pond 2, water quality readings were collected on 22 August and 6 September. Water quality was sampled on 22 August during the reconnaissance survey. Benthos was sampled on 24 August, and sediment was collected on 6 September. Water quality readings were not collected on 24 August. Water quality readings were collected at one location on each day, with the understanding that water quality reading could be generalized for the entire pond because the waterbody was shallow and well mixed. In the future, water quality readings will coincide with the date and sampling locations for each benthic and sediment sample.

23. *The term Cycle is not used in the Metal Mining EEM program as it is in the Pulp and Paper program. In the future, please include the year the study was done and the phase (e.g. confirmation phase, magnitude and extent phase etc) in the title of the report.*

Comment noted. In the future, Lupin Mine EEM reports will include year and phase in the report title.

CLOSURE

We trust that the above material meets your present requirements. If you have any questions or concerns, please feel free to contact Mark Dunnigan (780-930-8657) or Gary Ash (780-930-8666).

Sincerely,

GOLDER ASSOCIATES LTD.

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Encl.

LITERATURE CITED

Axtmann, E.V. and S.N. Luoma. 1991. Large-scale distribution of metal contamination in the fine-grained sediments of the Clark Fork River, Montana, U.S.A. Applied Geochemistry 6: 75-88.

Environment Canada. 2002. Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. EEM/2002. June 2002.

Filion, A. and A. Morin. 2000. Effect of local sources on metal concentrations in littoral sediments and aquatic macroinvertebrates of the St. Lawrence River, near Cornwall, Ontario. Canadian Journal of Fisheries and Aquatic Science 57: 113-125.

Golder Associates Ltd. (Golder). 2003a. Environmental effects monitoring site characterization and study design. Prepared for Miramar Con Mine Ltd. by Golder Associates Ltd., Yellowknife, NT. Golder Report No. 03-1328-006: 83 p. + 3 app.

Golder Associates Ltd. 2003b. Lupin Gold Mine environmental effects monitoring program historical information report. Prepared for Kinross Gold Corporation, Edmonton, Alberta. Golder Report No. 03-1370-049: 39 p. + 18 app.

Golder Associates Ltd. 2004. Lupin Gold Mine environmental effects monitoring study design. Prepared for Kinross Gold Corporation, Edmonton, Alberta. Golder Report No. 04-1373-046: 76 p. + 4 app.

Golder Associates Ltd. 2006. Lupin Gold Mine: environmental effects monitoring – cycle 1 interpretive report. Prepared for Kinross Gold Corporation, Edmonton, AB. Golder Report No. 05-1373-019: 85 p. + 6 app.

Moore, J.N., E.J. Brook, and C. Johns. 1989. Grain size partitioning of metals in contaminated, coarse-grained river floodplain sediment: Clark Fork River, Montana, U.S.A. Environmental Geology 14: 107-115.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research. 3rd edition. W.H. Freeman and Co., New York. 887 p.

SPSS (Statistical Package for the Social Sciences). 2002. SYSTAT 10.2 SPSS Inc., Chicago, Illinois.

Total metal concentrations in composite liver samples collected from the Lupin Mine EEM study area, 2005

Parameters	MRV[a]	MDL[a]	Exposure Area		Reference Area		
			LUP05UDIAP ARGR001C	LUP05UDIAP ARCR002C	LUP05UF3 ARGR001C	LUP05UF4 ARGR002C	LUP05UF5 ARGR003C
Number of Livers			19	17	13	11	11
Sample Weight (g)			2.37	2.08	2.47	2.45	2.6
Moisture (%)	0.01	0.01	78.1	81.9	79.8	81.2	83.3
Total Metals (µg/g)[b]							
Aluminum	0.0521	0.781	8.67	8.05	3.26	1.63	2.28
Antimony	0.0003	0.0003	0.0054	0.0029	0.0031	0.0018	0.0016
Arsenic	0.0013	0.0104	1.63	1.86	0.29	0.319	0.345
Barium	0.0026	0.026	0.359	0.387	0.405	0.488	0.398
Beryllium	0.0013	0.0026	0.0013	0.0025	0.0013	0.0013	0.0012
Bismuth	0.0002	0.0026	0.0034	0.0054	0.0102	0.0046	0.0062
Boron	0.013	0.208	0.645	1.26	1.02	0.393	0.456
Cadmium	0.00052	0.00156	0.349	0.297	0.0546	0.0628	0.0695
Calcium	1.04	13	588	753	1065	1090	1014
Chlorine	26	78.1	2592	518	2476	20403	28234
Chromium	0.013	0.078	2.19	3.84	0.39	0.378	0.516
Cobalt	0.0005	0.0026	1.96	2.11	1.12	1.23	1.26
Copper	0.013	0.026	29.2	29.2	8.16	8.27	8.01
Iron	5.21	10.4	380	366	290	309	309
Lead	0.00026	0.0026	0.495	0.335	0.0204	0.0115	0.0097
Lithium	0.0052	0.0521	0.0111	0.0241	0.014	0.0138	0.0167
Magnesium	0	0.1	820	863	844	838	883
Manganese	0.001	0.008	8.9	9.91	8.49	8.09	8.23
Mercury	0.0026	0.013	0.359	0.326	0.983	1.05	0.613
Molybdenum	0.00026	0.00208	0.51	0.488	0.369	0.363	0.408
Nickel	0.0013	0.0156	0.414	0.546	1.22	0.345	0.165
Phosphorus	2.6	13	16398	15823	12571	12998	13320
Potassium	2.6	13	12780	11311	12391	13458	14382
Selenium	0.026	0.052	3.8	3.6	3.46	3.55	3.86
Silicon	13	130	85	607	390	136	67
Silver	0.00016	0.0013	0.0869	0.0573	0.0199	0.0171	0.0166
Sodium	2.6	15.6	3123	2973	3592	3984	3933
Strontium	0.001	0.0021	1.06	1.25	2.43	2.6	2.22
Sulfur	26	130	13821	12134	13571	13943	13610
Thallium	0.00016	0.00078	0.163	0.142	0.0539	0.0488	0.0541
Thorium	0.00021	0.0078	0.0062	0.0106	0.0167	0.0042	0.003
Tin	0.013	0.0182	0.0259	0.0372	0.129	0.0715	0.0258
Titanium	0.01	0.018	46.3	45.4	41	37.8	37.6
Uranium	0.0002	0.0008	0.0012	0.0015	0.0005	0.0005	0.0004
Vanadium	0.0013	0.013	0.0781	0.0747	0.05	0.102	0.15
Zinc	0.01	0.05	110	109	96.5	95.3	94.8

[a] MRL= minimum reporting level; MDL=methodological detection limit.
[b] Dry weight.