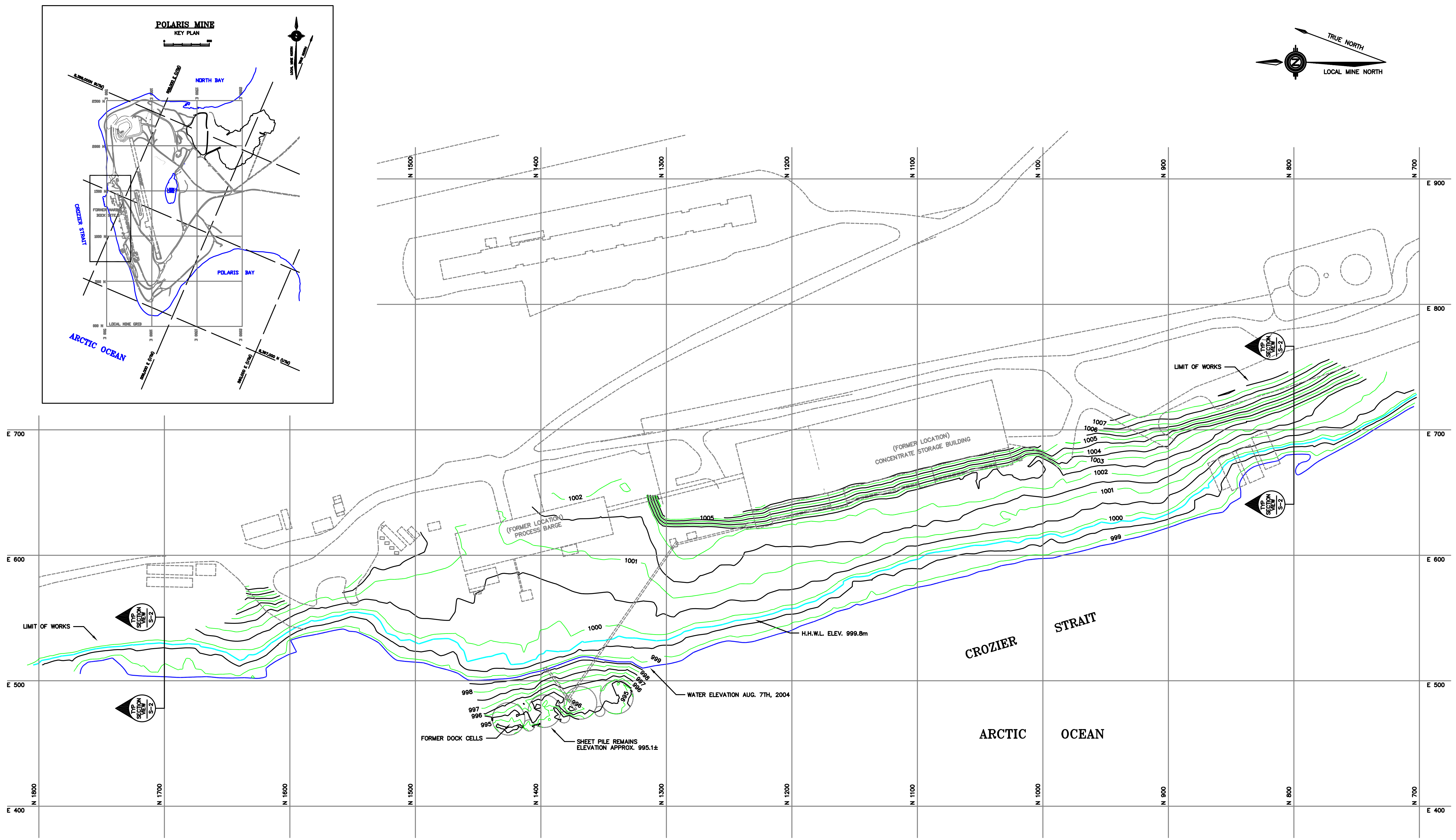
APPENDIX 4

PROJECT AS-BUILT DRAWINGS



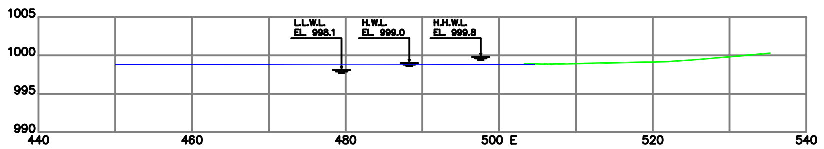
NOTES:
1. DATA COLLECTED AUGUST, 2004 BY TECK COMINCO REPRESENTATIVE.
2. SECTION CO-ORDINATES AND ELEVATIONS REFER TO LOCAL MINE DATUM.
3. CONTOUR INTERVAL = 0.5m.
4. FORMER ROADS AND STRUCTURES SHOWN FOR ORIENTATION ONLY.

LEGEND:
- FORMER LOCATION OF ROADS OR STRUCTURES
- WATER ELEVATION AUG. 7TH, 2004
- H.H.W.L. ELEV. 999.8m
- LIMIT OF WORKS

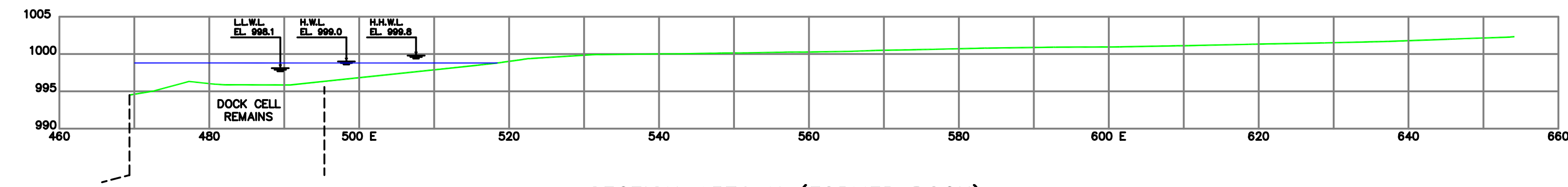
PROJECT:
POLARIS MINE CLOSURE
DECOMMISSIONING OF DOCK

DRAWING:
ASBUILT DRAWING
PLAN VIEW

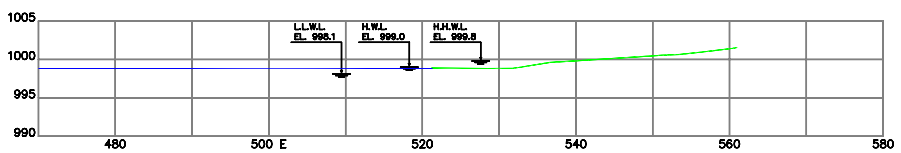
DRAWN BY: T. M. TECH SERVICES 6-355-2	CLIENT: teckcominco
DATE: DEC, 2005	SCALE: 1:1500 METRIC
FIGURE No.: PM 2005 DOCK	SHEET: 1 OF 2



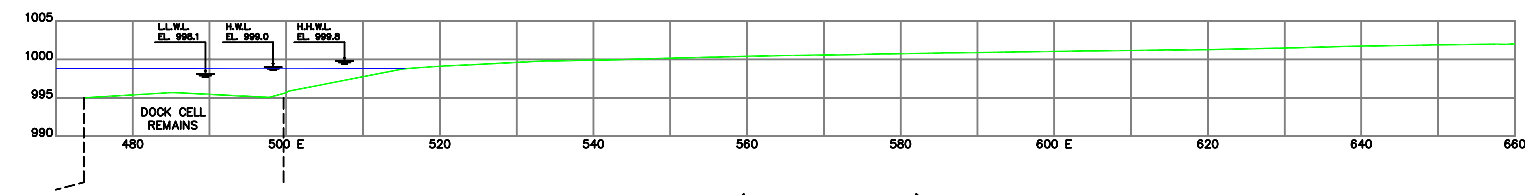
SECTION 1700 N



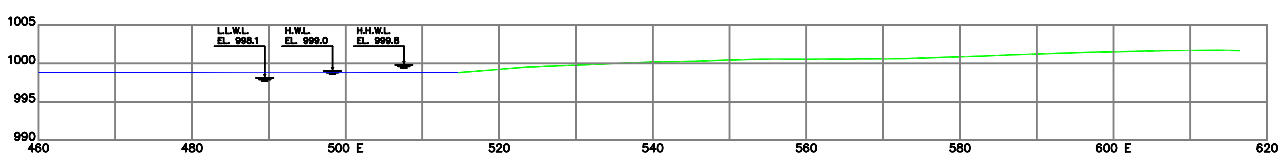
SECTION 1370 N (FORMER DOCK)



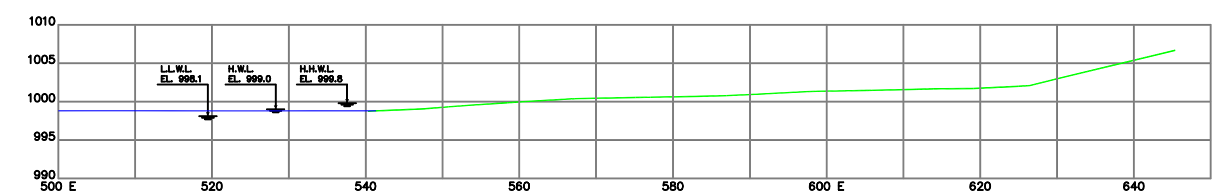
SECTION 1600 N



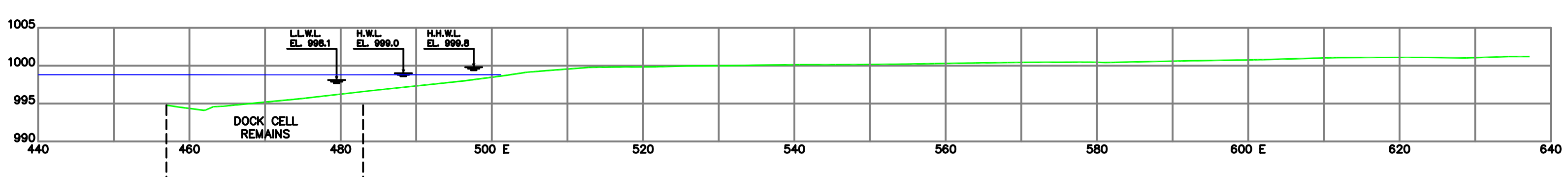
SECTION 1340 N (FORMER DOCK)



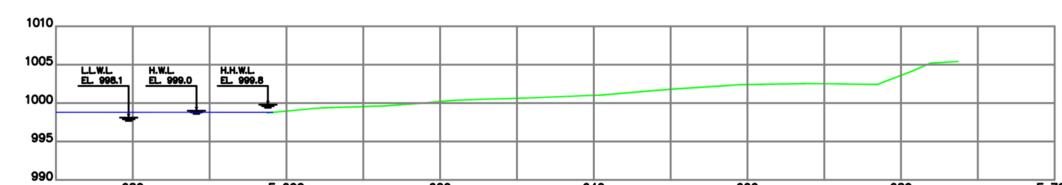
SECTION 1500 N



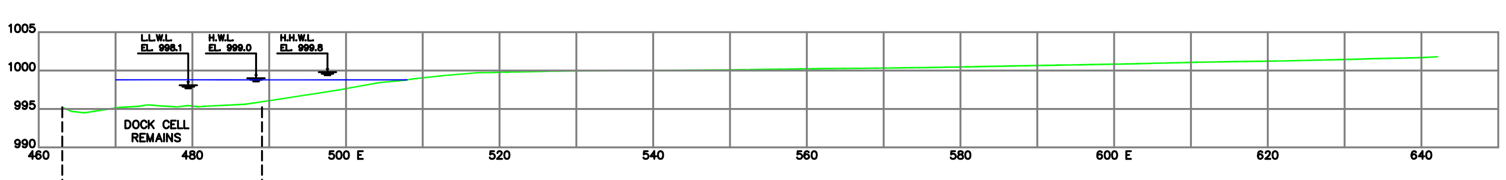
SECTION 1200 N



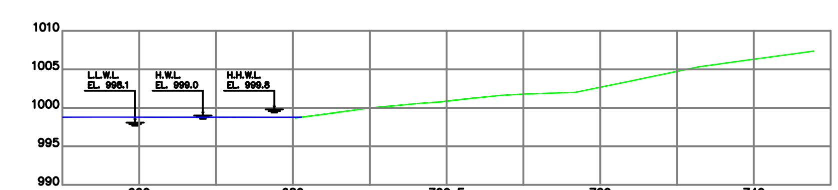
SECTION 1425 N (FORMER DOCK)



SECTION 1000 N



SECTION 1400 N (FORMER DOCK)



SECTION 800 N

NOTES:
1. DATA COLLECTED AUGUST, 2004 BY TECK COMINCO REPRESENTATIVE.
2. SECTION CO-ORDINATES AND ELEVATIONS REFER TO LOCAL MINE DATUM.

LEGEND:
WATER ELEVATION AUG. 7TH, 2004
RESLOPED SURFACE

PROJECT:
POLARIS MINE CLOSURE
DECOMMISSIONING OF DOCK

DRAWING:
ASBUILT DRAWING
SECTION VIEWS

DRAWN BY:
T. M. TECH SERVICES
6-355-2

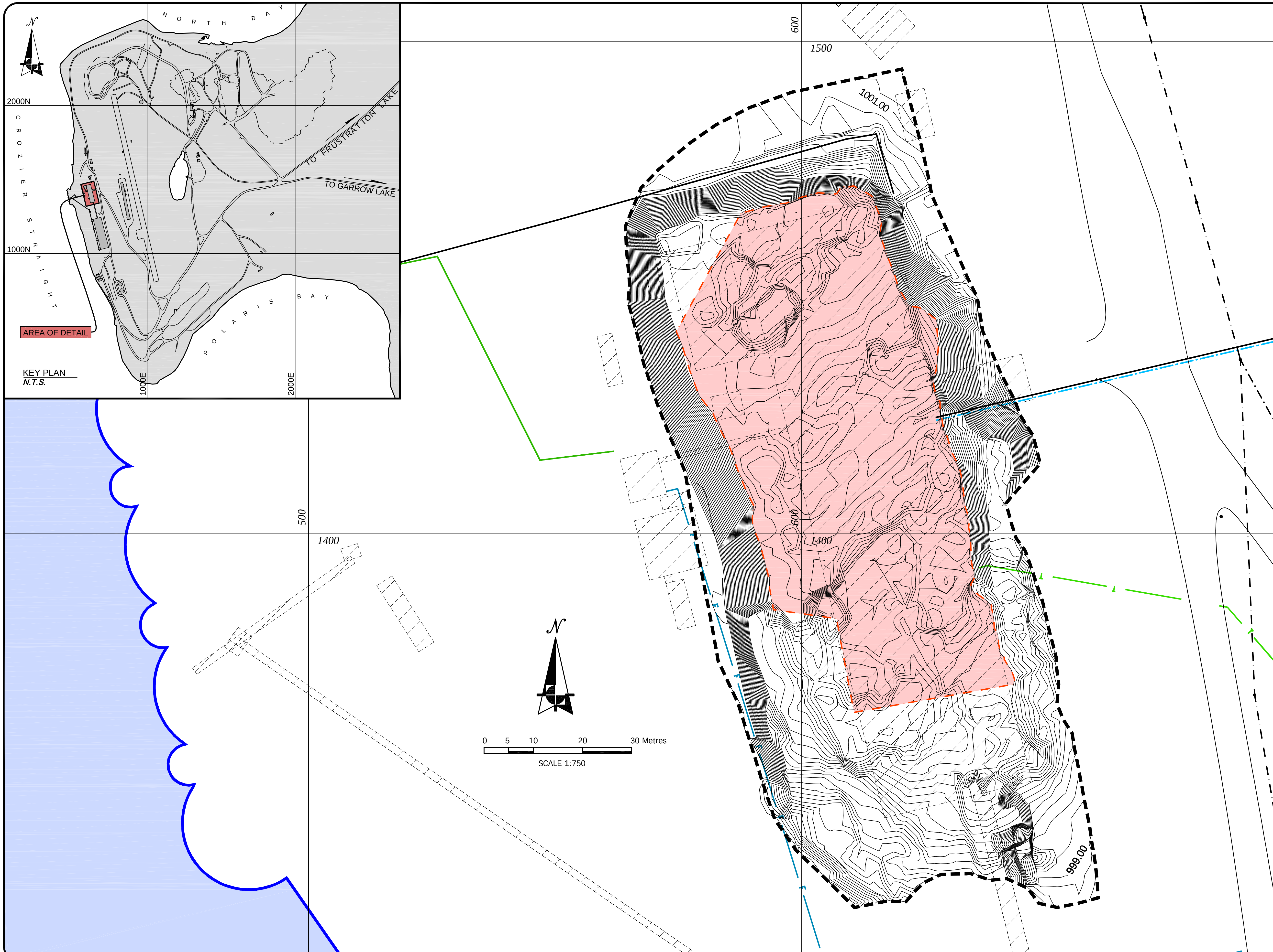
CLIENT:
teckcominco

DATE:
DEC, 2005

SCALE:
1:500 METRIC

FIGURE No.
PM 2005 DOCK

SHEET:
2 of 2



LEGEND:

- 2003 LIMIT OF BARGE EXCAVATION
- EXCAVATED BARGE CONTOURS (0.2m)
- BETWEEN OCT. 12/03 & OCT. 31/03, 6,300 sq. m. OF GARROW DAM CORE MATERIAL PLACED AT THE BASE OF EXCAVATION. 31,500 sq. m. OF CLEAN SAND & GRAVEL ALSO PLACED IN THIS AREA BETWEEN OCT. 12/03 & OCT 31/03. A FURTHER 25,200 sq. m. OF CLEAN SAND & GRAVEL USED TO BACKFILL THE EXCAVATION AFTER OCT. 31/03
- FORMER LOCATION OF BUILDING
- SHORE LINE
- ROADS
- TAILINGS LINE
- FUEL LINE
- GROUND WIRE
- SEWER LINE
- WATER LINE
- OVERHEAD POWER LINE
- POWER POLE

DRAWING INFORMATION:

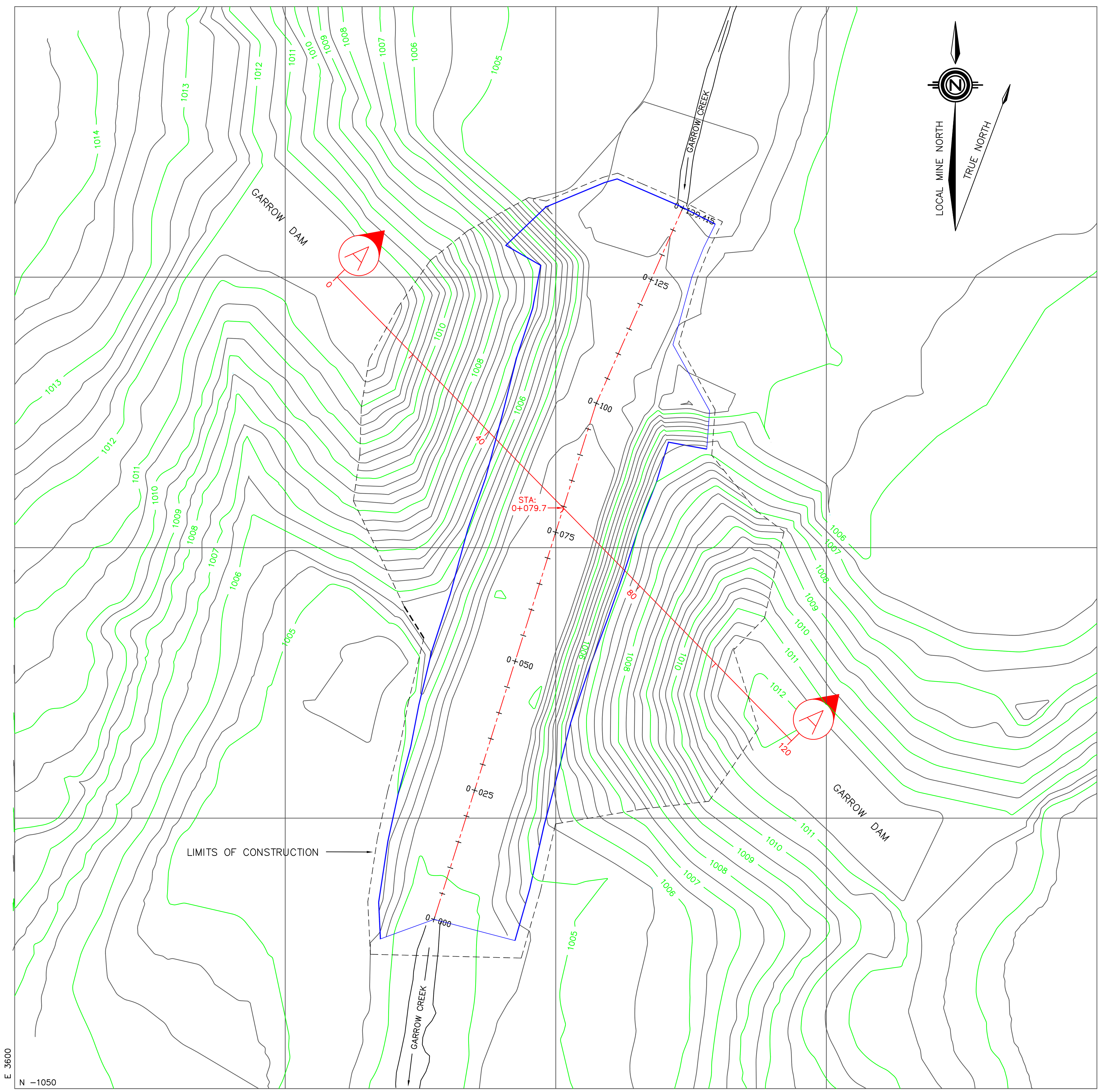
REVIEWED BY:	AL
DRAWN BY:	CHARONE
DATE ISSUED:	ISSUED – MAY 25, 2005
PROJECT NUMBER:	40–137
FILE NAME:	40137–BARGE–2003 BACKFILL.DWG
REVISION:	0

POLARIS MINE
CONTAMINATED SITE REMEDIATION
LITTLE CORNWALLIS ISLAND, NUNAVUT

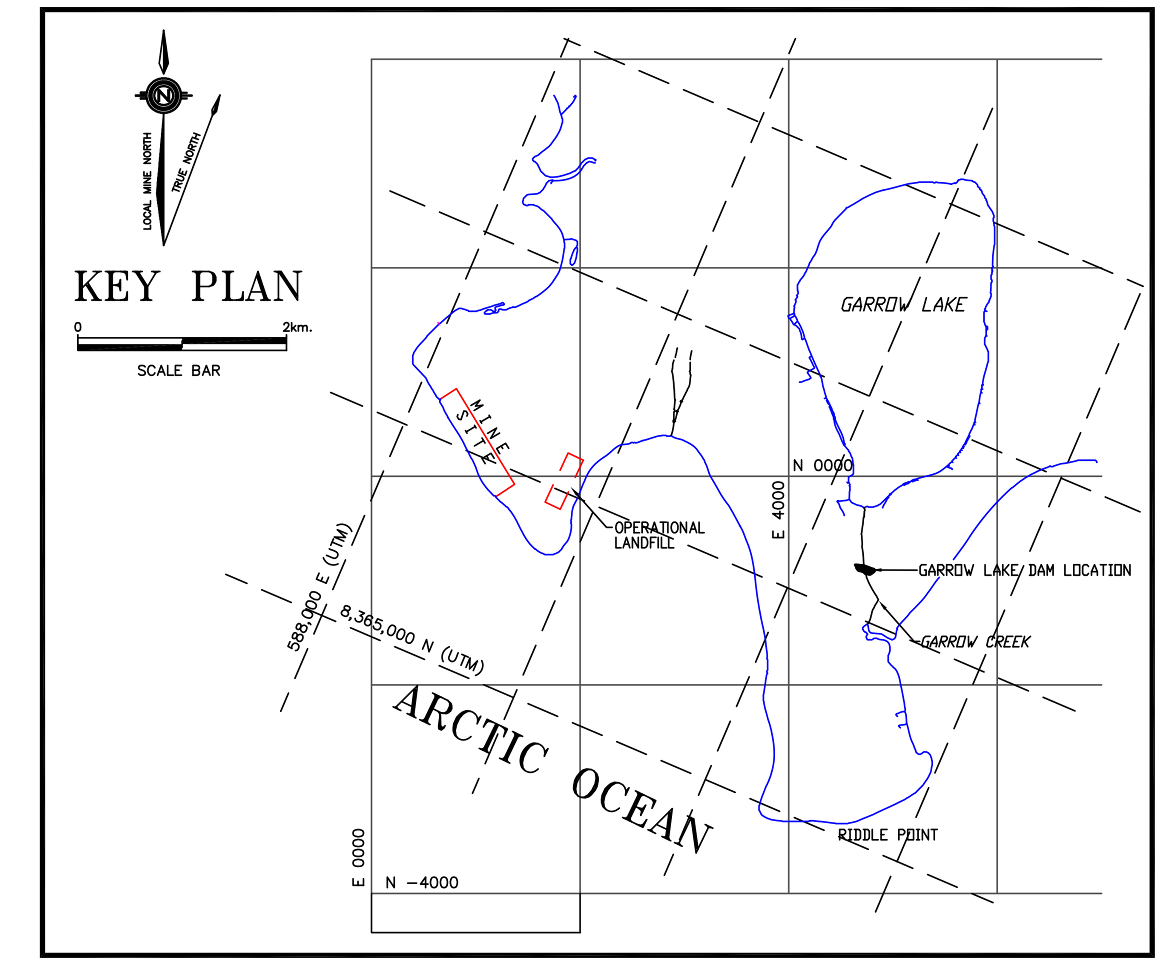
2003 BARGE BACKFILL - FINAL DISPOSAL LOCATION OF GARROW DAM CORE MATERIAL

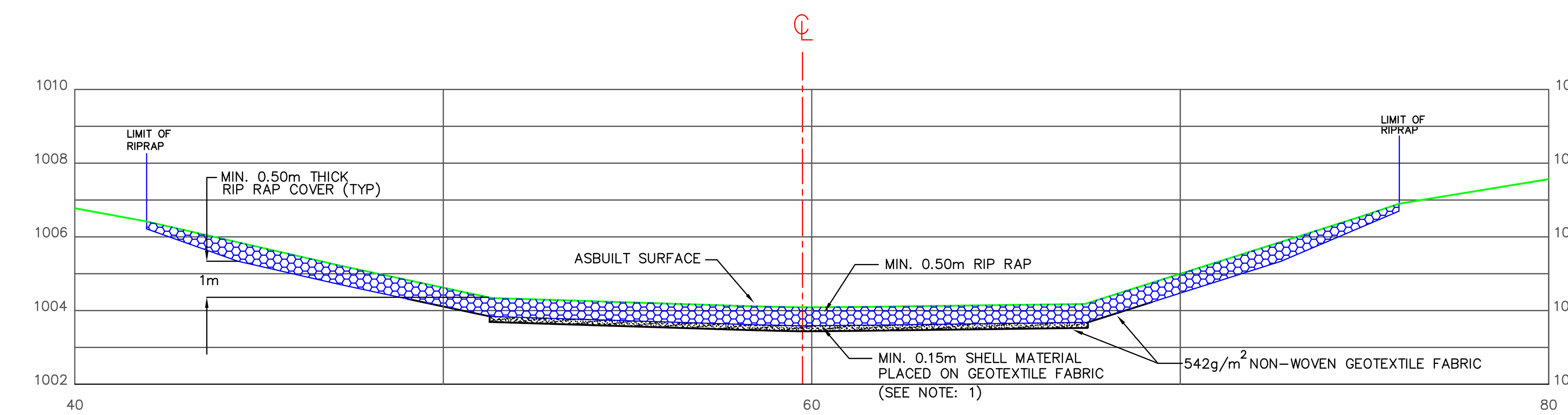
Gartner Lee

Figure No.
40137-BARGE-1



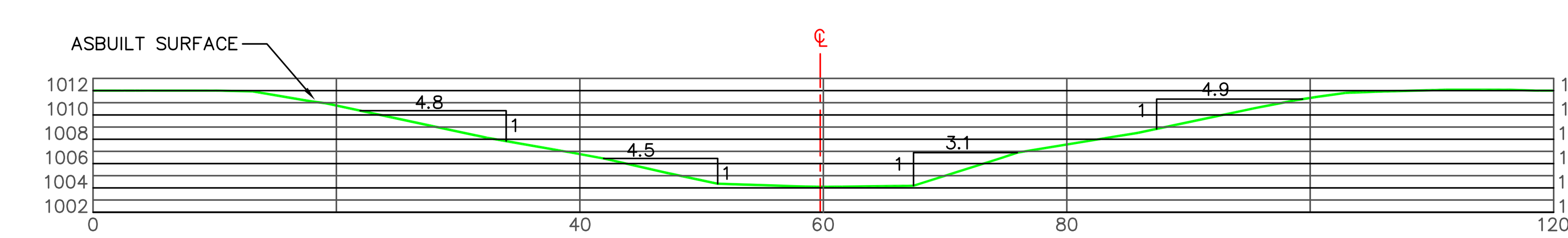
SCALE 1:500





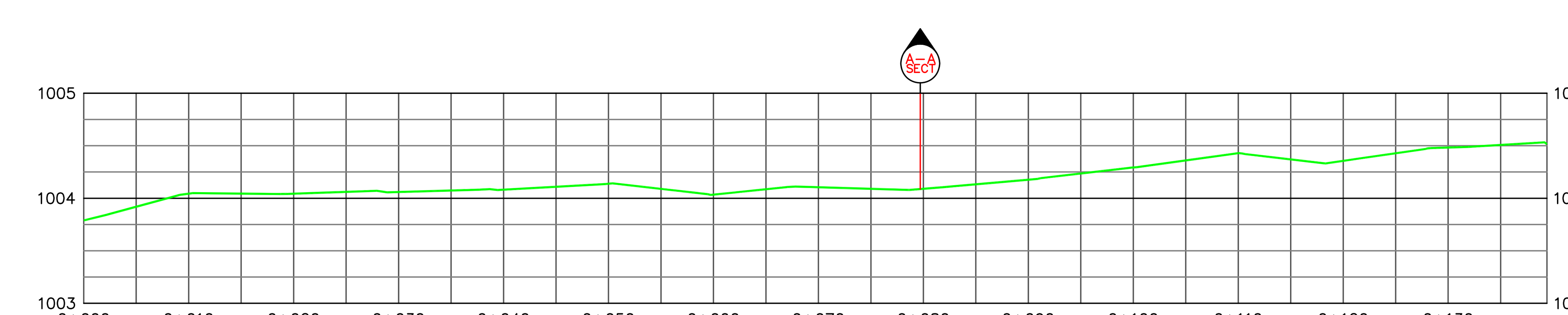
ASBUILT CHANNEL DETAILS (SECTION A–A)

SCALE 1:125



ASBUILT SECTION A–A

SCALE 1:500



ASBUILT ℄ CHANNEL PROFILE

SCALE ~ HORZ. 1:500
VERT. 1:50

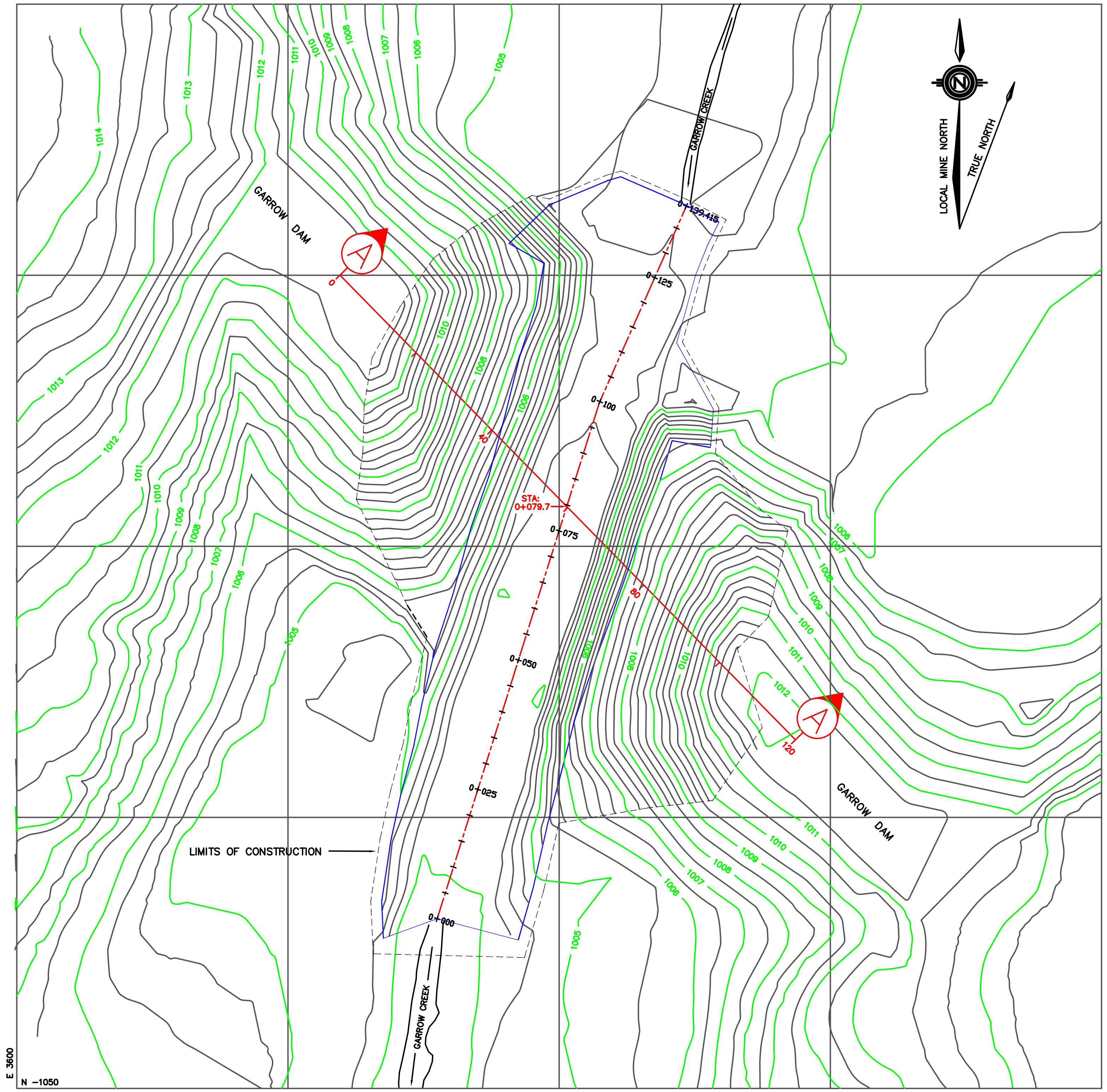
NOTES:
1. CHANNEL EXCAVATION DEPTH TO 0.15m BELOW ORIGINAL GROUND AND EXISTING SHELL MATERIAL. AND TO BASE OF DAM KEY TRENCH UNDER FROZEN CORE AND SATURATED SHELL MATERIAL.
2. DATA COLLECTED JUNE 18, 2004 BY TECK COMINCO REPRESENTATIVE.
3. ELEVATIONS REFER TO LOCAL MINE DATUM.
4. CONTOUR INTERVALS = 0.25m. WITHIN CONSTUCTION LIMITS
0.50m. OUTSIDE CONSTUCTION LIMITS

LEGEND:
- - - - LIMITS OF CONSTRUCTION
—— LIMITS OF CHANNEL IMPROVEMENTS

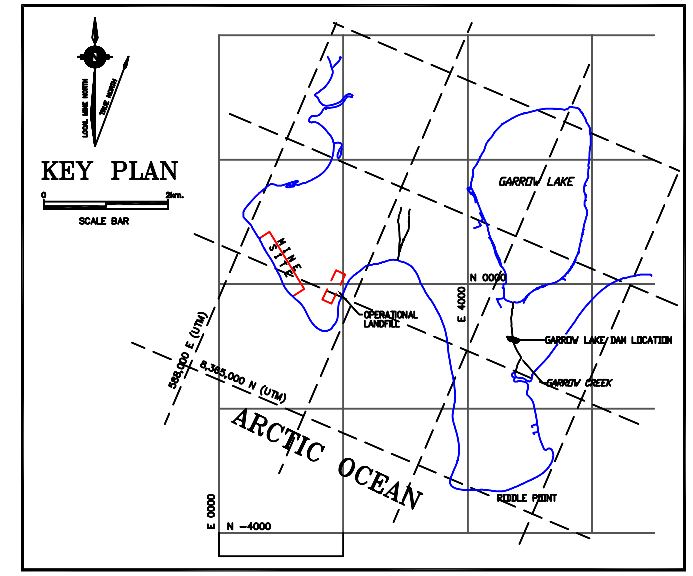
PROJECT:
POLARIS MINE, NUNAVUT
GARROW LAKE DAM DECOMMISSIONING

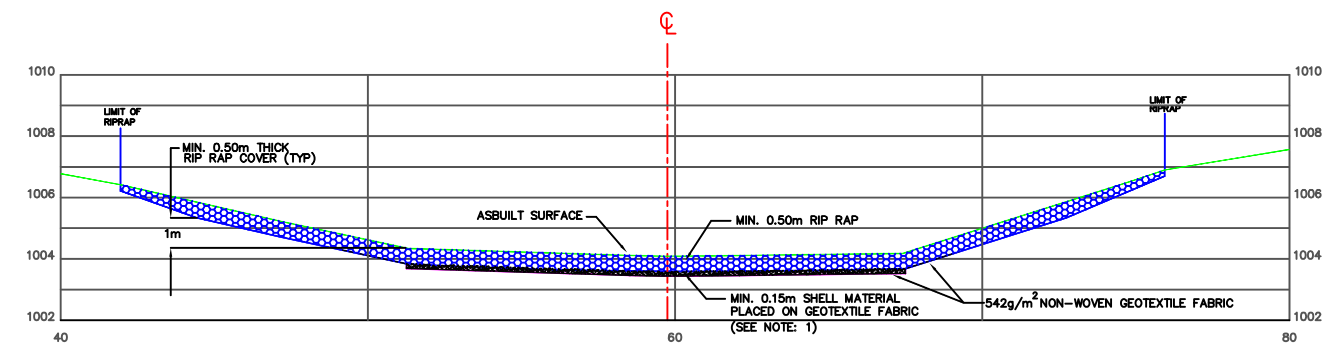
DRAWING:
ASBUILT DRAWING
PLAN AND SECTION VIEWS

DRAWN BY: T. M. TECH SERVICES
6-354-1
CLIENT: teckcominco
DATE: FEBRUARY 22, 2006
SCALE: AS NOTED
FIGURE No.: PM 2006 G-DAM
SHEET: 1 OF 1



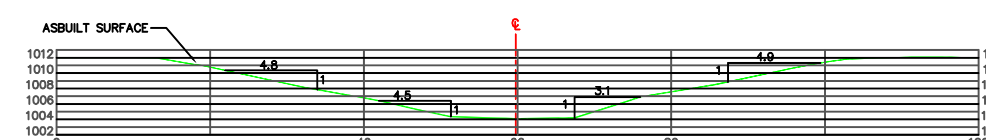
SCALE 1:500





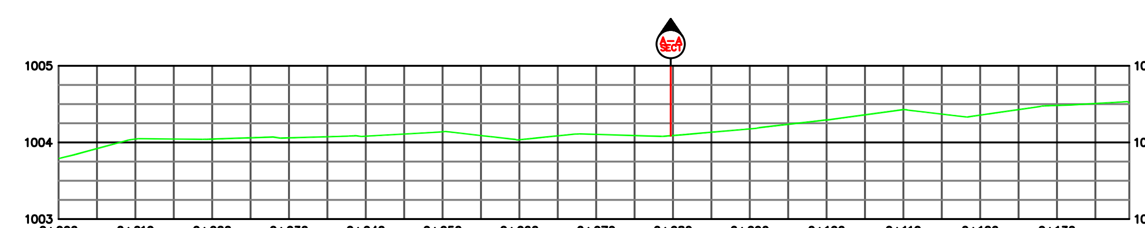
ASBUILT CHANNEL DETAILS (SECTION A–A)

SCALE 1:125



ASBUILT SECTION A–A

SCALE 1:500



ASBUILT ℄ CHANNEL PROFILE

SCALE ~ HORZ. 1:500
VERT. 1:50

NOTES:

1. CHANNEL EXCAVATION DEPTH TO 0.15m BELOW ORIGINAL GROUND AND EXISTING SHELL MATERIAL AND TO BASE OF DAM KEY TRENCH UNDER FROZEN CORE AND SATURATED SHELL MATERIAL.
2. DATA COLLECTED JUNE 18, 2004 BY TECK COMINCO REPRESENTATIVE.
3. ELEVATIONS REFER TO LOCAL MINE DATUM.
4. CONTOUR INTERVALS = 0.25m. WITHIN CONSTUCTION LIMITS
   0.50m. OUTSIDE CONSTUCTION LIMITS

LEGEND:

- - - - LIMITS OF CONSTRUCTION
—— LIMITS OF CHANNEL IMPROVEMENTS

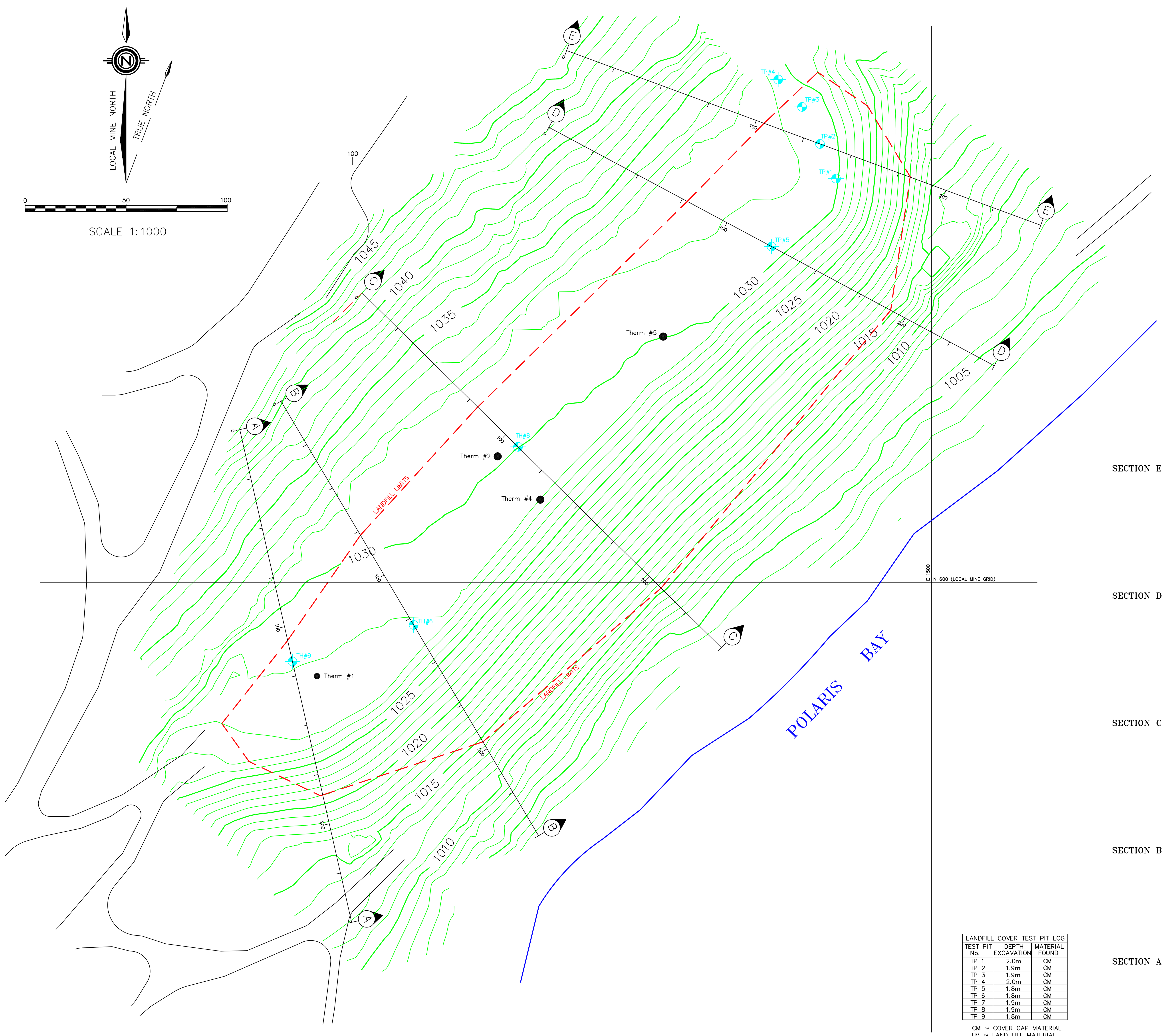
PROJECT:

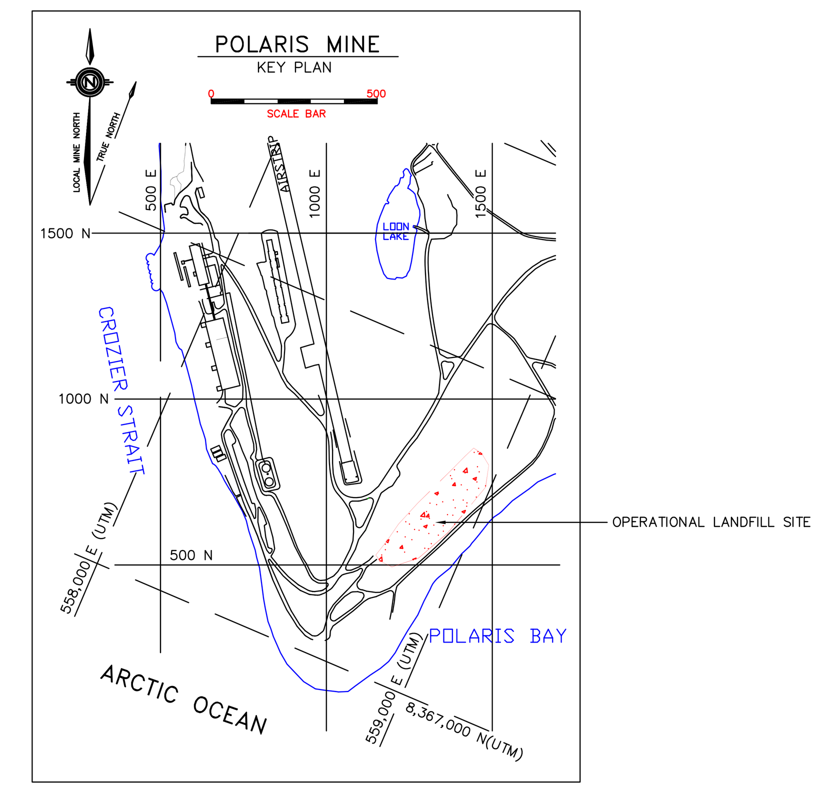
POLARIS MINE, NUNAVUT
GARROW LAKE DAM DECOMMISSIONING

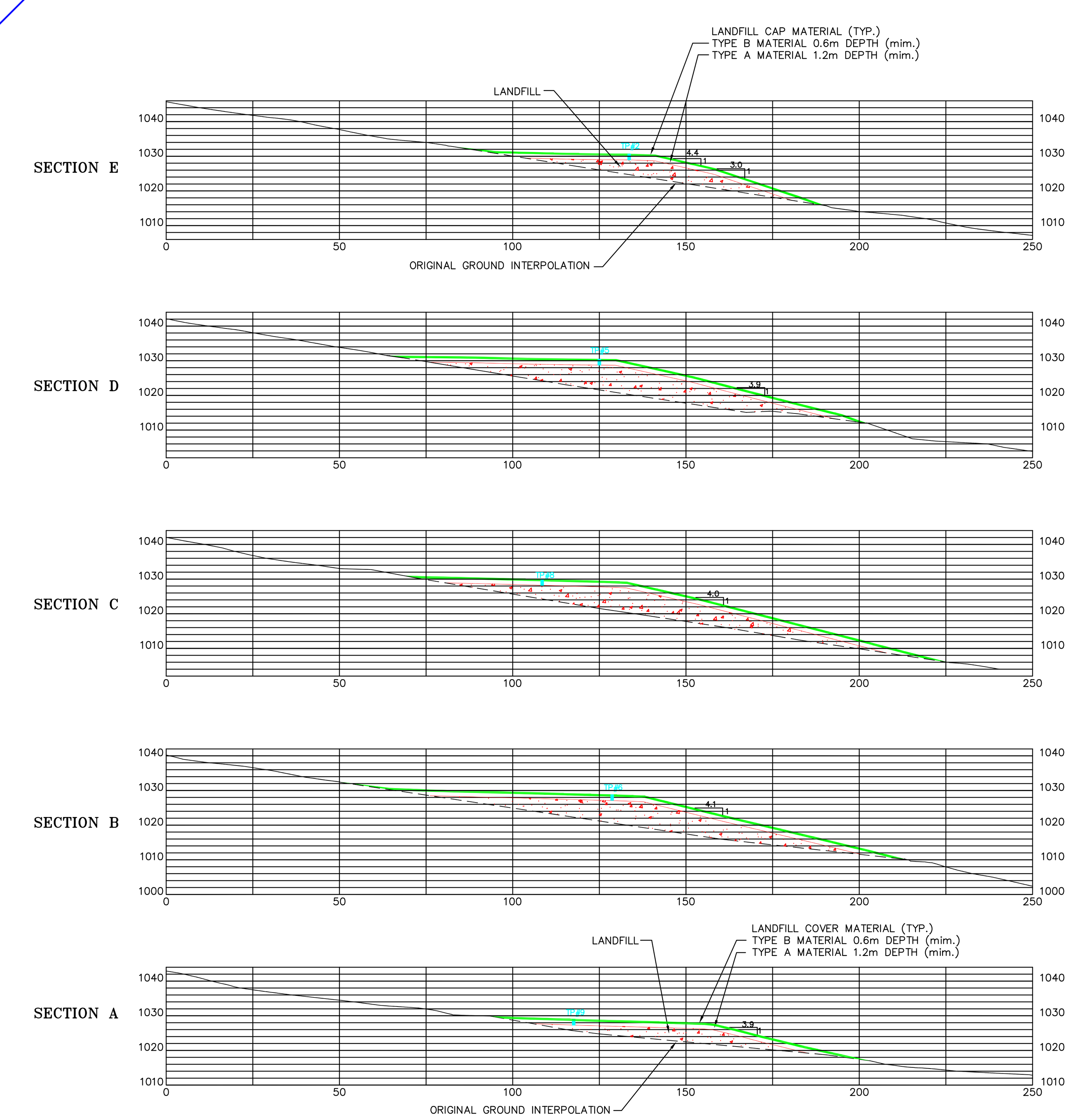
DRAWING:

ASBUILT DRAWING
PLAN AND SECTION VIEWS

DRAWN BY: T. M. TECH SERVICES 6-354-1	CLIENT: teckcominco
DATE: FEBRUARY 22, 2006	SCALE: AS NOTED
FIGURE No. PM 2006 G-DAM	SHEET: 1 OF 1







LANDFILL COVER TEST PIT LOG		
TEST PIT No.	DEPTH EXCAVATION	MATERIAL FOUND
TP 1	2.0m	CM
TP 2	1.9m	CM
TP 3	1.9m	CM
TP 4	2.0m	CM
TP 5	1.8m	CM
TP 6	1.8m	CM
TP 7	1.9m	CM
TP 8	1.9m	CM
TP 9	1.8m	CM

CM ~ COVER CAP MATERIAL
LM ~ LAND FILL MATERIAL

No.	REVISION	DATE
5		
4		
3	:	.
2	.	.
1	.	.

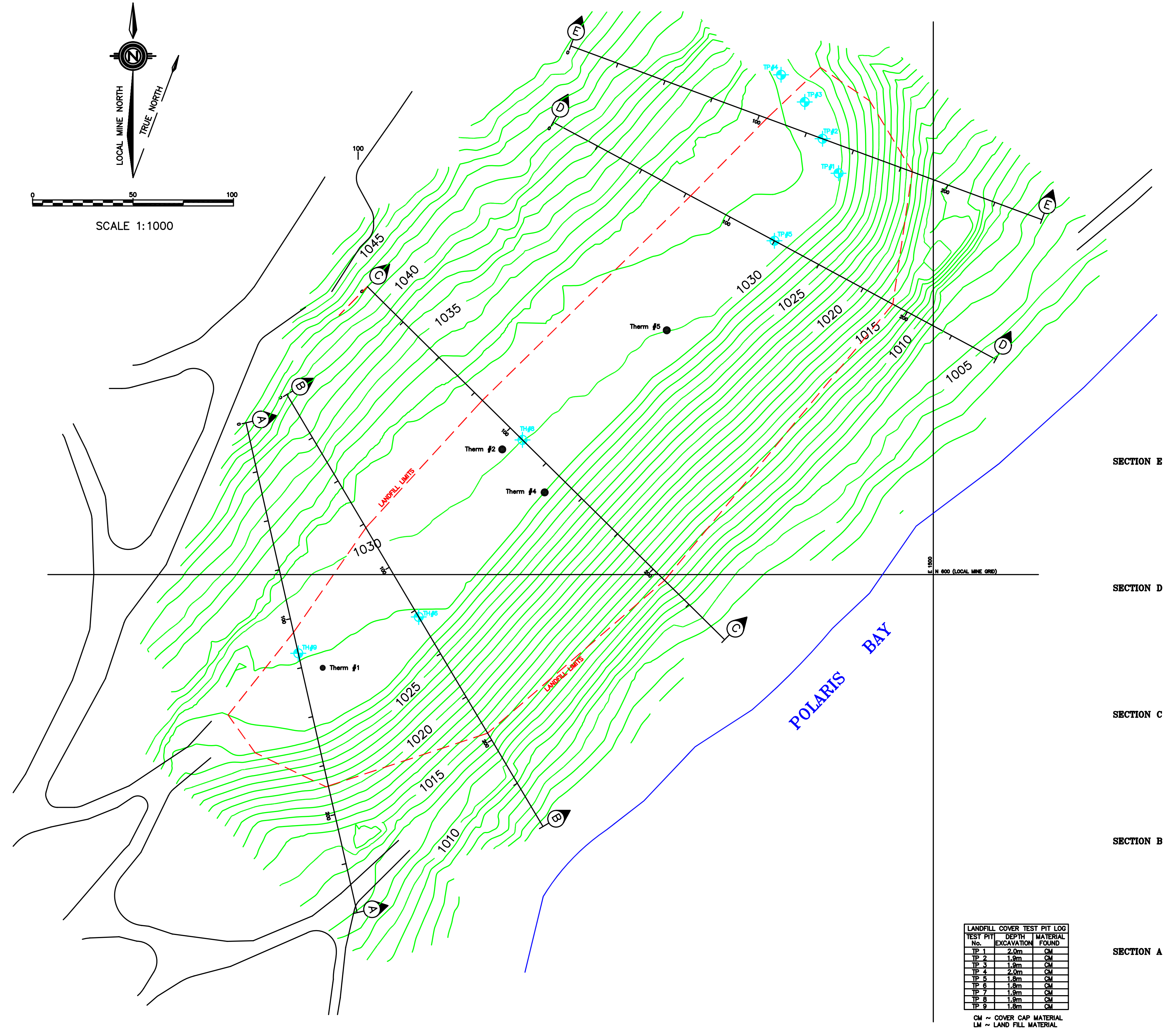
NOTES:
1. DATA COLLECTED JUNE, 2004 BY TECK COMINCO REPRESENTATIVE.
2. ELEVATIONS REFER TO LOCAL MINE DATUM.
3. CONTOUR INTERVAL = 1 METER.

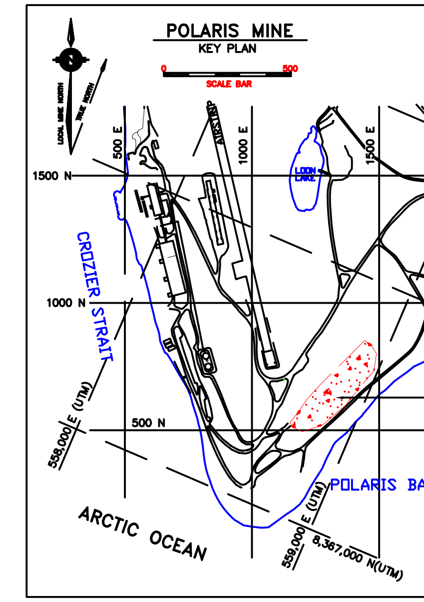
LEGEND:
Therm #1 ~ THERMISTOR LOCATION.
TH#9 ~ LANDFILL COVER TEST HOLE LOCATION.
TP#6 ~ LANDFILL COVER TEST HOLE LOCATION AND DEPTH ON SECTION VIEW.
LIMITS OF RESLOPED LANDFILL.

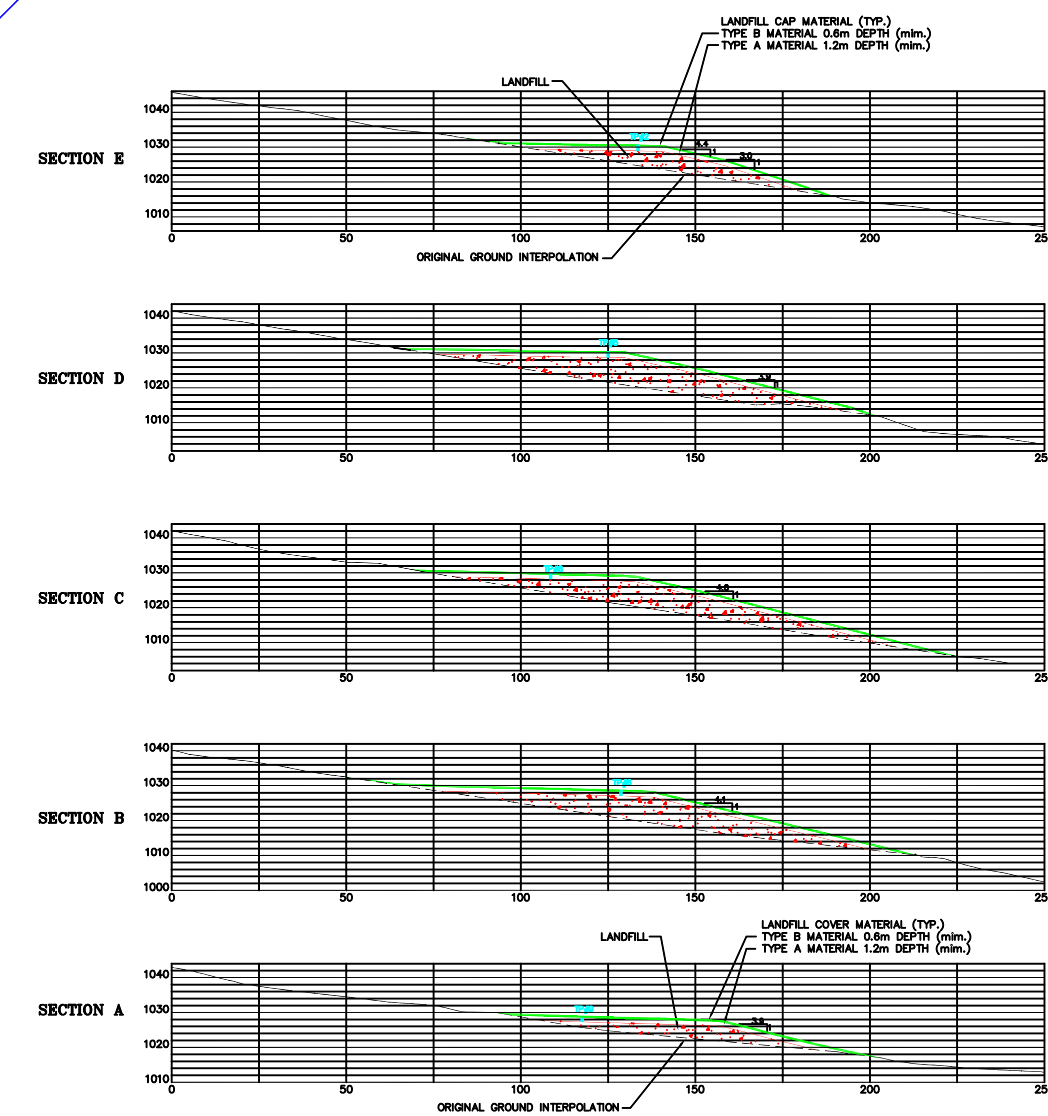
PROJECT:
POLARIS MINE
NUNAVUT

DRAWING:
AS–BUILT TOPOGRAPHIC PLAN
OPERATIONAL LANDFILL SITE

DRAWN BY: T. M. TECH SERVICES
5–348–3
CLIENT: teckcominco
DATE: DEC., 2005
SCALE: 1:1,000 HORZ. 1:1000 VERT.
FIGURE No. PM 2005 OLF
SHEET: 1 OF 1







LANDFILL COVER TEST PIT LOG		
TEST PIT No.	DEPTH EXCAVATION	MATERIAL FOUND
TP 1	2.0m	CM
TP 2	1.9m	CM
TP 3	1.9m	CM
TP 4	2.0m	CM
TP 5	1.8m	CM
TP 6	1.8m	CM
TP 7	1.9m	CM
TP 8	1.9m	CM
TP 9	1.8m	CM

CM ~ COVER CAP MATERIAL
LM ~ LAND FILL MATERIAL

No.	REVISION	DATE
5		
4		
3	.	.
2	.	.
1	.	.

NOTES:
1. DATA COLLECTED JUNE, 2004 BY TECK COMINCO REPRESENTATIVE.
2. ELEVATIONS REFER TO LOCAL MINE DATUM.
3. CONTOUR INTERVAL = 1 METER.

LEGEND:
- Therm #1 ~ THERMISTOR LOCATION.
- TH#9 ~ LANDFILL COVER TEST HOLE LOCATION.
- TP#8 ~ LANDFILL COVER TEST HOLE LOCATION AND DEPTH ON SECTION VIEW.
- LIMITS OF RESLOPED LANDFILL.

PROJECT:
POLARIS MINE
NUNAVUT

DRAWING:
AS-BUILT TOPOGRAPHIC PLAN
OPERATIONAL LANDFILL SITE

DRAWN BY:
T. M. TECH SERVICES
5-348-3

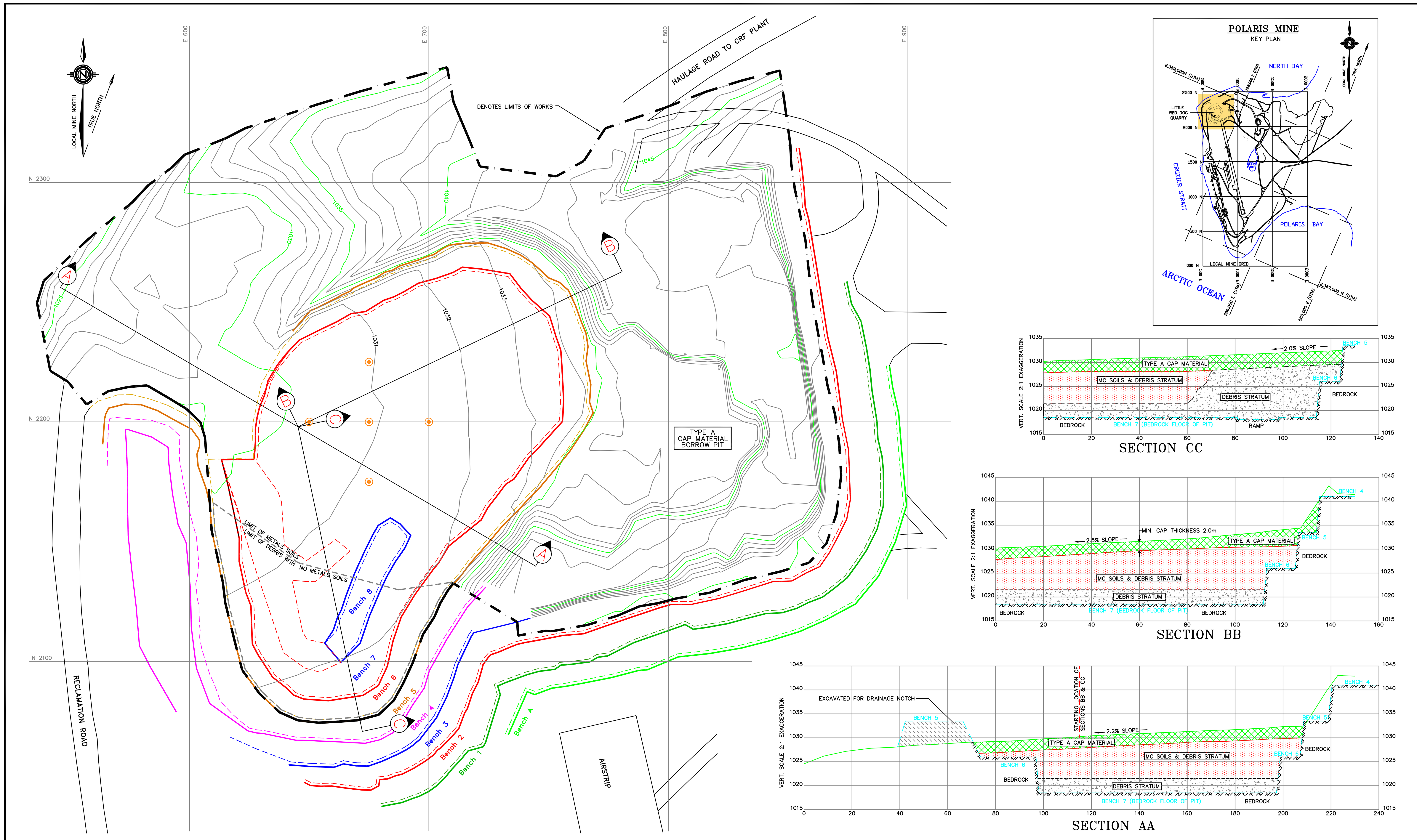
CLIENT:
teckcominco

DATE:
DEC., 2005

SCALE:
1:1,000 HORZ.
1:1000 VERT.

FIGURE No.
PM 2005 OLF

SHEET:
1 OF 1



NOTES:

1. DATA COLLECTED AUGUST, 2004 BY TECK COMINCO REPRESENTATIVE.
2. SECTION CO-ORDINATES AND ELEVATIONS REFER TO LOCAL MINE DATUM.
3. CONTOUR INTERVAL = 1 METER
4. MC SOILS REFERS TO METALS CONTAMINATED SOILS.
5. DEBRIS REFERS TO BUILDING AND EQUIPMENT DEBRIS.
6. TYPE A CAP MATERIAL SPECIFICATIONS ~ LIMESTONE OR LIMESTONE-DOLOMITE GRAIN SIZE MAX. 300mm SAND, GRAVEL AND COBBLES.

LEGEND:

- DENOTES TOE OF BENCHED BEDROCK SURFACES.
- DENOTES CREST OF BENCHED BEDROCK SURFACES.
- DENOTES 5m CONTOUR OF RESLOPED NATIVE MATERIAL..
- DENOTES 1m CONTOUR OF RESLOPED NATIVE MATERIAL..
- DENOTES LIMITS OF CONSTRUCTION.
- DENOTES LIMITS OF DEBRIS MATERIAL DUMP THAT DOES NOT CONTAIN METALS CONTAMINATED SOILS.
- DENOTES THERMISTOR LOCATION

PROJECT:

POLARIS MINE CLOSURE

DRAWING:

LITTLE RED DOG QUARRY
LANDFILL ASBUILT DRAWING
PLAN AND SECTION VIEWS

DRAWN BY:
T. M. TECH SERVICES
6-354-2

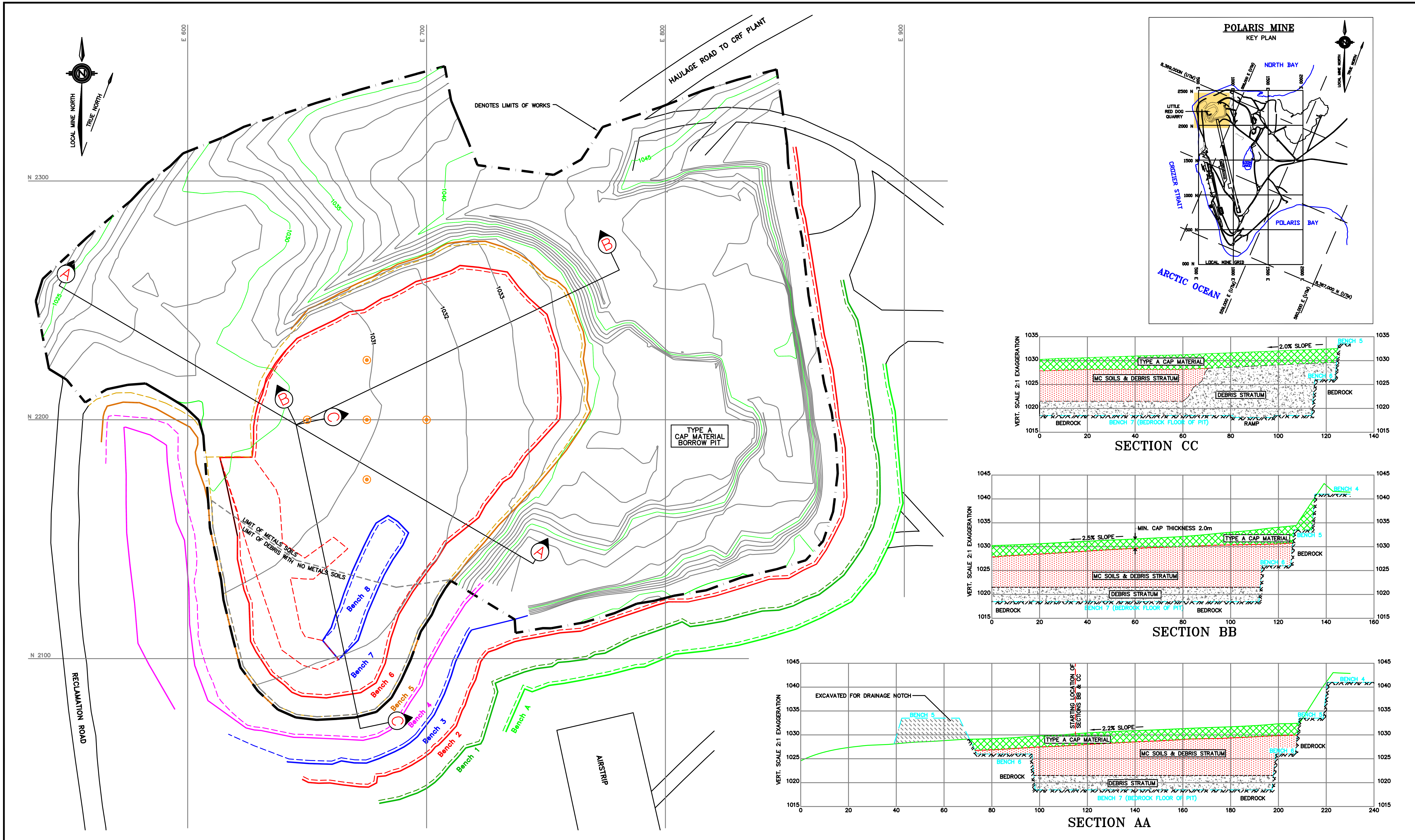
CLIENT:
teckcominco

DATE:
DECEMBER, 2005

SCALE:
1:750 (Metric)

FIGURE No.
PM 2005 LRD

SHEET:
1 OF 1



NOTES:

1. DATA COLLECTED AUGUST, 2004 BY TECK COMINCO REPRESENTATIVE.
2. SECTION CO-ORDINATES AND ELEVATIONS REFER TO LOCAL MINE DATUM.
3. CONTOUR INTERVAL = 1 METER
4. MC SOILS REFERS TO METALS CONTAMINATED SOILS.
5. DEBRIS REFERS TO BUILDING AND EQUIPMENT DEBRIS.
6. TYPE A CAP MATERIAL SPECIFICATIONS ~ LIMESTONE OR LIMESTONE-DOLOMITE GRAIN SIZE MAX. 300mm SAND, GRAVEL AND COBBLES.

LEGEND:

- DENOTES TOE OF BENCHED BEDROCK SURFACES.
- DENOTES CREST OF BENCHED BEDROCK SURFACES.
- DENOTES 5m CONTOUR OF RESLOPED NATIVE MATERIAL..
- DENOTES 1m CONTOUR OF RESLOPED NATIVE MATERIAL..
- DENOTES LIMITS OF CONSTRUCTION.
- DENOTES LIMITS OF DEBRIS MATERIAL DUMP THAT DOES NOT CONTAIN METALS CONTAMINATED SOILS.
- DENOTES THERMISTOR LOCATION

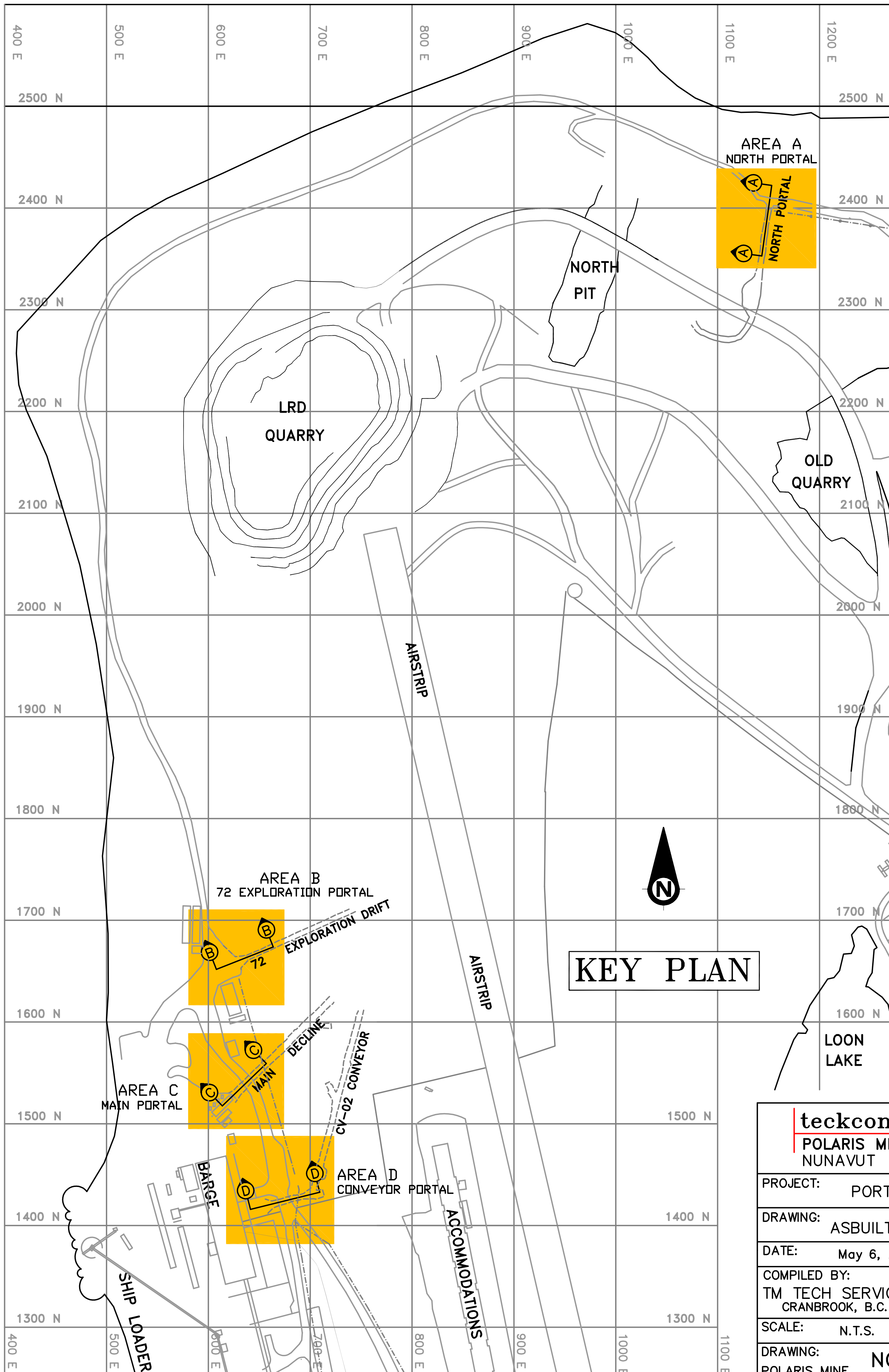
PROJECT:

POLARIS MINE CLOSURE

DRAWING:

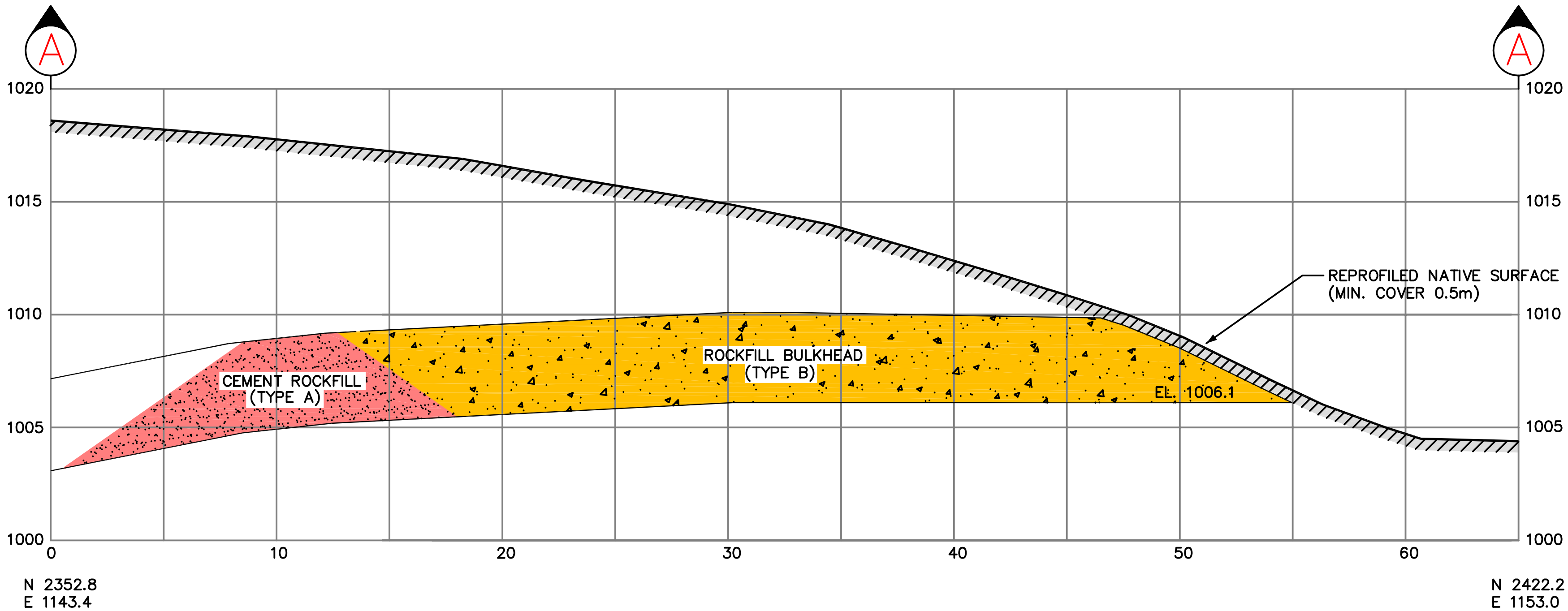
LITTLE RED DOG QUARRY
LANDFILL ASBUILT DRAWING
PLAN AND SECTION VIEWS

DRAWN BY: T. M. TECH SERVICES 6-354-2	CLIENT: teckcominco
DATE: DECEMBER, 2005	SCALE: 1:750 (Metric)
FIGURE No. PM 2005 LRD	SHEET: 1 OF 1



teckcominco
POLARIS MINE
NUNAVUT

PROJECT:	PORTAL PLUGS
DRAWING:	ASBUILT SECTIONS
DATE:	May 6, 2005
COMPILED BY:	TM TECH SERVICES CRANBROOK, B.C.
SCALE:	N.T.S.
DRAWING: POLARIS MINE SITE	NO. 1 KEY PLAN



SECTION AA
NORTH PORTAL

teckcominco
POLARIS MINE
NUNAVUT

PROJECT: PORTAL PLUGS

DRAWING: ASBUILT SECTIONS

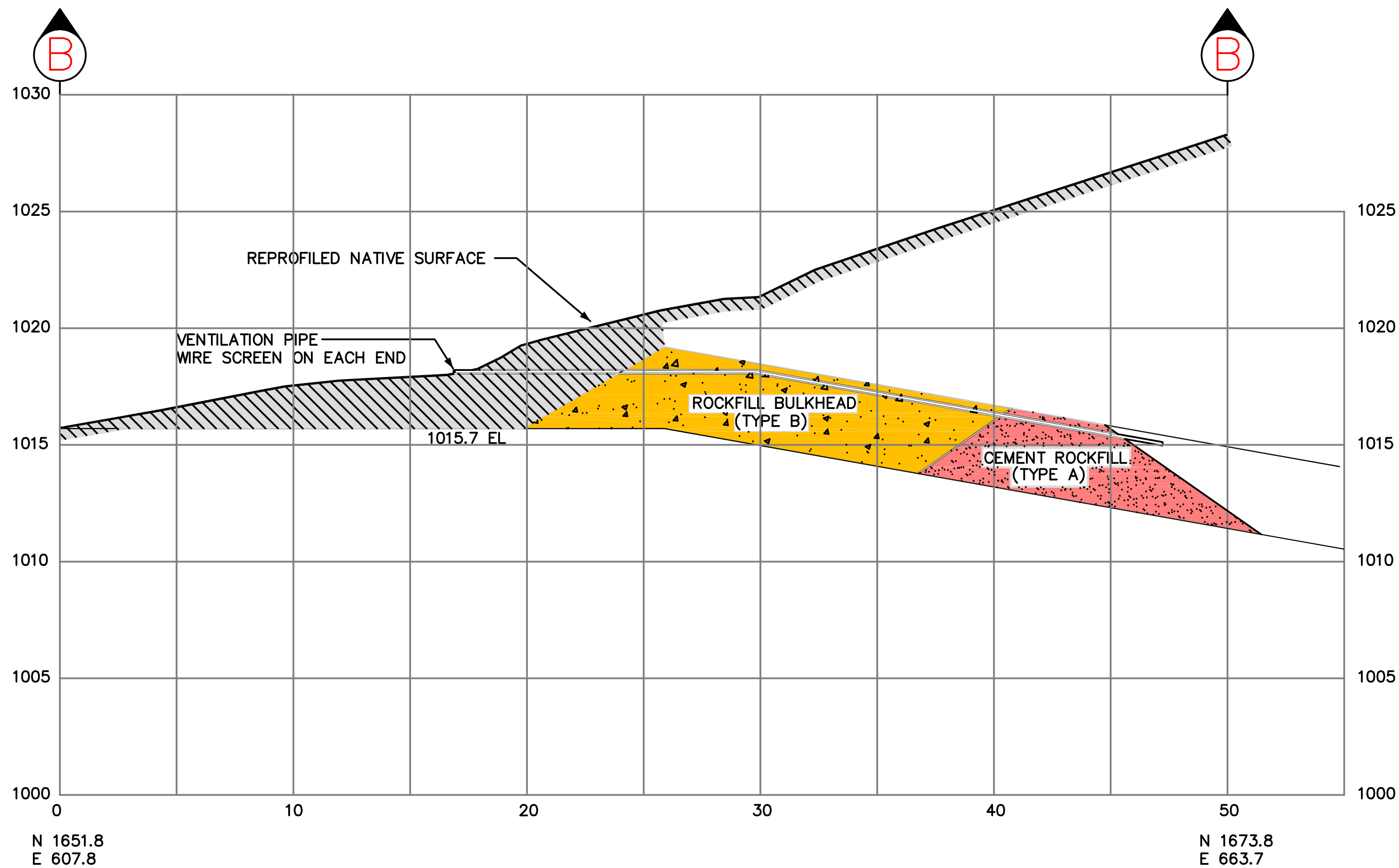
DATE: May 6, 2005

COMPILED BY: TM TECH SERVICES
CRANBROOK, B.C.

SCALE: 1:300 (metric)

DRAWING: NO. 2
SECT–AA

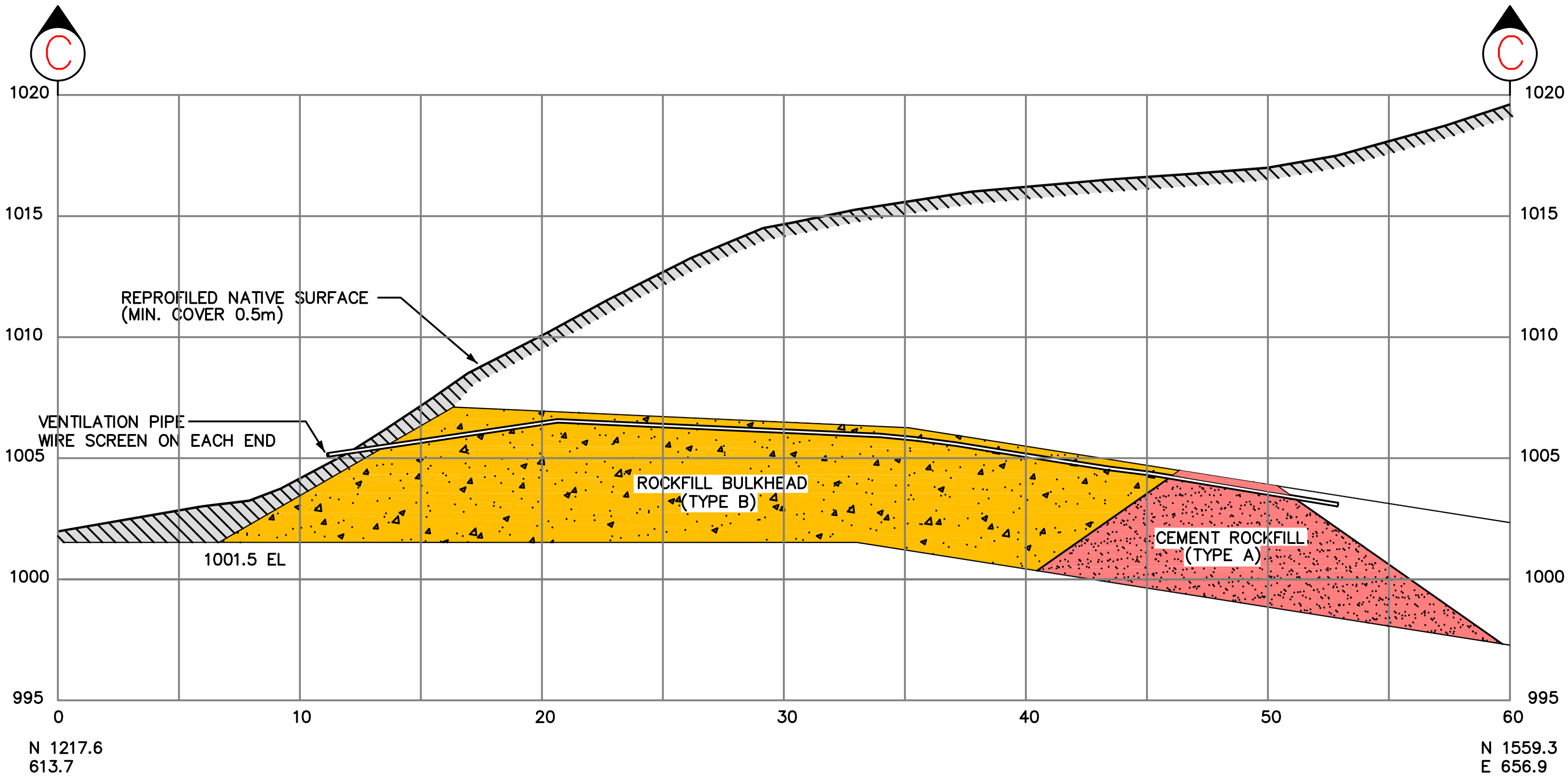
NORTH PORTAL



SECTION BB
72 EXPLORATION PORTAL

teckcominco
POLARIS MINE
NUNAVUT

PROJECT:	PORTAL PLUGS
DRAWING:	ASBUILT SECTIONS
DATE:	May 6, 2005
COMPILED BY:	TM TECH SERVICES CRANBROOK, B.C.
SCALE:	1:300 (metric)
DRAWING:	72 EXPLORATION PORTAL No. 3 SECT-BB



SECTION CC
MAIN PORTAL

teckcominco
POLARIS MINE
NUNAVUT

PROJECT: PORTAL PLUGS

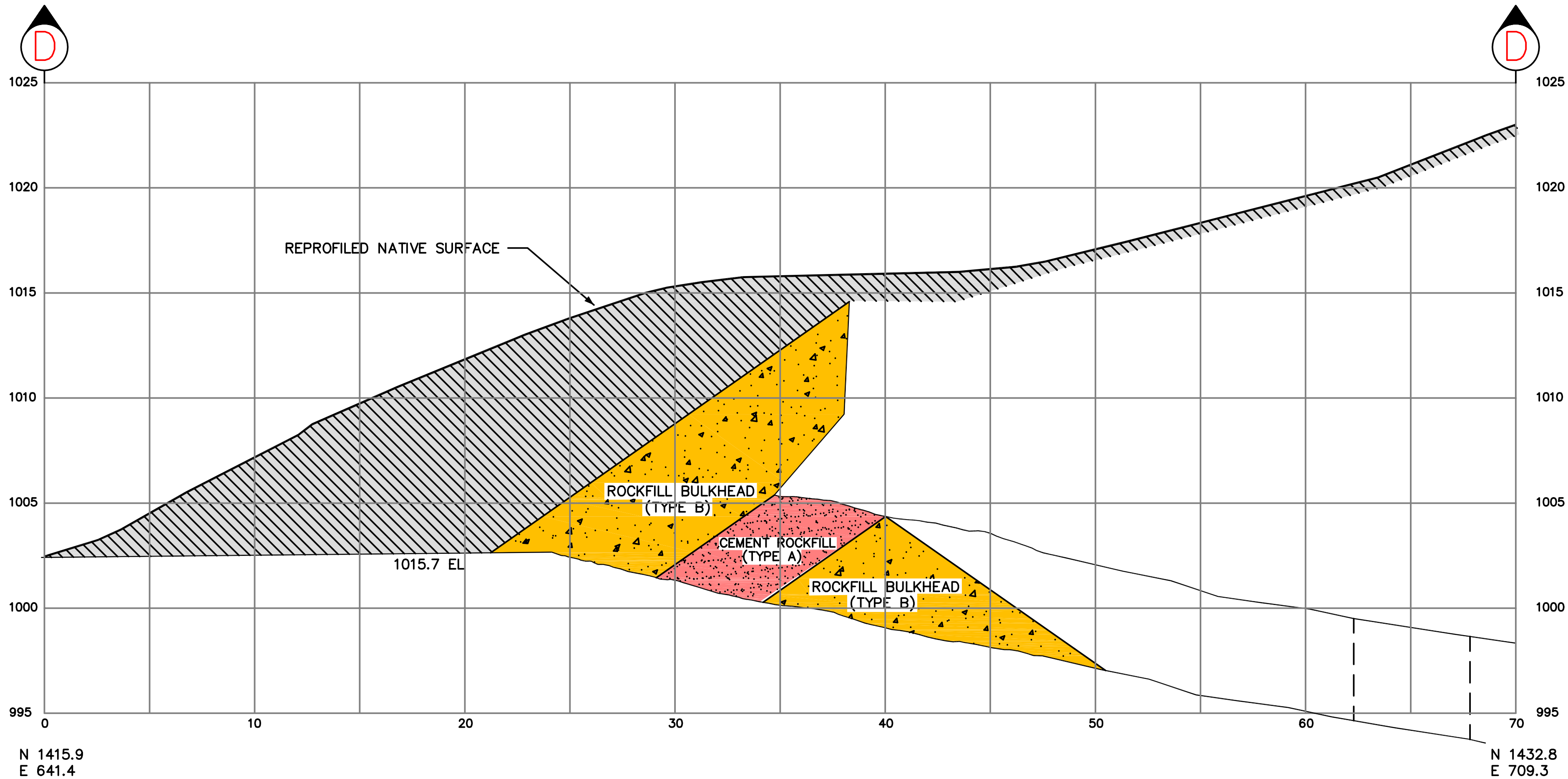
DRAWING: ASBUILT SECTIONS

DATE: May 6, 2005

COMPILED BY:
TM TECH SERVICES
CRANBROOK, B.C.

SCALE: 1:300 (metric)

DRAWING: No. 4
SECT-CC
MAIN PORTAL



SECTION DD
CONVEYOR PORTAL

teckcominco
POLARIS MINE
NUNAVUT

PROJECT: PORTAL PLUGS

DRAWING: ASBUILT SECTIONS

DATE: May 6, 2005

COMPILED BY: TM TECH SERVICES
CRANBROOK, B.C.

SCALE: 1:300 (metric)

DRAWING: No. 5
CONVEYOR PORTAL SECT–DD

summer vertical profiles of temperature, oxygen and salinity were very similar to pre-mining data (Figure 3) with two notable differences. Salinity of the monimolimnion and depth of the mixolimnion have both diminished, reflecting the physical effects of tailings deposition to the lake bottom.

Mixolimnion salinity ranged from 3.8 ppt (6.7 mS) at the surface to 7.1 ppt (12.5 mS) at the top of the pycnocline (9 m). Melting ice caused lower salinity and conductivity at the surface than at deeper depths, with a slight inverse stratification. In winter 2003, salinity and conductivity within the epilimnion was uniform (Appendix B). Oxygen concentration was stratified and high in winter (13 – 20 mg/L) and supersaturated, a condition also noted during pre-mine conditions, presumably from photosynthetic bacteria. In August oxygen was also high and uniform (11.5 mg/L), but was not supersaturated because absence of ice cover and mixing by wind allowed oxygen to escape to the atmosphere (Figure 3).

Winter and summer water temperatures were cold, ranging from –0.5 ^{o}C to 4 ^{o}C with very little difference between seasons. Surface water temperature (<2 m) was slightly warmer in summer than in winter. Below 2 m depth, water temperature ranged between 3^{o} and 4^{o}C. Field pH was 8.2 in the mixolimnion and declined through the pycnocline and monimolimnion to 7.35 that was unchanged with depth to the bottom (Appendix B). Limnological conditions within the mixolimnion were very similar in 2003 as pre-mining conditions and do not appear to have changed substantially.

Pycnocline depth below the surface is shallower and has become thinner compared to pre-mining profiles (BC Research, 1981; Fallis et al., 1987; Ouellet et al., 1989). The depth of the surface of the pycnocline, where large, rapid salinity increases occurred in 2003 was at 10 m, reaching near maximum salinity of the monimolimnion by 12 m, a thickness of only 2 m. Formerly, mixolimnion depth extended to 12 m and the bottom of the pycnocline ended at about 20 m. Salinity of the monimolimnion (field based Hydrolab data) was 58 ppt (Appendix B; Figure 3), which is about 32 ppt less than maximum salinity observed in pre-mining studies. Laboratory analysis of mixolimnion water showed a maximum salinity of 64 ppt. Nevertheless, salinity has diminished gradually over time as expected (AXYS, 2001) owing to the large amount of tailings deposited to the lake over more than 20 years, diluting bottom waters. Oxygen concentration was nil and there was a strong hydrogen sulphide odor to the water.

Tailings deposition between 1981 and 2002 has displaced the mixolimnion upwards and is 3 – 4 m shallower than pre-mining, beginning at 9 m, up from the pre-mine depth of about 12.5 m. However, lake elevation in 2003 was also about 2 m higher than pre-mine elevation because of the dam structure that was still in place at the lake outlet (Figure 2). The dam was installed in 1990 to increase water level of the lake to reduce zinc concentration in water discharged to Garrow Bay (see Section 1.3). Removal of the dam in spring 2004 will allow water level in the lake to return to near pre-dam elevations and will reduce lake level and depth of the mixolimnion by a further 2 m, beginning at a depth of approximately 7 or 8 m.

In 2000, Teck Cominco commissioned AXYS (2001) to determine if diminishing mixolimnion depth would risk turnover and mixing of the mixolimnion and monimolimnion. If this occurred, water chemistry of the entire lake and Garrow Creek would be considerably altered. AXYS (2001) concluded that the density barrier of the pycnocline is strong enough that it cannot be broken down or compromised by wind and wave action after decommissioning of the dam and lake drawdown. Thus, no mixing of the mixolimnion and monimolimnion is possible. Furthermore, AXYS (2001) stated that zinc concentration in the mixolimnion will remain below 300 µg/L and that levels should decline over time, however, no time frame was given.

3.1.3. Metals

Between 1980 and 2002 approximately 15 million tonnes of tailings solids were deposited to the monimolimnion of Garrow Lake (Gartner-Lee, 2001). Tailings were discharged via a pipe suspended in the water column, well below the pycnocline at a depth of about 26 – 31 m. The location of the pipe was moved horizontally and laterally on an annual basis, to distribute tailings more evenly over the bottom. Small, discrete piles of tailings are evident from the bathymetric map of Garrow Lake (Figure 2). These piles are spread out over the deep basin opposite the tailings disposal line. Maximum depth of Garrow Lake has diminished to about 42 m, which is approximately equivalent to the depth that the mixolimnion has been displaced upwards.

Prior to mining, it was believed that discharging tailings to the monimolimnion of Garrow Lake would prevent dissolved metals from diffusing upwards through the pycnocline and into the mixolimnion. The high density of the pycnocline presents a physical barrier, while the abundance of sulphides would bind and scavenge metals from the water column and act as a chemical barrier. The tailings disposal system has been effective at preventing upward migration of metals. However, as discussed below, three spills of tailings into surface waters has been responsible for elevated metal concentrations in the mixolimnion.

In winter 1981 the tailings pipe became clogged and resulted in a small tailings spill on the ice surface near the northwest corner of the lake (Dickman and Ouellet, 1987). This material was deposited into nearshore water and may have contributed to elevated metal concentrations in surface waters. A more substantive spill occurred in the winter of 1984 – 1985. At that time, the down-leg section of the pipe broke at about 0.6 m depth and discharged a considerable amount of thickened tailings under the ice. The break was not detected for about three months until results of water sampling indicated elevated zinc (150 µg/L) at 10 m depth. Repairs were made in February 1985.

The total amount of zinc spilled into the mixolimnion was estimated by BC Research (1988) to be in the order of 800 tonnes, based on a zinc content of 0.5%, assuming a discharge rate of tailings at 1,600 tonnes/day. They further estimated that 42.7 tonnes of zinc was dissolved in the upper 20 m of Garrow Lake. Another spill occurred in the winter of 1989 (Gartner Lee, 2001), however we could not determine how much tailings were spilled or at what location. In 1992, a submerged, double-walled pipe was installed to eliminate the possibility of future spills.

The tailings spill caused a minor increase in lead concentration and a large increase in zinc concentration within the mixolimnion from 10 µg/L (1977) to 230 µg/L (1987) (BC Research, 1988). The extent of surface contamination was not realized because zinc concentration in Garrow Creek continued to be relatively low (61 µg/L) in summer 1986. However, vertical mixing of water during summer and under-ice caused zinc trapped above the pycnocline to become mixed into the mixolimnion, causing zinc to increase from 170 µg/L to 280 µg/L throughout the upper water column. Sampling of the lake beneath the ice in January 1988 revealed a sharp increase in zinc concentration in the upper pycnocline at 11 and 12 m depth (BC Research, 1988) and an increase in the mixolimnion to 310 µg/L. At the time, it was not known if the pycnocline would continue to be a “reservoir” of dissolved zinc or if zinc would be precipitated by sulphides within the pycnocline, and removed from the active mixolimnion by settling. Dissolved lead concentration continued to be low and was likely precipitated by sulphides. BC Research (1988) speculated that upward displacement of the pycnocline would increase average and peak zinc concentrations discharged from Garrow Lake over time, threatening to exceed Teck Cominco’s permitted discharge concentration of 100 µg/L. Ice melt usually sufficiently diluted discharge of surface water to Garrow Creek such that limits were not exceeded except perhaps during first or last weeks of discharge from the lake.

In 1990 AXYS (1991) measured dissolved zinc concentrations of 410 µg/L and 1,800 µg/L within the mixolimnion and pycnocline respectively. Concentrations of total and dissolved zinc were very similar, suggesting that precipitation and loss to the monimolimnion was not occurring. These concentrations exceeded the discharge permit concentration. Therefore, Teck Cominco constructed a small dam across the creek in 1990 and 1991 about half way between the lake outlet and the creek mouth at Garrow Bay. The purpose of the dam was to prevent zinc contaminated surface water from reaching Garrow Bay by allowing lake level to increase by about 2.5 m and 10 Mm^3 in volume over a period of three years, diluting the mixolimnion and allowing tailings contaminated particulates in the lake to settle.

Water was not discharged from Garrow Lake until spring of 1994. During the intervening period several studies were undertaken to examine the effects of lead and zinc on receiving environment biota in Garrow Bay (AXYS, 1991; EVS, 1992). Results of these studies suggested that harmful effects of elevated zinc concentration were unlikely.

Consequently, the discharge limit for zinc was increased to 500 µg/L in 1992 (AXYS, 2001). This concentration was not exceeded during the remainder of mine life.

Subsequent to 1994, until removal of the dam, siphons were used to discharge water over the dam that allowed control over timing and volume of release. Gartner Lee (2001) reported that zinc concentration in the mixolimnion of Garrow Lake had gradually diminished from 400 µg/L in 1990 to 280 µg/L in 1999 and 2000. In 2003, mixolimnion dissolved zinc concentration was 240 µg/L, similar to 2000 data (Table 3).

Sampling of the water column at discrete depths in 2003 (GL-WQ-1) revealed that total metals concentrations within the mixolimnion (2 m and 6 m), pycnocline (11 m) upper monimolimnion (15 m) and deep monimolimnion (31 m) did not differ in concentration with the exception of lead and zinc (Table 3). Lead was more than an order of magnitude higher in concentration in the monimolimnion (12.1 µg/L) than the mixolimnion (0.8 µg/L). Zinc was higher in the monimolimnion (338 µg/L) than in the mixolimnion (240 µg/L) and highest within the pycnocline (1,140 µg/L), a pattern that was also observed in 1988 (1,800 µg/L at 16 m; BC Research, 1988) and 1990 (1,820 µg/L at 13 m; AXYS, 1991)(Table 2). Cadmium, lead and copper concentrations were also highest in the pycnocline. These data suggest that the pycnocline is a barrier, preventing transfer of metals from the monimolimnion upwards, but it also may prevent sinking of metals. Bacteria near the bottom of the pycnocline may be partly responsible for maintaining elevated metals in water owing to accumulation of zinc within the bacterial tissue.

Pre-mining, mining and post-mining water column metals data within the mixolimnion, pycnocline and monimolimnion are compared in Table 3. Concentrations of most metals, including arsenic, cadmium and copper, did not appear to change with any discernable pattern over mine life. Arsenic concentrations were low in the mixolimnion and pycnocline and were one to two orders of magnitude higher in the monimolimnion. Cadmium concentration was uniformly low and near detection limits in most water samples. Copper data were variable and did not demonstrate any trend or pattern over time or within discrete layers. Lead concentration in the mixolimnion increased after the metals spill in 1985 and has remained somewhat elevated since then, but has diminished over time.

Only zinc has demonstrated consistent trends in concentration over time and within discrete layers in Garrow Lake. During tailings discharge, prior to the spill, zinc concentration in the mixolimnion was low, less than 24 µg/L (0.024 mg/L) (Fallis et al., 1987; BC Research, 1978). BC Research (1981) measured higher concentrations in 1980, although Dickman and Ouellet (1987) measured low concentrations (16 µg/L) in 1981, the same year that tailings discharge was initiated. Zinc concentration increased in the monimolimnion shortly after tailings disposal was initiated, reflecting the addition of zinc rich material dispersed into the mid-water column. Zinc concentration in the monimolimnion has consistently been measured between 200 and 300 µg/L since tailings disposal began. Note that this concentration is still below the discharge limit in Garrow Creek of 500 µg/L and is only slightly higher than zinc concentration in the mixolimnion.

As discussed above, the tailings spill into surface waters of Garrow Lake has caused dissolved zinc concentration to become and remain elevated (~250 µg/L) in the mixolimnion and especially the pycnocline layer (1,140 µg/L). This concentration has remained consistent since the mid-1990s. Elevated concentrations of dissolved zinc will likely be maintained for some time due to high concentration in the pycnocline, but also by elevated zinc concentration in the sediment due to the spill in 1985. The widespread zinc contamination throughout nearshore, littoral zone sediment of the lake (see following section) may present an on-going source of dissolved zinc to the mixolimnion.

3.2. Sediment Chemistry

No study has examined sediment chemistry of Garrow Lake since deposition of mine tailings was initiated. This is because tailings were especially deposited into the monimolimnion, which has proven to be an effective barrier at preventing movement of metals upwards through the pycnocline into surface waters (see Section 3.1). Despite the tailing spill to shallow sediment in 1984/85, no survey of sediment chemistry was undertaken.

In 1976, prior to mining, Fallis et al. (1987) collected sediment from 9 stations around Garrow Lake from depths ranging between 3 m and 48 m (Table 4). Six stations were situated within littoral zone sediments in depths of 12 m or less, within the mixolimnion. Three stations were in depths of greater than 12 m within the pycnocline or monimolimnion, in the anoxic, lifeless (except bacteria) zone of the lake. BC Research (1978) collected sediment from only two stations (12 m and 19 m) in 1977 and from 19 stations in May (5) and August (14) in 1980 (BC Research, 1981) at depths ranging from 5 – 48 m.

Concentrations of most metals including lead (<0.25 – 11 mg/kg), zinc (30 – 103 mg/kg), cadmium (0.25 – 3.1 mg/kg), arsenic (4.2 – 11.4 mg/kg), copper (15 – 31 mg/kg) and manganese (59 – 209 mg/kg) did not differ markedly with depth, even between littoral zone (<12 m) and monimolimnion zone sediment. Metal concentrations were only slightly higher in the deepest part of the lake, otherwise there were no meaningful differences among depths or between different areas of the lake in both the BC Research (1978 and 1981) and Fallis et al. (1987) studies. Interestingly, Fallis et al. (1987) found that metal concentration tended to be positively correlated with grain size.

Unfortunately, several spills of tailings (1981, 1985/85, 1989) introduced metals contaminated material to littoral zone sediment. The substantive spill under the ice during the winter of 1984 – 1985 discharged approximately 800 tonnes of zinc in thickened tailings (BC Research, 1988). No study was conducted to determine the spatial extent and magnitude of contamination until the present study. However, given the designation of Garrow Lake as a tailings disposal facility, this was not necessary.

We sampled surface sediments from between 6 and 8 m within the mixolimnion at four locations around the lake, as well as two locations within the area of the 1984/85 tailings spill along the western shore of the lake (Figure 2). Grain size was predominantly silty-clay at all stations with a very fine, flocculent, oxidized surface layer with some organics, over grey colored sediment of uniform color, consistency and appearance (Table 1). With the exception of lead and zinc, sediment metal concentration throughout the littoral zone was no more than double pre-mining metal concentration (Table 5). Mean lead (137 µg/g dw) and zinc (742 µg/g dw) concentrations in littoral sediments from around the lake however, were considerably higher than pre-mine concentrations (0.25 µg/g and 61 µg/g dw respectively; Fallis et al., 1987) and are a reflection of the spill.

Given that sampling of sediment was conducted at similar depths over most of the lake that was accessible by boat (ice conditions permitting), these data indicate that the spill of metal contaminated tailings resulted in lake-wide contamination of surface sediment. Lead and zinc concentrations were only slightly higher at GL-2, nearest the historic spill area, than at the other three littoral stations. Suspended sediment introduced into the water column during the spill settled throughout most of the lake, causing contamination of surface (at least upper 1 – 2 cm) sediment in the littoral zone.

Two sediment samples collected from the immediate vicinity of the historic spill area had similar or lower concentrations for several metals (aluminum, barium, chromium, mercury, molybdenum, nickel, strontium) than littoral sediment and higher concentrations of lead (1,000 µg/g dw) and zinc (7360 µg/g dw)(Table 5). Most other metals for which pre-mine data were available are not substantially elevated or are lower than pre-mining concentrations.

3.3. Ecology

3.3.1. Zooplankton

No true zooplankton species were captured during the 2003 survey from the vertical tows at each of the four sediment stations (Figure 2), nor from a horizontal tow, conducted <1 m below the water surface. However, a single oligochaete worm and at least one cyclopoid copepod of benthic origin were sampled from each station.

Limnocalanus macrurus is the only species of zooplankton known to be present in Garrow Lake. This species was identified in 1976 by Fallis et al. (1987) and in 1977 and 1980 by BC Research (1978 and 1981 respectively). *L. macrurus* is a relatively common species in the Arctic and is also present in many large, deep freshwater lakes. *L. macrurus* is known as a glacial relict species (Pennack, 1978). BC Research (1978) also captured or observed amphipods (*Gammarus* sp.) and a mysid species (*Mysis oculata*). Apparently, mysids were relatively abundant and of a large size, based on observations made during SCUBA surveys of Garrow Lake by BC Research (1978). Each of these species was also observed in nearby Frustration Lake in 1977 beach seines (BC Research, 1978).

In 1980, BC Research (1981) determined the density of plankton in vertical hauls from different depths (10 m, 15 m and 19 m, just above the pycnocline) and found that abundance of *L. macrurus* was much greater at the deepest depth, corresponding with the depth where the greatest abundance of phytoplankton was found.

It is not known why zooplankton were apparently absent from the lake during the present survey. Abundance of zooplankters is normally low in oligotrophic Arctic lakes, however, if plankton were present, at least a few individuals should have been captured. Perhaps plankton were situated at a deeper depth than was sampled in 2003 (8 m), or the mesh size used in the current study (250 µm) was too large; Fallis et al. (1987) used a 73 µm net. However, adult zooplankters of this species reach 2 mm in length (Pennack, 1978) so this may not explain their absence.

It is also possible that changes in water quality of the mixolimnion since pre-mine surveys have diminished abundance of the primary food source of *L. macrurus*, phytoplankton, or has directly affected zooplankton abundance. Phytoplankton were not collected during the 2003 survey.

3.3.2. Benthic Invertebrates

Oligochaete worms of the Family Enchytraidae, nematodes and Foraminifera were the only benthic invertebrates retained on a 250 µm sieve from petite ponar sampling in Garrow Lake in 2003 (Table 6). Abundance and density of oligochaetes was reasonably good, however, diversity of species was low. Chironomid larvae were present in the lake because several larvae were collected from the stomachs of fourhorn sculpin (see Section 3.3.3). However, density of chironomids in the lake appears to be quite low because none were collected from sieving of sediment. Given the high northern latitude and brief open water period, abundance of flying insects is naturally very low in this region. In fact, few flying insects were observed, with no mosquitoes or blackflies, which was a blessing.

Nematodes and Foraminifera were not included in the density estimate because these organisms are smaller than the mesh size used (250 µm) although they can be retained in small numbers. Nematodes and Foraminifera are very abundant and widespread in all lakes and their density is very infrequently estimated.

Fallis et al. (1987) also found a depauperate benthic fauna in Garrow Lake, dominated by Foraminifera. They identified 19 species with *Protelphidium orbiculare* being most abundant, followed by *Elphidium translucens*, *Ammotium cassis* and *Trochamina rotaliformis*. A single mollusk species, *Astarte warhami*, and an unidentified harpacticoid copepod were the only other species identified. Fossils of polychaetes, echinoderms and ostracods were identified in sediments, probably species that had been weathered out of historic, marine sediments as the lake has risen since the most recent glaciation.

BC Research (1978) identified nematodes, oligochaetes and harpacticoid copepods from Garrow Lake, although their abundance was not determined.

Garrow Creek sediment contained nematodes, oligochaetes a single mayfly (Ephemeroptera) species *Baetis bicaudatus* and several chironomid species (Table 6). These data indicate that, despite the ephemeral flow of the creek, it is capable of supporting aquatic life, dominated by oligochaetes. Chironomids were present in low abundance and their presence confirms that these organisms are capable of surviving in the creek and therefore, presumably Garrow Lake.

3.3.3. Fish

Nineteen fourhorn sculpins (*M. quadricornis*) were captured in gill nets and a prawn trap from Garrow Lake in 2003 (Table 7). Eleven sculpins were sacrificed to determine gender, sexual maturity, gut contents, age (using otoliths), internal condition and tissue metals concentration (whole fish). All 19 fish were measured for total length and weight to determine condition factor (Table 8) and length-weight relationship (Table 9).

Fallis et al. (1987) and BC Research (1978, 1980) were the first investigators to document sculpin biology (length, weight, growth, age, metals) prior to mining. No biological study of the sculpin population of Garrow Lake had been conducted until the present investigation. So, comparisons made here represent data collected prior to mining and after mining had ceased.

3.3.3.1. Size

All sculpins captured in 2003 appeared to be healthy with no external or internal tumors (Photo’s 4 and 5), scars or other abnormalities (Table 7). Sculpins ranged from 85 mm to 184 mm (mean 149 mm) in length and 4.2 g to 40.3 g (mean 24.9 g) in weight. Mean condition factor (K) was 0.70 (Table 8). Fallis et al. (1987) captured 51 sculpins in 1976 using small-mesh, Swedish style gill nets, similar in size to the nets used in the current survey. All fish were acquired from above the pycnocline and none were found below 15 m. BC Research (1978) captured 137 sculpins using beach seines and observed that sculpins were found throughout the lake and appeared to be abundant and easily captured. Sculpins continued to be observed in the lake throughout the period of mining during

SCUBA maintenance of the tailings line (Gartner Lee, 2001; W. Gzowski, Arctic Divers Ltd., Yellowknife NWT personal communication, May 5, 2003), although no biological study was conducted.

Meristic data from 2003 were very similar to mean length (155 mm), weight (26.6 g) and condition factor (0.72) of sculpins captured by Fallis et al. (1987) using the same fishing gear (Table 8) prior to mining. Fish captured by BC Research (1978) in beach seines and nets had a wider size distribution (20 – 170 mm) and had a lower mean weight and condition factor.

Length – frequency distributions of sculpins from 1976 (Fallis et al. 1987), 1977 (BC Research, 1978) and 2003 demonstrate that the basic size distribution of adult sculpins has not changed markedly (Figure 4) since prior to mining. The maximum size of fish captured in 1976 was greater than in 2003, however, this is likely due to the small number of fish captured in 2003. Small, juvenile fish were collected, indicating that successful reproduction of fish had occurred and that recruitment of small fish into the population was occurring. Unfortunately, seining was not conducted, so many of the small fish captured in 1977 by BC Research (1978) were not represented here.

Length-weight relationships derived for each year (Table 9) were also quite similar suggesting that growth of sculpins, based on weight at length, has not changed since mining began. The 1976 data are most relevant to 2003 because similar fishing gear was used. Sculpins captured in 2003 (modal length of 155 mm) may have been slightly smaller than in 1976 (modal length of 175 mm). However, given the similarity in mean size and condition of fish caught in 1976 as in 2003 (Figure 4), suggests that the current size, size distribution and health of sculpins is similar to pre-mining conditions (Fallis et al. 1987).

3.3.3.2. Age

Mean age of sculpins captured in 2003 was 5.7 years, with a range of 3 – 9 years (Table 7). Fallis et al. (1987) and BC Research (1977) did not age sculpins. However, the small size, low lipid content (10%) and small size at age confirm that the sculpin population of Garrow Lake is very slow growing. Fallis et al. (1987) also stated that Garrow Lake sculpin have very slow growth rates relative to other Arctic sculpin populations (Bohn and Fallis, 1978), because of limited food as well as habitat. The deep, circular shape of the lake basin and the anoxic monimolimnion prevents sculpins from existing beneath the pycnocline, thus limiting benthic habitat for sculpins to littoral zone sediments. Given that 2 m of this shoreline habitat is eliminated during winter by ice, available habitat for food production is very limited indeed. The lack of food and cold water temperature explain their small size and slow growth rate relative to fish age.

3.3.3.3. Diet

Stomachs of 7 of 11 sculpins were empty. Of the four stomachs containing food, only a few chironomid larvae were distinguishable, as well as some unidentifiable plant matter and algae (Table 7). The presence of chironomids confirms that they do exist in Garrow Lake, despite the fact that chironomids were not identified from benthic grabs. This suggests that benthic productivity is very limited and even during the "height of summer" there is little food to be had.

Fallis et al. (1987) examined 27 sculpin stomachs of which half (14) were empty. Stomach contents included unidentified eggs, plant material, copepods and a few amphipods. BC Research (1977) found that the copepod *L. macrurus* dominated the diet. We did not identify copepods in the water column or in stomachs, suggesting that this species no longer comprises a significant portion of the sculpin diet. If the zooplankton community has diminished in Garrow Lake, and sculpins have been forced to become strictly dependent on benthic food sources, their population abundance would be expected to have declined. Although catch-per-unit-effort statistics were not recorded, Fallis et al. (1987) captured 51 sculpins in three net sets of 24 h each. The 2003 survey captured only 8 sculpins using gillnets over three days, with a baited prawn trap responsible for the remaining catch. Sculpins seemed to be more difficult to catch in 2003 and therefore may be less abundant than prior to mining (Fallis et al. 1987; BC Research, 1978). Given the lesser amount of habitat available to the population because of the reduced size of the mixolimnion, this result is not surprising.

3.3.3.4. Sex and Maturity

Sex ratio of sculpins captured in 2003 was split evenly between males and females and all fish autopsied appeared sexually mature, with nearly ripe gonads. Fallis et al. (1987) found that most sculpins were female (22 of 27) with 12 having developing eggs. Spawning by sculpins takes place in late fall or winter (Scott and Scott, 1988). Eggs are laid in a small clump within a shallow depression and are guarded by the male during incubation. Given the very slow growth rate and maturation of gonads, it is possible that all of the apparently mature sculpins may not have spawned in winter of 2003/2004 and some individuals may have waited an additional year. Nevertheless, the gonads of most individuals did appear to be quite ripe and these individuals would certainly spawn within the next few months. Fallis et al. (1987) observed eggs in sculpin stomachs in 1976. Presuming these were from sculpins, it is possible that some individuals may spawn during late summer.

3.3.3.5. *Tissue Metals*

Whole body concentrations of manganese, lead and zinc in sculpins were higher in 2003 than was measured in sculpin tissue prior to mining (Fallis et al., 1987; BC Research, 1978) (Appendix C; Table 10). Other metals including arsenic, cadmium, copper, mercury, and nickel were lower or did not differ among years. Elevated lead and zinc concentrations in sediment and the water column as a result of the spill have resulted in increased tissue metals concentrations, however the magnitude of increase is relatively small. Prior to mining, mean zinc concentration was about 30 mg/kg and increased to only 72 mg/kg in 2003. The magnitude increase in lead concentration between pre-mining (0.58 mg/kg) and post mining (0.81 mg/kg) was also similar (Fallis et al., 1987). Fallis et al. (1987) stated that only copper and iron were significantly positively correlated with fish size while all other metals showed no relationship or a declining trend.

Relative to metals in sculpins elsewhere, Bohn and Fallis (1978) found that Garrow Lake sculpins were higher in lead and zinc but lower in cadmium and arsenic than Strathcona Sound sculpins. Elevated lead and zinc concentration prior to mining is presumably due to naturally higher mineralization. The tailings spill has caused a further increase in lead and zinc concentration.

3.3.4. Summary

The sculpin community of Garrow Lake is unique and has survived in this small, brackish water meromictic lake since glacial uplift isolated it from the marine environment nearly 3,000 years ago. The sculpin population has survived twenty years of mining tailings disposal to the monimolimnion and at least one significant tailings spill into the mixolimnion.

Overall, it appears as if the size, distribution, growth rate and reproductive status of the sculpin community has not changed markedly since pre-mining studies by Fallis et al. (1987) and BC Research (1978; 1980) although population size appears to have diminished. Only concentrations of lead and zinc in tissue have increased over the course of mining, likely as a result of the tailings spill in 1984/85. However, based on a survey of the zooplankton and benthic communities and diet of sculpins, it appears that the planktonic invertebrate community of Garrow Lake may have declined since tailings deposition began and that sculpins may be relying solely on benthos as a food source.

Introduction of tailings into the monimolimnion of the lake has caused the bottom layer to become less saline, more homogeneous and has caused a gradual displacement of the pycnocline and mixolimnion upwards in the water column. In 2004, once the lake has been drawn down to its original level, the depth of the mixolimnion above the pycnocline should diminish to about 7.5 or 8 m. Although the magnitude of the thermal and salinity difference between the mixolimnion and the monimolimnion in the lake will be sufficient to maintain separation of the two layers and prevent turnover and mixing (AXYS, 2001) the largest change in the limnology of the lake is the reduced depth of the mixolimnion and surface area of the littoral zone.

Garrow Lake is very unproductive with low water column nutrient concentrations, a depauperate planktonic community and a benthic community dominated by oligochaetes, with very few insect larvae. A reduction in the planktonic community and diminishment in mixolimnion depth and littoral zone area will necessarily reduce habitat area and benthic invertebrate abundance. This loss of habitat and diminishment of food resources will ultimately, reduce population abundance. Sculpins seemed to be more difficult to capture in 2003 than in fishing efforts by Fallis et al. (1987) and BC Research (1978; 1980), which supports the hypothesis of a smaller population size in 2003 than pre-mining.

Nevertheless, sculpins have survived in Garrow Lake throughout the history of mining and tailings deposition to the lake, which is still designated as a tailings disposal facility (DFO, 2002). Provided that sufficient habitat and food resources exist within the spatially small littoral zone, the sculpin population will be sustained through the future.

4. REFERENCES

AXYS Environmental Consulting Ltd. (AXYS). 1991. Concentrations of zinc, lead, cadmium and copper in Garrow Bay, 1990. Prepared by AXYS Environmental Consulting Ltd., Sidney BC for Cominco Ltd. 40 p + App.

AXYS Environmental Consulting Ltd. (AXYS). 2001. Garrow Lake dam. Effect of removal on lake stability and outflow water quality. Prepared for Cominco Ltd. Polaris Operations by P. Erickson, AXYS Environmental Consulting and E. Bennett, Applied Ocean Sciences. March 2001.

Azimuth Consulting Group. 2004. Environmental Effects Monitoring (EEM) study design – Teck Cominco Polaris Mine, Nunavut. Prepared for Teck Cominco, Kimberley BC and Environment Canada, Edmonton AB, by Azimuth Consulting Group Inc. June 2004.

BC Ministry of Environment Lands and Parks. 2003. British Columbia field sampling manual. Prepared by Water, Air and Climate Change Branch, BC WLAP. January 2003. 401 p.

BC Research. 1975. Environmental study of Polaris Mine, Little Cornwallis Island. Project No. 1642. February, 1975. Prepared for Cominco Ltd., Trail BC.

BC Research. 1978. Polaris Mine aquatic environmental studies, 1977. Prepared for Cominco Ltd. Trail BC. 63 p.

BC Research. 1981. Polaris Mine aquatic studies. 1980. Garrow Lake, Pullen Strait. Prepared for Cominco Ltd., Yellowknife NWT. 59 p.

BC Research. 1988. Garrow Lake: Independent sampling (May 1988) and analyses of long term surveillance data. Prepared by BC Research, Vancouver BC for Cominco Ltd. Polaris Operations, NWT, July 1988.

Bohn, A. and B.W. Fallis. 1978. Metal concentrations (As, Cd, Cu, Pb and Zn) in shorthorn sculpin *Myoxocephalus scorpius* and Arctic char *Salvelinus alpinus* from the vicinity of Strathcona Sound, NWT. Water Research 12: 659 – 663.

Department of Fisheries and Oceans. 2002. Metal Mining Effluent Regulations. Ottawa, Ontario.

Dickman, M. and M. Ouellet. 1987. Limnology of Garrow Lake, NWT, Canada. Polar Record 23(146): 531 – 549.

Environment Canada. 1994. Guidance document on collection and preparation of sediments for physicochemical characterization and biological testing. Environmental Protection Series. Report EPS 1/RM/29. Ottawa, Ontario.

EVS Environment Consultants. 1992. Studies into the biological significance of Garrow Lake discharge to Arctic marine waters. Prepared for Cominco Ltd. Vancouver BC by EVS Consultants, North Vancouver BC. March 1992. 53 p. + App.

Fallis, B.W., S. M. Harbicht and B.J. Mackenzie. 1987. A preliminary study of the limnology and biology of Garrow Lake, Northwest Territories; an Arctic meromictic lake. Department of Fisheries and Oceans, Winnipeg, MB. Unpublished data. ii + 55 p.

Gartner Lee. 2001. Polaris Mine decommissioning and reclaimation plan. Prepared for Cominco Ltd., Polaris Mine by Gartner Lee Ltd. Vancouver BC. GLL 20-935

Ouellet, M. and M. Dickman. 1983. The meromictic Garrow Lake, Canadian Arctic Archipelago. INRS-Eau, Rep. 77. 85 p.

Page, P., M. Ouellet and M. Dickman. 1984. Isotopic analysis (^{18}O, ^{13}C, ^{14}C) of two meromictic lakes in the Canadian Arctic Archipelago. Limnol. Oceanogr. 29(3): 564 – 573.

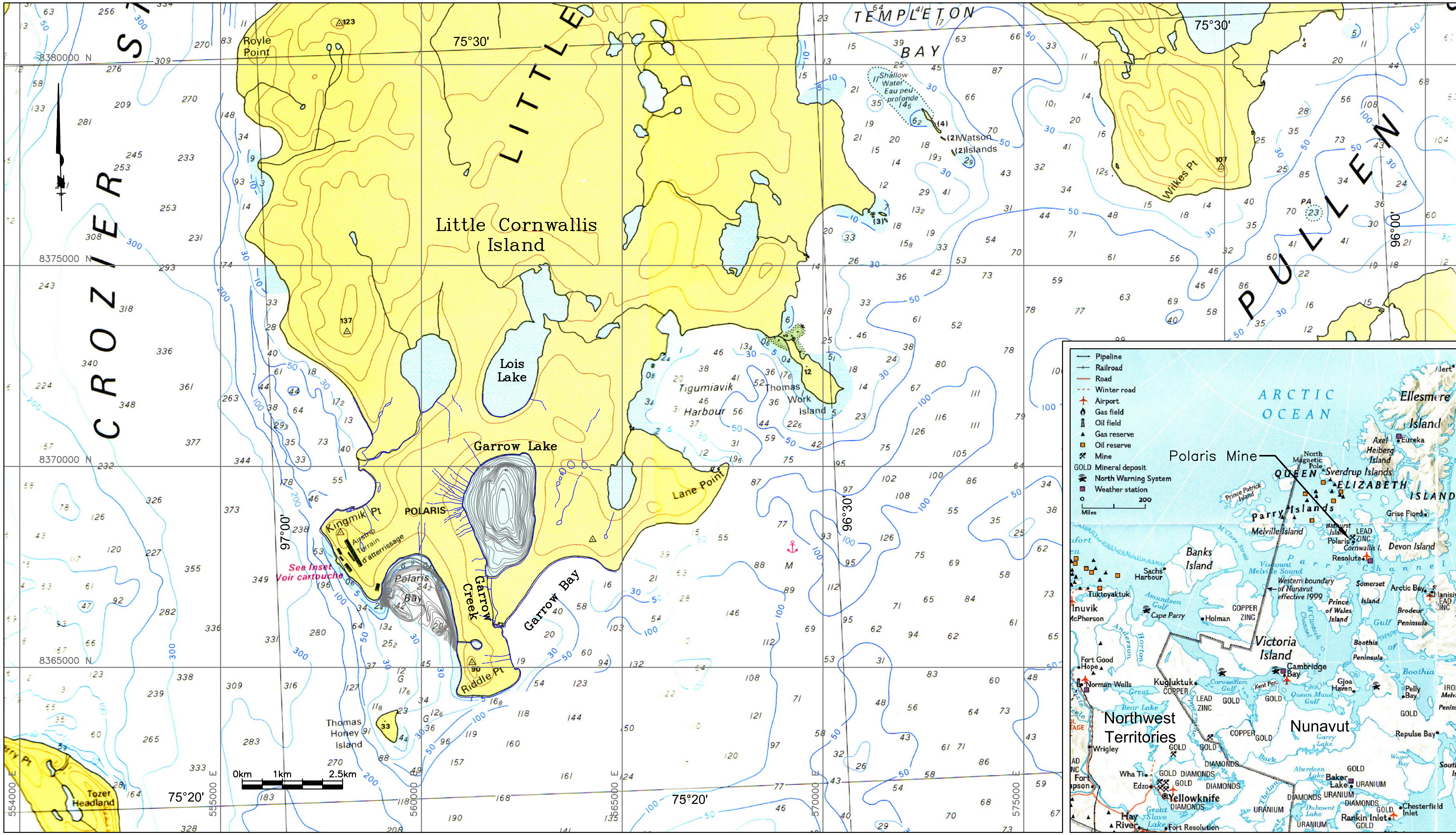
Pennack, R.W. 1978. Fresh-water invertebrates of the United States. Second Edition. John Wiley and Sons, Toronto. 803 p.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. No. 219. 731 p.

Stewart, K.M. and R.F. Platford. 1986. Hypersaline gradients in two Canadian high Arctic lakes. Can. J. Fish. Aquat. Sci. 43: 1795 – 1803.

Thornsteinsson, R. and J.W. Kerr. 1968. Cornwallis Island and adjacent smaller islands, Canadian Arctic archipelago. Geol. Surv. Can. Pap. 67-64: 1 – 16.

FIGURES



Garrow Lake, Polaris Bay contour data and surrounding creeks digitized from Map 1 Sampling Sites 1980 prepared by B.C. Research January 1978

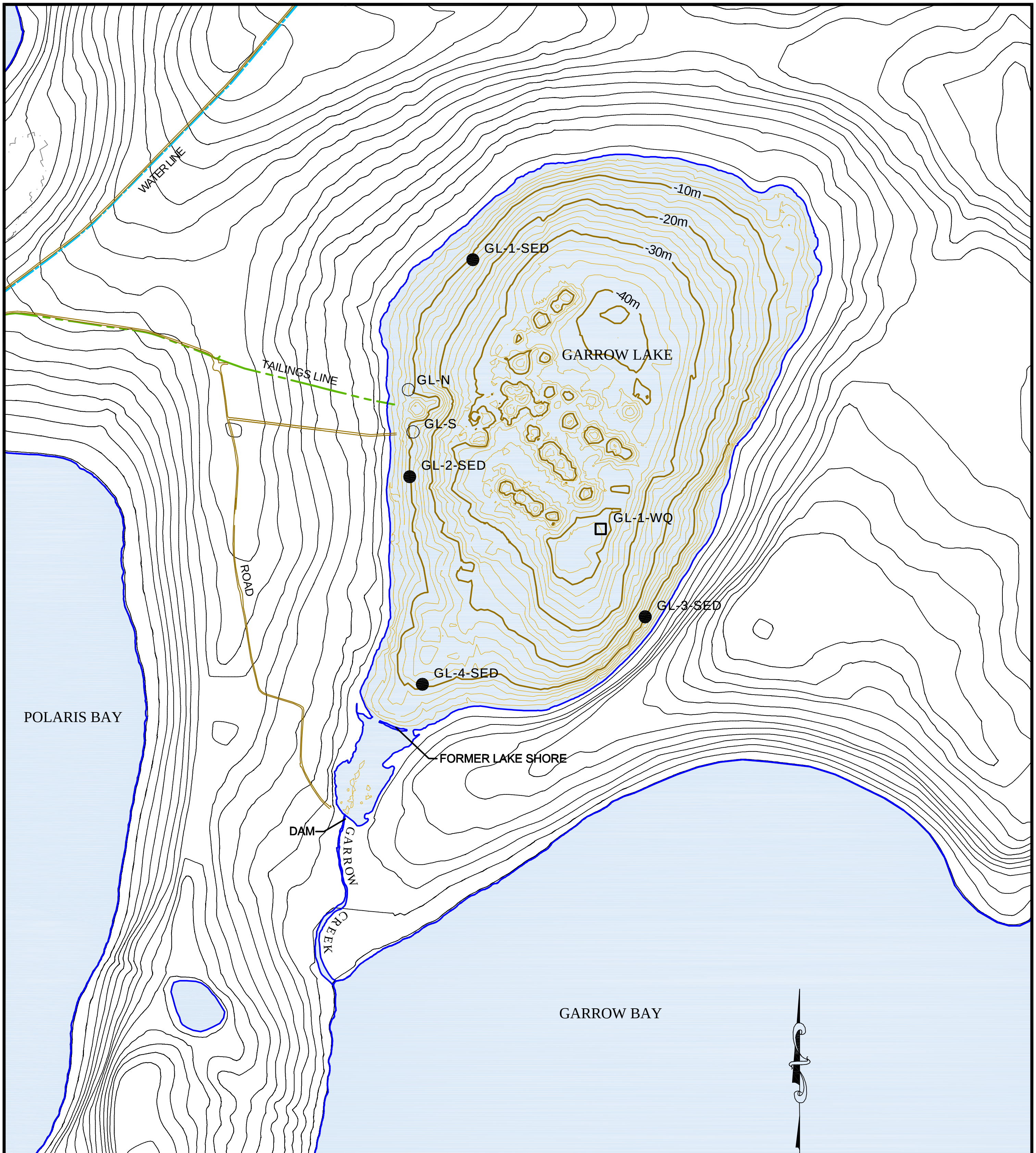
Other data from Crozier Strait And/Et Pullen Strait 7935 corrected 2003-03-28 published by the Canadian Hydrographic Service

Insert Location Map from The Modern North: Roads, Radar Stations, and the End of Isolation, Produced by National Geographic Maps for National Geographic Magazine, Sept. 1997

AZIMUTH

Azimuth Consulting Group Inc.
218-2902 West Broadway
Vancouver BC, V6K 2G8

PROJECT:	Polaris
TITLE:	**Polaris Mine Study Area**
DRAWN BY:	BT
CHK. BY:	RB
PROJECT No:	TC-03-03
SCALE:	
DATE:	6/10/2003 2:52 PM
CLIENT:	Teck Cominco
	Figure 1-1



LEGEND

- ● BENTHOS, ZOOPLANKTON, SEDIMENT
- □ LAKE WATER (VERTICAL PROFILE)
- ○ SEDIMENT

NOTE:

SURROUNDING CREEKS DIGITIZED FROM MAP 1 SAMPLING SITES 1980, PREPARED BY B.C. RESEARCH JANUARY 1978.

0 100 300 500 750 1,000

SCALE 1:25,000

AZIMUTH 218 - 2902 WEST BROADWAY VANCOUVER BC, V6K 2G8	CLIENT: TECK COMINCO	REVISIONS	JOB NO.: TC-03-03
	SHEET TITLE: LOCATION OF LITTORAL ZONE SEDIMENT / BIOTA STATIONS AND WATER QUALITY PROFILE STATION - GARROW LAKE, AUGUST 2003	CHECKED BY: RB	FIGURE: 002
	PROJECT: POLARIS	SCALE: 1:25,000	DATE: 11-22-2004
		Charone www.charone.ca	DRAWN BY: CCL

Figure 3a. Temperature (C) depth profile in Garrow Lake, 2003.

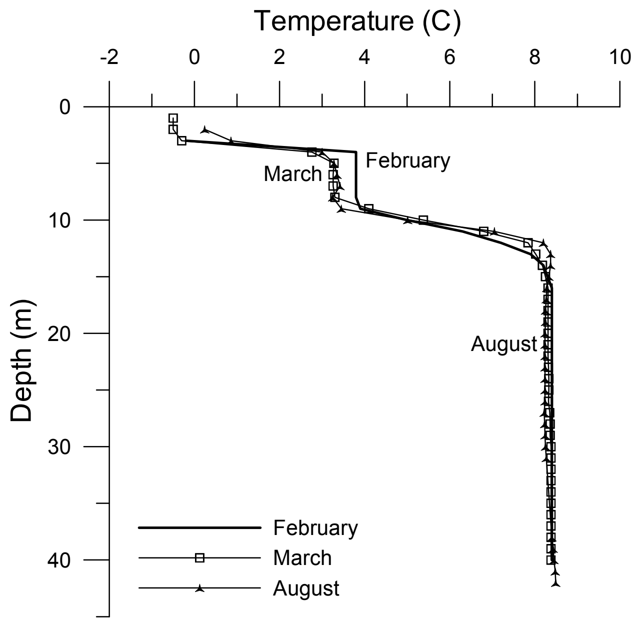


Figure 3b. Dissolved oxygen (mg/L) depth profile in Garrow Lake, 2003.

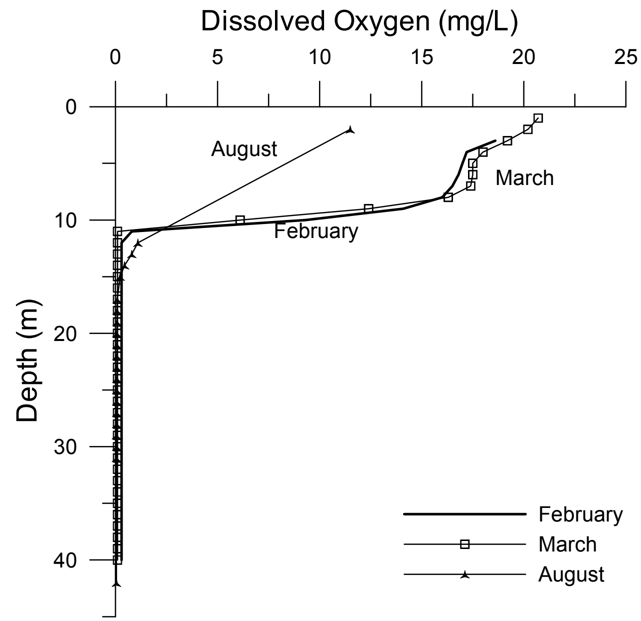


Figure 3a. Temperature (C) depth profile in Garrow Lake, 1976.

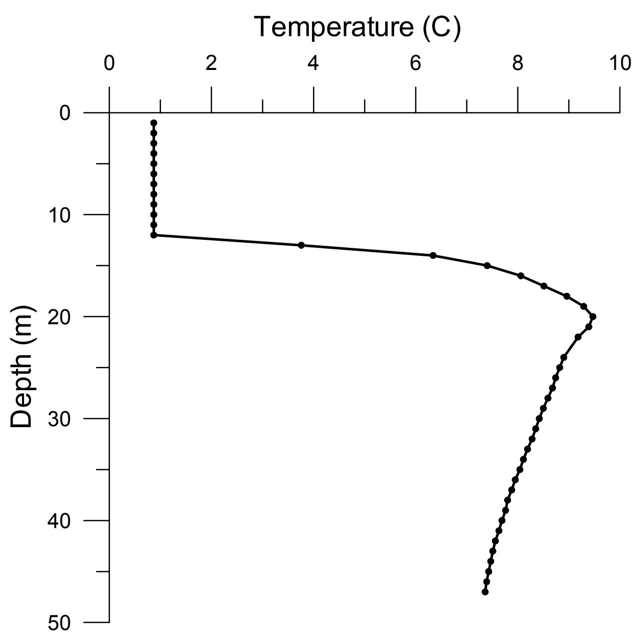


Figure 3b. Dissolved oxygen (mg/L) depth profile in Garrow Lake, 1976.

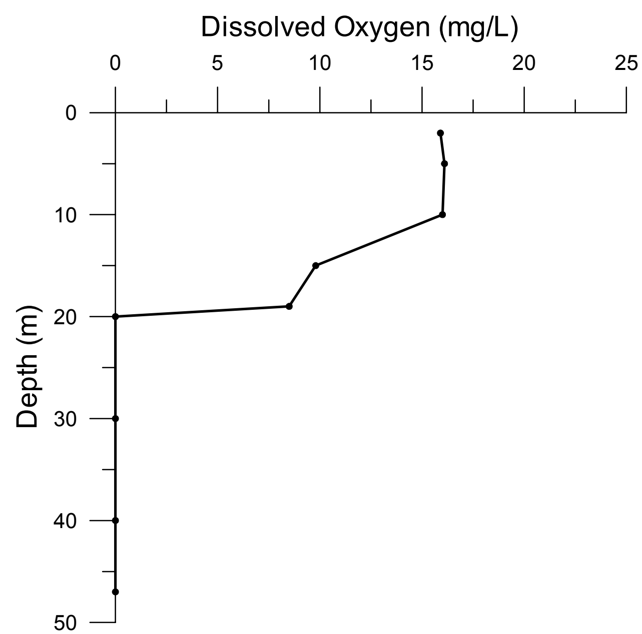


Figure 3c. Salinity (ppt) depth profile in Garrow Lake, 2003.

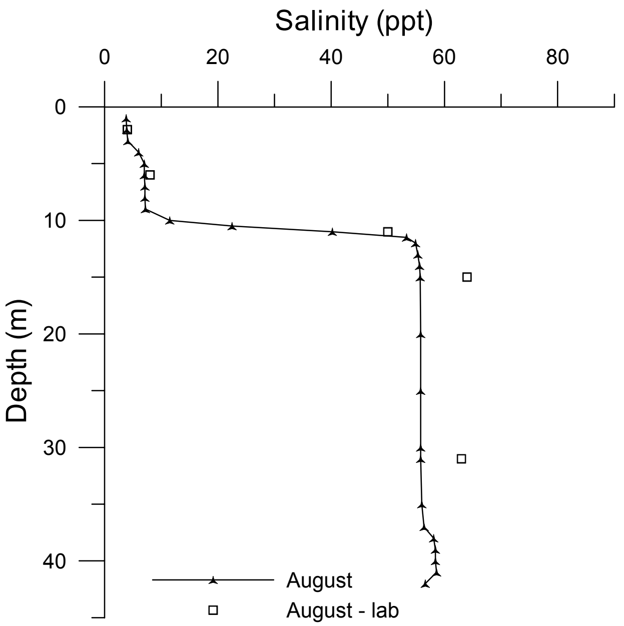


Figure 3c. Salinity (ppt) depth profile in Garrow Lake, 1976.

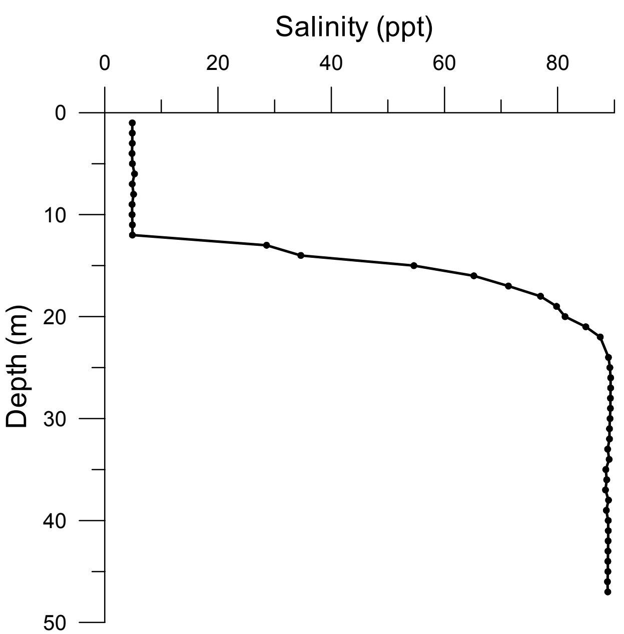
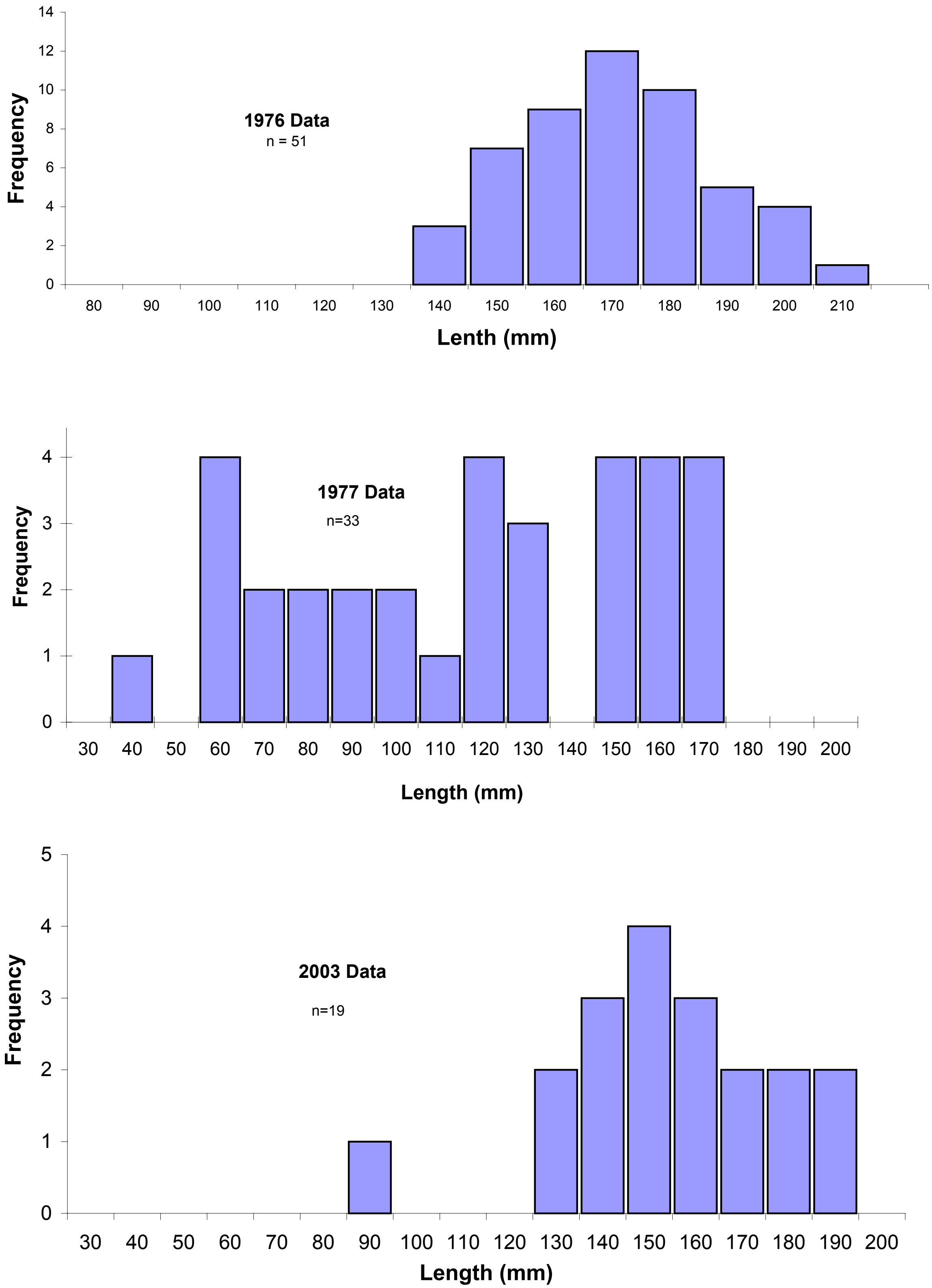


Figure 4. Comparison of length - frequency distribution of fourhorn sculpin from 1976 (Fallis et al., 1987) 1977 (BC Research (1978) and 2003.



TABLES

Table 1. Details of sediment, water and biota collections from Garrow Lake, August 8 – 10, 2003.

Station	UTM		Depth	Parameter				Observations
	N	E	(m)	Water	Benthos	Zooplankton	Sediment	
GL-1-SED	8369695	0561130	7.5		X	X	X	Thin light brown soft flocculent surface layer. Some algal growth on surface. Beneath, sediment is uniform grey clay, uniform consistency and appearance.
GL-2-SED	8368612	0561266	6.5 – 8.5		X	X	X	Similar in appearance to SED-1; rusty oxidized, brown surface layer over battleship grey layer of uniform consistency with fine organic matter.
GL-3-SED	8368424	0562669	6 – 8		X	X	X	Fine brown organic 2 – 3 mm layer over grey-brown clay. Grab 3 different from 1 and 2 with darker sediment and more organically rich layer.
GL-4-SED	8367556	0561764	7		X	X	X	Fine orangey-brown layer (2 – 3 mm) over grey-brown silty clay. Benthos not apparent.
GL-N-SED			8				X	Sediment appeared to be consistent with tailings; chalky white, fine grain flocculent sediment throughout grab with black sticky varves.
GL-S-SED			8				X	
GL-1-WQ	8369695	0561130	0 – 42	X				

Table 2. Summary of Garrow Lake water column metals concentration (mean, range; ug/L), 1976 - present.

			Arsenic		**Cadmium**		**Copper**		**Lead**		**Nickel**		**Zinc**	
		n	mean	range	mean	range	mean	range	mean	range	mean	range	mean	range
June 1976[AB]	Mixolimnion	19	0.3	0.1 - 1.1	0.3	0.1 - 1.3	1	0.2 - 2.7	0.3	0.1 - 0.5			3	1.3 - 6.7
(Fallis et al., 1987)	Pycnocline	4	1.9	0.3 - 3.5	0.2		2.8	1.5 - 4.1	0.4				2.9	1.9 - 3.8
	Monimolimnion	7	13.4	4.7 - 20.4	0.2	0.1 - 0.2	4	0.9 - 14.5	0.3	0.1 - 0.5			1	0.1 - 2.2
August 1977	Mixolimnion	12	<1		0.2	<0.1 - 0.6	10	1 - 60	5	<1 - 16			24	6 - 100
(BC Research 1978)	Pycnocline	17	<1		0.3	<0.1 - 0.6	12	2 - 22	3	<1 - 7			21	4 - 50
	Monimolimnion	13	4.6	<1 - 6.4	<0.5	<0.5	18	5 - 22	8	<5 - 27			18	8 - 28
May & August 1980	Mixolimnion	14	<1		>0.5		19	6 - 32	<1				49	20 - 95
(BC Research 1981)	Pycnocline	24	<1		>0.5		23	13 - 36	<5				46	28 - 85
	Monimolimnion	18	8	3.4 - 13	>0.5		16	3 - 50	<10				48	15 - 113
August 1981	Mixolimnion	2			>0.5		1.0		<10		7		10	9 - 12
(Ouellet & Dickman 87)	Pycnocline	1			1.0		>1		<10		10		9	
	Monimolimnion	7			<1.2		<2.4		<24		11		16	7 - 34
October 1981	Mixolimnion	2	0.06	0.06 - 0.06	0.06	0.06 - 0.06	0.35	0.3 - 0.4	0.35	0.3 - 0.4			3.3	2 - 4.6
(Fallis et al. 1987)	Pycnocline	3	0.29	0.17 - 0.34	0.3	0.2 - 0.4	5.5	1.5 - 8.9	1.0	0.8 - 1.2			5.7	4.2 - 6.8
	Monimolimnion	27	13.3	1.6 - 20	0.1	<0.05 - 0.2	1.3	<0.1 - 6.4	0.3	<0.1 - 1.8			4.1	1.2 - 6.3
September 1984	Mixolimnion	1							5				20	
(BC Research, 1988)	Pycnocline	1							5				40	
	Monimolimnion	1							14				30	
September 1987	Mixolimnion	1							7				230	
(BC Research, 1988)	Pycnocline	1							5				220	
	Monimolimnion	2							25				45	
May 1990	Mixolimnion	1							10				410	
(BC Research, 1988)	Pycnocline	1							21				1,820	
August 1998	Mixolimnion	4	<1		1.0	<1 - 1	1.0	<1 - 1	2	<1 - 5	<2		198	150 - 320
(Teck Cominco)														
August 1999	Mixolimnion	4	<1		1.0		2.3	<1 - 4	15.3	13 - 22	5	4 - 5	233	220 - 270
(Teck Cominco)														
August 2001	Mixolimnion	4	<1		<2		1.5	<1 - 2	1.8	<1 - 3	4	3 - 5	223	180 - 330
(Teck Cominco)														
August 2003	Mixolimnion	2	<1	<1 - 1	0.5	0.3 - 0.6	1	0.9 - 1.4	0.8		3	2.1 - 3.7	184	127 - 240
	Pycnocline	1	<1		2.5		7		4		9		1,140	
	Monimolimnion	2	1	<1 - 1	0.4	0.3 - 0.5	5	3.8 - 5.2	12	11.8 - 12.1	9	8.8 - 9.0	278	217 - 338

[A] Values below detection limit were treated as absolute values.

[B] Dissolved metals, otherwise, total metals

Table 3. Conventional parameters and total metal concentration (ug/L) in water samples collected from Garrow Lake, August 2003.

Sample ID	GL-1-WQ-2m	GL-1-WQ-6m	GL-1-WQ-11m	GL-1-WQ-15m	GL-1-WQ-31m
CONVENTIONAL PARAMETERS					
pH	8.2	8.0	7.2	7.3	7.4
Salinity o/oo	4.0	8.0	50.0	64.0	63.0
Temperature (C)	0.2	3.4	7.1	8.3	8.3
TOTAL METALS (μg/L)					
Aluminum	<100	<100	<100	<100	<100
Arsenic	<1	<1	<1	1.0	<1
Cadmium	0.3	0.6	2.5	0.3	0.5
Copper	0.9	1.4	7.1	5.2	3.8
Lead	0.8	0.8	4.3	11.8	12.1
Molybdenum	<2	3	2	4	<2
Nickel	2	4	9	9	9
Zinc	127	240	1140	338	217

Table 4. Total metals (mg/kg dw) in Garrow Lake sediment, prior to mining.

	Fallis et al. (1987) June 1976 (n=9)		BC Research (1978) August 1977 (n=2)		BC Research (1981) May and August 1980 (n~19)	
Total Metals	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Arsenic	6	2 - 11	5	4 - 6	4.7	3.2 - 57.6
Cadmium	1.00	<0.25 - 3.1	0.7	0.4 - 1.0	1.3	0.3 - 3.0
Copper	23	15 - 31	18.5	18 - 19	22	12 - 27
Lead	0.25	<0.25 - 0.75	8	8	8.4	5.9 - 11
Manganese	150	59 - 209				
Mercury	0.15	0.005 - 0.025			<0.05	<0.5 - 0.6
Nickel	19	12 - 39				
Zinc	61	30 - 103	65	59 - 70	84	52 - 96
Depth Range (m)		3 - 48		12 and 19		5 - 48

Table 5. Conventional sediment parameters and total metals concentration (mg/kg) in Garrow Lake littoral zone sediment.

	Garrow Lake Stations (Aug 2003)					Tailings Spill Area		1976 (Pre-Mine)
Sample ID	**GL-1**	**GL-2**	**GL-3**	**GL-4**		**GL-N North**	**GL-S South**	**Fallis et al. 1987**
Depth (m)	**7.5**	**6.5 - 8.5**	**6 - 8**	**2 - 7**	**Mean**	**7 - 8**	**7 - 8**	**3 - 48**
CONVENTIONAL PARAMETERS								
Organic Parameters								
Total Organic Carbon (% dw)	<0.8	1.2	<0.9	2.4	1.3	-	-	-
Particle Size (%)								
Gravel (>2.00mm)	<0.1	<0.1	0.9	<0.1	0.3	-	-	-
Sand (2.00mm - 0.063mm)	5.4	7.5	12.3	6.8	8.0	-	-	-
Silt (0.063mm - 4um)	64.2	68.3	70.3	76.1	69.7	-	-	-
Clay (<4um)	30.4	24.2	16.5	17.1	22.1	-	-	-
Total Metals								
Aluminum	8560	7380	6030	6680	7162	781	547	
Antimony	<10	<10	<10	<10	<10	<20	<20	
Arsenic	11	9	<5	9	8.5	<10	<10	6
Barium	1420	1070	1040	1150	1170	122	124	
Beryllium	0.6	<0.5	<0.5	<0.5	0.5	<1	<1	
Cadmium	1.9	3	1.1	1.4	1.9	17	15	1.0
Chromium	19	18	15	16	17	22	9	
Cobalt	6	6	4	5	5.3	<4	<4	
Copper	31	32	17	24	26	68	24	23
Lead	114	308	47	78	137	1000	680	0.25
Manganese	183	222	175	172	188	487	493	150
Mercury	0.1	0.09	0.05	0.17	0.1	0.08	0.06	0.15
Molybdenum	4	<4	<4	<4	4	<8	<8	
Nickel	36	30	19	26	28	<10	<10	19
Strontium	268	209	217	289	246	64	52	
Zinc	700	1210	498	560	742	7360	5980	61

Table 6. Abundance and density of benthic invertebrates in Garrow Lake and Garrow Creek, Little Cornwallis Island, August, 2003.

Location Date Species/Group	Stage**	Creek-mid 4-Aug-03	Creek-up 4-Aug-03	GL-1 7-Aug-03	GL-2 7-Aug-03	GL-3 8-Aug-03	GL-4 8-Aug-03
FORAMINIFERA							
Unidentified							350
NEMATODA							
Unidentified		5		1		20	
OLIGOCHAETA							
Unidentified	juv*	5		17	65	200	100
Enchytraidae		471	10	418	390	1470	550
COPEPODA							
Cyclopoida	juv*						1
EPHEMEROPTERA							
Baetidae							
Baetis bicaudatus	N	2					
DIPTERA							
Chironomidae	P	1					
Tanypodinae							
Procladius	L	1					
Orthocladiinae							
Eukiefferiella	L	1					
Orthocladius	L	1					
Diamesinae							
Diamesa	L	4	1				
Total		491	11	436	455	1690	1001
Oligochaete Abundance				435	455	1670	650
Oligochaete Density (#/m^2)				18125	18958	69583	27083

**Key:
L = Larva
N = Nymph
P - Pupa
juv = Juvenile
* = Too small to be idetified further, damaged

Table 7. Biological data for fourhorn sculpin from Garrow Lake, August 2003.

Code	Total Length (mm)	Body Weight (g)	Lipid (%)	Age (yrs)	K[1]	Gender	Maturity	Stomach Content	Condition	
									Liver	External
SC-1-03	149	24.8	14.3	6	0.75	F	Ripe	1 chironomid and plant material	large, healthy	good
SC-2-03	129	16.0	8.8	5	0.75	F	Ripe	3 chironomids, small stomach	healthy, pink	good
SC-3-03	138	20.5	12.8	6	0.78	M	Ripe	Empty	large, healthy	good
SC-4-03	163	34.5	15.7	4	0.80	F	Ripe	Empty	healthy	healthy
SC-5-03	184	37.9	7.2	9	0.61	M	Ripe	Unidentified material in stomach	healthy	healthy
SC-6-03	160	25.7	8.9	6	0.63	M	Ripe	Empty	healthy	healthy
SC-7-03	121	12.2	10.6	4	0.69	M	Ripe	Empty	healthy	healthy
SC-8-03	182	40.3	7.8	6	0.67	F	Ripe,well-developed, large	Empty	healthy	healthy
SC-9-03	146	21.4	10.6	7	0.69	M	Ripe	Empty	healthy	healthy
SC-10-03	142	20.0	8.7	7	0.70	F	Ripe	Empty, algae lower in intestine	healthy	healthy
SC-11-03	85	4.2	9.9	3	0.68	F	Ripe, large GSI, may spawn.	Empty	healthy	healthy
SC-12-03	176	34.8	-	-	0.64	-	-	-	-	-
SC-13-03	157	31.3	-	-	0.81	-	-	-	-	-
SC-14-03	159	31.2	-	-	0.78	-	-	-	-	-
SC-15-03	141	21.2	-	-	0.76	-	-	-	-	-
SC-16-03	139	17.7	-	-	0.66	-	-	-	-	-
SC-17-03	174	41.2	-	-	0.78	-	-	-	-	-
SC-18-03	132	14.9	-	-	0.65	-	-	-	-	-
SC-19-03	161	24.0	-	-	0.58	-	-	-	-	-
Mean	149	24.9	10.5	5.7	0.70	-	-	-	-	-
SD	23.8	10.1	2.7	1.7	0.07	-	-	-	-	-

[1]K = Condition Factor = (body weight x 10^5) / total length^3

Note: SC-1-03 to SC-11-03 used for tissue chemistry analyses, the other 8 were measured live and released.

Table 8. Mean (range) total length (mm), weight (g) and condition (K) of Garrow Lake sculpin from pre-mine (1976, Fallis et al. 1987; 1977, BC Research 1978) and 2003.

Year	n	Total Length (mm)			Body Weight (g)			Condition Factor (K)		
		Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
1976	51	155	120 - 194	2	26.6	10 - 45		- (0.72^)	-	-
1977	33	112	38 - 168	40	10.8	0.9 - 26.6	8.2	0.56# (0.77^)	(0.43 - 0.70)#	0.07#
2003	19	149	85 - 184	24	24.9	4.2 - 41.2	10.1	0.70 (0.75^)	(0.58 - 0.81)	0.07

[1]K = Condition Factor = (body weight x 10^5) / total length^3
^ calculated from mean length and weight
# using fish with minimum length of 90mm

Table 9. Length - weight relationship for Garrow Lake sculpin, 1976, 1977 and 2003.

Year	n	Regression	R^2
1976[A]	51	Log_{10}(weight) = 2.82 * Log_{10}(length) - 4.78	0.99[A]
1977	33	Log_{10}(weight) = 2.40 * Log_{10}(length) - 3.98	0.97
2003	19	Log_{10}(weight) = 2.96 * Log_{10}(length) - 5.06	0.97

[A] Regression equation for 1976 data derived using curvilinear plot.
1976 (Fallis et al. 1987); 1977 (BC Research, 1978)

Table 10. Mean (range) of fourhorn sculpin whole body metal concentration (mg/kg ww) from Garrow Lake during pre-mine (1976, Fallis et al. 1987; 1977, BC Research 1978; 1980, BC Research 1981) and 2003 (post-mine).

	Pre - Mine						**Post-Mine**	
	1976 (n=10)		**1977** (n=34)		**1980** (n = 35)		**2003** (n=11)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Body Length (mm)			112	38 - 168	132	78 - 164	145	85 - 184
Body Weight (g)			11	1 - 27	10	2 - 19.2	23	4 - 40
Total Metals (mg/kg ww)								
Aluminum							16	3 - 40
Antimony							<0.01	
Arsenic	0.74	0.47 - 1.18	1.15	0.53 - 2.58	0.55	0.22 - 1.1	0.88	0.53 - 1.48
Barium							3.33	1.59 - 5.36
Beryllium							<0.1	
Cadmium	0.07	0.04 - 0.12	0.11	0.01 - 0.24	0.1	0.02 - 0.33	0.057	0.026 - 0.103
Chromium							<0.1	
Cobalt							0.12	0.07 - 0.19
Copper	1.17	0.53 - 1.67	2.16	1.09 - 12.69	2.4	1.0 - 10.7	0.95	0.46 - 1.55
Lead	0.58	0.25 - 0.96	0.38	0.09 - 0.84	0.24	0.10 - 0.67	0.81	0.43 - 1.71
Manganese	0.77	0.56 - 1.03					3.15	1.24 - 6.46
Mercury	0.01	<0.01 - 0.02					0.006	<0.005 - 0.012
Molybdenum							<0.01	<0.01 - 0.01
Nickel	0.35	0.06 - 1.06					0.1	<0.1 - 0.2
Strontium							32	21 - 46.1
Zinc	28.9	15.6 - 41.8	34.4	16.0 - 66.7	34.5	16.3 - 55	72.3	50.4 - 120

PHOTOS

Photo 1 Garrow Lake showing ice cover August 4, 2003.

Photo 2 Launching the boat in Garrow Lake, August 8, 2003.

Photo 3 Garrow Lake showing gravel shoreline and mostly ice-free, August 8, 2003.

Photo 4 Garrow Lake Fourhorn sculpin *Myoxocephalus quadricornis*.

Photo 5 Garrow Lake fourhorn sculpin (140 mm total length) prior to dissection.

APPENDICES

Appendix A Department of Fisheries and Oceans Habitat Authorization

Fisheries and Oceans / Pêches et Océans

AUTHORIZATION FOR WORKS OR UNDERTAKINGS AFFECTING FISH HABITAT

AUTHORISATION POUR DES OUVRAGES OU ENTREPRISES MODIFIANT L'HABITAT DU POISSON

DFO File No. 02-HCAA-000-000063
Authorization No./N° de l'autorisation

Authorization Issued To/Autorisation délivrée à

Name: Bruce Donald

Address: Teck Cominco Ltd.
Polaris Operations
Box 188
Resolute Bay, Nunavut
Canada X0A 0E0

Telephone: (867) 253-2201

Facsimile: (867) 253- 6862

Location of Project/Emplacement du projet

Polaris Mine is located on Little Cornwallis Island (centred at 391500 E, 8 369 000 degrees N UTM zone 15) in the Qikiqtalluk Region of Nunavut (approximately 100 km northwest of Resolute Bay). The project site encompasses fish habitat at Garrow Lake, Garrow Creek, and Crozier Strait.

Valid Authorization Period/Période de validité

From/De: June 2, 2003 **To/À:** October 30th , 2004

Description of HADD Works or Undertakings/Description des ouvrages ou entreprises

In order to decommission Teck Cominco's (TCL) Polaris Mine, draining of water from the surface layer of Garrow Lake (the mine's tailings facility) and partial removal of Garrow Lake Dam will be required. This will result in the harmful alteration, disruption and/or destruction of fish habitat (HADD) due to lowering of the level of the lake and excavation of benthic fish habitat adjacent to the dam. Partial removal of a sheet-pile dock on Crozier Strait, and excavation to contour the adjacent marine foreshore area will also temporarily alter fish habitat during construction. The above works will hereafter be referred to as the "Project Activities".

Summary of Habitat Loss

- Lowering the lake level of Garrow Lake and removal of the Garrow Lake Dam will dewater approximately 30 ha. of fish habitat. Garrow Lake has been documented to be habitat for fourhorn sculpin *(Myoxocephalus quadricornus)* and has the potential to provide habitat for other fish species. Garrow Lake drains into Garrow Bay via Garrow Creek and provides supporting habitat for other fish species in Crozier Strait.

- Partial removal of the dock and excavation of the marine foreshore area at Polaris will alter 2512 m^2 of fish habitat. The marine foreshore area at Polaris is habitat for arctic charr, arctic cod, and marine mammals (e.g., narwhal, ringed seals, walrus).

Conditions of Authorization/Conditions de l'autorisation

1.0 All works and undertakings shall be undertaken in accordance with the documents approved by DFO entitled:

1.1 Application for Authorization for Works or Undertakings Affecting Fish Habitat submitted to DFO, dated October 5th, 2001 and signed by Bruce Donald, TCL.

1.2 The approved documents include the works or undertakings, proposed mitigative measures and compensation requirements (the *Project Plan*).

2.0 To compensate for the harmful alteration, disruption or destruction of fish habitat as a result of the Project Activities, the following shall be implemented, maintained and monitored by TCL, as indicated in the *Project Plan* or otherwise specified by DFO:

2.1 To rehabilitate and enhance fish habitat in Garrow Lake, upon completion of water withdrawal and dam removal, TCL shall conduct the following as indicated in the *Project Plan*:

Restore a natural stream channel to Garrow Bay by removing at least 19,000 cubic metres of dam fill material. The constructed 500 m long by 15 metre wide stream channel through the decommissioned dam will emulate natural stream conditions with a gravel/cobble streambed. Enhancement efforts will result in the banks of the remaining dam having a slope of at least 4:1.

The enhanced stream channel draining Garrow Lake will be on average 11 m wide and restore natural drainage patterns in the Garrow Lake area. Clean rock rip-rap will be placed to prevent erosion in the vicinity of the decommissioned dam;

2.1.3 A Fish Habitat Monitoring Report shall be submitted to DFO, including detailed photographs of Garrow Lake, stream channel development, prior to completion of the work. The intent of this Monitoring Report shall be to assess the success of fish habitat compensation upon implementation.

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2.2 To rehabilitate and enhance fish habitat in the area of the dock and marine foreshore area, TCL shall conduct the following as indicated in the *Project Plan*:

2.2.1 Partial removal of the dock pilings to a depth of 3m below the low tide water level will develop natural inter-tidal conditions with slope and substrate adequate to control erosion into Crozier Strait.

2.2.2 Excavation of the inter-tidal shoreline adjacent to the dock to develop 12,800 m^2 of marine nearshore habitat with a slope of less than 17.5:1 to prevent erosion.

2.2.3 A Fish Habitat Monitoring Report shall be submitted to DFO, including detailed photographs of the marine foreshore area adjacent to the dock. Underwater photographs or video footage of the dock will be provided to DFO. The intent of this Monitoring Report shall be to assess the success of fish habitat compensation upon implementation.

3.1 The following mitigation measures are intended to minimize or prevent further harmful alteration, disruption or destruction of fish habitat adjacent to Garrow Lake and Garrow Creek:

3.1.1 Excavation of the dam will be conducted prior to spring break-up in 2004 and all silt and loose fines shall be removed from the construction area prior to spring break-up.

3.1.2 Rock rip-rap will be placed on the banks of the stream channel adjacent to the dam to prevent erosion and sedimentation.

3.1.3 Appropriate mitigation measures will be implemented to control TSS, including the construction of a dam at the discharge of Garrow Lake, if water quality deteriorates due to release of sediment. Other contingencies may be required as mitigation measures to protect fish habitat such as silt fences.

3.2 Appropriate mitigation measures will be implemented in the marine foreshore area, at and adjacent to the dock, as follows:

3.2.1 To minimize erosion in the marine foreshore area mitigation measures will be implemented to prevent deposition of sediment into the marine waters by use of silt fences and a floating silt curtain along the perimeter of the marine foreshore area if this is deemed necessary.

Water quality sampling for turbidity will be conducted daily during work and mitigation measures will be implemented to address potential sediment release.

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4.0 Monitoring will be conducted to ensure that compensation measures are successfully implemented and identify potential long-term project effects:

- 4.1 Sampling of TSS and turbidity will be undertaken by TCL in different strata of Garrow Lake to monitor stability of the halocline and to confirm the absence of contaminants in the upper strata of the lake.
- 4.2 A study of the metal concentrations in sediments adjacent to the shore of Garrow Lake, Garrow Creek, and the centre of Garrow Bay will be commissioned by TCL. TCL will provide a study design prior to July 2003 for approval by DFO.
- 4.3 TCL will conduct a study on fish in Garrow Lake and Garrow Bay to examine metal levels in fish muscle tissue. A study design will be proposed by TCL to collect fish tissue samples for analysis by DFO. TCL will propose a sampling protocol for this study prior to July 2003.
- 4.4 Erosion will be monitored on the shore of Garrow Lake and Garrow Creek Stream channel. The study objective will be to quantify erosion rates adjacent to the lake and stream channel. This study will be proposed by TCL for DFO approval prior to July 2003.
- 4.5 TCL will conduct water quality sampling for TSS and turbidity at the Garrow Lake outflow in Garrow Creek. TCL will provide a Water Quality Sampling Report of TSS levels to the DFO Eastern Arctic Office on an annual basis for the duration of this authorization. Water quality sampling for TSS will not cease at the Garrow Lake outflow prior to 2004.
- 4.6 TCL will conduct water quality sampling for TSS and turbidity along the marine foreshore area prior to, during, and immediately following work in the inter-tidal zone. At least seven water quality samples will be routinely collected on a daily basis in the marine foreshore area during work in the inter-tidal zone. Two water quality samples per day will be collected adjacent to the dock.

5.0 A DFO Fishery Officer shall be notified at the Iqaluit Office ((867) 979-8000) of the proposed start time prior to commencement of the work.

6.0 Any deviation from the *Project Plan*, the construction schedule or the mitigation and compensation measures stated above that may potentially affect fish or fish habitat, must be discussed and approved in writing by DFO prior to implementation.

7.0 A copy of this Authorization shall be at the Polaris work site during all work periods. Work crews shall be made familiar with the conditions of this Authorization prior to implementation of the works or undertakings.

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The holder of this Authorization is hereby authorized under the authority of subsection 35(2) of the *Fisheries Act*, R.S.C., 1985, c. F. 14, to carry out the work or undertaking described herein. This Authorization is valid only with respect to fish habitat and for no other purposes. It does not purport to release the applicant from any obligation to obtain permission from or to comply with the requirements of any other regulatory agencies.

Failure to comply with any condition of this Authorization may result in charges being laid under the *Fisheries Act*.

This Authorization form should be held on site and work crews should be made familiar with the terms and conditions of this authorization.

Le détenteur de la présente est autorisé en vertu du paragraphe 35(2) de la *Loi sur les pêches*, L.R.C. 1985, ch. F. 14, à exploiter les ouvrages ou entreprises décrits aux présentes.
L'autorisation n'est valide qu'en ce qui concerne l'habitat du poisson et pour aucune autre fin. Elle ne dispense pas le requérant de l'obligation d'obtenir la permission d'autres organismes réglementaires concernés ou de se conformer à leurs exigences.

En vertu de la *Loi sur les pêches*, des accusations pourront être porteés contre ceux qui ne respectent pas les conditions prévues dans la présente autorisation.

Cette autorisation doit être conservée sur les lieux des travaux, et les équipes de travail devraient en connaître les conditions.

Date of Issuance: Following NIRB Environmental Assessment

Signed by:

Burt Hunt
Area Director
Eastern Arctic Area
Fisheries and Oceans Canada
Central and Arctic Region

Prepared by:

Jordan DeGroot
Area Habitat Biologist
Fish Habitat Management
Eastern Arctic Area
Fisheries and Oceans Canada

Bruce Donald- Reclamation Manager, Environment and Corporate Affairs

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Witness:

Teck Cominco Ltd.

Signature: Brian McKenzie

Teck Cominco Ltd.

Signature: B McDonald

Copy signed by TCL received by DFO

Signature: Stephanie Critch
Date: July 23, 2003

Appendix B Garrow Lake Water Chemistry Data

Appendix B. Vertical profile of water chemistry parameters pre-mining (Fallis et al. 1987) and in 2003, after mining.

	Pre-Mine Profile			**Post-Mine Profile**							
	June 1976 (Fallis et al. 1987)			**Winter 2003 (Teck Cominco)**			**August 2003**				
Depth (m)	**Temperature (oC)**	**Salinity ppt**	**D.O. mg/L**	**Temperature (oC)**	**Conductivity (mS)**	**D.O. mg/L**	**Temperature (oC)**	**Conductivity (mS)**	**pH**	**Salinity ppt**	**D.O. mg/L**
1	0.85	4.9		-0.5	14.5	20.7	0	6.74	8.18	3.8	11.5
2	0.85	4.9	15.9	-0.5	14.8	20.2	0.24	6.93	8.18	3.9	11.5
3	0.85	4.9		-0.3	13.8	18.9	0.86	7.38	8.14	4.1	11.5
4	0.85	4.8	16.1	3.3	14.6	17.6	3	11.45	7.98	6	11.5
5	0.85	4.9		3.5	14.5	17.2	3.28	12.18	8	7	11.5
6	0.85	5.3		3.5	14.5	17.1	3.35	12.28	8	7	11.5
7	0.85	4.9		3.5	14.6	16.9	3.42	12.37	8.07	7.1	11.5
8	0.85	5.1		3.6	14.6	16.1	3.25	12.43	8.08	7.1	11.5
9	0.85	4.8		4.0	15.3	13.2	3.45	12.51	8.07	7.2	11.5
10	0.85	4.8	16	5.2	27.1	7.7	5.01	18	7.83	11.5	11.5
10.5							6.0		7.26	22.5	6.7
11	0.85	4.9		6.6	77.4	0.4	7.05	65.6	7.16	40.2	4.3
12	0.85	4.9		7.5	94.0	0.2	8.2	78.9	7.2	54.9	1.1
13	3.76	28.6		8.0	94.2	0.2	8.37	79.8	7.24	55.3	0.8
14	6.34	34.6		8.2	94.4	0.2	8.37	80.1	7.26	55.6	0.45
15	7.4	54.6	9.8	8.3	94.4	0.2	8.33	80.3	7.27	55.7	0.23
16	8.06	65.2		8.4	94.5	0.2	8.28	80.4	7.3	55.7	0.0
17	8.51	71.3		8.4	94.5	0.2	8.27	80.4	7.3	55.7	0.0
18	8.96	77.0		8.4	94.5	0.2	8.25	80.5	7.31	55.7	0.0
19	9.29	79.8	8.5	8.4	94.5	0.2	8.25	80.5	7.31	55.7	0.0
20	9.47	81.3	0.0	8.4	94.5	0.2	8.24	80.5	7.32	55.8	0.0
21	9.39	85.0		8.4	94.5	0.2	8.24	80.4	7.33	55.8	0.0
22	9.18	87.5		8.4	94.5	0.2	8.24	80.5	7.33	55.8	0.0
23	9.0	88.8		8.4	94.5	0.2	8.24	80.5	7.33	55.8	0.0
24	8.9	89.0		8.4	94.5	0.2	8.24	80.5	7.34	55.8	0.0
25	8.82	89.2		8.4	94.6	0.2	8.24	80.5	7.34	55.8	0.0
26	8.74	89.4		8.4	94.6	0.2	8.24	80.5	7.34	55.8	0.0
27	8.68	89.3		8.4	94.6	0.2	8.22	80.5	7.35	55.8	0.0
28	8.59	89.3		8.4	94.6	0.2	8.23	80.5	7.35	55.8	0.0
29	8.5	89.3		8.4	94.5	0.2	8.24	80.5	7.35	55.8	0.0
30	8.42	89.2	0.0	8.4	94.7	0.2	8.25	80.5	7.35	55.8	0.0
31	8.35	89.1		8.4	94.6	0.2	8.25	80.5	7.35	55.8	0.0
32	8.28	89.1		8.4	94.6	0.2	8.25	80.5	7.35	55.8	0.0
33	8.19	88.8		8.4	94.7	0.2	8.25	80.5	7.35	55.8	0.0
34	8.11	89.1		8.4	94.7	0.2	8.25	80.5	7.35	55.8	0.0
35	8.04	88.5		8.4	94.6	0.2	8.27	80.5	7.35	55.8	0.0
36	7.95	88.7		8.4	94.6	0.2	8.27	80.5	7.35	56	0.0
37	7.88	88.4		8.4	94.7	0.2	8.27	80.5	7.35	56.4	0.0
38	7.8	89.0		8.4	94.7	0.2	8.4	83.4	7.35	58.1	0.0
39	7.76	88.6		8.4	94.7	0.2	8.43	83.9	7.35	58.4	0.0

Appendix C Fish Metals Concentrations, Garrow Lake 2003.

Appendix C. Total metal concentration (mg/kg ww) for individual fourhorn sculpin, Garrow Lake, August 2003.

Sample ID Total Metals (mg/kg ww)	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7	SC-8	SC-9	SC-10	SC-11	Mean	SD	Range
Aluminum	20	13	21	19	5	9	23	3	21	40	7	16	10.61	3 - 40
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.00	
Arsenic	0.59	0.93	0.59	1.10	1.42	1.48	0.66	0.82	0.77	0.81	0.53	0.88	0.33	0.53 - 1.48
Barium	3.63	2.93	3.70	3.00	2.55	2.32	2.83	1.59	5.36	5.15	3.61	3.33	1.14	1.59 - 5.36
Beryllium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	
Cadmium	0.087	0.051	0.044	0.038	0.062	0.042	0.103	0.026	0.051	0.075	0.043	0.057	0.023	0.026 - 0.103
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	
Cobalt	0.14	0.15	0.09	0.09	0.09	0.10	0.13	0.07	0.14	0.19	0.10	0.12	0.04	0.07 - 0.19
Copper	0.74	0.65	0.59	1.06	0.75	0.94	0.74	0.46	1.55	1.43	1.52	0.95	0.39	0.46 - 1.55
Lead	0.80	0.57	0.83	0.73	0.87	0.92	0.78	0.43	0.63	1.71	0.62	0.81	0.33	0.43 - 1.71
Manganese	3.37	6.46	2.29	3.15	1.24	2.78	3.34	1.60	3.36	4.31	2.77	3.15	1.40	1.24 - 6.46
Mercury	<0.005	<0.005	<0.005	0.005	0.012	0.006	<0.005	<0.005	<0.005	0.005	0.006	0.006	0.002	<0.005 - 0.012
Molybdenum	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.00	<0.01 - 0.01
Nickel	0.1	0.1	0.1	0.1	0.1	0.1	0.2	<0.1	0.2	0.2	0.2	0.1	0.1	<0.1 - 0.2
Strontium	21	30.4	27.9	36	46.1	41.5	25.1	35.7	30.8	29.8	25.6	31.8	7.4	21 - 46.1
Zinc	53.1	71.5	60.9	78.6	120	86.5	54.3	50.4	85.1	78	57.3	72.3	20.6	50.4 - 120