MN-060

Phase III ENVIRONMENTAL ASSESSMENT

PADDY MINE SITE

Final Report

Prepared for:

Action on Waste Program
Indian and Northern Affairs Canada

Prepared by:

Environmental Services
Public Works and Government Services Canada

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Executive Summary

The abandoned Paddy exploration site is located off the Hansen-McQueston Road, which joins Highway 11 approximately 5 km east of the village of Elsa. This Phase III assessment of the lower Paddy site was carried out by Environmental Services for Indian and Northern Affairs Canada to characterize environmental risks associated with slope stability and fish passage issues and input of metals to Christal Creek. Major findings of this assessment are summarised in the following Table:

Summary of Concerns at Paddy Mine Site

Site Assessment Component	Concern
Lower road slope stability	Probability that further slumps will transport waste rock and fines into Christal Creek
Waste rock slope stability	Probability that further slumps will transport waste rock and fines into Christal Creek
Fish passage obstruction	Upstream bridge has partially blocked Christal Creek and is likely obstructing fish passage
Acid rock drainage and water quality	The waste contains ample neutralizing capacity to buffer acid production. Water quality monitoring to date indicates no negative effect from the Paddy mine site.

Recommendation 1. To prevent further movement of waste rock material into Christal Creek, gabion baskets or other physical barrier should be placed at the toe of the waste rock slope.

Recommendation 2. The collapsed bridge upstream from the adit should be demolished. Bridge materials and jammed logs should be removed to improve fish passage through the canyon area.

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1. INTRODUCTION AND BACKGROUND

In 1993, initial assessments of 49 abandoned Yukon mine exploration and development sites were completed under the Arctic Environmental Strategy - Action on Waste program by DIAND Technical Services. These assessments provided a) a general overview of historical activities, b) described site infrastructure, workings and wastes, c) summarized existing environmental or ô£afetyconcerns on each site, and d) provided general recommendations for remediation or mitigation work. No rock, soil or water samples were collected for these assessments.

The abandoned Paddy exploration site is located off the Hansen-McQueston Road, which joins Highway 11 approximately 5 km east of the village of Elsa. conducted A Phase II assessment of the Paddy mine site was completed by Norecol, Dames & Moore, who inspected the site on 28 August, 1996. The purpose of the assessment was to identify specific environmental and human safety risks, describe aesthetic concerns, and recommend site-specific remediation or mitigation measures.

The Phase II assessment (Norecol, Dames & Moore, 1997) identified three concerns, namely 1) the physical stability of the waste rock dump, located in a canyon reach of Christal Creek, 2) localized slumps of the road bed into Christal Creek, and 3) blockage of fish passage through the Christal Creek canyon.

A waste rock dump extends between an upper hillside excavation and a mid-slope adit to Christal Creek. Waste rock slides have occurred between the upper road and Christal Creek. Soil instability along the last 500 metres of the lower access road has led to localized slumps into Christal Creek. Two wooden bridge structures have collapsed into the Creek due to the failure of the creek bank. The collapsed bridges may be interfering with fish migration through the Christal Creek canyon.

Cadmium, selenium and zinc concentrations in Christal Creek upstream and downstream of the Paddy mine site exceeded the CCME criterion for protection of freshwater aquatic life (FAL). A seep sample at the foot of the adit waste rock pile contained zinc exceeding the CCME FAL criterion.

Norecol recommended a geotechnical assessment to determine whether a) the instability of the dumps and road pose health and safety risks, and b) the lower road slope failure/bridge collapse has affected fish migration through the Christal Creek canyon. No recommendations were made with respect to surface water monitoring.

2. PURPOSE AND SCOPE OF WORK

This Phase III assessment of the lower Paddy site was completed to a) characterize environmental risks associated with slope stability and fish passage issues and b) input of metals to Christal Creek. The assessment involved site visits by Environmental Services on 18 August and 18 October, 1997 and on 23 April, 1998. The following assessment activities were completed:

- Geotechnical inspection of the waste rock disposal area
- Photo documentation of relevant site features
- Sampling of waste rock disposal areas and surface water (including waste rock seeps and receiving waters)
- Identification of environmental pathways and receptors for site contaminants
- Determination of acid rock drainage conditions and metal transport in leachate from the waste rock disposal area

Recommendations were made to meet the following remediation/mitigation requirements:

- Physical stabilization of the waste rock slope
- Removal of barriers to fish migration through the Christal Creek canyon

3. SITE ASSESSMENT METHODOLOGY

3.1 Assumptions

At the Paddy mine site, the assessment was limited to the area specifically developed or occupied for mine exploration or mining purposes and off-site environmental resources potentially affected by mine exploration or development activities.

3.2 Assessment Criteria

<u>CCME Criteria</u>

The Canadian Council of Ministers of the Environment (CCME) Interim Canadian Environmental Quality Criteria for Contaminated Sites are numerical limits for contaminants in soil and water intended to protect, maintain or improve environmental quality and human health at contaminated sites in general. For this Phase III mine assessment, Freshwater Aquatic Life criteria were used to assess surface water quality.

Mine Reclamation in Northwest Territories and Yukon (INAC, 1992)

This report defines factors which are to be considered in reclamation of abandoned mine sites operating in northern climates. Factors include:

- open pit and underground mines
- waste rock and tailings disposal
- acid generation and leaching, and
- estimating cleanup costs.

3.3 Methods

3.3.1 Site Assessment Components

The Phase III assessment included the following components:

An assessment of acid rock drainage and metal-contaminated leachate production in area waste rock by a professional geologist, involving:

- Confirmation of rock types, mineralization and alteration noted in the Phase II assessment;
- Collection of representative waste rock samples;
- Laboratory testing of selected samples, including whole rock analysis (solids assay), Acid Base Accounting (ABA) tests, and bottle roll (leachate) tests.

A professional geotechnical engineer was retained to inspect the mine site to identify:

- Possible obstruction of fish passage in Christal Creek, including factors leading to the collapse of two wooden bridges across the creek;
- Site-specific factor(s) involved in past and possible future slumping of the waste rock disposal area;
- Methods and preliminary costs for physical stabilization of the waste rock disposal area;
- Location, accessibility, and approximate quantity of suitable borrow materials in the vicinity of the Paddy site. Borrow materials would be used for future stabilization/reclamation of the waste rock disposal area, should that work be deemed necessary.

3.3.2 Sampling Methods and Quality Assurance

Mine Waste Sampling

Test pits were excavated to depths between 0.3 m and 1.0 m. Horizons in the test pit walls were logged, noting colour/weathering, rock composition, primary and secondary mineralization, particle size distribution, paste pH and paste conductivity, and moisture content. Test pits were photographed and the locations marked on the field map.

Approximately 2 kg of rock was collected at each sample site. For test pits showing a homogeneous wall face, a plastic sheet was placed at the bottom of the test pit and the pit wall was cut vertically down with a cleaned shovel. All rock larger than 75 mm in size was discarded. Where test pit walls showed distinct horizons (distinguishable by the sulphide and carbonate contents), each horizon was sampled.

Water Sampling

Samples were collected from Christal Creek upstream and downstream of the waste rock disposal area, and from a seep emanating from the waste rock slope. Field pH and conductivity measurements were recorded during the summer sampling period. Samples were collected on 19 August and 18 October, 1997 and on 23 April, 1998 to measure contaminant concentrations during the summer, fall, and spring seasons.

250 ml water samples were collected by hand, facing upstream, ensuring that the sample was not contaminated by disturbed sediment, debris and other floating materials. Sample bottles were rinsed three times with water from the sample stream prior to collecting the sample. 2 ml of HNO_3 were immediately added to water samples intended for metals analyses. For analyses of non-metallic parameters, water samples were brim-filled to minimise head space, placed in a cooler, and maintained at 4° C until delivery to the laboratory.

Quality Assurance

Quality Assurance (QA) is a set of procedures for ensuring that the results of chemical analyses are (and can be shown to be) accurately representative of field conditions. A complete QA program includes both a field component and a laboratory component.

In addition to the standard sample collection methods outlined above, the field QA measures that were implemented for this assessment study include:

- chain of custody procedures and forms;
- a sample labelling and sample location identification scheme;
- laboratory preparation of all sampling containers;
- laboratory defined sample preservation and shipping procedures; and
- regular maintenance (including re-calibration) and cleaning of field equipment.

4. ENVIRONMENTAL SETTING

4.1 Mineralization

The commodities of interest at the Paddy site on Galena Hill are silver, gold, lead and zinc. The Keno Hill-Galena Hill silver-lead ores occur in erratic shoots and lenses lying in vein faults that cut fine-bedded to massive quartzite, intercalated with greenstone sills and lenses, and various schistose rocks.

The Paddy veins are composed of siderite ($FeCO_3$) with variable, but small, amounts of quartz, sphalerite ((Zn,Fe)S), galena (PbS) and freiberigite (silver-bearing tetrahedrite ($(Cu,Fe)_{12}Sb_4S_{13}$)). The cubiform galena occurs as clots and clusters rarely more than a few centimetres in size. The vein has been affected by post-mineralization fault movement, as well as intense weathering. Siderite ($FeCO_3$) and galena are commonly weathered to limonite and anglesite. The footwall is greenstone and the hangingwall is graphite schist which is highly brecciated within a few metres of the vein.

4.2 Hydrology

Local drainage from the waste rock dump enters Christal Creek, a third-order stream which joins the South McQueston River. Waste rock extends from the upper access road to within 15 m of Christal Creek. No surface water bodies cross the Paddy mine site.

During the PWGSC site visit, a seep was discovered below the mid-slope adit. Seep water flowed into Christal Creek.

Hydrological/water quality records were not available for Christal Creek. During the 18 August, 1997 site visit, Christal Creek discharge was measured at 0.357 m^3/second at the collapsed bridge downstream from the Christal Creek canyon.

4.3 Climate

Meteorological data are incomplete, but inferences from surrounding locations and data presented by Burns (1973, 1974) suggest the mean annual precipitation to be about 500 mm in the Keno Hill area. The mean annual temperature is estimated to be -6°C.

4.4 Fisheries Resources

A 1995 fish and fish habitat assessment was conducted for United Keno Hill Mines (White Mountain Environmental Consulting, 1995). The principle areas of study were drainage areas influenced by historical and current mining activities, and included Christal Creek from Christal Lake to its mouth at the South McQuesten River.

Test fishing was carried out on Christal Creek during the summers of 1974 and 1975 by the Environmental Protection service (EPS); low fish numbers were found at sample stations in Christal Creek, but this was attributed to the fact it was a small creek with relatively steep gradient (these same locations on Christal Creek did not produce any fish during a 1994-1995 study).

During The summer of 1985, a receiving environment monitoring study was undertaken by EPS in Flat Creek, Christal Creek, and the South McQuesten River, all potentially influenced by UKHM operations. The report mentions a tailings pond release from a dam break that occurred in 1978, and states that water hardness exceeded levels recommended [or drinking water at all stations. The report contains historical comparisons of metal levels in the water at sample stations dating from 1974 to 1985. These comparisons showed copper levels dropping in Christal Creek over that period, but zinc levels were found to be increasing (<0.17 mg/l in 1974 to 0.825 mg/l in 1985). Alkalinity and hardness levels were shown to be rising in Christal Creek and the report suggests that sustained mining activity in the area may be associated with these increases. The study identified mine drainage from the Galkeeno 900 adit as the main source of metals in Christal Creek.

The White Mountain (1995) fisheries investigations began during August of 1994; fall habitat and fish utilization investigations were conducted between September 13 and 16, 1994 to determine the extent of fish distribution and to map and assess available fish habitat. Spring investigations ran from May 19 to 23, 1995 (when emphasis was placed on determining spring movements of all species and locating any areas used by Arctic grayling for spawning), and from June 1 to 4, 1995. Summer investigations were conducted between July 14 and 21,1995 to conduct intensive utilization assessments.

Extensive mining activities in the canyon below the former Paddy mine included the construction of a road through the canyon with bridges crossing the creek at either end. Both of these bridges

have collapsed and now pose barriers to fish passage. This reach does not provide much fish habitat In its present form; however, a pool adjacent to the lowest bridge does provide habitat with available cover inside an old culvert.

The Christal Creek reach beginning at the Keno Road crossing and extending for approximately 5 km down to the canyon has many pools and riffle areas that could provide excellent fish habitat for grayling and sculpins.

The last reach examined by White Mountain (1995) starts at the outlet of Christal Lake and flows 400m through a series of beaver ponds and a slow deep channel before flowing through culverts under the Keno City Road. Outflow from the Galkeeno 900 adit enters Christal Creek at the start of this reach. This reach has the potential to provide habitat to grayling and sculpins; the limiting factor to fish In this situation is most likely heavy metals in the water.

Juvenile Arctic grayling, burbot, slimy sculpins and a single adult gentling were recorded in the lowest reach of Christal Creek during White Mountain's (1995) summer and fall investigations, and no fish were recorded in this reach during spring investigations. Pool areas in this lowermost reach were the most heavily utilized areas of Christal Creek; grayling fry comprised 96% of the fish recorded in this reach.

Adult Arctic grayling utilized larger pool areas below the former Paddy mine canyon and in the pool below the obstruction located at the bottom of the canyon. Adult grayling comprised 53% of the fish recorded in Christal Creek excluding the mouth area. Although Christal Creek has potential spawning habitat for Arctic grayling, cold water temperature during the spring of 1995 makes it unlikely that graying would have used that habitat.

Slimy sculpins were the only fish found above the obstructing bridge. These were not abundant and comprised only 9% of all fish recorded in Christal Creek.

An Access Mining Consultants (1996) report identified arctic grayling, burbot, and slimy sculpins downstream from the two collapsed bridges. Slimy sculpins were the only species identified upstream of the collapsed bridges.

4.5 Site Topography and Soils

The Paddy area has been glaciated by ice from the Selwyn Lobe which moved in a westerly to north-westerly direction. The ice level reached about 1500 m above sea level; many higher areas were subjected to alpine glaciation. Lateral moraines, ice contact channels and kame terrace deposits occur on a number of hills in this area.

Generally, glacial scouring was not intense in this area. Middle and lower slopes are mantled with deep morainal and glaciofluvial material. Large lakes filled a number of valleys during deglaciation. Large deposits of silts occur in the Mayo Lake area, and small glaciolacustrine deposits are present throughout.

Paddy is situated on a 38° south-facing slope. Area soils typically are peaty silts and sands to a depth of 20-40 cm, underlain by well-mixed, compacted boulders, cobbles, sand and silt to depths varying between 3 and 8 m. A detailed description of site soils and topography is provided in Section 3 of the attached EBA Engineering Consultants (1997) geotechnical report.

5. SITE ASSESSMENT RESULTS

5.1 Surface Water Quality

On 18 August, 1997, a seep below the adit (sample PAD-WQ-SE1-1) was sampled at the point of seepage entry into Christal Creek. The seep was not active during the October 1997 and April 1998 sampling dates. Three surface water samples were collected from Christal Creek during the 19 August and 18 October, 1997 and 23 April, 1998 sampling events. Sample PAD-WQ-St1-1 was obtained from Christal Creek 50 m upstream of the northern edge of the waste rock slope. Sample PAD-WQ-St1-2 was collected approximately 1m downstream from the point where seepage entered the creek. Sample PAD-WQ-St1-3 was collected from Christal Creek approximately 600m downstream from the adit and below a collapsed bridge. The sample locations reflected those from the Norecol, Dames & Moore (1997) site assessment. Complete analytical results from the PWGSC and Norecol assessments are provided in Appendix C; significant results are summarized in Table 5.1.

In August 1997, seepage from the main waste rock pile was less than 1 L/min. On both the August 1996 and August 1997 sampling dates, the seep had a pH of approximately 7.7 and sulphate concentration between 459 mg/L and 502 mg/L. Zinc was above the CCME criterion for freshwater aquatic life in August 1996, while cadmium, copper, and zinc concentrations were above the criterion during August 1997. Concentrations of copper and zinc probably reflect the presence of freibergite and sphalerite in local rock; however, the cadmium source is unknown. No seepage was observed during October 1997 or April 1998.

Surface water quality was relatively consistent at the three Christal Creek sampling. pH at each sample location was between 7.5 and 8.1, and sulphate concentrations ranged between 161 mg/L and 243 mg/L. Aluminum, cadmium, iron, and zinc were near or above the CCME FAL concentrations upstream and downstream of the exploration site.

Selenium also exceeded CCME FAL criteria upstream and immediately downstream of the mine site in August 1997. However, selenium concentrations were either below the FAL criterion or non-detectable during October 1997 and April 1998.

Table 5.1 Significant Results - Paddy Surface Water Samples

Sample ID	Sample Location	Sample Date	pH	Conductivity (μmhos/cm)	Parameters > CCME FAL Criteria
PW1 (Norecol)	Christal Creek 50 m upstream of the northern edge of the waste rock dump	28 Aug 1996	8.1	-	Cd, Fe, Zn
PAD-WQ-ST1-1		18 Aug 1997	7.9 (7.8)	506 (718)	Al, Cd, Fe, Se, Zn
		18 Oct 1997	8	561	Cd, Zn
		23 April 1998	7.6	645	Al, Cd, Cr, Fe, Zn
PW2b (Norecol)	Christal Creek downstream from seepage entry to creek	28 Aug 1996	8	-	Cd, Zn
PAD-WQ-ST1-2	Christal Creek 1 m downstream from seepage entry to creek	18 Aug 1997	8.0 (7.8)	499 (724)	Al, Cd, Se, Zn
		18 Oct 1997	8.1	560	Cd, Zn
		23 April 1998	7.6	649	Al, Cd, Fe, Zn
PW3 (Norecol)	Christal Creek about 590 m downstream of adit and above collapsed bridge	28 Aug 1996	8.1	-	Cd, Zn
PAD-WQ-ST1-3	Christal Creek about 600 m downstream of adit and below collapsed bridge	18 Aug 1997	8.1 (7.9)	499 (707)	Zn
		18 Oct 1997	8.2	562	Cd, Zn
		23 April 1998	7.6	650	Al, Cd, Fe, Zn
PW2a (Norecol)	Below adit near point of entry into Christal Creek	28 Aug 1996	7.7	-	Zn
PAD-WQ-SE1-1	Below adit at point of entry into Christal Creek	18 Aug 1997	7.7 (7.3)	1060 (1639)	Cd, Se, Zn

Note: pH and conductivity readings in brackets are field measurements; unbracketed values are lab measurements. Field conductivity results reported as microsiemens. FAL = Freshwater Aquatic Life.

5.2 Waste Rock Geochemical Assessment

Waste rock samples collected in 1996 were not believed to be representative of the waste rock at the site. Therefore, two waste rock samples were collected during the 1997 visit. Samples PAD-WR 1-1 and PAD-WR 2-1 were collected from main waste rock pile below the adit and from the smaller pile to the south and west of the adit.

Results of ABA tests and metals analyses are summarized in Table 5.2. Both waste rock samples had paste pH values above 8 and conductivities below 300 µS/cm. Most of the sulphide remains unoxidized despite the waste having been deposited in 1969. Thus, sulphide oxidation is slow. The waste contains ample neutralizing capacity so that any acid produced should be buffered.

The waste rock samples contained moderate to high concentrations of arsenic (mean=324 ppm), chromium (145 ppm), copper (93 ppm), manganese (1216 ppm), lead (2328 ppm), and zinc (4406 ppm). The samples also contain nearly 5% iron.

Table 5.2 Waste Rock Sample Locations and Summarized ABA Test Results - Paddy Mine Site

Sample ID	Sample Location and Description	Summary of ABA Test Results
PAD-WR 1-1	Collected from main waste rock pile below the adit.	Low potential for acid generation (NP:AP= 5.0).
PAD-WR 2-1	Collected from the smaller waste rock pile to the south and west of the adit.	Low potential for acid generation (NP:AP= 5.3).

Bottle roll test slurries of samples from the Paddy Camp site had conductivities that increased from approximately 700 µS/cm to greater than 1800 µS/cm over a nine-day period indicating that sulphides in the samples are oxidizing. The slurries had above neutral pH values, which suggests that acidity from sulphide oxidation is being buffered.

The conductivity of the filtered leachates was higher than that of the slurries (2760 µS/cm and 3260 µS/cm). Most of this is attributable to the sulphate that was present in concentrations of 1470 mg/L and 1930 mg/L. The pH was above 8 for both filtered samples. The alkalinity of the samples were 104 mg/L and 305 mg/L CaCO3 eq. indicating that there is more buffering capacity available in the samples.

Metal concentrations were low in the filtered leachates. Copper ranged from 0.01 mg/L to 0.02 mg/L and zinc from 1.2 mg/L to 0.06 mg/L.

5.3 Paddy Mine Site Geotechnical Assessment

The geotechnical field work consisted of lateral surveys to verify site sketches taken from previous reports, visually observing the slope conditions by measuring the slope angle and inspecting the slope for tension cracks or other signs of mass wasting, and hand-digging test pits to estimate the near surface soil or waste rock profile for slope stability considerations. The areas inspected during the site visit at the Paddy Mine included the lower road, the two collapsed bridges along Christal Creek, the upper road near the excavation, and the waste rock dump located along the canyon slope near the adit.

Slight mass wasting was apparent at the lower access road, due either to erosional effects of Christal Creek or due to an excessive slope gradient leading toward the creek. Tension cracks and slump failures have occurred at those locations along the south edge of the lower road which are directly adjacent to the creek and which have a steep slope angle leading from the edge of road to the creek.

In the areas of the two bridges, it appears that the bridge abutments have been eroded, causing each bridge to collapse into the creek. The collapsed bridge downstream from the adit does not seriously impede the flow of Christal Creek since channels have been developed on either side of the bridge. There is an approximately 0.5 m drop in elevation of water level at the right side (west) and an approximately 0.3 m drop at the left side. Based on visual observation, it does not appear that this collapsed bridge would pose a barrier to fish in Christal Creek.

The collapsed bridge upstream of the adit is more seriously impeding the flow of Christal Creek. This bridge appears to dam the creek, causing a change in water elevation of approximately 0.6 m and creating a log jam at the upstream end. There was seepage through the collapsed bridge at various locations which allowed the creek to maintain flow downstream. Based on visual observation, this collapsed bridge could pose a barrier to fish.

Waste rock along the south canyon slope near the adit consisted of alternating lobes of fine grained, slightly pulverized schist rock and course grained quartzite rock. The slope angles of the waste rock material approached 38° due to the naturally steep slope of the canyon wall. During the site visit, it appeared that mass wasting at this site was restricted to gradual surface movement as there was no evidence of translational slip failure or more extensive slides of this nature. There were signs of slumping and creep at the upper road and western most waste rock lobe. In the

upper road area, some slumping has occurred at the top of the waste rock slope. There was no visual evidence of past deep seated failures along the waste rock slope. At the westernmost waste rock lobe, some slump failure appears to have occurred within the schist-based waste rock mass.

In areas along the slope where the coarse rock has been deposited, there is very little evidence of instability other than slight scree slide movements. There were larger diameter rocks located at the toe of the waste rock slide and within Christal Creek. This material was most likely deposited during the original development of the open pit excavation and has not been mobilized as a result of recent mass wasting. Slight scree slide movements may occur over the long term which could lead to a small quantity of the quartzite rock impacting Christal Creek.

6. CONCLUSIONS

Existing or potential environmental concerns associated with the Paddy mine sitÀ¨Pe are summarized in Table 6.1, and are examined more fully in the following sections.

Table 6.1 Summary of Concerns at Paddy Mine Site

Site Assessment Component	Concern
Lower road slope stability	Probability that further slumps will waste rock and fines into Christal Creek
Waste rock slope stability	Probability that further slumps will waste rock and fines into Christal Creek
Fish passage obstruction	Upstream bridge has partially blocked Christal Creek and is probably obstructing fish passage
Acid rock drainage and water quality	The waste contains ample neutralizing capacity so that any acid produced should be buffered. Water quality monitoring completed to date indicates no negative effect from the Paddy mine site.

6.1 Lower Road Slope Stability

Future slope failures along the lower road would involve a series of slumps of soil into Christal Creek. The creek's subsequent erosion of the slumped material would undermine the toe of the newly formed slope, which in turn would lead to further slumping. This cycle would typically be repeated until a natural slope angle for the fine grained material is realized. Based on the height

of the road above the creek, it does not appear that the volume of material at each particular slumping event would greatly impede the flow of the creek. Rather, the slumping and subsequent erosion will affect the creek by slightly increasing the sediment loading over a period of several years. It is not known whether this increase in sediment load would adversely impact fish in this creek.

In order to prevent further slumping of the soil along the lower road into Christal Creek, some grading work will be necessary at various locations along the road. The most notable areas which have been affected by the soil slumping are located at the collapsed bridge upstream of the adit and adjacent to the road approximately 225 m east of the downstream collapsed bridge.

6.2 Waste Rock Slope Stability

Based on the visual observations during the site visit, it appears that mass wasting of the fine grained material has been restricted to surface erosion and slumping. Mass wasting of the coarse grained material has been restricted to small scree slides. It appears that the waste rock pile has remained relatively stable over its 25-year existence. As for the future stability of the waste rock pile, it is anticipated that similar mass wasting will occur. Due to the close proximity of Christal Creek to the toe of the waste rock pile slope, there may be some long term impact of this surface movement since some waste rock material may reach the creek.

There is very little distance between the toe of the waste rock slope and the creek, and any cuts into the slope would undermine the toe support of the slope. Given this restriction and the prohibitive costs associated with mobilizing construction supplies to this site, a gabion wall system is probably the most cost-effective manufactured retaining structure.

6.3 Fish Passage Obstruction at the Upstream Bridge

The upstream bridge has partially dammed the creek, causing a change in water elevation of approximately 0.6 m and creating a log jam at the upstream end. There was seepage through the collapsed bridge at various locations which allowed the creek to maintain flow downstream. Based on visual observation, this collapsed bridge could pose a barrier to fish. This bridge should be demolished and the debris should be removed from the creek.

6.4 Acid Rock Drainage and Water Quality

The Phase II assessment of the Paddy mine site concluded the waste rock was potentially acid-consuming. However, the waste rock samples used for Acid Base Accounting (ABA) testing for the Phase II assessment may not have been representative. As well, the impact of leachate from waste rock was not fully determined.

To confirm the previous conclusion with respect to acid generation potential, two additional waste rock samples were obtained during the August 1997 site visit and subjected to ABA and leachate tests. Results of ABA tests and leachate metals analyses are provided in Appendix A. Both waste rock samples had paste pH values above 8 and conductivities below 300 µS/cm. Most of the sulphide remains unoxidized despite the waste having been deposited in 1969. Thus, sulphide oxidation is slow. The waste contains ample neutralizing capacity so that any acid produced should be buffered. Bottle roll tests (which measure metal concentrations in waste rock leachate) demonstrate that the acidity produced from sulphide oxidation is being buffered.

Water quality monitoring completed to date indicates no negative effect from the Paddy mine site. Although seasonal variations can be seen, a comparison of routine parameters (pH, conductivity, sulphate) and metals shows little or no differences in water quality between upstream and downstream sampling sites. Cadmium, copper and selenium inputs from the waste rock seep appear insignificant: levels of those metals immediately downstream of the main waste pile (essentially below the point of seep water entry into the creek) are almost indistinguishable from those measured in the upstream samples.

7. RECOMMENDATIONS

Recommended remediation and management actions are compliant with applicable federal or territorial regulations and criteria, rely upon available technology, and intended to be appropriate for local conditions and sensitivities.

Recommendation 1. To prevent further movement of waste rock material into Christal Creek, gabion baskets or other physical barrier should be placed at the toe of the waste rock slope.

Recommendation 2. The collapsed bridge upstream from the adit should be demolished. Bridge materials and jammed logs should be removed to improve fish passage through the canyon area.

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Appendix A

Detailed Geochemical Assessment of Waste Rock and Surface Water

Paddy Mine Site

Extracts from:

Yukon Abandoned Mine Sites Assessment

Report on 1997 Followup

Prepared by SRK Steffen Robertson & Kirsten

(1998)

PADDY CAMP

1. BACKGROUND

The Paddy Camp exploration site is located adjacent to Christal Creek. The site has one adit that is nearly surrounded by waste/development rock from road building and an excavation above. This rock covers the slope down to the bank of the creek. A spring daylights at the base of the pile and no water flows from the adit. Two small piles of ore are located on staging area above the adit.

The waste rock at the Paddy Camp site had a neutral pH and was not potentially acid generating. The ore piles are potentially acid generating but appear to be oxidizing slowly. The ore is located approximately 40 metres above Christal Creek. Therefore, the impact of runoff from the waste/development rock and the seep at its base pose the greatest environmental concern at the site.

The Paddy Camp deposit is associated with an altered basic intrusive that has intruded a package of schists and phyllites. Principle ore minerals include argentiferous (silver-bearing) galena, freigergite (silver-bearing tetrahedrite), and pyrargyrite (Ag3SbS2). Siderite and quartz are the primary gangue minerals.

2. OBSERVATIONS

No new seeps were identified at the site during the August 1997 visit, despite a recent period of high rainfall.

3. ACID GENERATING POTENTIAL AND METALS CONCENTRATIONS IN WASTE ROCK

Waste rock samples collected in 1996 were not representative of the waste rock at the site. Therefore, two waste rock samples were collected during the 1997visit. Samples PAD-WR-1-1 and PAD-WR-2-1 were collected from main waste rock pile below the adit and from the smaller pile to the south and west of the adit.

Results of ABA tests and metals analyses are listed in Table 1. Both waste rock samples had paste pH values above 8 and conductivities below 300 µS/cm. Most of the sulphide remains unoxidized despite the waste having been deposited in 1969. Thus, sulphide oxidation is slow. The waste contains ample neutralizing capacity so that any acid produced should be buffered.

The waste rock samples contained moderate to high concentrations of arsenic (mean=324 ppm), chromium (145 ppm), copper (93 ppm), manganese (1216 ppm), lead (2328 ppm), and zinc (4406 ppm). The samples also contain nearly 5% iron.

4. WATER QUALITY

The flow in Christal Creek during the August 1997 sampling event was 0.4 m3/s. Three samples were collected from Christal Creek: upstream of the Paddy Camp exploration site (PW1 (by Norecol in August 1996), PAD-WQ-STR1-1), downstream of the main waste rock pile (PW2b (by Norecol in August 1996), PAD-WQ-STR1-2), and downstream of the site near the collapsed bridge (PW3 (by Norecol in August 1996), PAD-WQ-STR1-3). Samples PW2a (by Norecol in August 1996) and PAD-WQ-SE-1 were collected from a seep at the bottom of the main waste rock pile.

Paddy Camp water quality results are presented in Table 2. The flow in the seep from the main waste rock pile was less than a 1 L/min, and likely had little impact on the water quality of the creek. In August of 1996 and 1997, the seep had a pH of approximately 7.7 and sulphate concentration between 459 mg/L and 502 mg/L. Cadmium, copper, and zinc concentrations were above the CCME guideline for aquatic life at one or more sampling event. Concentrations of copper and zinc reflect the presence of freibergite and sphalerite, respectively. However, the source of the cadmium is unknown.

Water quality at the three sample sites on Christal Creek (upstream and downstream of the exploration site, and below the waste rock pile) was similar. The pH at each sample location was approximately 8, and sulphate concentrations ranged between 161 mg/L and 220 mg/L. Cadmium and zinc were near or above the CCME guideline concentrations in all creek samples, upstream as well as downstream of the exploration site. Concentrations of these metals remained similar past the site.

Concentrations of aluminum, copper, and selenium were also above the CCME guidelines in the upstream sample during some sampling events. However, the concentrations of these elements generally decreased downstream, and all are below the guidelines downstream of the exploration site.

5. SOLUBLE METALS CONCENTRATIONS

Bottle roll test slurries of samples from the Paddy Camp site had conductivities that increased from approximately 700 µS/cm to greater than 1800 µS/cm over a nine day period (Tables 3 and 4), indicating that sulphides in the samples are oxidizing. The slurries had above neutral pH values, indicating that the acidity produced from sulphide oxidation is being buffered.

The conductivity of the filtered leachates was higher than that of the slurries (2760 µS/cm and 3260 µS/cm). Most of this is attributable to the sulphate that was present in concentrations of 1470 mg/L and 1930 mg/L. The pH was above 8 for both filtered samples. The alkalinity of the samples were 104 mg/L and 305 mg/L CaCO3 eq. indicating that there is more buffering capacity available in the samples.

Metal concentrations were low in the filtered leachates. Copper ranged from 0.01 mg/L to 0.02 mg/L and zinc from 1.2 mg/L to 0.06 mg/L.

6. DISCUSSION

The exploration site is not negatively impacting the quality of the water in Christal Creek, and in fact concentrations of many metals decrease past the site. The seep below the waste rock pile contains concentrations of cadmium, copper, and zinc that are above the CCME guidelines. However, the seep was not actually discharging into the creek and may infiltrate the banks of the creek, re-precipitating metals in the soils. Alternatively, metals in the seep may simply be diluted by the larger flow in the creek. In either case, the seep water quality is unlikely to have a significant impact on the creek water quality.

7. RECOMMENDATIONS

Besides monitoring of the creek and seepage water quality during the spring freshet, no further action is recommended regarding the environmental impact of this site.

Table 1
ABA Results and Metals Concentrations, Paddy Samples

Element	Unit	PAD-WR 1-1	PAD-WR 2-1	Lower Detection Limit
Paste pH		8.4	8.2	
Paste Conductivity	(uS/cm)	240	260	
S(T)	%	1.27	0.82	
$S(SO_4^{2-})$	%	0.03	0.03	
$S(S^{2-})$*	%	1.24	0.79	
AP		38.8	24.7	
NP		192.1	130.1	
NET NP		153.4	105.4	
NP/AP		5.0	5.3	
Aluminum	%	1.47	1.96	0.01
Antimony	ppm	28	13	1
Arsenic	ppm	510	138	1
Barium	ppm	29	0.1	1
Beryllium	ppm	0.1	0.1	0.1
Bismuth	ppm	1	1	1
Cadmium	ppm	84.3	26.0	0.1
Calcium	%	4.79	3.59	0.01
Chromium	ppm	179	111	1
Cobalt	ppm	21	19	1
Copper	ppm	75	111	1
Gallium	ppm	1	3	1
Iron	%	4.62	4.89	0.01
Lead	ppm	2829	1827	1
Lithium	ppm	27	31	1
Magnesium	%	1.96	1.89	0.01
Manganese	ppm	1281	1150	1
Molybdenum	ppm	2	4	1
Nickel	ppm	53	40	1
Phosphorus	ppm	560	820	10
Potassium	%	0.06	0.06	0.01
Silver	ppm	30.3	17.8	0.1
Sodium	%	0.02	0.01	0.01
Strontium	ppm	85	90	1
Thallium	ppm	27	29	1
Tin	ppm	1	1	1
Titanium	%	0.01	0.01	0.01
Tungsten	ppm	108	35	1
Uranium	ppm	15	15	1
Vanadium	ppm	51.2	102.6	1
Zinc	ppm	6634	2178	1

* Calculated: S(T) - S(S2-)
-- = not analyzed.

Table 2
Water Quality Data, Paddy Mine

PARAMETER	UNITS	D.L.	PW1	PAD-WQ-ST1-1	PAD-WQ-ST1-1	PAD-WQ-ST1-1	PW2b	PAD-WQ-ST1-2	PAD-WQ-ST1-2	PAD-WQ-ST1-2	PW3	PAD-WQ-ST1-3	PAD-WQ-ST1-3	PAD-WQ-ST1-3	PW2a	PAD-WQ-SE1-1	CCME
Sampling Event			Aug-96	Aug-97	Oct-97	Apr-98	Aug-96	Aug-97	Oct-97	Apr-98	Aug-96	Aug-97	Oct-97	Apr-98	Aug-96	Aug-97	FAL
Location			Christal Creek, upstream of mine site				Christal Creek below & downstream of main waste pile				Christal Creek 600m downstream of site				seep below waste dump		Criteria**
pH		0.1	8.05	7.87	7.99	7.57	8	8.01	8.05	7.55	8.11	8.07	8.15	7.6	7.72	7.65	
Electrical conductivity	uS/cm	0.1	--	506	561	645	--	499	560	649	--	499	562	650	--	1060	
Hardness	mg/L	0.1	--	294	381	370	--	294	379	369	--	297	381	365	--	761	
Alkalinity	mg/L	1	--	118	140	114	--	117	142	112	--	119	155	115	--	247	
Sulphate	mg/L	0.3	178	161	220	243	179	161	218	241	181	161	220	236	502	459	
Aluminum	mg/L	0.00005	<0.2	0.179	0.00408	0.155	<0.2	0.127	0.00394	0.144	<0.2	0.059	0.00447	0.147	<0.2	0.069	0.1
Antimony	mg/L	0.005	--	<0.005	<0.005	--	--	<0.005	<0.005	--	--	<0.005	<0.005	--	--	<0.005	
Arsenic	mg/L	0.01	0.002	<0.01	<0.01	<0.01	0.002	<0.01	<0.01	<0.01	0.002	<0.01	<0.01	<0.01	0.008	0.02	0.05
Cadmium	mg/L	0.00006	0.023	0.00396	0.00212	0.00214	0.023	0.00187	0.00209	0.00206	0.022	0.00176	0.00205	0.00199	0.0016	0.00187	0.0018
Calcium	mg/L	0.002	--	84	103	--	--	85.2	104	--	--	86	105	--	--	192	
Chromium	mg/L	0.00006	<0.001	<0.00006	0.00014	0.0506	<0.001	<0.00006	0.00019	0.01	<0.001	<0.00006	0.00016	<0.0008	<0.001	<0.00006	0.02
Cobalt	mg/L	0.00003	<0.001	0.00023	<0.00003	--	<0.001	0.00013	0.00011	--	<0.001	0.00011	<0.00003	--	<0.001	0.00018	
Copper	mg/L	0.00003	0.001	0.00344	0.00027	<0.001	0.001	0.00312	0.00033	<0.001	0.001	0.003	0.00041	<0.001	0.003	0.00552	0.004
Iron	mg/L	0.003	0.38	0.603	0.0540	0.321	0.29	0.157	0.0529	0.366	0.22	0.118	0.0508	0.354	<0.03	0.02	0.3
Lead	mg/L	0.0003	0.002	0.003	0.0009	0.0032	0.001	0.0006	0.0009	0.0041	0.001	0.0004	0.0008	0.0033	0.002	0.0064	0.007
Lithium	mg/L	0.00006	--	0.00611	0.00787	--	--	0.0115	0.00800	--	--	0.0072	0.00809	--	--	0.00449	
Magnesium	mg/L	0.005	--	15.3	19.2	--	--	15.4	19.3	--	--	15.7	19.6	--	--	56.2	
Manganese	mg/L	0.00002	0.095	0.128	0.128	--	0.088	0.105	0.122	--	0.084	0.0974	0.107	--	0.004	0.0115	
Mercury	mg/L	0.0001	<0.00005	<0.0001	<0.0001	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001	<0.00005	<0.0001	0.0001
Molybdenum	mg/L	0.00007	<0.001	0.00048	0.00022	--	<0.001	0.00053	0.00023	--	<0.001	0.00057	0.00020	--	<0.001	0.00052	
Nickel	mg/L	0.0001	0.002	0.0016	0.0011	0.005	0.002	0.0011	0.0011	0.004	0.001	0.0016	0.0012	0.004	0.004	0.0033	0.15
Selenium	mg/L	0.003	--	0.005	<0.003	0.0004	--	0.006	<0.003	<0.003	--	<0.003	<0.003	<0.0001	--	0.006	0.001
Silver	mg/L	0.00005	<0.0001	<0.00005	<0.00005	<0.00005	<0.0001	<0.00005	<0.00005	<0.00005	<0.0001	<0.00005	<0.00005	<0.00005	<0.0001	<0.00005	0.0001
Zinc	mg/L	0.0002	0.280	0.444	0.258	0.543	0.270	0.25	0.258	0.528	0.250	0.244	0.256	0.504	0.12	0.159	0.03

-- not analyzed for this parameter.
* Detection Limit for analyses of 1997 samples.
** Criteria values for cadmium, copper, lead, nickel and zinc adjusted for extreme water hardness in accordance with Canadian Water Quality Guidelines
CCME FAL= Canadian Council of Ministers of the Environment criteria for protection of Freshwater Aquatic Life
Exceeds CCME FAL criteria

Table 3
Results of Physical Parameters in Bottle Roll Test Leachates, Paddy Mine

SAMPLE	SOLID			SLURRY										FILTERED LEACHATE									
	pH	Conductivity (µS/cm)	NP/AP	pH (Hours)					CONDUCTIVITY (uS/cm) (Hours)					pH	COND. (uS/cm)	REDOX POT. (mV)	ACIDITY (mg/L CaCO3)		ALKALINITY (mg/L CaCO3)	SULPHATE (mg/L)	BICARBONATE CaCO3 (mg/L)	CARBONATE CaCO3 (mg/L)	CHLORIDE mg/L
				48	72	120	144	216	48	72	120	144	216				pH 4.	pH 8.3	pH 4.5				
PAD-WR-1-1	7.7	81	5	--	8.0	7.7	7.5	7.3	--	780	1490	1880	2400	8.31	3260	285	0.0	0.0	304.5	1930	320	<1	4.5
PAD-WR-2-1	7.6	77	5.3	--	8.3	8.1	8.0	8.1	--	670	1290	1590	1900	8.28	2760	288	0.0	0.5	104.0	1470	110	<1	4.2

-- = not analyzed for this element.

Table 4
Dissolved Metals Concentrations in Bottle Roll Test Leachates, Paddy Min

Sample No.		PAD-WR-1-1	PAD-WR-2-1
Lab. Samples No.		4064	4065
Aluminum	mg/L	<0.2	<0.2
Antimony	mg/L	<0.2	<0.2
Arsenic	mg/L	0.0335	0.0104
Barium	mg/L	0.07	0.04
Beryllium	mg/L	<0.005	<0.005
Bismuth	mg/L	0.1	<0.1
Boron	mg/L	<0.1	0.1
Cadmium	mg/L	<0.01	<0.01
Calcium	mg/L	261	130
Chromium	mg/L	<0.01	<0.01
Cobalt	mg/L	0.01	<0.01
Copper	mg/L	0.01	0.02
Iron	mg/L	<0.03	<0.03
Lead	mg/L	0.1	0.013
Lithium	mg/L	0.14	0.07
Magnesium	mg/L	131	44.7
Manganese	mg/L	0.681	0.175
Mercury	mg/L	<0.00005	<0.00005
Molybdenum	mg/L	<0.03	0.1
Nickel	mg/L	<0.02	<0.02
Phosphorus	mg/L	<0.3	<0.3
Potassium	mg/L	36	24
Selenium	mg/L	0.0046	0.0041
Silicon	mg/L	7.99	8.04
Silver	mg/L	<0.01	<0.01
Sodium	mg/L	360	486
Strontium	mg/L	0.879	0.625
Thallium	mg/L	<0.1	<0.1
Tin	mg/L	<0.03	<0.03
Titanium	mg/L	<0.01	<0.01
Uranium	mg/L	0.0087	0.006
Vanadium	mg/L	<0.03	<0.03
Zinc	mg/L	1.18	0.057

Appendix B

Site Photographs

Photo 1. Collapsed bridge approximately 600 m downstream from adit.

Photo 2. Collapsed bridge upstream from adit. Note ponded water behind cross-stream beams indicating partial flow blockage.

Photo 3. Paddy waste rock slope. Upper Road is visible at top left of photo; adit is visible at center of photo.

Photo 4. Paddy mine adit.

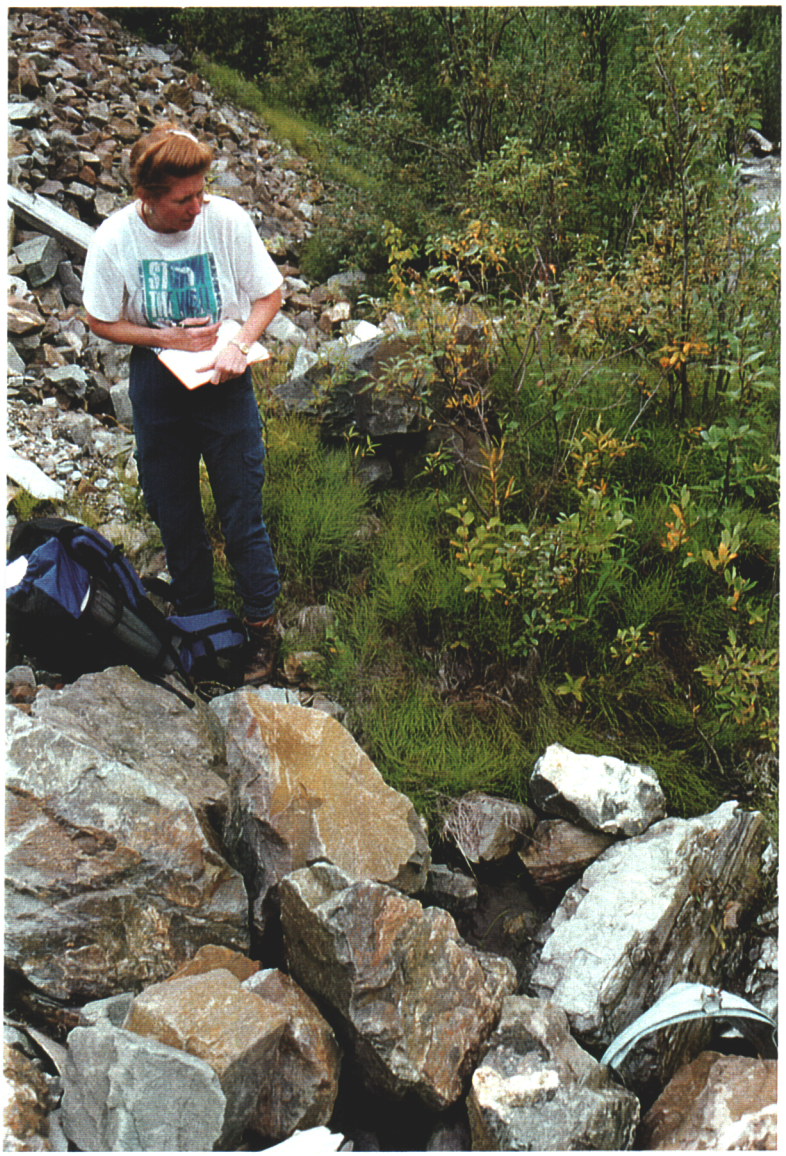

Photo 5. Toe of waste rock slope near Christal Creek. Waste rock seep is visible at lower center of photo.

Appendix C

Analytical Results

NORWEST LABS
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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE		4 FORMA FO-WQ-SE-1	5 FORMA FO-WQ-SE2-1	6 PADDY MINE PAD-WQ-ST1-1
TOTAL METALS				
SELENIUM	mg/L	0.0004	<0.0001	<0.0001
ROUTINE WATER				
pH			2.75	7.87
ELECTRICAL COND	uS/cm		6700	506
CALCIUM	mg/L		429	90.1
MAGNESIUM	mg/L		298	16.9
SODIUM	mg/L		3.4	1.2
POTASSIUM	mg/L		0.61	1.05
IRON	mg/L		980	0.06
MANGANESE	mg/L		53.7	0.109
SULPHATE	mg/L		7820	161
CHLORIDE	mg/L		<0.5	0.6
BICARBONATE	mg/L		<5	145
T ALKALINITY	mg/L		<1	118
HARDNESS	mg/L		2300	294
T DIS SOLIDS	mg/L		8550	342
IONIC BALANCE	%		~39.2	~104
WATER NUTRIENTS				
NO2&NO3-N	mg/L		<0.05	<0.05
TOTAL, COLD VAPO				
MERCURY	mg/L	<0.0001	<0.0001	<0.0001
TRACE ICP,TOTAL				
ALUMINUM	mg/L	1.55	21.2	0.179
ANTIMONY	mg/L	<0.005	0.024	<0.005
ARSENIC	mg/L	0.05	0.50	<0.01
BARIUM	mg/L	0.0221	0.00666	0.0454
BERYLLIUM	mg/L	0.00011	0.00164	<0.00001
BISMUTH	mg/L	<0.0004	0.0076	<0.0004
BORON	mg/L	0.006	<0.002	<0.002
CADMIUM	mg/L	2.19	1.63	0.00396
CALCIUM	mg/L	411	374	84.0
CHROMIUM	mg/L	<0.00006	0.00993	<0.00006

Lab Manager: D Smathers

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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE		4 FORMA FO-WQ-SE-1	5 FORMA FO-WQ-SE2-1	6 PADDY MINE PAD-WQ-ST1-1
TRACE ICP,TOTAL				
COBALT	mg/L	0.136	0.184	0.00023
COPPER	mg/L	0.0597	0.304	0.00344
IRON	mg/L	6.06	1010	0.603
LEAD	mg/L	0.195	0.681	0.0030
LITHIUM	mg/L	0.161	0.176	0.00611
MANGANESE	mg/L	6.99	4.45	0.128
MAGNESIUM	mg/L	333	251	15.3
MOLYBDENUM	mg/L	0.00041	<0.00007	0.00048
NICKEL	mg/L	0.389	0.396	0.0016
PHOSPHORUS	mg/L	0.188	0.262	<0.006
POTASSIUM	mg/L	5.67	3.86	4.40
SILVER	mg/L	0.00219	0.0112	<0.00005
SELENIUM	mg/L	0.025	0.302	0.005
SILICON	mg/L	8.97	25.8	2.86
STRONTIUM	mg/L	0.823	0.487	0.179
SODIUM	mg/L	4.38	3.98	1.15
THALLIUM	mg/L	0.028	<0.001	<0.001
SULPHUR	mg/L	1290	2440	50.6
TITANIUM	mg/L	0.0142	0.00277	0.00561
TIN	mg/L	0.0041	0.0093	0.0005
VANADIUM	mg/L	0.00151	0.0211	0.00043
ZINC	mg/L	49.9	49.0	0.444

Lab Manager: D Mathers

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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE		7 PADDY MINE PAD-WQ-ST1-2	8 PADDY MINE PAD-WQ-ST1-3	9 PADDY MINE PAD-WQ-SE1-1
TOTAL METALS				
SELENIUM	mg/L	<0.0001	<0.0001	<0.0001
ROUTINE WATER				
pH		8.01	8.07	7.65
ELECTRICAL COND	uS/cm	499	499	1060
CALCIUM	mg/L	90.0	90.7	204
MAGNESIUM	mg/L	16.8	17.0	61.0
SODIUM	mg/L	1.2	1.2	3.0
POTASSIUM	mg/L	0.73	1.14	1.29
IRON	mg/L	0.06	0.06	<0.04
MANGANESE	mg/L	0.090	0.087	0.009
SULPHATE	mg/L	161	161	459
CHLORIDE	mg/L	0.7	8.9	<0.5
BICARBONATE	mg/L	143	145	301
T ALKALINITY	mg/L	117	119	247
HARDNESS	mg/L	294	297	761
T DIS SOLIDS	mg/L	341	352	878
IONIC BALANCE	%	~104	99.8	~106
WATER NUTRIENTS				
NO2&NO3-N	mg/L	<0.05	0.61	<0.05
TOTAL, COLD VAPO				
MERCURY	mg/L	<0.0001	<0.0001	<0.0001
TRACE ICP,TOTAL				
ALUMINUM	mg/L	0.127	0.059	0.069
ANTIMONY	mg/L	<0.005	<0.005	<0.005
ARSENIC	mg/L	<0.01	<0.01	0.02
BARIUM	mg/L	0.0430	0.0410	0.0275
BERYLLIUM	mg/L	<0.00001	<0.00001	<0.00001
BISMUTH	mg/L	<0.0004	<0.0004	<0.0004
BORON	mg/L	0.010	<0.002	0.009
CADMIUM	mg/L	0.00187	0.00176	0.00187
CALCIUM	mg/L	85.2	86.0	192
CHROMIUM	mg/L	<0.00006	<0.00006	<0.00006

Lab Manager: D. Smallus

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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE		7 PADDY MINE PAD-WQ-ST1-2	8 PADDY MINE PAD-WQ-ST1-3	9 PADDY MINE PAD-WQ-SE1-1
TRACE ICP,TOTAL				
COBALT	mg/L	0.00013	0.00011	0.00018
COPPER	mg/L	0.00312	0.00300	0.00552
IRON	mg/L	0.157	0.118	0.020
LEAD	mg/L	0.0006	0.0004	0.0064
LITHIUM	mg/L	0.0115	0.00720	0.00449
MANGANESE	mg/L	0.105	0.0974	0.0115
MAGNESIUM	mg/L	15.4	15.7	56.2
MOLYBDENUM	mg/L	0.00053	0.00057	0.00052
NICKEL	mg/L	0.0011	0.0016	0.0033
PHOSPHORUS	mg/L	<0.006	<0.006	<0.006
POTASSIUM	mg/L	7.09	3.31	4.52
SILVER	mg/L	<0.00005	<0.00005	<0.00005
SELENIUM	mg/L	0.006	<0.003	0.006
SILICON	mg/L	2.75	2.70	2.41
STRONTIUM	mg/L	0.180	0.179	0.340
SODIUM	mg/L	1.15	1.16	3.36
THALLIUM	mg/L	<0.001	<0.001	<0.001
SULPHUR	mg/L	51.2	53.5	144
TITANIUM	mg/L	0.00206	0.00131	0.00064
TIN	mg/L	<0.0002	<0.0002	<0.0002
VANADIUM	mg/L	0.00016	<0.00003	<0.00003
ZINC	mg/L	0.250	0.244	0.159

Lab Manager: D Smathers

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YUKON PH3

WATER ANALYSIS REPORT

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*note*  pH              pH  REPORTED AT ROOM TEMP
*note*  ELECTRICAL COND 'ELECTRICAL COND' (EC) is in microsiemens/cm and is a measure of solids in
                       solution
                       E.C. CORRECTED TO 25C
*note*  T ALKALINITY    'ALKALINITY' is CARBONATE/BICARBONATE expressed as CALCIUM CARBONATE
*note*  HARDNESS        'HARDNESS' is calcium and magnesium expressed as CALCIUM CARBONATE
*note* NO2&NO3-N         is expressed as nitrogen
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Lab Manager: _____

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YUKON PH3

WATER ANALYSIS REPORT

--PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------	---PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------
SELENIUM	27Aug97	LANG QUE TRAN	pH	26Aug97	DARREN CRICHTON
ELECTRICAL COND	26Aug97	DARREN CRICHTON	CALCIUM	27Aug97	LANG QUE TRAN
MAGNESIUM	27Aug97	LANG QUE TRAN	SODIUM	27Aug97	LANG QUE TRAN
POTASSIUM	27Aug97	LANG QUE TRAN	IRON	27Aug97	LANG QUE TRAN
MANGANESE	27Aug97	LANG QUE TRAN	SULPHATE	27Aug97	LANG QUE TRAN
CHLORIDE	27Aug97	THERESA LIEU	BICARBONATE	26Aug97	DARREN CRICHTON
T ALKALINITY	26Aug97	DARREN CRICHTON	HARDNESS	0	LANG QUE TRAN
T DIS SOLIDS	0	LANG QUE TRAN	IONIC BALANCE	0	LANG QUE TRAN
NO2&NO3-N	27Aug97	THERESA LIEU	MERCURY	26Aug97	LANG QUE TRAN
ALUMINUM	27Aug97	LANG QUE TRAN	ANTIMONY	26Aug97	LANG QUE TRAN
ARSENIC	26Aug97	LANG QUE TRAN	BARIUM	27Aug97	LANG QUE TRAN
BERYLLIUM	27Aug97	LANG QUE TRAN	BISMUTH	27Aug97	LANG QUE TRAN
BORON	26Aug97	LANG QUE TRAN	CADMIUM	27Aug97	LANG QUE TRAN
CALCIUM	26Aug97	LANG QUE TRAN	CHROMIUM	27Aug97	LANG QUE TRAN
COBALT	27Aug97	LANG QUE TRAN	COPPER	27Aug97	LANG QUE TRAN
IRON	26Aug97	LANG QUE TRAN	LEAD	27Aug97	LANG QUE TRAN
LITHIUM	26Aug97	LANG QUE TRAN	MANGANESE	27Aug97	LANG QUE TRAN
MAGNESIUM	26Aug97	LANG QUE TRAN	MOLYBDENUM	27Aug97	LANG QUE TRAN
NICKEL	27Aug97	LANG QUE TRAN	PHOSPHORUS	26Aug97	LANG QUE TRAN
POTASSIUM	26Aug97	LANG QUE TRAN	SILVER	27Aug97	LANG QUE TRAN
SELENIUM	26Aug97	LANG QUE TRAN	SILICON	26Aug97	LANG QUE TRAN
STRONTIUM	27Aug97	LANG QUE TRAN	SODIUM	26Aug97	LANG QUE TRAN
THALLIUM	27Aug97	LANG QUE TRAN	SULPHUR	26Aug97	LANG QUE TRAN
TITANIUM	27Aug97	LANG QUE TRAN	TIN	27Aug97	LANG QUE TRAN
VANADIUM	27Aug97	LANG QUE TRAN	ZINC	27Aug97	LANG QUE TRAN

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YUKON PH3

WATER ANALYSIS REPORT

The following published METHODS OF ANALYSIS were used:

04011 SELENIUM
Total, perchloric acid digest, automated hydride atomic absorption spectroscopy.
Ref. APHA 3114 C

20301L pH
Electrometric (pH meter)
Ref. APHA 4500-H+

02041L ELECTRICAL COND
Conductance meter
Ref. APHA 2510 B

20103 CALCIUM
ICP spectroscopy @ 317.9 nm
Ref. APHA 3120 B

12102L MAGNESIUM
ICP spectroscopy @ 285.2 nm
Ref. APHA 3120 B

11102L SODIUM
29111 POTASSIUM
Diss.,ICP Spectroscopy, Ref. APHA 3120 B

16304L IRON
16306L SULPHATE
ICP spectroscopy @ 180.7 nm
Ref. APHA 3120 B

17203L CHLORIDE
Automated colorimetry, Thiocyanate
Ref. APHA 4500 Cl-,E

06201L BICARBONATE
Potentiometric titration with standard acid to pH 8.3 and pH 4.5
Ref. APHA 2320 B

20101 T ALKALINITY
Potentiometric titration with standard acid to pH 4.5 & pH 8.3. Report as CaCO3
Ref. APHA 2320 B

10602 HARDNESS
Calculation from 2.5*Ca + 4.1*Mg
Reported as CaCO3
Ref. APHA 2340 B

00203 T DIS SOLIDS
SUM OF IONS CALCULATION
Ca + Mg + K + Na + SO4 + Cl + 0.6*T Alk
Ref. APHA 1030 F

NWL4994 IONIC BALANCE
00100 IONIC BALANCE 2
%Diff=(Sum Cations-Sum Anions)/(Sum Cations+Sum Anions)*100
Ref. APHA 1030 F

07105L NO2&NO3-N
Automated colorimetry Cadmium reduction
Ref. APHA 4500-NO3-,F

Method References:

1. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., 17th ed.
2. EPA a. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846, 3rd ed., US EPA, 1986
   b. Methods for Chemical Analysis of Water and Wastewater, US EPA, 1983
3. MSS Manual on Soil Sampling and Methods of Analysis, Cdn. Soc. of Soil Science, J. A. McKeague, 2nd ed.

* NORWEST SOIL RESEARCH LTD has been accredited by the STANDARDS COUNCIL of CANADA for specific tests registered with the COUNCIL.

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE		7 PESO-WQ-ST1-2	8 PAD-WA-ST1-1	9 PAD-WQ-ST1-2
ROUTINE WATER				
pH		7.13	7.99	8.05
ELECTRICAL COND	uS/cm	161	561	560
CALCIUM	mg/L	18.6	114	113
MAGNESIUM	mg/L	8.4	23.4	23.4
SODIUM	mg/L	2.5	2.3	2.0
POTASSIUM	mg/L	0.94	1.04	0.90
SULPHATE	mg/L	59.2	220	218
CHLORIDE	mg/L	<0.5	0.5	<0.5
BICARBONATE	mg/L	30	170	174
T ALKALINITY	mg/L	24	140	142
HARDNESS	mg/L	81.2	381	379
T DIS SOLIDS	mg/L	105	445	443
IONIC BALANCE	%	-101	105	-104
WATER NUTRIENTS				
NO2&NO3-N	mg/L	0.07	0.10	0.10
ICP METALS,EXTR				
IRON	mg/L	0.06	0.06	0.06
MANGANESE	mg/L	0.070	0.128	0.122
DISS, COLD VAPOR				
MERCURY	mg/L	<0.0001	<0.0001	<0.0001
METALS,DISS,AAS				
SELENIUM	mg/L	<0.0001	<0.0001	<0.0001
TRACE ICP,DISS				
IRON	mg/L	0.0581	0.0540	0.0529
ALUMINUM	mg/L	0.0289	0.00408	0.00394
ANTIMONY	mg/L	<0.005	<0.005	<0.005
ARSENIC	mg/L	<0.01	<0.01	<0.01
BARIUM	mg/L	0.0297	0.0495	0.0489
BERYLLIUM	mg/L	<0.00001	<0.00001	<0.00001
BISMUTH	mg/L	0.0005	<0.0004	<0.0004
BORON	mg/L	<0.002	<0.002	<0.002

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE		7 PESO-WQ-ST1-2	8 PAD-WA-ST1-1	9 PAD-WQ-ST1-2
TRACE ICP,DISS				
CADMIUM	mg/L	0.00010	0.00212	0.00209
CALCIUM	mg/L	17.3	103	104
CHROMIUM	mg/L	0.00011	0.00014	0.00019
COBALT	mg/L	0.00067	<0.00003	0.00011
COPPER	mg/L	0.00033	0.00027	0.00033
LEAD	mg/L	<0.0003	0.0009	0.0009
LITHIUM	mg/L	0.00883	0.00787	0.00800
MANGANESE	mg/L	0.0641	0.122	0.116
MAGNESIUM	mg/L	7.11	19.2	19.3
MOLYBDENUM	mg/L	<0.00007	0.00022	0.00023
NICKEL	mg/L	0.0054	0.0011	0.0011
PHOSPHORUS	mg/L	<0.006	<0.006	<0.006
POTASSIUM	mg/L	0.94	1.04	0.90
SILVER	mg/L	<0.00005	<0.00005	<0.00005
SELENIUM	mg/L	<0.003	<0.003	<0.003
SILICON	mg/L	6.79	3.28	3.27
STRONTIUM	mg/L	0.0635	0.213	0.213
SODIUM	mg/L	1.38	1.37	1.38
THALLIUM	mg/L	<0.001	<0.001	<0.001
SULPHUR	mg/L	19.5	68.4	67.4
TITANIUM	mg/L	<0.00002	<0.00002	<0.00002
TIN	mg/L	0.0005	0.0014	0.0014
URANIUM	mg/L	0.0013	0.0020	0.0037
VANADIUM	mg/L	<0.00003	<0.00003	<0.00003
ZINC	mg/L	0.0182	0.258	0.258
ZIRCONIUM	mg/L	<0.00004	<0.00004	<0.00004

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE		10 PAD-WQ-ST1-3	11 VE-WA, A101	12 VE-WQ-A102
ROUTINE WATER				
pH		8.15	8.36	8.42
ELECTRICAL COND	uS/cm	562	285	352
CALCIUM	mg/L	114	51.3	52.0
MAGNESIUM	mg/L	23.6	13.2	28.5
SODIUM	mg/L	2.3	4.3	6.8
POTASSIUM	mg/L	0.89	0.60	<0.60
SULPHATE	mg/L	220	59.8	77.3
CHLORIDE	mg/L	<0.5	<0.5	<0.5
CARBONATE	mg/L			4.64
BICARBONATE	mg/L	189	148	192
P ALKALINITY	mg/L			4
T ALKALINITY	mg/L	155	122	165
HARDNESS	mg/L	381	182	247
T DIS SOLIDS	mg/L	454	203	265
IONIC BALANCE	%	-101	-104	-107
WATER NUTRIENTS				
NO2&NO3-N	mg/L	0.10	0.16	0.17
ICP METALS,EXTR				
IRON	mg/L	0.06	1.63	0.03
MANGANESE	mg/L	0.107	0.013	<0.003
DISS, COLD VAPOR				
MERCURY	mg/L	<0.0001	<0.0001	<0.0001
METALS,DISS,AAS				
SELENIUM	mg/L	<0.0001	<0.0001	<0.0001
TRACE ICP,DISS				
IRON	mg/L	0.0508	1.554	0.0254
ALUMINUM	mg/L	0.00447	0.0215	0.00394
ANTIMONY	mg/L	<0.005	<0.005	<0.005
ARSENIC	mg/L	<0.01	1.27	0.23
BARIUM	mg/L	0.0488	0.0333	0.0280
BERYLLIUM	mg/L	<0.00001	<0.00001	<0.00001

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE		10 PAD-WQ-ST1-3	11 VE-WA, A101	12 VE-WQ-A102
TRACE ICP,DISS				
BISMUTH	mg/L	<0.0004	0.0006	<0.0004
BORON	mg/L	<0.002	<0.002	<0.002
CADMIUM	mg/L	0.00205	0.0229	0.00111
CALCIUM	mg/L	105	49.3	48.8
CHROMIUM	mg/L	0.00016	0.00023	0.00027
COBALT	mg/L	<0.00003	0.00014	<0.00003
COPPER	mg/L	0.00041	0.00597	0.00016
LEAD	mg/L	0.0008	0.0500	0.0017
LITHIUM	mg/L	0.00809	0.00937	0.0174
MANGANESE	mg/L	0.104	0.0133	0.00207
MAGNESIUM	mg/L	19.6	11.2	23.5
MOLYBDENUM	mg/L	0.00020	0.00849	0.00830
NICKEL	mg/L	0.0012	0.0002	0.0001
PHOSPHORUS	mg/L	<0.006	<0.006	<0.006
POTASSIUM	mg/L	0.89	0.60	<0.60
SILVER	mg/L	<0.00005	<0.00005	<0.00005
SELENIUM	mg/L	<0.003	<0.003	<0.003
SILICON	mg/L	3.25	3.79	3.83
STRONTIUM	mg/L	0.218	0.716	1.10
SODIUM	mg/L	1.39	3.28	5.11
THALLIUM	mg/L	<0.001	<0.001	<0.001
SULPHUR	mg/L	67.1	18.1	23.1
TITANIUM	mg/L	<0.00002	<0.00002	<0.00002
TIN	mg/L	0.0014	0.0013	0.0016
URANIUM	mg/L	0.0029	0.0144	0.0063
VANADIUM	mg/L	<0.00003	<0.00003	<0.00003
ZINC	mg/L	0.256	0.376	0.0379
ZIRCONIUM	mg/L	<0.00004	<0.00004	<0.00004

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MIKE NAHIR

WATER ANALYSIS REPORT

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*note*  pH              pH  REPORTED AT ROOM TEMP
*note*  ELECTRICAL COND 'ELECTRICAL COND' (EC) is in microsiemens/cm and is a measure of solids in
                       solution
                       E.C. CORRECTED TO 25C
*note*  T ALKALINITY    'ALKALINITY' is CARBONATE/BICARBONATE expressed as CALCIUM CARBONATE
*note*  HARDNESS        'HARDNESS' is calcium and magnesium expressed as CALCIUM CARBONATE
*note* NO2&NO3-N         is expressed as nitrogen
```

Lab Manager: _____

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WATER ANALYSIS REPORT

---PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------	---PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------
pH	21Oct97	DARREN CRICHTON	ELECTRICAL COND	21Oct97	DARREN CRICHTON
CALCIUM	22Oct97	LANG QUE TRAN	MAGNESIUM	22Oct97	LANG QUE TRAN
SODIUM	22Oct97	LANG QUE TRAN	POTASSIUM	22Oct97	LANG QUE TRAN
SULPHATE	22Oct97	LANG QUE TRAN	CHLORIDE	21Oct97	THERESA LIEU
CARBONATE	21Oct97	DARREN CRICHTON	BICARBONATE	21Oct97	DARREN CRICHTON
P ALKALINITY	21Oct97	DARREN CRICHTON	T ALKALINITY	21Oct97	DARREN CRICHTON
HARDNESS	0	LANG QUE TRAN	T DIS SOLIDS	0	LANG QUE TRAN
IONIC BALANCE	0	LANG QUE TRAN	NO2&NO3-N	21Oct97	THERESA LIEU
IRON	21Oct97	LANG QUE TRAN	MANGANESE	21Oct97	LANG QUE TRAN
MERCURY	23Oct97	LANG QUE TRAN	SELENIUM	22Oct97	LANG QUE TRAN
IRON	22Oct97	LANG QUE TRAN	ALUMINUM	22Oct97	LANG QUE TRAN
ANTIMONY	22Oct97	LANG QUE TRAN	ARSENIC	22Oct97	LANG QUE TRAN
BARIUM	22Oct97	LANG QUE TRAN	BERYLLIUM	22Oct97	LANG QUE TRAN
BISMUTH	22Oct97	LANG QUE TRAN	BORON	22Oct97	LANG QUE TRAN
CADMIUM	22Oct97	LANG QUE TRAN	CALCIUM	22Oct97	LANG QUE TRAN
CHROMIUM	22Oct97	LANG QUE TRAN	COBALT	22Oct97	LANG QUE TRAN
COPPER	22Oct97	LANG QUE TRAN	LEAD	22Oct97	LANG QUE TRAN
LITHIUM	22Oct97	LANG QUE TRAN	MANGANESE	22Oct97	LANG QUE TRAN
MAGNESIUM	22Oct97	LANG QUE TRAN	MOLYBDENUM	22Oct97	LANG QUE TRAN
NICKEL	22Oct97	LANG QUE TRAN	PHOSPHORUS	22Oct97	LANG QUE TRAN
POTASSIUM	22Oct97	LANG QUE TRAN	SILVER	22Oct97	LANG QUE TRAN
SELENIUM	22Oct97	LANG QUE TRAN	SILICON	22Oct97	LANG QUE TRAN
STRONTIUM	22Oct97	LANG QUE TRAN	SODIUM	22Oct97	LANG QUE TRAN
THALLIUM	22Oct97	LANG QUE TRAN	SULPHUR	22Oct97	LANG QUE TRAN
TITANIUM	22Oct97	LANG QUE TRAN	TIN	22Oct97	LANG QUE TRAN
URANIUM	22Oct97	LANG QUE TRAN	VANADIUM	22Oct97	LANG QUE TRAN
ZINC	22Oct97	LANG QUE TRAN	ZIRCONIUM	22Oct97	LANG QUE TRAN

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MIKE NAHIR

WATER ANALYSIS REPORT

The following published METHODS OF ANALYSIS were used:

10301L pH
Electrometric (pH meter)
Ref. APHA 4500-H+

02041L ELECTRICAL COND
Conductance meter
Ref. APHA 2510 B

20103 CALCIUM
ICP spectroscopy @ 317.9 nm
Ref. APHA 3120 B

12102L MAGNESIUM
ICP spectroscopy @ 285.2 nm
Ref. APHA 3120 B

11102L SODIUM

19111 POTASSIUM
Diss.,ICP Spectroscopy, Ref. APHA 3120 B

16306L SULPHATE
ICP spectroscopy @ 180.7 nm
Ref. APHA 3120 B

17203L CHLORIDE
Automated colorimetry, Thiocyanate
Ref. APHA 4500 Cl-,E

06301L CARBONATE
Potentiometric titration with standard
acid to pH 8.3 and pH 4.5
Ref. APHA 2320 B

06201L BICARBONATE
Potentiometric titration with standard
acid to pH 8.3 and pH 4.5
Ref. APHA 2320 B

10151 P ALKALINITY
Potentiometric titration with standard
acid to pH 8.3. Report as CaCO3
Ref. APHA 2320 B

10101 T ALKALINITY
Potentiometric titration with standard
acid to pH 4.5 & pH 8.3. Report as CaCO3
Ref. APHA 2320 B

10602 HARDNESS
Calculation from 2.5*Ca + 4.1*Mg
Reported as CaCO3
Ref. APHA 2340 B

00203 T DIS SOLIDS
SUM OF IONS CALCULATION
Ca + Mg + K + Na + SO4 + Cl + 0.6*T Alk
Ref. APHA 1030 F

NWL4994 IONIC BALANCE
00100 IONIC BALANCE 2
%Diff=(Sum Cations-Sum Anions)/
(Sum Cations+Sum Anions)*100
Ref. APHA 1030 F

07105L NO2&NO3-N
Automated colorimetry Cadmium reduction
Ref. APHA 4500-NO3-,F

26321 IRON
Acid extr.,ICP Spectro. Ref. APHA 3120 B

25321 MANGANESE
Acid extr.,ICP Spectro. Ref. APHA 3120 B

80016 MERCURY
Dissolved, cold vapor atomic absorption
spectroscopy, with H2SO4/K2S2O8 digest
Ref. EPA 245.2

34102 SELENIUM
Dissolved, perchloric acid digest, auto.
hydride atomic absorption spectroscopy

Method References:

1. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., 17th ed.
2. EPA a. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846, 3rd ed., US EPA, 1986
   b. Methods for Chemical Analysis of Water and Wastewater, US EPA, 1983
3. MSS Manual on Soil Sampling and Methods of Analysis, Cdn. Soc. of Soil Science, J. A. McKeague, 2nd ed.

* NORWEST SOIL RESEARCH LTD has been accredited by the STANDARDS COUNCIL of CANADA for specific tests registered with the COUNCIL.

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DATE 23 OCT 97 07:58
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W.O. NO. 3 143128

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ENVIRONMENTAL SERVICES
1000, 9700 JASPER AVE
EDMONTON, AB
T5J 4E2

MIKE NAHIR

WATER ANALYSIS REPORT

Ref. APHA 3114 C

Method References:

1. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., 17th ed.
2. EPA a. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846, 3rd ed., US EPA, 1986
   b. Methods for Chemical Analysis of Water and Wastewater, US EPA, 1983
3. MSS Manual on Soil Sampling and Methods of Analysis, Cdn. Soc. of Soil Science, J. A. McKeague, 2nd ed.

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MIKE NAHIR
YUKON MINES III-
PADDY
23 04 98

WATER ANALYSIS REPORT

SAMPLE		1 PA-WQ-ST1-1	2 PA-WQ-ST1-2	3 PA-WQ-ST1-3
TOTAL METALS				
SELENIUM	mg/L	0.0004	<0.0001	<0.0001
ROUTINE WATER				
pH		7.57	7.55	7.60
ELECTRICAL COND	uS/cm	645	649	650
CALCIUM	mg/L	114	114	113
MAGNESIUM	mg/L	20.4	20.3	20.4
SULPHATE	mg/L	243	241	236
BICARBONATE	mg/L	139	137	140
T ALKALINITY	mg/L	114	112	115
HARDNESS	mg/L	370	369	365
LOW LEVEL HG TOT				
MERCURY	mg/L	<0.00001	<0.00001	<0.00001
TRACE ICP,TOTAL				
ALUMINUM	mg/L	0.155	0.144	0.147
ARSENIC	mg/L	<0.01	<0.01	<0.01
CADMIUM	mg/L	0.00214	0.00206	0.00199
CHROMIUM	mg/L	0.0506	0.0010	<0.0008
COPPER	mg/L	<0.001	<0.001	<0.001
IRON	mg/L	0.321	0.366	0.354
LEAD	mg/L	0.0032	0.0041	0.0033
NICKEL	mg/L	0.005	0.004	0.004
SILVER	mg/L	<0.00005	<0.00005	<0.00005
ZINC	mg/L	0.543	0.528	0.504

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YUKON MINES III-
PADDY
23 04 98

WATER ANALYSIS REPORT

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*note*  pH              pH  REPORTED AT ROOM TEMP
*note*  ELECTRICAL COND 'ELECTRICAL COND' (EC) is in microsiemens/cm and is a measure of solids in
                       solution
                       E.C. CORRECTED TO 25C
*note*  T ALKALINITY    'ALKALINITY' is CARBONATE/BICARBONATE expressed as CALCIUM CARBONATE
*note*  HARDNESS        'HARDNESS' is calcium and magnesium expressed as CALCIUM CARBONATE
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PADDY
23 04 98

WATER ANALYSIS REPORT

---PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------	---PARAMETER----	DATE OF-ANALYSIS	------ANALYZED BY-------
SELENIUM	30Apr98	LANG QUE TRAN	pH	29May98	DARREN CRICHTON
ELECTRICAL COND	29May98	DARREN CRICHTON	CALCIUM	29May98	LANG QUE TRAN
MAGNESIUM	29May98	LANG QUE TRAN	SULPHATE	29May98	LANG QUE TRAN
BICARBONATE	01Jun98	DARREN CRICHTON	T ALKALINITY	01Jun98	DARREN CRICHTON
HARDNESS	29May98	LANG QUE TRAN	MERCURY	28Apr98	LANG QUE TRAN
ALUMINUM	02Jun98	LANG QUE TRAN	ARSENIC	28Apr98	LANG QUE TRAN
CADMIUM	29Apr98	LANG QUE TRAN	CHROMIUM	28Apr98	LANG QUE TRAN
COPPER	28Apr98	LANG QUE TRAN	IRON	28Apr98	LANG QUE TRAN
LEAD	29Apr98	LANG QUE TRAN	NICKEL	28Apr98	LANG QUE TRAN
SILVER	29Apr98	LANG QUE TRAN	ZINC	28Apr98	LANG QUE TRAN

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YUKON MINES III-
PADDY
23 04 98

WATER ANALYSIS REPORT

The following published METHODS OF ANALYSIS were used:

34011 SELENIUM
Total, perchloric acid digest, automated hydride atomic absorption spectroscopy.
Ref. APHA 3114 C

10301L pH
Electrometric (pH meter)
Ref. APHA 4500-H+

02041L ELECTRICAL COND
Conductance meter
Ref. APHA 2510 B

20103 CALCIUM
ICP spectroscopy @ 317.9 nm
Ref. APHA 3120 B

12102L MAGNESIUM
ICP spectroscopy @ 285.2 nm
Ref. APHA 3120 B

16306L SULPHATE
ICP spectroscopy @ 180.7 nm
Ref. APHA 3120 B

06201L BICARBONATE
Potentiometric titration with standard acid to pH 8.3 and pH 4.5
Ref. APHA 2320 B

10101 T ALKALINITY
Potentiometric titration with standard acid to pH 4.5 & pH 8.3. Report as $CaCO_3$
Ref. APHA 2320 B

10602 HARDNESS
Calculation from 2.5*Ca + 4.1*Mg
Reported as $CaCO_3$
Ref. APHA 2340 B

Method References:

1. APHA Standard Methods for the Examination of Water and Wastewater, American Public Health Assoc., 17th ed.
2. EPA a. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods SW-846, 3rd ed., US EPA, 1986
b. Methods for Chemical Analysis of Water and Wastewater, US EPA, 1983
3. MSS Manual on Soil Sampling and Methods of Analysis, Cdn. Soc. of Soil Science, J. A. McKeague, 2nd ed.

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Appendix D

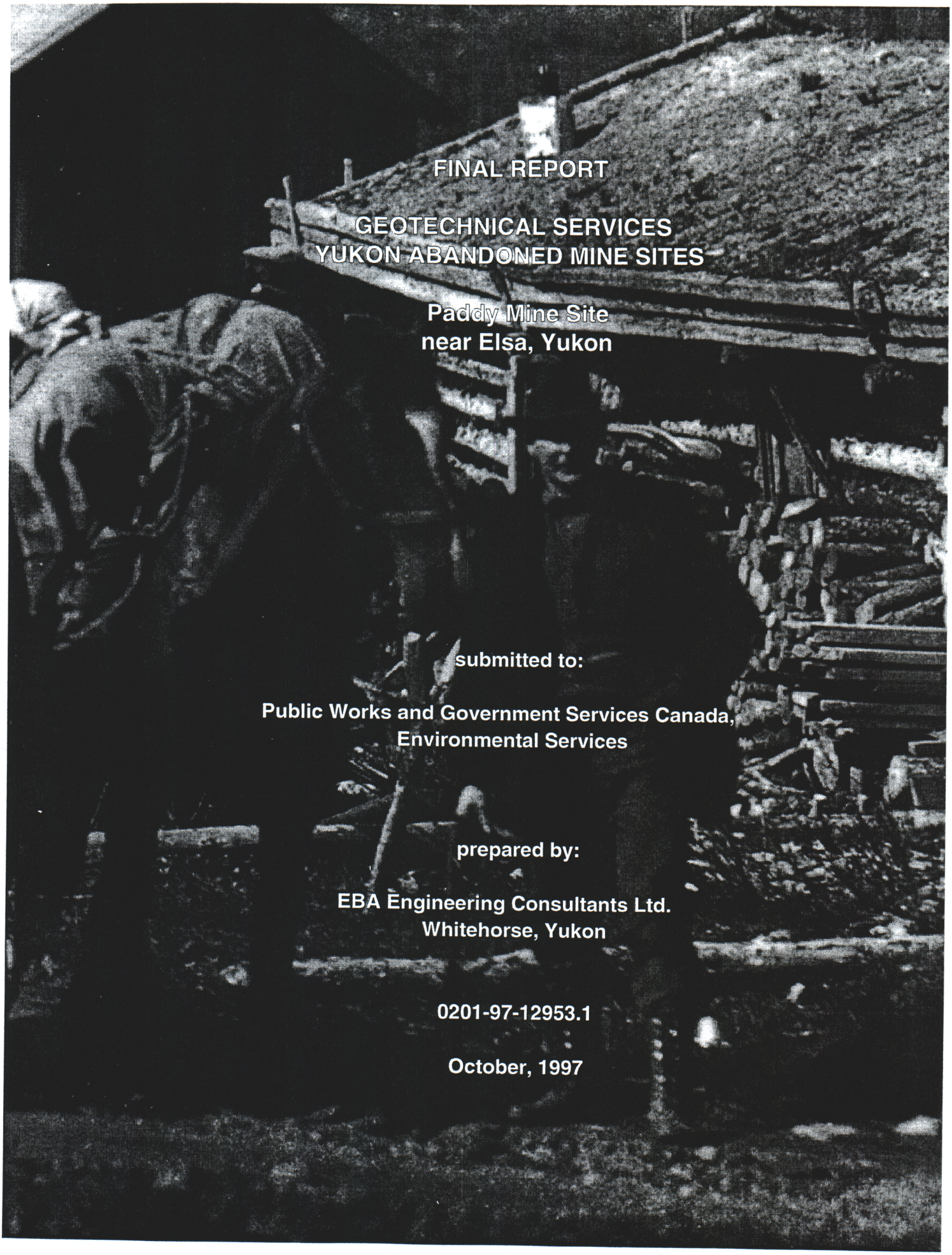
Geotechnical Services

Yukon Abandoned Mine Site

Paddy Mine Site

prepared by EBA Engineering Consultants Ltd.

(1997)



FINAL REPORT

GEOTECHNICAL SERVICES
YUKON ABANDONED MINE SITES

Paddy Mine Site
near Elsa, Yukon

submitted to:

Public Works and Government Services Canada,
Environmental Services

prepared by:

EBA Engineering Consultants Ltd.
Whitehorse, Yukon

0201-97-12953.1

October, 1997

EXECUTIVE SUMMARY

Public Works and Government Services Canada (PWGSC), Environmental Services retained EBA Engineering Consultants Ltd. (EBA) to perform geotechnical services in relation to a study focussed on the restoration of the Paddy Mine Site which is approximately 5 km east of Elsa, YT. In brief, the geotechnical aspect of the restoration study involved a field work component and a terrain analysis component. The purpose of the field work program was to visually observe and assess slope conditions at the site and to provide information for site specific slope stabilization options. The purpose of the terrain analysis work was to identify potential sources of fine grained borrow material.

From the site visit, there were three particular items which warranted geotechnical consideration: slump failures at various locations along the lower road, a collapsed bridge (#2) which was impeding the flow of Christal Creek, and various signs of slump and scree slide mass wasting along the waste rock slope which could potentially impact Christal Creek over the long term. In regards to the lower road, to prevent further slumping of the soil into Christal Creek, some grading work could be performed at unstable locations to achieve a final slope of 2.5H:1V. In order to alleviate potential negative impacts on the fisheries resource in Christal Creek as a result of collapsed bridge #2, the bridge could be demolished and the debris could be buried on site. In regards to the waste rock dump near the adit, the slope could be stabilized by placing a physical barrier between the waste rock on the canyon slope and the creek, grading the area of the existing slumped material at the west lobe, and clearing the middle road of debris so that this bench could serve as a catchment area. The Class "D" cost estimate to implement the restoration work for the lower road, the collapsed bridge #2, and the waste rock slope has been submitted under separate cover.

The results of the terrain analysis indicates that the area of the Paddy Mine Site is characterized by alternating till deposits of glacio-fluvial and morainal origin. An area approximately 600 m west of the waste rock dump has been identified as a possible morainal deposit which may be suitable for the development of a fine grained borrow source. It is recommended to proceed with a ground truthing and test pitting exercise in order to verify the quality and quantity of this potential fine grained borrow source prior to further design consideration.

TABLE OF CONTENTS

Cover photo: *J.K. (Paddy) Cram of the Consolidated Mining and Smelting Co. Ltd., pose with pack horse on his departure from Keno City to McKay Hill in the Beaver River country.[1926]. Yukon Archives. Hare Collection #6757.*

1.0 INTRODUCTION

1.1 General

Public Works and Government Services Canada (PWGSC), Environmental Services retained EBA Engineering Consultants Ltd. (EBA) to perform geotechnical services in relation to a study focussed on the restoration of five abandoned mines near the communities of Elsa and Carcross, Yukon. The property which is considered in this report is known as the Paddy Mine Site and is located approximately 5 km east of Elsa, YT.

The terms and conditions of the agreement for the project, including the scope of work and the basis for payment, was outlined in the fax by Tim Sackmann of PWGSC dated August 11, 1997. In brief, the geotechnical aspect of the restoration study involved a field work component and a terrain analysis component. The purpose of the field work program was to visually observe and assess slope conditions at the site and to provide information for site specific slope stabilization options. The purpose of the terrain analysis work was to perform the necessary air photo interpretation and review of existing borehole data in order to identify potential sources of fine grained borrow material for site restoration purposes.

It is understood that this report was intended to cover strictly the geotechnical aspects of the restoration work and as such, that it would be appended to a comprehensive document describing the overall restoration study. Therefore, to avoid redundancies, the writer has not described in detail the location, site access, past mining activities, climate, or other extraneous details of each site. Rather, the report contains background information which is related to geotechnical considerations, the results of the field work program, the slope stabilization options with cost estimates, and the results of the terrain analysis. Brief conclusions and recommendations have also been prepared in consideration of the findings.

2.0 BACKGROUND INFORMATION

Various background information was provided by PWGSC for the Paddy site. This included excerpts from an unpublished contract report prepared by Norecol, Dames & Moore (NDM) for PWGSC, Environmental Services. Prior to initiating the field work program, the report was reviewed in order to identify specific geotechnical concerns which were raised and to incorporate these concerns into the site inspection work. This section briefly describes the relevant geotechnical background information.

For a complete description of the findings of the initial site assessment, the reader is referred to the NDM report 20749-013-310 dated February 7, 1997. From the information provided by PWGSC, the following two geotechnical concerns were raised:

1. The waste rock dump material, which had derived from the open pit (just above the upper road) and was placed along the hillside above the main adit, had started to slump down the slope.
2. The lower road had started to slump down into Christal Creek at various locations. The largest area of failure occurred at the two bridge crossings, which was considered a potential threat to the fisheries resource of the creek.

Each of these geotechnical concerns were considered at the time of the field work program and for the subsequent analysis.

3.0 SITE CONDITIONS

The purpose of the field work program was to visually observe the slope conditions at each mine site in order to develop recommendations for site specific slope stabilization options. The field work was conducted on August 18, 1997 with representatives from PWGSC and Steffen, Robertson, and Kirsten (SRK).

The methodology of the field work program essentially consisted of performing lateral surveys to verify site sketches taken from previous reports, visually observing the slope conditions by measuring the slope angle and inspecting the slope for tension cracks or other signs of mass wasting, and excavating test pits (hand dug) in order to get an indication of the near surface soil or waste rock profile for slope stability considerations.

Those areas inspected during the site visit at the Paddy Mine included the lower road, the two collapsed bridges along Christal Creek, the upper road near the excavation, and the waste rock dump located along the canyon slope near the adit. Relevant site features observed during the field work program were essentially as noted on the plan and profile drawings enclosed in the Figures section of this report. The Site Plan of the mine site is depicted as Drawing 12953-2 and the plan and profile drawings of the waste rock dump are enclosed as Drawing 12953-3 and 12953-4, respectively.

In regards to the lower access road, there appeared to be slight mass wasting either due to erosional effects of Christal Creek or due to an excessive slope gradient leading toward the creek. The tension cracks and evidence of slump failures seen in Photos PA2 and PA3 have occurred at those locations along the south edge of the lower road which are directly adjacent to the creek and which have a steep slope angle (in excess of 35°) leading from the edge of road to the creek. These areas also correspond to locations where fill was placed for the construction of the road. Based on these observations, it appears that the failures have been primarily due to slope angles which are in excess of the maximum angle of repose for such a fine grained, schistose-based silty sand soil. To a lesser extent, it is likely that the fill for the road construction was not placed with adequate compaction, further reducing the shear strength of the soil mass.

Photo #PA1: Bridge#1 collapsed into creek. Note log crib construction with earthen fill; note approximately 0.5 m drop in water level at right side of creek.

Photo #PA2: Note slump failures along north bank of creek just down stream of collapsed bridge #2.

EBA Engineering Consultants Ltd.			PROJECT	GEOTECHNICAL SERVICES, YUKON ABANDONED MINES PROJECT	
CLIENT	PUBLIC WORKS AND GOVERNMENT SERVICES CANADA		TITLE	PADDY MINE PHOTO SHEET #1	
DATE 97 10 09	DWN. MEB	CHKD.	FILE NO. 0201-97-12953	DWNG. 12953-PHTO1	REVISION 0

From this, it is envisioned that future slope failures along the lower road would involve a series of slumping events of soil into and subsequent erosion by the creek. The erosion of the slumped material undermines the toe of the newly formed slope which in turn causes further slumping. This cycle is typically repeated until sufficient slumping has occurred such that a natural slope angle for the fine grained material is realized. Based on the height of the road above the creek, it does not appear that the volume of material at each particular slumping event would greatly impede the flow of the creek. Rather, the slumping and subsequent erosion will affect the creek by slightly increasing the sediment loading over a period of several years. It cannot be estimated with reasonable accuracy whether this increase in sediment loading would adversely impact the fisheries resource of this creek.

In the areas of the two bridges, it appears that the failure has resulted from the erosion of the bridge abutments over time, causing each bridge to collapse into the creek. The abutments and bridges themselves were constructed of log cribbing with earthen fill and were clearly not capable of withstanding large fluctuations in the creek flow or water elevations. As a result, the supports at either side of the bridge were eroded away, eventually causing the bridge to collapse into the creek. As seen in Photo PA1, the collapsed bridge #1 does not seriously impede the flow of Christal Creek since channels have been developed on either side of the bridge. There is an approximately 0.5 m drop in elevation of water level at the right side (west) and an approximately 0.3 m drop at the left side. Based on visual observation, it does not appear that the collapsed bridge #1 would pose a threat to the fisheries resource of Christal Creek.

The collapsed bridge #2 closer to the adit is more seriously impeding the flow of Christal Creek. The bridge appeared to dam the creek, causing a change in water elevation of approximately 0.6 m and creating a log jam at the upstream end. There was seepage through the collapsed bridge at various locations which allowed the creek to maintain flow downstream. Based on visual observation, the collapsed bridge #2 could represent a hindrance to the fisheries resource of Christal Creek. However, with little fisheries information available for this particular creek, the extent of this impact cannot be reasonably assessed. With this in mind, it is considered to be more effective to actually remove the obstruction in order to alleviate the problem rather than to engage in an assessment of the impact to the fisheries resource.

Photo #PA3: Evidence of slump failure along lower road. Movement due to eventual stabilization of loose fill material placed at excessive slope angles and without compactive effort.

Photo #PA4: Looking east along upper road near waste rock dump. Note slumping of road, extension cracks due to natural slope stabilization.

eba EBA Engineering Consultants Ltd.			PROJECT GEOTECHNICAL SERVICES, YUKON ABANDONED MINES PROJECT		
CLIENT PUBLIC WORKS AND GOVERNMENT SERVICES CANADA			TITLE PADDY MINE PHOTO SHEET #2		
DATE 97 10 09	DWN. MEB	CHKD.	FILE NO. 0201-97-12953	DWNG. 12953-PHTO2	REVISION 0

As seen in Drawing 12953-3, the waste rock along the south canyon slope near the adit consisted of alternating lobes of fine grained, slightly pulverized schist rock and course grained quartzite rock. The slope angles of the waste rock material approached 38° due to the naturally steep slope of the canyon wall. The canyon slopes appeared to have a thin veneer of colluvium soil over bedrock and the depth of the waste rock did not appear to exceed 1.0 m to 1.5 m. This depth estimate for the waste rock corresponds to the relatively small size of the open pit excavation from which the majority of the waste rock had derived and to the large surface area over which the waste rock has been placed. Based on this assumed subsurface profile, the most probable mode of slope failure would be either a gradual near surface movement of the waste rock itself through slumping, surface erosion, and scree slides or a sudden translation slip failure along the waste rock, soil interface. During the site visit, it appeared that mass wasting at this site was restricted to gradual surface movement as there was no evidence of translational slip failure or more extensive slides of this nature.

There were signs of slumping and creep at the upper road and western most waste rock lobe as indicated on Drawing 12953-3 and in Photo PA4. In the case of the upper road area, some slumping has occurred at the top of the waste rock slope. As seen on the particle size analysis of Sample Paddy 1 which was retrieved from this area, the sample was composed of sand and gravel sizes, with some silt. The material was schist based, with a fines content of close to 20%, and appeared to be placed in a relatively loose state. These collective factors are most likely the cause of the slump in this area. Namely, the relatively high fines content and platy, graphitic schist nature translates to relatively low shear strength characteristics of the waste rock material. The loose nature of the material also has lead to slumping due to the decrease in void spaces and corresponding consolidation of the waste rock mass. There was no visual evidence of past deep seated failures along the waste rock slope. Such a failure would most definitely adversely impact Christal Creek.

At the western most waste rock lobe, some slump failure appears to have occurred within the schist-based waste rock mass as a result of the excessive slope angle and of the change in the total stress conditions within that material following the initial deposition event. This was most likely due to the increase in pore water pressures which would have developed within the fine grained material following its deposition in a loose, relatively dry state. The gradual increase in pore water pressure

within the waste material and the corresponding decrease in the shear resistance has caused the waste rock to gradually mobilize further down slope. However, this has been a slow process and has been restricted to the near surface waste rock mass as apposed to a failure within the underlying soil mass.

In areas along the slope where the coarse rock has been deposited, there is very little evidence of instability other than slight scree slide movements. There were larger diameter rocks located at the toe of the waste rock slide and within Christal Creek. This material was most likely deposited during the original development of the open pit excavation and has not been mobilized as a result of recent mass wasting. The coarse rock is free draining and not susceptible to surface erosion as with the waste rock of schist origin. Further, the angular nature of the rock increases the interparticle shear resistance which translates to a higher slope stability. In this respect, the coarse waste rock slopes are considered stable and not susceptible to the soil slumping which is occurring with the fine grained schist waste rock. Slight scree slide movements may occur over the long term which could lead to a small quantity of the quartzite rock impacting Christal Creek.

Based on the visual observations during the site visit, it appears that mass wasting of the fine grained material has been restricted to surface erosion and slumping. Mass wasting of the coarse grained material has been restricted to small scree slides. As such, it appears that the waste rock pile has remained relatively stable over its more than 25 year presence along the south canyon slope near the adit and open pit excavation. In regards to the future stability of the waste rock pile, it is anticipated that similar mass wasting will occur. Due to the close proximity of Christal Creek to the toe of the waste rock pile slope, there may be some long term impact of this surface movement since some waste rock material may reach the creek.

Although a large scale translational slide is not considered probable, some uncertainty exists since the characteristics of the full depth of waste rock and of the underlying native soil are not known. There may be less stable strata below the near surface material which could fail in the future. However, it is more likely that such a failure would have occurred by now since the environmental conditions (moisture, permafrost, surcharge loads) within the waste rock which could effect such a slide most likely have reached an stable equilibrium during its 25 year history along the canyon slope.

4.0 SITE SPECIFIC SLOPE STABILIZATION OPTIONS

4.1 Description of Proposed Restoration Activities

As detailed above, it appears that there are three items noted during the site visit which warrant consideration with respect to restoration activities: the collapsed bridge #2, the slump failures along the lower road, and the slump failures and scree slides within the near surface waste rock along the south canyon wall near the adit. The following includes a description of the proposed restoration activities for each particular item.

4.1.1 Collapsed Bridge #2

The collapsed bridge #2, which is the further east of the two, has severely impeded the flow of the creek and caused log jams and similar disturbances to the creek. This bridge should be demolished and the debris should be removed from the creek and buried in the immediate area. This work could be accomplished with a Caterpillar 225 backhoe or similar with a thumb attachment on the bucket to facilitate debris removal from the creek. Access to the collapsed bridge could be accomplished via the road leading from the gravel pit on the Hanson Lakes Road as shown on Drawing 12953-1.

If this work is to be conducted in concert with the restoration of the waste rock slope as discussed in section 4.1.3, access across Cristal Creek would be possible following placement of the culverts at the location of collapsed bridge #1. However, if the waste rock slope restoration work does not proceed, the culverts would not be required. It is not considered practical to install culverts at this location strictly to allow access to demolish collapsed bridge #2. This is due to the much greater environmental impact which would be associated with placing and removing two culverts than with crossing the two short spans of the creek a single time with a backhoe.

4.1.2 Lower Road

In order to prevent further slumping of the soil along the lower road into Christal Creek, some grading work will be necessary at various locations along the road. The most notable areas which have been affected by the soil slumping are located at the collapsed bridge #2 and adjacent to the road approximately 225 m east of collapsed bridge #1. The work would involve grading the existing 1.5H:1V slope to a 2.5H:1V slope using a backhoe. The site access for this work would be similar to that described in section 4.1.1.

4.1.3 Waste Rock Slope Area

As mentioned, there is the possibility of furtherdown slopee movement of the waste rock as a result of slumping and scree slide mass wasting. Although the potential impact is not considered to be severe, if it is the intention to ensure that there are no long term effects on Christal Creek as a result of this mass wasting, several restoration activities could be implemented.

The restoration program would involve placing a physical barrier between the waste rock on the canyon slope and the creek to avoid material which has mobilized downslope from entering the creek. As well, some grading could be performed to stabilize the existing slumped material at the west lobe and to clear the middle road of debris so that this bench could serve as a catchment area.

As mentioned, there is very little distance between the toe of the waste rock slope and the creek and any cuts into the slope would undermine the toe support of the slope. As such, there is insufficient space for an earthen retaining structure. Given this restriction and the prohibitive costs associated with mobilizing construction supplies to this site, a gabion wall system is considered to be the most cost effective manufactured retaining wall. The gabion walls would be constructed with oversize rock material deriving from the gravel pit depicted on Drawing 12953-1. The rock would be screened at the borrow pit and then hauled by truck to the toe of the waste rock slope where the gabions would be built in place by hand and with a small backhoe.

Following the construction of the retaining wall, some grading work could be performed with a dozer to clear the existing road which is partially buried with slide debris. This would create a catchment area to provide further protection from waste rock mobilizing downslope. It would also provide access to the west waste rock lobe which has experienced slumping. In order to prevent further mass wasting in this area, it could be graded to a 27°-28° slope which is closer to the natural angle of repose for this material.

Since the restoration work will involve a significant amount of machinery crossing the creek at failed bridges #1 and #2, these areas will have to be rehabilitated with corrugated steel pipe culverts covered with earth fill. This will serve as a temporary bridge during the construction and could be subsequently removed to restrict other users from the area. Site access will also require some grading of the road approximately 175 m west of failed bridge #1 where a short length of the road was intentionally destroyed to prevent vehicular passage.

4.2 Class "D" Cost Estimate

As requested, the Class "D" cost estimate to implement the restoration program described above has been detailed under separate cover.

With respect to schedule, it is advised to proceed with the design and development of specifications this winter so that the contractor selection and construction program could be performed during the summer of 1998. To ensure that the access road is dry and suitable for vehicular traffic, it is advised to conduct the construction during the mid to latter part of the summer.

5.0 FINE GRAINED BORROW SOURCES

Aerial photography of the study area with an approximate scale of 1:20,000 was reviewed for terrain analysis considerations in order to determine the location of a fine grained borrow source. This was necessary so that fine grained material could be identified for potential use as an low permeability cap over the existing waste rock piles at the subject property. The results of the terrain analysis was cross referenced with available borehole information and with a Geological Survey of Canada surficial geology map of the study area.

The immediate area of the Paddy Mine Site is dominated by a thin veneer of till material over bedrock. The depth of till was noted as being less than 500 mm within the upper excavation during the site visit with extensive exposed bedrock throughout the canyon area. The depth of till increases with lower elevation. The area surrounding Christal Creek to the west of the canyon is characterized by alternating till materials of morrainal and glacio-fluvial depositional histories. The area enclosed by a dashed line on Drawing 12953-1 appears to be a possible morainal deposit which may be suitable for the development of a fine grained borrow source. The area is favourable since it is flat and thus less susceptible to permafrost and since it is road accessible and close to the site. Further, since the area has been previously developed the approval for the land use permit would be a less onerous process than with other undisturbed areas.

Borehole information from previous work in this area[1] was reviewed to supplement the terrain analysis program. The borehole results indicate the presence of both sandy silt and sandy gravel strata in the general area with no presence of permafrost or ground water within 3.5 m depth. The results of the terrain analysis and borehole review are consistent with the information present in the Geological Survey of Canada, Surficial Geology Map 4-1982 for this area.

It is recommended to proceed with a ground truthing and test pitting exercise in order to verify the quality and quantity of the potential fine grained borrow source prior to further design consideration.

[1] J.R. Paine & Associates Ltd. 1988. Report Y8002-84 - Geotechnical Investigation, Km 52-111, Silver Trail, YT, Unpublished contract report prepared for Government of Yukon, Community and Transportation Services.

5.0 CONCLUSIONS

The following conclusions are drawn from this study:

1. In regards to the lower road, it appears that the failures have been primarily due to slope angles which are in excess of the maximum angle of repose for such a fine grained, schistose-based silty sand soil. In order to prevent further slumping of the soil along the lower road into Christal Creek, some grading work will be necessary at various locations along the road to achieve a final slope of 2.5H:1V.
2. In the areas of the two bridges, it appears that the failure has resulted from the erosion of the bridge abutments over time, causing each bridge to collapse into the creek. Collapsed bridge #1 does not seriously impede the flow of Christal Creek since channels have been developed on either side of the bridge. The collapsed bridge closer to the adit (#2) is more seriously impeding the flow of Christal Creek. In order to alleviate potential negative impacts on the fisheries resource in Christal Creek, the collapsed bridge #2 should be demolished.
3. From the visual observations of the waste rock slope near the adit, it appears that mass wasting of the fine grained material has been restricted to surface erosion and minor slumping. Mass wasting of the coarse grained material has been restricted to small scree slides. Due to the close proximity of Christal Creek to the toe of the waste rock pile slope, there may be some impact over the long term of this surface movement since some waste rock material may reach the creek. To avoid this potential impact, the slope could be stabilized by placing a physical barrier between the waste rock on the canyon slope and the creek, grading the area of the existing slumped material at the west lobe, and clearing the middle road of debris so that this bench could serve as a catchment area.
4. The Class "D" cost estimate to implement the restoration work for the lower road, the collapsed bridge #2, and the waste rock slope has been submitted under separate cover.
5. The area depicted on Drawing 12953-1 appears to be a morainal deposit which may be suitable for the development of a fine grained borrow source. It is recommended to proceed with a ground truthing and test pitting exercise in order to verify the quality and quantity of the potential fine grained borrow source prior to further design consideration.