

Phase III Environmental Assessment

Formo Mine Site

Final Report

Prepared for:

Action on Waste Program
Indian and Northern Affairs Canada

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Executive Summary

The Formo exploration site is located at 63° 56' 26" N, 135° 22' 09" W, approximately 7 km east of the village of Elsa. This Phase III assessment was carried out by Environmental Services for Indian and Northern Affairs Canada to a) identify the cause of past slope failure(es) below the lower/eastern workings and assess the potential for further failure and transport of mineralized waste rock toward Christal Creek, and b) identify seasonal variations in contaminant loadings in Christal Creek upstream and downstream of the lower/eastern waste rock dump. Major findings of this assessment are summarised in the following Table:

Site Assessment Component	Concern
Christal Creek Water Quality	Zinc is the primary contaminant of concern. The lower/eastern waste rock dump is a contributor to downstream Zn levels: Zn has tended to be 2 - 4 times higher in water downstream from the waste rock dump compared to upstream levels. Further, the increase in downstream Zn concentration is greater than the FAL criteria, indicating that the Zn contribution from the lower/eastern waste rock dump would impact downstream fisheries use of Christal Creek.
Lower/eastern Waste Rock Dump Slope Stability	Waste rock dump has excessive slope angle for a schist-based rock. An unstable peat layer below the waste rock and the presence of underlying permafrost contribute to instability of the lower/eastern waste rock dump. Continued failure of waste rock stability is not likely to directly impact the creek but rather promote siltation due to overburden pushed from base of waste rock dump.
Acid Rock Drainage	Mineralized waste rock at the lower/eastern workings is acid-generating. Overburden has slumped into Christal Creek. Waste rock has slumped to within 20 m of Christal Creek; massive sulphides are evident in the mixed overburden/waste rock slump material.

Recommendation 1. Physically stabilize the toe of the slope to prevent future slumping into Christal Creek. The proposed slope stabilization method would involve building a toe berm to provide lateral support and to act as a physical barrier to migration of surficial soils into Christal Creek.

Recommendation 2. Due to practical and financial constraints no further site assessment work is recommended at this time.

Recommendation 3. Site drainage and upstream and downstream Christal Creek water quality should be sampled at five year intervals to identify significant longer-term trends or changes.

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Phase III Environmental Assessment

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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 safety concerns on each site, and d) provided general recommendations for remediation or mitigation work. No rock, soil or water samples were collected for these assessments.

Environmental Services, Public Works and Government Services Canada conducted a Phase II environmental assessment of the abandoned Formo mine on 13 and 20 August, 1996. The Formo exploration site is located at 63° 56' 26" N, 135° 22' 09" W, approximately 7 km east of the village of Elsa. The mine site straddles Highway 11 connecting Elsa and Keno Hill, with the middle and lower/eastern workings downslope and north of the highway.

Conclusions of the phase II findings indicate that two waste rock disposal areas ("middle" and "lower/eastern"/"eastern" workings) were identified on the slope above Christal Creek. A series of slope failures below the lower/eastern workings has transported mineralized waste rock toward Christal Creek. Slumped material had crossed and blocked the creek, although the creek channel had since been re-established.

Zinc concentrations in Christal Creek upstream of the lower/eastern workings exceeded the CCME criterion for protection of freshwater aquatic life. Zinc, silver and cadmium in samples downstream of the middle and lower/eastern workings also exceeded the CCME freshwater aquatic life criteria (zinc and silver levels were roughly double those measured in the upstream sample).

Most of the Formo waste rock was found to be either acid generating or potentially acid-generating; however, waste rock piles on the hillside above Christal Creek contribute little in terms of metal loads to the creek. The major source of water contaminants was believed to be the failed mineralized waste rock lying within Christal Creek below the lower/eastern workings.

The recommendations of the Phase II assessment were to:

5. Assess physical stability for future slope failure and potential impact on creek.

6. Perform detailed assessment of receiving water quality.
7. Water quality monitoring program 3 or 4 times annually.
8. Determine metals in WR available for transport - leach extraction test.
9. Locate potential borrow source if remediation required.

2. PURPOSE AND SCOPE OF WORK

This Phase III assessment was carried out by Environmental Services for Indian and Northern Affairs Canada to a) identify the cause of past slope failure(es) below the lower/eastern workings and assess the potential for further failure and transport of mineralized waste rock toward Christal Creek, and b) identify seasonal variations in contaminant loadings in Christal Creek upstream and downstream of the lower/eastern waste rock dump. Accordingly, the following assessment activities were completed:

- Geotechnical inspection of the lower/eastern waste rock disposal area, including field observation of the lower/eastern waste rock dump area and terrain analysis to identify potential borrow source(es) for site restoration purposes
- 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
- Assessment of contaminant loadings caused by acid rock drainage at the lower/eastern waste rock disposal area

Recommendations and preliminary cost estimates were then generated to meet the following remediation/mitigation requirements:

- Physical stabilization of waste rock disposal areas
- Chemical stabilization of waste rock disposal areas, taking into account onsite resources and accessibility

3. SITE ASSESSMENT METHODOLOGY

3.1 Assumptions

At the Formo 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

CCME Criteria

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

A professional geologist assessed the acid rock drainage and metal leaching potential of the lower/eastern waste rock disposal area by:

- Confirming variations in rock type, mineralization and alteration noted in the Phase II assessment;

- Laboratory leach testing of selected archived waste rock samples (originally collected during the 1996 site visit).

A professional geotechnical engineer was retained to inspect the lower/eastern waste rock disposal area to identify:

- 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 Formo site for future stabilization/reclamation of the waste rock disposal area (should that work be deemed necessary).

3.3.2 *Sampling Methods and Quality Assurance*

Water Sampling

Samples were collected from Christal Creek upstream and downstream of the middle and lower/eastern waste rock disposal areas, and from seeps emanating from the lower/eastern 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 respectively.

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 HNO₃ 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 Formo site on Galena Hill are silver, gold, lead and zinc. Keno Hill-Galena Hill silver-lead ores occur in erratic lenses lying in vein faults that cut fine-bedded to massive quartzite, intercalated with greenstone sills and lenses and various schistose rocks.

The Formo veins are composed of siderite (FeCO_3) with variable, but small, amounts of quartz, sphalerite ($(\text{Zn,Fe})\text{S}$), galena (PbS) and freiberigite (silver-bearing tetrahedrite ($(\text{Cu,Fe})_{12}\text{Sb}_4\text{S}_{13}$)). 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 upper, middle and lower workings enters Christal Creek, a third-order stream which joins the South McQuesten River about 7.5 km west of Formo. The upper, middle and lower/eastern workings are approximately 110m, 75m, and 50m in elevation above Christal Creek respectively. No surface water bodies cross the Formo mine site.

Two active seeps were discovered at the lower/eastern waste rock dump during the August 19, 1997 site visit: the first seep was found about 35m below the crest of the dump slope, and the second seep was near the toe of the slope about 8m above Christal Creek. Neither seep was active during the August 1996, October 18, 1997, or April 23, 1998 site visits.

During the 19 August 1997 site visit, Christal Creek discharge immediately below the toe of the lower/eastern waste rock slope was measured. Discharge on that date was measured at 0.334 m³/second.

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 drainages 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 grayling 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.

4.5 Site Topography and Soils

Formo is situated on a 28° north-facing slope. The upper workings are located at an approximate elevation of 880 m above sea level, the middle workings at about 850 m elevation, and lower/eastern workings at about 820 m elevation. The lower east waste rock disposal area and associated slumped soils extend from the 820 m level to Christal Creek at 775 m. Slumped soil has recently blocked Christal Creek, which has cut through the slumped material to re-establish its original channel.

A detailed description of the lower/eastern waste rock dump is provided in Section 3 of the attached EBA Engineering Consultants (1997) geotechnical report.

5. SITE ASSESSMENT RESULTS

5.1 Surface Water Quality

Three water samples were collected from Christal Creek on each of 19 August and 18 October, 1997 and 23 April, 1998. Sample FO-WQ-St1-1 was collected 100 m upstream of the eastern edge of the lower/eastern waste rock dump, and sample FO-WQ-St1-2 was collected from Christal Creek at the west edge of the lower/eastern waste rock dump. Sample FO-WQ-St1-3 was collected 300m downstream from the west edge of the lower/eastern waste rock dump.

Two seep samples were obtained during the 19 August, 1997 site visit. Sample FO-WQ-SE-1 was collected from the lower/eastern waste rock slope approximately 8 m above Christal Creek. The seep water was slightly silty and drained an area of peaty organics. Sample FO-WQ-SE2-1 was obtained about 35 m below the crest of the lower/eastern dump slope. Neither seep was active during the 13 August, 1996, 18 October, 1997, or 23 April, 1998 site visits.

Complete analytical results are provided in Appendix B; significant results are summarized in Table 5.1. All creek water samples had pH values between 7.6 and 8.1 and elevated conductivity readings (484 to 651S/cm).

Near Formo, Christal Creek water quality was most negatively affected in spring. At all three sample points, aluminum, cadmium, and iron were 2 to 3 times higher and zinc was about 5 times higher in spring compared to levels of these metals in summer or fall. Aluminum and iron levels in spring samples were slightly higher immediately downstream from the waste rock slope compared to the upstream or farthest-downstream samples. Upstream water quality in Christal Creek shows

seasonal fluctuation: aluminum, cadmium, iron, silver, and zinc levels were higher in April and August than in October.

Table 5.1 Significant Results - Formo Surface Water Samples

Sample ID	Sample Location	Sample Date	pH	Conductivity ($\mu\text{S/cm}$)	Parameters > CCME FAL Criteria
FO-WQ-ST1-1	Christal Creek 100 m upstream of the eastern edge of the lower/eastern waste rock dump	13 Aug 1996	8.1 (7.7)	633 (440)	Ag, Zn
		19 Aug 1997	7.8 (6.9)	484 (460)	Al, Zn
		18 Oct 1997	8	566	Zn
		23 April 1998	7.6	651	Al, Cd, Fe, Ag, Zn
FO-WQ-ST1-2	Christal Creek west edge of the lower/eastern waste rock dump	13 Aug 1996	8.1 (7.0)	618 (450)	Ca, Ag, Zn
		19 Aug 1997	7.9 (7.8)	466 (471)	Cd, Zn
		18 Oct 1997	8	560	Zn
		23 April 1998	7.6	645	Al, Cd, Fe, Zn
FO-WQ-ST1-3	Christal Creek 50 to 100 m downstream of the drainage area affected by the middle workings	13 Aug 1996	7.7 (7.4)	1020 (600)	Ca, Ag, Zn
		19 Aug 1997	8.0 (7.5)	485 (467)	Cd, Zn
		18 Oct 1997	8.1	564	Zn
		23 April 1998	7.7	649	Al, Cd, Fe, Ag, Zn
FO-WQ-SE-1	Seep from lower/eastern waste rock slope approx. 8 m above Christal Creek	19 Aug 1997	(4.7)	(3830)	Al, Cd, Fe, Pb, Ni, Ag, Zn
FO-WQ-SE2-1	Seep from lower/eastern waste rock slope approx. 35 m below dump crest	19 Aug 1997	2.75 (2.6)	6700 (6010)	Al, As, Cd, Fe, Pb, Ni, Ag, Zn

Notes: pH and conductivity readings in brackets are field measurements; unbracketed values are lab measurements.
Field conductivity results reported as microsiemens (μS).
FAL = Freshwater Aquatic Life corrected for hardness.

For all summer and fall samples, analyses show a consistent increase in zinc levels downstream of the lower/eastern waste rock slope compared to upstream levels. Zinc levels in both downstream samples tended to be 2 to 4 times higher than upstream levels. Zinc concentrations in spring samples were essentially uniform through the three sampling points. Zinc exceeded the CCME FAL criterion at all sampling points and in all seasons.

The two seep samples obtained in August 1997 contained zinc, silver, nickel, lead, iron, copper, cadmium and aluminum in excess of CCME FAL criteria. Both samples also exhibited high hardness and sulphate levels. The seep sample taken from mid-slope had a pH of 2.75, but the sample from near the toe of the waste rock slope (and closest to Christal Creek) had a pH of 5.1.

In August 1997, water sampled immediately downstream of the lower/eastern waste rock slope showed increased levels of cadmium and zinc compared to upstream samples. The elevated levels may have reflected cadmium and zinc inputs from the observed waste rock seepage. However, the analytical evidence suggests observed seepage did not significantly affect overall downstream water quality:

1. The aluminum arsenic, copper, iron, lead, nickel and silver levels in seep water did not significantly affect downstream levels of those metals in August 1997 samples; and
2. Cadmium and zinc increased below the waste rock slope in August 1996, October 1997, and April 1998 downstream samples, even though no surface seepage was present.

5.2 Lower/Eastern Waste Rock Dump Geochemical Assessment

Seven pits were dug and eight samples collected of the predominately schistose waste rock. Samples FOWR/P301 and FOWR/P302 were collected from the rock pile at the middle workings. Pit P301 was dug in unmineralized material and pit P302 in the mineralized material. Samples FOWR/P303 and FOWR/P304 were collected from the overburden and weathered bedrock excavated and spread by bulldozer at the upper workings. Samples FOWR/P305, FOWR/P306, FOWR/P307/1, FOWR/P307/2 and FOWR/P308 were collected from the rock pile at the lower/eastern workings. Pit P305 was dug in unmineralized material. Pits P306 and P308 were dug in similar mineralized material, and P307 was dug in an area exhibiting iron carbonate staining on the surface. Sample descriptions and discussion of ABA test results are summarized in Table 5.2.

Table 5.2 Waste Rock Sample Descriptions and Summarized ABA and Bottle Roll Test Results - Formo Mine Site

Sample No.	Sample Location and Description	Summary of Original ABA Test Results	Summary of Bottle Roll Test Results
FOWR/P301	Unmineralized rock from east lobe of middle workings. Black/grey coloured graphite schist with 1% quartz carbonate vein material and 1% visible pyrite collected over a thickness of 30cm. Surface is covered with moss and small alders. Field paste pH measured 7.0 and paste conductivity 260 μ S/cm.	Low potential for acid generation (NP:AP= 6.4).	
FOWR/P302	Mineralized rock from west lobe middle workings. Graphite schist with 3% quartz carbonate vein material and 3% visible pyrite collected over a thickness of 40 cm. Field paste pH measured 7.60 and conductivity 180 μ S/cm.	Potentially acid generating (NP:AP=0.5) with high metal concentrations; 125 ppm As, >100 ppm Cd, >10000 ppm Pb, >200 ppm Ag, >10000 ppm Zn.	After the 6 days of testing, the slurry of sample P302 had a pH of 8.1. During testing, the conductivity increased from 2300 μ S/cm to 3000 μ S/cm.
FOWR/P303	Chlorite schist waste rock at upper workings, 1% visible pyrite, Field paste pH measured 6.4. Included fragments up to 5cm in diameter.	Potentially acid generating (NP:AP=1.2) with high metal concentrations; >100 ppm Cd, >10000 ppm Pb, 154.6 ppm Ag, >10000 ppm Zn.	
FOWR/P304	Chlorite sericite schist typical of waste rock at upper workings. Sample collected over a thickness of 40 cm with fragments up to 5cm in diameter. Contained <1% quartz carbonate vein material. Field paste conductivity measured 210 μ S/cm.	Potentially acid generating (NP:AP=0.2) with high metal concentrations; 3148 ppm As, >100 ppm Cd, >10000 ppm Pb, >200 ppm Ag, >10000 ppm Zn.	

Table 5.2 Waste Rock Sample Descriptions and Summarized ABA and Bottle Roll Test Results - Formo Mine Site (Cont'd)

Sample No.	Sample Location and Description	Summary of Original ABA Test Results	Summary of Bottle Roll Test Results
FOWR/P305	Unmineralized rock from west lobe lower/eastern workings. Sample collected over a thickness of 40cm; upper 12cm consisted of bands of dark brown iron carbonate altered material and graphite chlorite schist bands over a 20cm band of graphite schist and 13cm of dark red brown coloured sand and silt size material. Includes fragments up to 7cm in diameter.	Potentially acid generating (NP:AP=2.3).	
FOWR/P306	Mineralized rock from face of east lobe at lower/eastern workings. Chlorite sericite schist, with bands of limonite. Surface is weathered to a black colour and contains 15% pyrite, and 30% quartz carbonate vein material. Samples collected over a thickness of 30cm.	Acid generating (NP:AP=<0.1) with high metal concentrations; >10000 ppm Pb, 103.8 ppm Ag.	
FOWR/P307/1	Sample of iron carbonate stained surface material collected over a thickness of 18cm in schist.	Acid generating (NP:AP=<0.1) with high metal concentrations; 55.3 ppm Cd, >10000 ppm Pb, 133.7 ppm Ag, >10000 ppm Zn.	
FOWR/P307/2	Collected below FOWR/P307/1 over a thickness of 17cm in brown red coloured schist with grey silt lenses and wood fragments.	Potentially acid generating (NP:AP=<0.1) with high metal concentrations; >100 ppm Cd, 9900 ppm Pb, 151.3 ppm Ag, >10000 ppm Zn.	After 6 days of testing, the slurry of sample P307/2 maintained a pH of 4.3. During testing, the conductivity decreased from 4500 μ S/cm to 3800 μ S/cm.
FOWR/P308	Mineralized rock from top of dump at lower/eastern workings similar to P306. Bands of schist including graphite schist, chlorite schist and limonite collected over a thickness of 35cm.	Acid generating (NP:AP=0.75) with high metal concentrations; >10000 ppm Pb, >200 ppm Ag, 3448 ppm Zn.	

The Acid Rock Drainage Assessment prepared by SRK (PWGSC 1996) found most of the waste rock at the lower adit is either generating acidic drainage or is potentially acid-generating. The material from the upper workings, the middle workings and the unmineralized rock located at the lower/eastern workings were not currently generating acid; however the mineralized material at the lower/eastern workings is acidic. Acid Base Accounting results indicated that only the unmineralized lobe at the middle workings is not a potential source of acid.

The material collected from the mineralized rock piles and the upper workings also contained elevated concentrations of cadmium, lead, silver and zinc. Arsenic was elevated in the material from the mineralized lobe of the pile at the middle workings.

Leach extraction testing to determine metals available for transport was performed in December 1997 (Appendix A). The samples analysed by bottle roll testing included FOR-WR-P307/2 collected outside the lower adit, and FO-WR-P302 collected from the waste dump below the middle adit. Sample P307/2 had a paste pH value of 5.5, indicating that it is slightly acidic, and a NP/AP ratio of <0.1. Sample P302 had a paste pH above neutral and an NP/AP ratio of 0.5.

After the 6 days of testing, the slurry of sample P307/2 maintained a pH of 4.3 whereas sample P302 had a pH of 8.1. The conductivity of the first sample decreased during testing from 4500 $\mu\text{S}/\text{cm}$ to 3800 $\mu\text{S}/\text{cm}$. The conductivity of sample P302 increased from 2300 $\mu\text{S}/\text{cm}$ to 3000 $\mu\text{S}/\text{cm}$. These results indicate that sulphide in both samples is oxidizing to produce sulphate and acidity, but that sample P302 contains greater capacity to neutralize the acid. This is supported by the alkalinity content of 32 mg/L CaCO_3 equivalent detected in the filtered leachate of sample P302 compared to 1 mg/L in sample P307/2.

Both samples had elevated soluble metals concentrations. However, concentrations of metals such as aluminum, cadmium, iron, lead, manganese and zinc are several times higher in sample P307/2, probably due to the lower pH.

5.3 Lower/Eastern Waste Rock Dump Geotechnical Assessment

EBA's (Appendix D) geotechnical assessment of the lower/eastern waste rock dump estimated the area covered by waste rock at 4800 m². The cause of the slumpage described in PWGSC (1997) was excessive loading of dumped waste rock on a peat-covered bench below the adit, causing a slip failure between the peat and underlying till. The slide caused extensive disturbance of the surface peat layer farther down the slope. Waste rock has not extended to Christal Creek as previously reported in PWGSC (1997); rather, the runout apron of the slide appears to end about 150 m from Christal Creek. Surface erosion of the waste rock within a small drainage course has resulted in waste rock movement downslope towards the creek.

The presence of numerous tension cracks above the existing slide area and in the area of the west lobe is evidence of probable future slope failures. There is also significant downslope movement of waste rock material resulting from erosion by surface runoff. Mass wasting is occurring in the form of both active creep and surface erosion.

6. CONCLUSIONS

Existing or potential environmental concerns associated with the Formo mine site are summarized in Table 6.0, and are examined more fully in the following sections.

Table 6.0 Summary of Concerns at Formo Mine Site

Site Assessment Component	Concern
Christal Creek Water Quality	Zinc is the primary contaminant of concern. The lower/eastern waste rock dump is a contributor to downstream Zn levels: Zn has tended to be 2 - 4 times higher in water downstream from the waste rock dump compared to upstream levels. Further, the increase in downstream Zn concentration is greater than the FAL criteria, indicating that the Zn contribution from the lower/eastern waste rock dump would impact downstream fisheries use of Christal Creek.
Lower/eastern Waste Rock Dump Slope Stability	Waste rock dump has excessive slope angle for a schist-based rock. An unstable peat layer below the waste rock and the presence of underlying permafrost contribute to instability of the lower/eastern waste rock dump. Continued failure of waste rock stability is not likely to directly impact the creek but rather promote siltation due to overburden pushed from base of waste rock dump.
Acid Rock Drainage	Mineralized waste rock at the lower/eastern workings is acid-generating. Overburden has slumped into Christal Creek. Waste rock has slumped to within 20 m of Christal Creek; massive sulphides are evident in the mixed overburden/waste rock slump material.

6.1 Lower/Eastern Waste Rock Dump Slope Stability

The greatest environmental concerns identified at Formo in the 1996 Phase II site assessment were the presence of slumped material in Christal Creek below the lower/eastern workings and the high probability of future slope failures which would transport waste rock into Christal Creek. In the event that remediation was to proceed the assessment recommended installation of gabion baskets, concrete lock blocks, or some other physical barrier at the toe of the lower/eastern waste rock dump to prevent further movement of slumped waste rock into Christal Creek. Recommended stabilization measures also included a) grading the upper portion of the waste rock dump to a natural angle of repose, and b) construction of a lined diversion ditch across the top of the dump to reduce water flows into potential areas of slope failure.

EBA's (1997) geotechnical assessment confirmed the probability of future failures of the lower/eastern waste rock dump slope. At the lower/eastern workings, the translational slide failure and the presence of numerous tension cracks above the existing slide area and in the area of the west lobe are evidence that future failures could occur. There is also a significant amount of down slope movement of the dump material occurring as a result of erosion from surface runoff. From these visual observations, it is apparent that mass wasting is occurring in the form of active creep and surface erosion and that future slide failures are possible at the lower/eastern waste rock dump.

The excessive slope angle for a schist-based rock, the presence of an unstable peat layer below the waste rock, and the presence of underlying permafrost along this north-facing slope are the three factors which promote instability of the lower/eastern waste rock dump. The continued failure of waste rock stability is not likely to directly impact the creek but rather promote siltation due to downward movement of native soils pushed from below the waste rock dump.

Recontouring of the lower/eastern waste rock slope at Formo will disturb peat and organics which insulate underlying permafrost. This may result in permafrost thaw and downslope movement of thawed soil for several years until a new thermal equilibrium is reached. However, a toe berm should prevent excessive downslope movement of thawed soil and destabilisation of any soil cover.

6.2 Acid Rock Drainage and Water Quality

ABA testing of waste rock materials during the 1996 Phase II assessment of the Formo mine site indicated most of the waste rock was acid-generating or potentially acid-generating. However, the impact of the lower/eastern waste rock pile on Christal Creek water quality had not been fully determined. Supplementary water quality sampling of Cristal Creek was carried out in August and October of 1997 and April, 1998.

Zinc is the primary contaminant of concern: while Cd and Ag concentrations were just slightly above CCME FAL limits in August 1996, August 1997, and April 1998, and within those limits during October 1997, Zn levels were consistently above the FAL criterion during all sampling periods. In part, zinc exceedances are attributable to one or more upstream sources; for example, the White Mountain Environmental Consulting (1995) report implicates United Keno Hill Mines' Galkeeno 900 adit as the main source of metal contaminants in Christal Creek. Formo's lower/eastern waste rock dump also contributes zinc to Christal Creek on a seasonal basis. In summer and fall, Zn was 2 to 4 times higher in water downstream from the waste rock dump compared to upstream levels.

Because waste rock has not entered Christal Creek, waste rock is not directly affecting downstream water quality. The source of zinc and cadmium is instead believed to be groundwater flowing beneath the waste rock into Christal Creek. Confirmation of groundwater transport of metal contaminants would require six groundwater monitoring wells drilled into bedrock (1 upgradient, 1 immediately below the adit entrance, 2 midslope, and 2 immediately above the toe of the waste rock slope). Drill rig access would require significant expenditure for road construction and stabilization, and these practical constraints of site access and cost preclude further intrusive investigation of Formo's lower/eastern waste rock slope.

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. Physically stabilize the toe of the slope to prevent future slumping into Christal Creek. The proposed slope stabilization method would involve building a toe berm to provide lateral support and to act as a physical barrier to migration of surficial soils into Christal Creek.

Recommendation 2. Due to practical and financial constraints no further site assessment work is recommended at this time.

Recommendation 3. Site drainage and upstream and downstream Christal Creek water quality should be sampled at five year intervals to identify significant longer-term trends or changes.

REFERENCES

- Burns, B.M. 1973. "The climate of the Mackenzie Valley - Beaufort Sea." Vol. I. Environment Canada, Atmospheric Environment Service, Climatological Studies No. 24.
- Burns, B.M. 1974. "The climate of the Mackenzie Valley - Beaufort Sea." Vol. II. Environment Canada, Atmospheric Environment Service, Climatological Studies No. 24.
- EBA Engineering Consultants Limited. 1997. "Final Report, Geotechnical Services, Yukon Abandoned Mine Sites. Formo Mine Site near Elsa, Yukon." Prepared for Public Works and Government Services Canada, Environmental Services, October 1997.
- Indian and Northern Affairs Canada. 1994. "Yukon Abandoned Mines Assessment. Assessment Report 105M-14-4 Formo". Prepared by DIAND Technical Services, February 1994.
- Indian and Northern Affairs Canada. 1992. "Mine Reclamation in Northwest Territories and Yukon". Prepared by Steffen, Robertson and Kirsten (B.C.) Inc. for DIAND Northern Affairs Program, April 1992.
- Public Works and Government Services Canada 1997. "Phase II Environmental Assessment of the Formo Mine Site." Prepared for Action on Waste Program, Indian and Northern Affairs Canada by Public Works and Government Services Canada Environmental Services, March 1997
- White Mountain Environmental Consultants. 1995. "Fish and Fish Habitat Assessment Conducted Near Elsa, Yukon for United Keno Hill Mines, August 1994 - September 1995". December 1995.

Appendix A

**Detailed Geochemical Assessment of Waste Rock and Surface Water
Formo Mine Site**

Extracts from:

**Yukon Abandoned Mine Sites Assessment
Report on 1997 Followup**

**Prepared by SRK Steffen Robertson & Kirsten
(1998)**

Formo Mine Site

1. BACKGROUND

The Formo Mine is adjacent to Christal Creek. There are two adits at the site and several waste rock piles; the lower/eastern waste rock pile is located below the lower adit on a slope above Christal Creek. This waste rock pile failed about half way down its length, and the base of the slump entered Christal Creek, altering its course. The impact of the waste on the water quality of the creek is of concern since the waste rock is generating acid.

The waste at the Formo site contains siderite (FeCO_3), sphalerite (ZnS), galena (PbS), and freibergite (silver-bearing tetrahedrite ((Cu, Fe) $_{12}\text{Sb}_4\text{S}_{13}$)). The waste was not negatively impacting the local vegetation.

2. 1997 OBSERVATIONS

The failure in the lower/eastern waste rock dump at Formo is believed to have been caused by the weight of the waste placed on a plane of weakness located approximately a meter below the original ground surface. Waste rock originally deposited outside of the adit was carried approximately half way down the slope by the slump. However, waste rock did not enter the creek. The material that composed the lower half of the slumps and that altered the course of Christal Creek was composed of soil and organic mat that covered most of the areas' surface. Rocks at the base of the slump near the creek were rounded stream pebbles and gravel, indicating that the waste rock did not travel this far down slope. The organic material at the base of the slump had a hummocky surface indicating movement (slow creep) down slope as a result of disturbance of the permafrost by the slide action.

There were a few seeps in the waste rock slope. The largest of these daylighted approximately half way down the slope (Figure 3) and, after becoming disseminated, entered the creek at several points at the base of the slope. This seep had a flow of approximately 1 L/min. The source of this seep is unknown but could be either groundwater, surface infiltration, or water from lower adit. Water could be heard flowing from the adit, but could not be sampled because of fallen timbers blocking the entrance. The flow disappeared into the waste rock beneath the timbers.

3. WATER QUALITY

Sample locations are shown on Figure 3. Samples were collected in Christal Creek approximately 100 m upstream of the lower/eastern waste rock area (FO-WQ-ST1-1 and FO-WQ-STR-002), immediately downstream of the waste rock dump (FO-WQ-ST1-2 and FO-WQ-STR-001), and downstream of the mine site (approximately 300 m downstream of the lower/eastern waste rock dump; FO-WQ-ST1-3 and FO-WQ-301). The flow in Christal Creek during the 1997 sample event was 0.33 m³/s. In August 1996, sample FO-WQ-STR-302 was collected from a seep approximately 250 m below the middle workings, within a metre of Christal Creek. In August 1997, a seep was sampled as it daylighted approximately half way

down the lower/eastern waste rock slope. (FO-WQ-SE2-1). This seep was also sampled lower on the slope, about a meter from the creek (FO-WQ-SE-1). No seeps were flowing in October 1997.

Water quality data for the Formo Mine site are listed in Table 1. The upper seep sample (FO-WQ-SE2-1) had a pH of 2.8 and conductivity of 6700 $\mu\text{S}/\text{cm}$. The sulphate concentration was greater than 7800 mg/L. Concentrations of aluminum (21.2 mg/L), arsenic (0.5 mg/L), cadmium (1.63 mg/L), copper (0.30 mg/L), iron (1010 mg/L), lead (0.681 mg/L), nickel (0.396 mg/L), silver (0.0112 mg/L), and zinc (49 mg/L) were above the CCME Commercial/Industrial guidelines.

The lower seep sample (FO-WQ-SE-1) had a pH of 5.1 and conductivity of 3120 $\mu\text{S}/\text{cm}$. The sulphate concentration was greater than 3800 mg/L. Concentrations of aluminum (1.55 mg/L), arsenic (0.05 mg/L), cadmium (2.19 mg/L), copper (0.59 mg/L), iron (6.06 mg/L), lead (0.195 mg/L), nickel (0.389 mg/L), silver (0.0021 mg/L), and zinc (49.9 mg/L) were at or above the CCME C/I guideline limits. Concentrations of these metals were generally lower in sample FO-WQ-SE-1 at the bottom of the waste rock slope compared to metals in FO-WQ-SE2-1 at the middle of the slope. An exception was the cadmium concentration, which was greater in the higher-pH sample.

These concentrations reflect the presence of siderite, sphalerite, galena, and freibergite identified in the waste. Aluminum is found in many minerals. Concentrations found in the seep water are likely the result of redissolution of aluminum oxides at low pH. Arsenic, cadmium, and nickel minerals were not reported in the earlier report on the Formo site (SRK 1997) and are probably related to mineralization at the site.

For the initial 20 meters that the seep flowed on the ground surface, dark red iron oxides were deposited. Further down slope, light blue and green aluminum oxide precipitates replaced the iron oxides. The pH increased to 5 and the conductivity had decreased to 3120 $\mu\text{S}/\text{cm}$. The change from iron oxide precipitation near the source of the spring to blue and green precipitates lower down indicates buffering of acidic water by the country rock and soil over which the seep flowed. In the low pH environment, iron oxides precipitate and aluminum stays in solution. As the pH rises the solubility of aluminum decreases and aluminum oxides precipitate.

The nine samples collected from Christal Creek during the three monitoring events had near-neutral pH, and conductivities ranged from 484 $\mu\text{S}/\text{cm}$ to 633 $\mu\text{S}/\text{cm}$. During each sampling event, zinc concentrations in upstream and downstream samples were above the CCME guideline of 0.03 mg/L (range=0.05 mg/L to 0.29 mg/L). However, the zinc concentrations were 2 to 3 times higher downstream of the site than upstream, indicating that the Formo site is contributing zinc to Christal Creek. Cadmium concentrations also increased downstream of the mine site and were above the guidelines. The concentrations of all other metals were below the CCME guidelines downstream of the site. The lower concentrations of metals besides cadmium and zinc indicate that either the seeps are not discharging into the creek, or that, with the low seepage flow, concentrations of most metals are being diluted.

Aluminum and silver concentrations were at or above the guidelines during particular sampling events. The upstream sample collected in August 1997 was the only sample that contained aluminum concentrations above the guideline. The reason for this anomalous concentration is unknown. Silver concentrations were elevated only upstream of the site and, therefore, are not attributable to the Formo site.

4. SOLUBLE METALS CONCENTRATIONS

The samples analysed by bottle roll testing included FOR-WR-P307/2 collected outside the lower adit, and FO-WR-P302 collected from the waste dump below the middle adit. Sample P307/2 had a paste pH value of 5.5, indicating that it is slightly acidic, and a NP/AP ratio of <0.1 (Table 2). Sample P302 had a paste pH above neutral and an NP/AP ratio of 0.5.

After the 6 days of testing, the slurry of sample P307/2 maintained a pH of 4.3 whereas sample P302 had a pH of 8.1. The conductivity of the first sample decreased during testing from 4500 $\mu\text{S}/\text{cm}$ to 3800 $\mu\text{S}/\text{cm}$. The conductivity of sample P302 increased from 2300 $\mu\text{S}/\text{cm}$ to 3000 $\mu\text{S}/\text{cm}$. These results indicate that sulphide in both samples is oxidizing to produce sulphate and acidity, but that sample P302 contains greater capacity to neutralize the acid. This is supported by the alkalinity content of 32 mg/L CaCO_3 eq. detected in the filtered leachate of sample P302 compared to 1 mg/L in sample P307/2.

Both samples had elevated soluble metals concentrations (Table 3). However, concentrations of metals such as aluminum, cadmium, iron, lead, manganese, and zinc are several times higher in sample P307/2, probably due to the lower pH.

5. DISCUSSION

It appears that the failure of the lower/eastern waste rock slope did not move waste rock into Christal Creek. Increased concentrations of cadmium and zinc in the creek downstream of the slump area are probably attributable to seeps emanating from the middle of the dump slope. However, in October 1997 metal concentrations increased downstream of the slump although the seeps were not visible. There could be another source of the metals, but it is more likely that the seeps continued to flow beneath the ground surface.

The source of the seepage water is unknown, but could be adit water that infiltrates the top of the waste rock pile and daylight part way down the slope. Alternatively, the water could be groundwater that is seeping through the waste rock, or infiltration into the waste. The latter is least likely because seepage flow was the same in August of 1996 and 1997, despite the unusually high rainfall in 1996.

6. RECOMMENDATION

Water quality monitoring should be conducted during the spring freshet. No other action is recommended at this site.

Table 1
Water Quality Data, Formo Mine

Sampling Event Location	UNITS	D.L.*	FO-WQ-STR-002	FO-WQ-ST1-1	FO-WQ-ST1-1	FO-WQ-ST1-1	FO-WQ-STR-001	FO-WQ-ST1-2	FO-WQ-ST1-2	FO-WQ-ST1-2	FO-WQ-STR-301	FO-WQ-ST1-3	FO-WQ-ST1-3	FO-WQ-ST1-3
			Aug-96	Aug-97	Oct-97	Apr-98	Aug-96	Aug-97	Oct-97	Apr-98	Aug-96	Aug-97	Oct-97	
			100 m upstream from waste rock slope				immediately downstream from waste rock slope				300 m downstream from waste rock slope			
pH		0.1	8.06	7.97	8.01	7.56	8.08	7.88	8.02	7.55	8.11	7.98	8.05	
Conductivity	uS/cm	0.1	633	484	633	651	618	486	560	645	615	485		
Hardness	mg/L	0.1	333	299	377	380	339	298	378	376	336	299		
Alkalinity	mg/L	1	138	119	142	115	136	119	143	114	--	119		
Sulphate	mg/L	0.3	193	162	216	251	192	162	216	250	168	163		
Aluminum	mg/L	0.00005	0.018	0.119	0.00172	0.299	0.017	0.05	0.00694	0.422	0.008	0.062		
Antimony	mg/L	0.005	--	<0.005	<0.005	--	--	<0.005	<0.005	--	--	<0.005		
Arsenic	mg/L	0.01	0.0026	<0.01	<0.01	<0.01	0.0024	<0.01	<0.01	<0.01	0.0024			
Cadmium	mg/L	0.00006	0.0011	0.00068	0.00047	0.002	0.0019	0.00222	0.00152	0.00221	0.0018			
Calcium	mg/L	0.002	102	87.2	106	--	103	84.9	105	--	102			
Chromium	mg/L	0.00006	<0.001	0.00132	<0.00006	0.0012	<0.001	0.00063	0.00019	0.0012	<0.001			
Cobalt	mg/L	0.00003	<0.02	0.00017	<0.00003	--	0.02	0.00011@h 56X	0.00014	--	<0.02			
Copper	mg/L	0.00003	<0.001	0.00339	<0.00003	0.002	0.001	0.00386	0.00041	0.002	<0.001			
Iron	mg/L	0.003	0.11	0.195	0.0395	0.772	0.11	0.126	0.0700	0.87	0.1			
Lead	mg/L	0.0003	0.002	0.0004	<0.0003	0.0043	0.001	<0.0003	0.0006	0.0056				
Lithium	mg/L	0.00006	<0.02	0.0056	0.00833	--	<0.02	0.00592	0.00798	--				
Magnesium	mg/L	0.005	18.9	15.9	20.0	--	19.5	15.5	19.7	--				
Manganese	mg/L	0.00002	0.113	0.129	0.137	--	0.106	0.132	0.140	--				
Mercury	mg/L	0.0001	<0.00005	<0.0001	<0.0001	<0.00001	<0.00005	<0.0001	<0.0001	<0.00001				
Molybdenum	mg/L	0.00007	<0.03	0.00049	0.00029	--	<0.03	0.00057	0.00021	--				
Nickel	mg/L	0.0001	<0.02	0.0018	0.0009	0.005	<0.02	0.0014	0.0010	0.006				
Selenium	mg/L	0.0001	0.0008	0.0005	<0.0001	0.0003	0.0009	0.0005	<0.0001	<0.0001				
Silver	mg/L	0.00005	0.0001	<0.00005	<0.00005	0.00011	0.0002	<0.00005	<0.00005	<0.00054				
Zinc	mg/L	0.0002	0.122	0.0873	0.0507	0.652	0.237	0.288	0.199	0.670				

Table 1 (con't)
Water Quality Data, Formo Mine

Sampling Event Location	UNITS	D.L.*	FO-WQ-STR-302	FO-WQ-SE-1	FO-WQ-SE2-1	CCME FAL Criteria**
			Aug-96	Aug-97	Aug-97	
			downstream from middle workings	seep near toe of waste rock slope	seep at middle of waste rock slope	
pH		0.1	7.73	5.09	2.75	
Conductivity	uS/cm	0.1	1020	3120	6700	
Hardness	mg/L	0.1	589	2540	2300	
Alkalinity	mg/L	1	234	10	<1	
Sulphate	mg/L	0.3	409	3850	7820	
Chloride	mg/L	0.5	--	8.6	<0.5	
Bicarbonate	mg/L	5	--	13	<5	
NO2&NO3-N	mg/L	0.05	--	1.02	<0.05	
Ionic Balance	%	0.1	--	63.3	-39.2	
Total Dissolved	mg/L	1	--	4670	8550	
Aluminum	mg/L	0.00005	0.083	1.55	21.2	0.1
Antimony	mg/L	0.005	--	<0.005	0.024	
Arsenic	mg/L	0.01	0.0014	0.05	0.5	0.05
Cadmium	mg/L	0.00006	0.0009	2.19	1.63	0.0018
Calcium	mg/L	0.002	145	411	374	
Chromium	mg/L	0.00006	<0.001	<0.00006	0.00993	0.02
Cobalt	mg/L	0.00003	<0.02	0.136	0.184	
Copper	mg/L	0.00003	0.002	0.0597	0.304	0.004
Iron	mg/L	0.003	0.15	6.06	1010	0.3
Lead	mg/L	0.0003	0.004	0.195	0.681	0.007
Lithium	mg/L	0.00006	<0.02	0.161	0.176	
Magnesium	mg/L	0.005	54.9	333	251	
Manganese	mg/L	0.00002	0.006	6.99	4.45	
Mercury	mg/L	0.0001	<0.00005	<0.0001	<0.0001	0.0001
Molybdenum	mg/L	0.00007	<0.03	0.00041	<0.00007	
Nickel	mg/L	0.0001	<0.02	0.389	0.396	0.15
Selenium	mg/L	0.0001	--	0.025	0.302	
Selenium	mg/L	0.0001	0.0007	0.0004	<0.0001	0.001
Zinc	mg/L	0.00002	0.0022	0.0029	0.0012	0.00081

-- not analyzed for this parameter.

* Detection Limit for analyses of 1997 samples.

** Criteria values for cadmium, copper, lead, nickel and zinc are
CCME FAL= Canadian Council of Ministers of the Environment
Exceeds CCME FAL criteria

Table 2
Results of Physical Parameters in Bottle Roll Test Leachates, Formo Mine

SAMPLE	SOLID			SLURRY										FILTERED LEACHATE									
	pH	Conductivity (μ S/cm)	NP/AP	pH (Hours)					CONDUCTIVITY (uS/cm) (Hours)					pH	COND. (uS/cm)	REDOX POT. (mV)	ACIDITY		ALKALINITY pH 4.5 (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 (mg/L CaCO3)					
FO-WR-P302	7.8	180	0.49	--	7.8	8.0	8.1	--	--	2300	2800	3000	--	7.52	4180	282	0.0	5.0	32.0	2140	<1	<1	754
FOR-WR-P307/	4.6	--	<0.1	--	4.0	4.3	4.3	--	--	4500	3900	3800	--	4.60	5280	365	0.0	1300.5	1.0	4570	<1	<1	5.9

-- = not analyzed for this element.

Table 3
Dissolved Metals Concentrations in Bottle Roll Test Leachates, Formo Mine

Sample No. Lab. Samples No.		FO-WR-P302 4067	FOR-WR-P307/2 4066
Aluminum	mg/L	<0.2	5
Antimony	mg/L	<0.2	<1
Arsenic	mg/L	0.0133	0.0124
Barium	mg/L	0.09	<0.05
Beryllium	mg/L	<0.005	<0.03
Bismuth	mg/L	<0.1	0.6
Boron	mg/L	1.0	0.8
Cadmium	mg/L	0.02	11.2
Calcium	mg/L	614	488
Chromium	mg/L	<0.01	<0.05
Cobalt	mg/L	<0.01	0.41
Copper	mg/L	0.03	0.12
Iron	mg/L	<0.03	167
Lead	mg/L	0.22	3.7
Lithium	mg/L	0.06	0.82
Magnesium	mg/L	78.4	433
Manganese	mg/L	1.09	97.7
Mercury	mg/L	0.00008	0.00032
Molybdenum	mg/L	<0.03	<0.2
Nickel	mg/L	<0.02	1.2
Phosphorus	mg/L	<0.3	<2
Potassium	mg/L	93	20
Selenium	mg/L	<0.2	<1
Silicon	mg/L	3.19	30.3
Silver	mg/L	0.004	0.008
Sodium	mg/L	290	132
Strontium	mg/L	0.396	0.045
Thallium	mg/L	<0.1	<0.5
Tin	mg/L	<0.03	<0.2
Titanium	mg/L	<0.01	<0.05
Uranium	mg/L	<0.0001	0.0007
Vanadium	mg/L	<0.03	<0.2
Zinc	mg/L	0.524	702

Appendix B

Site Photographs



Photo 1. View from top of lower/eastern waste rock slope, looking downslope towards area of slumped overburden and dead vegetation above Christal Creek.



Photo 2. Tension cracks at crest of lower/eastern waste rock slope.



Photo 3. Slumped overburden and waste rock below crest of waste rock slope.



Photo 4. Slumped, eroded peaty overburden; note vegetation mortality caused by the disturbance of root systems.



Photo 5. West edge of slumped overburden and waste rock, viewed from approximate midpoint of waste rock dump slope.



Photo 6. Lower region of slumped, peaty overburden looking towards crest of waste rock dump.



Photo 7. Christal Creek surface water sampling station FO-WQ-ST1-2, with disturbed peaty overburden and vegetation mortality visible down to Creek's edge.



Photo 8. Seep sample station FO-WQ-SE-1, visible as a small brown patch at lower centre of photo.



Photo 9. Seep sample location FO-WQ-SE2-1, approximately 35m below crest of waste rock slope.



Photo 10. Christal Creek discharge measurement below toe of lower/eastern waste rock slope, 19 August 1997.

Appendix C

Analytical Results



NORWEST LABS

EDMONTON PH. (403) 438-5522 FAX (403) 438-0396
 CALGARY PH. (403) 291-2022 FAX (403) 291-2021
 LANGLEY PH. (604) 530-4344 FAX (604) 534-9996
 LETHBRIDGE PH. (403) 329-9266 FAX (403) 327-8527
 WINNIPEG PH. (204) 982-8630 FAX (204) 275-6019

DATE 28 AUG 97 08:39

P.O. NO.

W.O. NO. 3 138240

PAGE 1

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

YUKON PH3

WATER ANALYSIS REPORT

SAMPLE	1	2	3
	FORMA	FORMA	FORMA
	FO-WQ-ST1-1	FO-WQ-ST1-2	FO-WQ-ST1-3

TOTAL METALS

SELENIUM	mg/L	0.0005	0.0005	0.0006
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ROUTINE WATER

pH		7.97	7.88	7.98
ELECTRICAL COND	uS/cm	484	486	485
CALCIUM	mg/L	91.7	91.3	91.6
MAGNESIUM	mg/L	17.1	17.0	17.1
SODIUM	mg/L	1.3	1.3	1.2
POTASSIUM	mg/L	1.05	0.79	0.86
IRON	mg/L	0.06	0.05	0.06
MANGANESE	mg/L	0.094	0.124	0.118
SULPHATE	mg/L	162	162	163
CHLORIDE	mg/L	0.6	1.0	<0.5
BICARBONATE	mg/L	145	145	145
T ALKALINITY	mg/L	119	119	119
HARDNESS	mg/L	299	298	299
T DIS SOLIDS	mg/L	345	345	346
IONIC BALANCE	%	-105	-105	-105

WATER NUTRIENTS

NO2&NO3-N	mg/L	<0.05	<0.05	<0.05
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TOTAL, COLD VAPO

MERCURY	mg/L	<0.0001	<0.0001	<0.0001
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TRACE ICP, TOTAL

ALUMINIUM	mg/L	0.119	0.050	0.062
ANTIMONY	mg/L	<0.005	<0.005	<0.005
ARSENIC	mg/L	<0.01	<0.01	<0.01
BARIUM	mg/L	0.0457	0.0430	0.0425
BERYLLIUM	mg/L	<0.00001	<0.00001	<0.00001
BISMUTH	mg/L	<0.0004	<0.0004	<0.0004
BORON	mg/L	<0.002	<0.002	<0.002
CADMIUM	mg/L	0.00068	0.00222	0.00188
CALCIUM	mg/L	87.2	84.9	84.8
CHROMIUM	mg/L	0.00132	0.00063	0.00038
COBALT	mg/L	0.00017	0.00011	0.00016

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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE	1	2	3
	FORMA FO-WQ-ST1-1	FORMA FO-WQ-ST1-2	FORMA FO-WQ-ST1-3

TRACE ICP, TOTAL

COPPER	mg/L	0.00339	0.00386	0.00388
IRON	mg/L	0.195	0.126	0.135
LEAD	mg/L	0.0004	<0.0003	<0.0003
LITHIUM	mg/L	0.00560	0.00592	0.00681
MANGANESE	mg/L	0.129	0.132	0.125
MAGNESIUM	mg/L	15.9	15.5	15.5
MOLYBDENUM	mg/L	0.00049	0.00057	0.00052
NICKEL	mg/L	0.0018	0.0014	0.0013
PHOSPHORUS	mg/L	<0.006	<0.006	<0.006
POTASSIUM	mg/L	2.34	0.87	2.84
SILVER	mg/L	<0.00005	<0.00005	<0.00005
SELENIUM	mg/L	0.003	0.003	0.004
SILICON	mg/L	2.89	2.70	2.70
STRONTIUM	mg/L	0.185	0.181	0.180
SODIUM	mg/L	1.21	1.16	1.16
THALLIUM	mg/L	<0.001	<0.001	<0.001
SULPHUR	mg/L	53.5	50.9	51.1
TITANIUM	mg/L	0.00352	0.00154	0.00151
TIN	mg/L	0.0007	0.0021	<0.0002
VANADIUM	mg/L	0.00027	<0.00003	0.00013
ZINC	mg/L	0.0973	0.288	0.257

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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

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YUKON PH3

WATER ANALYSIS REPORT

SAMPLE	4		5		6	
	FORMA		FORMA		PADDY MINE	
	FO-WQ-SE-1		FO-WQ-SE2-1		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

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YUKON PH3

WATER ANALYSIS REPORT

- *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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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
ALKALINITY	26Aug97	DARREN CRICHTON	HARDNESS	0	LANG QUE TRAN
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:

4011	SELENIUM		acid to pH 4.5 & pH 8.3. Report as CaCO3
	Total, perchloric acid digest, automated hydride atomic absorption spectroscopy.	10602	Ref. APHA 2320 B
	Ref. APHA 3114 C		HARDNESS
0301L	pH		Calculation from 2.5*Ca + 4.1*Mg
	Electrometric (pH meter)		Reported as CaCO3
	Ref. APHA 4500-H+	00203	Ref. APHA 2340 B
02041L	ELECTRICAL COND		T DIS SOLIDS
	Conductance meter		SUM OF IONS CALCULATION
	Ref. APHA 2510 B		Ca + Mg + K + Na + SO4 + Cl + 0.6*T Alk
0103	CALCIUM	NWL4994	Ref. APHA 1030 F
	ICP spectroscopy @ 317.9 nm	00100	IONIC BALANCE
	Ref. APHA 3120 B		IONIC BALANCE 2
12102L	MAGNESIUM		%Diff=(Sum Cations-Sum Anions)/
	ICP spectroscopy @ 285.2 nm		(Sum Cations+Sum Anions)*100
	Ref. APHA 3120 B	07105L	Ref. APHA 1030 F
11102L	SODIUM		NO2&NO3-N
9111	POTASSIUM		Automated colorimetry Cadmium reduction
	Diss., ICP Spectroscopy, Ref. APHA 3120 B		Ref. APHA 4500-NO3-,F
6304L	IRON		
16306L	SULPHATE		
	ICP spectroscopy @ 180.7 nm		
	Ref. APHA 3120 B		
7203L	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		
0101	T ALKALINITY		
	Potentiometric titration with standard		

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

WATER ANALYSIS REPORT

SAMPLE	1	2	3
	BT-WQ-STR102	BT-WQ-STR208	FO-WQ-ST1-1
	97/10	97/10	

ROUTINE WATER

pH		7.11	7.04	8.01
ELECTRICAL COND	uS/cm	35.0	49.0	566
CALCIUM	mg/L	3.6	5.7	113
MAGNESIUM	mg/L	0.9	1.2	23.1
SODIUM	mg/L	1.6	1.7	2.5
POTASSIUM	mg/L	1.22	1.11	<0.60
SULPHATE	mg/L	6.6	12.7	216
CHLORIDE	mg/L	<0.5	<0.5	<0.5
BICARBONATE	mg/L	26	25	174
T ALKALINITY	mg/L	21	21	142
HARDNESS	mg/L	12.8	19.0	377
T DIS SOLIDS	mg/L	27	35	441
IONIC BALANCE	%	-59.0	-67.9	-104

WATER NUTRIENTS

NO2&NO3-N	mg/L	0.30	0.33	0.10
-----------	------	------	------	------

ICP METALS, EXTR

IRON	mg/L	0.02	<0.02	0.05
MANGANESE	mg/L	<0.003	<0.003	0.140

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	0.0150	0.0064	0.0395
ALUMINUM	mg/L	0.0284	0.0131	0.00172
ANTIMONY	mg/L	<0.005	<0.005	<0.005
ARSENIC	mg/L	0.02	0.03	<0.01
BARIUM	mg/L	0.00099	0.00148	0.0524
BERYLLIUM	mg/L	<0.00001	<0.00001	<0.00001
BISMUTH	mg/L	<0.0004	<0.0004	<0.0004
BORON	mg/L	<0.002	<0.002	<0.002

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE	1			2			3		
	BT-WQ-STR102			BT-WQ-STR208			FO-WQ-ST1-1		
	97/10			97/10					
TRACE ICP, DISS									
CADMIUM	mg/L	<0.00006		<0.00006		0.00047			
CALCIUM	mg/L	3.62		5.72		106			
CHROMIUM	mg/L	<0.00006		<0.00006		<0.00006			
COBALT	mg/L	<0.00003		<0.00003		<0.00003			
COPPER	mg/L	<0.00003		<0.00003		<0.00003			
LEAD	mg/L	<0.0003		<0.0003		<0.0003			
LITHIUM	mg/L	0.00095		0.00078		0.00833			
MANGANESE	mg/L	0.00034		0.00022		0.137			
MAGNESIUM	mg/L	0.828		1.07		20.0			
MOLYBDENUM	mg/L	0.00030		0.00025		0.00029			
NICKEL	mg/L	<0.0001		<0.0001		0.0009			
PHOSPHORUS	mg/L	<0.006		<0.006		<0.006			
POTASSIUM	mg/L	1.22		1.11		<0.60			
SILVER	mg/L	<0.00005		<0.00005		<0.00005			
SELENIUM	mg/L	<0.003		<0.003		<0.003			
SILICON	mg/L	2.03		2.20		3.33			
STRONTIUM	mg/L	0.0170		0.0247		0.226			
SODIUM	mg/L	0.765		0.885		1.41			
THALLIUM	mg/L	<0.001		<0.001		<0.001			
SULPHUR	mg/L	2.16		4.16		66.5			
TITANIUM	mg/L	0.00037		0.00015		<0.00002			
TIN	mg/L	0.0003		0.0002		0.0009			
URANIUM	mg/L	0.0034		0.0018		0.0057			
VANADIUM	mg/L	<0.00003		<0.00003		<0.00003			
ZINC	mg/L	0.0008		0.0013		0.0507			
ZIRCONIUM	mg/L	<0.00004		<0.00004		<0.00004			

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE	4				5				6			
	FO-WQ-ST1-2				FO-WQ-ST1-3				PESO-WQ-ST1-1			
ROUTINE WATER												
pH			8.02				8.05				7.43	
ELECTRICAL COND	uS/cm		560				564				163	
CALCIUM	mg/L		113				113				19.4	
MAGNESIUM	mg/L		23.0				23.1				8.5	
SODIUM	mg/L		2.3				2.3				2.8	
POTASSIUM	mg/L		0.81				<0.60				2.13	
SULPHATE	mg/L		216				216				60.6	
CHLORIDE	mg/L		<0.5				<0.5				<0.5	
BICARBONATE	mg/L		175				175				33	
T ALKALINITY	mg/L		143				144				27	
HARDNESS	mg/L		378				376				83.5	
T DIS SOLIDS	mg/L		442				442				110	
IONIC BALANCE	%		-104				-103				-101	
WATER NUTRIENTS												
NO2&NO3-N	mg/L		0.10				0.10				0.08	
ICP METALS, EXTR												
IRON	mg/L		0.09				0.07				0.12	
MANGANESE	mg/L		0.148				0.137				0.063	
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		0.0700				0.0632				0.1100	
ALUMINUM	mg/L		0.00694				0.00365				0.0382	
ANTIMONY	mg/L		<0.005				<0.005				<0.005	
ARSENIC	mg/L		<0.01				<0.01				<0.01	
BARIUM	mg/L		0.0523				0.0519				0.0304	
BERYLLIUM	mg/L		<0.00001				<0.00001				<0.00001	
BISMUTH	mg/L		<0.0004				<0.0004				<0.0004	
BORON	mg/L		<0.002				<0.002				<0.002	

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MIKE NAHIR

WATER ANALYSIS REPORT

SAMPLE	4			5			6		
	FO-WQ-ST1-2			FO-WQ-ST1-3			PESO-WQ-ST1-1		
TRACE ICP, DISS									
CADMIUM	mg/L	0.00152		0.00140		0.00010			
CALCIUM	mg/L	105		104		17.8			
CHROMIUM	mg/L	0.00019		0.00018		0.00018			
COBALT	mg/L	0.00014		0.00014		0.00056			
COPPER	mg/L	0.00041		0.00028		0.00051			
LEAD	mg/L	0.0006		0.0003		<0.0003			
LITHIUM	mg/L	0.00798		0.00788		0.00894			
MANGANESE	mg/L	0.140		0.132		0.0580			
MAGNESIUM	mg/L	19.7		19.5		7.38			
MOLYBDENUM	mg/L	0.00021		0.00021		<0.00007			
NICKEL	mg/L	0.0010		0.0011		0.0054			
PHOSPHORUS	mg/L	<0.006		<0.006		<0.006			
POTASSIUM	mg/L	0.81		<0.60		2.13			
SILVER	mg/L	<0.00005		<0.00005		<0.00005			
SELENIUM	mg/L	<0.003		<0.003		0.004			
SILICON	mg/L	3.32		3.31		6.77			
STRONTIUM	mg/L	0.218		0.220		0.0654			
SODIUM	mg/L	1.41		1.39		1.41			
THALLIUM	mg/L	<0.001		<0.001		<0.001			
SULPHUR	mg/L	67.1		67.1		19.2			
TITANIUM	mg/L	<0.00002		<0.00002		<0.00002			
TIN	mg/L	0.0017		0.0015		0.0003			
URANIUM	mg/L	0.0037		0.0063		<0.0009			
VANADIUM	mg/L	<0.00003		<0.00003		<0.00003			
ZINC	mg/L	0.199		0.201		0.0176			
ZIRCONIUM	mg/L	0.00013		<0.00004		<0.00004			

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MIKE NAHIR

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:

0301L	pH		Ref. APHA 2320 B
	Electrometric (pH meter)	10101	T ALKALINITY
	Ref. APHA 4500-H+		Potentiometric titration with standard acid to pH 4.5 & pH 8.3. Report as CaCO ₃
02041L	ELECTRICAL COND		Ref. APHA 2320 B
	Conductance meter	10602	HARDNESS
	Ref. APHA 2510 B		Calculation from 2.5*Ca + 4.1*Mg
0103	CALCIUM		Reported as CaCO ₃
	ICP spectroscopy @ 317.9 nm		Ref. APHA 2340 B
	Ref. APHA 3120 B		
12102L	MAGNESIUM	00203	T DIS SOLIDS
	ICP spectroscopy @ 285.2 nm		SUM OF IONS CALCULATION
	Ref. APHA 3120 B		Ca + Mg + K + Na + SO ₄ + Cl + 0.6*T Alk
1102L	SODIUM		Ref. APHA 1030 F
9111	POTASSIUM	NWL4994	IONIC BALANCE
	Diss., ICP Spectroscopy, Ref. APHA 3120 B	00100	IONIC BALANCE 2
16306L	SULPHATE		%Diff=(Sum Cations-Sum Anions)/ (Sum Cations+Sum Anions)*100
	ICP spectroscopy @ 180.7 nm		Ref. APHA 1030 F
	Ref. APHA 3120 B		
7203L	CHLORIDE	07105L	NO ₂ &NO ₃ -N
	Automated colorimetry, Thiocyanate		Automated colorimetry Cadmium reduction
	Ref. APHA 4500 Cl-,E		Ref. APHA 4500-NO ₃ -,F
06301L	CARBONATE	26321	IRON
	Potentiometric titration with standard acid to pH 8.3 and pH 4.5		Acid extr., ICP Spectro. Ref. APHA 3120 B
	Ref. APHA 2320 B	25321	MANGANESE
06201L	BICARBONATE	80016	MERCURY
	Potentiometric titration with standard acid to pH 8.3 and pH 4.5		Dissolved, cold vapor atomic absorption spectroscopy, with H ₂ SO ₄ /K ₂ S ₂ O ₈ digest
	Ref. APHA 2320 B		Ref. EPA 245.2
10151	P ALKALINITY	34102	SELENIUM
	Potentiometric titration with standard acid to pH 8.3. Report as CaCO ₃		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.

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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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 FORMO
 23 04 98

WATER ANALYSIS REPORT

SAMPLE		1 FO-WQ-ST1-1	2 FO-WQ-ST1-2	3 FO-WQ-ST1-3
TOTAL METALS				
SELENIUM	mg/L	0.0003	<0.0001	<0.0001
ROUTINE WATER				
pH		7.56	7.55	7.68
ELECTRICAL COND	uS/cm	651	645	649
CALCIUM	mg/L	118	117	116
MAGNESIUM	mg/L	20.7	20.5	20.6
SULPHATE	mg/L	251	250	250
BICARBONATE	mg/L	140	138	134
T ALKALINITY	mg/L	115	114	110
HARDNESS	mg/L	380	376	374
LOW LEVEL HG TOT				
MERCURY	mg/L	<0.00001	<0.00001	<0.00001
TRACE ICP, TOTAL				
ALUMINUM	mg/L	0.299	0.422	0.232
ARSENIC	mg/L	<0.01	<0.01	<0.01
CADMIUM	mg/L	0.00200	0.00221	0.00217
CHROMIUM	mg/L	0.0012	0.0012	0.0014
COPPER	mg/L	0.002	0.002	0.001
IRON	mg/L	0.772	0.870	0.620
LEAD	mg/L	0.0043	0.0056	0.0050
NICKEL	mg/L	0.005	0.006	0.009
SILVER	mg/L	0.00011	0.00054	0.00011
ZINC	mg/L	0.652	0.670	0.632

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FORMO
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WATER ANALYSIS REPORT

- *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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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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FORMO
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 CaCO₃
Ref. APHA 2320 B
- 10602 HARDNESS
Calculation from 2.5*Ca + 4.1*Mg
Reported as CaCO₃
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

Formo Mine Site

prepared by EBA Engineering Consultants Ltd.

(1997)

A black and white photograph of a mine site. In the foreground, several pack animals, likely mules or horses, are harnessed together, carrying large packs. They are standing in a dirt area. In the background, there are several wooden buildings, some with corrugated metal roofs. The scene is set in a rugged, mountainous area.

FINAL REPORT

**GEOTECHNICAL SERVICES
YUKON ABANDONED MINE SITES**

**Formo Mine Site
near Elsa, Yukon**

submitted to:

**Public Works and Government Services Canada,
Environmental Services**

prepared by:

**EBA Engineering Consultants Ltd.
Whitehorse, Yukon**

0201-97-12953.2

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 Formo Mine Site which is approximately 7.5 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 for potential use in site restoration work.

The middle and lower waste rock dumps were inspected for slope stability considerations. In regards to the middle workings, the waste rock was considered stable due to the extensive vegetation growing on the slopes and the absence of visual clues of the potential for failure. At the lower workings, it is apparent that mass wasting is occurring in the form of active creep and surface erosion and that future slide failures are probable.

The proposed remediation system would address the slope stability concerns at the lower waste rock dump by placing the waste rock at the lower reaches of the slope and grading the material to 2.5H:1V, constructing a diversion ditch to prevent surface runoff from entering the waste rock slope, and building a toe berm to provide lateral support and to act as a physical barrier for future migration of the waste rock into Christal Creek. This system would also involve placing a low permeability cover over the waste rock material to adopt a containment and isolation approach to minimize acid rock drainage. The Class "D" cost estimate for this work is presented under separate cover.

The borrow area identified at the adjacent Paddy Mine Site consisting of a possible morainal till deposit would be a favourable location of borrow material for the Formo Site as well. The area is favourable since it is flat, road accessible, and close to the Formo site. A ground truthing and test pitting exercise should be conducted prior to further design consideration in order to verify the quality and quantity of the potential fine grained borrow source.

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3.0 SITE CONDITIONS	3
4.0 SITE SPECIFIC SLOPE STABILIZATION OPTIONS	6
4.1 Description of Proposed System	6
4.2 Class "D" Cost Estimate	7
5.0 FINE GRAINED BORROW SOURCE	9
6.0 CONCLUSIONS	10
7.0 RECOMMENDATIONS	12
8.0 LIMITATIONS	13
9.0 REPORT CLOSURE	14

Cover photo: *Members of the Consolidated Mining and Smelting Co. Ltd., pose with their pack horses on their departure from Keno City to McKay Hill in the Beaver River country. The men are from L to R, Hans Formo and J.K. (Paddy) Cram. [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 Formo Mine Site and is located on Highway 11, approximately 7 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 the subject 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 Formo site. This included excerpts from unpublished reports prepared by PWGSC, Environmental Services (March, 1997) and by Steffen, Roberston, and Kirsten (Report P118105, February, 1997). Prior to initiating the field work program, background information was reviewed in order to identify specific geotechnical concerns which were raised and to incorporate these concerns into the site inspection work.

From the information provided by PWGSC, the following geotechnical concerns were raised:

1. The general instability of the waste rock dump material. Specifically, the area of the lower workings was considered unstable where a significant slide had occurred and where future failures were anticipated.
2. The failed dump material in Christal Creek and the potential for further failures to occur within the waste rock pile at the lower workings.
3. The potential undermining of the waste rock pad supporting a storage shed.

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

3.0 SITE CONDITIONS

Those areas which were inspected for slope stability considerations included the waste rock dumps at the middle workings and at the lower workings. The location of each area of interest is depicted on the site plan for the Formo site which is enclosed as Drawing 12953-6.


The middle workings consisted of two lobes of waste rock down slope of the adit. The waste rock pile which was immediately down slope of the adit consisted primarily of overburden soil and weathered schist which was most likely the initial material removed when driving the adit. This waste rock lobe was approximately 30 m wide and 45 m long and had a slope angle of approximately 29° to 30°. The slope was considered stable due to the extensive vegetation growing on the slopes and the absence of visual clues of instability such as tension cracks, tilted vegetation, or bulging at the toe of the slope. A shallow test pit was excavated 15 m north (down slope) and 10 m east of the adit and sample Formo 1 was taken for subsequent laboratory testing. As noted in the grain size analysis enclosed in the Figures section of the report, the material has a grain size similar to a gravelly sand, some silt.

The second waste rock lobe was located just west of the adit and was approximately 16 m wide and 30 m long, was not vegetated, and had a slope angle of approximately 32°. The material appeared to be stable with no obvious signs of mass wasting as determined from visual observations. An exception to this was some slight bulging at the toe of the waste rock pile, however, this was not considered severe. Two test pits were hand excavated into the waste rock to get an indication of the profile of the material. One test pit was located 5 m north (down slope) and 5 m west of the top of the pile and the other was located 5 m south, 7 m east of the north west corner of the pile. The upper test pit was excavated to 0.9 m and the lower test pit was excavated to 0.7 m where refusal had occurred in each case due to the dense, oxidized rock. The profile of the waste rock observed in the test pits consisted of a thin layer (0.15-0.2 m) of pulverized schist underlain by heavily oxidized sulphides and pyritic rock material. Photo #F2 is illustrative of the near surface waste rock profile encountered in the hand dug test pits at the Formo mine site. The oxidized rock appeared to exhibit a cementation property due to the bonding resulting from the heavy oxidization of the rock particles.



Photo #F1: Looking up the lower waste rock pile slope at the old garage. Note rivuleting due to surface runoff.

Photo #F2: Looking at hand dug test pit in waste rock pile (sample Formo 4) Note fine grained schist over heavily oxidized sulfide rich rock.

	EBA Engineering Consultants Ltd.	PROJECT GEOTECHNICAL SERVICES, YUKON ABANDONED MINES PROJECT			
CLIENT	PUBLIC WORKS AND GOVERNMENT SERVICES CANADA	TITLE FORMO MINE PHOTO SHEET #1			
DATE 97 10 09	DWN. MEB	CHKD.	FILE NO. 0201-96-12953	DWNG. 12953-PHTO3	REVISION 0

This material seemed to be quite stable from a slope stability viewpoint due to the high shear strength which could be expected from the oxidized rock mass.

The lower workings consisted of a waste rock pile covering an area of approximately 80 m by 60 m as described in Drawing 12953-7. The waste rock pile area was slightly vegetated with young poplar and willow and the slope angle ranged from 28° to 34°. The primary area of waste rock material is located immediately below the adit and level pad where the two old structures are located. The most notable feature of this area was the presence of a large slide failure within the waste rock pile at the location shown in Drawing 12953-7 and as depicted in Photo #F3. The slide appeared to be caused by a translational slip which involves a failure surface developing at the interface of an adjacent stratum with significantly different strength. This stratum is typically at a relatively shallow depth and the failure surface tends to be planar and roughly parallel to the slope¹. The failure surface appeared to occur between the native gravel and sand till material and the overlying peat layer. The peat layer, which represented the original ground surface prior to the deposition of the waste rock, was noted as being up to 0.5 m thick as seen in Photo# F4. The instability of this weak layer was compounded by the excessive surcharge load which had accumulated on a slight bench formation along the slope near the bottom of the waste rock area. The natural bench along the slope can be seen on the right hand side of Photo# F3. The peat layer would have virtually no resistance to shear failure induced by surcharge loads from the overlying waste rock. Further, the compression of the peat would decrease its insulating capabilities causing an increase in the active layer and a corresponding decrease in the shear strength of the previously frozen underlying soil. It is believed that the waste rock had accumulated at the bench along the slope until the increase in surcharge load on the unstable peat layer had eventually caused a translational slip failure along the peat and underlying till interface.

It appears that the slide described above had caused an extensive disturbance of the surface peat layer further down the slope. The force of the slide most likely caused the peat to be sheared and subsequently severed from the underlying till soil. The lobate bulge that formed appeared similar to a solifluction type of near surface creep, although this particular process was much more sudden due

¹ Craig, R., F. 1987. Soil Mechanics, 4th Edition. Van Nostrand Reinhold (UK) Co. Ltd., England.



Photo #F3: Looking down slope at area of slump failure at lower workings waste rock dump. Note slight bench formation on right side of photo and extensive peat material.



Photo #F4: Looking east from within slump failure area at natural ground surface. Note extensive peat material (up to 0.5 m thick) underlain by gravelly silt till material.

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to the slide. As seen on Photo# F5, the disturbed peat formed terraces along the approximately 24° slope and also undermined the existing vegetation as evidenced by the leaning trees. Although it was reported by SRK that the waste rock had extended to the creek, this was not apparent during the site visit. Rather, the run out apron of the slide appeared to extend approximately 60 metres below the previous lower extent of the pile and approximately 150 metres from the creek. Exception to this was in the area of the drainage course shown on Drawing 12953-7 where some surface erosion of the waste rock had occurred which resulted in some further down slope movement.

In regards to the stability of the existing waste rock material at the lower workings, there is evidence that future failures could occur. This is due to the presence of numerous tension cracks located above the existing slide area and in the area of the west lobe as shown on Photos #F3 and #F6, respectively. There is also a significant amount of down slope movement of the dump material occurring as a result of erosion from surface runoff. Rivuletting is apparent at the areas described in Photo# F1 and in Drawing 12953-7. From these visual observations, it is apparent that mass wasting is occurring in the form of active creep and surface erosion and that future slide failures are possible at the lower workings waste rock pile.



Photo #F5: Looking up at end of flow slide area near Christal Creek.
Note terraced disturbed near surface peat and leaning trees.



Photo #F6: Looking down slope at west lobe of lower workings; note evidence of slump failures along top of slope.



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DWNG. 12953-PHT05

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4.0 SITE SPECIFIC SLOPE STABILIZATION OPTIONS

4.1 Description of Proposed System

As noted above, there were several indications that future slope failures could occur at the area of the lower waste rock dump. The excessive slope angle for a schist-based rock, the presence of an unstable peat layer below the waste rock, and the presence of permafrost within the underlying soils along this north facing slope are the three primary factors which are related to the instability of the waste rock dump. Further, the results of the SRK study which indicate the potential for this material to be net acid generating suggests that the restoration design would require provision for a containment and isolation approach. The difficulty in providing a cost effective design which would address each of these issues clearly makes the Formo site the most challenging of the five which have been considered in the Yukon Abandoned Mine Sites study.

The most technically effective restoration system would involve excavating and removing the waste rock material from its existing location and placing it in the open pit at the upper workings. This location would be designed to act as an effective long term containment system for the acid generating waste rock. Further, the design and long term stability of the containment system would not be complicated by the steep slope angle and the presence of peat and permafrost as it would be with the current location of the waste rock dump. However, such a restoration program may be prohibitively expensive and cause extensive disturbance to the existing slope and vegetation due to the need for access roads to transport the waste rock up the slope. The existing road was built steeper than the maximum allowable grade to transport loaded equipment up the slope. Therefore, a new road would have to be built at moderate slope angles and of suitable quality for hauling purposes. The difficulty and costs of transporting the material to the upper workings is also considered to be prohibitively expensive. Finally, removing this material from the slope will further disturb the peat/organic insulation for the permafrost, resulting in additional thaw and slumping to the depth of the bedrock surface or until a new thermal equilibrium is achieved.

A more cost effective alternative would be to deal with the problem of the excessive slope angle of the waste rock dump by pushing the material down to the lower slope area where the natural slope angle is approximately 24° to 26° and grading the material to a final surface which would be 2.5H:1V.

This work would not disturb existing vegetation but rather would involve pushing and placing the waste rock over the existing dead vegetation which is in the area of the flow slide debris as seen in Drawing 12953-7. The 2.5H:1V graded surface would be suitable for placement of a fine grained cover to be placed at an estimated depth of 0.6 m. The waste rock material and fine grained cover would be placed over the existing disturbed peat material. This disturbance to the existing peat/organic cover insulating the permafrost may result in additional permafrost thaw and subsidence which could affect the site for several years after restoration or until a new thermal equilibrium is reached. With this in mind, a toe berm most likely would be required to prevent excessive movements from affecting the stability of the containment system. As well, due to extensive evidence of surface water runoff from the slope above entering onto the existing waste rock dump, it would be necessary to make provision for a diversion trench in order to direct runoff away from the containment area.

The material used for the toe berm and cover would derive from the gravel pit and fine grained borrow source in the area of the Paddy Mine Site. The existing road leading from the lower workings up to Highway 11 should be adequate for transporting the material, however, some initial clearing and grading would have to be performed to provide a more suitable surface for this purpose.

Prior to design of the restoration system, more site investigation work is considered necessary. This would involve performing a survey of the existing road and waste rock pile and conducting a geotechnical investigation. The survey would be necessary to confirm that the road would be suitable for hauling soil down to the lower workings or to gather sufficient information to design an alternate route and to survey the waste rock area for design of the containment system.

The geotechnical investigation would be necessary to verify the depth of the waste rock for quantity estimations and to determine the native soil profile throughout the lower waste rock area. At this

time, the investigation could include verifying the quality and quantity of available fine grained material at the possible borrow location described in Section 5.0, following.

4.2 Class "D" Cost Estimate

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

5.0 FINE GRAINED BORROW SOURCE

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. The immediate area of the Formo Mine Site is dominated by a thin veneer of till material over bedrock. The depth of till is estimated at less than 2.0 metres in this area. Further, as a north facing slope and with a thick peat vegetative layer, the soil is likely to be perennially frozen with a very thin active layer. The thin layer of till and the presence of permafrost does not make this area favourable from a borrow source development perspective.

The possible borrow area identified at the Paddy Mine Site would be a favourable location for borrow material at the Formo Site as well. This borrow site is less than 5 km from the Formo Mine Site along well maintained roads. As described in the Paddy Mine Site report (EBA report 0201-97-12953.1), the area surrounding Christal Creek to the west of the canyon is characterized by alternating till materials of morainal and glacio-fluvial depositional histories. The area enclosed by a dashed line on Drawing 12953-5 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 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 area² 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.

² 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.

6.0 CONCLUSIONS

The following conclusions are drawn from this study:

1. In regards to the middle workings, the first waste rock lobe was approximately 30 m wide and 45 m long and had a slope angle of approximately 29° to 30°. The slope was considered stable due to the extensive vegetation growing on the slopes and the absence of visual clues of instability such as tension cracks, tilted vegetation, or bulging at the toe of the slope. The second waste rock lobe was located just west of the adit and was approximately 16 m wide and 30 m long, was not vegetated, and had a slope angle of approximately 32°. The material appeared stable with no obvious signs of mass wasting as determined from visual observations.
2. In regards to the stability of the existing waste rock material at the lower workings, there is evidence that future failures could occur. This is due to the previous translational slide failure which has occurred in this area, and due to the presence of numerous tension cracks located above the existing slide area and in the area of the west lobe. There is also a significant amount of down slope movement of the dump material occurring as a result of erosion from surface runoff. From these visual observations, it is apparent that mass wasting is occurring in the form of active creep and surface erosion and that future slide failures are possible at the lower workings waste rock pile.
3. The excessive slope angle for a schist-based rock, the presence of an unstable peat layer below the waste rock, and the presence of permafrost within the underlying soils along this north facing slope are the three primary factors which are related to the instability of the waste rock dump at the lower workings.
4. Restoration activities should encompass stabilizing the waste rock at the lower workings to prevent future failures from occurring. The proposed remediation system to address the slope stability concerns at this site involve placing the waste rock at the lower reaches of the slope and grading the material to 2.5H:1V, constructing a diversion ditch to prevent surface runoff from entering the waste rock slope, and building a toe berm to provide lateral support and to act as a physical barrier for future migration of the waste rock into Christal Creek. This

system would also involve placing a low permeability cover over the waste rock material to adopt a containment and isolation approach in avoiding acid rock drainage. The Class "D" cost estimate for this restoration work is presented under separate cover.

5. It should be noted that any restoration work at the subject site (removal or re-contouring of materials) will result in further disturbance to the peat and organics which insulate existing underlying permafrost. This will result in additional thaw and possible down slope movement of thawed materials after restoration work is complete. This process will continue for several years until a new thermal equilibrium is reached.
6. The possible borrow area identified at the Paddy Mine Site would be a favourable location for borrow material at the Formo Site as well. This is a possible morainal deposit consisting of a heterogeneous mixture of silt, sand, and gravel till material. The area is favourable since it is flat, 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. A ground truthing and test pitting exercise should be conducted prior to further design consideration in order to verify the quality and quantity of the potential fine grained borrow source.

7.0 RECOMMENDATIONS

The following recommendations have been formulated in consideration of the objectives and results of the study:

1. It is recommended to proceed with the slope stabilization work to ensure long term stability of the waste rock dump. If the waste rock material is considered net acid generating and could negatively impact Christal Creek, it is recommended to provide a low permeability cover over the waste rock as previously discussed.
2. If the above restoration activities are not adopted, it is recommended to perform a detailed survey and to monitor the slope conditions at this site. The monitoring work would involve a site visit by a qualified geotechnical engineer on an annual basis in order to determine if the mass wasting is negatively impacting Christal Creek and to recommend measures to remedy the situation if required.
3. If a fine grained borrow source is required as a low permeability cover, it is recommended to proceed with a ground truthing and test pitting exercise at the proposed borrow location in the vicinity of the Paddy Mine Site once this area has been confirmed as being suitable from a land use perspective. At this time, the quality and quantity of the proposed borrow source could be determined and samples could be retained for the purpose of laboratory verification testing.

8.0 LIMITATIONS

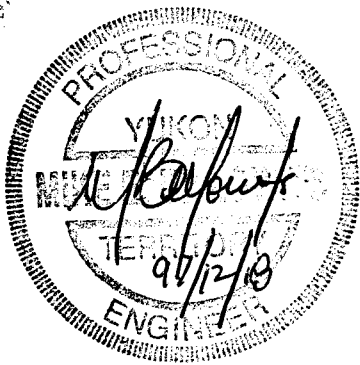
Recommendations presented herein are based on a geotechnical evaluation following the scope of work described in Section 1.0 of this report. The conditions encountered during the field work are considered to be reasonably representative of the site. If, however, conditions other than those reported be noted during subsequent construction work, monitoring activities or otherwise, EBA should be notified and given the opportunity to review our current recommendations in light of new findings.

This report has been prepared for the exclusive use of Public Works and Government Services Canada, Environmental Services for the specific application described in Section 1.0 of this report. It has been prepared in accordance with generally accepted geotechnical engineering practices. Engineering judgement has been applied in developing the recommendations in this report, in an attempt to strike a reasonable balance between risk of failure and economic factors. No other warranty is made, either expressed or implied. For further limitations on the use of this report, reference should be made to the General Conditions enclosed immediately following the text of this report.

9.0 REPORT CLOSURE

We trust this report meets your present requirements. We would be pleased to provide any further services needed for the design and to advise on the geotechnical aspects of specifications for inclusion in contract documents. Should you require any additional information, please do not hesitate to contact our office.

Respectfully submitted,
EBA Engineering Consultants Ltd.



Michael E. Billowits, M.Sc., P.Eng.
Project Engineer



J. Richard Trimble, M.Sc., P.Eng.
Project Director, Yukon Region

MEB/meb

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GEOTECHNICAL REPORT
GENERAL CONDITIONS**

A.1 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site and development. It is not applicable to adjacent sites nor is it valid for types of development other than that to which it refers. Any variation from the site, or development, necessitates a geotechnical review in order to determine the validity of the design concepts evolved herein.

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A.2 NATURE AND EXACTNESS OF SOIL DESCRIPTION

Classification and identification of soils are based upon commonly accepted methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system prevail, they are specifically mentioned.

Classification and identification of soil and geologic units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

A.3 LOGS OF BORINGS

The boring logs are a compilation of conditions and classification of soils as obtained from field observations and laboratory testing of selected samples. Soil zones have been interpreted. Change from one geologic zone to the other, indicated on the logs as a distinct line, is in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil zone transition elevations may require special evaluation.

A.4 STRATIGRAPHIC AND GEOLOGIC SECTIONS

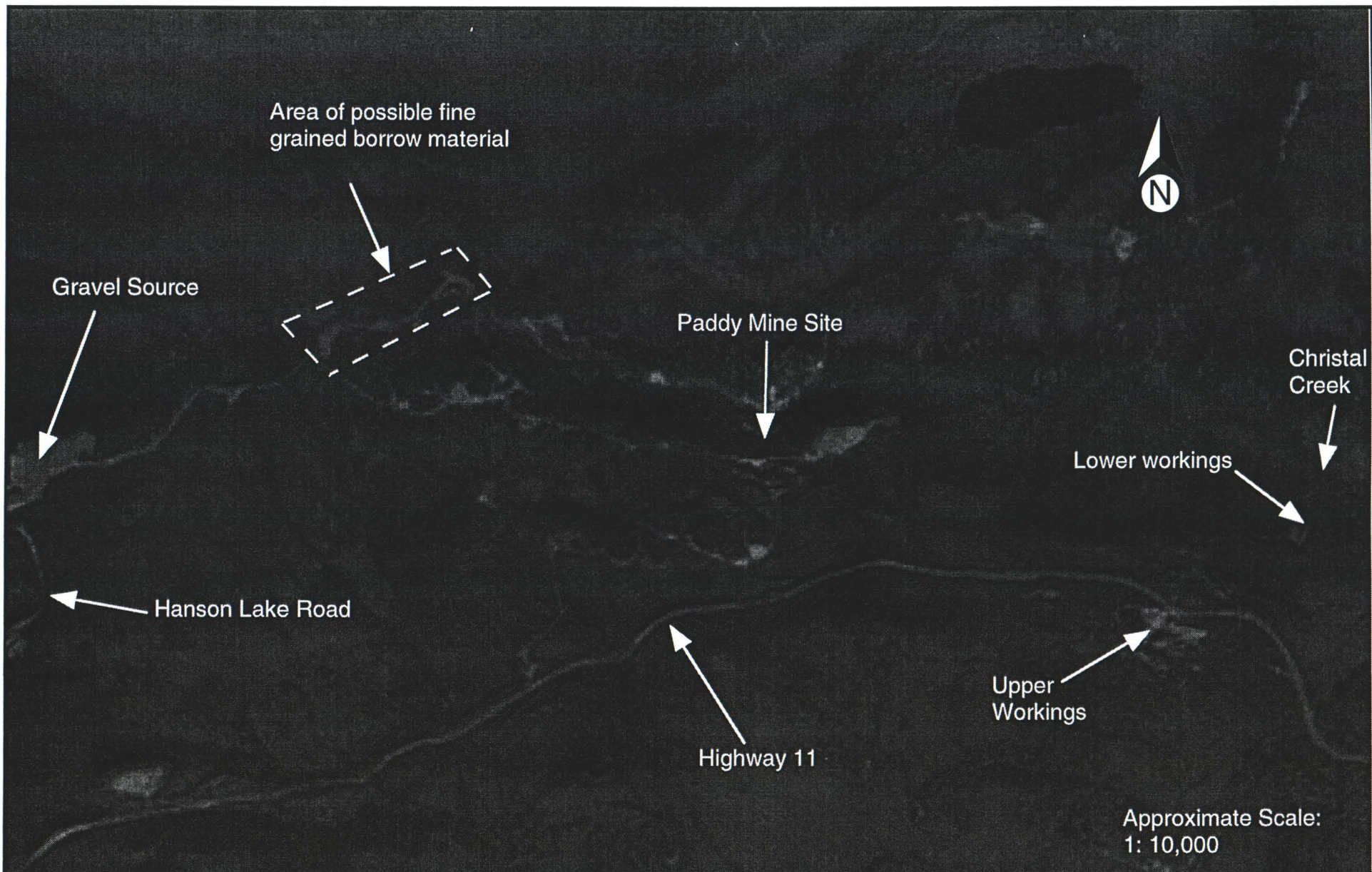
The stratigraphic and geologic sections indicated on drawings contained in this report are evolved from logs of borings. Stratigraphy is known precisely only at the locations of the borings. Actual geology and stratigraphy between borings may vary from that shown on these drawings. Natural variations in geologic conditions are inherent and a function of historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of exact locations of geologic units is necessary, it is cautioned that such determination requires special attention.


A.5 GROUNDWATER CONDITIONS

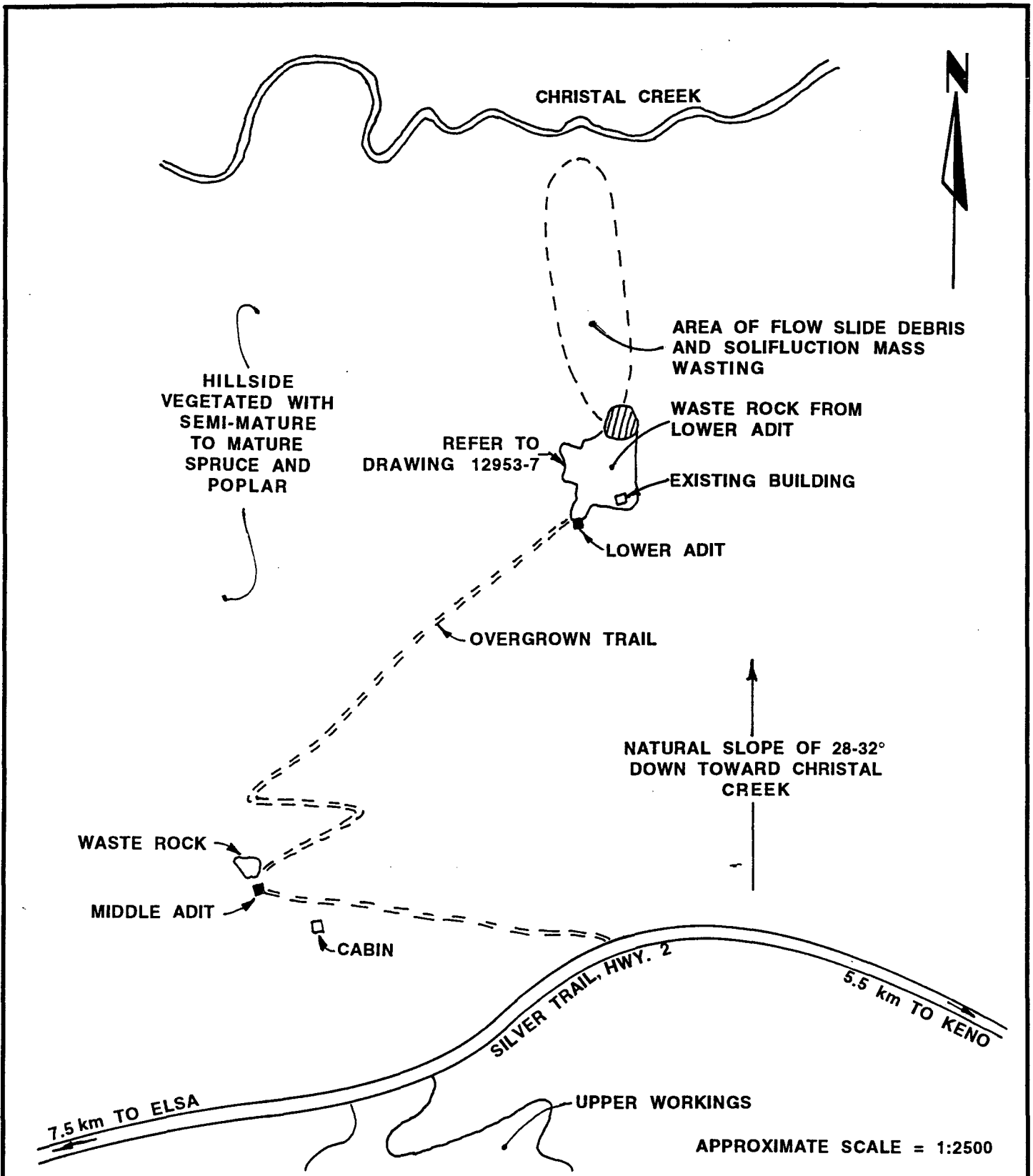
Groundwater conditions represented in this report refer only to those observed at the times recorded on logs of borings, and/or within the text of this report. These conditions vary with geologic detail between borings; annual, seasonal and special meteorologic conditions; and with construction activity. Where instruments have been established to record groundwater variations on an ongoing basis, the records will be specifically referred to. Interpretation of groundwater conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and construction activity. Deviations from these observations, may occur. No other warranty, express, or implied, is made by EBA.


A.6 PROTECTION OF EXPOSED GROUND

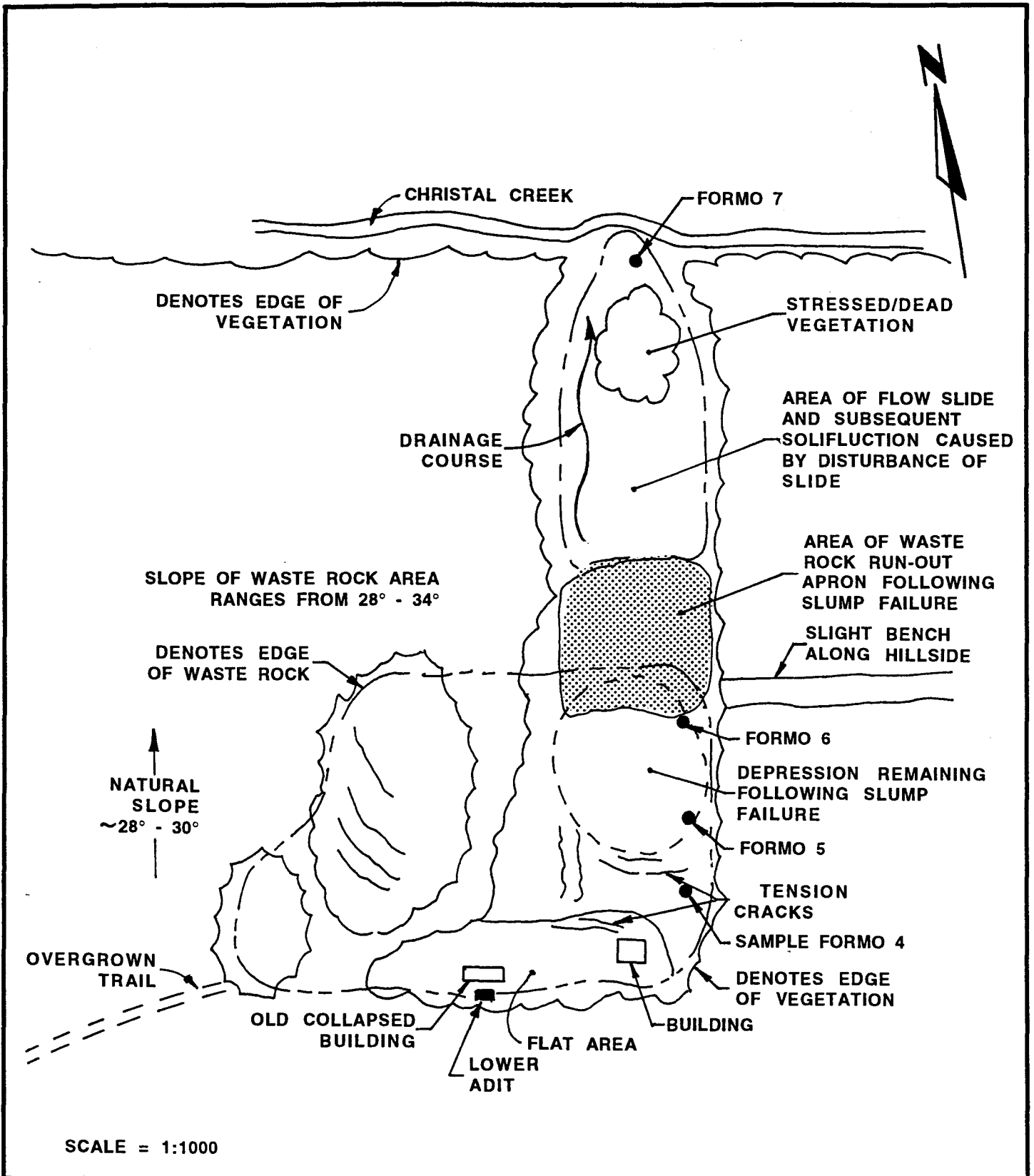
Excavation and construction operations expose geologic materials to meteorological elements. Many geologic materials deteriorate rapidly upon exposure to climatic elements. Severe deterioration of materials may be caused by precipitation and/or the action of frost on exposures. Unless otherwise specifically indicated in this report, walls and floors of excavations must be protected from elements, particularly all forms of moisture, desiccation from arid conditions and frost action.




 EBA Engineering Consultants Ltd.		PROJECT GEOTECHNICAL SERVICES, YUKON ABANDONED MINES PROJECT	
CLIENT PUBLIC WORKS AND GOVERNMENT SERVICES CANADA		TITLE Air Photo Depicting Features of Formo Mine Site	
DATE 9710 28	DWN. MEB	CHKD. MEB	FILE NO. 0201-97-12953
		DWNG. 12953-5	REVISION 0



 EBA Engineering Consultants Ltd.	PROJECT GEOTECHNICAL SERVICES YUKON ABANDONED MINE SITES			
CLIENT PUBLIC WORKS & GOVERNMENT SERVICES CANADA	TITLE SITE PLAN OF FORMO MINE			
DATE 97/10/08	DWN. MEB	CHKD. MEB	DRWG NO. 12953-6	FILE NO. 0201-97-12953

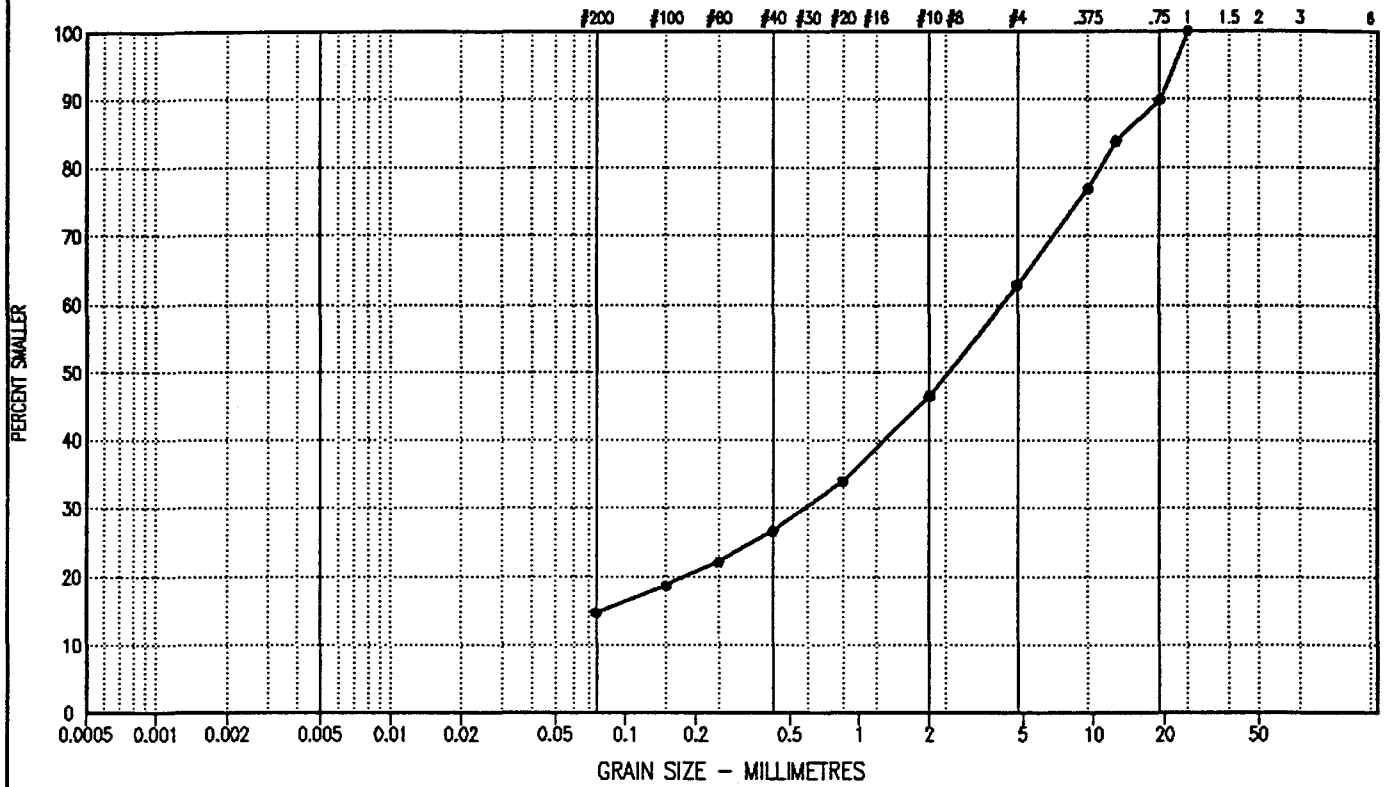


 EBA Engineering Consultants Ltd.			PROJECT GEOTECHNICAL SERVICES YUKON ABANDONED MINE SITES		
CLIENT PUBLIC WORKS & GOVERNMENT SERVICES CANADA			TITLE PLAN DETAILS OF LOWER ADIT AREA - FORMO SITE		
DATE	97/10/08	DWN. MEB	CHKD. MEB	DRWG NO.	12953-7
				FILE NO.	0201-97-12953

PARTICLE SIZE - ANALYSIS OF SOILS

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE

U.S. STANDARD SIEVE SIZES



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●—●	FORM01	0.00	14.7	48.2	37.1	83.4	1.8	SM

Project: 0201-97-12953

Date Tested: 97/10/14

BY: JSB

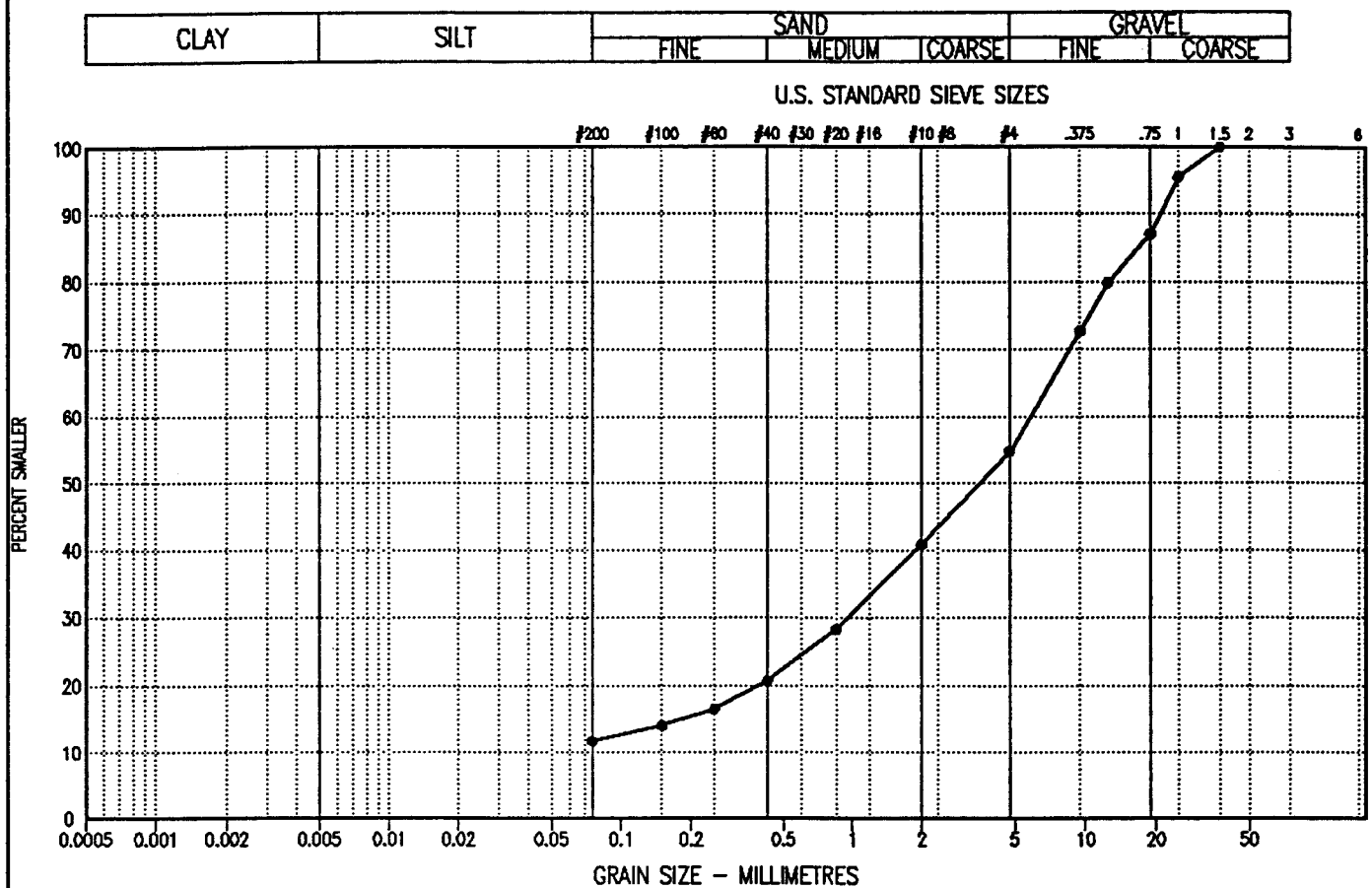
Tested in accordance with ASTM D422 unless otherwise noted.

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PARTICLE SIZE - ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
●—●	FORM05	0.00	11.7	43.0	45.3	96.3	2.6	GW-GM

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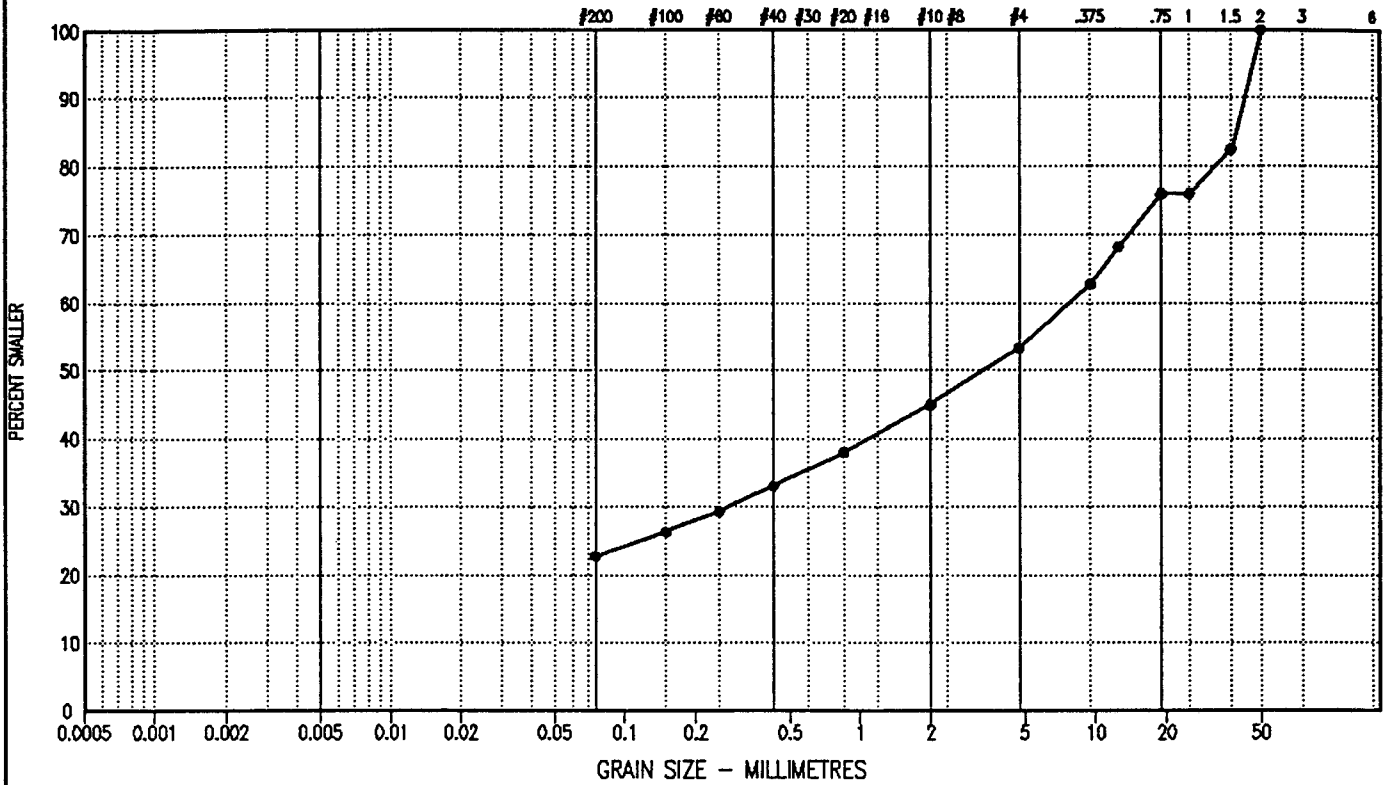
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PARTICLE SIZE - ANALYSIS OF SOILS

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE

U.S. STANDARD SIEVE SIZES



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
—●—	FORM06	0.00	22.7	30.6	46.7	245.7	0.3	GM

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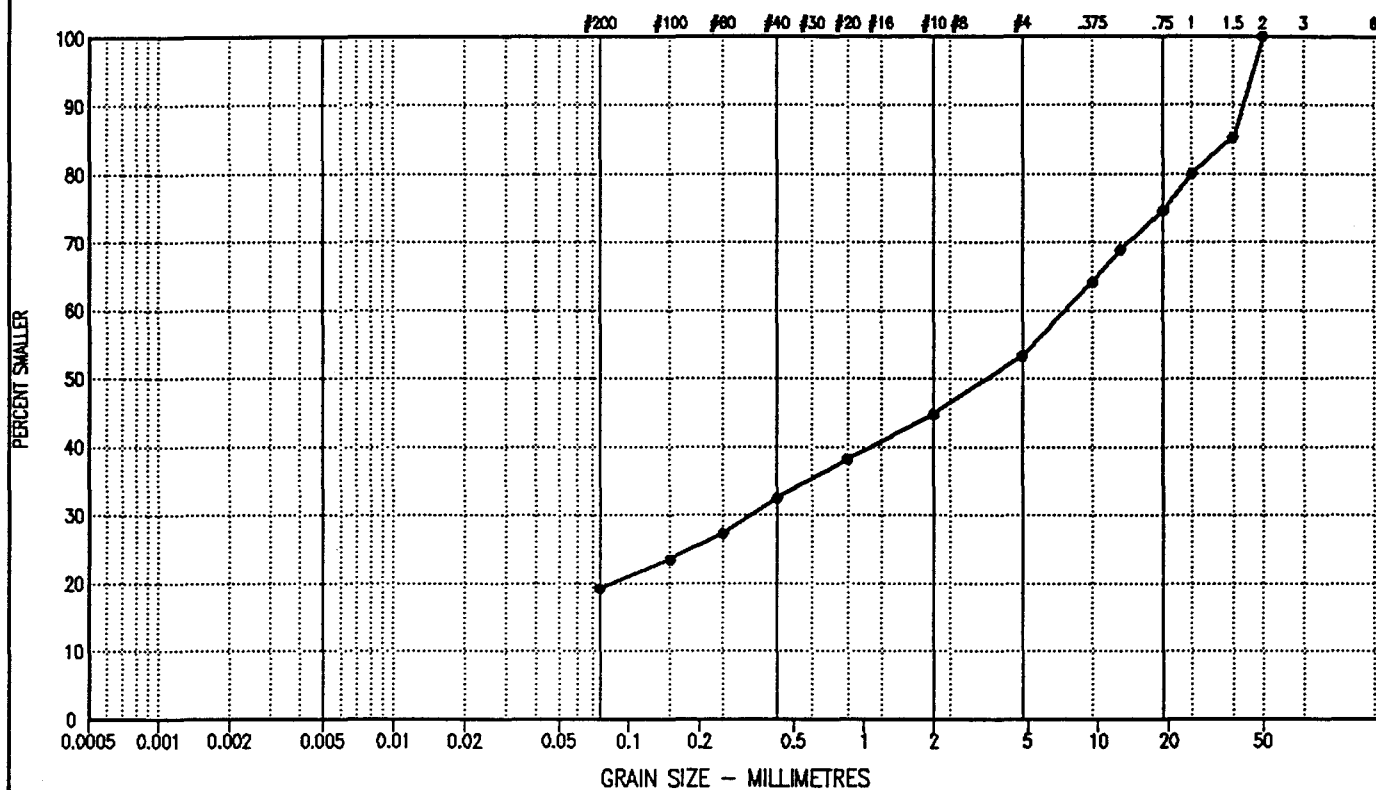
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PARTICLE SIZE - ANALYSIS OF SOILS

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE

U.S. STANDARD SIEVE SIZES



SYMBOL	BOREHOLE NUMBER	DEPTH (ft)	DESCRIPTION			Cu	Cc	U.S.C
			CLAY & SILT %	SAND %	GRAVEL %			
—●—	FORM07	0.00	19.2	34.1	46.7	197.0	0.4	GM

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