MERG Report 2000-3

Investigations Into Passive Wetlands Treatment Of Mine Drainage to Remove Heavy Metals at Various Sites at UKHM

By Laberge Environmental Services

March 2000

MERG is a cooperative working group made up of the Federal and Yukon Governments, Yukon First Nations, mining companies, and non-government organizations for the promotion of research into mining and environmental issues in Yukon.

MERG (Mining Environment Research Group) reports are available at Geoscience Information and Sales, Yukon Geological Survey, Department of Energy, Mines and Resources, Room 102, Elijah Smith Building, Whitehorse, Yukon.

Mailing Address:
102-300 Main Street
Whitehorse, Yukon Y1A 2B5
Phone (867) 667-5200
toll free within the Yukon
1-800-661-0408 ext. 5200
Fax (867) 667-5150
E-mail geosales@gov.yk.ca

The reports are also available electronically at the MERG Website:

http://www.emr.gov.yk.ca/mining/merg/

Laberge
ENVIRONMENTAL SERVICES

P.O. BOX 5111
WHITEHORSE, YT
Y1A 4S3

OFFICE PHONE (867) 668-6838
CELL PHONE (867) 668-1043
FAX (867) 667-6956

INVESTIGATIONS INTO PASSIVE WETLANDS TREATMENT OF MINE DRAINAGE TO REMOVE HEAVY METALS AT VARIOUS SITES AT UKHM, CENTRAL YUKON

(*Carex aquatilis*)

PREPARED FOR THE
MINING ENVIRONMENT RESEARCH GROUP (MERG)

SUBMITTED BY
B.E. Burns
LABERGE ENVIRONMENTAL SERVICES
March 2000

Yukon
Economic Development

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

ISBN 1-55018-982-4

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Wetlands have been used for decades in the treatment of municipal wastewater (sewage) in many parts of the world. Since the 1980s, wetlands have been used in the treatment of acid mine drainage, usually resulting from coal mining. Recently, natural and constructed wetlands have been researched and utilized for the removal of metals from mine drainage. Most of these wetland treatment systems have been designed and used in temperate climatic areas where permafrost, extreme minimum temperatures, and limited plant productivity is not a great concern. There is interest in northern regions on the possibility of the application of wetlands as a passive treatment system for metal contaminated mine drainage.

A research program investigating this possibility was initiated in the summer of 1995 in the vicinity of the United Keno Hill Mine property in central Yukon. A pilot wetland treatment system was constructed in May 1995 near the Galkeno 900 adit to determine whether it could improve the quality of its discharge. Sedges (*Carex aquatilis*) were obtained from a local natural wetland unaffected by any mine drainage and planted in the plot. After the plants were allowed to establish, untreated mine drainage was introduced to the wetland. Monitoring of the wetland continued for one season. Initial results showed that treatment within the wetland reduced concentrations of zinc, cadmium, manganese and nickel. Sulphate reduction in the sediments and formation of insoluble metal sulphides appeared to be the primary process responsible for their removal.

In 1999, further investigations were completed on this pilot project and on some of the natural wetlands which receive untreated mine drainage. Due to insufficient volumes of water flowing through the examined wetlands, they could not be fully evaluated as to their performance in the treatment of waste water. However sediment analyses showed that metals had been attenuated. The colonization of the transplanted sedges (Carex aquatilis) in the constructed wetland was evaluated. Successful growth and propagation was apparent. These local sedges appear to be a hardy species capable of withstanding transplanting, and appear to thrive with a minimum of effort.

Metal uptake in plant tissues was also examined. Low levels were documented throughout the study area with the exception of high zinc concentration in sedges that were collected from the No Cash wetland. As *Carex aquatilis*, the dominant sedge found in the local wetlands, is generally unpalatable to herbivores, the low and incidental levels of metals found within the tissue of the sedges, poses little environmental concern.

Overall, the preliminary results indicate that there is good potential for the use of wetlands to treat metal contaminated mine drainage.

ACKNOWLEDGEMENTS

The author wishes to thank the Mining Environmental Research Group for the funding for this project.

Acknowledgements are also extended to United Keno Hill Mines for the provision of lodging for the field crew during their stay in Elsa. The assistance of the on-site personnel was appreciated.

The support of the Nacho Nyak Dun First Nation was also appreciated.

The author wishes to thank Stuart Withers of Laberge Environmental Services for the collection and identification of all plant species.

Gratitude is extended to the Environmental Protection Branch of Environment Canada, Whitehorse, Yukon, for assuming some of the analytical costs through the use of their laboratory, Pacific Environmental Science Centre, in North Vancouver, B.C.

Thanks are also extended to Andre Sobolewski of Microbial Technologies for his advice and peer review.

1.0 INTRODUCTION

Wetlands have been used for decades in the treatment of municipal wastewater (sewage) in many parts of the world. Wetland systems provide wastewater treatment by significantly reducing oxygen-demanding substances such as BOD and ammonia, suspended solids, and nutrients such as nitrogen and phosphorus. Applications have expanded to include treatment from industrial wastewater.

Mining for metals disturbs large volumes of soil and rock material and exposes them to the environment. Through this exposure to air and water, sulphide minerals which are commonly associated with metal deposits, are oxidized (react with oxygen) and hydrolized (react with water) resulting in acid mine drainage (AMD). Since the 1980s, wetlands have been used in the treatment of acid mine drainage resulting from coal mining. Recently, wetlands, natural and constructed, have been researched and utilized for the removal of metals from mine drainage. These passive systems offer a low-cost approach to mine wastewater treatment. They may either completely or partially treat the water, thereby reducing treatment costs with chemicals (and their associated environmental concerns). Passive treatment utilizes the vegetation and sediment microbial communities found in natural and constructed wetlands to reduce acidity and precipitate the metals.

Long-term effectiveness of constructed wetlands is not well known. Since wetlands are self-sustaining ecosystems, they may be able to remediate contaminated mine drainage as long as it is generated, and may represent a long-term solution for mine drainage treatment. But treatment may be finite, after which the system must be replaced or replenished. Wetland aging may contribute to a decrease in contaminant removal rates over time. Wetlands do not destroy the metals, but do restrict their mobility. Metal release through decomposition of wetland plant tissue is undetermined.

Construction of wetlands on mined lands is beneficial to reclamation as they are recognized as a precious ecological system. They provide important habitat for a number of wildlife species and can enhance the aesthetic appeal of an area. A wetland filled with plants is considerably more pleasing to the eye than a treatment pond. They can be used as a relatively inexpensive tool for treating mine discharges.

Most of the wetland treatment systems have been designed and used in temperate climatic areas where permafrost, extreme minimum temperatures, and limited plant productivity is not a great concern. Similar design criteria are limited for other types of mine drainage (other than AMD treatment) and under northern conditions, and data necessary for their design must be generated through field studies. A field program was initiated in the summer of 1995 in the vicinity of the

United Keno Hill Mine property in central Yukon. A pilot wetland treatment system was constructed in May 1995 near the Galkeno 900 adit to determine whether it could improve the quality of its discharge. Sedges (*Carex sp*) were obtained from a natural wetland unaffected by any mine drainage and planted in the plot. After the plants were allowed to establish, untreated mine drainage was introduced to the wetland. Monitoring of the wetland continued for one season. Initial results showed that the pilot wetland significantly reduced zinc concentrations.

1.1 Objectives of Current Study

The Keno Hill mining district, 350 road kilometres north of Whitehorse, Yukon, was a major silver producer in Canada for 70 years, consisting of several underground and open pit silver/lead/zinc mines. Although the mill has not operated since 1989, mine water has continued to flow into the environment. Discharge from several adits, and lime-treated discharge from the tailings pond system and from Galkeno 900 adit comprise the most significant on-going metal laden flows.

The pilot wetland treatment system at UKHM represents the only one of its kind in the Yukon Territory. Although the wetland has not received direct discharge from the Galkeno 900 adit since 1995, it appears that seepage has entered the wetland. One purpose of this project was to re-visit the pilot project to evaluate the success and colonization of the transplanted sedge species, *Carex aquatilis*. In 1995, sedges were also transplanted to sites within Tailings Pond #3 near Tailings Dam #2 to evaluate different transplantation techniques. The colonization success rate was evaluated at these sites as well.

In addition, investigations were conducted on natural wetlands receiving drainages from several adits to attempt to evaluate the transport and fate of metals. For several decades the metal laden discharges from some of these mines has been flowing into natural wetland areas. Investigations were conducted on the natural wetlands receiving drainages from Husky and No Cash 500. A natural wetland down gradient from Galkeno 900 was also investigated.

The objectives of investigation at each site were to:

- determine the degree of biomass accumulation
- identify the transplanted species, *Carex aquatilis*', colonization of the wetland
- identify invader species within the wetland and degree of colonization
- assess the water quality entering and discharging the wetland systems
- determine the degree of metal uptake in the plants in the various wetlands
- collect sediment samples to determine the degree of metals attenuation
- determine presence of sulphate reduction within the wetland sediments by collecting samples for sulphur reducing bacteria

2.0 STUDY AREA

The study area is located in central Yukon, situated on the Silver Trail approximately 50 kilometres northeast of Mayo in the vicinity of the small communities Elsa and Keno. The study area lies within the ecoregion Yukon Plateau North with the terrain consisting of rolling upland plateaus and small mountain groups. The Tintina Trench traverses the ecoregion from southeast to northwest.

The ecoregion is characterized by long cold winters (mean temperature of -20°C) and warm summers (mean temperature of 10.5°C). Mean annual precipitation ranges from 300 mm in the major valleys up to 600 in the mountains to the northeast. The extreme cold causes extensive areas of permafrost.

Sedge or sphagnum tussocks are common in wetlands and in black spruce stands. Extensive shrub lands occur at mid-elevations and on valley bottoms due to cold air drainage. Northern boreal forests exist at elevations up to 1500 m asl. White spruce in a matrix of dwarf willow, birch, ericaceous shrubs, and, occasionally, lodgepole pine forms extensive open forests. Black spruce, scrub willow, birch, and mosses are found on poorly drained sites. Turbic Cryosolic and Eutric Brunisolic soils predominate.

Five areas of interest were examined within the study area; the constructed and natural wetlands near Galkeno 900 adit, the natural wetland downstream of No Cash 500 adit, the small natural wetland at Husky, the transplanted sites near tailings dam #2, and the natural uncontaminated wetland near the South McQuesten River by the freshwater pumphouse (Figure 1).

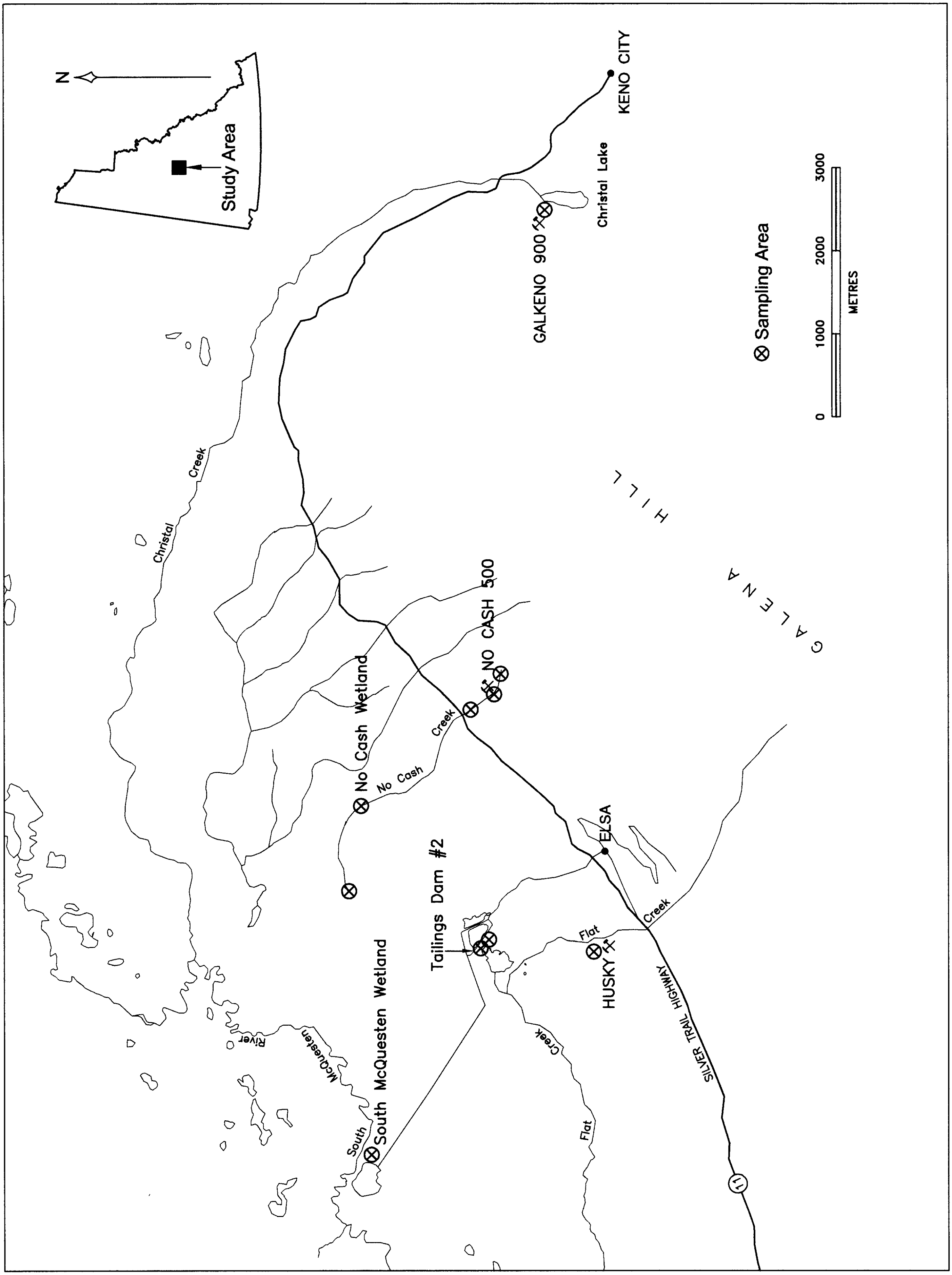

Figure1 Location of Study Area and Sample Sites

3.0 METHODS

3.1 Water

In-situ Measurements

In-situ water measurements were taken at each site where possible. Conductivity and temperature were determined with an Orion conductivity meter model 126. Measurements for pH were made using an Accumet AP5 pH meter. Meters were calibrated using approved standards prior to measurements.

Chemistry Analysis

Water samples were collected from strategic locations to be analyzed for a suite of parameters. New one litre plastic bottles were used to collect water to be analyzed for total alkalinity, hardness, sulphate and total suspended solids. Samples to be analyzed for total metals were collected in new 250 ml plastic bottles.The dissolved metals samples were filtered in the field using a hand operated pump with disposable nalgene filter kits (filter pore size 0.45 microns) and placed into new 250 mL plastic bottles. Dissolved and total metals samples were preserved with nitric acid. All sample bottles with the exception of the dissolved metals sample, were partially filled and rinsed three times prior to collecting sample waters. The dissolved metals sample bottle was rinsed three times with the filtrate. Samples were kept cool prior to shipment to Norwest Labs in Surrey, B.C. or the Pacific Environmental Science Centre. The methods used by the labs are based on *Standard Methods for the Examination of Water and Wastewater,* 19th Edition, published by the American Public Health Association.

3.2 Sediment

Sediment samples were collected from most sites. Samples were collected with a teflon trowel and placed in zip-lock plastic bags. The samples were kept cool and packed with ice packs when shipped to Norwest Labs or to the Pacific Environmental Science Centre.

At the lab the samples were dried, sieved, and analyzed by ICP analysis to determine total metals levels, using methods described in *Test Methods for Evaluating Solid Waste, Physical/Chemical Method, SW846*, 3rd Edition.

3.3 Vegetation

At each of the survey sites the percent cover of the major plant species was noted along with the height of the plants, the percentage of plants bearing inflorescence, and the amount of detritus from previous year's growth. All plant species observed on the wetlands were identified in the field where possible. Plant species not identifiable in the field were collected and pressed. All plant species were identified according to Cody (1996). In addition, vegetation was collected at most sites for the analyses of metal content. The above ground portion of the plants (sedges, equisetum or grasses) was placed in large ziplock plastic bags, frozen to prevent decay, and shipped to either Norwest Labs or to the Pacific Environmental Science Centre where they were dried and analyzed for metal content.

3.4 Sulphur Reducing Bacteria

Three samples were collected to determine the presence of sulphur reducing bacteria (SRB); one each from Plot #3 and Plot #4 in the constructed wetland at Galkeno, and one from the natural wetland of the South McQuesten swamp. These samples were kept cool and shipped to Microbial Technologies in Gibsons, B.C. SRB were enumerated according to the procedure described by Battersby (1988). Cells were grown in an anaerobic medium in the dark at room temperature for one month. The presence of hydrogen sulphide was detected by injecting a copper sulphate solution and observing the formation of a dark copper sulphide precipitate. Bacterial numbers were calculated using the Most Probable Number method (APHA, 1995).

3.5 Observations

Field notes were made at all locations, complemented with photographs and video footage. To successfully locate the plots which were transplanted in 1995, photographs supplied by Microbial Technologies were carefully examined and ground truthed at each site.

4.0 RESULTS

Photographs of the sites are presented in Appendix A. The lab results for the chemical analyses of water, sediment and vegetation tissue are included in Appendices B, C and D, respectively. A complete list of the plant species observed at each site is presented in Appendix E.

4.1 Galkeno Constructed Wetland

In the summer of 1995, a pilot wetland treatment system was constructed by Microbial Technologies, down gradient from the Galkeno 900 adit. A south facing plot of 9 x 18.5 x 0.5 m was excavated and planted in May with sods of sedges (*Carex aquatilis*) and underlying soil/peat obtained from the South McQuesten wetland. Fertilizer was broadcast on the plot prior to transplanting the sods. Lime-treated mine water was added until good plant growth was observed. Contaminated mine water was fed into the wetland from July to September. In August it appeared that the flow was by-passing a portion of the wetland and to prevent short-circuiting, plywood baffles were inserted across the wetland, dividing the wetland into four plots (see Photo 1). Water quality was monitored at the inflow and decant from August 20 to September 26, 1995.

Although the wetland was only operational for a very short time and had definitely not reached a steady state, the results indicated that good reduction in concentrations of sulphate, cadmium, nickel, manganese and zinc was achieved when the water had reached the decant. Most significantly was the reduction of zinc from 25 mg/L at the inflow, to 4 to 5 mg/L at the decant. At the direction of DIAND, Water Resources, flow through the wetland was discontinued in the fall of 1995, and redirected through the lime treatment system within the adit and to settling ponds, before discharging to Christal Lake.

Although there was no visible flow through the wetland in 1999, there was some standing water in Plots 3 and 4. It appears that some below-surface seepage was reporting to the wetland at the base of Plot 4 from the adjacent waste rock pile. Temperature and pH were measured and a chemistry water sample was collected. Sediment and vegetation samples were collected from the four plots and analyzed for metals. Results are summarized in Table 1. Concentrations of metals in the water sample were low where detected. There appears to be a general trend of decreasing concentrations of metals in the sediments from Plot 1 through to Plot 4. As this was the flow path of the contaminated mine water, it appears that metals were attenuated and/or settling in the sediments within a short distance of entering the constructed wetland. Metal concentrations in the plant tissues were relatively consistent in each plot except for zinc which displayed a reduction from Plots 1 through 4.

Carex aquatilis dominated the vegetation of the Galkeno constructed wetland. Current year's growth of *Carex aquatilis* covered about 30 percent of the wetland. A layer of the previous years' vegetative litter, about 20 cm thick, made up the remaining 70 percent. The current year's sedge was about 45 cm high. About 10 percent of it had inflorescence, mostly at the outer, wet perimeter of the wetland. Other graminoids found in insignificant numbers were *Carex utriculata* and *Calamagrostis canadensis*. The colonizing of the wetland by shrubs (*Alnus incana* and *Salix glauca*) had also begun.

Table 1 SUMMARIZED DATA FOR THE CONSTRUCTED WETLAND AT GALKENO 900, AUGUST 10 & 11, 1999

PARAMETER	PLOT 1	PLOT 2	PLOT 3	PLOT 4
WATER:				
In-situ Temp °C	-	-	11.8	10.5
In-situ pH	-	-	6.86	7.13
In-situ Cond.	-	-	1850	2080
Total Alkalinity	-	-	-	315
Hardness	-	-	-	1370
Sulphate	-	-	-	1190
TSS	-	-	-	29
Cadmium	-	-	-	<0.0005
Lead	-	-	-	<0.005
Nickel	-	-	-	0.013
Silver	-	-	-	<0.001
Zinc	-	-	-	0.045
SEDIMENT / VEGETATION (ppm dry weight)				
Arsenic	140/0.6	160/0.6	153 / <2	90 / <2
Cadmium	13/0.13	9.7/ 0.17	6.9 / 0.13	2.4 / 0.11
Copper	48 / 6.9	63 / 5	43.2 / 7.4	30.6 / 5.2
Lead	60 / 0.3	96 / 0.3	194 / <1	37 / <1
Mercury	0.061 / 0.007	0.078 / 0.008	0.09 / 0.06	0.06 / 0.06
Nickel	61 / 4	71 / 4	24.9 / 1.1	21.5 / 0.9
Silver	3.2 / <0.5	2.9 / <0.5	4.6 / <0.1	<0.5 / <0.1
Zinc	1480 / 216	1920 / 140	914 / 121	393 / 94.4
SULPHUR REDUCING BACTERIA (cells/dry gram)				
SRB			2,970	15,556

4.2 Galkeno Natural Wetland

The abandoned road to the old Galkeno mill site near Christal Lake has revegetated naturally over the decades. The mill was operated by MacKeno Mines in the 1950s (UKHM did not use this mill). All of the buildings were removed from the area and some contouring was done. Water stagnates in some areas of the revegetated road and supports small sedge wetlands. Water enters the wetland area from a series of three ponds (see Photos 2 and 3). The water seeps into the upper portion of the wetland but the bulk of the flow travels through willows to the south of the wetland area eventually discharging into Christal Lake.

The three discharge ponds below the constructed wetland were very sparsely vegetated and had about a two percent coverage of sedge (*Carex praticola* and *Carex utriculata*) and *Equisetum arvense*. The rest was standing water and mud. The current year's growth of sedge was about 50 cm high and bore no inflorescence. The berm around the constructed wetland and the berms between the discharge ponds have been invaded by a number of locally common forb and shrub species.

A groundwater monitoring well (UK95G9/1) exists near Pond 3 and water samples were collected to characterize the groundwater of the vicinity. These wells, although installed in 1995, have yet to be developed properly, consequently the retrieved water sample was very turbid and high in suspended solids.

Water, vegetation and sediment samples were collected at various locations depicted in Figure 2, and the data are summarized in Table 2. Concentration of zinc in the water was reduced from 3.03 mg/L at the discharge of the third pond to 0.331 mg/L just upstream of Christal Lake. Metal attenuation processes are occurring in this reach. Concentrations of several metals in the sediments collected within the natural wetland were substantially high, indicating that this wetland had received metal laden drainage in the past. Zinc and lead concentrations were high in the sediments of Ponds 1, 2 and 3.

The vegetation in the natural wetland below the Galkeno 900 discharge was almost entirely *Carex aquatilis* (with minor occurrences of *Salix glauca*). The current year's growth covered about 60 percent of the wetland, along with a 15 cm thick layer of vegetative litter (35 percent coverage) and standing water (five percent coverage). The sedge in this wetland was about 40 cm high, with 15 percent of it bearing inflorescence.

A similar situation was found at the point of discharge into Christal Lake. The current year's growth of *Carex aquatilis* here formed 60 percent of the cover, along with a 15 cm thick detritus layer (30 percent coverage) and standing water (10 percent coverage). About 20 percent of the 50 cm high sedge bore inflorescence.

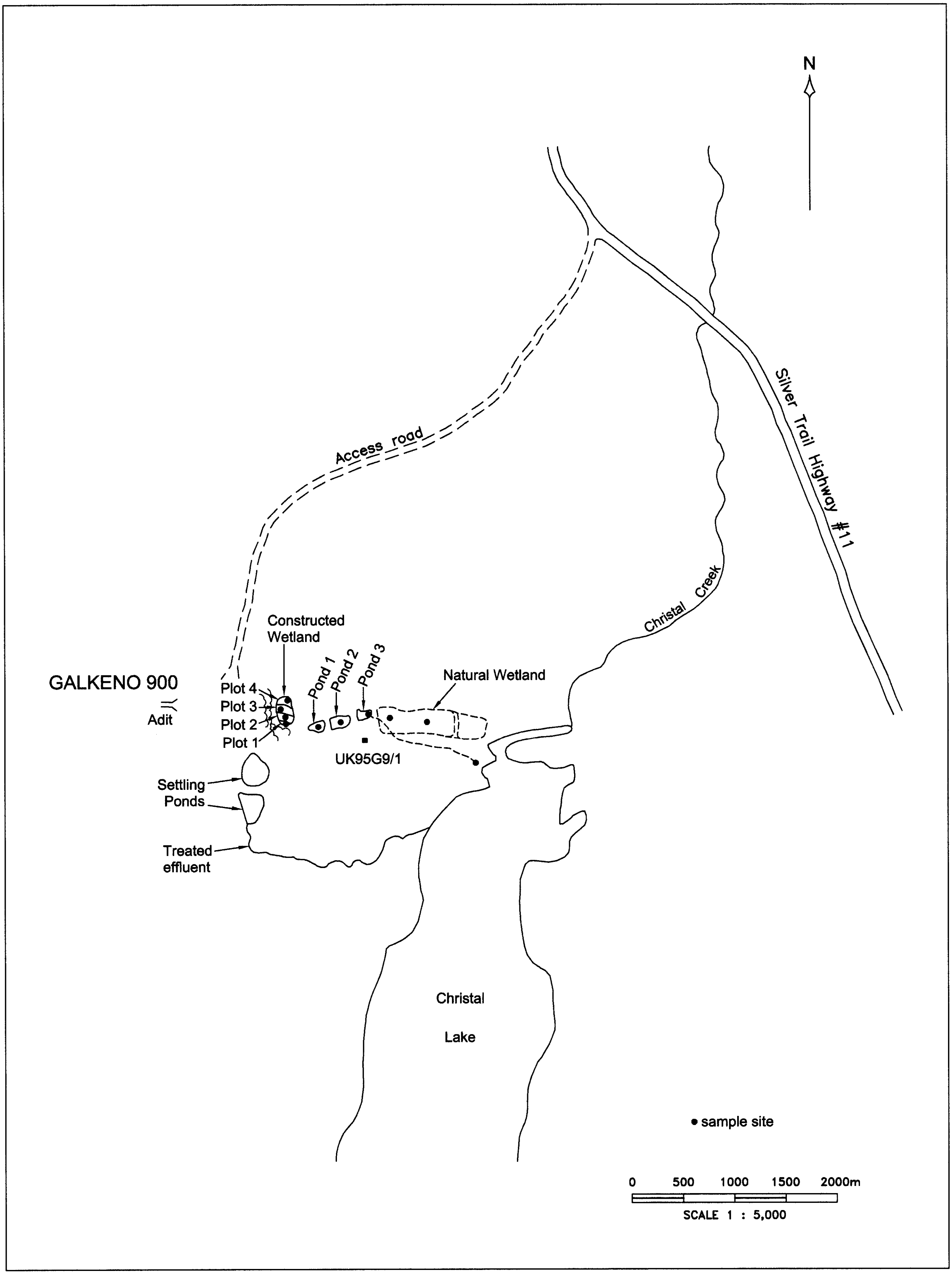

Figure 2 Sample locations in the Galkeno 900 area

Table 2 SUMMARIZED DATA FOR SITES DOWNGRADIENT OF GALKENO 900, AUGUST 10 & 11, 1999

Parameter	Pond #1	Pond #2	Pond #3	UK95G9/1	Natural Wetland #1	Natural Wetland #2	Discharge to Christal L
Water:							
In-situ Temp °C	9.5	-	18.3	10.8	-	-	-
pH	6.7	-	7.05	7.16	7.2 - 7.6	-	-
Cond	2100	-	2060	1884	-	-	-
Alkalinity	214	-	189	207	-	-	-
Hardness	1520	-	1400	1420	-	-	-
Sulphate	1300	-	1330	1300	-	-	-
TSS	5	-	<5	3780	-	-	-
CHEMISTRY : Water (dissolved ppm) / Sediment (dry weight ppm)/ Vegetation (dry weight ppm)							
Arsenic	0.0012 / 220 / 1.0	- / 230 / 1.0	<0.02 / 90 / 0.7	<0.02 / - / -	- / 80 / <2	- / 190 / -	<0.02 / 100 / <2
Cadmium	0.021 / 18/ /1.08	- / 28 / 0.097	0.0063 / 19.6 / 0.52	<0.0005 / - / -	- / 5.1 / 0.09	- / 19.8 / -	<0.0005 / 8.7 / 0.06
Copper	0.0008 / 64 / 5.8	- / 61 / 5.1	0.005 / 50 / 8.1	<0.002 / - / -	- / 44 / 14.6	- / 80 / -	0.006 / 32 / 4.5
Lead	<0.0005 / 580 / <0.2	- / 100 / <0.2	<0.005 / 170/ 0.6	<0.005 / - / -	- / 36 / <1	- / <80 / -	<0.005 / 33 / <1
Mercury	- / 0.058 / 0.005	- / 0.056 / 0.006	<0.0001 / 0.108 / 0.008	<0.0001 / - / -	- / 0.07 / 0.06	- / 0.082 / -	<0.0001 / 0.08 / 0.06
Nickel	<0.2 / 280 / 2	- / 200 / <2	0.069 / 100 / 2	0.026 / - / -	- / 52.8 / 1.7	- / 390 / -	0.015 / 148 / 1.8
Silver	<0.0005 / 6.3 / <0.5	- / 1 / <0.5	<0.001 / 1 / <0.5	<0.001 / - / -	- / <0.5 / <0.1	- / <0.9 / -	<0.001 / <0.5 / <0.1
Zinc	5.98 / 5940 / 194	- / 5540 / 84.5	3.03 / 4910 / 133	0.288 / - / -	- / 1940 / 69	- / 12500 / -	0.331 / 5060 / 108

4.3 No Cash 500 Creek and Wetland

The No Cash underground mine was mined from two levels, 100 and 500, from 1948 to 1988. Water from the adit occurs at the 500 level and is discharged to No Cash Creek via a culvert through the waste rock dump at the portal. Recharge to the No Cash Mine is primarily from groundwater, including connections to other underground workings such as the Calumet Mine (Access Mining Consultants, 1996). Water samples were collected at several locations: upstream of the adit, from the adit itself, at No Cash Creek at the road crossing, in the small sedge wetland downstream of the road, and at the confluence of No Cash Creek and the interceptor ditch. Sediment and vegetation samples were collected in the wetland and sediment samples were also collected from areas of deposition along No Cash Creek. Summarized data are presented in Table 3. In the water samples, conductivity, alkalinity, sulphate and the concentration of most metals increased significantly at the adit then decreased as one progressed downstream. The sediments in No Cash Creek at the highway contained one of the highest concentrations of zinc and of lead documented during the 1999 study. Metals in the sediments of No Cash Creek downstream of the highway were significantly reduced.

The entire length of No Cash Creek was traversed from the road crossing to the interceptor ditch. A small wetland supporting sedge growth was located approximately 1.5 km from the road (see Photo 4). The small wetland was covered primarily with *Carex aquatilis*, along with minor occurrences of *Carex praticola* and *Equisetum arvense*. The current year's sedge covered 30 percent of the wetland. It was about 40 cm high, with 15 percent in inflorescence. The remaining 70 percent of the wetland cover consisted of a 5 cm thick layer of vegetative litter. Although other "wet areas" were noted along the length of the creek, these consisted of willow, birch and alder communities and were not sampled. The area is underlain by permafrost and supports typical black spruce communities throughout.

Table 3 SUMMARIZED DATA FOR NO CASH CREEK, AUGUST 11, 1999

PARAMETER	U/S ADIT	ADIT	AT ROAD CROSSING	WETLAND	DITCH
Water:					
Temp °C	2.8	4	4.4	12	12
pH	7.68	7.78	8.21	8.05	7.74
Cond	243	1152	1033	895	941
Alkalinity	38.9	137	154	177	158
Hardness	131	721	666	613	606
Sulphate	85	610	500	497	400
TSS	<5	14	<5	36	7

PARAMETER	U/S ADIT	ADIT	AT ROAD CROSSING	WETLAND	DITCH
CHEMISTRY: Water (dissolved ppm) / Sediment (dry weight ppm) / Vegetation (dry weight ppm)					
Arsenic	<0.0005 / 53 / -	0.0027 / - / -	0.0012 / 260 / -	<0.02 / 13 / <2	0.0008
Cadmium	<0.0002 / 6.4 / -	0.187 / - / -	0.02 / 160 / -	0.0012 / 4 / 0.26	0.0005
Copper	0.0013 / 56.4 / -	0.021 / - / -	0.036 / 140 / -	0.005 / 28.6 / 7.5	0.01
Lead	0.0018 / 350 / -	<0.0005 / - / -	<0.0005 / 1910 / -	<0.005 / 35 / <1	<0.0005
Mercury	- / 0.068 / -	- / - / -	- / 0.125 / -	<0.0001 / 0.08 / 0.06	-
Nickel	<0.02 / 34 / -	0.12 / - / -	0.03 / 100 / -	0.004 / 18.6 / 0.4	<0.02
Silver	<0.0005 / 42 / -	<0.005 / - / -	<0.0005 / 79 / -	<0.001 / 0.7 / <0.1	<0.0005
Zinc	0.041 / 604 / -	18.8 / - / -	2.38 / 12300 / -	0.397 / 435 / 416	0.303

4.4 Husky

The Husky underground mine was operational from 1968 to 1988. A small seep emerges from the base of the waste rock dump at the mine site. Iron in the seep is immediately oxidized and the rust-coloured water fans out over the waste rock (Photo 5). Some of this water appears to flow into a small grassy swamp (Photo 6), with portions of the flow skirting the swamp (Figure 3).

Water and sediment samples were collected at the base of the waste rock dump and in the wetland (swamp). The characteristics of the sediment sample from the waste rock dump was consistent with deposited precipitates, rather than actual sediment. A vegetation sample (grass) was collected for metal analysis. Summarized data are presented in Table 4. Metal concentrations were greatly reduced in the water of the swamp. The low temperature and sulphate level may however indicate that the water in the swamp originates from groundwater and not from the waste rock. Further studies on the origin of this water would need to be conducted.

The vegetation of the swamp consisted mostly of grasses. *Agrostis scabra* and *Calamagrostis stricta* made up most of the ground cover. *Alopecurus aequalis* and *Hordeum jubatum* were also found. *Calamagrostis stricta* was 70 cm high and the other grasses were about 40 cm. Detritus from previous years' *Agrostis scabra* made up a dense 30 cm thick layer. Inflorescence was found on approximately 90 percent of *Agrostis scabra*, 40 percent of *Calamagrostis stricta* and ten percent of the other grasses. No sedges were noted at this site. This oasis of a swamp supported healthy growth of vegetation; mosquito larvae were observed in pooled water; and one large wood frog was seen.

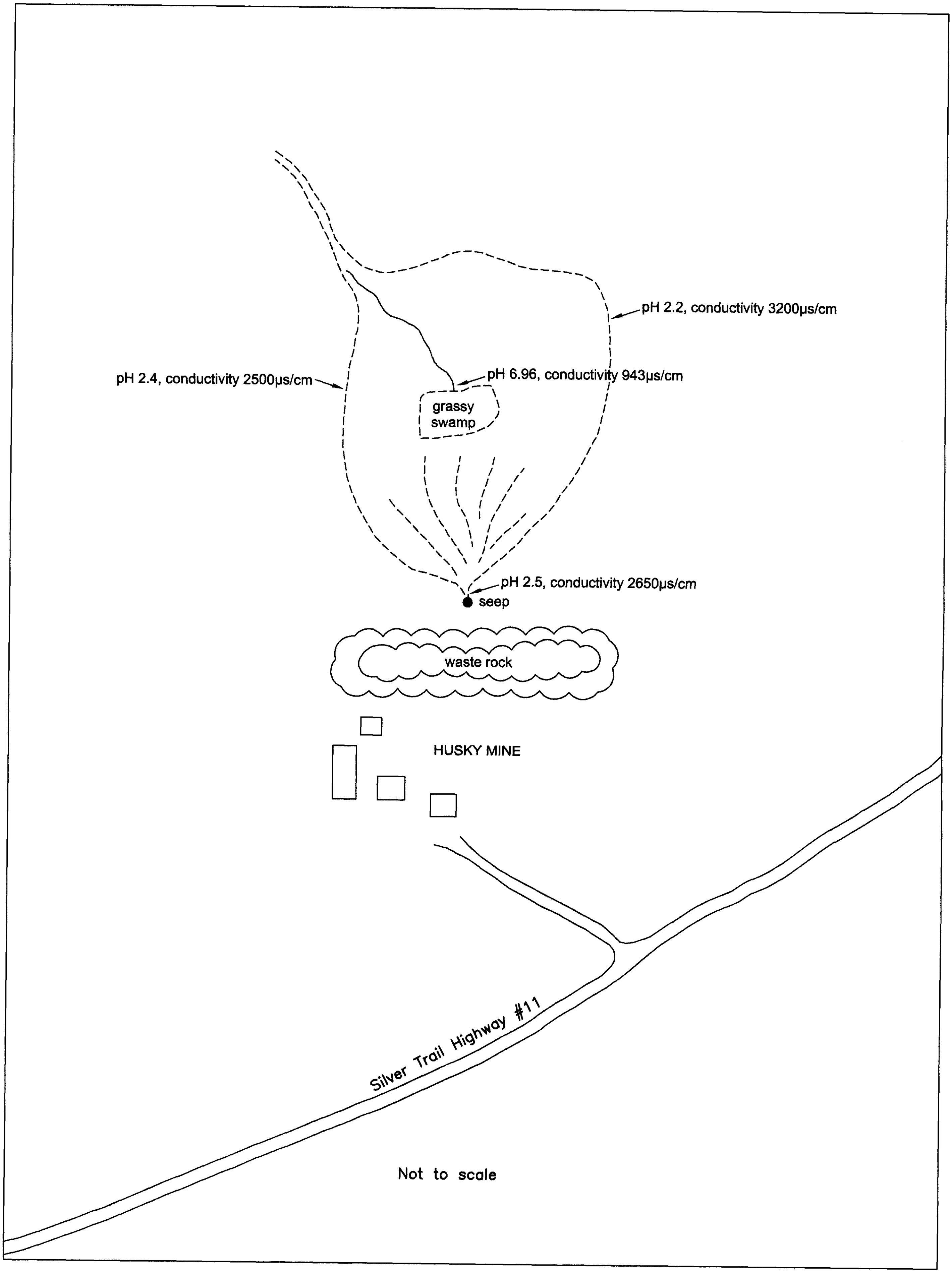

Figure 3 The seep flow path below Husky, August 11, 1999

Table 4 SUMMARIZED DATA FOR HUSKY, AUGUST 11, 1999

PARAMETER	SEEP	SWAMP
Water:		
Temp °C	12.0	5.0
pH	2.52	6.96
Cond	2650	943
Alkalinity	<5	236
Hardness	732	552
Sulphate	2520	251
TSS	25	12
CHEMISTRY: Water (dissolved ppm) / Sediment (dry weight ppm) / Vegetation (dry weight ppm)		
Arsenic	6.1 / 3420 / -	<0.02 / 1750 / <2
Cadmium	0.714 / 1.41 / -	0.001 / 11.7 / 0.41
Copper	1.93 / 86.3 / -	0.005 / 234 / 5.8
Lead	<0.005 / 246 / -	<0.005 / 2390 / 2
Mercury	<0.0001 / 0.14 / -	<0.0001 / 0.25 / 0.006
Nickel	0.625 / 9.2 / -	0.007 / 31 / 0.8
Silver	<0.001 / 26.1 / -	<0.001 / 49.4 / <0.1
Zinc	17.9 / 131 / -	0.093 / 1180 / 57.6

4.5 Transplanted Sites near Tailings Dam #2

In 1995, Microbial Technologies transplanted sedges from the South McQuesten Wetland to four sites in the north section of tailing pond #3, near the Tailings #2 dam (pers. comm. Andre Sobolewski[1]). These sites were visited on August 10, 1999 but only two of the plots could be positively identified. The fact that the other two plots could not be distinguished indicates that they have successfully recolonized, mostly with terrestrial plants, and have consequently blended in with the surrounding areas. The lack of sedge growth in the vicinity of these plots could indicate that there has been a lack of water over the preceding years.

The two identifiable plots were evaluated in terms of growth and sampled for chemistry (water where possible, sediment and vegetation). The summarized data are presented in Table 5. There were very high concentrations of lead and silver in the sediments possibly signifying that tailings may have been deposited in this area. However, concentrations of these metals in the tissues of the plants were similar to the concentrations in plant tissue that grew in areas of low lead and silver levels.

There were notable differences between the vegetation on the two plots inspected at the tailings impoundment transplant site. *Carex aquatilis* dominated the vegetation on plot one while *Equisetum* spp. was most prevalent on plot two. Plugs of sedges were originally planted at one metre intervals but the plants have successfully colonized to eradicate this pattern. It is not readily known why equisetum dominated plot two, effectively preventing the colonization of the sedges throughout this plot.

The current year's growth of *Carex aquatilis*, along with six other graminoid species (see Appendix D), covered 45 percent of plot one. The remainder of the ground cover was 35 percent sedge detritus (15 cm thick) and 20 percent moss and bare ground. *Carex aquatilis* on the plot was about 65 cm high and 40 percent of it bears inflorescence.

An estimated 80 percent of the ground cover on plot two was *Equisetum (E. arvense* and *E. hynemale*). Only five percent was *Carex aquatilis*, occurring in small patches along with six other graminoid species. A ten cm thick layer of organic litter made up the remaining 15 percent of the ground cover. About 30 percent of the 60 cm high *Carex aquatilis* had inflorescence.

The berms around the tailings transplant plots have been colonized by a number of locally common forb and shrub species.

Table 5 SUMMARIZED DATA FOR TRANSPLANTED SITES NEAR TAILINGS DAM #2, AUGUST 10, 1999

PARAMETER	PLOT #1	PLOT #2, Sedges	PLOT #2, Equisetum	DITCH
Water:				
Temp °C	-	-	15.2	17.0
pH	-	-	7.05	7.28
Cond	-	-	2910	1435
Alkalinity	-	-	197	301
Hardness	-	-	1530	755
Sulphate	-	-	1530	644
TSS	-	-	8	27
CHEMISTRY: Water (dissolved ppm) / Sediment (dry weight ppm) / Vegetation (dry weight ppm)				
Arsenic	- /940 / <2	- / 1180 / 4	<0.02 / 760 / 86	<0.02 / 414 / 2
Cadmium	- / 58.6 / 0.2	- / 55.4 / 1.27	0.0017 / 54.5 / 2.27	0.0009 / 282 / 0.2
Copper	- / 95.5 / 4.4	- / 112 / 13.3	0.014 / 91.2 / 11.1	<0.002 / 89 / 6
Lead	- / 3980 / 5	- / 6300 / 20	<0.005 / 4870 / 5	<0.005 / 3750 / 3
Mercury	- / 0.75 / 0.06	- / 0.65 / 0.06	<0.0001 / 0.65 / 0.06	<0.0001 / 0.45 / 0.06
Nickel	- / 13.4 / 0.4	- / 10.6 / 0.9	0.009 / 10.3 / 0.99	0.043 / 34.6 / 0.4
Silver	- / 49.4 / <0.1	- / 87.1 / 0.3	<0.001 / 51.6 / 0.5	<0.001 / 36.2 / <0.1
Zinc	- / 5500 / 50.8	- / 5280 / 114	0.277 / 4740 / 128	3.25 / 26100 / 86.4

4.6 South McQuesten Wetland

The South McQuesten wetland is located adjacent to the South McQuesten River in the drinking water reservoir serving the hamlet of Elsa, and is uncontaminated by any mine drainage (Photo 7). This wetland represents the control for this region, and in 1995 was the donor site for the transplanted sedges at the constructed wetland at Galkeno 900 and at the sites in tailings pond #3 near Tailings Dam #2. The excavated sites where the donor plants were removed, were located and were revegetating with sedges. Growth was not as dense as in the surrounding areas but many of the plants had seed heads and appeared healthy. Water depth in the excavated sites was approximately 20 cm, with a modest amount of detritus on the sediment.

The current year's growth of *Carex aquatilis*, along with a few other species including *Carex utriculata*, made up 70 percent of the ground cover of the wetland. The remainder was a 20 cm thick layer of litter from previous years' sedge growth. Fifty percent of the 80 cm high *Carex aquatilis* bore inflorescence.

The water level in the wetland appeared to be unusually low, exposing a number of normally submerged aquatic plant species, including *Hippuris vulgaris*, *Sparganium multipedunculata*, and *Potamogeton* sp.

Samples for chemistry (water, sediment and sedges) and sulphur reducing bacteria were collected in the submerged area. The summarized data are presented in Table 6.

Table 6 SUMMARIZED DATA FOR SOUTH MCQUESTEN WETLAND, AUGUST 12, 1999

PARAMETER	WETLAND	PARAMETER	WETLAND
Temp °C	10.7	Alkalinity	102
pH	6.86	Hardness	276
Cond	484	Sulphate	176
SRB (cells/dry g)	5,704	TSS	<5
CHEMISTRY: Water (dissolved ppm) / Sediment (dry weight ppm) / Vegetation (dry weight ppm)			
Arsenic	<0.02 / 55 / <2	Mercury	<0.001 / 0.12 / 0.006
Cadmium	<0.0005 / 1.8 / 0.06	Nickel	0.004 / 26.6 / 0.3
Copper	0.006 / 36.8 / 4.9	Silver	<0.001 / <0.5 / <0.1
Lead	<0.005 / 52 / <1	Zinc	0.11 / 231 / 42.3

5.0 DISCUSSION

5.1 Metal Accumulation in Sediments

Metals can accumulate in sediments through several processes. Metals can settle out via gravitational processes, or precipitate out with variations in pH. Generally the solubility of metals increases as pH decreases. This does not always hold true, as with the example of molybdenum which becomes more soluble as conditions become more alkaline, but forms insoluble compounds when water becomes acidic. Zinc and cadmium, on the other hand, are quite soluble under neutral conditions.

Metals, both dissolved and particulate forms, are also retained in wetlands through sorption onto organic matter. There appears to be an order of preference for metals by organic matter. Copper and iron tend to form the most stable complexes and will prevent the sorption of zinc onto organic matter. Zinc is the main metal of concern in the mine drainages in the Elsa-Keno area. For wetland removal of zinc, iron may need to be removed from the mine discharge in a settling pond prior to wetland treatment.

Some metals such as copper, can form soluble complexes with dissolved organic matter and will not settle from solution. However, it is recognized that these soluble metal complexes are less toxic compared with the free metal ion (Nor, 1994). It is likely that a large proportion of the dissolved metals in the discharge of wetlands is complexed with soluble organic matter and thus produces a less toxic effluent than the analyses may imply (Sobolewski, 1995).

Dissolved metals react with dissolved carbonate and sulphide (both of which are produced in anaerobic sediments by sulphate-reducing bacteria) forming insoluble carbonates and sulphides which are retained in the sediments. These insoluble compounds are susceptible to oxidation, usually under acidic conditions, which can lead to mobilization of the metals, but will remain stable if oxygen is excluded and anaerobic conditions allowed to exist. Calcium carbonate may accumulate in wetland sediments creating a reservoir of buffering capacity which can neutralize incoming acidic mine water.

Iron and manganese are removed from the water column through the formation of oxides, creating precipitates. Metals such as cadmium, copper, lead and zinc sorb onto the surface of iron and manganese oxides. These oxides can contribute significantly to metal removal in wetlands.

How long metals will be retained in the sediments and not be remobilized is dependent on the species of the metal. To determine this, sequential leach analysis was performed on sediment samples from the Galkeno natural wetland and the No Cash wetland in 1995 (Sobolewski, 1995).

Results showed that most of the zinc and cadmium were bound to iron and or manganese oxides in the Galkeno sediments. Cadmium was present predominantly as a sulphide in the No Cash sediments and zinc was equally distributed as oxides and sulphides. These findings suggest that removal of these metals will continue for several years. The stability of these metals were tested by leaching the samples with increasingly acidic waters. The strong buffering capacity of the wetland sediments prevented their acidification and any significant metal leaching. The test was further modified to titrate out the buffering capacity to determine if leaching could be enhanced. Very little zinc was released from the sediments. These results clearly show that metals retained in the sediments of the No Cash and Galkeno natural wetlands are stable and will not be remobilized should the respective mine drainages become acidified.

The above tests are very expensive and lengthy processes, and were not repeated or conducted on the other wetlands in 1999 due to budget constraints. However, the testing conducted in 1995 indicates that metals in the mentioned wetlands are stable and will resist leaching.

There was significant metal removal in No Cash Creek upstream of the wetland (Figure 4). The dissolved zinc introduced by mine water at the No Cash 500 portal decreased from approximately 19 mg/L to 2.4 mg/L at the road crossing. Kwong et al (1984) documented attenuation of zinc within this reach. Ferrous ion sorbs onto sediments along the stream bed and undergoes oxidation to precipitate ferric hydroxide, especially under open water conditions. Extensive iron oxide coatings occur along No Cash Creek (Photo 8). Based on the results of sequential extraction analyses, iron oxide is an efficient scavenger of the trace metals investigated (Kwong et al, 1994). Thus sorption onto precipitating ferric hydroxide is an important metal attenuation mechanism in No Cash Creek. The sediment data at the highway shows one of the highest zinc concentrations documented during the 1999 study (12,300 ppm). It appears that most of the zinc has been removed by the time No Cash Creek reaches the wetland where the concentration of zinc was 0.4 mg/L in the water and 435 ppm in the sediment.

Metal concentrations fluctuated at the other sites. The highest concentration of most of the metals in the sediments was recorded in Tailings pond #3 in the drainage channel. Of the actual wetlands studied, the one near Husky had the highest concentrations of 13 of the metals tested. Most notable of these were arsenic, cadmium, copper, lead, manganese and silver.

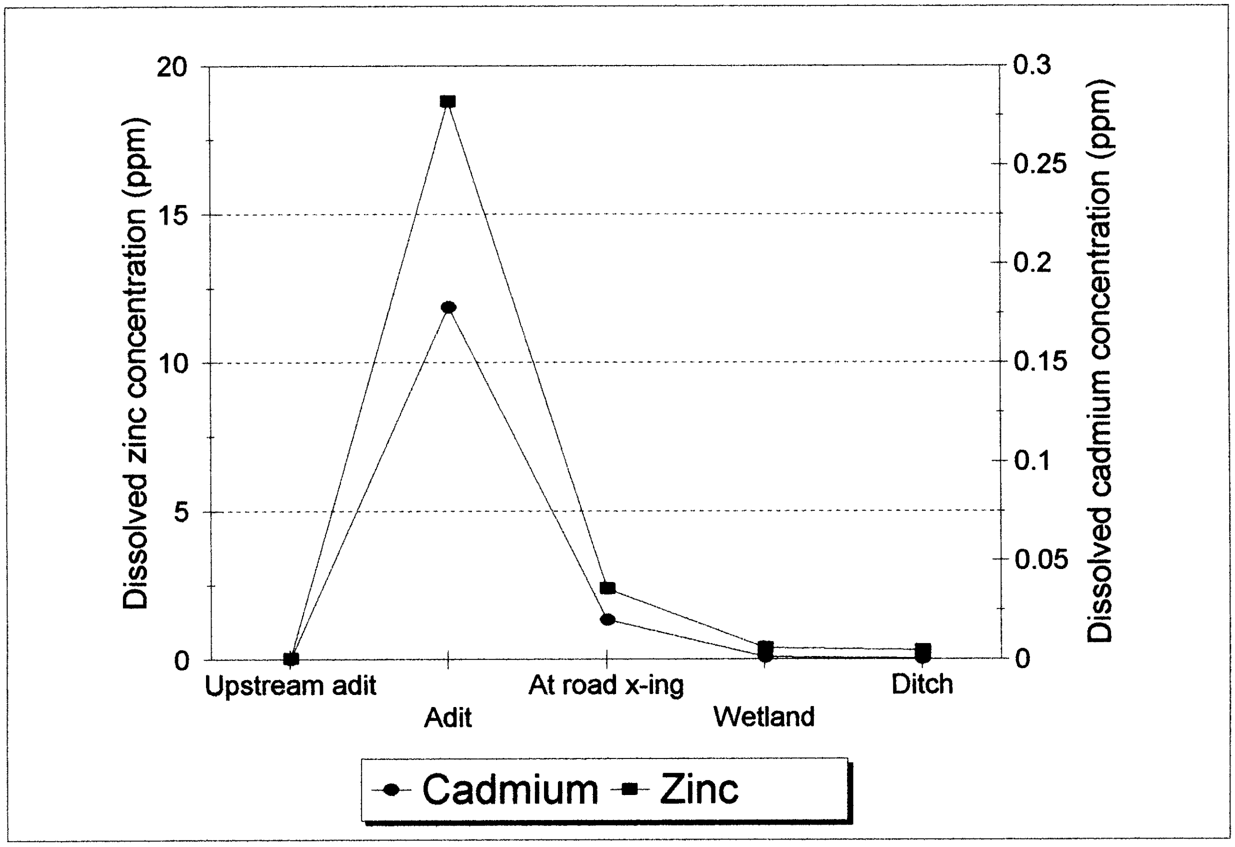

Figure 4 Dissolved Metal Concentrations in No Cash Creek, August 11, 1999

5.2 Microbial Processes

Microbiological processes play a major role in metal removal. Microorganisms (bacteria) live in the wetland detritus layer and sediments where sources of organic matter, used as nutrients, are abundant. As the microorganisms break down (decompose) the organic matter, anaerobic conditions in the sediments are maintained because oxygen is consumed faster than it is replenished. Anaerobic conditions allow certain chemical reactions to take place (see Section 5.1).

One microbial process shown to be responsible for metal removal is sulphate reduction. Under anaerobic conditions, sulphate reducing bacteria (SRB) of the genera Desulfovibrio and Desulfotomaculum, reduce sulphate ions to hydrogen sulphide. Hydrogen sulphide reacts directly with dissolved metals to form insoluble precipitates that are retained in wetland sediments.

SRB samples that were collected from the constructed wetland at Galkeno and the natural wetland at South McQuesten showed the presence of SRB, however populations were not large. Plot 4 in the constructed wetland had the greatest population of 1.5×10^4 cells/dry gram. This compares with the SRB sample collected at a similar location when the wetland was operational in the summer of 1995, of 2.9 x 10^6. The population is determined by the concentration of sulphate in the water. The sulphate concentration in the standing water in Plot 4 was high, 1190 mg/L, and a greater population of SRB would be expected. Black deposits were observed in the SRB sediment sample indicating the presence of SRB. SRB counts may be low because water levels appear to fluctuate. There was insufficient water volume in Plot 3 to adequately sample, preventing a sulphate measurement, however in the South McQuesten wetland, a sulphate concentration of 176 mg/L was recorded. The enumeration of cells in Plot 3 and South McQuesten of 3 x 10^3 and 5.7 x 10^3 respectively, are considered to be comparable.

5.3 Metal Uptake by Plants

Plants play an important role in wetland treatment systems. The roots hold the substrate together, prevent channels from forming and increase residence time of water in the wetland. They also play a role in removing metals but their role is indirect. Wetland plant species vary in their ability to accumulate metals. Some may have elevated tissue concentrations while others show little accumulation. However, their uptake of metals is insignificant in relation to other metal removal process which occur in wetlands. The plants produce detritus which provide habitat and organic matter required by microorganisms (bacteria). The microbiological processes produced by bacteria play a major role in metal removal (see Section 5.1).

Samples of wetland sediments and plant tissues were collected to determine the extent of metal uptake by plants (Table 7). Three different plants were collected for analysis: sedges (*Carex aquatilis*), horsetail (*Equisetum arvense* and *Equisetum hynemale*), and grasses (*Agrostis scabra* and *Calamagrostis stricta*). Equisetum was collected separately with sedges from Plot #2 in tailings pond #3. There was very little difference in metal content of these two types of plants except for arsenic (see Table 3). Arsenic levels were over 20 times greater in the equisetum than in the sedges, although arsenic levels in the sediment were moderately lower. Grasses were collected from the Husky wetland, as sedges were absent at this site. The metal content of the grasses was similar to that of the sedges.

Data for the South McQuesten wetland represents background metal concentrations for the area and exhibits the lowest concentrations for the parameters and sites presented in Table 7. The level of metals varied throughout and there appears to be no relationship between concentrations in the sediments and concentrations in the plant tissues. The main anomaly noted was the very high zinc concentration in the plant tissues collected from the No Cash wetland, which was very similar to the zinc concentration in the sediments. A request was made of the lab to run the vegetation sample again, and the concentration was confirmed. Other than this example, metal uptake at the other sites was low. Zinc concentrations were high in the sediments in the Galkeno natural wetland and in the transplanted plots in tailings pond #3, however the concentrations in the plant tissues at these sites were not much higher than the levels at the background site. Zinc is an essential micronutrient required for normal growth of plants. It is essential to the synthesis of the important plant hormone indole acetic acid and may be involved in protein synthesis (Barbour et al, 1987). Typical concentrations of zinc in healthy plants range from 15 to 100 ppm dry weight (Raven et al, 1986). With the exception of the sedges at No Cash wetland, the zinc levels in the plants at the other sites were in or near this range.

Sedges, notably *Carex aquatilis*, were the predominant plant found within the wetlands studied. Rodents and occasionally browsing moose, will use sedges as a food source, however, *Carex aquatilis* is less palatable to herbivores as it tends to concentrate silicates (Bailey et al, 1992). Therefore, although metal levels were high in the sedges in the No Cash wetland, there should be little concern that they will enter the food web.

Overall, it appears that the plants examined take up very little in the way of metals, irrelevant of the metal concentrations in the growth sediment.

TABLE 7 METAL UPTAKE BY PLANTS IN THE ELSA - KENO AREA, AUGUST 1999

Metal (ppm dry weight)	**Arsenic**		**Cadmium**		**Zinc**	
Matrix	Sediment	Plants	Sediment	Plants	Sediment	Plants
South McQuesten wetland n=1	56	<2	1.8	0.06	231	42.3
Galkeno constructed wetland n=4	136	<2	8	0.14	1,177	143
Galkeno natural wetland n=2	135	<2	12.4	0.09	7,220	69
No Cash Wetland n=1	13	<2	4	0.26	435	416
Husky wetland n=1	1750	<2	11.7	0.41	1,180	57.6
Tailings pond #3 sites Sedges n=3	845	2	132	0.6	12,293	83.7
Tailings pond #3 sites Equisetum n=1	760	86	54.5	2.27	4,740	128

5.4 Potential of Long Term Treatment of the Studied Wetlands

5.4.1 Galkeno Constructed Wetland

The constructed wetland at Galkeno has been abandoned since the autumn of 1995. The wetland has not received any mine discharge for four years and thus its performance as a treatment system could not be completely evaluated. However, the wetland is receiving some groundwater seepage from the adjacent waste rock dump, providing enough moisture to sustain plant growth. The annual growth for 1999 covered about 30 per cent of the wetland with approximately 10 per cent having inflorescence, mostly in the wetter perimeter. The apparently low reproductive rate of the *Carex aquatilis* transplants may be partly in response to the relative drought conditions observed at the site. This sedge is normally found in shallow standing water at the margins of lakes and sloughs. Except for the lower peripheries of the sloping wetland, the site was quite dry.

Although the wetland has been neglected and existed under near drought conditions, sedges continue to grow and propagate. This indicates that local sedges (*Carex aquatilis*) are a hardy species and are a good candidate as transplants in constructed wetlands in this region.

Contaminated mine drainage circulated through the wetland for less than three months in 1995, but sediment results indicate that metals were removed. Concentrations of some metals, notably cadmium, copper, manganese, nickel and zinc, were significantly greater than background levels (South McQuesten wetland sediments where the transplants originated). There appears to be a general trend of decreasing concentrations of metals in the sediments from Plot 1 through to Plot 4. As this was the flow path of the contaminated mine water, it appears that metals were attenuated and/or settling in the sediments within a short distance of entering the constructed wetland.

Water testing in 1995 during active operation of the wetland, showed significant removal of metals. In summary, the constructed wetland at Galkeno displayed high potential as a treatment system for the removal of metals, even though its operational time was very short. In addition, the metals were retained in the sediments in spite of drought conditions experienced over recent years.

5.4.2 Galkeno Natural Wetland

Unlike 1995 (Sobolewski, 1995), there was no flow through the natural wetland near Galkeno, and hence this wetland could not be evaluated. Results from 1995 showed good reduction in zinc from 3.2 mg/L at the inflow to 0.27 mg/L at the discharge. Alkalinity increased at the discharge indicating that anaerobic mineralization was taking place in the sediments. SRB were present in the sediments at 1.1 x 10^7 cells/dry gram.

In 1999, the majority of the watercourse discharging from the third discharge pond, skirted the natural wetland and flowed through willows to another small sedge area at Christal Lake. Concentration of zinc was reduced from 3.03 mg/L at the discharge of the third pond to 0.331 mg/L just upstream of Christal Lake (see Table 2). Metal attenuation processes are occurring in this reach.

Sediment samples were collected from two sites within the natural wetland in 1999. Concentrations of several metals were substantially high, indicating this wetland had received metal laden drainage in the past.

The vegetation in the natural wetland was more robust than in the constructed wetland and covered approximately 60 per cent of the wetland, with about 20 per cent of the sedges bearing inflorescence.

5.4.3 No Cash Wetland

The current year's sedge growth covers 30 per cent of the very small wetland with 15 per cent in inflorescence. Water quality within the wetland was good with most parameters meeting the CCME (1999) guidelines. Sampling in 1999 indicated that most of the metal content originating from the No Cash 500 discharge is attenuated by ferric hydroxide along the stream bed.

5.4.4 Husky Wetland

This small wetland did not support sedges but was comprised of healthy grasses. The Husky seep was the only acid mine drainage encountered in the study area. The seep pH of 2.52 was neutralized to 6.96 in the water flowing from the wetland. Conversely, the seeps which bypassed the small wetland had a pH of 2.2 and a pH of 2.4 (see Figure 3 in Section 4.4). All water parameters were significantly reduced at the discharge point of the swamp.

Given the vastly different water chemistry and temperature of the seep and the water from the swamp, it is a possibility that the grasses are groundwater fed. However, of the wetland sediments tested, the Husky wetland had the highest concentrations of thirteen metals. Either these plants are growing on actual tailings, or the sediment has been retaining metals from inflowing sources. Investigations should be conducted into the flow regime seeping from the Husky waste rock. If this small wetland is receiving metal laden drainage, then it displays great potential as a wetland treatment system.

5.4.5 Transplanted Sites Near Tailings Dam #2

It appeared that only one of the transplanted plots supported growth of sedges. The other plot sampled had largely been invaded by *Equisetum sp.* However, sedge colonization has expanded beyond these plots. In 1995, there was a relatively small population of sedges growing in tailings pond #3 (pers. comm. Andre Sobolewski[2]), however, in 1999 there were substantial sedge communities at the terminus of the drainage ditch and along the surrounding shorelines (Photo 9).

The sedges, including the sods, in Plots 1 and 2 were transplanted from the South McQuesten wetland. Metal analyses of these sediments shows considerably higher concentrations of metals than in the South McQuesten sediments, indicating that metal removal has occurred within these plots. Cadmium and zinc concentrations were much higher in the sediments supporting sedge growth near the mouth of the ditch than in the sediments in the plots. These volunteer sedges have probably taken root on deposited tailings, rather than having removed metals from the water column. The unintended successful spread of sedge growth within tailings pond #3 probably aids in metal reduction prior to the decant.

All three of the tailings ponds appeared to provide habitat for several species of waterfowl. Geese and ducks were observed frequently and a swan appeared to have taken up residence in tailings pond #3.

6.0 DATA GAPS AND RECOMMENDATIONS

The major gap in data was the inability to fully evaluate the constructed or natural wetlands due to poor flow-through conditions. This was due to the flow being discontinued at the constructed wetland near Galkeno in 1995, and also partially to the fact that generally the Yukon has experienced drier than normal conditions in recent years.

Since such a great opportunity exists, it is recommended that a portion of untreated Galkeno 900 mine water be re-routed to the constructed wetland and allowed to flow continuously all year round. This would allow for further examination of the processes that occur in a wetland treatment system in a northern environment.

Another significant gap is the lack of information regarding what processes, if any, continue under winter conditions. Biological processes slow or stop as temperatures decreases, but chemical processes may or may not still be on-going. If the constructed wetland was operational, monitoring could take place throughout the year and answer some very critical questions as to the viability of using wetland remediation for metals in the north.

It is also recommended that monitoring of the sedge growth in tailings pond #3 be conducted. Sampling of various matrices should occur concurrently with the evaluation of growth. The creation of wetlands within the existing tailings ponds may be a treatment option for mine abandonment and this possibility should be explored.

It is recommended that further studies be carried out on the Husky site to determine the flow regime of the seep. If this small wetland it is indeed treating the drainage, consideration should be given to the design and implementation of a wetland treatment system at this site.

7.0 REFERENCES

Access Mining Consultants Ltd. 1996. *United Keno Hill Mines Ltd Closure Plan*. Report No. UKH/96/01 Site Characterization.

APHA. 1995. M.A.H. Franson (Ed). *Standard Methods for the Examination of Water and Wastewater, 19th Ed.* American Public Health Association. Washington, D.C.

Battersby, N.S. (1988). *Sulfate-reducing Bacteria. In: Methods in Aquatic Bacteriology*, B. Austin (Ed), John Wiley and Sons Ltd, New York, pp. 269-299.

Bailey, Arthur, Michael Willoughby, Robert Johansen and Scott Smith. 1992. *Management of Yukon Rangelands*. Canada/Yukon Economic Development Agreement and Yukon Renewable Resources.

Barbour, Michael, Jack Burk and Wanna Pitts. 1987. *Terrestrial Plant Ecology.* The Benjamin/Cummings Publishing Company, Inc. California.

Canadian Council of Ministers of the Environment (CCME). 1999. *Canadian Environmental Guidelines*. Task Force of Water Quality Guidelines. Ottawa, Canada.

Cody, W.J. 1996. *Flora of the Yukon Territory*. NRC Research Press, Ottawa, Ontario, Canada.

Ecological Stratification Working Group. 1996. *A National Ecological Framework for Canada*, ISBN 0-662-24107-X, Agriculture and Agri-Food Canada, and Environment Canada.

Kent, Donald, M. (Editor). 1994. *Applied Wetlands Science and Technology*. Lewis Publishers, USA

Kwong, Y.T.J, C. Roots, and W. Kettley. 1994. *Lithochemistry and Aqueous Metal Transport in the Keno Hill Mining District, Central Yukon Territory*. In: Current Research 1994-E; Geological Survey of Canada, pp. 7-15.

Nor, Y.M. 1994. *Chemical Speciation and Bioavailability of Metal-humic Complexes to Plants*. In: Humic Substances in the Global Environment and Implications on Human Health. Senesi, N. and T.M. Miano (Eds). Elsevier Science B.V. pp. 1055-1062.

Sobolewski, André, Microbial Technologies. 1995. *Design of a Passive System for Treatment of Discharges from the Galkeno 900 Adit at the United Keno Hill Mine Camp*. Draft Technical Report. Submitted to Access Mining Consultants Ltd.

Sobolewski, André[1]. Personal communication. July, 1999.

Sobolewski, André[2]. Personal communication. Oct, 1999.

Raven, Peter, Ray Evert, and Susan Eichhorn. 1987. *Biology of Plants, Fourth Edition*. Worth Publishers, Inc. New York.

APPENDIX A

PHOTOGRAPHS, 1999

Photo 1 The constructed wetland near Galkeno 900. Plot 1 is in the foreground. Taken on August 10, 1999.

Photo 2 Water from these three ponds seeps into the natural wetland downgradient from Galkeno 900. Taken August 11, 1999

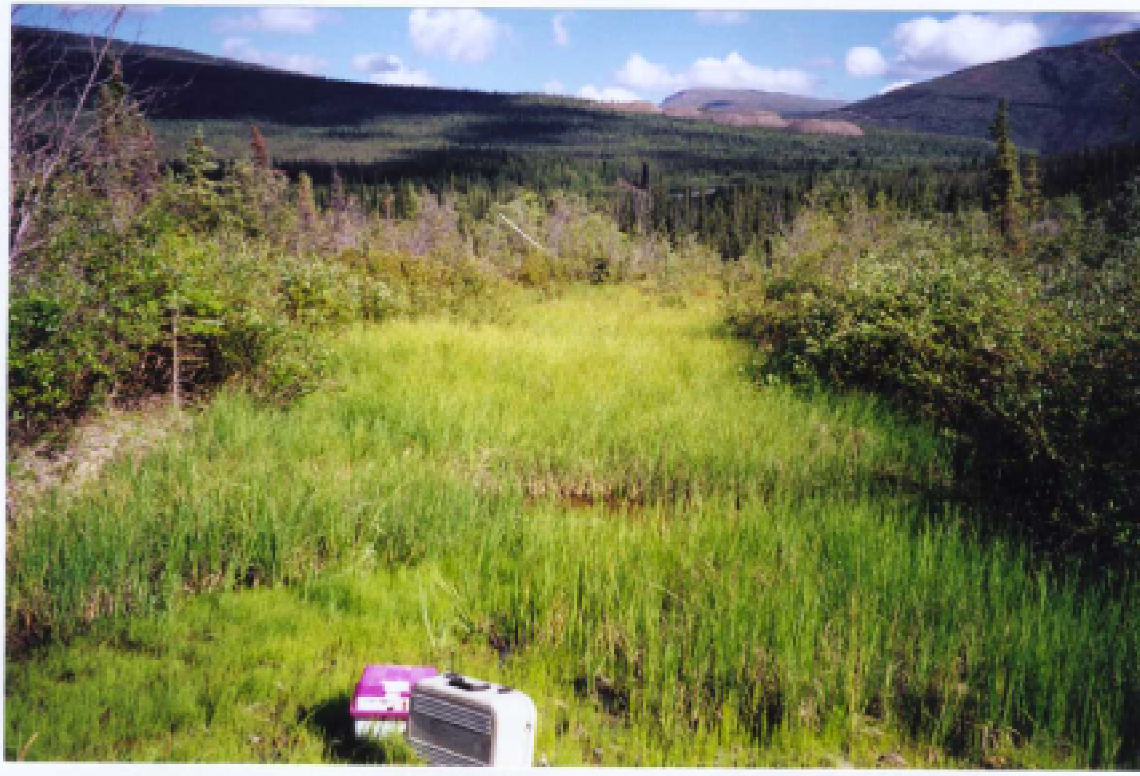

Photo 3 The natural wetland near Galkeno 900. The majority of the flow enters the willows at the lower right. Taken on August 10, 1999

Photo 4 The small wetland on No Cash Creek, August 11, 1999.

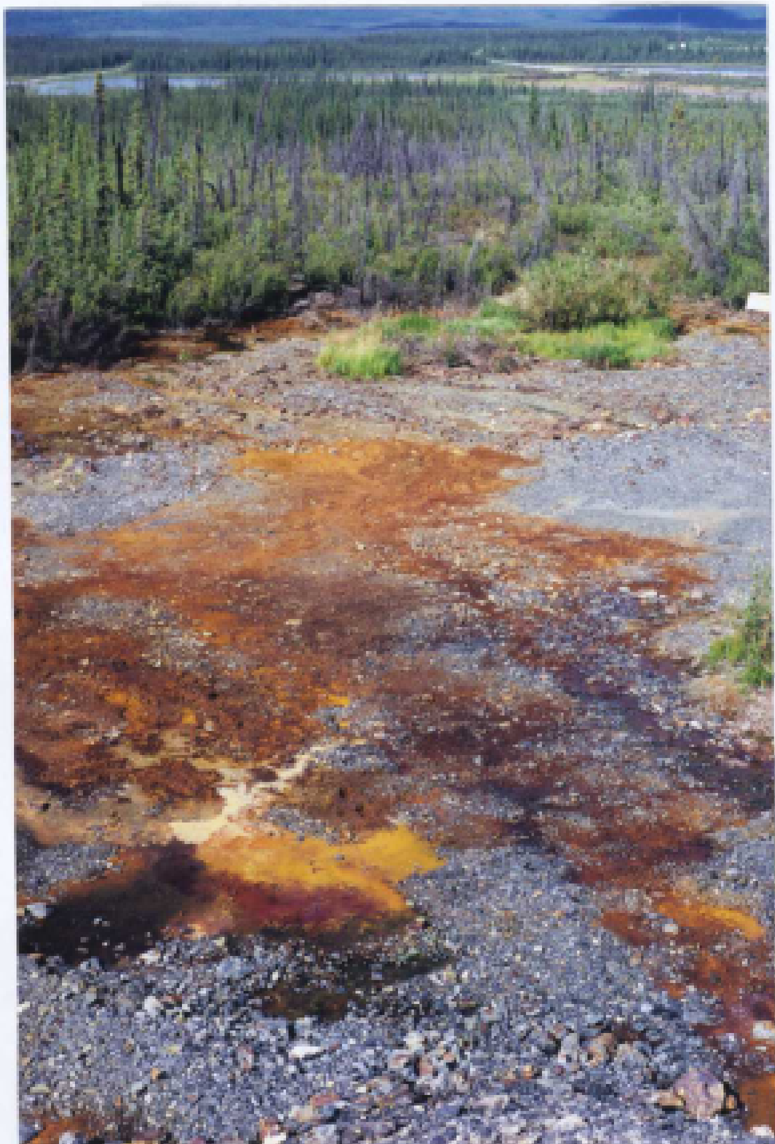

Photo 5 The seep flowing from the waste rock dump at Husky, August 11, 1999

Photo 6 The small grassy wetland below Husky, August 11, 1999.

Photo 7 The natural wetland near the South McQuesten River, August 12, 1999.

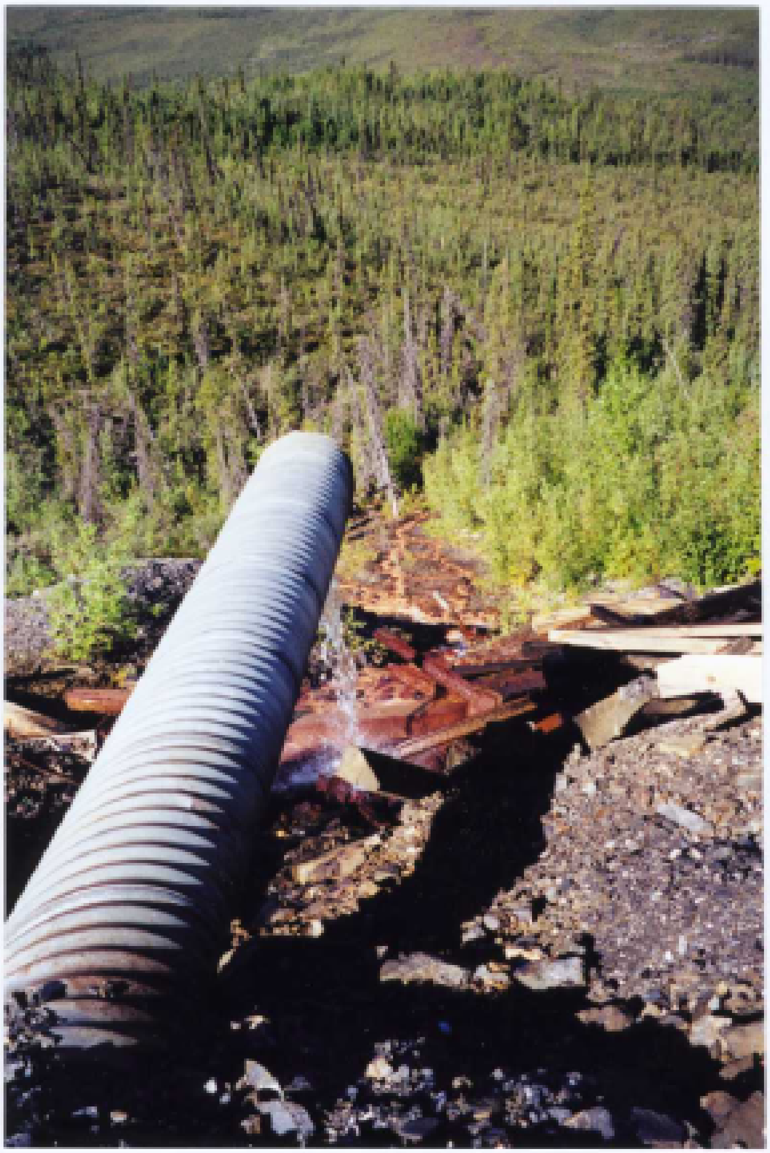

Photo 8 Iron oxide deposits in No Cash Creek below the portal, August 11, 1999.

Photo 9 Volunteer sedge growth in tailings pond #3.

APPENDIX B

WATER CHEMISTRY DATA, 1999

APPENDIX B

Samples analyzed by Norwest: as labelled

Samples analyzed by Pacific Environment Research Centre:

Sample #	Sample Description
995128-001	No Cash 500 adit
995128-002	Ditch at confluence with No Cash Creek
995128-003	No Cash Creek at road crossing
995128-004	No Cash Creek upstream of adit
995128-005	Discharge from first settling pond
995128-006	Groundwater well UK95G/9/1
995128-007	Husky just below grassy swamp
995128-008	Husky seep
995128-009	Ditch by tailings dam #2
995128-0010	No Cash Wetland
995128-0011	Plot 4 in Galkeno constructed wetland
995128-0012	Plot 2 in tailings pond #3
995128-0013	Discharge from third pond downgradient from Galkeno 900
995128-0014	Discharge to Christal Lake
995128-0015	South McQuesten wetland

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46727**
Address: BOX 5111	WO (Other):
	PO Num: Waters
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 23, 1999
Fax: (867) 667-6956	

Metal Analysis

	Detection Limit	Units	46727-1 #1 - McQuesten Swamp - Aug 12/99	46727-2 #2 - 95UKG9/1 - Aug 10/99	46727-3 #4 - Wetland Plot #4 - Aug 10/99	46727-4 #5 - Old Pond #3 - Aug 10/99
Dissolved ICP Metals Scan in Water						
Aluminum	0.01	mg/L	<0.01	<0.01	<0.01	<0.01
Antimony	0.02	mg/L	<0.02	<0.02	<0.02	<0.02
Arsenic	0.02	mg/L	<0.02	<0.02	<0.02	<0.02
Barium	0.0005	mg/L	0.0446	0.0253	0.0186	0.0073
Beryllium	0.0002	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	0.02	mg/L	<0.02	<0.02	<0.02	<0.02
Cadmium	0.0005	mg/L	<0.0005	<0.0005	<0.0005	0.0063
Calcium	0.01	mg/L	77.5	451	462	466
Chromium	0.001	mg/L	<0.001	<0.001	0.001	<0.001
Cobalt	0.001	mg/L	<0.001	0.007	0.005	0.006
Copper	0.002	mg/L	0.006	<0.002	0.003	0.005
Iron	0.003	mg/L	0.071	0.915	5.89	0.166
Lead	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Lithium	0.002	mg/L	0.006	0.053	0.047	0.05
Magnesium	0.01	mg/L	20.2	52.2	52	57.4
Manganese	0.0005	mg/L	0.038	11.2	11.7	6.51
Mercury	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Nickel	0.002	mg/L	0.004	0.026	0.013	0.069
Phosphorus	0.06	mg/L	<0.06	<0.06	<0.06	<0.06
Potassium	0.2	mg/L	<0.2	1.6	1.6	1.4
Selenium	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Silicon	0.05	mg/L	0.34	4.59	5.83	3.83
Silver	0.001	mg/L	<0.001	<0.001	<0.001	<0.001
Sodium	0.05	mg/L	6.3	2.5	2.23	2.31
Strontium	0.005	mg/L	0.212	0.578	0.595	0.555
Sulphur	0.1	mg/L	57.7	391	373	404
Thallium	0.003	mg/L	<0.003	<0.003	<0.003	<0.003
Thorium	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Tin	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Titanium	0.001	mg/L	<0.001	<0.001	<0.001	<0.001
Uranium	0.06	mg/L	<0.06	<0.06	<0.06	<0.06
Vanadium	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Zinc	0.005	mg/L	0.11	0.288	0.045	3.03
Zirconium	0.001	mg/L	<0.001	<0.001	<0.001	0.001

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association
na = not available

NORWEST LABS

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46727**
Address: BOX 5111	WO (Other):
	PO Num: Waters
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 23, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46727-5 #8 - Discharge - Christal L. - Aug 10/99	46727-6 #9 - No Cash Wetland - Aug 11/99	46727-7 #10 - Husky Mine Seep - Aug 11/99	46727-8 #11 - Husky Mine @ Veg - Aug 11/99
Dissolved ICP Metals Scan in Water						
Aluminum	0.01	mg/L	<0.01	<0.01	30.2	<0.01
Antimony	0.02	mg/L	<0.02	<0.02	<0.02	<0.02
Arsenic	0.02	mg/L	<0.02	<0.02	6.1	<0.02
Barium	0.0005	mg/L	0.0081	0.0617	0.0394	0.013
Beryllium	0.0002	mg/L	<0.0002	<0.0002	0.0033	<0.0002
Bismuth	0.02	mg/L	<0.02	<0.02	<0.02	<0.02
Cadmium	0.0005	mg/L	<0.0005	0.0012	0.174	0.001
Calcium	0.01	mg/L	467	190	168	165
Chromium	0.001	mg/L	<0.001	<0.001	0.031	<0.001
Cobalt	0.001	mg/L	<0.001	<0.001	0.227	<0.001
Copper	0.002	mg/L	0.006	0.005	1.93	0.005
Iron	0.003	mg/L	0.038	0.035	540	0.1
Lead	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Lithium	0.002	mg/L	0.054	0.014	0.078	0.015
Magnesium	0.01	mg/L	48.9	33.9	76.1	34.3
Manganese	0.0005	mg/L	0.95	0.278	145	1.51
Mercury	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum	0.005	mg/L	<0.005	<0.005	0.014	<0.005
Nickel	0.002	mg/L	0.015	0.004	0.625	0.007
Phosphorus	0.06	mg/L	<0.06	<0.06	2.86	<0.06
Potassium	0.2	mg/L	1.3	0.6	0.2	1.1
Selenium	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Silicon	0.05	mg/L	3.81	2.93	13.5	5.94
Silver	0.001	mg/L	<0.001	<0.001	<0.001	<0.001
Sodium	0.05	mg/L	2.25	2.51	1.39	1.99
Strontium	0.005	mg/L	0.564	0.391	0.19	0.208
Sulphur	0.1	mg/L	399	148	769	10
Thallium	0.003	mg/L	<0.003	<0.003	<0.003	<0.003
Thorium	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Tin	0.005	mg/L	<0.005	<0.005	<0.005	<0.005
Titanium	0.001	mg/L	0.002	<0.001	<0.001	<0.001
Uranium	0.06	mg/L	<0.06	<0.06	<0.06	<0.06
Vanadium	0.002	mg/L	<0.002	<0.002	<0.002	<0.002
Zinc	0.005	mg/L	0.331	0.397	17.9	0.093
Zirconium	0.001	mg/L	<0.001	<0.001	0.015	<0.001

na = not available

NORWEST LABS

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46727**
Address: BOX 5111	WO (Other):
	PO Num: Waters
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 23, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46727-9 #13B - Tailings Dam, Plot #2 - Aug 10/99	46727-10 #14 - Drainage Ditch by Dam - Aug 10/99	46727-11 #15 - Blank - Aug 11/99
Dissolved ICP Metals Scan in Water					
Aluminum	0.01	mg/L	<0.01	0.46	<0.01
Antimony	0.02	mg/L	<0.02	<0.02	<0.02
Arsenic	0.02	mg/L	<0.02	<0.02	<0.02
Barium	0.0005	mg/L	0.0129	0.0609	<0.0005
Beryllium	0.0002	mg/L	<0.0002	<0.0002	<0.0002
Bismuth	0.02	mg/L	<0.02	<0.02	<0.02
Cadmium	0.0005	mg/L	0.0017	0.0009	<0.0005
Calcium	0.01	mg/L	420	201	<0.01
Chromium	0.001	mg/L	<0.001	0.002	<0.001
Cobalt	0.001	mg/L	0.001	0.012	<0.001
Copper	0.002	mg/L	0.014	<0.002	0.004
Iron	0.003	mg/L	0.378	0.096	0.021
Lead	0.005	mg/L	<0.005	<0.005	<0.005
Lithium	0.002	mg/L	0.017	0.015	<0.002
Magnesium	0.01	mg/L	116	61.5	0.01
Manganese	0.0005	mg/L	3.58	15.3	0.01
Mercury	0.0001	mg/L	<0.0001	<0.0001	<0.0001
Molybdenum	0.005	mg/L	<0.005	<0.005	<0.005
Nickel	0.002	mg/L	0.009	0.043	<0.002
Phosphorus	0.06	mg/L	<0.06	<0.06	<0.06
Potassium	0.2	mg/L	0.6	3.3	<0.2
Selenium	0.002	mg/L	<0.002	<0.002	<0.002
Silicon	0.05	mg/L	1.58	6.47	<0.05
Silver	0.001	mg/L	<0.001	<0.001	<0.001
Sodium	0.05	mg/L	39.4	21.1	<0.05
Strontium	0.005	mg/L	0.662	0.503	<0.005
Sulphur	0.1	mg/L	466	180	<0.1
Thallium	0.003	mg/L	<0.003	<0.003	<0.003
Thorium	0.005	mg/L	<0.005	<0.005	<0.005
Tin	0.005	mg/L	<0.005	<0.005	<0.005
Titanium	0.001	mg/L	<0.001	<0.001	<0.001
Uranium	0.06	mg/L	<0.06	<0.06	<0.06
Vanadium	0.002	mg/L	<0.002	<0.002	<0.002
Zinc	0.005	mg/L	0.277	3.25	<0.005
Zirconium	0.001	mg/L	<0.001	0.003	<0.001

Approved By: ____________________

John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association

na = not available

NORWEST LABS

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL Address: BOX 5111 WHITEHORSE YT Y1A 4S3 Attn: Bonnie Burns Phone: (867) 668-6838 Fax: (867) 667-6956	Workorder: **46727** WO (Other): PO Num: Waters Project: UKHM Wetland Study Date Sampled: Date Received: Aug 16, 1999 Date Reported: Aug 23, 1999

Water Analysis

	Detection Limit	Units	46727-1 #1 - McQuesten Swamp - Aug 12/99	46727-2 #2 - 95UKG9/1 - Aug 10/99	46727-3 #4 - Wetland Plot #4 - Aug 10/99	46727-4 #5 - Old Pond #3 - Aug 10/99
Alkalinity,total						
Total Alkalinity	5	mg CaCO3/L	102	na	315	189
Hardness						
Hardness (CaCO3 equiv)	0.01	mg/L	276	1340	1370	1400
Sulphate in Water						
Sulphate	1	mg/L	176	na	1190	1330
Total Suspended Solids						
Total Suspended Solids	5	mg/L	<5	na	29	<5

	Detection Limit	Units	46727-5 #8 - Discharge - Christal L. - Aug 10/99	46727-6 #9 - No Cash Wetland - Aug 11/99	46727-7 #10 - Husky Mine Seep - Aug 11/99	46727-8 #11 - Husky Mine @ Veg - Aug 11/99
Alkalinity,total						
Total Alkalinity	5	mg CaCO3/L	166	177	<5	236
Hardness						
Hardness (CaCO3 equiv)	0.01	mg/L	1370	613	732	552
Sulphate in Water						
Sulphate	1	mg/L	1240	497	2520	251
Total Suspended Solids						
Total Suspended Solids	5	mg/L	8	36	25	12

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association

na = not available

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46727**
Address: BOX 5111	WO (Other):
	PO Num: Waters
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 23, 1999
Fax: (867) 667-6956	

Water Analysis (con't.)

	Detection Limit	Units	46727-9 #13B - Tailings Dam, Plot #2 - Aug 10/99	46727-10 #14 - Drainage Ditch by Dam - Aug 10/99	46727-11 #15 - Blank - Aug 11/99
Alkalinity,total					
Total Alkalinity	5	mg CaCO3/L	197	301	na
Hardness					
Hardness (CaCO3 equiv)	0.01	mg/L	1530	755	0.05
Sulphate in Water					
Sulphate	1	mg/L	1530	644	na
Total Suspended Solids					
Total Suspended Solids	5	mg/L	8	27	na

Approved By: [signature]
John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association
na = not available

Environment Canada -Laboratories
Pacific Environmental Science Centre
2645 Dollarton Hwy.
North Vancouver, B.C.
V 1V2 (604)924-2500

Lab Reference #
9 9 5 1 2 8

01:39 15-Oct-99

RECEIVED
ENVIRONMENTAL
PROTECTION
NOV 09 1999
LETTER #
FILE #

FINAL REPORT

Identification: UKHM WETLANDS (MERG)JULY 99

Type of Sample: Fresh Water

Submitted by: DAVIDGE,DOUG
EP WHITEHORSE YT
YUKON PROGRAMS
YUKON
ENV PROTECTION

Logged in: 17-Sep-99 (15 samples)

Completed: 15-Oct-99 (721 results)

Charged to: 2562-101
EP YUKON POLLUTION ABATEMENT

Analyzed for: INORGANICS, METALS

Authorized by: [signature]
Richard Strub
QA Officer

1 ;:

[1] -NO MERCURY BOTTLES RECEIVED.
[2] -dissolved metals: use graphite furnace (GF) results, where reported, in preference to ICP results due to better precision and accuracy.
[3] -Hardness, Ca+Mg, and hardness, total, are expressed as mg equivalent CaCO3/L.
[4] -total metals: use graphite furnace (GF) results, where reported, in preference to ICP results due to better precision and accuracy.
[5] -"Metals/unfiltered" data are determined by directly analyzing unfiltered, unpreserved water samples as received.
Hardness, Ca+Mg, and hardness, total, are expressed as mg equivalent CaCO3/L.

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-001	995128-002	995128-003	995128-004	99512?
ALKALINITY,TOTAL- PH 4.5		mg/l	137	158	154	38.9	214
ANIONS/IC - SULPHATE		mg/l	610	400	500	85	1300
METALS/DISS.(WATER-GF)	AG	mg/l	<.0005	<.0005	<.0005	<.0005	<.0005
	AS	mg/l	0.0027	0.0008	0.0012	<0.0005	0.0012
	CD	mg/l	-	.0005	-	<.0002	.021
	CU	mg/l	-	-	-	.0013	.0008
	PB	mg/l	<.0005	<.0005	<.0005	.0018	<.0005
	SE	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
(WATER-ICP SCAN)	AG	mg/l	.02	<.01	.02	<.01	.2
	AL	mg/l	.11	<.05	.16	.08	<.5
	AS	mg/l	<.05	<.05	<.05	<.05	<.5
	B	mg/l	<.01	<.01	.01	<.01	.3
	BA	mg/l	<.001	.056	.02	.029	<.01
	BE	mg/l	.005	.002	.005	<.001	<.01
	CA	mg/l	240	184	214	35.5	496
	CD	mg/l	.178	<.005	.02	<.005	<.05
	CO	mg/l	<.005	<.005	.005	<.005	<.05
	CR	mg/l	.006	<.005	<.005	.022	.1
	CU	mg/l	.021	.01	.036	<.005	<.05
	FE	mg/l	<.005	.034	.019	.007	2.3
	K	mg/l	.3	.2	.8	<.1	<1
	MG	mg/l	29.3	35.3	32	10.3	68
	MN	mg/l	16.3	.669	.457	<.001	11.8
	MO	mg/l	<.01	<.01	<.01	<.01	<.1
	NA	mg/l	.6	1	1.4	.5	<1
	NI	mg/l	.12	<.02	.03	<.02	<.2
	P	mg/l	.1	<.1	.1	<.1	<1
	PB	mg/l	<.05	<.05	<.05	<.05	<.5
	S	mg/l	200	137	160	28.3	415
	SB	mg/l	.13	<.05	.08	<.05	.6
	SE	mg/l	<.05	<.05	<.05	<.05	<.5
	SI	mg/l	2.5	3.14	3.14	3.82	4.5
	SN	mg/l	<.05	<.05	<.05	<.05	<.5
	SR	mg/l	.245	.414	.333	.067	.75
	TI	mg/l	<.002	<.002	.007	<.002	<.02
	V	mg/l	.01	<.01	.02	.01	<.1
	ZN	mg/l	18.8	.303	2.38	.041	5.98
.HARDNESS/CA+MG	HC	mg/l	721	606	666	131	1520
/TOTAL	HT	mg/l	780	607	671	132	1560
/TOT.(WATER-GF)	AG	mg/l	<.0006	<.0006	<.0006	<.0006	<.0006
	AS	mg/l	0.019	0.0018	0.0019	<0.0005	0.0025
	CD	mg/l	-	.0017	.02	<.0002	.022
	CU	mg/l	-	-	-	.002	.0015
	PB	mg/l	.0259	.0028	.0016	.0025	<.0006
	SE	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
/TOTAL (WATER-ICP)	AG	mg/l	<.01	<.01	<.01	<.01	<.1
	AL	mg/l	.1	.79	<.06	<.06	.6
	AS	mg/l	<.06	<.06	<.06	<.06	<.6
	B	mg/l	<.01	<.01	<.01	<.01	.4
	BA	mg/l	.004	.081	.02	.032	<.01
	BE	mg/l	.005	.004	.005	<.001	<.01
	CA	mg/l	274	211	243	40	532
	CD	mg/l	.2	<.006	.022	<.006	<.06

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-001	995128-002	995128-003	995128-004	995128-005
METALS/TOTAL (WATER-ICP)	CO	mg/l	.019	<.006	<.006	<.006	<.06
	CR	mg/l	.007	.025	<.006	.009	.09
	CU	mg/l	.068	.038	.038	<.006	<.06
	FE	mg/l	2.92	1.59	.07	.038	4.83
	K	mg/l	.8	.9	.9	.2	<1
	MG	mg/l	34	40	37.4	12.1	71
	MN	mg/l	16.5	.728	.465	.005	12.6
	MO	mg/l	<.01	<.01	<.01	<.01	<.1
	NA	mg/l	2.1	2.4	2.7	2.2	8
	NI	mg/l	.12	<.02	.02	<.02	<.2
	P	mg/l	.1	<.1	<.1	<.1	<1
	PB	mg/l	<.06	<.06	<.06	<.06	<.6
	S	mg/l	228	157	183	31.9	445
	SB	mg/l	<.06	<.06	<.06	<.06	.7
	SE	mg/l	<.06	<.06	<.06	<.06	<.6
	SI	mg/l	2.92	4.41	3.64	4.41	5.2
	SN	mg/l	<.06	<.06	<.06	<.06	<.6
	SR	mg/l	.281	.52	.447	.078	.8
	TI	mg/l	<.002	.032	<.002	.003	<.02
	V	mg/l	<.01	<.01	<.01	<.01	<.1
	ZN	mg/l	20.3	.396	2.4	.044	6.42
/UNFILT-UNPRES(ICP)	CA	mg/l	219	147	181	31.6	492
	K	mg/l	1.4	.4	.5	<.1	2
	MG	mg/l	24.9	25.8	24.2	8.3	71
	NA	mg/l	1.1	1.5	.7	.8	3
	SI	mg/l	2.72	2.74	2.61	3.51	5
/UNFILT.HARDNESS/CA+MG	HC	mg/l	649	472	551	113	1520
H.		Rel.U.	7.67	7.90	8.03	7.63	7.27
RESIDUE/NON-FILTERABLE		mg/l	14	7	<5	<5	5

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-006	995128-007	995128-008	995128-009	99512
ALKALINITY,TOTAL- PH 4.5		mg/l	207	–	–	–	–
ANIONS/IC - SULPHATE		mg/l	1300	–	–	–	–
METALS/DISS.(WATER-GF)	AG	mg/l	–	–	–	–	–
	AS	mg/l	–	–	–	–	–
	CD	mg/l	–	–	–	–	–
	CU	mg/l	–	–	–	–	–
	PB	mg/l	–	–	–	–	–
	SE	mg/l	–	–	–	–	–
(WATER-ICP SCAN)	AG	mg/l	–	–	–	–	–
	AL	mg/l	–	–	–	–	–
	AS	mg/l	–	–	–	–	–
	B	mg/l	–	–	–	–	–
	BA	mg/l	–	–	–	–	–
	BE	mg/l	–	–	–	–	–
	CA	mg/l	–	–	–	–	–
	CD	mg/l	–	–	–	–	–
	CO	mg/l	–	–	–	–	–
	CR	mg/l	–	–	–	–	–
	CU	mg/l	–	–	–	–	–
	FE	mg/l	–	–	–	–	–
	K	mg/l	–	–	–	–	–
	MG	mg/l	–	–	–	–	–
	MN	mg/l	–	–	–	–	–
	MO	mg/l	–	–	–	–	–
	NA	mg/l	–	–	–	–	–
	NI	mg/l	–	–	–	–	–
	P	mg/l	–	–	–	–	–
	PB	mg/l	–	–	–	–	–
	S	mg/l	–	–	–	–	–
	SB	mg/l	–	–	–	–	–
	SE	mg/l	–	–	–	–	–
	SI	mg/l	–	–	–	–	–
	SN	mg/l	–	–	–	–	–
	SR	mg/l	–	–	–	–	–
	TI	mg/l	–	–	–	–	–
	V	mg/l	–	–	–	–	–
	ZN	mg/l	–	–	–	–	–
.HARDNESS/CA+MG	HC	mg/l	–	–	–	–	–
/TOTAL	HT	mg/l	–	–	–	–	–
/TOT.(WATER-GF)	AG	mg/l	–	<.0006	.0066	<.0006	<.0006
	AS	mg/l	–	0.0056	–	0.0091	0.0228
	CD	mg/l	–	.0013	.19	.017	.0025
	CU	mg/l	–	–	–	–	–
	PB	mg/l	–	.0201	.0071	.0289	.0041
	SE	mg/l	–	<0.001	<0.001	<0.001	<0.001
/TOTAL (WATER-ICP)	AG	mg/l	–	<.01	.2	<.01	<.01
	AL	mg/l	–	<.06	26.9	<.06	.78
	AS	mg/l	–	<.06	6.2	<.06	<.06
	B	mg/l	–	<.01	.5	<.01	<.01
	BA	mg/l	–	.015	.05	.07	.086
	BE	mg/l	–	.002	.02	.005	.003
	CA	mg/l	–	170	134	212	197
	CD	mg/l	–	<.006	.14	.019	<.006

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-006	995128-007	995128-008	995128-009	995128-010
METALS/TOTAL (WATER-ICP)	CO	mg/l	-	<.006	.18	.01	<.006
	CR	mg/l	-	.008	<.06	<.006	.007
	CU	mg/l	-	.029	1.57	.045	.04
	FE	mg/l	-	.476	420	7.68	1.34
	K	mg/l	-	1.4	<1	3.2	.9
	MG	mg/l	-	37.7	64	67.2	37.3
	MN	mg/l	-	2.28	128	17.8	.333
	MO	mg/l	-	<.01	<.1	<.01	<.01
	NA	mg/l	-	1.8	2	18.9	2.2
	NI	mg/l	-	<.02	.7	.1	.02
	P	mg/l	-	<.1	3	.2	<.1
	PB	mg/l	-	<.06	<.6	<.06	<.06
	S	mg/l	-	104	599	188	154
	SB	mg/l	-	<.06	.9	.1	.09
	SE	mg/l	-	<.06	<.6	.06	<.06
	SI	mg/l	-	6.44	13.5	7.21	4.5
	SN	mg/l	-	<.06	<.6	<.06	<.06
	SR	mg/l	-	.257	.26	.614	.483
	TI	mg/l	-	<.002	<.02	<.002	.023
	V	mg/l	-	<.01	.2	<.01	<.01
	ZN	mg/l	-	.083	15.7	4.84	.53
/UNFILT-UNPRES(ICP)	CA	mg/l	472	-	-	-	-
	K	mg/l	<3	-	-	-	-
	MG	mg/l	59	-	-	-	-
	NA	mg/l	5	-	-	-	-
	SI	mg/l	4.8	-	-	-	-
/UNFILT.HARDNESS/CA+MG	HC	mg/l	1420	-	-	-	-
PH		Rel.U.	7.11	-	-	-	-
RESIDUE/NON-FILTERABLE		mg/l	3780	-	-	-	-

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-011	995128-012	995128-013	995128-014	995128
ALKALINITY,TOTAL- PH 4.5		mg/l	-	-	-	-	-
ANIONS/IC - SULPHATE		mg/l	-	-	-	-	-
METALS/DISS.(WATER-GF)	AG	mg/l	-	-	-	-	-
	AS	mg/l	-	-	-	-	-
	CD	mg/l	-	-	-	-	-
	CU	mg/l	-	-	-	-	-
	PB	mg/l	-	-	-	-	-
	SE	mg/l	-	-	-	-	-
(WATER-ICP SCAN)	AG	mg/l	-	-	-	-	-
	AL	mg/l	-	-	-	-	-
	AS	mg/l	-	-	-	-	-
	B	mg/l	-	-	-	-	-
	BA	mg/l	-	-	-	-	-
	BE	mg/l	-	-	-	-	-
	CA	mg/l	-	-	-	-	-
	CD	mg/l	-	-	-	-	-
	CO	mg/l	-	-	-	-	-
	CR	mg/l	-	-	-	-	-
	CU	mg/l	-	-	-	-	-
	FE	mg/l	-	-	-	-	-
	K	mg/l	-	-	-	-	-
	MG	mg/l	-	-	-	-	-
	MN	mg/l	-	-	-	-	-
	MO	mg/l	-	-	-	-	-
	NA	mg/l	-	-	-	-	-
	NI	mg/l	-	-	-	-	-
	P	mg/l	-	-	-	-	-
	PB	mg/l	-	-	-	-	-
	S	mg/l	-	-	-	-	-
	SB	mg/l	-	-	-	-	-
	SE	mg/l	-	-	-	-	-
	SI	mg/l	-	-	-	-	-
	SN	mg/l	-	-	-	-	-
	SR	mg/l	-	-	-	-	-
	TI	mg/l	-	-	-	-	-
	V	mg/l	-	-	-	-	-
	ZN	mg/l	-	-	-	-	-
.HARDNESS/CA+MG	HC	mg/l	-	-	-	-	-
/TOTAL	HT	mg/l	-	-	-	-	-
/TOT.(WATER-GF)	AG	mg/l	<.0006	.0014	<.0006	<.0006	<.0006
	AS	mg/l	0.0171	0.0113	0.0060	0.0027	0.0029
	CD	mg/l	.0008	.0019	.0075	.0002	.0003
	CU	mg/l	.0045	.0043	.0034	.0006	.0013
	PB	mg/l	.0135	.0074	.0009	<.0006	.0025
	SE	mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
/TOTAL (WATER-ICP)	AG	mg/l	<.1	<.1	<.1	<.1	<.01
	AL	mg/l	.8	.8	<.6	.9	<.06
	AS	mg/l	<.6	<.6	<.6	<.6	<.06
	B	mg/l	.4	.4	.4	.3	<.01
	BA	mg/l	<.01	<.01	<.01	<.01	.058
	BE	mg/l	<.01	<.01	<.01	<.01	.002
	CA	mg/l	551	471	445	476	93.1
	CD	mg/l	<.06	<.06	<.06	<.06	<.006

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995128-011	995128-012	995128-013	995128-014	995128-015
METALS/TOTAL (WATER-ICP)	CO	mg/l	<.06	<.06	<.06	<.06	<.006
	CR	mg/l	.2	.1	.17	.19	<.006
	CU	mg/l	.07	.1	<.06	.1	.02
	FE	mg/l	24.8	1.21	1.64	.06	.346
	K	mg/l	3	<1	<1	<1	<.1
	MG	mg/l	71	137	58	53	23.9
	MN	mg/l	10.7	4.53	6.48	1.1	.175
	MO	mg/l	<.1	<.1	<.1	<.1	<.01
	NA	mg/l	2	40	2	9	7.4
	NI	mg/l	<.2	<.2	<.2	<.2	<.02
	P	mg/l	<1	<1	<1	<1	<.1
	PB	mg/l	<.6	<.6	<.6	<.6	<.06
	S	mg/l	423	492	368	382	63.9
	SB	mg/l	.8	.9	<.6	.9	<.06
	SE	mg/l	<.6	<.6	<.6	<.6	<.06
	SI	mg/l	7.6	2.2	4.2	3.9	.46
	SN	mg/l	<.6	<.6	<.6	<.6	<.06
	SR	mg/l	.9	.92	.65	.73	.281
	TI	mg/l	<.02	<.02	<.02	<.02	<.002
	V	mg/l	.1	.2	<.1	.2	<.01
	ZN	mg/l	.17	.33	3.17	.38	.147
/UNFILT-UNPRES(ICP)	CA	mg/l	-	-	-	-	-
	K	mg/l	-	-	-	-	-
	MG	mg/l	-	-	-	-	-
	NA	mg/l	-	-	-	-	-
	SI	mg/l	-	-	-	-	-
/UNFILT.HARDNESS/CA+MG	HC	mg/l	-	-	-	-	-
		Rel.U.	-	-	-	-	-
RESIDUE/NON-FILTERABLE		mg/l	-	-	-	-	-

APPENDIX C

SEDIMENT CHEMISTRY DATA, 1999

APPENDIX C

Samples analyzed by Norwest: as labelled

Samples analyzed by Pacific Environment Research Centre:

Sample #	Sample Description
995127-001	No Cash Creek upstream of adit
995127-002	No Cash Creek at road crossing
995127-003	Plot 1 in Galkeno constructed wetland
995127-004	Plot 2 in Galkeno constructed wetland
995127-005	First pond downgradient from Galkeno 900
995127-006	Second pond downgradient from Galkeno 900
995127-007	Third pond downgradient from Galkeno 900
995127-008	Galkeno natural wetland, east end

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46724**
Address: BOX 5111	WO (Other):
	PO Num: Soils
WHITEHORSE	Project: UKHM - Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis

	Detection Limit	Units	46724-1 #1 - McQuesten Swamp - Aug 12/99	46724-2 #3 - Wetland Plot #3 - Aug 10/99	46724-3 #4 - Wetland Plot #4 - Aug 10/99	46724-4 #6 - Natural Wetland - Aug 10/99
ICP Semi-Trace Metals Scan in Soil						
Aluminum	5	µg/g	27300	19400	19100	23000
Antimony	2	µg/g	<2	<2	<2	<2
Arsenic	2	µg/g	55	153	90	80
Barium	0.05	µg/g	703	456	449	528
Beryllium	0.1	µg/g	0.8	0.4	0.5	0.7
Bismuth	5	µg/g	<5	<5	<5	<5
Cadmium	0.1	µg/g	1.8	6.9	2.4	5.1
Calcium	5	µg/g	10500	13600	18300	16600
Chromium	0.5	µg/g	39	25.7	26.6	31.4
Cobalt	0.1	µg/g	9.6	8.1	8	13.7
Copper	0.5	µg/g	36.8	43.2	30.6	44
Iron	1	µg/g	27000	63000	45000	36000
Lead	1	µg/g	52	194	37	36
Lithium	0.5	µg/g	20.5	19.6	14.4	17.5
Magnesium	1	µg/g	5930	4610	7160	6950
Manganese	0.5	µg/g	791	1910	762	3090
Mercury	0.01	µg/g	0.12	0.09	0.06	0.07
Molybdenum	1	µg/g	2	2	2	2
Nickel	1	µg/g	26.6	24.9	21.5	52.8
Phosphorus	5	µg/g	838	801	775	781
Potassium	20	µg/g	6700	4360	4500	5000
Selenium	2	µg/g	<2	<2	<2	<2
Silicon	5	µg/g	650	82	607	803
Silver	0.5	µg/g	<0.5	4.6	<0.5	<0.5
Sodium	5	µg/g	1370	911	1310	1370
Strontium	1	µg/g	61	43	53	50
Sulphur	10	µg/g	5500	5700	2190	2990
Thorium	1	µg/g	2	<1	<1	<1
Tin	1	µg/g	2	<1	2	<1
Titanium	0.2	µg/g	731	541	676	752
Uranium	5	µg/g	<5	<5	<5	<5
Vanadium	1	µg/g	75	50	54	61
Zinc	0.5	µg/g	231	914	393	1940
Zirconium	0.1	µg/g	17.5	12.8	12.6	15.9

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association
na = not available

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46724**
Address: BOX 5111	WO (Other):
	PO Num: Soils
WHITEHORSE	Project: UKHM - Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46724-5 # 8 - Discharge - Christal L. - Aug 10/99	46724-6 #9 - No Cash Wetland - Aug 11/99	46724-7 #10 - Husky Mine Seep - Aug 11/99	46724-8 #11 - Husky Mine @ Veg - Aug 11/99
ICP Semi-Trace Metals Scan in Soil						
Aluminum	5	µg/g	18400	20600	17700	13700
Antimony	2	µg/g	<2	<2	25	36
Arsenic	2	µg/g	101	13	3420	1750
Barium	0.05	µg/g	432	428	407	313
Beryllium	0.1	µg/g	0.7	0.6	0.5	0.6
Bismuth	5	µg/g	<5	<5	<5	<5
Cadmium	0.1	µg/g	8.7	4	1.4	11.7
Calcium	5	µg/g	14000	10900	8690	10100
Chromium	0.5	µg/g	23.9	30.2	24.2	16.8
Cobalt	0.1	µg/g	34.8	7.6	3.3	14.2
Copper	0.5	µg/g	32	28.6	86.3	234
Iron	1	µg/g	57000	19000	100000	140000
Lead	1	µg/g	33	35	246	2390
Lithium	0.5	µg/g	17.1	14.4	9.6	8.8
Magnesium	1	µg/g	4570	5720	2520	2290
Manganese	0.5	µg/g	30100	489	423	6770
Mercury	0.01	µg/g	0.08	0.08	0.14	0.25
Molybdenum	1	µg/g	4	<1	3	3
Nickel	1	µg/g	148	18.6	9.2	31
Phosphorus	5	µg/g	707	855	2020	1200
Potassium	20	µg/g	3790	4500	4130	2180
Selenium	2	µg/g	<2	<2	<2	<2
Silicon	5	µg/g	148	618	588	313
Silver	0.5	µg/g	<0.5	0.7	26.1	49.4
Sodium	5	µg/g	959	1390	962	478
Strontium	1	µg/g	41	48	46	24
Sulphur	10	µg/g	1250	850	2870	3850
Thorium	1	µg/g	<1	2	4	40
Tin	1	µg/g	<1	1	3	<1
Titanium	0.2	µg/g	600	911	409	273
Uranium	5	µg/g	<5	<5	<5	<5
Vanadium	1	µg/g	47	61	43	26
Zinc	0.5	µg/g	5060	435	131	1180
Zirconium	0.1	µg/g	11.8	15.2	9.6	6.9

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association
na = not available

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46724**
Address: BOX 5111	WO (Other):
	PO Num: Soils
WHITEHORSE	Project: UKHM - Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46724-9 #12 - Tailings Dam, Plot #1 - Aug 11/99	Sedges 46724-10 #13A - Tailings Dam, Plot #2 - Aug 10/99	Equi 46724-11 #13B - Tailings Dam, Plot #2 - Aug 10/99	46724-12 #14 - Drainage Ditch by Dam - Aug 10/99
ICP Semi-Trace Metals Scan in Soil						
Aluminum	5	µg/g	8510	6900	8580	7400
Antimony	2	µg/g	130	170	130	103
Arsenic	2	µg/g	940	1180	760	414
Barium	0.05	µg/g	183	110	167	204
Beryllium	0.1	µg/g	0.2	0.2	0.3	0.5
Bismuth	5	µg/g	<5	<5	<5	<5
Cadmium	0.1	µg/g	58.6	55.4	54.5	282
Calcium	5	µg/g	6960	3300	6720	115000
Chromium	0.5	µg/g	9.88	8.4	10.6	7.9
Cobalt	0.1	µg/g	4.6	3.7	3.5	9
Copper	0.5	µg/g	95.5	112	91.2	89
Iron	1	µg/g	93000	104000	83000	58000
Lead	1	µg/g	3980	6300	4870	3750
Lithium	0.5	µg/g	3.1	1.7	3.1	2.2
Magnesium	1	µg/g	3620	3370	3650	16700
Manganese	0.5	µg/g	32600	42100	32400	53800
Mercury	0.01	µg/g	0.75	0.65	0.65	0.45
Molybdenum	1	µg/g	2	2	2	4
Nickel	1	µg/g	13.4	10.6	10.3	34.6
Phosphorus	5	µg/g	239	199	222	229
Potassium	20	µg/g	2730	2390	2910	2320
Selenium	2	µg/g	<2	<2	<2	<2
Silicon	5	µg/g	310	808	575	3010
Silver	0.5	µg/g	49.4	87.1	51.6	36.2
Sodium	5	µg/g	568	184	504	369
Strontium	1	µg/g	8	<1	7	90
Sulphur	10	µg/g	28500	24800	19700	11000
Thorium	1	µg/g	<1	<1	<1	<1
Tin	1	µg/g	4	4	4	2
Titanium	0.2	µg/g	80	23.1	87.8	39.8
Uranium	5	µg/g	<5	21	19	<5
Vanadium	1	µg/g	15	12	17	<1
Zinc	0.5	µg/g	5500	5280	4740	26100
Zirconium	0.1	µg/g	3.6	2.3	4.3	1.8

Approved By: ______________________
John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association

na = not available

NORWEST LABS

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name:	LABERGE ENVIRONMENTAL	Workorder:	**46724**
Address:	BOX 5111	WO (Other):	
		PO Num:	Soils
	WHITEHORSE	Project:	UKHM - Wetland Study
	YT Y1A 4S3	Date Sampled:	
Attn:	Bonnie Burns	Date Received:	Aug 16, 1999
Phone:	(867) 668-6838	Date Reported:	Aug 20, 1999
Fax:	(867) 667-6956		

Soil Analysis

	Detection Limit	Units	46724-1 #1 - McQuesten Swamp - Aug 12/99	46724-2 #3 - Wetland Plot #3 - Aug 10/99	46724-3 #4 - Wetland Plot #4 - Aug 10/99	46724-4 #6 - Natural Wetland - Aug 10/99
pH in Soil (1:2 water)						
pH	0.01	pH	5.43	6.99	7.28	7.21

	Detection Limit	Units	46724-5 # 8 - Discharge - Christal L. - Aug 10/99	46724-6 #9 - No Cash Wetland - Aug 11/99	46724-7 #10 - Husky Mine Seep - Aug 11/99	46724-8 #11 - Husky Mine @ Veg - Aug 11/99
pH in Soil (1:2 water)						
pH	0.01	pH	7.61	7.18	7.21	7.47

	Detection Limit	Units	46724-9 #12 - Tailings Dam, Plot #1 - Aug 11/99	46724-10 #13A - Tailings Dam, Plot #2 - Aug 10/99	46724-11 #13B - Tailings Dam, Plot #2 - Aug 10/99	46724-12 #14 - Drainage Ditch by Dam - Aug 10/99
pH in Soil (1:2 water)						
pH	0.01	pH	7.12	7.28	7.52	9.07

Approved By: ______________________

John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

na = not available

Environment Canada -Laboratories
Pacific Environmental Science Centre
2645 Dollarton Hwy.
North Vancouver, B.C.
V 1V2 (604)924-2500

Lab Reference #
9 9 5 1 2 7

23:33 15-Oct-99

F I N A L   R E P O R T

Identification: UKHM WETLANDS (MERG)JULY 99

Type of Sample: Sediment

Submitted by: DAVIDGE,DOUG
EP WHITEHORSE YT
YUKON PROGRAMS
YUKON
ENV PROTECTION

Logged in: 17-Sep-99 (8 samples)

Completed: 15-Oct-99 (252 results)

Charged to: 2562-101
EP YUKON POLLUTION ABATEMENT

Analyzed for: METALS

Authorized by: ___________________
Richard Strub
QA Officer

:

[1] -use graphite furnace (GF) results, where reported, in preference to ICP results due to better precision and accuracy.
[2] -metals data are reported in dry weight.

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	995127-001	995127-002	995127-003	995127-004	995127
METALS/SEDIMENT (GF)	AG	ug/g	42	79	3.2	2.9	6.3
	CD	ug/g	-	-	-	-	18
(HG)	HG	ug/g	.068	.125	.061	.078	.058
(ICP)	AG	ug/g	<2	<20	<2	<2	<20
	AL	ug/g	19300	12600	13700	16600	16900
	AS	ug/g	53	260	140	160	220
	B	ug/g	<2	50	<2	<2	50
	BA	ug/g	400	238	324	356	419
	BE	ug/g	<.2	<2	.3	.5	<2
	CA	ug/g	7930	16000	17500	17200	13000
	CD	ug/g	6.4	160	13	9.7	23
	CO	ug/g	20.6	56	21.1	22.8	93
	CR	ug/g	33.1	20	24.2	28	26
	CU	ug/g	56.4	140	48	63	64
	FE	ug/g	32600	40500	27500	34200	52600
	K	ug/g	2790	2070	2500	3080	3860
	MG	ug/g	6650	8300	6860	8050	5600
	MN	ug/g	2190	18800	3580	3090	44100
	MO	ug/g	<2	<20	<2	<2	<20
	NA	ug/g	220	200	250	280	500
	NI	ug/g	34	100	61	71	280
	P	ug/g	740	1000	980	1000	800
	PB	ug/g	350	1910	60	96	580
	S	ug/g	1320	6630	918	808	3250
	SB	ug/g	35	<80	<8	<8	<80
	SE	ug/g	<8	<80	<8	<8	<80
	SI	ug/g	1330	1400	1330	1340	1600
	SN	ug/g	<8	<80	<8	<8	<80
	SR	ug/g	37.7	50	54.1	55.8	59
	TI	ug/g	1040	503	714	652	546
	V	ug/g	72	30	43	49	30
	ZN	ug/g	604	12300	1480	1920	5940

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed			Units	995127-006	995127-007	995127-008
M...LS/SEDIMENT	(GF)	AG	ug/g	1	1	<.9
		CD	ug/g	28	19.6	19.8
	(HG)	HG	ug/g	.056	.108	.082
	(ICP)	AG	ug/g	<20	<20	<20
		AL	ug/g	12100	11000	19300
		AS	ug/g	230	90	190
		B	ug/g	50	60	70
		BA	ug/g	299	217	510
		BE	ug/g	<2	<2	<2
		CA	ug/g	14000	11000	16000
		CD	ug/g	33	17	18
		CO	ug/g	100	32	99
		CR	ug/g	28	54	25
		CU	ug/g	61	50	80
		FE	ug/g	53100	28500	48100
		K	ug/g	2250	1200	2580
		MG	ug/g	5500	4400	6400
		MN	ug/g	22900	7900	43600
		MO	ug/g	<20	<20	<20
		NA	ug/g	300	300	400
		NI	ug/g	200	100	390
		P	ug/g	900	800	900
		PB	ug/g	100	170	<80
		S	ug/g	2840	3560	5370
		SB	ug/g	<80	<80	<80
		SE	ug/g	<80	<80	<80
		SI	ug/g	1500	1600	1700
		SN	ug/g	<80	<80	<80
		SR	ug/g	55	37	65
		TI	ug/g	594	559	749
		V	ug/g	30	30	50
		ZN	ug/g	5540	4910	12500

APPENDIX D

VEGETATION CHEMISTRY DATA, 1999

APPENDIX D

Samples analyzed by Norwest: as labelled

Samples analyzed by Pacific Environment Research Centre:

Sample #	Sample Description
Old Pond 1	First pond downgradient from Galkeno 900
Old Pond 2	Second pond downgradient from Galkeno 900
Old Pond 3	Third pond downgradient from Galkeno 900
Upper Plot 1	Plot 1 in Galkeno constructed wetland
Upper Plot 2	Plot 2 in Galkeno constructed wetland

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46726**
Address: BOX 5111	WO (Other):
	PO Num: Tissues
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis

	Detection Limit	Units	46726-1 #1 - McQuesten Swamp - Aug 12/99	46726-2 #3 - Wetland Plot #3 - Aug 10/99	46726-3 #4 - Wetland Plot #4 - Aug 10/99	46726-4 #6 - Natural Wetland - Aug 10/99
ICP Semi-Trace Metals Scan						
Aluminum	1	µg/g	73	177	133	93
Antimony	2	µg/g	<2	<2	<2	<2
Arsenic	2	µg/g	<2	<2	<2	<2
Barium	0.05	µg/g	25.4	11.9	10.1	7.2
Beryllium	0.02	µg/g	<0.02	<0.02	<0.02	<0.02
Bismuth	2	µg/g	<2	<2	<2	<2
Cadmium	0.05	µg/g	0.06	0.13	0.11	0.09
Calcium	1	µg/g	4900	7960	9200	5390
Chromium	0.1	µg/g	0.3	0.2	0.5	0.3
Cobalt	0.1	µg/g	<0.1	<0.1	<0.1	<0.1
Copper	0.2	µg/g	4.9	7.4	5.2	14.6
Iron	0.3	µg/g	77.6	146	129	131
Lead	1	µg/g	<1	<1	<1	<1
Lithium	0.2	µg/g	<0.2	<0.2	<0.2	0.6
Magnesium	1	µg/g	2910	1890	1640	1790
Manganese	0.1	µg/g	368	1000	1100	473
Mercury	0.01	µg/g	0.06	0.06	0.06	0.06
Molybdenum	0.5	µg/g	0.8	0.7	0.9	1.4
Nickel	0.2	µg/g	0.3	1.1	0.9	1.7
Phosphorus	5	µg/g	1640	1480	1540	1900
Potassium	20	µg/g	5510	10900	11700	14100
Selenium	2	µg/g	<2	<2	<2	<2
Silicon	5	µg/g	6620	2090	9410	2860
Silver	0.1	µg/g	<0.1	<0.1	<0.1	<0.1
Sodium	5	µg/g	15	<5	5	20
Strontium	1	µg/g	13	21	22	10
Sulphur	10	µg/g	1920	2130	2290	2380
Thorium	1	µg/g	<1	<1	<1	<1
Tin	1	µg/g	<1	<1	<1	<1
Titanium	0.1	µg/g	1.6	0.8	1	3.2
Uranium	5	µg/g	<5	<5	<5	<5
Vanadium	0.2	µg/g	<0.2	<0.2	<0.2	<0.2
Zinc	0.5	µg/g	42.3	121	94.4	69
Zirconium	0.1	µg/g	0.3	<0.1	0.2	0.1

na = not available

NORWEST LABS
Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46726**
Address: BOX 5111	WO (Other):
	PO Num: Tissues
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46726-5 #8 - Discharge Christal L. - Aug 10/99	46726-6 #9 - No Cash Wetland - Aug 11/99	46726-7 #11 - Husky Mine @ Veg - Aug 11/99	46726-8 #12 - Tailings Dam, Plot #1
ICP Semi-Trace Metals Scan						
Aluminum	1	µg/g	71	91	60	71
Antimony	2	µg/g	<2	<2	<2	<2
Arsenic	2	µg/g	<2	<2	<2	<2
Barium	0.05	µg/g	6.61	12.7	12.8	9.72
Beryllium	0.02	µg/g	<0.02	<0.02	<0.02	<0.02
Bismuth	2	µg/g	<2	<2	<2	<2
Cadmium	0.05	µg/g	0.06	0.26	0.41	0.2
Calcium	1	µg/g	7950	6750	6480	5150
Chromium	0.1	µg/g	0.2	0.2	0.2	0.2
Cobalt	0.1	µg/g	0.2	<0.1	<0.1	<0.1
Copper	0.2	µg/g	4.5	7.5	5.8	4.4
Iron	0.3	µg/g	121	85.1	85.9	113
Lead	1	µg/g	<1	<1	2	5
Lithium	0.2	µg/g	0.8	<0.2	<0.2	<0.2
Magnesium	1	µg/g	1580	2370	2090	2420
Manganese	0.1	µg/g	732	918	1460	468
Mercury	0.01	µg/g	0.06	0.06	0.06	0.06
Molybdenum	0.5	µg/g	0.7	0.6	<0.5	1.2
Nickel	0.2	µg/g	1.8	0.4	0.8	0.4
Phosphorus	5	µg/g	2080	1300	1070	1250
Potassium	20	µg/g	14400	10000	9400	9400
Selenium	2	µg/g	<2	<2	<2	<2
Silicon	5	µg/g	229	2600	11100	6040
Silver	0.1	µg/g	<0.1	<0.1	<0.1	<0.1
Sodium	5	µg/g	15	11	14	6
Strontium	1	µg/g	12	12	15	19
Sulphur	10	µg/g	3200	2500	2140	2140
Thorium	1	µg/g	<1	<1	<1	<1
Tin	1	µg/g	<1	<1	<1	<1
Titanium	0.1	µg/g	1.1	0.9	1.2	0.8
Uranium	5	µg/g	<5	<5	<5	<5
Vanadium	0.2	µg/g	<0.2	<0.2	<0.2	<0.2
Zinc	0.5	µg/g	108	416	57.6	50.8
Zirconium	0.1	µg/g	0.5	<0.1	0.1	<0.1

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
na = not available
For specific tests registered with the Association

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

NORWEST LABS

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46726**
Address: BOX 5111	WO (Other):
	PO Num: Tissues
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Metal Analysis (con't.)

	Detection Limit	Units	46726-9 #13A - Tailings Dam, Plot #2 - Aug 10/99	46726-10 #13B - Tailings Dam, Plot #2 - Aug 10/99	46726-11 #14 - Drainage Ditch by Dam - Aug 10/99
ICP Semi-Trace Metals Scan					
Aluminum	1	µg/g	257	153	65
Antimony	2	µg/g	<2	<2	<2
Arsenic	2	µg/g	4	86	2
Barium	0.05	µg/g	10.3	8.22	12.1
Beryllium	0.02	µg/g	<0.02	<0.02	<0.02
Bismuth	2	µg/g	<2	<2	<2
Cadmium	0.05	µg/g	1.27	2.27	0.2
Calcium	1	µg/g	5560	21400	5060
Chromium	0.1	µg/g	0.3	0.2	0.2
Cobalt	0.1	µg/g	0.1	0.3	<0.1
Copper	0.2	µg/g	13.3	11.1	6
Iron	0.3	µg/g	264	88.1	115
Lead	1	µg/g	20	5	3
Lithium	0.2	µg/g	<0.2	0.6	<0.2
Magnesium	1	µg/g	2560	6040	1920
Manganese	0.1	µg/g	658	555	512
Mercury	0.01	µg/g	0.06	0.06	0.06
Molybdenum	0.5	µg/g	<0.5	0.7	0.7
Nickel	0.2	µg/g	0.9	0.99	0.4
Phosphorus	5	µg/g	1730	1240	1300
Potassium	20	µg/g	10600	14000	12100
Selenium	2	µg/g	2	<2	<2
Silicon	5	µg/g	3310	6840	3650
Silver	0.1	µg/g	0.3	0.5	<0.1
Sodium	5	µg/g	31	2390	45
Strontium	1	µg/g	16	45	19
Sulphur	10	µg/g	2280	7000	3160
Thorium	1	µg/g	<1	<1	<1
Tin	1	µg/g	<1	<1	<1
Titanium	0.1	µg/g	1.5	0.7	0.9
Uranium	5	µg/g	<5	<5	<5
Vanadium	0.2	µg/g	<0.2	<0.2	<0.2
Zinc	0.5	µg/g	114	128	86.4
Zirconium	0.1	µg/g	0.1	0.1	<0.1

Approved By:

John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association

na = not available

NORWEST LABS

Surrey Ph (604) 514-3322 FAX (604) 514-3323
Edmonton Ph (403) 438-5522 FAX (403) 438-0396
Calgary Ph (403) 291-2022 FAX (403) 291-2021
Lethbridge Ph (403) 329-9266 FAX (403) 327-8527
Winnipeg Ph (204) 982-8630 FAX (204) 275-6019

Client Code: LABENV

Name: LABERGE ENVIRONMENTAL	Workorder: **46726**
Address: BOX 5111	WO (Other):
	PO Num: Tissues
WHITEHORSE	Project: UKHM Wetland Study
YT Y1A 4S3	Date Sampled:
Attn: Bonnie Burns	Date Received: Aug 16, 1999
Phone: (867) 668-6838	Date Reported: Aug 20, 1999
Fax: (867) 667-6956	

Analysis

	Detection Limit	Units	46726-1 #1 - McQuesten Swamp - Aug 12/99	46726-2 #3 - Wetland Plot #3 - Aug 10/99	46726-3 #4 - Wetland Plot #4 - Aug 10/99	46726-4 #6 - Natural Wetland - Aug 10/99
pH (1:2 water)						
pH	0.01	pH	6.36	6.2	6.24	6.29

	Detection Limit	Units	46726-5 #8 - Discharge Christal L. - Aug 10/99	46726-6 #9 - No Cash Wetland - Aug 11/99	46726-7 #11 - Husky Mine @ Veg - Aug 11/99	46726-8 #12 - Tailings Dam, Plot #1
pH (1:2 water)						
pH	0.01	pH	6.33	6.19	6.14	6.08

	Detection Limit	Units	46726-9 #13A - Tailings Dam, Plot #2 - Aug 10/99	46726-10 #13B - Tailings Dam, Plot #2 - Aug 10/99	46726-11 #14 - Drainage Ditch by Dam - Aug 10/99
pH (1:2 water)					
pH	0.01	pH	6.35	6.11	5.94

Approved By:

John Davidson, Dipl. T., C.P.H.I. (C)
Supervisor, Inorganics Lab

Accredited By: CANADIAN ASSOCIATION FOR ENVIRONMENTALANALYTICAL LABORATORIES (CAEAL)
For specific tests registered with the Association
na = not available

Environment Canada -Laboratories
Pacific Environmental Science Centre
2645 Dollarton Hwy.
North Vancouver, B.C.
V' 1V2 (604)924-2500

Lab Reference #
9 9 5 1 2 9

23:33 15-Oct-99

F I N A L R E P O R T

Identification: UKHM WETLANDS (MERG)JULY 99

Type of Sample: Biota

Submitted by: DAVIDGE,DOUG
EP WHITEHORSE YT
YUKON PROGRAMS
YUKON
ENV PROTECTION

Logged in: 17-Sep-99 (5 samples)

Completed: 15-Oct-99 (170 results)

Charged to: 2562-101
EP YUKON POLLUTION ABATEMENT

Analyzed for: METALS

Authorized by: Richard Strub
Richard Strub
QA Officer

:

[1] -use graphite furnace (GF) results, where reported, in preference to ICP results due to better precision and accuracy.
[2] -metals data are reported in dry weight.

RESULTS FOR UKHM WETLANDS (MERG)JULY 99 SAMPLES

Parameter Analyzed		Units	OLD POND 1 995129-001	OLD POND 2 995129-002	OLD POND 3 995129-003	UPPER PLOT 1 995129-004	UPP PLO 995129-005
METALS/BIOTA (GF)	AG	ug/g	<.5	<.5	<.5	<.5	<.5
	AS	ug/g	1.0	1.0	0.7	0.6	0.6
	CD	ug/g	1.08	.097	.52	.13	.17
	PB	ug/g	<.2	<.2	.6	.3	.3
	SE	ug/g	<0.5	<0.5	<0.5	<0.5	<0.5
(HG)	HG	ug/g	.005	.006	.008	.007	.008
(ICP)	AL	ug/g	85.1	42	15	53	67
	AS	ug/g	<4	<4	<4	<4	<4
	B	ug/g	8	8	8	15	18
	BA	ug/g	4.3	3.4	5.8	7.3	10.3
	BE	ug/g	.2	.1	.1	.2	.2
	CA	ug/g	8200	4640	6580	8620	8890
	CD	ug/g	1.2	<.4	<.4	<.4	<.4
	CO	ug/g	<.4	<.4	<.4	<.4	<.4
	CR	ug/g	<.4	.7	1.3	<.4	1.8
	CU	ug/g	5.8	5.1	8.1	6.9	5
	FE	ug/g	1380	374	164	103	121
	K	ug/g	11100	16200	14200	12000	11800
	MG	ug/g	2390	1240	1950	1160	1300
	MN	ug/g	917	453	689	361	945
	MO	ug/g	.9	<.8	<.8	1	1
	NA	ug/g	100	40	60	110	88
	NI	ug/g	2	<2	2	4	4
	P	ug/g	1720	1350	1800	1190	1300
	PB	ug/g	6	<4	<4	<4	<4
	S	ug/g	3620	2180	2520	2130	1690
	SB	ug/g	8.3	5	<4	<4	5
	SE	ug/g	8	<4	5	<4	<4
	SI	ug/g	1530	1730	1170	257	244
	SN	ug/g	<4	<4	<4	<4	<4
	SR	ug/g	20.5	9.77	18.5	14.6	16.2
	TI	ug/g	2.2	4.8	.9	1.6	1.3
	V	ug/g	<.8	<.8	<.8	1	<.8
	ZN	ug/g	194	84.5	133	216	140

APPENDIX E

PLANT SPECIES LIST PER SITE, 1999

	Galkeno 900 Wetland							
	constructed wetland plot	**constructed wetland berm**	**discharge pond 1**	**discharge pond 2**	**discharge pond 3**	**pond berms**	**natural wetland**	**Christal Lake**
graminoids								
Agrostis scabra		X				X		
var. *scabra*								
Arctagrostis latifolia						X		
Calamagrostis canadensis	X							
Calamagrostis stricta						X		
ssp. *stricta*								
Carex aquatilis	X					X	X	X
Carex praticola					X			
Carex utriculata	X		X	X	X			
Hordeum jubatum		X						
Juncus castaneus					X			
forbs								
Achillea millefolium		X						
Achillea sibirica		X						
Cerastium arvense		X						
Epilobium angustifolium		X						
Erigeron acris		X						
ssp. *politus*								
Equisetum arvense		X		X	X	X		
Geum aleppicum	X							
Matricaria matricarioides		X						
Plantago major		X						
Potentilla norvegica	X	X						
Potentilla palustris	X							
Rorippa palustris						X		
ssp. *palustris*								
Stellaria longipes		X						
Taraxacum officinale		X						
shrubs								
Alnus incana	X							
Salix alaxensis		X						
Salix glauca	X	X					X	X

	No Cash Creek			
	adit discharge	highway crossing	small wetland	ditch confluence
graminoids				
Calamagrostis canadensis	X			X
Carex aquatilis			X	
Carex praticola			X	X
Elymus sp.	X			
Hordeum jubatum	X	X		
forbs				
Achillea millefolium		X		
Achillea sibirica		X		
Crepis elegans	X			
Dryopteris fragrans		X		
Epilobium angustifolium		X		
Epilobium latifolium	X	X		
Equisetum arvense	X		X	
Mertensia paniculata		X		
Potentilla norvegica		X		
Stellaria longipes	X	X		
Taraxacum officinale		X		
shrubs				
Alnus crispa	X	X		
Arctostaphylos rubra				X
Betula glandulosa				X
Betula papyrifera				X
Ledum decumbens				X
Picea mariana			X	X
Populus balsamifera				X
Potentilla fruticosa				X
Rhododendron lapponicum				X
Salix alaxensis	X	X		X
Salix arbusculoides		X	X	
Salix glauca	X		X	
Salix planifolia			X	X
Vaccinium uliginosum				X

Husky Mine	
	waste rock seepage
graminoids	
Agrostis scabra	X
var. *scabra*	
Alopecurus aequalis	X
Calamagrostis stricta	X
ssp. *inexpansa*	
Hordeum jubatum	X
forbs	
Equisetum arvense	X
Euphrasia subarctica	X
shrubs	
Betula glandulosa	X
Picea mariana	X
Salix glauca	X
Salix planifolia	X

UKHM Tailings Impoundment Transplant Site

	Plot 1			Plot 2	
	plot	berm		plot	berm
graminoids					
Agrostis scabra	X			X	
var. *scabra*					
Beckmannia syzigachne	X				
Calamagrostis canadensis		X			X
Carex aquatilis	X			X	
Carex utriculata	X			X	
Hordeum jubatum	X	X		X	X
Juncus castaneus	X			X	
Luzula sp.	X			X	
Scirpus validus				X	
forbs					
Achillea millefolium		X			
Epilobium hornemannii		X		X	
Epilobium angustifolium	X	X			X
Equisetum arvense	X	X		X	X
Equisetum hynemale				X	
ssp. *affine*					
Platanthera hyperborea		X			
Potentilla norvegica		X			
Rorippa palustris	X				
ssp. *palustris*					
Senecio congestus	X				
Stellaria longipes	X	X		X	
Taraxacum officinale		X			X
shrubs					
Betula glandulosa		X			
Salix sp.	X	X		X	X

South McQuesten River Wetland		
	sedge	
	donor site	
graminoids		
Carex aquatilis	X	
Carex utriculata	X	
Eleocharis palustris	X	
Hordeum jubatum	X	
forbs		
Epilobium hornemannii	X	
Epilobium palustre	X	
Hippuris vulgaris	X	
Plantago major	X	
Potamogeton sp.	X	
Potentilla sp.	X	
Ranunculus gmelinii	X	
ssp. *gmelinii*		
Senecio congestus	X	
Sparganium multipedunculata	X	

	No Cash Creek			
	adit discharge	highway crossing	small wetland	ditch confluence
graminoids				
Calamagrostis canadensis	X			X
Carex aquatilis			X	
Carex praticola			X	X
Elymus sp.	X			
Hordeum jubatum	X	X		
forbs				
Achillea millefolium		X		
Achillea sibirica		X		
Crepis elegans	X			
Dryopteris fragrans		X		
Epilobium angustifolium		X		
Epilobium latifolium	X	X		
Equisetum arvense	X		X	
Mertensia paniculata		X		
Potentilla norvegica		X		
Stellaria longipes	X	X		
Taraxacum officinale		X		
shrubs				
Alnus crispa	X	X		
Arctostaphylos rubra				X
Betula glandulosa				X
Betula papyrifera				X
Ledum decumbens				X
Picea mariana			X	X
Populus balsamifera				X
Potentilla fruticosa				X
Rhododendron lapponicum				X
Salix alaxensis	X	X		X
Salix arbusculoides		X	X	
Salix glauca	X		X	
Salix planifolia			X	X
Vaccinium uliginosum				X

Husky Mine	
	waste rock
	seepage
graminoids	
Agrostis scabra	X
var. *scabra*	
Alopecurus aequalis	X
Calamagrostis stricta	X
ssp. *inexpansa*	
Hordeum jubatum	X
forbs	
Equisetum arvense	X
Euphrasia subarctica	X
shrubs	
Betula glandulosa	X
Picea mariana	X
Salix glauca	X
Salix planifolia	X

UKHM Tailings Impoundment Transplant Site

	Plot 1			Plot 2	
	plot	**berm**		**plot**	**berm**
graminoids					
Agrostis scabra	X			X	
var. *scabra*					
Beckmannia syzigachne	X				
Calamagrostis canadensis		X			X
Carex aquatilis	X			X	
Carex utriculata	X			X	
Hordeum jubatum	X	X		X	X
Juncus castaneus	X			X	
Luzula sp.	X			X	
Scirpus validus				X	
forbs					
Achillea millefolium		X			
Epilobium hornemannii		X		X	
Epilobium angustifolium	X	X			X
Equisetum arvense	X	X		X	X
Equisetum hynemale				X	
ssp. *affine*					
Platanthera hyperborea		X			
Potentilla norvegica		X			
Rorippa palustris	X				
ssp. *palustris*					
Senecio congestus	X				
Stellaria longipes	X	X		X	
Taraxacum officinale		X			X
shrubs					
Betula glandulosa		X			
Salix sp.	X	X		X	X

South McQuesten River Wetland		
	sedge	
	donor site	
graminoids		
Carex aquatilis	X	
Carex utriculata	X	
Eleocharis palustris	X	
Hordeum jubatum	X	
forbs		
Epilobium hornemannii	X	
Epilobium palustre	X	
Hippuris vulgaris	X	
Plantago major	X	
Potamogeton sp.	X	
Potentilla sp.	X	
Ranunculus gmelinii	X	
ssp. *gmelinii*		
Senecio congestus	X	
Sparganium multipedunculata	X	