AQUATIC EFFECTS TECHNOLOGY EVALUATION (AETE) PROGRAM

1996 Preliminary Field Survey
Myra Falls Mine Site,
British Columbia

AETE Project 4.1.2

1996 Preliminary Field Survey
Myra Falls Mine Site, British Columbia

Sponsored by :

Canada Centre for Mineral and Energy Technology (CANMET)
Mining Association of Canada (MAC)

on Behalf of :

Aquatic Effects Technology Evaluation (AETE) Program

Prepared by :

EVS Environment Consultants
195 Pemberton Avenue
North Vancouver, B.C.
V7P 2R4

in consortium with :

Ecological Services for Planning Ltd.
361 Southgate Drive
Guelph, ON
N1G 3M5

Jacques Whitford Environment Ltd.
711 Woodstock Road
P.O. Box 1116
Fredericton, N.B.
E3B 5C2

December 1996

AQUATIC EFFECTS TECHNOLOGY EVALUATION PROGRAM

Notice to Readers

Aquatic Effects Monitoring
1996 Preliminary Field Surveys

The Aquatic Effects Technology Evaluation (AETE) program was established to review appropriate technologies for assessing the impacts of mine effluents on the aquatic environment. AETE is a cooperative program between the Canadian mining industry, several federal government departments and a number of provincial governments; it is coordinated by the Canada Centre for Mineral and Energy Technology (CANMET). The program is designed to be of direct benefit to the industry, and to government. Through technical evaluations and field evaluations, it will identify cost-effective technologies to meet environmental monitoring requirements. The program includes three main areas: acute and sublethal toxicity testing, biological monitoring in receiving waters, and water and sediment monitoring. The program includes literature-based technical evaluations and a comprehensive three year field program.

The program has the mandate to do a field evaluation of water, sediment and biological monitoring technologies to be used by the mining industry and regulatory agencies in assessing the impacts of mine effluents on the aquatic environment; and to provide guidance and to recommend specific methods or groups of methods that will permit accurate characterization of environmental impacts in the receiving waters in as cost-effective a manner as possible. A pilot field study was conducted in 1995 to fine-tune the study design.

A phased approach has been adopted to complete the field evaluation of selected monitoring methods as follows:

Phase I: 1996- Preliminary surveys at seven candidate mine sites, selection of sites for further work and preparation of study designs for detailed field evaluations.

Phase II: 1997-Detailed field and laboratory studies at selected sites.

Phase III: 1998- Data interpretation and comparative assessment of the monitoring methods: report preparation.

Phase I is the focus of this report. The overall objective of this project is to conduct a preliminary field/laboratory sampling to identify a short-list of mines suitable for further detailed monitoring, and recommend study designs. The objective is NOT to determine the detailed environmental effects of a particular contaminant or extent and magnitude of effects of mining at the sites.

In Phase I, the AETE Technical Committee has selected seven candidates mine sites for the 1996 field surveys:

1) Myra Falls, Westmin Resources (British Columbia)
2) Sullivan, Cominco (British Columbia)
3) Lupin, Contwoyto Lake, Echo Bay (Northwest Territories)
4) Levack/Onaping, Inco and Falconbridge (Ontario)
5) Dome, Placer Dome Canada (Ontario)
6) Gaspé Division, Noranda Mining and Exploration Inc. (Québec)
7) Heath Steele Division, Noranda Mining and Exploration Inc. (New-Brunswick)

Study designs were developed for four sites that were deemed to be most suitable for Phase II of the field evaluation of monitoring methods (Myra Falls, Dome, Heath Steele, Lupin). Lupin was subsequently dropped based on additional reconnaissance data collected in 1997. Mattabi Mine, (Ontario) was selected as a substitute site to complete the 1997 field surveys.

For more information on the monitoring techniques, the results from their field application and the final recommendations from the program, please consult the *AETE Synthesis Report* to be published in September 1998.

Any comments regarding the content of this report should be directed to:

Diane E. Campbell
Manager, Metals and the Environment Program
Mining and Mineral Sciences Laboratories - CANMET
Room 330, 555 Booth Street, Ottawa, Ontario, K1A 0G1
Tel.: (613) 947-4807 Fax: (613) 992-5172
E-mail: dicampbe@nrcan.gc.ca

PROGRAMME D'ÉVALUATION DES TECHNIQUES DE MESURE D'IMPACTS EN MILIEU AQUATIQUE

Avis aux lecteurs

Surveillance des effets sur le milieu aquatique
Études préliminaires de terrain - 1996

Le Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ÉTIMA) vise à évaluer les différentes méthodes de surveillance des effets des effluents miniers sur les écosystèmes aquatiques. Il est le fruit d'une collaboration entre l'industrie minière du Canada, plusieurs ministères fédéraux et un certain nombre de ministères provinciaux. Sa coordination relève du Centre canadien de la technologie des minéraux et de l'énergie (CANMET). Le programme est conçu pour bénéficier directement aux entreprises minières ainsi qu'aux gouvernements. Par des évaluations techniques et des études de terrain, il permettra d'évaluer et de déterminer, dans une perspective coût-efficacité, les techniques qui permettent de respecter les exigences en matière de surveillance de l'environnement. Le programme comporte les trois grands volets suivants : évaluation de la toxicité aiguë et sublétale, surveillance des effets biologiques des effluents miniers en eaux réceptrices, et surveillance de la qualité de l'eau et des sédiments. Le programme prévoit également la réalisation d'une série d'évaluations techniques fondées sur la littérature et d'évaluation globale sur le terrain.

Le Programme ÉTIMA a pour mandat d'évaluer sur le terrain les techniques de surveillance de la qualité de l'eau et des sédiments et des effets biologiques qui sont susceptibles d'être utilisées par l'industrie minière et les organismes de réglementation aux fins de l'évaluation des impacts des effluents miniers sur les écosystèmes aquatiques; de fournir des conseils et de recommander des méthodes ou des ensembles de méthodes permettant, dans une perspective coût-efficacité, de caractériser de façon précise les effets environnementaux des activités minières en eaux réceptrices. Une étude-pilote réalisée sur le terrain en 1995 a permis d'affiner le plan de l'étude.

L'évaluation sur le terrain des méthodes de surveillance choisies s'est déroulée en trois étapes:

Étape I	1996 - Évaluation préliminaire sur le terrain des sept sites miniers candidats, sélection des sites où se poursuivront les évaluations et préparation des plans d'étude pour les évaluations sur le terrain.
Étape II	1997- Réalisation des travaux en laboratoire et sur le terrain aux sites choisis
Étape III	1998 -Interprétation des données, évaluation comparative des méthodes de surveillance; rédaction du rapport.

Ce rapport vise seulement les résultats de l'étape I. L'objectif du projet consiste à réaliser des échantillonnages préliminaires sur le terrain et en laboratoire afin d'identifier les sites présentant les caractéristiques nécessaires pour mener les évaluations globales des méthodes de surveillance en 1997 et de développer des plans d'études. Son objectif N'EST PAS de déterminer de façon détaillée les effets d'un contaminant particulier, ni l'étendue ou l'ampleur des effets des effluents miniers dans les sites.

À l'étape I, le comité technique ÉTIMA a sélectionné sept sites miniers candidats aux fins des évaluations sur le terrain:

1) Myra Falls, Westmin Resources (Colombie-Britannique)
2) Sullivan, Cominco (Colombie-Britannique)
3) Lupin, lac Contwoyto, Echo Bay (Territoires du Nord-Ouest)
4) Levack/Onaping, Inco et Falconbridge (Ontario)
5) Dome, Placer Dome Mine (Ontario)
6) Division Gaspé, Noranda Mining and Exploration Inc.(Québec)
7) Division Heath Steele Mine, Noranda Mining and Exploration Inc.(Nouveau-Brunswick)

Des plans d'études ont été élaborés pour les quatres sites présentant les caractéristiques les plus appropriées pour les travaux prévus d'évaluation des méthodes de surveillance dans le cadre de l'étape II (Myra Falls, Dome, Heath Steele, Lupin). Toutefois, une étude de reconnaissance supplémentaire au site minier de Lupin a révélé que ce site ne présentait pas les meilleures possibilités. Le site minier de Mattabi (Ontario) a été choisi comme site substitut pour compléter les évaluations de terrain en 1997.

Pour des renseignements sur l'ensemble des outils de surveillance, les résultats de leur application sur le terrain et les recommandations finales du programme, veuillez consulter le *Rapport de synthèse ÉTIMA* qui sera publié en septembre 1998.

Les personnes intéressées à faire des commentaires sur le contenu de ce rapport sont invitées à communiquer avec M^{me} Diane E. Campbell à l'adresse suivante :

Diane E. Campbell
Gestionnaire, Programme des métaux dans l'environnement
Laboratoires des mines et des sciences minérales - CANMET
Pièce 330, 555, rue Booth, Ottawa (Ontario), K1A 0G1
Tél.: (613) 947-4807 / Fax : (613) 992-5172
Courriel : dicampbe@nrcan.gc.ca

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

As part of the Aquatic Effects Technology Evaluation (AETE) Program, a field survey was conducted of the Myra Falls Mine Site in British Columbia. This site has been suggested as a candidate for detailed testing of monitoring tools in 1997 studies sponsored by the AETE Program. The purpose of this survey was to provide information whether or not to include this site in 1997 studies and, if so, for what particular hypotheses.

As part of this field survey, available historical information was reviewed. Changes in water and sediment quality in Buttle Lake (e.g., copper, zinc concentrations) have occurred related to effluent discharges. In addition, plankton have been adversely affected in the lake and fish have accumulated metals in their tissues. Historic metallothionein measurements in Buttle Lake rainbow trout liver tissue have been correlated with metal concentrations in the water column. However, process changes at the mine have reduced historic impacts (e.g., differences between exposure and reference areas).

Effluent discharge is continuous. Sublethal toxicity testing indicated that the effluent affects survival and reproduction of *Ceriodaphnia dubia*, survival and growth of fathead minnows, and growth of both *Selenastrum capricornutum* and *Lemna minor*.

Field studies were conducted in both Buttle Lake (5 reference and 6 exposure stations) and in Myra Creek, which conveys mine effluent to Buttle Lake (1 reference and 1 exposure station). Significant elevations in some parameters (e.g., pH, conductivity, total dissolved solids, several total and dissolved metals) occurred at the exposure area compared to the reference area. Some parameters exceeded Canadian freshwater guidelines for the protection of aquatic life at both exposure and reference areas.

Buttle Lake appears to be unique among the seven sites due to a relative lack of sediment or benthic studies in Buttle Lake (the focus has been on the water column and phytoplankton). It is also unique because water levels in Buttle Lake are controlled by B.C. Hydro for power generation and can vary substantially over short time periods. One of the results of this variation is periodic exposure of littoral sediments.

Despite efforts to sample similar sediment habitats, there were differences between the reference and exposure areas (e.g., fines, total organic carbon, loss on ignition). All metals were present at higher concentrations in the exposure than the reference area, but this difference may be partly related to substrate differences. Cadmium, copper, lead and particularly zinc exceeded Canadian sediment quality criteria in the exposure area.

There was no significant difference between reference and exposure areas for total abundance or species richness of the benthos in Buttle Lake. The Myra Creek exposure station had higher abundance and lower species richness than the reference area.

Only one potential sentinel fish species (rainbow trout) was collected in any numbers during this field survey. Historic data indicate additional sentinel species include cutthroat trout and Dolly Varden. Neither tissue nor metallothionein analyses were conducted because good historical data were available. Additional information regarding this site is provided in Table ES-1.

Overall, this is not an ideal site for 1997 studies by the AETE Program. Fine-grained sediment is limited and collection is difficult due to extensive wood debris. More importantly, benthic invertebrates may not be as important to the Buttle Lake food web as zooplankton.

Table ES-1. Summary information for specific study elements for the Myra Falls mine site (stream/lake discharge)

ELEMENT	SAMPLED 1996	SUMMARY/COMMENTS
1.0 Historical Data Review 1.1 Effluent Characterization	na	Some rainbow trout and *Daphnia* toxicity in Buttle Lake, but results not consistent
1.2 Water Chemistry	na	Monitoring data exist Although inputs are well defined, delineation of mixing zone confounded by changing water level controlled by B.C. Hydro
1.3 Sediment Chemistry	na	There are no historic data
1.4 Benthos	na	Emphasis has been on plankton Benthos changes observed below the mine
1.5 Fisheries 1.5.1 Population	na	No trends apparent in historic data
1.5.2 Tissue	na	Fish tissue and metallothionein studies indicate differences between reference and exposure areas but differences have decreased over time
2.0 Study Area 2.1 Site Access	na	Boat launch within 20min boat ride of reference site; another boat launch within 60min boat ride of exposure site
2.2 Availability of Multiple Reference and Exposure Areas	na	Multiple reference and exposure stations of relatively uniform habitat type available
2.3 Confounding Discharges	na	None
3.0 Effluent/Sublethal Toxicity 3.1 Frequency of Effluent Discharge	na	Effluent continuously discharged (easy access)
3.2 Sublethal Toxicity 3.2.1 *Ceriodaphnia dubia*	Yes	Survival and reproduction affected
3.2.2 Fathead Minnow	Yes	Survival and growth affected
3.2.3 *Selenastrum capricornutum*	Yes	Growth affected (most sensitive end-point of all tested)
3.2.4 *Lemna minor*	Yes	Growth affected
3.2.5 Trout embryo	Yes	No data; controls failed

Table ES-1. Continued

ELEMENT	SAMPLED 1996	SUMMARY/COMMENTS
4.0 Habitats	Yes	Main habitat difference between exposure and reference areas is finer sediments in former Multiple reference and exposure stations of relatively uniform habitat type available
5.0 Water Chemistry	Yes	Significant elevations in conventional parameters (e.g., pH, conductivity) and several metals at exposure compared to reference area
6.0 Sediments	Yes	Difficult to find appropriate sediment at both exposure and reference areas Increased level of effort would be required to find other depositional areas and these may not be representative (i.e., may only represent a small portion of the system) Fluctuating water level exposes littoral sediment depositional areas
7.0 Benthic Invertebrates	Yes	Buttle Lake steep-sided; shore drops off quickly Littoral zone varies as water levels are altered Zooplankton may be more useful in this system for determining effects; artificial substrates are another possibility
8.0 Fisheries 8.1 Communities	Yes	Potential sentinel species are rainbow trout, cutthroat trout, Dolly Varden Sentinel species available with reasonable effort Size difference noted but may be an artifact of sampling methods
8.2 Tish Tissue	No	Good historical data available

SOMMAIRE

Dans le cadre du Programme d'évaluation des techniques de mesure d'impacts en milieu aquatique (ÉTIMA), une étude sur le terrain a été menée à la mine Myra Falls en Colombie-Britannique. L'endroit a été proposé comme site possible pour l'essai détaillé d'outils de surveillance aux fins de recherches prévues pour 1997 dans le cadre du programme ÉTIMA. Le but de l'étude était de fournir des renseignements permettant de décider s'il fallait utiliser ou non ce site en 1997, et dans l'affirmative, pour la vérification de quelles hypothèses en particulier.

Au cours de cette étude sur le terrain, on a passé en revue les données historiques existantes. Des changements se sont produits quant à la qualité de l'eau et des sédiments dans le lac Buttle (p. ex., concentrations de cuivre et de zinc) qui seraient liés aux rejets d'effluent. Par ailleurs, on a observé des effets négatifs sur le plancton dans le lac et une accumulation de métaux dans les tissus des poissons. On a établi des corrélations entre les mesures de métallothionéine effectuées par le passé sur les tissus hépatiques de truites arc-en-ciel prélevées dans le lac Buttle, et les concentrations de métaux dans la colonne d'eau. Toutefois, des changements aux procédés à la mine ont permis de réduire les impacts historiques (p. ex., les différences entre les zones de référence et d'exposition).

Le rejet de l'effluent est continu. Les tests de toxicité sublétale indiquent que l'effluent entrave la survie et la reproduction de *Ceriodaphnia dubia*, la survie et la croissance de la tête-de-boule, et la croissance de *Selenastrum capricornutum* et de *Lemna minor*.

Des études sur le terrain ont été menées sur le lac Buttle (à cinq sites de référence et six sites d'exposition) et le ruisseau Myra (un site de référence et un site d'exposition), qui transporte l'effluent minier jusqu'au lac Buttle. Certains paramètres (p. ex., pH, conductivité, matières totales dissoutes, concentrations totales et concentrations sous forme dissoute de plusieurs métaux) présentaient des augmentations importantes dans la zone d'exposition par rapport à la zone de référence. Les valeurs de certains paramètres dépassaient les seuils établis dans les directives canadiennes de qualité de l'eau douce pour la protection des organismes aquatiques dans les zones de référence et d'exposition.

Le lac Buttle semble être un site unique parmi les sept sites évalués en raison du manque relatif d'études sur les sédiments ou le benthos pour cet endroit (les études ont porté principalement sur la colonne d'eau et le phytoplancton). Il s'agit également d'un site unique parce que les niveaux d'eau du lac sont régis par B.C. Hydro pour la production d'électricité, et qu'ils peuvent varier grandement en peu de temps. L'un des résultats de ces variations de niveau est l'exposition périodique des sédiments en bordure de la rive.

Malgré les efforts déployés afin de trouver des habitats similaires pour l'échantillonnage des sédiments, on a trouvé des différences entre les zones de référence et d'exposition (p. ex., particules fines, carbone organique total, perte par calcination). Les concentrations de tous les métaux présents étaient plus élevées dans la zone d'exposition que dans la zone de référence, mais ces différences peuvent découler en partie des différences de substrats. Les concentrations

de cadmium, de cuivre, de plomb et surtout de zinc dépassaient les critères canadiens de qualité des sédiments dans la zone d'exposition.

On n'a pas observé de différence importante entre les zones de référence et d'exposition quant à l'abondance totale ou à la diversité des espèces benthiques dans le lac Buttle. Au poste du site d'exposition du ruisseau Myra, on a observé une plus grande abondance et une moins grande diversité d'espèces que dans la zone de référence.

Une seule espèce indicatrice potentielle (truite arc-en-ciel) a été prélevée en quantité suffisante au cours de cette étude de terrain. Les données historiques mentionnent la présence d'autres espèces indicatrices, notamment la truite fardée et la Dolly Varden (*Salvelinus malma*). Il n'y a pas eu d'analyses des tissus ni des concentrations de métallothionéine étant donné la disponibilité de données historiques satisfaisantes. On trouvera d'autres informations au sujet de ce site dans le tableau ES-1.

Dans l'ensemble, il ne s'agit pas d'un site idéal pour les études de 1997 dans le cadre du programme ÉTIMA. La quantité de sédiments à grain fin est limitée, et le prélèvement difficile à cause des nombreux débris de bois. Fait plus important encore, les invertébrés benthiques pourraient ne pas avoir autant d'importance dans le réseau trophique que le zooplancton.

Tableau ES-1. Résumé de l'information concernant certains éléments de l'étude relative à la mine Myra Falls (rejet dans le cours d'eau et le lac).

Élément	Échantillons prélevés en 1996	Sommaire/remarques
1.0 Revue des données historiques 1.1 Caractérisation de l'effluent	s.o.	Des tests de toxicité ont été effectués sur la truite arc-en-ciel et *Daphnia* du lac Buttle, mais les résultats ne sont pas cohérents.
1.2 Chimie de l'eau	s.o.	On dispose de données de surveillance. Bien que les apports soient définis précisément, la délimitation de la zone de mélange est faussée par les variations du niveau d'eau, contrôlé par B.C. Hydro.
1.3 Chimie des sédiments	s.o.	Pas de données historiques.
1.4 Benthos	s.o.	Les études ont été axées sur le plancton. On a observé des variations relativement au benthos en aval de la mine.
1.5 Pêches 1.5.1 Population	s.o.	Aucune tendance ne se dégage des données historiques.
1.5.2 Tissus	s.o.	Des études des tissus de poisson et de la métallothionéine démontrent des différences entre les zones de référence et d'exposition, mais celles-ci se sont atténuées avec le temps.
2.0 Zone d'étude 2.1 Accès au site	s.o.	La rampe de mise à l'eau des embarcations est à 20 minutes (par bateau) de la zone de référence; une autre rampe de mise à l'eau se trouve à 60 minutes (par bateau) de la zone d'exposition.
2.2 Disponibilité de plusieurs zones de référence et d'exposition	s.o.	Plusieurs zones d'exposition et de référence présentant un type d'habitat relativement uniforme sont disponibles.
2.3 Rejets au même endroit	s.o.	Aucun.
3.0 Effluent et toxicité sublétale 3.1 Fréquence des rejets d'effluent	s.o.	L'effluent est rejeté de façon continue (d'accès facile).
3.2 Toxicité sublétale 3.2.1 *Ceriodaphnia dubia*	Oui	Impact sur la survie et la reproduction de l'organisme
3.2.2 Tête-de-boule	Oui	Impact sur la survie et la croissance de l'organisme.
3.2.3 *Selenastrum capricornutum*	Oui	Impact sur la croissance de l'organisme (de tous les tests effectués, vulnérabilité la plus grande à toutes les valeurs de seuil).
3.2.4 *Lemna minor*	Oui	Impact sur la croissance de l'organisme.
3.2.5 Embryon de truite	Oui	Aucune donnée disponible; échec des contrôles.
4.0 Habitats	Oui	La principale différence relative à l'habitat entre les zones d'exposition et de référence est l'existence de sédiments au

Tableau ES-1. Suite.

Élément	Échantillons prélevés en 1996	Sommaire/remarques
		grain plus fin dans la zone d'exposition. Plusieurs zones de référence et d'exposition disponibles présentant un habitat relativement uniforme.
5.0 Chimie de l'eau	Oui	Dans la zone d'exposition, on a noté des valeurs plus élevées pour les paramètres classiques (p. ex., pH, conductivité) et pour plusieurs métaux par rapport à la zone de référence.
6.0 Sédiments	Oui	Il est difficile de trouver des sédiments appropriés, tant dans la zone de référence que dans la zone d'exposition. Pour trouver d'autres zones de dépôt des sédiments, il faudrait fournir beaucoup d'efforts, et il est possible que ces secteurs ne soient pas représentatifs (c.à-d. qu'ils pourraient représenter seulement une portion du réseau hydrographique). À cause des fluctuations du niveau d'eau, certains secteurs de dépôt de sédiments en bordure de la rive sont parfois exposés.
7.0 Invertébrés benthiques	Oui	Les berges du lac Buttle sont abruptes (pente forte). La zone riveraine varie selon les niveaux d'eau. Le zooplancton pourrait être plus utile pour la détermination des impacts dans ce réseau hydrographique; des substrats artificiels seraient une autre possibilité.
8.0 Pêches 8.1 Communautés	Oui	Les espèces indicatrices potentielles sont la truite arc-en-ciel, la truite fardée et la Dolly Varden (*Salvelinus malma*). Espèces indicatrices disponibles moyennant des efforts raisonnables. Les différences de taille des spécimens peuvent être attribuables aux méthodes d'échantillonnage.
8.2 Tissus de poissons	Non	Données historiques satisfaisantes disponibles.

1.0
INTRODUCTION

The Aquatic Effects Technology Evaluation (AETE) Program was established to conduct field and laboratory evaluation and comparison of selected environmental effects monitoring technologies for assessing impacts of mine effluents on the aquatic environment. The focus of the Program is on robustness, costs, and the suitability of monitoring sites.

Building upon previous work, which includes literature reviews, technical evaluations, and pilot field studies, the AETE Program sponsored, in 1996, preliminary evaluations of aquatic effects monitoring at seven candidate mine sites. Based on the results of these preliminary evaluations, some of these sites have been recommended for further work in 1997.

This final field survey report provides detailed information on work conducted at one of these seven sites. Separate reports are provided for each of the other six sites. Recommendations regarding selection of sites for 1997 work are provided under separate cover together with a field study design for each of the recommended sites.

2.0
SITE SPECIFIC BACKGROUND INFORMATION

2.1 SITE DESCRIPTION

Buttle Lake is an oligotrophic lake that lies in a "U" shaped valley in the mountains of Strathcona Park, Vancouver Island, British Columbia at an altitude of 218 metres. With a length of 35 km, surface area of 35.3 km^2 and a mean depth of 45 metres, it is the largest lake in the Campbell River watershed (Deniseger and Erickson, 1991). Buttle Lake drains northward through a short channel into Upper Campbell Lake, BC (Figure 2-1). B.C. Hydro controls water levels of both lakes at Strathcona Dam. Water levels in Buttle Lake are typically lowered 8.4 metres, but can be lowered as much as 12 metres by B.C. Hydro. The Campbell River system continues eastward some 20 km through lower Campbell Lake, John Hart Lake and the Campbell River, and eventually flows to the sea.

The Myra Falls flotation mill and underground mine located on the southern end of Buttle Lake have been in operation since 1967. The ore deposits are complexly zoned volcanic, massive sulphides within the Myra Formation of the Slicker Group volcanic assemblage. The lenses of the massive sulphides comprise banded chalcopyrite, galena, sphalerite, barite, and pyrite. Most of the commodities mined in this operation, such as copper, lead, zinc, silver, and gold, come from these sulphide deposits.

Similar to the Sullivan orebody, sulphide mineralization of this area is known to be conducive to production of acid rock drainage (ARD). Sulphuric acid and ferric iron are produced when pyrite in the orebody is exposed to air and water. The acidity and ferric iron then solubilize metals, such as copper and zinc, contained within the ore rock. These metals can eventually drain into Myra Creek and Buttle Lake. However, the mine installed a water-collection and treatment system in 1983 that reduced metal loadings into Myra Creek by an estimated 80% (Deniseger et al., 1990).

2.2 HISTORICAL DATA REVIEW

Since 1980, a number of groups (e.g., academic, consulting, government, mine) have conducted chemical and biological monitoring of Buttle Lake to determine the extent of the mine's impact on the receiving environment. Available historical information is summarized in Table 2-1. Early studies showed that concentrations of zinc and copper in water had increased significantly in some of the lakes within the Campbell River watershed since mining operations began in 1966 (Roch et al., 1985; Deniseger et al., 1990). For example,

10

Figure 2-1. Site location map: Myra Falls Mine

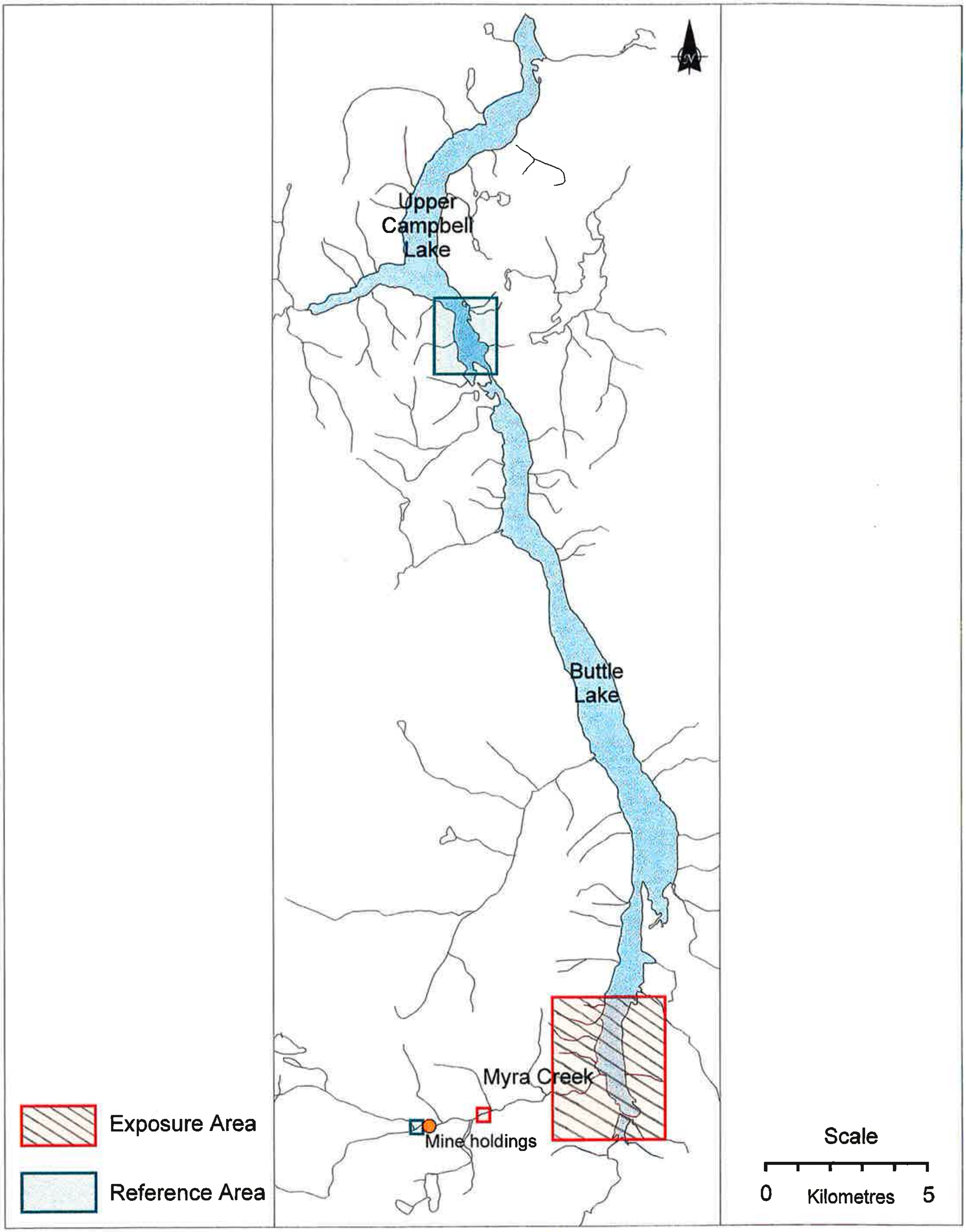


Table 2-1. Summary of the available historical information from Myra Creek and Buttle Lake, Vancouver Island, BC.

SOURCE	TOXICITY (BIOASSAYS)	WATER QUALITY	SEDIMENT QUALITY	PLANKTON	BENTHOS	FISH	SUMMARY
Clark, 1980		+					Metals in water samples taken at depth in Buttle Lake were elevated compared to surface water samples.
Clark and Morrison, 1982a				+			Tailings disposal did not affect zooplankton populations in Buttle lake except for Daphnids.
Clark and Morrison, 1982b		+					Concentration of zinc in water at Buttle Lake has increased since mine operations began.
Clark and Morrison, 1982c						+	Copper was elevated by a factor of 6 in fish livers from Buttle Lake compared with reference lakes.
Clark and Morrison, 1982d		+				+	Zinc and cadmium levels were elevated in water samples from exposure sites as compared with reference sites. Fish liver metallothionien levels were also higher at exposure sites.
Clark and Morrison, 1982			+				Copper, zinc and cadmium levels were elevated in sediment grabs from exposure sites as compared with reference sites.
Kelso and Jones, 1982		+					Water samples taken in several locations in Myra Creek showed contamination downstream of the mine water collection system.

Table 2-1 (continued).

SOURCE	TOXICITY (BIOASSAYS)	WATER QUALITY	SEDIMENT QUALITY	PLANKTON	BENTHOS	FISH	SUMMARY
Roch et al., 1982						+	Copper and cadmium were elevated in fish livers from exposure sites compared with reference sites while zinc was not.
Austin and Munteanu, 1984		+		+			Heavy metal sensitive plankton species were rare compared with previous years and control lakes. Copper, cadmium and zinc were above background for the region.
Austin et al., 1985				+			Plankton species richness had declined over time at Buttle Lake.
Godin and Jones, 1985		+					High metal concentrations found in Myra Creek; particularly downstream of the mine water collection system.
Roch et al., 1985	+	+		+			Zinc was elevated in water at exposure sites compared with reference sites. Phytoplankton species diversity had declined since mining activity began. Steelhead parr 96 hr toxicity tests indicated toxicity at the exposure site but none at the reference site.

Table 2-1 (continued).

SOURCE	TOXICITY (BIOASSAYS)	WATER QUALITY	SEDIMENT QUALITY	PLANKTON	BENTHOS	FISH	SUMMARY
Deniseger et al., 1990		+		+		+	Zinc, copper and cadmium decreased with distance from the mine. Phytoplankton diversity had decreased since metal loading into Buttle Lake began. Copper and cadmium liver tissue levels were elevated compared with reference sites.
Deniseger and Erickson, 1991		+		+		+	Metals in the water column and fish tissue at Buttle Lake have decreased since 1986, although copper and cadmium in fish livers remained high. Plankton species richness has increased since 1985.
Westmin Resources, 1996		+					Zinc in water was slightly elevated in the exposure area compared with the reference area. 1995 concentrations in the exposure area were higher than in 1994.

in 1981 surface water concentrations at the south basin of Buttle Lake reached as high as 370 µg/L zinc, 40 µg/L copper, 25 µg/L lead, and 3.6 µg/L cadmium (Deniseger et al., 1990). Since the early 1980s metal concentrations have been decreasing in the receiving environment (Table 2-2), which is attributable to several process changes that have improved effluent quality (Deniseger et al., 1990). In addition, tailings disposal to the lake was also eliminated. Metals levels in Myra Creek were also lower in 1995 than 1982 (Table 2-3).

Table 2-2. Comparison of chemical water quality parameters (µg/L) among years for Buttle Lake Stations.

TOTAL METALS	1995[A]	1989[B]	1985[B]	1980[B]
Station 0130082 - south end of Buttle Lake near Station E1 of this study (exposure)				
Cadmium	0.1 - 0.2	0.1 - 0.3	<0.5	<0.5 - 1.3
Copper	1 - 8	<1 - 6	<1 - 7	5 - 30
Lead	<1	<1 - 2	<1 - 1	<1 - 4
Zinc	10 - 53	12 - 40	30 - 70	110 - 370
Station 0130088 - northern end of Buttle Lake (reference)				
Cadmium	-	<0.1 - 0.3	<0.5 - 1.5	<0.5 - 1.3
Copper	-	<1 - 5	<1 - 6	5 - 10
Lead	-	<1 - 2	<1 - 4	<1 - 1
Zinc	-	7 - 30	24 - 50	85 - 143
Station 0130080 - southern end of Upper Campbell Lake (reference)				
Cadmium	<0.1 - 0.4	<0.5	<0.5 - 0.6	<0.5 - 0.8
Copper	2 - 7	<1 - 4	<1 - 4	3 - 10
Lead	<1 - 1	<1 - 3	<1 - 2	<1 - 13
Zinc	6 - 21	10 - 55	20 - 70	70 - 150

a Westmin Resources, 1996
b Deniseger and Erickson, 1991

Table 2-3. Comparison of chemical water quality parameters (μg/L) among years for Myra Creek.

TOTAL METALS	1995[A]	1985[B]	1982[C]
Station M2 - downstream of mine discharge (exposure)			
Cadmium	<0.1 - 0.7	3 - 4	0.6 - 0.7
Copper	3 - 12	135 - 142	23 - 26
Lead	<1 - 1	<1	-
Zinc	48 - 512	706 - 718	288 - 291
Station M1 - upstream of mine discharge (reference)			
Cadmium	<0.1	<0.6	<0.6
Copper	1 - 4	<1	<1
Lead	<1	<1 - 2	-
Zinc	<5	<2	<2

a Westmin, 1996
b Godin and Jones, 1987
c Kelso and Jones, 1983

Little sediment data are available. Early data indicate that metals tended to accumulate in the southern end of the Buttle Lake and decrease northward (Table 2-4).

Table 2-4. Comparison of chemical parameters (μg/g) in sediments among sample stations in Buttle Lake (Clark and Morrison, 1982a-d).

SITE	CADMIUM	COPPER	ZINC	LEAD
Site A(near E1, this study)	19/20	1220/1110	6380/6380	122/72
Site B(north of E2, this study)	11	1800	3980	349
Site C	6/<1	916/183	2230/144	559/50
Site D	<1/<1	188/187	115/109	38/29
Site E	1/<1/<1	304/181/168	626/133/124	118/53/39
Site F	<1	216	280	67
Site G (northern end of Buttle Lake)	<1/<1/<1	277/176/190	406/96/101	73/53/42

Some samples were bi- or tri- sectioned as noted (x/x or x/x/x), surface is left most value.

Past research has shown that increased metal levels in water at Myra Creek and Buttle Lake negatively affected aquatic organisms. For example, algal species diversity was lower at Myra Creek downstream of mine operations compared with the upstream control site (Deniseger et al., 1986). Furthermore, plytoplankton diversity was lower in Buttle Lake compared to pre-mining operations (Roch et al., 1985).

Kathman (1982) observed lower species richness and abundance of benthic organisms in Buttle Lake than in downstream lakes (i.e., Lower Campbell, John Hart, and Upper Quinsam Lakes). Furthermore, a number of pollution tolerant species, such as the chironomid larvae *Procladius* and *Thienemannimya*, were found at stations closest to the mine. Zooplankton diversity was also lower in areas of Buttle Lake closest to the mine. Specifically, cladoceran and calanoid copepod numbers and species diversity increase as metal concentrations decline downstream from the mine (Roch et al., 1985). Bioassay experiments with *Daphnia pulex* showed that a 60-70% dilution of Buttle Lake water resulted in 50% mortality (Roch et al., 1985).

Copper and cadmium concentrations in liver tissue and hepatic metallothionein levels from rainbow trout (*Onchorhynchus mykiss*) collected from Buttle Lake were correlated with metals in water, whereas zinc levels in fish tissue from Buttle Lake were not different from fish collected in reference lakes (Roch et al., 1985). Using rainbow trout, field toxicity tests conducted in 1982 at the south end of the lake showed that mortality was less than 2%. In addition, laboratory tests using water from Buttle Lake indicated no toxicity to swim-up rainbow trout (Roch et al., 1985).

Implementation of improved mine drainage in 1980 has improved the water quality of the effluent and of Buttle Lake. For example, metal concentrations in water have decreased throughout the Campbell River watershed since 1980 (Deniseger et al., 1990). By late 1985, some metal sensitive phytoplankton and zooplankton taxa appeared. In addition, metal and hepatic metallothionein levels in rainbow trout muscle tissue have decreased significantly. Hepatic metallothionein levels have declined to levels thought to be representative of minimum biological stress (Deniseger and Erickson, 1991). This apparent improvement in fish health is thought to be responsible for dramatic improvement in angler success and catch statistics.

3.0
METHODS

3.1 STUDY AREA

The study area was located in Strathcona Park, Vancouver Island, BC in Myra Creek, Buttle Lake and Upper Campbell Lake. The reference area was located upstream of all mine activities and the exposure area was located downstream of Myra Creek. Exposure stations were located at the southern end of Buttle Lake on the east shore just north of the mouth of Myra Creek. Reference stations were located north of the Gold River bridge on the east shore of Upper Campbell Lake. The general locations of these sites were selected on the basis of historical information (Deniseger et al., 1990; Deniseger and Erickson, 1991).

3.2 EFFLUENT CHARACTERIZATION AND SUBLETHAL TOXICITY

The sublethal toxicity tests performed by B.A.R. Environmental were: *Lemna minor* growth inhibition, *Ceriodaphnia dubia* survival and reproduction, fathead minnow survival and growth inhibition, and salmonid embryo tests. The sublethal toxicity test performed by Eco-CNFS was the *Selenastrum capricornutum* microplate growth inhibition test.

Methods for receiving water and effluent collection are specified in *Project # 4.1.2a, Extrapolation Study (August 23, 1996).* Receiving water samples were collected by mine personnel from each reference station prior to commencement of the 1996 field program. These samples were necessary to determine if receiving waters cause toxicity to either *Ceriodaphnia dubia* or fathead minnow and, if so, to acclimate these organisms to the water before toxicity evaluation. Receiving water samples (413 L) were collected from the reference sites and shipped cooled to B.A.R. Environmental. Approximately 0.2 L was shipped cooled to Eco-CNFS. At the end of each mine field program, effluent samples were shipped within 72 hours of sampling to B.A.R. Environmental (139 L) and Eco-CNFS (0.2 L). All sample containers, chain of custody forms were provided by B.A.R. Environmental.

In addition to the effluent collected for toxicity testing, samples of effluent were collected and shipped to MDS Laboratories to be analyzed for the same suite of parameters as were analyzed for the receiving water.

3.3 HABITAT CHARACTERIZATION, CLASSIFICATION AND SAMPLE STATION SELECTION

A Petite Ponar grab was used to collect and characterize sediment in the reference and exposure areas. To assess sediment characteristics (e.g., relative particle size, presence of organic matter, colour), five replicate grabs were collected from random points at each of the reference and exposure stations. If the grab was deemed acceptable (e.g., minimal leakage of sediment from sampler), the material collected in the sampler was placed in a Pyrex dish and evaluated. In addition, pictures were taken of sediment collected for most grabs, especially if the sediment was uncharacteristic of previous grabs.

For habitat characterization of Myra Creek, we used methods similar to those in the Department of Fisheries and Oceans (DFO) and the New Brunswick Department of Natural Resources and Energy (NBDNRE) habitat characterization form.

One of the objectives of this years' field program was to determine whether there are significant differences in various chemical and biological measures between the reference and exposure areas. As a result, our method for sample station selection at all of the mine sites was to locate stations that would maximize the probability of detecting differences if they existed. Historical sampling stations were used when feasible because this allowed the possibility of using historical data in station selection for this year and for site selection in 1997. Using more recent data collected from historic sampling stations allowed us to assess the potential for using these stations as "benchmarks" for selection of the remaining stations within a particular area (reference and exposure). For example, if metal levels in water collected from a historical reference area were below analytical detection, then this site could provide an appropriate reference station to be used as a starting point, or benchmark, for selection of the remaining reference stations. When possible, we attempted to locate sampling stations within the exposure and reference areas that were as alike as possible in regards to physical and chemical parameters to minimize other sources of variation. By doing this, we increase our probability of detecting biological and chemical differences that result from metal inputs into that system.

Buttle Lake was unique among the seven sites in that very little sediment or benthic work has been conducted to date and the lake is extremely deep making quick, visual or physical assessments of the lake bottom difficult. One study on the benthic invertebrate fauna of the Campbell River watershed collected samples from the littoral zone (i.e., portion of the lake where sunlight penetration is to the bottom) (Kathman, 1982). There appear to be no other studies that could have provided information on sediment characteristics of Buttle Lake, and therefore would have helped in station selection for 1996. Without extensive prior information on substrate characteristics of Buttle Lake, we also used historical water quality data and site logistics to help determine station selection.

Positional information for field sampling stations was collected using a Trimble GeoExplorer global positioning system (GPS) receiver. Approximately 120 position readings were acquired for each station for differential post-processing. All GPS data collected in the field were downloaded to a personal computer for post-processing using Trimble Geo-PC software. These position readings were corrected using base station data from the BC Active Control System in Victoria. Expected accuracies using this method are within 10 m in the horizontal. Following correction, a visual check to determine possible anomalies in the field collected and/or corrected data was conducted. This check involved comparing the corrected data to the uncorrected data with additional information drawn from field log books. Following averaging and data inspection, any unexpected results were discussed with field personnel and positions within a file were averaged to provide a single positional solution for each station. All positions were then combined into a single file and output to the AutoCAD DXF file format for possible future incorporation into AutoCAD or GIS spatial files.

3.4 WATER SAMPLES

Field measurements of temperature, conductivity, and pH were taken at a number of depths in Buttle Lake and at the surface in Myra Creek using a Hydrolab H_20 multiprobe. All field instruments were calibrated prior to use and values were recorded manually in the field.

One replicate water sample was collected from 5 reference stations (located fairly close together and 6 exposure stations in Buttle Lake, as well as two locations (one reference and one exposure station) in Myra Creek. Sub-surface (i.e., mid-depth) grab samples were collected from Buttle Lake using a plexiglass Sutek sampler. Samples were collected for total and dissolved (i.e., operationally defined as water filtered through a 0.45 µm filter) metals. The dissolved samples were field-filtered according to standard methods (APHA 1995 - Section 3030B). Both metals samples (total and dissolved) were placed in bottles that were acidified with ultrapure HNO_3 (provided by the analytical laboratory) to a pH <2. Sample bottles, sample preservatives and sample analyses are summarized in Table 3-1. All samples were shipped on ice to MDS Laboratories for analysis. In the laboratory, samples were analysed for the following parameters: total and dissolved metals (an ICPMS low level metals scan was conducted), cations and anions, nutrients, hardness, alkalinity, dissolved organic and inorganic carbon, turbidity, and total suspended solids.

Table 3-1. Summary of bottles and preservatives used and analyses conducted on water chemistry samples collected at each sampling station.

SAMPLE BOTTLE	PRESERVATIVE	ANALYSES
1 - 500 mL HDPE	none	Total Suspended Solids (TSS)
1 -1 500 mL HDPE	none	General Chemistry Cations and Anions *(Alkalinity as $CaCO_3$, Chloride, Sulphate, Anion Sum., Bicarbonate as $CaCO_3$, Carbonate as $CaCO_3$, Cation Sum., Colour, Conductivity, Hardness as $CaCO_3$, Ion Balance, Langelier Index at 20 °C, Langelier Index at 4 °C, pH, Saturation pH at 20 °C, Saturation pH at 4 °C, Total Dissolved Solids, Turbidity)*
1 - 100 mL glass	none	Dissolved organic carbon (DOC) Dissolved Inorganic Carbon (DIC)
1 - 250 mL glass	H_2SO_4	Nutrients *(Nitrate, Nitrite, Ammonia, Total Kjeldahl Nitrogen, Phosphorus, Orthophosphate)*
1 - 250 mL HDPE	HNO_3	Total Metals *(Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Chromium, Cobalt, Copper, Calcium, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Reactive Selenium, Silica (SiO_2), Silver, Sodium, Strontium, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc)*
1 - 250 mL HDPE	HNO_3	Dissolved Metals (as for total metals)

QA/QC of receiving water chemistry included, in addition to all three firms submitting samples to the same analytical laboratory, collection and analysis of one transport or trip blank, one filter blank and one field replicate (collected at the exposure station closest to the effluent discharge). Because a Sutek sampler was used, a sampler blank was collected.

The untransformed water chemistry data were first assessed for normality and then log transformed (log base 10) as required. All data were log transformed, as review of data indicated non-homogeneity of variances. Exposure and reference data were compared using Students *t*-test (SYSTAT, 1992). Prior to *t*-test analysis, Bartlett's test for homogeneity of variance was conducted. Pooled variance *t*-test results were used when variances were homogeneous. Separate variance *t*-test results were used when variances were heterogenous. Means were considered to be significantly different at $p < 0.05$.

3.5 SEDIMENT SAMPLES

Sediment samples for chemistry were collected using a 0.059 m^2 (23 cm x 23 cm) galvanized Standard Ponar grab as our 0.0225 m^2 (15 cm x 15 cm) stainless-steel Petite Ponar grab was lost at the first station. Grabs were accepted based on several criteria (Environment Canada, 1995): 1) sediment was not extruded from the upper face of the sampler, 2) overlying water was present indicating minimal leakage, 3) overlying water was not excessively turbid and the sediment surface within the grab was relatively flat indicating minimal disturbance/winnowing, 4) the penetration depth was at least 4-5 cm. Samples not meeting these criteria were rejected.

Five field replicate grab samples were collected at each station to test sediment chemistry. Sampling for chemistry analyses involved using a pre-cleaned plastic spoon to deposit the top 2 cm of sediment collected from the centre of each Ponar grab (i.e., sediment not in contact with the walls of the grab) into a pre-cleaned Pyrex glass bowl. The Ponar grab, mixing bowls and plastic utensils were cleaned between sampling stations using the following protocol: 1) water rinse, 2) phosphate-free soap wash, 3) deionized water rinse, 4) 20% nitric acid rinse, 5) deionized water rinse. Once five successful grabs were collected, the sediment (i.e., composite of five grab samples) was thoroughly stirred until homogenous in colour and texture.

Homogenized samples were placed into two pre-cleaned 250-mL glass containers for chemical analysis. Sample containers were filled to capacity with minimal head space. Duplicate jars were collected at all stations in case of breakage during shipping. Between stations, the Ponar grab was washed as noted above.

All sample jars were labeled, and sample collection information was entered onto a field data sheet. Sediment samples were stored and transported in coolers packed with ice packs. Samples were shipped to MDS Laboratories for analyses of metals, total organic carbon, particle size and loss on ignition. All pertinent information was included on the chain-of-custody (COC) sheets which accompanied the samples to the various laboratories. If any anomalies in sample submission had been detected (none were), they would have been immediately communicated to field personnel for clarification.

Quality assurance/quality control (QA/QC) for sediment sampling included, in addition to all three firms submitting samples to the same analytical laboratory, a split sample from the exposure station, and a swipe blank collected to determine the effectiveness of field decontamination procedures (e.g., a deionized water-wetted, ashless filter paper was used to wipe down the sampler and mixing bowl/spoon surfaces likely to contact the sample media). Details of the QA/QC procedures followed are provided in Appendix A.

The untransformed sediment chemistry data were first assessed for normality and then log transformed (log base 10) as required. All data were log transformed, as review of data distribution showed the data violated assumption of normality. Exposure and reference data were compared using Students *t*-test. Prior to *t*-test analysis, Bartlett's test for homogeneity of variance was conducted. Pooled variance *t*-test results were used when variances were homogeneous. Separate variance *t*-test results were used when variances were heterogenous. Means were considered to be significantly different at $p< 0.05$.

3.6 BENTHOS SAMPLES

3.6.1 Sample Collection

In Myra Creek samples for benthic invertebrates were collected from one reference and one exposure station using a Hess sampler with a 250 µm mesh net. Both stations were historical water quality stations with the reference station upstream of all mine activities and the exposure station downstream of all mine activities. Substrate within the area (0.1 m^2) of the sampler was disturbed to a depth of 5 cm and each rock within the sampler area was thoroughly scrubbed clean of invertebrates. Samples were preserved and shipped as described below.

In Buttle Lake or Upper Campbell Lake, samples for benthic invertebrates were collected using a 0.0225 m^2 stainless steel Petite Ponar grab or a 0.059 m^2 galvanize Standard Ponar grab. Benthic samples were collected synoptically with sediment chemistry samples (when sediment samples were collected). One grab sample was collected from each station. Samples were used if there was full penetration of the grab and it remained closed at the surface. Samples were carefully sieved in the field using 250 and 500 µm plastic mesh sieves. All macroinvertebrates retained on each sieve were fixed with 100% buffered formalin (shipboard) to attain approximately 10% final concentration separately. Labeling and field records were prepared as for water and sediment chemistry samples and accompanied the samples to the sorting and taxonomic facilities (Zaranko Environmental Assessment Services, Guelph, ON).

3.6.2 Sorting and Taxonomy

Invertebrates in each sample were counted and identified to genus level. QA/QC for the benthic invertebrate sample analyses included: 1) 10% resort of samples to confirm 95% sorting efficiency, 2) 10% of each sample sub-sampled for determination of sub-sampling error, 3) all sorted of sorted and unsorted fractions retained until taxonomy and sorting efficiency confirmed, 4) development of a voucher collection, 5) taxonomy verified by an independent expert, 6) all three firms submitted samples to the same taxonomist. Details of the QA/QC procedures followed are provided in Appendix A.

The untransformed benthic community variables (i.e., total abundance, total richness, EPT abundance and EPT richness) were first assessed for normality and then log transformed (log base 10) as required. Exposure and reference data were compared using Students *t*-test. Prior to *t*-test analysis, Bartlett's test for homogeneity of variance was conducted. Pooled variance *t*-test results were used when variances were homogeneous. Separate variance *t*-test results were used when variances were heterogenous. Means were considered to be significantly different at $p< 0.05$.

3.7 FISHERIES

3.7.1 Collection

Extensive fisheries work has been done in the Campbell River drainage (Roch et al., 1985; Deniseger et al. 1990, Deniseger and Erickson, 1991). Objectives of the present study were, therefore, limited to confirming species presence/absence in the Buttle Lake exposure area and in the Upper Campbell River reference area and to estimating catch per unit effort (CPUE) for selected catch methods. Fish collection in Buttle Lake was confined to the south end of the lake immediately adjacent to the effluent discharge via Myra Creek. Stations selected duplicated historical sampling stations on the south-east side of the lake. The reference area was located at the south end of Upper Campbell Lake just north of the narrows separating Buttle and Upper Campbell Lakes. Analysis of historical water quality data indicated that Upper Campbell Lake was not influenced by the effluent discharge. Although a brief reconnaissance of Myra Creek indicated the presence of fish in deep pools upstream of the mine site, lack of time precluded attempting fish collection in the creek.

Gillnetting was the primary fish capture method employed by previous studies in Buttle Lake and was used during the present study. Sinking and floating gillnets were used to collect fish at reference and exposure areas. At least two multi-panel gillnets were set in each area. Combination gillnets included: one sinking four panel net comprising alternating 15 m long and 2.5 m deep panels of 5 cm and 10 cm stretched mesh; one sinking three panel net comprising alternating panels of 10 cm, 5 cm, and 10 cm mesh; and. one floating two panel net comprising panels of 5 cm and 10 cm mesh. Gillnet type (i.e., floating versus sinking) and mesh size selection were determined through review of historical sampling data. Placement of gillnets was determined by water depth and prevailing current and wind conditions.

Gillnets were checked frequently (i.e., every hour) to determine catch success and to prevent mortality among fish captured. Although limited catch sizes were achieved during daylight sets, gillnets were removed each day as required by the license requirements (i.e., no overnight sets were attempted due to the licence requirement that nets not remain unattended for longer than a one hour period). Gillnets were placed in a shallow, sheltered area along the lake bank to avoid deep water and rough water conditions experienced at the middle of the lake. A third three-panel sinking gillnet was deployed at this location to maximize potential catch in the exposure area given the shorter overall duration of individual gillnet sets (i.e., gillnets were generally deployed later in the morning and retrieved earlier in the evening compared to the reference area as a consequence of the increased travel time to access the exposure area by boat).

A total of two days fishing effort was completed at each of the exposure and reference areas. Fishing effort was extended beyond the projected single day in each area in an attempt to compensate for the license restriction which prevented overnight gillnet sets undertaken during previous studies in Buttle Lake. Some angling was also attempted in the reference area. Beach seining was also conducted and minnow traps deployed adjacent to the boat launch at the north end of Buttle Lake, near the Upper Campbell Lake reference area. Beach seining was not attempted in the exposure area due to the steeply sloping banks found in this area of Buttle Lake. All fish captured were weighed and measured (standard, fork, and total length) and released unharmed where possible.

3.7.2 Tissue Processing for Metal and MT Analysis

At each of the seven mine sites an evaluation was conducted to determine if fish tissue would be collected for metals and metallothionein analyses. The evaluation was based upon the criteria listed in Table 3-2.

No dissections of captured fish were undertaken to obtain tissue for metal and metallothionein analysis. Although sufficient numbers of rainbow trout might have been captured during the present study if the fishing effort had been extended, this option was not pursued given the considerable data that have been collected in previous programs and the limited time available to complete all components of the present study.

Table 3-2. Criteria used for determination of site suitability for collection of fish tissue for metals and metallothionein analyses.

CRITERIA	ASSESSMENT
1) Presence of Suitable Sentinel Species	a) Are the fish species present benthic feeding? Benthic feeding fish are preferable as a sentinel species due to their greater exposure to metals. If however, no benthic species are present at a site, then the other feeding guilds (e.g., insectivores) must be considered.
	b) Are the fish present relatively sedentary (i.e., Are fish caught in reference and exposure areas species likely to spend most of their time in these areas?) If the selected sentinel species are not sedentary, then is there a barrier (e.g., waterfall, dams, long distance) that physically isolates the reference population from the exposure area and vice versa?
	c) Is the sampling period (September and October) suitable for the selected species? Specifically, fish that are spawning, and therefore possibly moving in and out of reference and exposure areas may not be appropriate sentinel species for the 1996 field surveys. However, if the 1997 field studies occur during a different time period, these fish may be appropriate sentinel species.
	d) Do the fish species at a site have an intermediate life span? Long lived fish may have acclimated to metal exposure, and thus not be suitable for measuring metals in tissue.
	e) Are the fish present large enough to supply the tissue for metals and MT? The approximate size of fish that would have large enough organs to be split is 15-20 cm. Fish larger than 20 cm are preferred. Fish smaller than 10 cm should be frozen whole.
	f) Are species present abundant enough to collect the number of fish needed (8 fish of 2 species/preferably 4 males and 4 females of each species) within a reasonable time limit?
	g) Are similar sentinel species found at the reference and exposure areas? If there is no possibility of collecting similar species at the two locations, it is not worthwhile to consider the site for sampling fish tissue this year.
2) Quality/Quantity of Historical Data and Logistics	a) Have the data been published in peer-reviewed literature (i.e., scientific journal, government publication, consultant report)? If a site has fish tissue data that show a clear difference in metal levels, then further collection of tissue for metals and metallothionein analysis is not warranted.
	b) Is it feasible to maintain fish frozen at a site for the required amount of time? Is it possible to maintain a 100 kg block of dry ice for a week depending on outside temperatures and how often the cooler is opened and closed?

When applying the criteria to a site, Criterion #1 was of primary importance, especially regarding sub-criteria "b" (i.e., mobility) and "f" (i.e., fish abundance). If these two sub-criteria were not met, then fish tissue was not collected. Of particular importance in Criterion #2, is sub-criterion "a". Specifically, if a site already had sufficient fish tissue data to provide enough information for planning the sampling element for fish collection for 1997 at this site, then no further destructive sampling occurred.

4.0
RESULTS

4.1 STATUS OF SAMPLE COLLECTION AND ANALYSIS

Field work was conducted October 7 - 11, 1996. Samples collected and the status of data availability are summarized in Table 4-1.

Table 4-1. Status of sample collection and analysis.

MATRIX	PARAMETERS	NUMBER	DATE COLLECTED	STATUS
Effluent	*Lemna minor* growth inhibition; *Ceriodaphnia dubia* survival & reproduction; Salmonid embryo; *Selinashrum capricornutum* micro plate growth inhibition;	1	collected week of October 21	results received November 18 and December 3
Receiving Water	total & dissolved metals major ions nutrients hardness/alkalinity DOC/DIC turbidity/TSS	13	October 7 - 11	final revised results received December 5
Sediment	metals TOC loss on Ignition particle size	7	October 7 - 11	final revised results received December 5
Benthos	id + enumeration	14	October 7 - 11	results received December 10

4.2 EFFLUENT CHARACTERIZATION AND SUBLETHAL TOXICITY

4.2.1 Effluent Chemistry

Water chemistry data from effluent samples are summarized in Table 4-2. In general, the effluent was elevated in metals compared with the receiving environment; however, one noteable exception was the presence of lead in the receiving environment and its absence in the effluent. This may indicate a natural source for lead. Lead was measured in receiving waters in the 1980s, but was at or below detection limits in 1995 (Table 2-2). There are limited historic data available on lead in the effluent with which to compare the receiving water trend. Conductivity and major ions were also elevated in the effluent compared with the receiving environment.

Table 4-2. Chemistry in effluent samples collected from the Westmin Mine, Myra Falls, BC.

PARAMETER		TOTAL(MG/L)[1]
Metals		
	Arsenic	nd
	Aluminum	0.41
	Cadmium	nd
	Copper	nd
	Iron	1.32
	Lead	0.0005
	Zinc	0.03
Conventionals		
	Conductivity (us/cm)	1120
	Hardness	600
	Turbidity	1
	pH	7.1

nd : not detected
1: Raw data provided in Appendix C.4.

4.2.2 Sublethal Toxicity

Sublethal toxicity data from effluent samples are summarized in Table 4-3. This effluent was sublethally toxic. *Selanstrum capricornutum* was the most sensitive of the species tested, followed by *Lemna minor*, *Ceriodaphnia dubia*, and Fathead Minnow. This trend in species sensitivity is comparable to that observed in study of eight(8) metal mine effluents tested in 1996 (B.A.R. Environmental, 1996).

Table 4-3. Toxicity test results as % v/v of effluent.

TOXICITY TEST	ENDPOINT	IC25	IC50/LC50
7-d *Lemna minor*	Growth	18.3%	42.1%
72-h *Selenastrum capricornutum*	Growth	7.0%	13.5%
7-d *Ceriodaphnia dubia*	Survival	na	80.4%
	Reproduction	33.5%	44.0%
7-d Fathead Minnow	Survival	72.9%	>100%
	Growth	64.4%	93.5%
7-d Rainbow trout embryo	-		-

- controls (lab and receiving water) failed

4.3 SAMPLE STATION SELECTION

Sample stations are shown in Figures 4-1(a) and 4-2(a) and GPS coordinates are provided in Table 4-4. As has already been mentioned, we had limited historical information on the nature of the substrate in Buttle Lake. Ideally, we would have conducted a preliminary survey of the substrate in Buttle Lake in order to determine the type and variation in substrate type between our potential reference and exposure areas. However, since our field program is serving as the preliminary survey for 1997, and the fact that Buttle Lake is both long (35 km) and deep (mean depth = 45 m) (Deniseger and Erickson, 1991), a separate preliminary survey of the lake bottom was not possible. Therefore, we used historical water quality data to drive station selection within the reference and exposure areas. We used the historical station (station #0130080) at Gold River bridge as our benchmark for station selection in the reference area (Figure 4-1(a)). To ensure we minimized the effects of past mining impacts at this site, we began our sample collection 3-4 km north of this historic station. Subsequent stations within the reference area were located 10-30 metres apart, proceeding northward or away from Myra Creek and the mine. Initial grabs were made at 15-20 metres, but it was determined that this depth would be difficult to sample efficiently and we did not observe any benthic invertebrates in these samples. Therefore, to increase the abundance and diversity of benthos and to improve sampler efficiency, additional samples were collected from shallower depths (2-4 m average depth). For the exposure area, we also used the historical station near Henshaw Creek (station #0130082) as our benchmark, with sampling stations proceeding northward from the mouth of Henshaw Creek (Figure 4-2(a)).

Figure 4-1a. Site study area, including historic and reference area sample stations: Upper Campbell Lake

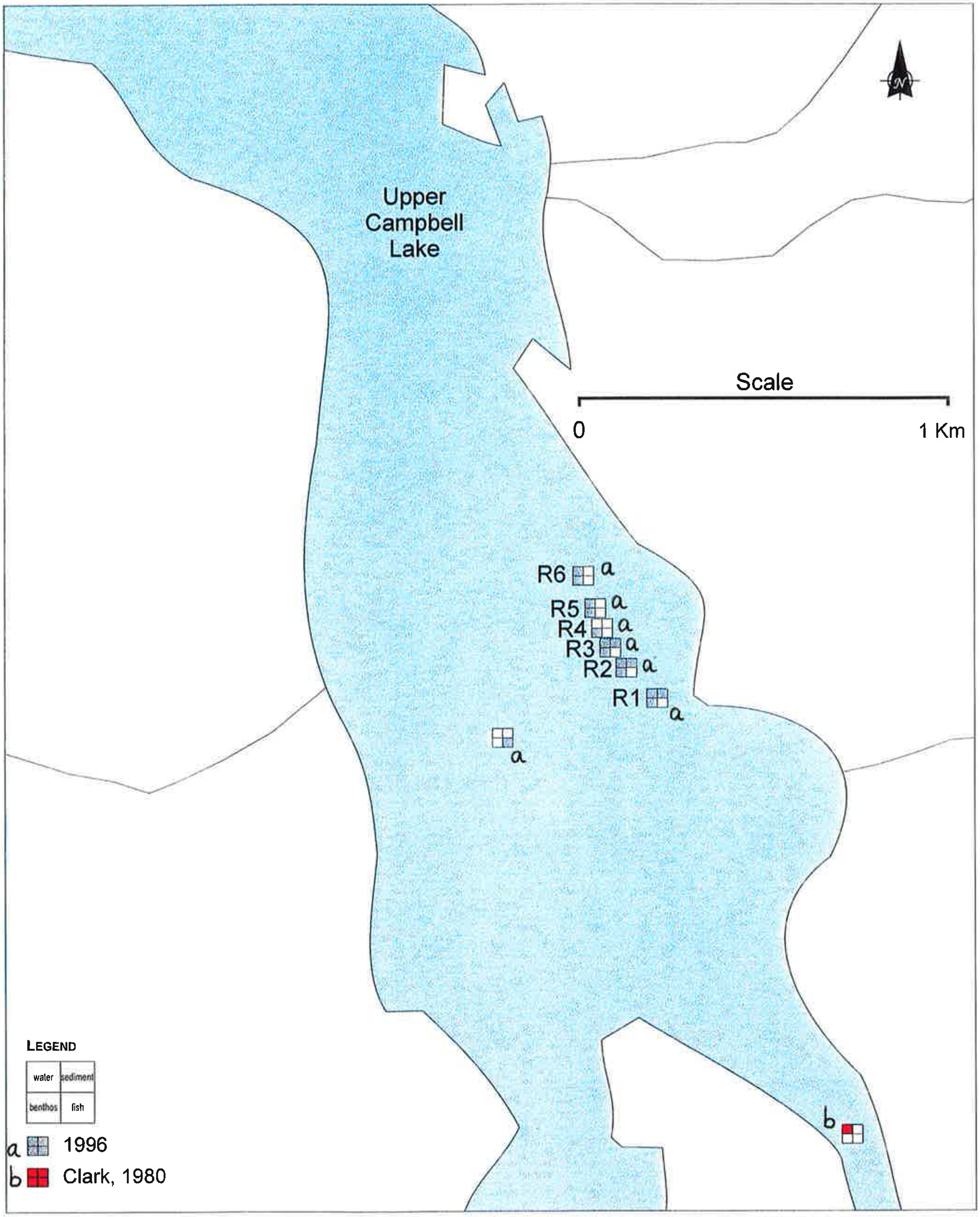


Figure 4-1b. Reference area habitat characterization: Upper Campbell Lake

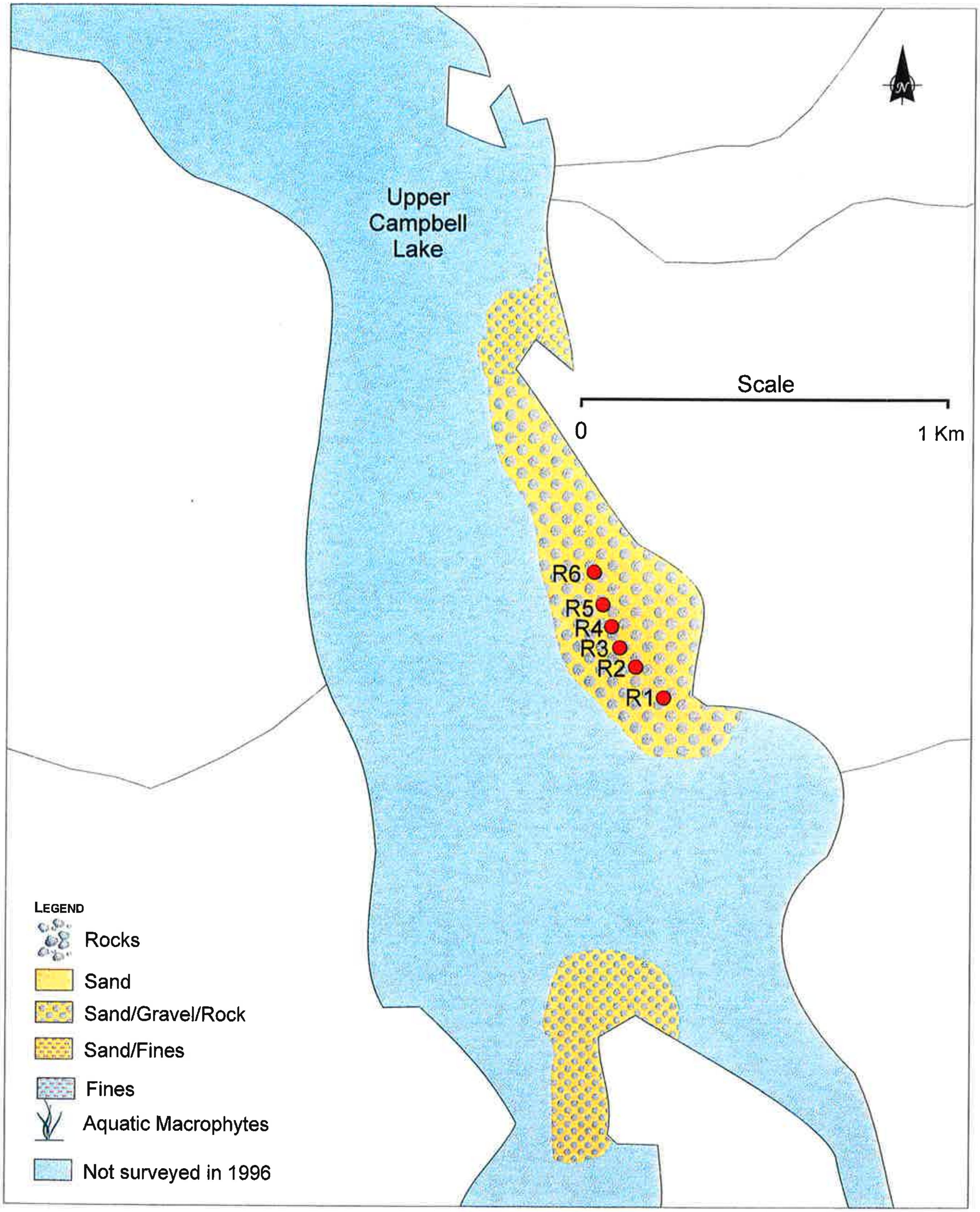


Figure 4-2a. Site study area, including historic and exposure area sample stations: Buttle Lake

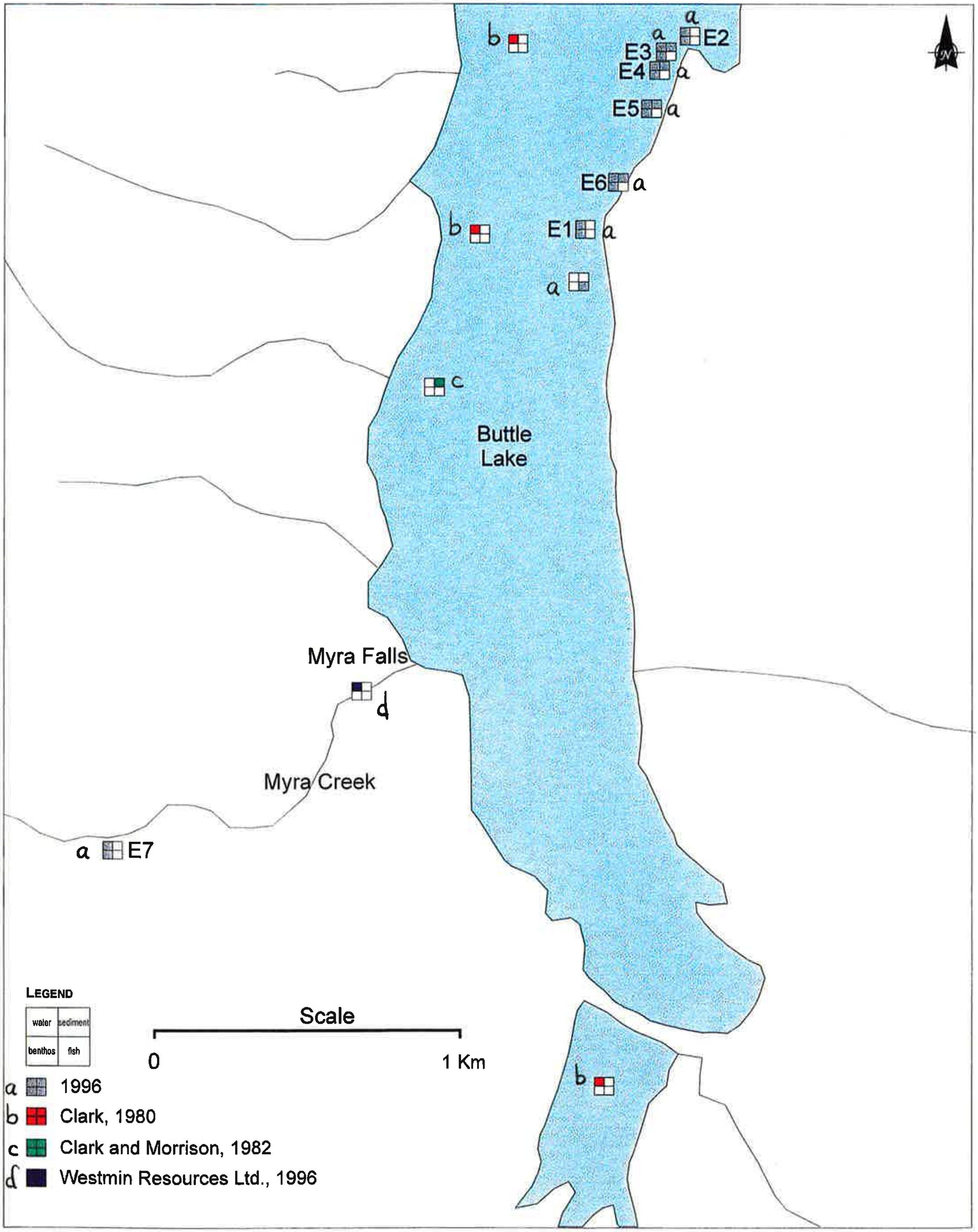


Table 4-4. GPS location of reference and exposure stations, Myra Falls mine.

AREA	STATION	VTM COORDINATES	
		NORTHING	EASTING
Reference	R1	5527940	742268.563
	R2	5528007.5	742227.438
	R3	5528040	742174
	R4	5528087	742143.875
	R5	5528135	742108.438
	R6	5528219.5	742050.313
Exposure			
	E1	5499043.5	749169.938
	E2	5499761	749549.438
	E3	5499708.5	749789.375
	E4	5499661.5	749486.938
	E5	5499548	749430.813
	E6	5499234.5	749313.625
	E7	5496668.5	747231.938

4.4 HABITAT CHARACTERIZATION AND CLASSIFICATION

Selected photographs are provided in Appendix B and habitat characteristics are summarized in Table 4-5.

Table 4-5. Habitat characteristics for Buttle and Upper Campbell Lake stations.

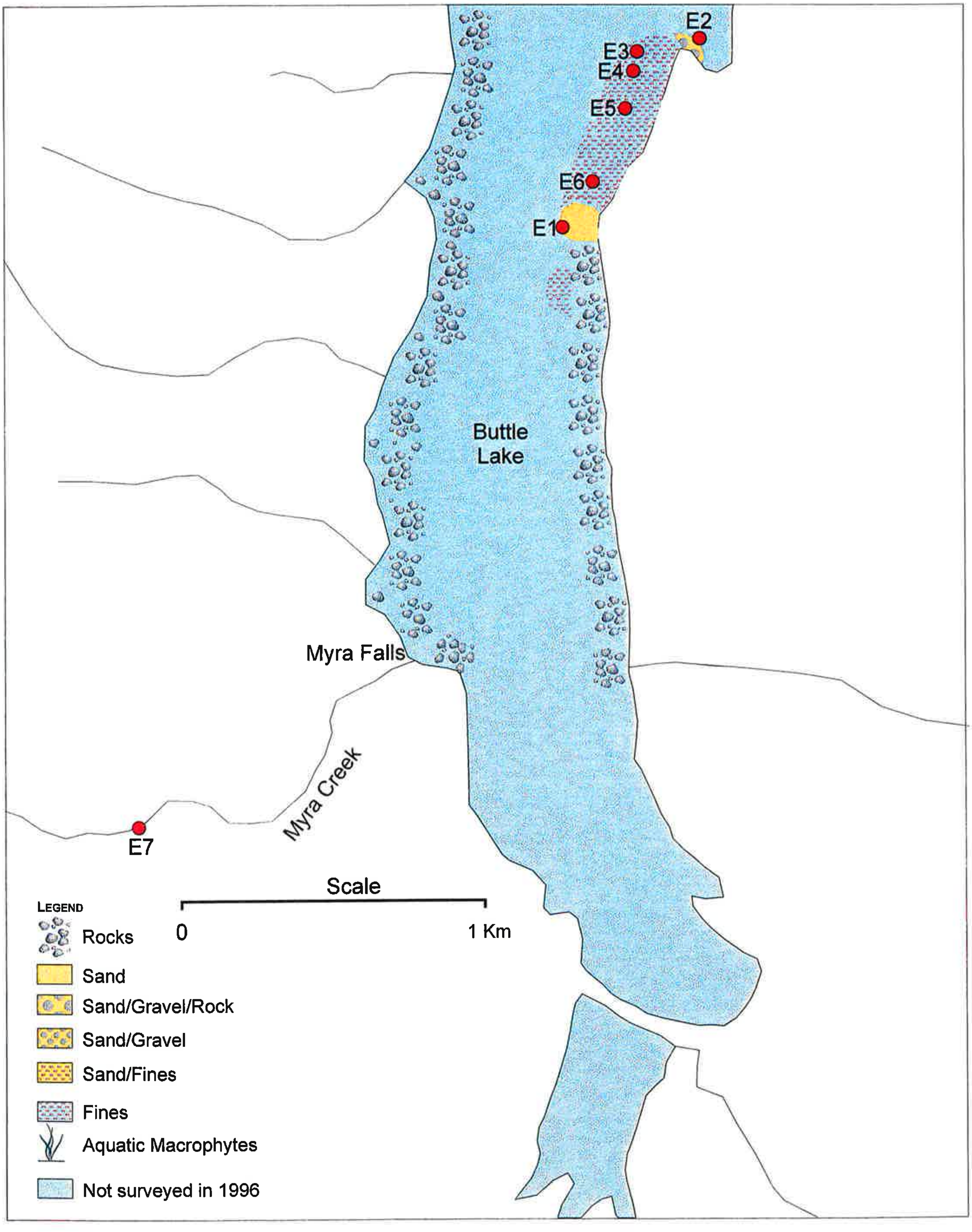
STATION	DEPTH (M)	SUBSTRATE TYPE	OTHER	COLOUR
E-1	2.5	Sand/Gravel	organic debris (e.g., bark)	grey
E-2	0.9	Sand/Gravel	epiphytic mats/balls	grey
E-3	2.4	Silt/Organic Debris	organic debris (e.g., twigs)	brown
E-4	2.9	Silt	high organic debris; brown layer at surface (0.5 cm); epiphytes	grey/brown
E-5	4.2	Silt	wood debris; brown/grey floc	grey with brown top layer and some black
E-6	4.9	Silt	moderate organic debris; brown/grey floc	dark grey with rust/brown layer at surface
R-1	6.2	Sand/Gravel	wood debris	brown
R-2	5.0	Silt/Sand	debris	dark brown
R-3	3.2	Gravel some clay	light organic layer on surface of rocks	brown/grey
R-4	1.7	Grave	light organic layer	brown
R-5	2.3	Sand/Gravel	some organic debris	grey
R-6	1.7	Gravel	some organic debris	grey

4.4.1 Upper Campbell Lake/Buttle Lake

Habitat characteristics are summarized in Table 4-5. The reference area (Upper Campbell Lake) was dominated by steep-sided shores and rocky substrate. Water depth at the reference stations was approximately 2 - 4 m with one station being 6.2 m deep. Little organic matter (primarily algal mats and small woody debris) was observed in grabs from these stations (Figure 4-1(b)).

Similar to the reference area, the exposure area was dominated by steep sided shores and rocky substrate. The shores were generally steeper and the substrate more angular compared with the reference area. There was a small area on the east shore that was primarily silt with wood debris and some rocky sections. Sediment at four of the stations was primarily silt, while one was sandy with some cobble and the other mostly gravel. Water depth at reference stations ranged from 1 to 3.5 m. Organic matter present was primarily woody debris (i.e., no live macrophytes were present). In addition, there was a light grey/beige floc observed at the silty stations. Its origin is unknown (i.e., it could be organic in nature, some type of precipitate, or tailings from previous discharges) (Figure 4-2(b)).

Figure 4-2b. Exposure area habitat characterization: Buttle Lake



4.4.2 Myra Creek

The reference station at Myra Creek was approximately 4-5 metres wide (main channel width) and 70-100 cm deep. Substrate was primarily bedrock (60%), boulder (20%), rock (10%), and gravel (10%). A large, deep pool was located upstream of the reference station, while the sampling station and downstream of the station was riffle/run habitat. Riparian canopy was dense, and there was no woody debris in the immediate vicinity (Figure 4-2(c)).

Water depth and channel width at the exposure station were similar to that of the reference area. In contrast, substrate size was different, as the overall substrate at the exposure site was smaller (i.e., primarily boulder [20%], rock [40%], rubble [30%], and gravel [10%]). In addition, there was no riparian canopy at the exposure station. Habitat at this site was riffle/run (Figure 4-2(d)).

Figure 4-2c. Reference area habitat characterization: Myra Creek

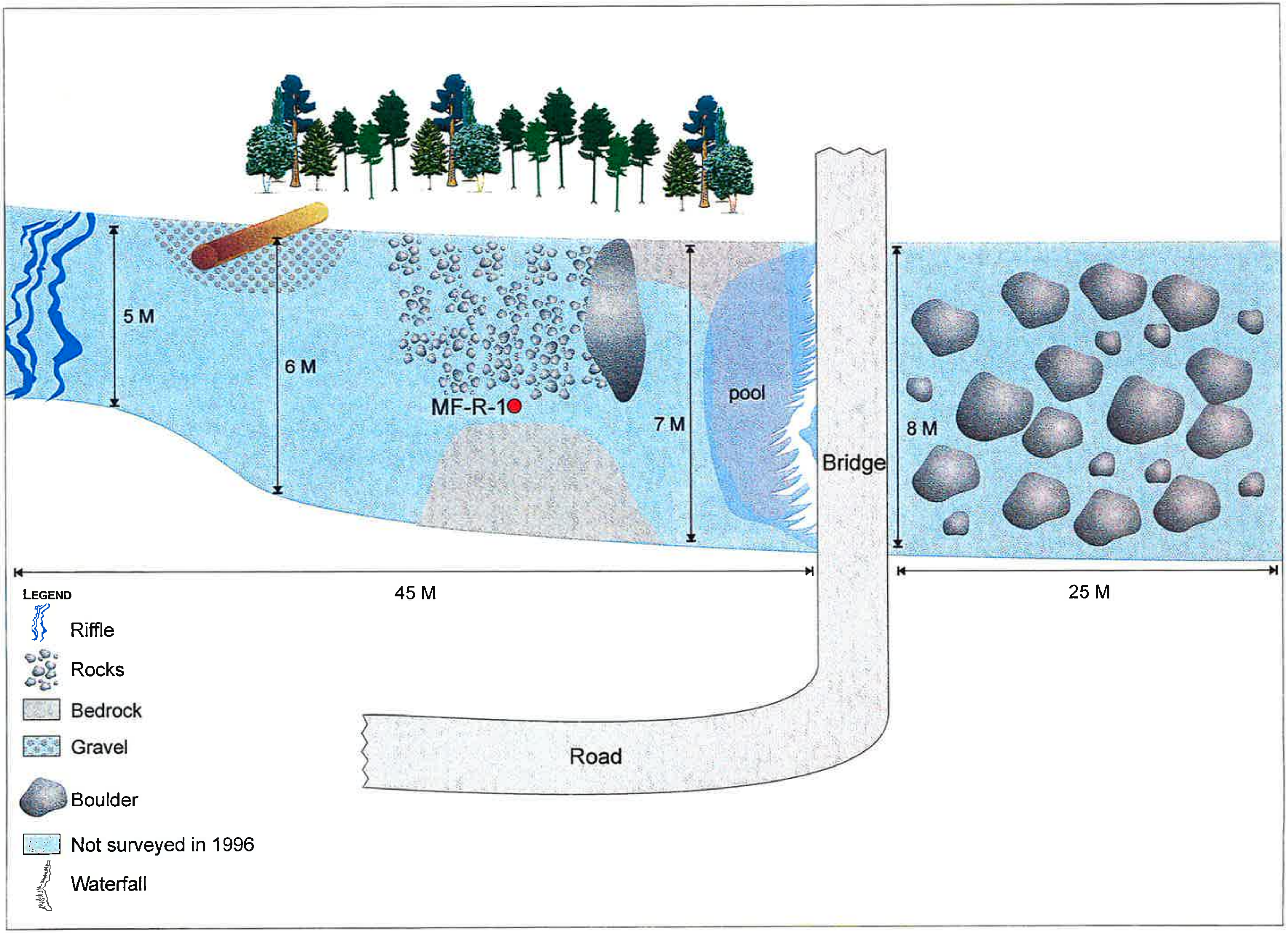
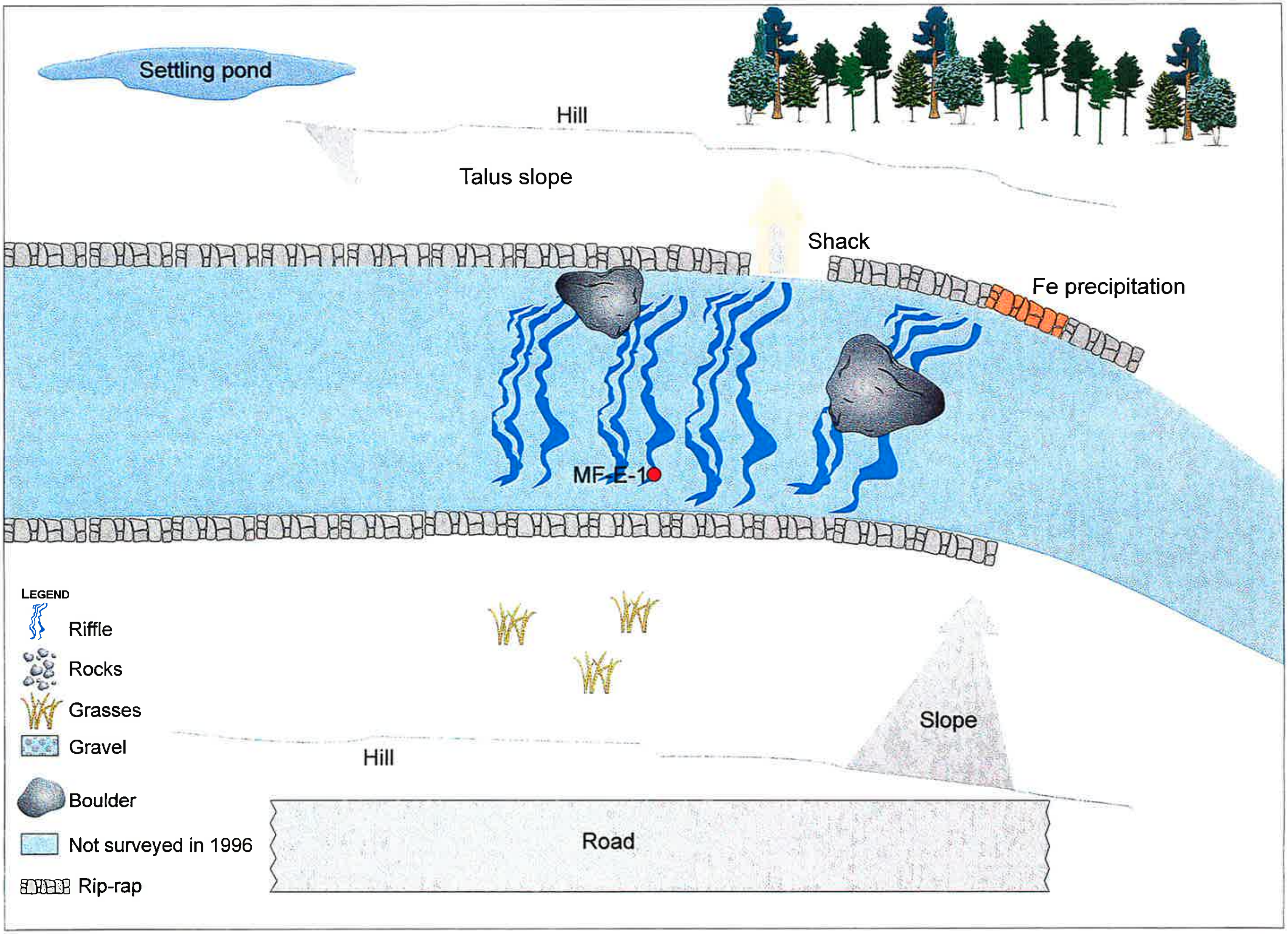


Figure 4-2d. Exposure area habitat characterization: Myra Creek



4.5 WATER CHEMISTRY

4.5.1 QA/QC

Method Blanks:

Method blanks were used by the laboratory to assess possible laboratory-derived contamination, as well as providing information on the stability of established instrumental baselines. Lead, selenium and zinc were detected (within 1 order of magnitude of the limit of quantitation) in the method blanks. This indicates that there was no laboratory-derived contamination except for the parameters detected and that the instrumental baselines were stable (Appendix C.2). Analyte results were background corrected for the process blank by the analytical laboratory.

Certified Reference Materials:

The analysis of certified reference materials (CRMs) provided information on the accuracy of the laboratory performing the analysis. The percent recoveries for the certified reference materials (CRMs) are listed in Appendix C.2. All CRM results were between 85 and 115% recovery and within the range considered acceptable by the laboratory.

Matrix Spikes:

Matrix spikes are sample to which a known amount of analyte has been added. The analysis of matrix spikes provided information on the extraction efficiency of the method on the sample matrix. The percent recovery for matrix spikes is presented in Appendix C.2. All matrix spike recovery results were within 20% of the target concentration and within the range considered acceptable by the laboratory. This indicates that the matrix of samples collected from the study site did not affect analyte recovery (accuracy).

Travel Blanks:

The travel blanks for general water chemistry and total metals (Appendix C.2) did not reveal any contaminants with the exception of total Kjeldahl nitrogen. The deionized water for the travel blanks for these two tests was brought to the field from the EVS Laboratory as the analytical lab did not provide any.

Laboratory Replicates:

Laboratory replicates were taken by splitting a sample before analysis. The replicates were analyzed as an additional sample to provide information on precision. The results of the replicate samples were compared to determine the relative percent difference (RPD). The RPDs of the laboratory replicates are listed in Appendix C.2 (Table C2.1). Laboratory replicates had RPDs less than 16% indicating acceptable precision, with the exception of dissolved sodium. The RPD for one set of replicates was 52.6%; however, the RPD for a second replicate was 15.4%. We were informed by the laboratory that this discrepancy was due to the fact that these samples were within an order of magnitude of the detection limit of 0.2 mg/L, and in this range better duplication is often difficult.

Filter Blanks for Dissolved Metals:

Sodium (0.1 mg/l), lead (0.0002 mg/L) and zinc (0.004 mg/L) were detected in the field filter blank. This analysis was conducted on deionized water shipped from our EVS laboratory to Myra Falls. As the sodium detected was at the LOQ and sodium measured in the field samples was low and comparable between areas, there is no cause for concern. The lead and zinc detected was near the LOQ (0.0001 mg/L and 0.002 mg/L, respectively). Lead measured in the field samples was either low or within an order of magnitude at both areas. Because of this variability it is not likely that the level of lead detected in the filter blank would make a difference. Zinc measured in the field samples was generally one order of magnitude greater than the level detected in the field samples and therefore not likely a significant contributor in terms of what was measured.

Field Homogenization Replicates:

Field homogenization replicates are replicate samples that are taken from the water from the same sampler grab. These samples provided information on laboratory precision and sample heterogeneity. The RPD results of the field homogenization replicates are listed in Appendix C.2 (Table C2.2). The majority of parameters for field replicates had RPDs less than 25% indicating acceptable precision and sample collection in the field. The exceptions were dissolved lead, ion balance and total Kjeldahl nitrogen. These differences were at or near the detection limits. Ion balance differences were due to the low TDS content making ion balance determination difficult.

Field Cross-Contamination (Sutek Sampler) Blank:

Trace amounts of calcium, iron, zinc, aluminum, and lead were present in the Sutek Sampler Blank. Trace amounts of sodium, zinc and lead were present in the Filter Blank sample. Trace amounts of the metals were lower in the filter blank indicating a potential source of trace metals from the Sutek Sampler. However, concentrations in the samples were always lower and often an order of magnitude lower than the trace metals observed in the Sutek Sampler indicating that these same trace amounts were not transferred to the samples.

Other :

The analytical laboratory did not give an ionic balance for some samples as the ionic strength was low. Ion balance is mostly based on samples having a total dissolved solids content between 25 and 1500 mg/L. Although some dissolved metals were greater than total metals, the data are considered acceptable as they were with the analytical capability of the method.

4.5.2 Chemistry

Field collected water quality data are summarized in Table 4-6. Dissolved oxygen data were not collected due to technical difficulties (i.e., faulty meters). Field water quality parameters were comparable between the reference and exposure stations, except for conductivity and pH which were slightly higher at the exposure stations. A field survey of conductivity from north of Myra Creek to north of exposure station E-1, indicated a mixing zone which extended to the vicinity of the exposure stations. Therefore, the differences observed are probably due to mine discharges via Myra Creek.

Table 4-6. Field water quality parameters ($\bar{x} \pm se$) collected at reference and exposure stations (se = standard error).

PARAMETER	REFERENCE	EXPOSURE	t^1	p^2
Temperature (°C)	14.9 ± 0.08	15.0 ± 0.1	0.443	0.669
pH	7.6 ± 0.01	7.7 ± 0.004	3.754	0.006*
Conductivity (mS/cm)	0.057 ± 0.00004	0.063 ± 0.0004	19.325	<0.001*
Turbidity (NTU)	2.6 ± 1.3	25.2 ± 13.5	1.334	0.219

* Statistically significant difference between exposure and reference stations ($p < 0.05$)
[1] Student's *t* statistic
[2] probability value

Water chemistry data for conventional parameters are summarized in Table 4-7 and raw data are provided in Appendix C. There were significant differences between the reference and exposure areas for anion sum, conductivity, pH, and total dissolved solids (TDS).

Water chemistry data for total metals are summarized in Table 4-8 and raw data are provided in Appendix C. There were significant differences between the reference and exposure areas for aluminum, manganese, strontium, calcium, magnesium and sodium. Manganese, strontium, calcium and sodium were elevated in the exposure area compared with the reference area, while aluminum, lead, zinc, and magnesium were elevated in the reference area. Canadian freshwater guidelines for the protection of aquatic life were exceeded for aluminum at both reference and exposure area and for zinc at the reference station.

Water chemistry analysis for dissolved metals is summarized in Table 4-9 and raw data are provided in Appendix C. There were significant differences between the reference and exposure areas for strontium, calcium, magnesium and sodium. Strontium, calcium and sodium were elevated in the exposure area compared with the reference area, while magnesium was elevated in the reference area. Canadian freshwater guidelines for the protection of aquatic life were exceeded for zinc at the reference station

Table 4-7. Conventional parameters ($\bar{x}$ ± se; mg/L unless otherwise noted) in water samples collected from reference and exposure sites compared with Canadian freshwater guidelines (CCME, 1987).

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	T^1	P^2
Alkalinity	-	22.8 ± 0.2	22.5 ± 0.2	-0.980	0.353
Anion Sum	-	0.574 ± 0.004	0.623 ± 0.009	4.909	0.001*
Cation Sum	-	0.61 ± 0.024	0.613 ± 0.003	0.192^3	0.857
Colour (TCU)	-	13.4 ± 5.0	8.7 ± 1.3	-0.899	0.392
Conductivity (μS/cm)	-	60.4 ± 0.7	66.3 ± 0.9	5.309	0.000*
Hardness (as $CaCO_3$)	-	28.5 ± 1.2	28.7 ± 0.2	0.199^3	0.851
Ion Balance (%)	-	3.3 ± 1.63	1.23 ± 0.56	-0.667	0.521
Langlier Index @ 20°	-	-1.39 ± 0.11	-1.13 ± 0.03	$2.421^{3,4}$	0.066
Langlier Index @ 4°	-	-1.79 ± 0.11	-1.53 ± 0.03	$2.421^{3,4}$	0.066
pH	6.5-9.0	7.7 ± 0.1	7.92 ± 0.03	3.016	0.015*
Saturation pH (@20°C)	-	9.04 ± 0.02	9.04 ± 0.01	0.101^3	0.923
Saturation pH (@4°C)	-	9.44 ± 0.02	9.44 ± 0.01	0.101^3	0.923
TDS	-	33.6 ± 0.5	35.7 ± 0.3	3.490	0.007*
Turbidity (NTU)	-	0.2 ± 0.1	0.15 ± 0.02	-1.574	0.150
Ammonia (as N)	-	0.04 ± 0.01	0.04 ± 0.02	-0.208	0.840
TKN (as N)	-	0.11 ± 0.06	0.06 ± 0.02	-0.282	0.785
DIC	-	5.9 ± 0.1	5.87 ± 0.04	-0.754	0.470
Total Dissolved Solids	-	39.6 ± 3.4	15.7 ± 11.8	-3.228^3	0.021*

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded**.
Means include half detection values for stations where parameters were non-detects.
- no guideline available
* Statistically significant difference between exposure and reference stations ($p<0.05$)
1 Students *t*-statistic; all data were logged prior to analyses unless otherwise stated
2 Probability level
3 Variances were not homogeneous as per Bartlett's Test; separate variances T used
4 Values were not logged, as they were negative

Parameters analyzed but not detected at 5 or more stations at either the reference or exposure areas include: Chloride, Fluoride, Nitrate, Nitrite, Ortho-phosphorus, Sulphate, Reactive Silica, Bicarbonate, Carbonate, Dissolved Organic Carbon, Total suspended solids, Acidity, Total Cyanide

Table 4-8. Total metals ($\bar{x}$ ± se; mg/L) in water samples collected from the reference and exposure sites compared with Canadian freshwater guidelines (CCME, 1987) (se= standard error).

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	*t*[1]	*p*[2]
Aluminum	0.005	**0.013** ± 0.003	**0.006** ± 0.001	-2.686	0.025*
Iron	0.3	0.026 ± 0.002	0.02 ± 0.01	-1.383	0.200
Lead	-	0.0084 ± 0.004	0.0019 ± 0.0005	-1.830	0.100
Manganese	-	0.004 ± 0.0004	0.0072 ± 0.0005	4.750	0.001*
Nickel	-	0.001 ± 0.000	0.0012 ± 0.0002	-0.129	0.900
Strontium	-	0.0144 ± 0.0002	0.0172 ± 0.0002	9.499	0.000*
Zinc	0.03	**0.149** ± 0.026	0.021 ± 0.001	-9.978	0.000*
Calcium	-	9.56 ± 0.11	10.60 ± 0.17	4.990	0.001*
Magnesium	-	0.68 ± 0.02	0.50 ± 0.05	-3.200[3]	0.019*
Sodium	-	0.62 ± 0.06	0.83 ± 0.06	2.462	0.036*

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded**

Means include half detection values for stations where parameters were non-detects.

-	no guideline available
*	Statistically significant difference between exposure and reference stations ($p<0.05$)
1	Students *t*-statistic; all data were logged prior to analysis unless otherwise noted
2	Probability level
3	Variances were not homogeneous per Bartlett's test; separate variances T used
nd	not detected
na	not applicable

Parameters analyzed but not detected at 5 or more stations at either the reference or the exposure area include: Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Chromium, Cobalt, Copper, Molybdenum, Selenium, Silver, Thallium, Tin, Titanium, Uranium, Vanadium, Phosphorus, Potassium.

Table 4-9. Dissolved metals ($\bar{x}$ ± se; mg/L;) in water samples collected from the reference and exposure sites compared with Canadian freshwater guidelines (CCME, 1987) (se= standard error).

PARAMETER	GUIDELINE	REFERENCE	EXPOSURE	T[1]	P[2]
Lead	-	0.0016 ± 0.0009	0.0018 ± 0.0005	0.703	0.500
Manganese	-	0.0016 ± 0.0003	0.002 ± 0.001	-0.442	0.669
Strontium	-	0.014 ± 0.000	0.0177 ± 0.0002	9.564	0.000*
Zinc	0.03	**0.166** ± 0.043	0.024 ± 0.003	-2.429[3]	0.066
Calcium	-	9.66 ± 0.20	10.55 ± 0.11	4.073	0.003*
Magnesium	-	0.70 ± 0.03	0.50 ± 0.06	-2.698	0.024*
Sodium	-	0.68 ± 0.02	0.85 ± 0.05	2.966	0.016*

Notes: Means exceeding guidelines for the protection of aquatic life are **bolded**
Means include half detection values for stations where parameters were non-detects.
- no guideline available
* Statistically significant difference between exposure and reference stations ($p<0.05$)
[1] Students *t*-statistic; all data were logged prior to analysis unless otherwise noted
[2] Probability level
[3] Variances were not homogeneous per Bartlett's test; separate variances T used
nd not detected
na not applicable
Parameters analyzed but not detected at 5 or more stations at either the reference or the exposure area include: Antimony, Arsenic, Barium, Beryllium, Bismuth, Cadmium, Chromium, Cobalt, Copper, Lead, Molybdenum, Selenium, Silver, Thallium, Tin, Vanadium, Phosphorus

4.6 SEDIMENT CHEMISTRY

4.6.1 QA/QC

Method Blanks:

Method blanks were used by the laboratory to assess possible laboratory-derived contamination, as well as providing information on the stability of established instrumental baselines. Only zinc was detected in the method blanks. This indicates that there was no laboratory-derived contamination except for zinc and that the instrumental baselines were stable (Appendix D.2). Analyte results were background corrected for the method blank.

Certified Reference Materials:

The analysis of certified reference materials (CRMs) provided information on the accuracy of the laboratory performing the analysis. The percent recoveries for the certified reference materials (CRMs) are listed in Appendix D.2. All CRM results were between 100 and 109% recovery and within the range considered acceptable by the laboratory (±20%).

Matrix Spikes:

Matrix spikes are samples to which a known amount of analyte has been added. The analysis of matrix spikes provided information on the extraction efficiency of the method on the sample matrix. The percent recovery for matrix spikes are presented in Appendix D.2. All matrix spike recovery results were within 30% of the target concentration and within the range considered acceptable by the laboratory (± 40%). This indicates that the sediment matrix of samples collected from the study site did not affect analyte recovery (accuracy).

Laboratory Replicates:

Laboratory replicates were taken by splitting a sample before analysis. The replicates were analyzed as an additional sample to provide information on precision. The results of the replicate samples were compared to determine the relative percent difference (RPD). The RPDs of the laboratory replicates are listed in Appendix D.2 (Table D2.1). All laboratory replicates had RPDs less than 14% indicating acceptable precision.

Field Homogenization Replicates:

Field homogenization replicates are replicate samples that are split in the field once the sediment has been homogenized. These samples provided information on laboratory precision and sample heterogeneity. The RPD results of the field homogenization replicates are listed in Appendix D2 (Table D2.1). All field replicates had RPDs less than 13% indicating acceptable precision and sample homogenization in the field.

Field Cross-Contamination Blanks:

Field cross-contamination blanks were used to assess the degree to which contaminants may be exchanged from one sample to the next during sample collection and processing. The concentrations found in the cross-contamination swipes of the compositing equipment and ponar grab (minus the swipe blank, i.e., filter) are provided in Table 4-10:

Table 4-10. Results of cross-contamination swipes for sediment sampling.

PARAMETER	COMPOSITE EQUIPMENT (UG/FIL)	STANDARD PONAR (UG/FIL)
Al	5.9	43.3
Ba	nd	0.6
B	2.7	1.7
Cd	nd	435
Ca	7.9 - 3.3 = 4.6	59.8 - 3.3 = 56.5
Fe	9.2 - 1.3 = 7.9	303 - 1.3 = 301.7
K	46 - 42 = 4	35 - 42 = 0
Mg	nd	27.1
Mn	nd	4.8
Ni	0.5	0.9
Na	8.4 - 10.5 = 0	17 - 10.5 = 6.5
Sr	nd	0.39
T	nd	3
Zn	2.5 - 0.4 = 2.1	22.1 - 0.4 = 21.7

The contamination potential from the standard ponar is relatively high, since it was only galvanized and not of stainless steel. The standard ponar was brought only as a contingency. Unfortunately, the stainless steel petite ponar was lost at the first sampling station and consequently all stations were sampled using the standard ponar. Sediment was taken approximately 4 cm in from the edge to avoid sediment that had contacted the ponar grab, and thereby avoid contamination. For a 1500 g sample (worst case scenario based on highest metal concentration and smallest estimated sample size), the additional amount of contamination possible was about 0.29 mg/kg for cadmium. Concentrations in the reference (range: <0.5 to 0.6 mg/kg) and exposure (range: 2.3 to 2.8 mg/kg) stations were at least double indicating that most of the cadmium in the samples likely did not come from the sampler, especially considering the precautions taken. Although Table 4-10 results indicate potential for contamination, it is unlikely that significant contamination occurred based on sampling methods and concentrations detected in those samples.

4.6.2 Sediment

Although every effort was made to sample similar habitats at the reference and exposure areas, significant differences were observed for fines, TOC, and loss on ignition (Table 4-11). Sediment data were normalized to fines to reduce the effect of habitat differences on chemistry. Metals data are summarized in Table 4-12, and the raw data are provided in Appendix D. All metals that were detected tended to be elevated in the exposure stations compared with the reference sites. Cadmium, copper, lead and particularly zinc exceeded Canadian sediment quality criteria in the exposure area. However, this difference may not be attributable to exposure alone as the substrate at the exposure area was primarily silt/clay, while at the reference station it was primarily sand/gravel. Therefore, it is difficult to interpret these data.

4.6.3 Benthos

Total invertebrate abundance was higher at the Myra Creek exposure site (16,218 individuals combining both sieve fractions) versus the reference site (713), while species richness was lower at the exposure site (e.g., 22 taxa; 250 μm size fraction) versus the reference site (e.g., 36 taxa; 250 μm size fraction) for both size fractions (Table 4-13). The greater invertebrate abundance at the exposure site can be attributed to higher densities of oligochaetes, primarily *Nais communis* and chironomids, primarily *Cricotopus* and *Orthocladius*. In addition, there were more species of mayflies, stoneflies, and caddisflies at the reference site compared with the exposure site.

Benthic samples from the Upper Campbell Lake reference area and the Buttle Lake exposure area were dominated by chironomids (Chironominae; Tanypodinae), oligochaetes (Tubificidae; Naididae), *Hydracarina*, and Harpacticoida (Appendix E.3). There were no statistical differences in total abundance or species richness between reference and exposure for either size fraction.

Table 4-11. Summary of sediment physical characteristics ($\bar{x}$ ± se) collected from Buttle Lake, October 23 - 27, 1996 (se = standard error).

PARAMETER	REFERENCE	EXPOSURE	t^1	p^2
Water depth (m)	4.39 ± 1.28	3.61 ± 0.57	-0.366	0.730
Percent fines (<63μm)[3]	10.73 ± 3.36	83.65 ± 0.68	5.737	0.029*
Total Organic Carbon (%)	1.61 ± 0.72	8.17 ± 1.04	3.802	0.013*
Moisture Content (%)	39.50 ± 7.73	80.08 ± 0.55	3.454	0.074
Loss on Ignition (%)	8.93 ± 1.61	20.60 ± 1.87	4.351	0.007*

Notes:
[1] Students *t*-statistic; all data were logged prior to analysis unless otherwise noted
[2] Probability level
[3] Percent fines include the silt and clay fractions
* Statistically significant difference between exposure and reference stations ($p<0.05$)

Table 4-12. Total metals (x̄ ± se; mg/kg) in sediment samples collected from exposure and reference areas compared with Federal sediment criteria (Environment Canada, 1994) (se = standard error).

PARAMETER	CRITERIA TEL	CRITERIA PEL	REFERENCE	EXPOSURE	*t*[1]	*p*[2]
Barium	-	-	18.3 ± 1.9	68.1 ± 8.7	7.806 (-3.234)	0.001* (0.023*)
Cadmium	0.596	3.53	0.4 ± 0.1	**2.5 ± 0.1**	6.785[4] (-0.594[4])	0.018* (0.610)
Chromium	37.3	90.0	10.1 ± 1.1	6.8 ± 0.1	3.454[4] (5.358[4])	0.071 (0.033*)
Cobalt	-	-	7.2 ± 0.7	4.4 ± 0.1	-5.156[4] (-5.801[4])	0.004* (0.028*)
Copper	35.7	196.6	4.56 ± 1.0	**135.3 ± 9.6**	12.356 (-2.770[4])	0.001* (0.103)
Lead	35.0	91.3	2.6 ± 0.9	**70.0 ± 9.0**	10.715 (7.807)	0.000* (0.001*)
Nickel	18.0	35.9	10.7 ± 1.1	4.8 ± 0.1	-7.356[4] (-6.211)	0.0016* (0.025*)
Silver	-	-	0.4 ± 0.1	1.8 ± 0.3	4.311 (0.930)	0.008* (0.395)
Vanadium	-	-	46.5 ± 3.6	19.9 ± 0.3	-12.071 (-7.083)	0.000* (0.019*)
Zinc	123.1	314.8	87.5 ± 18.4	**538.8 ± 17.8**	8.673[4] (-1.692)	0.011* (0.227)

Means exceeding threshold effects level (TEL) criteria are **bolded**.
Means include half detection values for stations where parameters were no-detects.
Means exceeding probable effects level (PEL) criteria are **bolded and underlined**.

[1] Students *t*-statistic
[2] Probability level
[3] Only 1 value, no standard deviation exists
[4] Variances were not homogenous as per Bartlett's Test; separate variances T used

Values in brackets are for Students t-test on data normalized to % fines
Parameters analysed but not detected at 5 or more stations at either the reference or exposure areas include: Antomony, Beryllium Cadmium, Molybdenum, Selenium, Silver
- no criteria available
* Statistically significant difference between exposure and reference stations, $p<0.05$.

Table 4-13. Summary of benthic invertebrates ($\bar{x}$ ± se) collected from Buttle Lake and Myra Creek with 250 μm and 500 μm sieves, October 7 - 10, 1996 (se = standard error).

PARAMETER	REFERENCE	EXPOSURE	t^1	p^2
250 μm sieve				
BUTTLE LAKE				
Species Abundance	1464 ± 262	1357 ± 171	-0341	0.740
Species Richness	23 ± 2	24 ± 2	0.122	0.905
MYRA CREEK				
Species Abundance	513	15453	na	na
Species Richness	36	22	na	na
500 μm sieve				
BUTTLE LAKE				
Species Abundance	362 ± 83	631 ± 127	1.853	0.094
Species Richness	12 ± 1	15 ± 1	1.889	0.088
MYRA CREEK				
Species Abundance	218	757	na	na
Species Richness	24	20	na	na

Notes:

1	Students *t*-statistic; all data were logged prior to analysis unless otherwise noted
2	Probability level
*	Statistically significant difference between exposure and reference stations (p<0.05)
na	Not applicable; not sufficient data to conduct analysis

4.7 FISHERIES

4.7.1 Relative Abundance

Gillnet catch data for both the exposure and reference areas and CPUE are summarized in Table 4-14 while raw data are provided in Appendix F. Rainbow trout were the only large sentinel species captured in both areas during the present study. Greater numbers of fish were generally captured in the smaller mesh size (i.e., 5 cm), especially in the exposure area where fewer large fish were captured compared to the reference area. Abundances in the exposure and reference areas are generally comparable despite the slightly differing gillnet configurations and duration of sets between the areas. Sculpin and stickleback were captured by beach seining and minnow trapping in the reference area and stickleback were observed in the exposure area.

4.7.2 Tissue Analysis

As discussed in Section 3.7.2, no tissue samples were collected for metals and metallothionein analysis due primarily to the availability of historical data.

Table 4-14. Catch per unit effort (CPUE) for Buttle Lake (Myra Falls mine).

		# OF FISH CAPTURED					
AREA	SPECIES	ANGLING	GILLNETS	BEACH SEINE	ELECTROSHOCKING	MINNOW TRAP	CPUE[1]
Exposure	Rainbow Trout		9				0.013
Reference	Rainbow Trout		7				0.016
	Threespine Stickleback			350		1	700 (BS) 0.2 (MT)
	Prickly Sculpin			3		1	6 (BS) 0.2 (MT)

[1] Gillnetting (GN) CPUE calculation is based on capture rate/15 m panel/hour of gillnet time.
Beach Seine (BS) CPUE calculation is based on capture rate per hour . Total crew time seining was 30 minutes.
Minnow Trap (MT) CPUE calculation is based on capture rate/trap/hour. (4 traps used for 1.25 hours)

Total Gillnetting Effort was:

Reference: 7 fish captured in 71.46 hours by 6 panels.
Exposure: 9 fish captured in 74.5 hours by 9 panels

4.8 LEVEL OF EFFORT

Level of effort is summarized in Table 4-15. Disbursement expenses are summarized in Table 4-16. Note that the levels of effort and disbursements do not include time spent reviewing the suitability of this site for testing hypotheses in 1997, scoring the site criteria or completing the 1997 study design.

Table 4-15. Level of effort (person hours) for the Myra Falls Mine Site in Strathcona Park, Vancouver Island, BC.

TASK		LEVEL OF EFFORT
Project Initiation Meeting		9
Literature Review and 1996 Study Design		35
Field Surveys		
Planning and Preparation of Field Logistics		82
Site reconnaissance, Habitat Characterization, and Station Selection		41
Sublethal Toxicity Sample Collection		8
Sediment Chemistry		19
Water Chemistry		20
Benthos		35
Fish	*Population*	64
	Tissue Processing	n/a
Data Analysis and Interpretation		60
Preliminary Surveys and Recommendation Report		80
Final Draft Survey Report		64
Progress Reports		10
Conference calls		10

n/a not applicable

Table 4-16. Expenses and Disbursements for the Preliminary Field Survey at the Myra Falls Mine Site in Strathcona Park, Vancouver Island, BC.

EXPENSE	SUBLETHAL TOXICITY SAMPLE COLLECTION	WATER CHEMISTRY	SEDIMENT CHEMISTRY	BENTHOS	FISH
Travel	<------------ $ 665.00 ------------>				
Accommodations	<------------ $1120.00 ------------>				
Meals	<------------ $1100.00 ------------>				
Miscellaneous Supplies	<------------ $2700.00 ------------>				
Shipping	<------------ $ 400.00 ------------>				
Analyses	na	$3,520.00	$1,750.00	$3,200.00	na

na invoiced directly to AETE; not sampled

5.0
DISCUSSION

5.1 COMPARISON OF RESULTS WITH HISTORICAL DATA

As far as we know, there have been no benthic studies conducted on Myra Creek, thus we are unable to make historical comparisons with the 1996 data.

There is only one study that has examined invertebrate community structure in the Campbell River lake system; however, we were unable to obtain this report from BCME despite numerous attempts to do so. Data from this study were cited in Roch et al. (1985), and this review states that Buttle Lake sites downstream of Myra Creek had lower total abundance and diversity compared with sites at Lower Campbell and John Hart Lake (i.e., stations farther downstream from the mine discharge). Furthermore, Kathman et al. (1985) found that South Buttle Lake was dominated by supposedly metal-tolerant species, such as the chironomids *Procladius*, *Thiennemannimyia* and the oligochaete *Rhyacodrilus montana*. In 1996, there were no differences in species diversity or total invertebrate abundance between reference and exposure areas. Furthermore, *Thiennemannimyia* was found in very low numbers at both areas, while *Rhyacodrilus* abundance was higher in the exposure area which was similar to 1985. *Procladius* was not collected in 1996. This comparison with the limited historical data suggests that discharge quality from the Myra Falls mine operations has improved, as we observed no perceivable difference in benthic community structure between reference and exposure areas.

Despite the limited numbers of fish and the single species captured during the present study, catches are consistent with previous studies where rainbow trout, cutthroat trout, and Dolly Varden were captured in Buttle Lake and Upper Campbell Lake. Of these species, rainbow trout were captured in the highest numbers followed by Dolly Varden and cutthroat trout. Sculpin and stickleback are found throughout the Campbell River drainage.

Due to the restricted duration of gillnet sets during the present study, CPUE cannot be directly compared with previous studies. Generally catch rates are highest during the early morning and evening period when fish are more active. In the reference area, more fish were captured at the beginning and end of each day while fewer fish were captured around midday. Limitations on the timing and duration of gillnet sets in the present study effectively restricted gillnetting to daylight hours when the gillnets could be constantly attended. These limitations greatly reduced the effectiveness of fish collection efforts compared to previous, more extensive, studies completed in Buttle Lake.

5.2 COMPARISON OF REFERENCE VERSUS EXPOSURE AREAS

Although total invertebrate abundances at the Myra Creek exposure area were much higher than the reference station, these samples were dominated by metal-tolerant oligochaetes and chironomids. In contrast, the upstream reference station had more taxa belonging to the more metal-sensitive mayflies, stoneflies, and caddisflies (19 EPT taxa) versus the downstream exposure site (9 EPT taxa). These differences may be attributed to higher metal levels at the exposure station. In 1995, zinc levels ranged from 48-512 μg/L (CCME [1987] criteria for zinc = 50 μg/L) at this site versus <5 μg/L at the reference site (Westmin, 1996).

Although sediment chemistry data suggest that metals were elevated at the exposure area compared to the reference area, there were few differences in benthic invertebrate community structure between locations. For example, zinc sediment concentrations at the exposure area (538.8 mg/kg; Table 4-12) exceeded probable effects level (314.8 mg/kg), while copper levels at the exposure area (135 mg/kg) were three times higher than the threshold effects level (35.7 mg/kg; Environment Canada, 1994). Because we observed no relationship between sediment metal levels and benthic invertebrate community structure, metals in sediment may have limited bioavailability. Others have shown that metal associated with sediment in Buttle Lake downstream from Myra Creek have little reactivity with the surrounding waters (AQUAMIN, 1995).

Given the limited nature of the fish collection efforts completed during the present study, few comparisons between the exposure and reference areas are possible. Sample sizes were generally similar in the two areas when timing and duration of gillnets sets are considered. The only difference observed between the exposure and reference areas in the present study was that no large fish were captured in the exposure area. Although fish captured in the exposure area were small compared to the reference area, no significant differences in size and weight of fish captured were apparent. Further analysis of historical fish data would be necessary to determine whether size differences actually exist between areas sampled in Buttle and Upper Campbell Lake. Comparability of fish populations within the Campbell River drainage should be considered in the selection of a reference area for future monitoring programs.

6.0

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE SAMPLING

This mine site was very accessible by road. In addition, there a number of boat launches along the lake that are relatively close to historic stations. There is also easy access to sampling locations on Myra Creek. However, successful collection of grab samples for benthos and sediment was extremely difficult due to large amounts of woody debris and coarse substrate. Furthermore, the lake is deep (mean depth <45 m) making collection of numerous grabs burdensome. Another possible factor to consider when sampling Buttle Lake is that BC Hydro periodically releases water from downstream dams. As a result of these drawdowns, water levels can drop as much as 30 cm/day, which can dramatically alter lake hydrology and habitats.

Observations from the sediment and benthic survey provide some guidance for any future sampling at this site. First, sediment collection showed that fine-grained sediment within the reference and exposure area sampled is limited. Extensive wood debris and a high proportion of large substrate make collection of sediment logistically difficult. Thus, more effort should be placed on determining whether sediment collection from Buttle Lake is worthwhile. Secondly, benthic invertebrates may not be as biologically important to the Buttle Lake food web as zooplankton. Previous monitoring studies have shown significant differences in zooplankton abundance and diversity between the reference and exposure area before implementation of effluent treatment. Furthermore, these organisms may serve as a more important food source to the various resident salmonids in Buttle Lake. Therefore, we suggest that future field programs at this site include zooplankton collections.

Results of the fish collection component of the present study partially confirmed species distribution and abundance data available from previous studies completed in Buttle Lake. Although only one species (rainbow trout) was captured during the present study, results are consistent with previous studies where comparatively larger numbers of rainbow trout were captured compared to the other two species captured (cutthroat trout and Dolly Varden). Level of effort in the present study was significantly lower than for previous studies completed in Buttle Lake due to the limited time allocated to the fisheries component of the present study and the reduced effectiveness of gillnetting as a result of restrictions in the fish collection license. Despite the reduced level of effort, low to moderate capture rates were achieved for rainbow trout in both the reference and exposure areas. These results suggest that target catches of potential sentinel species could be achieved by more intensive fishing effort in future monitoring programs. Gillnetting appears to be the most effective capture method and should be used for future studies.

Potential sentinel species in Buttle Lake are rainbow and cutthroat trout, and Dolly Varden. Other species present are sculpin and three-spine stickleback. Table 6-1 lists characteristics used to evaluate sentinel species. In general, suitable sentinel species will be abundant, benthic, and invest considerable energy in both reproduction and growth. Table 6-2 summarizes life history characteristics of the three potential sentinel species for the Myra Creek mine site. A preliminary ranking of these species reveals few significant differences. All species are expected to have low to moderate sediment exposure and share food preferences (i.e., benthos/insects/fish). Of these species, rainbow trout would be expected to have the highest sediment exposure as a results of the larger benthos component in their diet. Additional information is needed on mobility of all three species in the Campbell River drainage to establish residency, especially in the Buttle Lake exposure area. Comparison of migration behavior among species with results of metals and metallothionein analyses completed during previous studies may provide a clearer understanding of the extent and duration of exposure to Westmin mine discharges to Buttle Lake. Notwithstanding the ratings based on life history characteristics provided in Table 6-2, an important factor influencing the selection of sentinel species in the Campbell River system is their distribution throughout the exposure and reference areas. Based on abundance and distribution data from previous studies, all three of the potential sentinel species can be captured in moderately high numbers in both Buttle Lake and Upper Campbell Lake. Although only small numbers of one species were captured during the present study, it is assumed that a more intensive fish collection effort could achieve target capture rates for at least two of the sentinel species present. This assumption should be tested in future sampling programs before target sentinel species are selected.

6.1 SUMMARY

Buttle Lake supports an important recreational fishery for rainbow and cutthroat trout. Because these fish feed on pelagic organisms in lake ecosystems, we suggest that future monitoring programs focus on these invertebrates rather than benthic ones. Furthermore, an historical database for zooplankton exists for Buttle Lake and, therefore, it would be possible to track temporal and spatial changes in water quality in relation to mine activities by using this important source of historical information. In addition, we observed no significant differences in invertebrate community structure between reference and exposure areas which suggests mine activities have had little affect on the benthos.

Table 6-1. Life history requirements for a sentinel species to allow the rapid detection of environmental impact (Munkittrick and Dixon, 1989).

Life History Trait	Description	Rating	
Sediment Exposure	Many contaminants accumulate in sediments. Species which are benthic feeders and are intimately exposed to sediment-associated contaminants would show a stronger response.	benthic mid-water surface	+ 0 -
Food	Species which feed on benthic invertebrates will respond faster, and with greater initial magnitude to food chain alterations associated with sediment contamination. Species which feed on organisms external to the aquatic food web (e.g., terrestrial insects) would not reflect changes in the aquatic food web.	benthos mid-water terrestrial	+ 0 -
Food Chain Position	Species which are intermediate in the food chain will reflect changes in both lower (invertebrate) and higher (piscivore) populations.	prey (intermediate) predator (top)	+ -
Spawning Time	Spring spawners face pre-spawning stress and mortality from harsh overwintering conditions, as well as stress from contaminant exposure. Fall spawners spawn immediately after the summer, when food is most abundant, and before any overwintering stress. Therefore, contaminant effects on reproductive parameters would occur more quickly, and be more evident, for spring spawners. Also, spring spawners are more desirable for our study, because we plan to sample in late summer-fall when fall spawners may already be migrating to spawning grounds.	spring spawners fall spawners	+ -
Mobility	Species which spend most of their time in a restricted area, at least for some months prior to sampling, will better reflect exposure conditions and effects in the area of capture.	stationary mobile	+ -
Fecundity	Changes in reproductive effort would be most evident in a species with a high reproductive energy demand.	>20,000 eggs <10,000 eggs	+ -
Growth Rate	Changes in environmental conditions (habitat or food availability) would be reflected quickly in a species with fast growth. A rough estimate of the growth rate can be obtained from change in length from ages 3 to 7. These ages overlap the age of maturity for most species, and food limitations will be reflected in a fish species with rapid growth over this interval.	>50% changes <40% changes	+ -
Longevity	Fish species which have a very short lifespan (e.g., guppies) are difficult to use for monitoring long-term effects. Fish species which have a very long lifespan (e.g., sturgeon) can be slow to respond to environmental changes, or can exhibit resilience which results in a considerable time lag before the detection of adverse effects.	10 to 15 y <5 or >15 y	+ -
Age at Maturity	Species which mature earlier will show effects on reproduction more rapidly.	3 to 6 y >6 y	+ -
Abundance	Obviously, species which are abundant would be easier, and less expensive to monitor. There are also concerns about sampling mortality effects on populations of rare species.	abundant rare/seasonal	+ -

Table 6-2. Suitability of potential Buttle Lake (Myra Falls mine) sentinel species.

SPECIES	SEDIMENT EXPOSURE	FOOD	FOOD CHAIN	SPAWNING TIME	MOBILITY	FECUNDITY	GROWTH RATE	LONGEVITY	AGE AT MATURITY	ABUNDANCE	RANKING (MAX.= +10)
Cutthroat Trout	-	0	-	+	+	-	+	-	+	+	+1
Dolly Varden	-	0	-	-	+	-	+	+	+	+	+1
Rainbow Trout	0	0	+	+	-	-	+	0	+	+	+3

7.0

REFERENCES

APHA (American Public Health Association). 1995. Standard methods for the examination of water and wastewater. APHA, American Water Works Association, Water Environment Federation. 19th Edition.

AQUAMIN (Working Groups 7 and 8). 1996. Assessment of the Aquatic Effects of Mining in Canada: AQUAMIN. Final Report. Prepared for AQUAMIN Steering Group April 30, 1996. Environment Canada. Evaluation and Interpretation Branch, Ottawa, ON. 127 pages.

Austin, A., and N. Munteanu. 1984. Evaluation of changes in a large oligotrophic wilderness park lake exposed to mine tailing effluent for 14 years: the phytoplankton. Environ. Poll. (Series A). 33: 39-62

Austin, A., J. Deniseger, and M.J.R. Clark. 1985. Lake algal populations and physico-chemical changes after 14 years input of metallic mining wastes. Water Res. 19(3): 299-308.

CCME (Canadian Council of Ministers of the Environment). 1987. Canadian Water Quality Guidelines. Environment Canada. Water Quality Branch. Inland Waters Directorate.

B.A.R. Environmental Inc. (BAR Environmental). 1996. An evaluation of chronic toxicity tests for selected mine effluents. Prepared for CANMET, Department of Natural Resources, Ottawa, ON. August 1996 - DRAFT. 50 pp + Appendices

Clark, M.J.R. 1980. A preliminary review of Buttle Lake water quality. Environment Canada. Waste Management Branch. 14 pp + appendices.

Clark, M.J.R. and T.O. Morrison. 1982a. Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Volume II. Appendix 1.7. Ministry of Environment. Waste Management Branch. 558 pp.

Clark, M.J.R. and T.O. Morrison. 1982b. Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Volume II. Appendix 1.15. Ministry of Environment. Waste Management Branch. 558 pp.

Clark, M.J.R. and T.O. Morrison. 1982c. Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Volume II. Appendix 1.18. Ministry of Environment. Waste Management Branch. 558 pp.

Clark, M.J.R. and T.O. Morrison. 1982d. Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Volume II. Appendix 1.28. Ministry of Environment. Waste Management Branch. 558 pp.

Clark, M.J.R. and T.O. Morrison. 1982. Impact of the Westmin Resources Ltd. Mining Operation on Buttle Lake and the Campbell River Watershed. Volume I. Ministry of Environment. Waste Management Branch. 277 pp.

Deniseger, J., A. Austin and W.P. Lucey. 1986. Periphyton communities in a pristine mountain stream above and below heavy metal mining operations. Freshwater Biol. 16:209-218.

Deniseger, J., and L.J. Erickson. 1991. Trends in Water Quality of Buttle lake and the Campbell River - Continuing Decreases in Metal Concentrations from 1987 through 1990. Ministry of Environment. Environmental Protection. Nanaimo, B.C. 38 pp.

Deniseger, J., L.J. Erickson, A. Austin, M. Roch and M.J.R. Clark. 1990. The effects of decreasing heavy metal concentrations on the biota of Buttle Lake, Vancouver Island, British Columbia. Water Res. 24(4): 403-416.

Environment Canada. 1994. Interim sediment quality assessment values. Environment Canada. Soil and Sediment Quality Section. Guidelines Division. 7 pp.

Environment Canada. 1995. Guidance document on the collection and preparation of sediments for physico-chemical characterization and biological testing. Report EPS 1/RM. Ottawa, Ontario. 139 pp.

Godin, B., and M. Jones. 1985. Progress Report No.4 - October 1985. Water Quality Sampling in Myra Creek at Westmin Resources Ltd. Mine on Vancouver Island. Environment Canada. Conservation and Protection. Environmental Protection Service. Pacific and Yukon Region. 50 pp.

Kathman, R.D. 1982. Benthic invertebrates of Buttle and surrounding lakes. Report prepared for Aquatic Studies Branch/Waste Management Branch. BC Ministry of Environment. Victoria, BC. 36p.

Kelso, B.W. and M. Jones. 1982. Progress Report on the December 7, 1982 Water Quality Sampling in Myra Creek after the Implementation of the Groundwater and Surface Collection and Treatment System at Westmin Resources Limited on Vancouver Island. Department of Environment. Environmental Protection Service. Pacific Region. 33 pp.

Munkittrick, K.R. and D.G. Dixon. 1989. A holistic approach to ecosystem health assessment using fish population characteristics. Hydrobiologia 188/189:123-135.

Roch, A., J.A. McCarter, A.T. Matheson, M.J.R. Clark and R.W. Olafson. 1982. Hepatic metalothionein in rainbow trout (*Salmo gairdneri)* as an indicator of metal pollution in the Campbell River System. Can. J. Fish. Aquat. Sci. 39: 1596-1601

Roch, M., R.N. Nordin, A. Austin, C.J.P. McKean, J. Deniseger, R.D. Kathman, J.A. Carter and M.J.R. Clark. 1985. The effects of heavy metal contamination on the aquatic biota of Buttle Lake and the Campbell River drainage. Arch. Environ. Contam. Toxicol. 14:347-362

SYSTAT. 1992. Systat for Windows, Version 5. Evanston, IL. Systat, Inc.

Westmin Resources. 1996. 1995 Annual Report to the Waste Management Branch BC Environment. 7 pp+tables, figures and appendices.

APPENDIX A

Quality Management Plan (QMP)

INTRODUCTION

Appropriate quality assurance and quality control (QA/QC) protocols are essential to ensure that environmental data achieve a high level of quality commensurate with the intended use of the data. This quality management plan (QMP) served as a general set of protocols covering both laboratory and field operations to be used by all members of the EVS-ESP-JWEL consortium. Use of this QMP ensured both a high quality of data as well as uniformity and comparability in the data generated at each study site.

DATA QUALITY OBJECTIVES

For all field and laboratory measurements, data quality objectives (DQOs) have been set where applicable. Data quality objectives are defined by the US EPA as "qualitative and quantitative statements of the level of uncertainty that a decision maker is willing to accept in decisions made with environmental data" (QUAMS; 1986, 1990). The DQOs define the degree to which the total error in the results derived from the data must be controlled to achieve an acceptable confidence in a decision that will be made with the data. In terms of this project, the AETE committee has already stipulated that analytical measurements will achieve a detection limit of 1/10 that of the CCME guidelines for protection of the aquatic environment. The quality control officer ensured that the required detection limits were made known to the analytical laboratory well in advance. In this way, the correct methodology, volume of samples and methods of preservation were established before the field work was underway. Detection limits for field instruments (Hydrolab, YSI etc.) and the gravimetric measurements for biological analyses (e.g. fish organ weights) were also sent to each team.

QUALITY CONTROL OFFICER

The quality control officer (QCO) for the project (Ms. Monique Dubé) has the following responsibilities:

- to ensure that all data quality objectives are known to both field personnel and the chosen analytical laboratory
- to ensure that standard operating procedures (SOPs) are followed for each field component at each study site
- to ensure that both the toxicity and analytical laboratories follow established SOPs for each analysis
- to ensure the all analyses were under statistical control during each analytical run. This requires that the quality control data for each analysis be reviewed and compared with

historic control limits to be requested from the analytical and toxicity laboratories. The QC data will include percent recoveries of spiked samples, and results for blanks, replicates and certified reference materials. Logical checks of the data will also be conducted, especially for toxicity.

The quality control officer (QCO) has authority for requiring corrective actions (e.g., repetition of the analysis) if the SOPs were not followed or the analytical systems were not under control. The QCO will also be made aware of all outliers.

FIELD PROTOCOLS FOR WATER, SEDIMENT AND BENTHIC SAMPLING

RESPONSIBILITIES AND TRAINING

For each field team, a team leader was chosen with authority to make decisions in the field related to implementation of the study plan. The team leader was responsible for ensuring that all field personnel were trained and competent in use of each field instrument, that all SOPs were followed and that adequate heath and safety measures were followed.

STANDARD OPERATING PROCEDURES

Whenever feasible, water, sediment and benthic samples were taken at the same sampling stations. The location of each station was recorded either as a GPS reading or with reference to a large scale map and known landmarks. The location of each station was known to the nearest 20 m. At each station the field information to be reported included:

- station location
- date and time
- field crew members
- habitat descriptions
- sampling methods
- depth
- wind and climatic conditions
- water temperature
- substrate type (sand/gravel/cobble/silt/clay)
- water velocity (rivers)

This information was recorded on field data sheets.

BENTHIC SAMPLING

Benthic collections were made by Eckman, standard (or petite) ponar grab, Hess sampler, Surber sampler or hand-inserted core tubes depending on substrate type. The Eckman is used primarily on soft sediments in deep water (>2 m), although a pole mounted version can be used in harder substrates and shallower waters. The ponar grab is used for substrates consisting of hard and soft sediments such as clay, hard pan, sand, gravel and mud where penetration of the substrate by the sampler is possible. The standard ponar is set with a spring loaded pin, lowered to the bottom and allowed to penetrate the substrate. When the ponar penetrates the sediment, the pin is released and the jaws are allowed to close on the sediment sample when the sampler is withdrawn. The ponar (plus sample) is then pulled through the water column and placed in a plastic basin on the bottom of the boat. Because of the weight of the standard ponar a frame and electrically driven winch should be used to raise and lower the grab. After the sample has been removed and whenever the ponar is not being used, the safety pin must be inserted into the lever bar to prevent the bar from closing on the operator. Care must also be taken when using the winch to avoid catching hands and clothes. The petit ponar is considerably lighter, safer and easier to use. A winch may not be necessary under most conditions.

Both the Eckman and ponar samplers were made of stainless steel rather than brass. The choice of using an Eckman or ponar sampler depends on the nature of the sediment and the depth of the water column. In hard sediments, use of the Eckman sampler is limited as penetration is poor. The pole mounted Eckman is able to penetrate some hard substrate, but its use is limited to shallow depths. If sediments are very soft, the Eckman may be preferable to the ponar because the latter tends to fill entirely with sediments, thereby obliterating the sediment-water interface. At depths greater than 20 m the ponar may be more successful because of its greater weight and stability in the water column. If both samplers are available, a certain amount of trial and error may be required to determine the most appropriate sampler.

The Surber sampler was used in shallow (<32 cm), flowing waters on rocky substrates where a grab sample cannot be taken. The Surber sampler consists of two square frames hinged together; one frame rests on the surface while the other remains upright and holds a nylon collecting net and bucket. A base extension is used when sampling areas of fine, loose sediments or rubble. The base frame fits into the base extension which is pushed into the sediments to decrease the lateral movement of invertebrates out of the area to be sampled. The sampler is positioned with its net mouth open facing upstream. When in use, the two frames are locked at right angles, the base frame (and base extension) marking off the area of substrate to be sampled and the other frame supporting a net to strain out organisms washed into it from the sample area.

The Hess sampler is especially useful for sampling gravel and cobble bottoms in streams. The Hess sampler consists of a stainless steel cylinder with two large windows and a pair of handles for pushing the cylinder while rotating it into the gravel or cobble. Penetration depths of 75 or 150 mm can be varied by attaching the handles to either end of the sampler. Water flows in through the upstream window of the Hess sampler and out through the downstream window and into the collecting net and bucket.

General operating procedures for the Surber and Hess samplers were as follows:

- Position the sampler securely to the bottom substrate, parallel to the water flow with the net pointing downstream.
- The sampler is brought down quickly to reduce the escape of rapidly-moving organisms.
- There should be no gaps under the edges of the frame that would allow for washing of water under the net and loss of benthic organisms. Eliminate gaps that may occur along the edge of the Hess/Surber sampler frame by shifting of rocks and gravel along the outside edge of the sampler.
- To avoid excessive drift into the sampler from outside the sample area, the substrate upstream from the sampler should not be disturbed.
- Once the sampler is positioned on the stream bottom, it should be maintained in position during sampling so that the area delineated remains constant.
- Hold the sampler with one hand or brace with the knees from behind.
- Heavy gloves should be required when handling dangerous debris; for example, glass or other sharp objects present in the sediment.
- Turn over and examine carefully all rocks and large stones and rub carefully in front of the net with the hands or a soft brush to dislodge the organisms and pupal cases, etc., clinging to them before discarding.
- Wash larger components of the substrate within the enclosure with stream water; water flowing through the sampler should carry dislodged organisms into the net.
- Stir the remaining gravel and sand vigorously with the hands to a depth of 5-10 cm where applicable, depending upon the substrate, to dislodge bottom-dwelling organisms.

- It may be necessary to hand pick some of the heavier mussels and snails that are not carried into the net by the current.

- Remove the sample by washing out the sample bucket, if applicable, into the sample container (wide-mouthed jar) with 10% buffered formalin fixative.

- Examine the net carefully for small organisms clinging to the mesh, and remove them (preferably with forceps to avoid damage) for inclusion in the sample.

- Rinse the sampler net after each use.

In the case of soft sediments at shallow depths, plastic core tubes (2.5 " ID) can be inserted by hand into the sediments. Stoppers are placed at each end as the tube is withdrawn.

Sieving of Benthic Samples

Samples were sieved in the field using a mesh size of 250 µm, and preserved with sufficient buffered formalin to produce a 10 % concentration. If further sieving was required (e.g., 500 µm sieve) to allow for data collected to be comparable across studies, then this additional step was done in the field, and both sized fractions were preserved and identified.

Quality Control Protocols for Benthic Identification

Invertebrate samples were sorted on a low power microscope and keyed to the generic level. A reference collection of identified organisms will be maintained for both the receiving and reference environments. Taxonomy will be verified by an independent expert. Sorting efficiency will be estimated by recounts of the sorted material on 10% of the samples. If subsampling is deemed necessary, an estimate will be made of the subsampling error. All unsorted and sorted fractions of the samples will be retained until taxonomy and sorting efficiency are confirmed. All data transcriptions will be checked for accuracy.

WATER CHEMISTRY

As indicated in the study plan, water quality samples were taken as grab samples at 12 sampling stations plus the effluent. In shallow receiving environments (<2m) 1 grab sample was collected at the surface from each station with clean bottles prepared by the analytical laboratory. Samples were collected by removing the cap below the surface (approximately 15 cm depth) to avoid any surface contamination. Latex (or nitryl) gloves were used during this procedure to avoid all contamination. In deeper receiving environments (> 2 m), one sub-surface grab were collected at each station using a Van Dorn-type sampler. Separate samples will be collected for total and dissolved metals. The dissolved sample will be field filtered according to standard methods (APHA 1995 -Section 3030B). Both metals samples (total and dissolved) were acidified with ultrapure HNO_3 (provided by the analytical laboratory) to a pH <2. Samples were also taken in separatc bottles for analysis of other water quality parameters.

Field measurements of temperature, conductivity, dissolved oxygen and pH were also taken at each station using a Hydrolab H_20 or YSI meters. The analytical methods for calibration and use of each field instrument were those outlined in each respective instruction manual. A log was kept of each field instrument indicating its usage and any problems encountered. In using an oxygen electrode, care was taken to change the membrane on a regular basis, or if it became dried out, torn or damaged in any way. Certain chemicals found in effluent discharge can interfere with oxygen measurements. Conductivity was used where appropriate to characterize mixing zones and exposure zones. All values including calibration readings were recorded on the field sheets.

Quality Control Protocols for Water Chemistry

At each mine site quality control samples for water chemistry included collection and analysis of one transport or trip blank, one filter blank and one field replicate (collected at the exposure station). If subsurface samples were collected using a Van Dorn-type sampler, then a sampler blank were also collected. The transport blank and filter blank water were provided by the analytical laboratory. The transport blank consisted of a sample bottle filled with distilled deionized water in the laboratory. The transport blank was brought to the field, opened, then shut immediately. A filter blank consisted of a field-filtered sample of distilled, deionized water provided by the analytical laboratory. When a van Dorn type bottle was used to collect samples, a sampler blank was also taken in which distilled, deionized water was poured into the sampler and then taken as a normal sample. One field replicate from a station in the affected area was taken using a separate bottle and separate filtration. These field QC samples were excusive of those analysed routinely in the laboratory as part of normal laboratory QC.

QC Requirements for Choice of an Analytical Laboratory

A common analytical laboratory was selected for all three regions (West, Ontario, East). The laboratory was certified by CAEAL and the project QCO ensured that the laboratory followed these quality control practices :

- Written (or referenced) SOPs for each analytical system
- Instrument calibration and maintenance records
- Clearly enunciated responsibilities of Q/A officer
- Adequate and training of personnel

14

- Good Laboratory Practices (GLPs)
- Sample preservation and storage protocols
- Sample tracking system (e.g., LIMS system)
- Use of QC samples to ensure control of precision and accuracy (Blanks, replicates, spikes, certified reference materials (minimum effort should be 15-20%)
- Maintenance of control charts and control limits on each QC sample
- Data handling and reporting (blanks, replicates, spike recovery, significant figures)
- Policy for reporting low level data (e.g., ASTM L,W)
- Participation in external audits and round robbins.

The QCO requested that all QC data (including control limits) be contained in the analytical reports and ensured that all analytical runs were under statistical control at the time of analysis. The QCO also ensured that the analytical laboratory attained the required detection limits or had a valid technical reason when these limits were not attained. These values were flagged in the analytical report. The QCO examined all outliers and can request repeat analysis if the data are questionable.

SEDIMENT SAMPLING

Sediment samples were collected only if a station had an area > 1 m^2 of depositional habitat. If not, detailed notes on the site were made and pictures taken to provide evidence that the station was not suitable for sediment collection (This information is important to indicate the occurrence or the non-occurrence of depositional sediments for the sediment toxicity testing in the 1997 field program). The sampling device to be used (Eckman or ponar samplers) depended on the nature of the substrate and depth of water (SE benthic sampling). Again, all sampling devices were of stainless steel construction. Only the upper two cm of the sediment column were used and the sampler penetration was a minimum of 4-5 cm depth to ensure the upper two cm was not disturbed. One composite sediment sample, consisting of five grab samples was collected per station. The upper two cm of substrate from each of the 5 grabs were placed in a glass or plastic mixing bowl. The composite sample was then homogenized in the bowl with a plastic spoon. Sample jars provided by the laboratory (i.e., pre-cleaned glass with teflon-lined lids) were filled to the top to minimize air space. Duplicate jars were collected at all stations in case of breakage and suspected contamination.

Quality Control Protocols for Sediment Sampling

The following guidelines were used to determine the acceptability of a grab sample: a) the sampler is not over-filled, b) overlying water is present indicating minimal leakage, c) overlying water is not excessively turbid indicating minimal disturbance, d) the desired penetration depth is achieved (i.e., 4-5 cm for a 2 cm deep surficial sample). If any of the above criteria were not met, the sample was rejected. The samples were placed in sample jars provided by the analytical laboratory (precleaned glass, teflon lined lids). The grab samplers were cleaned between stations using a phosphate-free detergent wash and a rinse with deionized water. The plastic utensils and bowls were cleaned between sampling stations using the following protocol: 1) a water rinse, 2) a phosphate-free soap wash, 3) a deionized water rinse, 4) a 5% HNO_3 rinse and 5) a final rinse in deionized water. Three swipe blanks were collected, each in the reference and affected areas, to determine the effectiveness of field decontamination procedures. The swipes consisted of acid-wetted, ashless filter paper wiped along the inside of the sampler and mixing bowl/spoon surfaces that are likely to contact sample media. These samples were placed in whirl-pack bags and sent to the analytical laboratory for extraction and metals analysis. One of the duplicate samples taken at each station was analyzed as a field replicate.

All samples were cooled and shipped to the designated laboratory for analysis. Each sample was analyzed for site specific metals, total organic carbon (TOC), particle size and loss on ignition. The quality control procedures to be followed by the analytical laboratory and the review of the quality of the data were the same as outlined above for the water quality parameters.

TOXICITY SAMPLES

The laboratory (B.A.R.) has already been chosen for the sublethal toxicity analyses. The samples were taken with sample pails provided by the laboratory. The procedures for effluent sampling followed those outlined in the document *Aquatic Effects Technology Evaluation Program Project #4.1.2a Extrapolation Study.* B.A.R. is expected to comply with the following QA/QC protocols:

- Written or referenced SOPs for each test
- Adequate training of personnel
- Appropriate instrument calibration and maintenance
- GLPs
- Dilution water controls
- Test record sheets
- Dose selection
- Reference toxicants

- Control charts
- Adequate data handling and reporting procedures.

The QCO will review all the reports and determine whether the reference toxicants fall within control limits, control mortality is limited etc.

FISH SAMPLES

Metallothionein and metals analysis were, where possible and appropriate, conducted on a minimum of 8 fish of 2 species at both the reference and exposure areas (total of 32 fish for each mine site). Where possible, 4 females and 4 males of each species were collected. Only fish collected for metallothionein and metals analysis were sacrificed in the study and all measurements were conducted on these fish. No field splitting of organs for metallothionein and metals analysis (kidney, gill, liver) was done with whole tissue samples forwarded to Dr. Klaverkamp's laboratory for processing and handling. Where fish larger than 20 cm were not available, whole fish (i.e., 10-15 cm length) were used for analyses with no dissection of fish attempted. Fish smaller than 10 cm were not targeted for metallothionein and metals analysis. Tissue and whole fish samples were frozen on dry ice and forwarded to the laboratory for analysis.

Standard operating procedures for gill netting, trap netting and backpack electrofishing are presented below. The maximum effort to be expended on electrofishing was 1 full day per station (reference and exposed; total 2 days). The maximum fishing effort for gill netting was 2 days per station (reference and exposed; total 4 days). Gill nets were checked frequently to collect living fish.

Protocol for Gill Netting

The protocol employed during gill netting was as follows:

1) Individual panels of various mesh sizes were assembled to comprise a gang of nets of required sizes. The order of assembly of sizes was the same for each gang. A bridle was attached to each end, and anchor/float lines were attached to the bridle appropriate for the water depth in which the nets were deployed. The section of rope between the anchor and the bridle was of sufficient length that the anchor could be placed on bottom before any netting is deployed.

2) Netting locations were selected that were free of major bottom irregularities or obstructions (steep drop-offs, tree stumps, etc). Upon selection of the preferred site, the net was deployed in a continuous fashion along the selected route. Care was taken to avoid tangles or twists of the net, and to ensure that marker buoys at each end were visible (i.e.,

above water) after setting. Water temperatures were taken on the bottom and at 2 m above the bottom at each end of the net if other than isothermal conditions were present. The location and orientation of the net relative to shoreline features were marked on an appropriate map and/or obtained by electronic positioning equipment (GPS). The above noted information, the water depth at each end of the net, the date, time of day and other relevant information (wind direction and weather conditions, wave height, etc) were recorded in the field book for each netting location.

3) Upon retrieval, the same information as noted above (as applicable) was recorded. All fish collected were identified and enumerated. Those fish not required for further testing/analysis were live released provided they were in good condition. The remaining fish were analyzed, packaged and preserved, or disposed of according to the requirements of the sampling program.

Protocol for Trap Netting

The protocol for trap netting was as follows:

1) Prior to use in the water, the net was spread out on land and examined for holes and signs of excessive wear (broken and/or frayed lines or attachment points) if the condition of the net could not be determined from previous users. The lead, wings, house and all attachment lines were examined, as well as the house access point opening. All damages were repaired, the house opening was secured and the net was repacked to facilitate ease of deployment.

2) Netting sites were selected that are relatively smooth bottomed, of a substrate suitable for anchoring (i.e. mud, sand, and/or gravel; smooth bedrock not suitable) and free of major irregularities (large boulders, tree stumps or snags, etc.). If water visibility permitted, the selected location was examined from above to confirm its suitability.

3) The net was set perpendicular to shore such that the lead was in shallow water near shore and the house was in deeper water offshore. The net was continuously deployed from the bow of the boat, while backing offshore, until all parts of the net and all anchors were in the water. Upon setting the house anchor, the net was then tensioned. The wing anchors were then lifted and repositioned such that the wings were aligned at a 45° angle to the lead, and lightly tensioned. The date, time of day, water temperature and other appropriate information were recorded in the field book.

4) When servicing the net, the house float was lifted and the boat was pulled under the anchor line between the house and the house anchor. The boat was then manually pulled sideways to the house of the net, which was then passed over the boat until all fish were concentrated at the near shore end of the house. The house access point was then opened and

the fish were removed, identified and enumerated. The fish required for analysis were retained, while the remainder were released live. The catch and the ancillary environmental data (as above) were recorded in the field book. The house opening was then closed and the boat backed out from beneath the net. Anchors were lifted and reset to re-tension the net as required.

Protocols for Back-Pack Electrofishing

The operators of the electrofishing gear will follow procedures outlined in standard fisheries text books. Before the electrofishing operations began, the amount of effort, either by distance, time or desired sample size was agreed upon in order to calculate catch per unit effort.

Health and safely procedures were followed strictly. These are also outlined in standard text books.

Analysis of Fish

At least 8 (preferably adult) fish of each sentinel species were, where possible and appropriate, collected from the reference and exposure areas. The biological variables measured on large (i.e., >20 cm) fish included, where possible and appropriate:

- fork length
- fresh weight
- external/internal conditions
- sex
- age
- gonad weight
- kidney weight
- egg size and mass (if appropriate)
- liver weight

No internal variables were measured on fish of less than 20 cm in length. Information on each fish species were recorded on the data logging sheets provided.

Length was measured to the nearest ±2 mm. Fork length is the length from the tip of the snout to the depth of the fork in the tail. Fish were towel dried and weighed to the nearest 1 g or 5% of total body weight.

An external examination was conducted for lumps and bumps, secondary sexual characteristics, missing fins or eyes, opercular, fin or gill damage, external lesions, presence of parasites, and other anomalous features. All external lesions were recorded as to position, shape, size, colour, depth, appearance on cut surface and any other features of note. Photographs were taken of lesions to aid in their interpretation. The external conditions were assessed according to the health assessment index of Adams et al. (1993); or Goede (1993) on data logging sheets.

Age were determined by the appropriate structure (scales, otoliths, pectoral spines) following established protocols. A single person (John Tost; North Shore Environmental) will perform the age determinations on all the fish. Aging structures were archived for future reference. Fish age will be confirmed by a second expert (minimum 10%).

The body cavity were opened to expose the internal organs. The internal examination of each fish included the recording and/or photographing of evident tumors, neoplasms and lesions in major organs including the liver and skin. The internal conditions will be assessed according to the health assessment index of Adams et al. (1993) or Goede and Barton (1990) on data logging sheets.

All internal organs were examined for lumps, bumps or abnormal features. The lower intestine and oesophagus were cut to allow total removal of the gastrointestinal tract. The liver was removed and weighed on pre-weighed aluminum pans. The liver samples must be weighed immediately to avoid loss of water. Care was taken to avoid rupturing the gall bladder and to remove the spleen before weighing. If the liver tissue was diffuse, it was teased from the intestines starting from the posterior and proceeding anteriorly. The liver was weighed, divided in half and frozen in separate plastic bags for metals and metallothionein analysis (SE latest protocols from AETE).

The gonads were removed from the dorsal wall of the body cavity from the anterior to the posterior and weighed on a pre-weighed pan to the nearest 0.01 g or ±1% of the total organ weight. Care was taken to remove external mesenteries and visceral lipid deposits before weighing the gonads; gonadal membranes, however, remained intact. Egg volume and mass were measured on fresh eggs. One hundred eggs were counted in a stereoscopic microscope and added to a small graduated cylinder containing a known volume of water. The cylinder was placed on a balance so that the mass of the 100 eggs could be measured. The volume of the eggs was then determined from the displacement of the water in the cylinder.

The kidneys were removed by making lengthwise incisions along each edge of the tissue and then detached using the spoon end of a stainless steel weighing spatula by applying firm but gentle pressure against the upper abdominal cavity wall (dorsal aorta). In this procedure the kidney was scraped away from the dorsal aorta and associated connective tissue. The kidney was divided in half, placed in separate whirlpack bags and frozen on dry ice for both metals and metallothionein analysis.

The gills arches and attached filaments were removed by severing the dorsal and ventral cartilaginous attachment of the arches to the surrounding oral cavity. The gill arches were placed in whirlpack bags and frozen on dry ice for metals and metallothionein analysis.

REFERENCES

Adams, S.M., A.M. Brown and R.W. Goede. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. Transactions of the American Fisheries Society. 122:63-73.

APHA (American Public Health Association). 1995. Standard methods for the examination of water and wastewater. APHA, American Water Works Association, Water Environment Federation.

Goede, R.W. 1993. Fish health/condition assessment procedures. Utah Division of Wildlife Resources, Fisheries Experiment Station, Logan, UT.

QAMS. 1986. Development of data quality objectives. Description of Stages I and II (draft). Quality Assurance Management Staff. Environmental Protection Agency, Washington, D.C.

QAMS. 1990. Proposed glossary of quality assurance related terms. Quality Assurance Management Staff. Environmental Protection Agency, Washington, D.C.

APPENDIX B

Selected Site Photographs

Photograph B-1. Buttle Lake - exposure area, October 1996.

Photograph B-2. Upper Campbell Lake - reference area, October 1996.

Photograph B-3. Myra Creek - exposure area, October 1996.

Photograph B-4. Myra Creek - reference area, October 1996.

Photograph B-5. Standard ponar grab of typical substrate from the reference area.

Photograph B-6. Standard ponar grab of typical substrate from the exposure area.

APPENDIX C

Water Quality and Chemistry

ATTACHMENT C.1

Detailed Methods

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

ttn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Analysis Performed:

- ICP 25 ELEMENT SCAN, FILTERS
- 30 ELEMENT ICPAES AND ICP-MS SCAN
- Acid Digestion
- ICP-MS, Decommissioning Package Metals
- Loss on Ignition
- Acid Digestion
- Moisture Content
- Particle Size Analysis(per fraction)
- Total Organic Carbon
- Alkalinity
- Anions(Cl,NO2,NO3,o-PO4 & SO4)
- Fluoride, Ion Chromatography
- Reactive Silica
- RCAP Calculations
- Manual Conventionals(pH,Turbidity,Conductivity,Color)
- Mercury, Cold Vapour AA, Digestion Required
- Ammonia
- Total Kjeldahl Nitrogen, Digestion Required
- Dissolved Inorganic Carbon, as Carbon(Autoanalyzer)

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Analysis Performed:

Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Total Suspended Solids
Acidity
Cyanide, Total(UV-Visible)
Acid Digestion

Methodology:

1) **Analysis of trace metals in filters by Inductively Coupled Plasma.**
   U.S. EPA Method No. 200.7
   (Ministry of Environment ELSCAN)
2) **The analysis of alkaline metals in filters by Inductively Coupled Plasma Emission Spectroscopy.**
   NIOSH Method No. 7300(Modification)
   (Ministry of Environment ELSCAN)
3) Acid digestion of filters for metals determination by ICP AES.
   NIOSH Method No. 7300(Modification)
4) Analysis of trace metals in soil by Inductively Coupled Plasma Mass Spectrophotometry.
   U.S. EPA Method No. 6020(Modification)

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

5) The determination of the loss on ignition of organic matter by heating to constant weight @420°C.
McKeague Methods of Soil Analysis # 3.81
6) Acid digestion of soils for metals determination by inductively coupled plasma atomic emission spectrometry and/or flame or furnace atomic absorption spectroscopy.
U.S. EPA Method No. 3050(Modification)
7) Determination of the moisture content of soil by weight.
ASTM Method No. D2216-80
8) PSA-SBC-SO add missing information
9) LECO Induction Furnace and coulometric detection.
Based upon ASTM methodology
10) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
11) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1,
365.1 and 375.4.

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

12) Analysis of fluoride in water by Ion Chromatography.
U.S. EPA Method No. 300.0
Standard Methods(1985) No. 429.0

13) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7

14) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G

15) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)

16) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method

17) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1
and 110.3

51

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4
Fax:	604-662-8548
Attn:	Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

18) Cold Vapour Atomic Absorption Analysis of water for mercury.
U.S. EPA Method No. 245.2
(Reference - Varian Method No. AA-51)
19) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
ASTM Method No. D1426-79 C
Refer - Method No. 1100106 Issue 122289
20) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289
21) The determination of dissolved inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
MOE Method No. ROM - 102AC2.1
(Refer Method No. 1102106 Issue 122989)
22) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted: October 15/96
Date Reported: December 4/96
MDS Ref#: 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01
Sampled By: PMK

Certificate of Analysis

Methodology: (Cont'd)

23) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
24) Determination of acidity in water by titration to pH 8.3.
Standard Methods (17th ed.) No. 2310B
U.S. EPA Method No. 305.1
25) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2
26) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
U.S. EPA Method No. 3020

Instrumentation:

1, 2,13,14) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
3, 6,26) Thermolyne Hotplate/Hot Block
4,15) PE Sciex ELAN 6000 ICP-MS Spectrometer
5) Precision Mechanical Convention Oven/Neytech Furnace
7,23) Precision Mechanical Convention Oven/Sartorius Basic Balance
8) PSA-SBC-SO add missing information
9) LECO Induction Furnace, UIC CM5012 CO2 Analyzer
10) Cobas Fara Centrifugal Analyzer
11) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
12) Dionex Ion Chromatograph, Series 4500i
16) Calculation from existing results; no instrumentation required.
17) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
18) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
19) Skalar Segmented Flow Analyzer, Model SA 20/40

MDS
Environmental Services Limited

ient: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

ttn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

strumentation:

20,21,22) Technicon Autoanalyzer
24) Titrator
25) Hach UV - Visible Spectrophotometer, Model DR/3000

mple Description: Filter, Soil, Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

esults: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

Certified By
for M. Hartwell, M.Sc.
Director, Laboratory Operations

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted: October 15/96
Date Reported: November 28/96
MDS Ref#: 967232
MDS Quote#: 96-697-GS

Client Ref#: 3/729-01
Sampled By: IMW/EBS

Certificate of Analysis

Analysis Performed:

- Alkalinity
- Anions(Cl,NO2,NO3,o-PO4 & SO4)
- RCAP MS Package, 8 Element ICPAES Scan
- Reactive Silica
- RCAP MS Package, 22 Element ICP-MS Scan
- RCAP Calculations
- Manual Conventionals(pH,Turbidity,Conductivity,Color)
- Mercury, Cold Vapour AA, Digestion Required
- Ammonia
- Total Kjeldahl Nitrogen, Digestion Required
- Dissolved Inorganic Carbon, as Carbon(Autoanalyzer)
- Dissolved Organic Carbon, as Carbon(Autoanalyzer)
- Total dissolved Solids
- Total Suspended Solids
- Cyanide, Total(UV-Visible)
- Acid Digestion
- Filtration (0.45 micron)

Methodology:

1) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	November 28/96
MDS Ref#:	967232
MDS Quote#:	96-697-GS
Client Ref#:	3/729-01
Sampled By:	IMW/EBS

Certificate of Analysis

Methodology: (Cont'd)

2) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.
3) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7
4) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G
5) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)
6) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method
7) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1 and 110.3

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	November 28/96
MDS Ref#:	967232
MDS Quote#:	96-697-GS
Client Ref#:	3/729-01
Sampled By:	IMW/EBS

Certificate of Analysis

Methodology: (Cont'd)

8) Cold Vapour Atomic Absorption Analysis of water for mercury.
U.S. EPA Method No. 245.2
(Reference - Varian Method No. AA-51)
9) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
ASTM Method No. D1426-79 C
Refer - Method No. 1100106 Issue 122289
10) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289
11) The determination of dissolved inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
MOE Method No. ROM - 102AC2.1
(Refer Method No. 1102106 Issue 122989)
12) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	November 28/96
MDS Ref#:	967232
MDS Quote#:	96-697-GS
Client Ref#:	3/729-01
Sampled By:	IMW/EBS

Certificate of Analysis

Methodology: (Cont'd)

13) Determination of total dissolved solids in water by weight.
U.S. EPA Method No. 160.1
14) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
15) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2
16) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
U.S. EPA Method No. 3020
17) Filtration of waters by 0.45 membrane filter.

Instrumentation:

1) Cobas Fara Centrifugal Analyzer
2) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
3, 4) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
5) PE Sciex ELAN 6000 ICP-MS Spectrometer
6) Calculation from existing results; no instrumentation required.
7) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
8) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
9) Skalar Segmented Flow Analyzer, Model SA 20/40

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted:	October 15/96
		Date Reported:	November 28/96
		MDS Ref#:	967232
		MDS Quote#:	96-697-GS
Fax:	604-662-8548	Client Ref#:	3/729-01
		Sampled By:	IMW/EBS
Attn:	Peter Kiffney		

Certificate of Analysis

Instrumentation:

10,11,12) Technicon Autoanalyzer
13,14) Precision Mechanical Convention Oven/Sartorius Basic Balance
15) Hach UV - Visible Spectrophotometer, Model DR/3000
16) Thermolyne Hotplate/Hot Block
17) Filtration Unit

Sample Description: Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

Results: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

Certified By
for M. Hartwell, M.Sc.
Director, Laboratory Operations

63

MDS
Environmental Services Limited

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted:	October 23/96
		Date Reported:	December 9/96
		MDS Ref#:	967590
		MDS Quote#:	96-697-GS
		Client PO#:	Canmet Project
Fax:	604-662-8548	Client Ref#:	Westmin
		Sampled By:	Gavin Diron
Attn:	Gavin Diron		

Certificate of Analysis

Analysis Performed:

30 ELEMENT ICPAES AND ICP-MS SCAN
20 Element ICP Scan(18 Scan + Ti and P)
ICP Alkaline Scan(Ca,Mg,Na,K,Sr), Digestion Required
Acid Digestion
Alkalinity
Ammonia
Anions(Cl,NO2,NO3,o-PO4 & SO4)
Reactive Silica
RCAP Calculations
Manual Conventionals(pH,Turbidity,Conductivity,Color)
Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Courier, Original Sample for London
Acid Digestion

Methodology:

1) Analysis of trace metals on a swab by Inductively Coupled Plasma Spectrophotometry, following an acidic extraction.
MDS Internal Method No. 96-MET-1
(Reference - NIOSH Method No. 7300)

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4
Fax:	604-662-8548
Attn:	Gavin Diron

Date Submitted:	October 23/96
Date Reported:	December 9/96
MDS Ref#:	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin
Sampled By:	Gavin Diron

Certificate of Analysis

Methodology: (Cont'd)

2) Analysis of alkaline metals in a swab by Inductively Coupled Plasma Spectrophotometry.
U.S. EPA Method No. 6010
(Ministry of Environment ELSCAN)
3) Acid digestion of swabs for metals determination by inductively coupled plasma atomic emission spectrometry and/or flame or furnace atomic absorption spectroscopy.
U.S. EPA Method No. 3050(Modification)
4) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
5) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
ASTM Method No. D1426-79 C
Refer - Method No. 1100106 Issue 122289
6) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1,
365.1 and 375.4.

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4
Fax:	604-662-8548
Attn:	Gavin Diron

Date Submitted:	October 23/96
Date Reported:	December 9/96
MDS Ref#:	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin
Sampled By:	Gavin Diron

Certificate of Analysis

Methodology: (Cont'd)

7) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7

8) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G

9) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)

10) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method

11) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1
and 110.3

12) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Gavin Diron

Date Submitted:	October 23/96
Date Reported:	December 9/96
MDS Ref#:	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin
Sampled By:	Gavin Diron

Certificate of Analysis

Methodology: (Cont'd)

13) Courier, Original sample for London
14) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy. U.S. EPA Method No. 3020

Instrumentation:

1, 2, 7, 8) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
3,14) Thermolyne Hotplate/Hot Block
4, 5) Cobas Fara Centrifugal Analyzer
6) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
9) PE Sciex ELAN 6000 ICP-MS Spectrometer
10) Calculation from existing results; no instrumentation required.
11) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
12) Technicon Autoanalyzer
13) COUR-LO-WT add missing information

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Gavin Diron

Date Submitted:	October 23/96
Date Reported:	December 9/96
MDS Ref#:	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin
Sampled By:	Gavin Diron

Certificate of Analysis

Instrumentation:	
Sample Description:	Swab, Water
QA/QC:	Refer to CERTIFICATE OF QUALITY CONTROL report.
Results:	Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

Certified By
for M. Hartwell, M.Sc.
Director, Laboratory Operations

ATTACHMENT C.2

QA/QC

Table C2-1 Relative percent difference (RPD) of water chemistry laboratory replicates.

Parameter	BL-E-1-3 Dissolved Station	BL-E-1-3 Dissolved Replicate	RPD	BL-E-1-3 total Station	BL-E-1-3 total Replicate	RPD	BL-R-1-2 Dissolved Station	BL-R-1-2 Dissolved Replicate	RPD	BL-R-1-6 Dissolved Station	BL-R-1-6 Dissolved Replicate	RPD
METALS												
Aluminum	nd	nr	na	nd	nd	np	nd	nd	np	0.01	nd	np
Antimony	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Arsenic	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Barium	nd	nr	na	0.005	0.005	0	nd	nd	np	nd	nd	np
Beryllium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Bismuth	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Boron	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Cadmium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Chromium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Cobalt	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Copper	0.002	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Cyanide, Total	nd	nr	na	-	-	-	nd	nr	na	nd	nr	na
Iron	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Lead	0.0031	nr	na	0.0036	0.0032	11.8	0.0033	0.0032	3.1	nd	nd	np
Manganese	nd	nr	na	0.007	0.007	0	nd	nd	np	0.002	0.002	0
Mercury	nd	nr	na	-	-	-	nd	nr	na	0.3	nr	na
Molybdenum	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Nickel	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Selenium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Silver	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Strontium	0.018	nr	na	0.017	0.017	0	0.013	0.014	7.4	0.014	0.014	0
Thallium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Tin	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Titanium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Uranium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Vanadium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Zinc	0.02	nr	na	0.02	0.022	9.5	0.013	0.014	7.4	0.084	0.077	8.7
CONVENTIONALS												
Major Ions												
Alkalinity(as CaCO3)	22	22	0	-	-	-	23	24	4.3	23	nr	na
Anion Sum	0.606	nr	na	-	-	-	0.58	nr	na	0.582	nr	na
Bicarbonate(as CaCO3, calculated	22	nr	na	-	-	-	23	nr	na	23	nr	na
Calcium	10.6	nr	na	10.5	10.8	2.8	9.7	9.8	1	9.5	9.4	1.1
Carbonate(as CaCO3, calculated)	nd	nr	na	-	-	-	nd	nr	na	nd	nr	na
Cation Sum	0.614	nr	na	-	-	-	0.697	nr	na	0.57	nr	na
Chloride	nd	nd	np	-	-	-	nd	nd	np	nd	nr	na
Fluoride	nd	nd	np	-	-	-	-	-	-	-	-	-
Hardness(as CaCO3)	28.2	nr	na	-	-	-	32.8	nr	na	26.8	nr	na
Ion Balance	0.62	nr	na	-	-	-	9.21	nr	na	1.01	nr	na
Magnesium	0.4	nr	na	0.4	0.4	0	0.7	0.7	0	0.7	0.7	0
Phosphorus	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Potassium	nd	nr	na	nd	nd	np	nd	nd	np	nd	nd	np
Sodium	1	nr	na	0.9	0.9	0	0.7	1.2	52.6	0.7	0.6	15.4
Nutrients												
Ammonia(as N)	0.07	nr	na	-	-	-	0.07	nr	na	0.07	nr	na
Dissolved Inorganic Carbon(as C)	5.9	nr	na	-	-	-	5.8	nr	na	6	nr	na
Dissolved Organic Carbon(DOC)	0.6	nr	na	-	-	-	0.7	nr	na	0.7	nr	na
Nitrate(as N)	nd	nd	np	-	-	-	nd	nd	np	nd	nr	na
Nitrite(as N)	nd	nd	np	-	-	-	nd	nd	np	nd	nr	na
Orthophosphate(as P)	nd	nd	np	-	-	-	nd	nd	np	nd	nr	na
Sulphate	7	7	0	-	-	-	5	5	0	5	nr	na
Total Kjeldahl Nitrogen(as N)	0.05	nr	na	-	-	-	0.14	nr	na	nd	nr	na
Other												
Reactive Silica(SiO2)	2.1	2.1	0	-	-	-	2.3	2.3	0	2.3	nr	na
Colour	8	7	13.3	-	-	-	7	nr	na	6	nr	na
Conductivity - @25°C	65	66	1.5	-	-	-	60	nr	na	60	nr	na
Langelier Index at 20°C	-1.1	nr	na	-	-	-	-0.97	nr	na	-1.48	nr	na
Langelier Index at 4°C	-1.5	nr	na	-	-	-	-1.37	nr	na	-1.88	nr	na
pH	8	8	0	-	-	-	8	nr	na	7.6	nr	na
Saturation pH at 20°C	9.06	nr	na	-	-	-	8.97	nr	na	9.06	nr	na
Saturation pH at 4°C	9.46	nr	na	-	-	-	9.37	nr	na	9.46	nr	na
Total Dissolved Solids	nd	nr	na	-	-	-	37	nr	na	52	nr	na
Total Dissolved Solids(Calculated)	35	nr	na	-	-	-	35	nr	na	33	nr	na
Total Suspended Solids	nd	nr	na	-	-	-	nd	nr	na	nd	nr	na
Turbidity	0.2	0.2	0	-	-	-	0.3	nr	na	0.1	nr	na

nd not detected
np not possible to determine
nr replicate not analyzed
na not applicable because replicate not analyzed
- analysis not requested

Table C2-2 Relative percent difference (RPD) of water chemistry field homogenization replicates.

Parameter	BL-E-1-6 Dissolved	BL-E-1-D Dissolved Field Rep	RPD	BL-E-1-6 Total	BL-E-1-D Total Field Rep	RPD
METALS						
Aluminum	nd	nd	np	nd	nd	np
Antimony	nd	nd	np	nd	nd	np
Arsenic	nd	nd	np	nd	nd	np
Barium	0.005	0.005	0	nd	nd	np
Beryllium	nd	nd	np	nd	nd	np
Bismuth	nd	nd	np	nd	nd	np
Boron	nd	nd	np	nd	nd	np
Cadmium	nd	nd	np	nd	nd	np
Chromium	nd	nd	np	nd	nd	np
Cobalt	nd	nd	np	nd	nd	np
Copper	nd	nd	np	nd	nd	np
Cyanide, Total	nd	nd	np	-	-	-
Iron	nd	nd	np	nd	nd	np
Lead	0.0003	0.0006	66.7	nd	0.0004	np
Manganese	nd	nd	np	0.006	0.006	0
Mercury	nd	nd	np	-	-	-
Molybdenum	nd	nd	np	nd	nd	np
Nickel	nd	nd	np	nd	nd	np
Selenium	nd	nd	np	nd	nd	np
Silver	nd	nd	np	nd	nd	np
Sodium	0.9	0.9	0	0.9	0.9	0
Strontium	0.018	0.018	0	0.018	0.018	0
Thallium	nd	nd	np	nd	nd	np
Tin	nd	nd	np	nd	nd	np
Titanium	nd	nd	np	nd	nd	np
Uranium	nd	nd	np	nd	nd	np
Vanadium	nd	nd	np	nd	nd	np
Zinc	0.021	0.02	4.9	0.024	0.026	8
CONVENTIONALS						
Major Ions						
Alkalinity(as CaCO3)	23	22	4.4	-	-	-
Anion Sum	0.666	0.618	7.5	-	-	-
Bicarbonate(as CaCO3, calculated	22	22	0	-	-	-
Calcium	10.8	10.9	0.9	10.9	10.9	0
Carbonate(as CaCO3, calculated)	nd	nd	np	-	-	-
Cation Sum	0.614	0.618	0.6	-	-	-
Chloride	2	nd	np	-	-	-
Fluoride	nd	nd	np	-	-	-
Hardness(as CaCO3)	28.8	29	0.7	-	-	-
Ion Balance	4.01	0.05	195.1	-	-	-
Magnesium	0.4	0.4	0	0.5	0.4	22.2
Phosphorus	nd	nd	np	nd	nd	np
Potassium	nd	nd	np	nd	nd	np
Sulphate	8	8	0	-	-	-
Nutrients						
Ammonia(as N)	nd	nd	np	-	-	-
Dissolved Inorganic Carbon(as C)	5.7	5.8	1.7	-	-	-
Dissolved Organic Carbon(DOC)	0.8	0.8	0	-	-	-
Nitrate(as N)	nd	nd	np	-	-	-
Nitrite(as N)	nd	nd	np	-	-	-
Orthophosphate(as P)	nd	nd	np	-	-	-
Total Kjeldahl Nitrogen(as N)	0.08	0.15	60.9	-	-	-
Other						
Colour	7	8	13.3	-	-	-
Conductivity - @25°C	68	66	3	-	-	-
Langelier Index at 20°C	-1.2	-1.21	0.8	-	-	-
Langelier Index at 4°C	-1.6	-1.61	0.6	-	-	-
pH	7.8	7.8	0	-	-	-
Reactive Silica(SiO2)	2.1	2.1	0	-	-	-
Saturation pH at 20°C	9.03	9.04	0.1	-	-	-
Saturation pH at 4°C	9.43	9.44	0.1	-	-	-
Total Dissolved Solids	nd	nd	np	-	-	-
Total Dissolved Solids(Calculated)	37	36	2.7	-	-	-
Total Suspended Solids	nd	nd	np	-	-	-
Turbidity	0.2	0.2	0	-	-	-

nd	not detected
np	not possible to determine
nr	replicate not analyzed
na	not applicable because replicate not analyzed
-	analysis not requested

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01

Client : EVS Consultants Limited
Contact: Peter Kiffney

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	91	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	110	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	BL-E-1-3	0.05	mg/L	nd(b)	0.1	yes	109	88	114	yes	0.31	0.30	0.18	0.42	yes	yes
Nitrite(as N)	na	0.01	mg/L	nd(b)	0.03	yes	85	80	116	yes	na	na	na	na	na	yes
Orthophosphate(as P)	BL-E-1-3	0.01	mg/L	nd(b)	0.03	yes	102	90	110	yes	0.98	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	101	90	113	yes	na	na	na	na	na	yes
Fluoride	BL-E-1-3	0.02	mg/L	nd(b)	0.04	yes	108	80	120	yes	0.21	0.20	0.12	0.28	yes	yes
Boron	BL-E-1-3 total	0.005	mg/L	nd(b)	0.02	yes	106	85	115	yes	1.17	1.00	0.60	1.40	yes	yes
Calcium	BL-E-1-3 total	0.1	mg/L	nd(b)	0.2	yes	107	85	115	yes	0.8	1.0	0.2	1.8	yes	yes
Iron	BL-E-1-3 total	0.02	mg/L	nd(b)	0.03	yes	101	85	115	yes	1.09	1.00	0.60	1.40	yes	yes
Magnesium	BL-E-1-3 total	0.1	mg/L	nd(b)	0.2	yes	107	85	115	yes	1.0	1.0	0.2	1.6	yes	yes
Phosphorus	BL-E-1-3 total	0.1	mg/L	nd(b)	0.2	yes	92	85	115	yes	1.0	1.0	0.4	1.6	yes	yes
Potassium	BL-E-1-3 total	0.5	mg/L	nd(b)	1.0	yes	100	85	115	yes	4.4	5.0	1.0	8.0	yes	yes
Sodium	BL-E-1-3 total	0.1	mg/L	nd(b)	0.2	yes	107	85	115	yes	1.1	1.0	0.2	1.6	yes	yes
Zinc	BL-E-1-3 total	0.002	mg/L	nd(b)	0.02	yes	101	85	115	yes	1.06	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	101	80	120	yes	na	na	na	na	na	yes
Aluminum	BL-E-1-3 total	0.01	mg/L	nd(b)	0.03	yes	109	85	115	yes	0.11	0.100	0.050	0.140	yes	yes
Antimony	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.100	0.100	0.050	0.140	yes	yes
Arsenic	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Barium	BL-E-1-3 total	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.100	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported:	December 4/96
MDS Ref # :	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Beryllium	BL-E-1-3 total	0.005	mg/L	nd(b)	0.01	yes	104	85	115	yes	0.114	0.100	0.050	0.140	yes	yes
Bismuth	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	102	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cadmium	BL-E-1-3 total	0.0005	mg/L	nd(b)	0.0010	yes	106	85	115	yes	0.1040	0.100	0.050	0.140	yes	yes
Chromium	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cobalt	BL-E-1-3 total	0.001	mg/L	nd(b)	0.002	yes	105	85	115	yes	0.104	0.100	0.050	0.140	yes	yes
Copper	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.103	0.100	0.050	0.140	yes	yes
Lead	BL-E-1-3 total	0.0001	mg/L	0.0007(	0.002	yes	103	85	115	yes	0.1100	0.100	0.050	0.140	yes	yes
Manganese	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Molybdenum	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.104	0.100	0.050	0.140	yes	yes
Nickel	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.104	0.100	0.050	0.140	yes	yes
Selenium	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Silver	BL-E-1-3 total	0.0003	mg/L	nd(b)	0.0006	yes	109	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Strontium	BL-E-1-3 total	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Thallium	BL-E-1-3 total	0.0001	mg/L	nd(b)	0.0002	yes	103	85	115	yes	0.1090	0.100	0.050	0.140	yes	yes
Tin	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.096	0.100	0.050	0.140	yes	yes
Titanium	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Uranium	BL-E-1-3 total	0.0001	mg/L	nd(b)	0.0002	yes	104	85	115	yes	0.1150	0.100	0.050	0.140	yes	yes
Vanadium	BL-E-1-3 total	0.002	mg/L	nd(b)	0.004	yes	105	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Colour	na	5	TCU	nd(b)	10	yes	98	85	115	yes	na	na	na	na	na	yes
Conductivity - @25°C	na	1	us/cm	na(b)	na	na	98	91	109	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported: December 4/96
MDS Ref # : 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01

Client : EVS Consultants Limited
Contact: Peter Kiffney

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
pH	na	0.1	Units	na(b)	na	na	99	98	102	yes	na	na	na	na	na	yes
Turbidity	na	0.1	NTU	nd(b)	0.5	yes	95	81	129	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	na	na	na	na	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	108	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	na	na	na	na	na	na	na	na	na	yes
Dissolved Inorganic Carbon(as C)	na	0.5	mg/L	nd	1.0	yes	na	na	na	na	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	99	80	116	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	98	82	118	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	99	82	118	yes	na	na	na	na	na	yes
Acidity(as CaCO3)	na	1	mg/L	nd	2	yes	na	na	na	na	na	na	na	na	na	yes
Cyanide, Total	na	0.005	mg/L	nd	0.010	yes	100	82	115	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported: November 28/96
MDS Ref # : 967232
MDS Quote#: 96-697-GS

Analysis of Water

Client Ref#: 3/729-01

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	91	87	113	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	110	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	BL-R-1-2	0.05	mg/L	nd(b)	0.1	yes	109	88	114	yes	0.29	0.30	0.18	0.42	yes	yes
Nitrite(as N)	na	0.01	mg/L	nd(b)	0.03	yes	85	80	116	yes	na	na	na	na	na	yes
Orthophosphate(as P)	BL-R-1-2	0.01	mg/L	nd(b)	0.03	yes	102	90	110	yes	0.93	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	101	90	113	yes	na	na	na	na	na	yes
Boron	BL-R-1-6	0.005	mg/L	nd(b)	0.02	yes	95	85	115	yes	0.954	1.00	0.60	1.40	yes	yes
Boron	na	0.005	mg/L	nd(b)	0.02	yes	95	85	115	yes	na	na	na	na	na	yes
Calcium	BL-R-1-6	0.1	mg/L	nd(b)	0.2	yes	96	85	115	yes	0.9	1.0	0.2	1.8	yes	yes
Calcium	na	0.1	mg/L	nd(b)	0.2	yes	94	85	115	yes	na	na	na	na	na	yes
Iron	BL-R-1-6	0.02	mg/L	nd(b)	0.03	yes	94	85	115	yes	0.96	1.00	0.60	1.40	yes	yes
Iron	na	0.02	mg/L	nd(b)	0.03	yes	94	85	115	yes	na	na	na	na	na	yes
Magnesium	BL-R-1-6	0.1	mg/L	nd(b)	0.2	yes	108	85	115	yes	1.0	1.0	0.2	1.6	yes	yes
Magnesium	na	0.1	mg/L	nd(b)	0.2	yes	107	85	115	yes	na	na	na	na	na	yes
Phosphorus	BL-R-1-6	0.1	mg/L	nd(b)	0.2	yes	90	85	115	yes	0.8	1.0	0.4	1.6	yes	yes
Phosphorus	na	0.1	mg/L	nd(b)	0.2	yes	93	85	115	yes	na	na	na	na	na	yes
Potassium	BL-R-1-6	0.5	mg/L	nd(b)	1.0	yes	97	85	115	yes	4.5	5.0	1.0	8.0	yes	yes
Potassium	na	0.5	mg/L	nd(b)	1.0	yes	96	85	115	yes	na	na	na	na	na	yes
Sodium	BL-R-1-6	0.1	mg/L	nd(b)	0.2	yes	95	85	115	yes	1.0	1.0	0.2	1.6	yes	yes
Sodium	na	0.1	mg/L	nd(b)	0.2	yes	102	85	115	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported:	November 28/96
MDS Ref # :	967232
MDS Quote#:	96-697-GS
Client Ref#:	3/729-01

Client : EVS Consultants Limited
Contact: Peter Kiffney

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Zinc	BL-R-1-6	0.002	mg/L	0.003(b	0.02	yes	96	85	115	yes	0.996	1.00	0.60	1.40	yes	yes
Zinc	na	0.002	mg/L	nd(b)	0.02	yes	96	85	115	yes	na	na	na	na	na	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd	1.0	yes	101	80	120	yes	na	na	na	na	na	yes
Aluminum	BL-R-1-2	0.01	mg/L	nd(b)	0.03	yes	109	85	115	yes	0.12	0.100	0.050	0.140	yes	yes
Aluminum	BL-R-1-6	0.01	mg/L	nd(b)	0.03	yes	113	85	115	yes	0.11	0.100	0.050	0.140	yes	yes
Antimony	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Antimony	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Arsenic	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Arsenic	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Barium	BL-R-1-2	0.005	mg/L	nd(b)	0.01	yes	110	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Barium	BL-R-1-6	0.005	mg/L	nd(b)	0.01	yes	108	85	115	yes	0.115	0.100	0.050	0.140	yes	yes
Beryllium	BL-R-1-2	0.005	mg/L	nd(b)	0.01	yes	99	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Beryllium	BL-R-1-6	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.116	0.100	0.050	0.140	yes	yes
Bismuth	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Bismuth	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cadmium	BL-R-1-2	0.0005	mg/L	nd(b)	0.0010	yes	109	85	115	yes	0.1090	0.100	0.050	0.140	yes	yes
Cadmium	BL-R-1-6	0.0005	mg/L	nd(b)	0.0010	yes	109	85	115	yes	0.1070	0.100	0.050	0.140	yes	yes
Chromium	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	111	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Chromium	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	114	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Cobalt	BL-R-1-2	0.001	mg/L	nd(b)	0.002	yes	111	85	115	yes	0.109	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported: November 28/96
MDS Ref # : 967232
MDS Quote#: 96-697-GS

Analysis of Water

Client Ref#: 3/729-01

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Cobalt	BL-R-1-6	0.001	mg/L	nd(b)	0.002	yes	113	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Copper	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	86	85	115	yes	0.086	0.100	0.050	0.140	yes	yes
Copper	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	89	85	115	yes	0.087	0.100	0.050	0.140	yes	yes
Lead	BL-R-1-2	0.0001	mg/L	nd(b)	0.002	yes	107	85	115	yes	0.1150	0.100	0.050	0.140	yes	yes
Lead	BL-R-1-6	0.0001	mg/L	0.0009(	0.002	yes	109	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Manganese	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	111	85	115	yes	0.110	0.100	0.050	0.140	yes	yes
Manganese	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	115	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Molybdenum	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.107	0.100	0.050	0.140	yes	yes
Molybdenum	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Nickel	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Nickel	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Selenium	BL-R-1-2	0.002	mg/L	0.002(b	0.004	yes	106	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Selenium	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Silver	BL-R-1-2	0.0003	mg/L	nd(b)	0.0006	yes	113	85	115	yes	0.1050	0.100	0.050	0.140	yes	yes
Silver	BL-R-1-6	0.0003	mg/L	nd(b)	0.0006	yes	100	85	115	yes	0.1060	0.100	0.050	0.140	yes	yes
Strontium	BL-R-1-2	0.005	mg/L	nd(b)	0.01	yes	107	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Strontium	BL-R-1-6	0.005	mg/L	nd(b)	0.01	yes	109	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Thallium	BL-R-1-2	0.0001	mg/L	nd(b)	0.0002	yes	108	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Thallium	BL-R-1-6	0.0001	mg/L	nd(b)	0.0002	yes	111	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Tin	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	108	85	115	yes	0.107	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported:	November 28/96
MDS Ref # :	967232
MDS Quote#:	96-697-GS
Client Ref#:	3/729-01

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	**SAMPLE ID (spike)**	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Tin	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	106	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Titanium	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.111	0.100	0.050	0.140	yes	yes
Titanium	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	114	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Uranium	BL-R-1-2	0.0001	mg/L	nd(b)	0.0002	yes	106	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Uranium	BL-R-1-6	0.0001	mg/L	nd(b)	0.0002	yes	111	85	115	yes	0.1120	0.100	0.050	0.140	yes	yes
Vanadium	BL-R-1-2	0.002	mg/L	nd(b)	0.004	yes	109	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Vanadium	BL-R-1-6	0.002	mg/L	nd(b)	0.004	yes	112	85	115	yes	0.112	0.100	0.050	0.140	yes	yes
Colour	BL-R-1-2	5	TCU	nd(b)	10	yes	98	85	115	yes	ns	ns	ns	ns	ns	yes
Conductivity - @25°C	BL-R-1-2	1	us/cm	na(b)	na	na	98	91	109	yes	ns	ns	ns	ns	ns	yes
pH	BL-R-1-2	0.1	Units	na(b)	na	na	99	98	102	yes	ns	ns	ns	ns	ns	yes
Turbidity	BL-R-1-2	0.1	NTU	nd(b)	0.5	yes	95	81	129	yes	ns	ns	ns	ns	ns	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Mercury	na	0.1	ug/L	nd	0.2	yes	105	79	120	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	95	79	119	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd	0.1	yes	na	na	na	na	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	106	77	122	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported: November 28/96
MDS Ref # : 967232
MDS Quote#: 96-697-GS

Analysis of Water

Client Ref#: 3/729-01

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	108	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	110	77	122	yes	na	na	na	na	na	yes
Total Kjeldahl Nitrogen(as N)	na	0.05	mg/L	nd	0.1	yes	na	na	na	na	na	na	na	na	na	yes
Dissolved Inorganic Carbon(as C)	na	0.5	mg/L	nd	1.0	yes	na	na	na	na	na	na	na	na	na	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	99	80	116	yes	na	na	na	na	na	yes
Total Dissolved Solids	na	10	mg/L	nd	20	yes	98	85	115	yes	na	na	na	na	na	yes
Total Suspended Solids	na	5	mg/L	nd	2	yes	99	82	118	yes	na	na	na	na	na	yes
Cyanide, Total	na	0.005	mg/L	nd	0.010	yes	100	82	115	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported:	December 9/96
MDS Ref # :	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin

Client : EVS Consultants Limited
Contact: Gavin Diron

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Alkalinity(as CaCO3)	na	1	mg/L	nd(b)	2	yes	97	87	113	yes	na	na	na	na	na	yes
Ammonia(as N)	na	0.05	mg/L	nd(b)	0.10	yes	100	81	118	yes	na	na	na	na	na	yes
Chloride	na	1	mg/L	nd(b)	2	yes	106	90	113	yes	na	na	na	na	na	yes
Nitrate(as N)	MF-EFF	0.05	mg/L	nd(b)	0.1	yes	108	88	114	yes	0.29	0.30	0.18	0.42	yes	yes
Nitrite(as N)	MF-EFF	0.01	mg/L	nd(b)	0.03	yes	91	80	116	yes	0.18	0.20	0.12	0.28	yes	yes
Orthophosphate(as P)	MF-EFF	0.01	mg/L	nd(b)	0.03	yes	99	90	110	yes	0.75	1.0	0.6	1.4	yes	yes
Sulphate	na	2	mg/L	nd(b)	3	yes	100	90	113	yes	na	na	na	na	na	yes
Boron	MF-EFF	0.005	mg/L	nd(b)	0.02	yes	102	85	115	yes	0.781	1.00	0.60	1.40	yes	yes
Calcium	MF-EFF	0.1	mg/L	nd(b)	0.2	yes	98	85	115	yes	*	*	*	*	*	yes
Iron	MF-EFF	0.02	mg/L	nd(b)	0.03	yes	98	85	115	yes	0.79	1.00	0.60	1.40	yes	yes
Magnesium	MF-EFF	0.1	mg/L	nd(b)	0.2	yes	104	85	115	yes	*	*	*	*	*	yes
Phosphorus	MF-EFF	0.1	mg/L	nd(b)	0.2	yes	96	85	115	yes	0.7	1.0	0.4	1.6	yes	yes
Potassium	MF-EFF	0.5	mg/L	nd(b)	1.0	yes	97	85	115	yes	*	*	*	*	*	yes
Sodium	MF-EFF	0.1	mg/L	nd(b)	0.2	yes	99	85	115	yes	*	*	*	*	*	yes
Zinc	MF-EFF	0.002	mg/L	nd(b)	0.02	yes	100	85	115	yes	0.824	1.00	0.60	1.40	yes	yes
Reactive Silica(SiO2)	na	0.5	mg/L	nd(b)	1.0	yes	99	80	120	yes	na	na	na	na	na	yes
Aluminum	Q3 90809	0.01	mg/L	nd(b)	0.03	yes	106	85	115	yes	*	*	*	*	*	yes
Antimony	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	101	85	115	yes	0.104	0.100	0.050	0.140	yes	yes
Arsenic	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	96	85	115	yes	0.097	0.100	0.050	0.140	yes	yes
Barium	Q3 90809	0.005	mg/L	nd(b)	0.01	yes	105	85	115	yes	0.116	0.100	0.050	0.140	yes	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Gavin Diron

Date Reported: December 9/96
MDS Ref # : 967590
MDS Quote#: 96-697-GS
Client PO#: Canmet Project
Client Ref#: Westmin

Analysis of Water

Parameter	SAMPLE ID (spike)	LOQ	Units	Process Blank			Process % Recovery				Matrix Spike					Overall QC Acceptable
				Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	
Beryllium	Q3 90809	0.005	mg/L	nd(b)	0.01	yes	114	85	115	yes	0.123	0.100	0.050	0.140	yes	yes
Bismuth	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	102	85	115	yes	*	*	*	*	*	yes
Cadmium	Q3 90809	0.0005	mg/L	nd(b)	0.0010	yes	103	85	115	yes	0.1070	0.100	0.050	0.140	yes	yes
Chromium	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.109	0.100	0.050	0.140	yes	yes
Cobalt	Q3 90809	0.001	mg/L	nd(b)	0.002	yes	107	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Copper	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	107	85	115	yes	0.118	0.100	0.050	0.140	yes	yes
Lead	Q3 90809	0.0001	mg/L	0.0006(	0.002	yes	103	85	115	yes	0.1110	0.100	0.050	0.140	yes	yes
Manganese	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	110	85	115	yes	0.116	0.100	0.050	0.140	yes	yes
Molybdenum	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	100	85	115	yes	0.122	0.100	0.050	0.140	yes	yes
Nickel	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	104	85	115	yes	0.106	0.100	0.050	0.140	yes	yes
Selenium	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	100	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Silver	Q3 90809	0.0003	mg/L	nd(b)	0.0006	yes	97	85	115	yes	*	*	*	*	*	yes
Strontium	Q3 90809	0.005	mg/L	nd(b)	0.01	yes	102	85	115	yes	*	*	*	*	*	yes
Thallium	Q3 90809	0.0001	mg/L	nd(b)	0.0002	yes	104	85	115	yes	0.1100	0.100	0.050	0.140	yes	yes
Tin	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.105	0.100	0.050	0.140	yes	yes
Titanium	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	95	85	115	yes	0.100	0.100	0.050	0.140	yes	yes
Uranium	Q3 90809	0.0001	mg/L	nd(b)	0.0002	yes	104	85	115	yes	0.1160	0.100	0.050	0.140	yes	yes
Vanadium	Q3 90809	0.002	mg/L	nd(b)	0.004	yes	103	85	115	yes	0.108	0.100	0.050	0.140	yes	yes
Colour	MF-EFF	5	TCU	nd(b)	10	yes	98	85	115	yes	ns	ns	ns	ns	ns	yes
Conductivity - @25°C	MF-EFF	1	us/cm	na(b)	na	na	97	91	109	yes	ns	ns	ns	ns	ns	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

MDS Environmental Services Limited.

Certificate of Quality Control

Date Reported:	December 9/96
MDS Ref # :	967590
MDS Quote#:	96-697-GS
Client PO#:	Canmet Project
Client Ref#:	Westmin

Client : EVS Consultants Limited
Contact: Gavin Diron

Analysis of Water

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
pH	MF-EFF	0.1	Units	na(b)	na	na	99	98	102	yes	ns	ns	ns	ns	ns	yes
Turbidity	MF-EFF	0.1	NTU	nd(b)	0.5	yes	96	81	129	yes	ns	ns	ns	ns	ns	yes
Dissolved Organic Carbon(DOC)	na	0.5	mg/L	nd	1.0	yes	104	80	116	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

ATTACHMENT C.3

Receiving Water Results

Table C3-1: Conventional parameters (mg/L; unless otherwise specified) in water samples collected from reference and exposure stations at Buttle Lake and Myra Creek on October 7-10, 1996.

Parameter	LOQ	Effluent	Buttle Lake																		Myra Creek	
			Reference Stations								Exposure Stations										Reference	Exposure
			BL-R-1-1	BL-R-1-2	BL-R-1-3	BL-R-1-5	BL-R-1-6	mean	sd	se	BL-E-1-1	BL-E-1-2	BL-E-1-3	BL-E-1-4	BL-E-1-5	BL-E-1-6	mean	sd	sd	MF-R-1-1	MF-E-1-1
Alkalinity(as CaCO3)	1	13	22	23	23	23	23	22.8	0.4	0.2	23	23	22	22	22	23	22.5	0.5	0.2	8	3
Chloride	1	17	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	2	0.8	0.6	0.2	nd	3
Fluoride		-	-	-	-	-	-				-	-	nd	nd	nd	nd				-	-
Nitrate(as N)	0.05	2.05	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	0.26
Nitrite(as N)	0.01	0.09	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Orthophosphate(as P)	0.01	nd	nd	nd	nd	nd	nd				nd	nd	nd	0.03	nd	nd	0.009	0.010	0.004	nd	nd
Sulphate	2	581	5	5	5	5	5	5.00	0.00	0.00	7	7	7	7	7	8	7.2	0.4	0.2	nd	97
Reactive Silica(SiO2)	0.5	2.8	2.3	2.3	2.3	2.3	2.3	2.30	0.00	0.00	2.1	2.1	2.1	2.1	2.1	2.1	2.10	0.00	0.00	1.8	2.6
Anion Sum (meq/L)	na	13	0.562	0.58	0.572	0.576	0.582	0.574	0.008	0.004	0.618	0.614	0.606	0.613	0.619	0.666	0.623	0.022	0.009	0.193	2.18
Bicarbonate(as CaCO3, calculated)	1	13	22	23	23	23	23	22.8	0.4	0.2	22	22	22	22	22	22	22.0	0.0	0.0	8	3
Carbonate(as CaCO3, calculated)	1	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Cation Sum (meq/L)	na	13.2	0.563	0.697	0.624	0.598	0.57	0.610	0.054	0.024	0.628	0.603	0.614	0.607	0.613	0.614	0.613	0.009	0.003	0.216	2.13
Colour (TCU)	5	14	33	7	10	11	6	13.4	11.1	5.0	7	6	8	9	15	7	8.7	3.3	1.3	nd	5
Conductivity - @25°C (µs/cm)	1	1120	59	60	63	60	60	60.4	1.5	0.7	70	65	65	65	65	68	66.3	2.2	0.9	24	245
Hardness(as CaCO3)	0.1	600	26.3	32.8	29.7	27.1	26.8	28.5	2.7	1.2	29.6	28.6	28.2	28.2	28.7	28.8	28.7	0.5	0.2	9.2	97.2
Ion Balance (%)	0.01	0.7	0.1	9.21	4.27	1.89	1.01	3.30	3.65	1.63	0.83	0.89	0.62	0.55	0.49	4.01	1.23	1.37	0.56	5.64	1.05
Langelier Index at 20°C (na)	na	-0.993	-1.45	-0.97	-1.57	-1.49	-1.48	-1.39	0.24	0.11	-1.03	-1.1	-1.1	-1.14	-1.18	-1.2	-1.13	0.06	0.03	-2.42	-2.32
Langelier Index at 4°C (na)	na	-1.39	-1.85	-1.37	-1.97	-1.89	-1.88	-1.79	0.24	0.11	-1.43	-1.5	-1.5	-1.54	-1.58	-1.6	-1.53	0.06	0.03	-2.82	-2.72
pH (units)	0.1	7.1	7.6	8	7.5	7.6	7.6	7.7	0.2	0.1	8	7.9	8	7.9	7.9	7.8	7.92	0.08	0.03	7.5	7.1
Saturation pH at 20°C (units)	na	8.04	9.08	8.97	9.02	9.06	9.06	9.04	0.04	0.02	9.02	9.04	9.06	9.05	9.04	9.03	9.04	0.01	0.01	9.93	9.4
Saturation pH at 4°C (units)	na	8.44	9.48	9.37	9.42	9.46	9.46	9.44	0.04	0.02	9.42	9.44	9.46	9.45	9.44	9.43	9.44	0.01	0.01	10.3	9.8
Total Dissolved Solids(Calculated)	1	886	32	35	34	34	33	33.6	1.1	0.5	36	35	35	35	36	37	35.7	0.8	0.3	13	149
Turbidity (NTU)	0.1	1	0.4	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.15	0.05	0.02	nd	0.2
Mercury (µg/L)	0.1	-	nd	nd	nd	nd	0.3	0.10	0.11	0.05	nd	nd	nd	nd	nd	nd				nd	nd
Ammonia(as N)	0.05	-	nd	0.07	nd	nd	0.07	0.04	0.02	0.01	nd	nd	0.07	0.07	nd	nd	0.04	0.02	0.02	nd	0.2
Total Kjeldahl Nitrogen(as N)	0.05	-	0.33	0.14	nd	nd	nd	0.11	0.13	0.06	0.05	nd	0.05	nd	0.13	0.08	0.06	0.04	0.02	0.15	0.32
Dissolved Inorganic Carbon(as C)	0.5	-	5.8	5.8	5.9	6.1	6	5.9	0.1	0.1	5.9	6	5.9	5.9	5.8	5.7	5.87	0.10	0.04	2.5	2.6
Dissolved Organic Carbon(DOC)	0.5	4	0.7	0.7	0.7	0.7	0.7	0.70	0.00	0.00	0.7	0.6	0.6	0.7	0.6	0.8	0.67	0.08	0.03	0.9	1.2
Total Dissolved Solids	10	-	39	37	39	31	52	39.6	7.7	3.4	36	38	nd	nd	nd	nd	15.7	16.5	11.8	13	143
Total Suspended Solids	5	-	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Cyanide, Total	0.005	-	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

Table C3-2: Total metals (mg/L) in water samples collected from reference and exposure stations at Buttle Lake and Myra Creek on October 7-10, 1996.

Parameter	LOQ	Effluent	Buttle Lake																		Myra Creek	
			Reference Stations								Exposure Stations										Reference	Exposure
			BL-R-1-1	BL-R-1-2	BL-R-1-3	BL-R-1-5	BL-R-1-6	mean	sd	se	BL-E-1-1	BL-E-1-2	BL-E-1-3	BL-E-1-4	BL-E-1-5	BL-E-1-6	mean	sd	se	MF-R-1-1	MF-E-1-1
Aluminum	0.01	0.41	nd	0.01	0.01	0.02	0.02	0.013	0.007	0.003	nd	0.01	nd	nd	nd	nd	0.006	0.002	0.001	0.03	0.06
Antimony	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Arsenic	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Barium	0.005	0.027	nd	nd	nd	nd	nd				nd	nd	0.005	nd	0.005	nd	0.003	0.001	0.001	nd	0.01
Beryllium	0.005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Bismuth	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Boron	0.005	0.041	nd	0.056	nd	nd	0.007	0.014	0.024	0.010	nd	nd	nd	nd	nd	nd				nd	0.008
Cadmium	0.0005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Chromium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Cobalt	0.001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Copper	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	0.002	nd	0.0012	0.0004	0.0002	nd	nd
Iron	0.02	nd	0.02	0.03	0.02	0.03	0.03	0.026	0.005	0.002	0.02	0.04	nd	nd	0.03	nd	0.02	0.01	0.01	nd	0.03
Lead	0.0001	0.0005	0.0078	0.0066	0.0024	0.0015	0.0237	0.0084	0.0090	0.0040	0.0013	0.002	0.0036	0.0023	0.0023	nd	0.0019	0.0012	0.0005	nd	nd
Manganese	0.002	0.006	0.004	0.003	0.003	0.005	0.005	0.0040	0.0010	0.0004	0.006	0.009	0.007	0.007	0.008	0.006	0.0072	0.0012	0.0005	0.003	0.057
Molybdenum	0.002	0.044	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	0.007
Nickel	0.002	0.007	nd	nd	nd	0.002	nd	0.001	0.000	0.000	nd	0.002	nd	nd	nd	nd	0.0012	0.0004	0.0002	nd	nd
Selenium	0.002	0.025	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	0.003
Silver	0.0003	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Strontium	0.005	0.885	0.014	0.015	0.014	0.014	0.015	0.0144	0.0005	0.0002	0.017	0.017	0.017	0.017	0.017	0.018	0.0172	0.0004	0.0002	0.008	0.119
Thallium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Tin	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Titanium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Uranium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Vanadium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Zinc	0.002	0.05	0.08	0.168	0.141	0.119	0.238	0.149	0.059	0.026	0.017	0.02	0.02	0.024	0.023	0.024	0.021	0.003	0.001	0.256	0.409
Calcium	0.1	244	9.2	9.5	9.5	9.8	9.8	9.56	0.25	0.11	10.4	10	10.5	10.6	11.2	10.9	10.60	0.41	0.17	3.4	35.7
Magnesium	0.1	5.8	0.7	0.7	0.6	0.7	0.7	0.68	0.04	0.02	0.7	0.6	0.4	0.4	0.4	0.5	0.50	0.13	0.05	0.1	0.9
Phosphorus	0.1	0.3	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	nd
Potassium	0.5	14.9	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd				nd	3
Sodium	0.1	18.3	0.6	0.7	0.5	0.5	0.8	0.62	0.13	0.06	0.7	0.6	0.9	0.9	1	0.9	0.83	0.15	0.06	0.6	2.8

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

Table C3-3: Dissolved metals (mg/L) in water samples collected from reference and exposure stations at Buttle Lake and Myra Creek on October 7-10, 1996.

Parameter	LOQ	Effluent	Buttle Lake																		Myra Creek	
			Reference Stations								Exposure Stations										Reference	Exposure
			BL-R-1-1	BL-R-1-2	BL-R-1-3	BL-R-1-5	BL-R-1-6	mean	sd	se	BL-E-1-1	BL-E-1-2	BL-E-1-3	BL-E-1-4	BL-E-1-5	BL-E-1-6	mean	sd	se		MF-R-1-1	MF-E-1-1
Aluminum	0.01	0.39	nd	nd	0.01	0.01	0.01	0.008	0.003	0.001	nd	nd	nd	nd	nd	nd					0.03	0.04
Antimony	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Arsenic	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Barium	0.005	0.026	nd	nd	nd	nd	nd				nd	nd	nd	nd	0.005	0.005	0.0050	0.0000	0.0000		nd	0.01
Beryllium	0.005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Bismuth	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Boron	0.005	0.038	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Cadmium	0.0005	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Chromium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Cobalt	0.001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Copper	0.002	0.005	nd	nd	nd	nd	nd				nd	nd	0.002	nd	nd	nd	0.0012	0.0004	0.0002		nd	nd
Iron	0.02	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Lead	0.0001	nd	0.0027	0.0033	0.002	nd	nd	0.0016	0.0015	0.0009	0.0002	0.0013	0.0031	0.003	0.0026	0.0003	0.0018	0.0013	0.0005		nd	nd
Manganese	0.002	0.005	nd	nd	0.002	0.002	0.002	0.0016	0.0005	0.0003	nd	0.005	nd	nd	nd	nd	0.002	0.002	0.001		0.003	0.055
Molybdenum	0.002	0.043	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	0.008
Nickel	0.002	0.005	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Selenium	0.002	0.026	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	0.004
Silver	0.0003	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Strontium	0.005	0.883	0.014	0.013	0.015	0.014	0.014	0.014	0.001	0.000	0.017	0.018	0.018	0.017	0.018	0.018	0.0177	0.0005	0.0002		0.008	0.128
Thallium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Tin	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Titanium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Uranium	0.0001	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Vanadium	0.002	nd	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Zinc	0.002	0.009	0.123	0.013	0.272	0.088	0.084	0.116	0.096	0.043	0.041	0.019	0.02	0.022	0.02	0.021	0.024	0.008	0.003		0.238	0.289
Calcium	0.1	231	9.2	9.7	10.4	9.5	9.5	9.66	0.45	0.20	10.4	10.1	10.6	10.6	10.8	10.8	10.55	0.27	0.11		3.5	36.7
Magnesium	0.1	5.6	0.7	0.7	0.8	0.6	0.7	0.70	0.07	0.03	0.7	0.7	0.4	0.4	0.4	0.4	0.50	0.15	0.06		0.1	0.9
Phosphorus	0.1	0.5	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Potassium	0.5	13.2	nd	nd	nd	nd	nd				nd	nd	nd	nd	nd	nd					nd	nd
Sodium	0.1	17.6	0.7	0.7	0.7	0.6	0.7	0.68	0.04	0.02	0.7	0.7	1	0.9	0.9	0.9	0.85	0.12	0.05		0.6	3.1

LOQ	Limit of quantification
sd	standard deviation
se	standard error
nd	not detected

ATTACHMENT C.4

Effluent Results

C4-1: Effluent Chemistry during 1996 discharge, Myra Falls Mine.

Parameter	LOQ	Units	Effluent	Total
Metals				
Aluminum	0.01	mg/L	-	0.41
Antimony	0.002	mg/L	-	nd
Arsenic	0.002	mg/L	-	nd
Barium	0.005	mg/L	-	0.027
Beryllium	0.005	mg/L	-	nd
Bismuth	0.002	mg/L	-	nd
Boron	0.005	mg/L	-	0.041
Cadmium	0.0005	mg/L	-	nd
Chromium	0.002	mg/L	-	nd
Cobalt	0.001	mg/L	-	nd
Copper	0.002	mg/L	-	nd
Iron	0.02	mg/L	-	nd
Lead	0.0001	mg/L	-	0.0005
Manganese	0.002	mg/L	-	0.006
Molybdenum	0.002	mg/L	-	0.044
Nickel	0.002	mg/L	-	0.007
Selenium	0.002	mg/L	-	0.025
Silver	0.0003	mg/L	-	nd
Strontium	0.005	mg/L	-	0.885
Thallium	0.0001	mg/L	-	nd
Tin	0.002	mg/L	-	nd
Titanium	0.002	mg/L	-	nd
Uranium	0.0001	mg/L	-	nd
Vanadium	0.002	mg/L	-	nd
Zinc	0.002	mg/L	-	0.03
CONVENTIONALS				
Major Ions				
Alkalinity(as CaCO3)	1	mg/L	13	-
Anion Sum	na	meq/L	13	-
Bicarbonate(as CaCO3, calculated)	1	mg/L	13	-
Calcium	0.1	mg/L	-	244
Carbonate(as CaCO3, calculated)	1	mg/L	nd	-
Cation Sum	na	meq/L	13.2	-
Chloride	1	mg/L	17	-
Hardness(as CaCO3)	0.1	mg/L	600	-
Ion Balance	0.01	%	0.7	-
Magnesium	0.1	mg/L	-	5.8
Phosphorus	0.1	mg/L	-	0.3
Potassium	0.5	mg/L	-	14.9
Sodium	0.1	mg/L	-	18.3
Sulphate	2	mg/L	581	-
Nutrients				
Ammonia(as N)	0.05	mg/L	0.81	-
Dissolved Organic Carbon(DOC)	0.5	mg/L	4	-
Nitrate(as N)	0.05	mg/L	2.05	-
Nitrite(as N)	0.01	mg/L	0.09	-
Orthophosphate(as P)	0.01	mg/L	nd	-
Other				
Colour	5	TCU	14	-
Conductivity - @25°C	1	us/cm	1120	-
Langelier Index at 20°C	na	na	-0.993	-
Langelier Index at 4°C	na	na	-1.39	-
pH	0.1	Units	7.1	-
Reactive Silica(SiO2)	0.5	mg/L	2.8	-
Saturation pH at 20°C	na	units	8.04	-
Saturation pH at 4°C	na	units	8.44	-
Total Dissolved Solids(Calculated)	1	mg/L	886	-
Turbidity	0.1	NTU	1	-

nd not detected
np not possible to determin
na not applicable as replicate not analyzed
LOQ limit of quantitation

APPENDIX D

Sediment Chemistry

ATTACHMENT D.1

Detailed Methods

MDS
Environmental Services Limited

Particle Size Distribution of Soils and Sediments

1. Scope and Application

This method is designed for the determination of grain size distribution in soil and sediment samples as referenced in Land Resource Research Institute - Analytical Methods.

2. Summary of Method

A 20 - 30 gram portion of wet sample is spooned into a 250 mL wide-mouth polyproplyene bottle. Excess organic matter and carbonates are destroyed by the addition of hydrogen peroxide and allowing to stand overnight. The sample is dispersed in a distilled water and Calgon solution by mechanical shaking. The sand fraction is separated from the silt and clay by wet sieving through a 63 micron mesh size sieve. The particles remaining on the sieve (i.e. the gravel and sand fractions) are dried and then passed through a nest of sieves in order to separate the fractions using a Rotap. Each fraction is determined gravimetrically.

The silt and clay suspension passing through the 63 micron sieve are transferred to a 1000 mL graduated cylinder for pipette analysis. The sample is diluted to 1000 mL and mixed for 1 minute using a plunger. Twenty mL aliquots are extracted at specific depths and times as defined by a pipetting schedule. These aliquots are transferred to pre-weighed dishes which are placed in a convection oven at 105C and allowed to dry to constant weight. The diameter for each fraction is determined based upon Stoke's Law which relates the settling velocity of spherical particles to their diameter.

3. Quality Assurance

Duplicate analysis of samples is performed at a frequency of 10%. Standard deviation for any given size fraction is +/- 5%.

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Analysis Performed:

- ICP 25 ELEMENT SCAN, FILTERS
- 30 ELEMENT ICPAES AND ICP-MS SCAN
- Acid Digestion
- ICP-MS, Decommissioning Package Metals
- Loss on Ignition
- Acid Digestion
- Moisture Content
- Particle Size Analysis(per fraction)
- Total Organic Carbon
- Alkalinity
- Anions(Cl,NO2,NO3,o-PO4 & SO4)
- Fluoride, Ion Chromatography
- Reactive Silica
- RCAP Calculations
- Manual Conventionals(pH,Turbidity,Conductivity,Color)
- Mercury, Cold Vapour AA, Digestion Required
- Ammonia
- Total Kjeldahl Nitrogen, Digestion Required
- Dissolved Inorganic Carbon, as Carbon(Autoanalyzer)

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Analysis Performed:

Dissolved Organic Carbon, as Carbon(Autoanalyzer)
Total Suspended Solids
Acidity
Cyanide, Total(UV-Visible)
Acid Digestion

Methodology:

1) Analysis of trace metals in filters by Inductively Coupled Plasma.
   U.S. EPA Method No. 200.7
   (Ministry of Environment ELSCAN)
2) The analysis of alkaline metals in filters by Inductively Coupled Plasma Emission Spectroscopy.
   NIOSH Method No. 7300(Modification)
   (Ministry of Environment ELSCAN)
3) Acid digestion of filters for metals determination by ICP AES.
   NIOSH Method No. 7300(Modification)
4) Analysis of trace metals in soil by Inductively Coupled Plasma Mass Spectrophotometry.
   U.S. EPA Method No. 6020(Modification)

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4
Fax:	604-662-8548
Attn:	Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

5) The determination of the loss on ignition of organic matter by heating to constant weight @420°C.
McKeague Methods of Soil Analysis # 3.81
6) Acid digestion of soils for metals determination by inductively coupled plasma atomic emission spectrometry and/or flame or furnace atomic absorption spectroscopy.
U.S. EPA Method No. 3050(Modification)
7) Determination of the moisture content of soil by weight.
ASTM Method No. D2216-80
8) PSA-SBC-SO add missing information
9) LECO Induction Furnace and coulometric detection.
Based upon ASTM methodology
10) Determination of alkalinity in water by automated colorimetry.
U.S. EPA Method No. 310.2
11) Analysis of anions in water by ion chromatography and/or by colorimetry.
U.S. EPA Method No. 300.0 or
U.S. EPA Method No. 350.1, 354.1, 353.1, 365.1 and 375.4.

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted:	October 15/96
Date Reported:	December 4/96
MDS Ref#:	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01
Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

12) Analysis of fluoride in water by Ion Chromatography.
U.S. EPA Method No. 300.0
Standard Methods(1985) No. 429.0

13) Analysis of trace metals in water by inductively coupled plasma atomic emission spectrometry.
U.S. EPA Method No. 200.7

14) Analysis of silicon in water by ICPAES and conversion to silica.
Standard Methods(17th ed.) No. 4500-Si G

15) Analysis of trace metals in water by Inductively Coupled Plasma Mass Spectrophotometry.
U.S. EPA Method No. 200.8(Modification)

16) Determination of theoretical RCAP parameters by calculation.
EPL Internal Reference Method

17) Analysis of water for pH(by electrode), conductivity(by measuring resistance in micro siemens/cm), turbidity(by nephelometry) and color(by UV Visible Spectrometry).
U.S. EPA Method No. 150.1, 120.1, 180.1
and 110.3

Client:	EVS Consultants Limited 195 Pemberton Avenue North Vancouver, BC, CANADA V7P 2R4	Date Submitted:	October 15/96
		Date Reported:	December 4/96
		MDS Ref#:	967231
		MDS Quote#:	96-697-GS
Fax:	604-662-8548	Client PO#:	CANMET
		Client Ref#:	EVS 3/729-01
Attn:	Peter Kiffney	Sampled By:	PMK

Certificate of Analysis

Methodology: (Cont'd)

18) Cold Vapour Atomic Absorption Analysis of water for mercury.
U.S. EPA Method No. 245.2
(Reference - Varian Method No. AA-51)
19) Analysis of ammonia in water by colourimetry in a continuous liquid flow.
ASTM Method No. D1426-79 C
Refer - Method No. 1100106 Issue 122289
20) Analysis of total Kjeldahl Nitrogen in water by colourimetric determination in a continuous liquid flow.
ASTM Method No. D3590-84AFD
Refer - Method No. 1100106 Issue 122289
21) The determination of dissolved inorganic carbon by converting species to carbon dioxide and measuring the decrease in absorbance of a colour reagent.
MOE Method No. ROM - 102AC2.1
(Refer Method No. 1102106 Issue 122989)
22) Sample is filtered, followed by the colourimetric determination of dissolved organic carbon in a continuous liquid flow.
MOE Method No. ROM - 102AC2
Refer - Method No. 1102106 Issue 122989

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted: October 15/96
Date Reported: December 4/96
MDS Ref#: 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01
Sampled By: PMK

Certificate of Analysis

Methodology: (Cont'd)

23) The determination of Total Suspended Solids by weight.
U.S. EPA Method No. 160.2
24) Determination of acidity in water by titration to pH 8.3.
Standard Methods (17th ed.) No. 2310B
U.S. EPA Method No. 305.1
25) Analysis of cyanide in water by Ultra Violet Spectophotometry.
U.S. EPA Method No. 335.2
26) Acid digestion of water for metal determination by Inductively Coupled Plasma Emission Spectrometry and/or flame or furnace Atomic Absorption Spectroscopy.
U.S. EPA Method No. 3020

Instrumentation:

1, 2,13,14) Thermo Jarrell Ash ICAP 61E Plasma Spectrophotometer
3, 6,26) Thermolyne Hotplate/Hot Block
4,15) PE Sciex ELAN 6000 ICP-MS Spectrometer
5) Precision Mechanical Convention Oven/Neytech Furnace
7,23) Precision Mechanical Convention Oven/Sartorius Basic Balance
8) PSA-SBC-SO add missing information
9) LECO Induction Furnace, UIC CM5012 CO2 Analyzer
10) Cobas Fara Centrifugal Analyzer
11) Dionex Ion Chromatograph, 4500i/4000i or Cobas Fara II Analyzer
12) Dionex Ion Chromatograph, Series 4500i
16) Calculation from existing results; no instrumentation required.
17) Orion pH meter/Radiometer Conductometer/Turbidity meter/UV-Visible
18) Varian SpectrAA 400 Plus AA/VGA 76/MCA 90 Mercury Analyzer
19) Skalar Segmented Flow Analyzer, Model SA 20/40

MDS
Environmental Services Limited

Client: EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC, CANADA
V7P 2R4

Fax: 604-662-8548

Attn: Peter Kiffney

Date Submitted: October 15/96
Date Reported: December 4/96
MDS Ref#: 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01
Sampled By: PMK

Certificate of Analysis

Instrumentation:

20,21,22) Technicon Autoanalyzer
24) Titrator
25) Hach UV - Visible Spectrophotometer, Model DR/3000

Sample Description: Filter, Soil, Water

QA/QC: Refer to CERTIFICATE OF QUALITY CONTROL report.

Results: Refer to REPORT of ANALYSIS attached.

for Certified By
Brad Newman
Service Manager

Certified By
for M. Hartwell, M.Sc.
Director, Laboratory Operations

ATTACHMENT D.2

QA/QC

Table D2-1: Relative percent differences (RPD) of (a) laboratory and (b) field replicates of sediment samples.

(a) laboratory

Parameter (mg/kg)	BL-R-2-1	BL-R-2-1 Replicate	RPD
Antimony	nd	nd	np
Arsenic	nd	nd	np
Barium	20.8	22	5.6
Beryllium	nd	nd	np
Cadmium	nd	nd	np
Chromium	10.4	9.2	12.2
Cobalt	7.9	7.2	9.3
Copper	43.6	39.5	9.9
Lead	2.7	2.7	0
Molybdenum	nd	nd	np
Nickel	10.9	10.7	1.9
Selenium	nd	nd	np
Silver	nd	nd	np
Vanadium	51.3	44.7	13.8
Zinc	84.9	79	7.2
Loss on Ignition	10.9	nr	na
Moisture Content	44.5	42.1	5.5

(b) field

Parameter (mg/kg)	BL-E-2-6	BL-E-2-D Field Rep	RPD
Antimony	nd	nd	np
Arsenic	8.6	8.6	0
Barium	93	98.3	5.5
Beryllium	nd	nd	np
Cadmium	2.6	2.6	0
Chromium	6.7	7	4.4
Cobalt	4.3	4.4	2.3
Copper	155	156	0.6
Lead	91.3	92	0.8
Molybdenum	2.1	2.1	0
Nickel	4.6	5.2	12.2
Selenium	nd	nd	np
Silver	1.7	2.3	30
Vanadium	19.3	20.1	4.1
Zinc	546	562	2.9
Loss on Ignition	18.1	18	0.6
Moisture Content	79.8	79.8	0

Table D2-2: Field cross contamination swipes, and relative percent difference (RPD) of laboratory repli

Parameter (µg/filter)	BL-E-XCON-1 (ponar)	BL-E-XCON-2 (composite equipment)	BL-E-XCON-3 (blank)	BL-E-XCON-1	BL-E-XCON-1 Replicate	RPD
Aluminum	43.3	5.9	nd	43.3	44.4	2.5
Barium	0.6	nd	nd	0.6	1.3	73.7
Beryllium	nd	nd	nd	nd	nd	np
Bismuth	nd	nd	nd	nd	nd	np
Boron	1.7	2.1	nd	1.7	1.9	11.1
Cadmium	435	nd	nd	435	450	3.4
Calcium	59.8	7.9	3.3	59.8	61.8	3.3
Chromium	nd	nd	nd	nd	nd	np
Cobalt	nd	nd	nd	nd	nd	np
Copper	2.2	0.3	nd	2.2	2.3	4.4
Iron	303	9.2	1.3	303	311	2.6
Lead	nd	nd	nd	nd	nd	np
Magnesium	27.1	2.4	nd	27.1	28.3	4.3
Manganese	4.8	nd	nd	4.8	4.9	2.1
Molybdenum	nd	nd	nd	nd	nd	np
Nickel	0.9	0.5	nd	0.9	1	10.5
Phosphorus	nd	nd	nd	nd	3.1	np
Potassium	35	46	42	35	46	27.2
Silver	nd	nd	nd	nd	nd	np
Sodium	17	8.4	10.5	17	18.9	10.6
Strontium	0.39	nd	nd	0.39	0.42	7.4
Tin	nd	nd	nd	nd	nd	np
Titanium	3	nd	nd	3	3.1	3.3
Vanadium	nd	nd	nd	nd	nd	np
Zinc	22.1	2.5	0.4	22.1	23.4	5.7

nd not detected
np not possible to determine

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported: December 4/96
MDS Ref # : 967231
MDS Quote#: 96-697-GS
Client PO#: CANMET
Client Ref#: EVS 3/729-01

Analysis of Soil, expressed on a dry weight basis

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Antimony	BL-R-2-1 (A+B)	2.0	mg/kg	nd(b)	4.0	yes	103	80	120	yes	12.6	12.5	7.5	17.5	yes	yes
Arsenic	BL-R-2-1 (A+B)	2.0	mg/kg	nd(b)	4.0	yes	104	80	120	yes	12.3	12.5	7.5	17.5	yes	yes
Barium	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	12.8	12.5	7.5	17.5	yes	yes
Beryllium	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	107	80	120	yes	11.1	12.5	7.5	17.5	yes	yes
Cadmium	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	12.5	12.5	7.5	17.5	yes	yes
Chromium	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	10.6	12.5	7.5	17.5	yes	yes
Cobalt	BL-R-2-1 (A+B)	0.8	mg/kg	nd(b)	1.6	yes	103	80	120	yes	9.9	12.5	7.5	17.5	yes	yes
Copper	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	106	80	120	yes	12.0	12.5	7.5	17.5	yes	yes
Lead	BL-R-2-1 (A+B)	2.5	mg/kg	nd(b)	5.0	yes	103	80	120	yes	12.8	12.5	7.5	17.5	yes	yes
Molybdenum	BL-R-2-1 (A+B)	1.0	mg/kg	nd(b)	2.0	yes	105	80	120	yes	12.4	12.5	7.5	17.5	yes	yes
Nickel	BL-R-2-1 (A+B)	1.5	mg/kg	nd(b)	3.0	yes	105	80	120	yes	9.8	12.5	7.5	17.5	yes	yes
Selenium	BL-R-2-1 (A+B)	1.0	mg/kg	nd(b)	2.0	yes	103	80	120	yes	12.5	12.5	7.5	17.5	yes	yes
Silver	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	12.2	12.5	7.5	17.5	yes	yes
Vanadium	BL-R-2-1 (A+B)	0.5	mg/kg	nd(b)	1.0	yes	105	80	120	yes	14.4	12.5	7.5	17.5	yes	yes
Zinc	BL-R-2-1 (A+B)	0.8	mg/kg	1.1(b)	1.6	yes	109	80	120	yes	15.9	12.5	7.5	17.5	yes	yes
Loss on Ignition	na	0.1	%	nd	0.2	yes	100	74	138	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

MDS Environmental Services Limited.

Certificate of Quality Control

Client : EVS Consultants Limited
Contact: Peter Kiffney

Date Reported:	December 4/96
MDS Ref # :	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01

Analysis of Filter

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	**LOQ**	**Units**	**Result**	**Upper Limit**	**Accept**	**Result**	**Lower Limit**	**Upper Limit**	**Accept**	**Result**	**Target**	**Lower Limit**	**Upper Limit**	**Accept**	**QC Acceptable**
Aluminum	na	1.5	ug/Filt	nd(b)	3.0	yes	97	80	120	yes	na	na	na	na	na	yes
Barium	na	0.2	ug/Filt	nd(b)	0.4	yes	100	80	120	yes	na	na	na	na	na	yes
Beryllium	na	0.3	ug/Filt	nd(b)	0.6	yes	101	80	120	yes	na	na	na	na	na	yes
Bismuth	na	2.5	ug/Filt	nd(b)	5.0	yes	102	80	120	yes	na	na	na	na	na	yes
Boron	na	0.5	ug/Filt	nd(b)	1.0	yes	102	80	120	yes	na	na	na	na	na	yes
Cadmium	BL-E-XCON- 1	0.2	ug/Filt	nd(b)	0.4	yes	100	80	120	yes	*	*	*	*	*	yes
Chromium	na	0.3	ug/Filt	nd(b)	0.6	yes	103	80	120	yes	na	na	na	na	na	yes
Cobalt	na	0.3	ug/Filt	nd(b)	0.6	yes	103	80	120	yes	na	na	na	na	na	yes
Copper	na	0.2	ug/Filt	nd(b)	0.4	yes	99	80	120	yes	na	na	na	na	na	yes
Iron	BL-E-XCON- 1	0.3	ug/Filt	0.3(b)	0.6	yes	98	80	120	yes	*	*	*	*	*	yes
Lead	na	1.5	ug/Filt	nd(b)	3.0	yes	100	80	120	yes	na	na	na	na	na	yes
Manganese	na	0.3	ug/Filt	nd(b)	0.6	yes	100	80	120	yes	na	na	na	na	na	yes
Molybdenum	na	0.5	ug/Filt	nd(b)	1.0	yes	102	80	120	yes	na	na	na	na	na	yes
Nickel	na	0.5	ug/Filt	nd(b)	1.0	yes	100	80	120	yes	na	na	na	na	na	yes
Phosphorus	na	3.0	ug/Filt	nd(b)	6.0	yes	95	70	130	yes	na	na	na	na	na	yes
Silver	na	0.3	ug/Filt	nd(b)	0.6	yes	na	na	na	na	na	na	na	na	na	yes
Tin	na	2.5	ug/Filt	nd(b)	5.0	yes	107	80	120	yes	na	na	na	na	na	yes
Titanium	na	2.5	ug/Filt	nd(b)	5.0	yes	105	80	120	yes	na	na	na	na	na	yes
Vanadium	na	0.5	ug/Filt	nd(b)	0.5	yes	100	80	120	yes	na	na	na	na	na	yes
Zinc	na	0.3	ug/Filt	nd(b)	0.6	yes	99	80	120	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ
(b) = Analyte results on REPORT of ANALYSIS have been background corrected for the process blank.

Certificate of Quality Control

Date Reported:	December 4/96
MDS Ref # :	967231
MDS Quote#:	96-697-GS
Client PO#:	CANMET
Client Ref#:	EVS 3/729-01

Client : EVS Consultants Limited
Contact: Peter Kiffney

Analysis of Filter

				Process Blank			Process % Recovery				Matrix Spike					Overall
Parameter	SAMPLE ID (spike)	LOQ	Units	Result	Upper Limit	Accept	Result	Lower Limit	Upper Limit	Accept	Result	Target	Lower Limit	Upper Limit	Accept	QC Acceptable
Calcium	na	0.5	ug/filt	0.9	1.0	yes	98	80	120	yes	na	na	na	na	na	yes
Magnesium	na	1.0	ug/filt	nd	2.0	yes	106	80	120	yes	na	na	na	na	na	yes
Potassium	na	20	ug/filt	nd	40	yes	104	80	120	yes	na	na	na	na	na	yes
Sodium	na	2.0	ug/filt	nd	4.0	yes	101	80	120	yes	na	na	na	na	na	yes
Strontium	na	0.25	ug/filt	nd	0.5	yes	106	80	120	yes	na	na	na	na	na	yes

LOQ = Limit of Quantitation = lowest level of the parameter that can be quantified with confidence
* = Unavailable due to dilution required for analysis
na = Not Applicable
ns = Insufficient Sample Submitted
nd = parameter not detected
TR = trace level less than LOQ

ATTACHMENT D.3

Results

Table D3-1: Total metals (mg/kg; unless otherwise specified) in sediment samples collected from reference and exposure stations at Buttle Lake on October 7-10, 1996.

Parameter	LOQ	Reference Stations						Exposure Stations						
		BL-R-2-1B	BL-R-2-2A	BL-R-2-3A	mean	sd	se	BL-E-2-3A	BL-E-2-4A	BL-E-2-5A	BL-E-2-6A	mean	sd	se
Antimony	2	nd	nd	nd				nd	nd	nd	nd			
Arsenic	2	nd	nd	nd				5.8	5.6	8	8.6	7.0	1.5	0.8
Barium	0.5	20.8	19.5	14.7	18.3	3.2	1.9	53.2	61	65.3	93	68.1	17.3	8.7
Beryllium	0.5	nd	nd	nd				nd	nd	nd	nd			0.0
Cadmium	0.5	nd	0.6	nd	0.4	0.2	0.1	2.3	2.3	2.8	2.6	2.5	0.2	0.1
Chromium	0.5	10.4	8.1	11.7	10.1	1.8	1.1	6.8	7.1	6.7	6.7	6.8	0.2	0.1
Cobalt	0.8	7.9	5.8	8	7.2	1.2	0.7	4.1	4.7	4.5	4.3	4.4	0.3	0.1
Copper	0.5	43.6	46.2	46.9	45.6	1.7	1.0	113	126	147	155	135.3	19.2	9.6
Lead	2.5	2.7	3.8	nd	2.6	1.3	0.9	51.9	58.7	78.2	91.3	70.0	18.0	9.0
Molybdenum	1	nd	nd	nd				1.5	1.3	2	2.1	1.7	0.4	0.2
Nickel	1.5	10.9	8.7	12.5	10.7	1.9	1.1	4.9	4.9	4.9	4.6	4.8	0.2	0.1
Selenium	1	nd	nd	nd				nd	nd	nd	nd			
Silver	0.5	nd	nd	0.7	0.4	0.2	0.1	2.1	1	2.4	1.7	1.8	0.6	0.3
Vanadium	0.5	51.3	39.5	48.6	46.5	6.2	3.6	20.3	20.7	19.4	19.3	19.9	0.7	0.3
Zinc	0.8	84.9	120	57.6	87.5	31.3	18.4	515	508	586	546	538.8	35.6	17.8

Table D3-2: Physical characteristics of sediment samples collected from reference and exposure stations at Buttle Lake on October xx, 1996.

Parameter	Reference Stations						Exposure Stations						
	BL-R-2-1	BL-R-2-2	BL-R-2-3	mean	sd	se	BL-E-2-3	BL-E-2-4	BL-E-2-5	BL-E-2-6	mean	sd	se
Water Depth (m)	6.2	5	1.98	4.39	2.17	1.28	2.41	2.93	4.21	4.88	3.61	1.14	0.57
Substrate fines (%)	12	15.7	4.5	10.73	5.71	3.36	82	83.4	83.9	85.3	83.65	1.36	0.68
Total Organic Carbon (%)	1.53	2.88	0.43	1.61	1.23	0.72	8.43	10.95	6.12	7.18	8.17	2.08	1.04
Moisture Content (%)	44.5	49.4	24.6	39.50	13.13	7.73	79.3	79.5	81.7	79.80	80.08	1.10	0.55
Loss on Ignition (%)	10.9	10.1	5.8	8.93	2.74	1.61	22.2	25.1	17	18.1	20.60	3.74	1.87

MDS
Environmental Services Limited

FAX TRANSMITTAL

TO: Linda Nestic
EVS

FAX NO: 604-662-8548
DATE: Nov 26'96

No. of pages including transmittal cover page 17

Original to follow by mail: Yes ____ No ____

MESSAGE: As per your discussion with Luc Dionne. we are refaxing your particle size analysis with reference to your sample ID #'s.

FROM: ____________

MDS Environmental Services Ltd.
6850 Goreway Drive
Mississauga, Ontario
L4V 1P1

Fax #: 905-673-7399

Phone #: 905-673-3255
1-800-701-7092

If you experience difficulty with this transmission, please call (905) 673-3255, ext. 352.

MDS ENVIRONMENTAL SERVICES LIMITED

EVS
LINDA NESTIC.

Ref #EVS 3(729-01)

Sample : 96-H037526
Client ID : SO 3C 86384 BL-R-2-1 (A+B)
Project : 967231

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	75.0	% Finer	0.1	Grav.
PHI 0 (1 mm)	59.7	% Finer	0.1	Grav
PHI +1 (1/2 mm)	29.2	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	15.4	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	13.7	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	12.0	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	10.9	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	9.2	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	6.7	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	5.8	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	3.7	% Finer	0.1	Grav.
Gravel	25.0	%	0.1	Wentworth
Sand	63.0	%	0.1	Wentworth
Silt	6.2	%	0.1	Wentworth
Clay	5.8	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 21, 1996

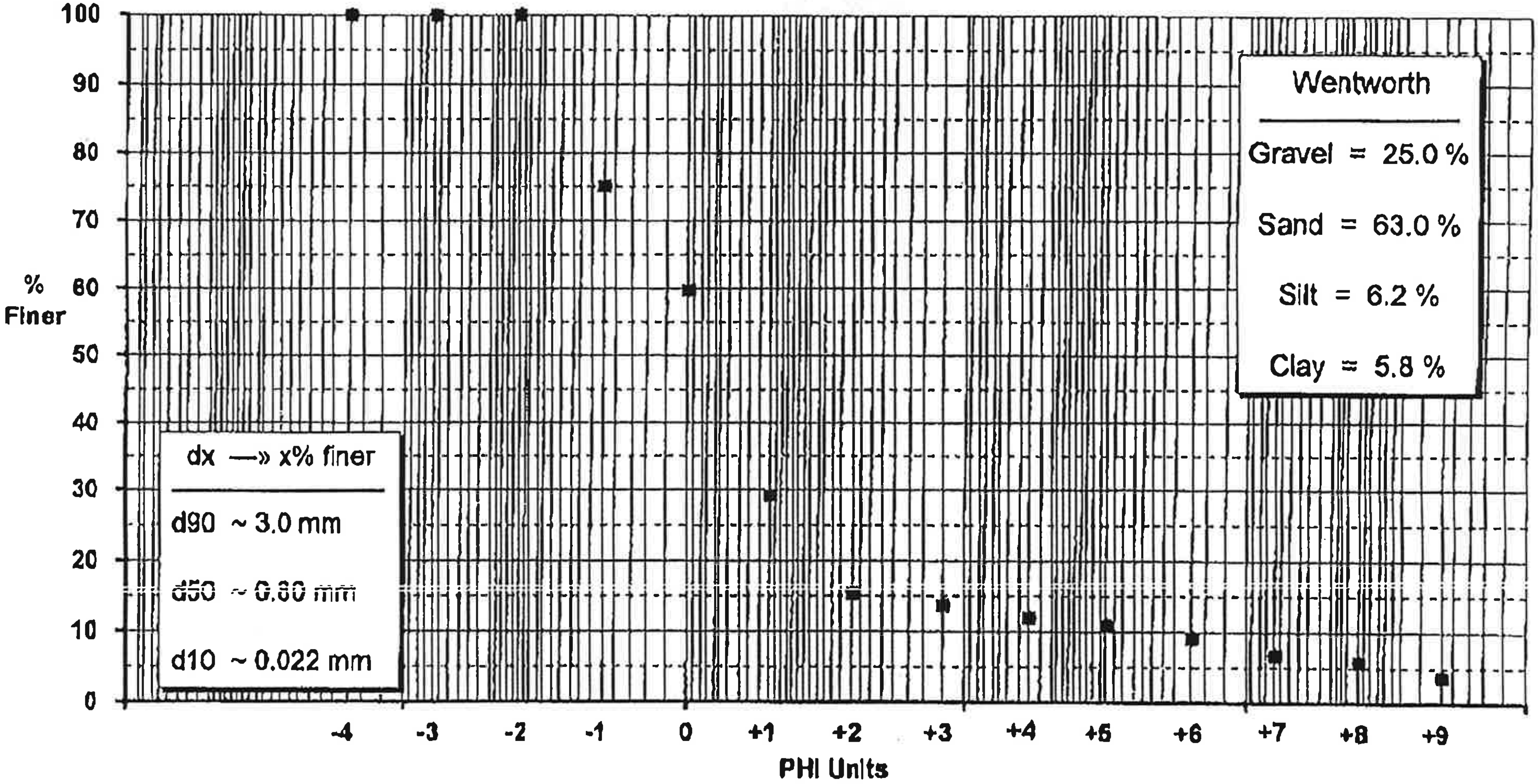
Inorganics Manager
Jerry Arenovich

SO 3C 86384

BL-R-2-1 (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037526



Wentworth

Gravel = 25.0 %

Sand = 63.0 %

Silt = 6.2 %

Clay = 5.8 %

dx —» x% finer

d90 ~ 3.0 mm

d50 ~ 0.80 mm

d10 ~ 0.022 mm

MDS ENVIRONMENTAL SERVICES LIMITED

Linda Nestic

Sample : 96-H037527
Client ID : SO 3C 86385
Project : 967231
Bi-R-2-2(A+B)

EVS Consultants Limited
195 Pemberton Avenue
North Vancouver, BC V7P 2R4
ATTENTION: Peter Kiffney

Inorganic Analytes		Value	Units	MDL	Method
12.5 mm		100.	% Finer	0.1	Grav.
9.5 mm		100.	% Finer	0.1	Grav.
4.75 mm		100.	% Finer	0.1	Grav.
PHI -1	(2 mm)	60.1	% Finer	0.1	Grav.
PHI 0	(1 mm)	46.0	% Finer	0.1	Grav
PHI +1	(1/2 mm)	27.9	% Finer	0.1	Grav.
PHI +2	(1/4 mm)	19.3	% Finer	0.1	Grav.
PHI +3	(1/8 mm)	17.2	% Finer	0.1	Grav.
PHI +4	(1/16 mm)	15.7	% Finer	0.1	Grav.
PHI +5	(1/32 mm)	14.4	% Finer	0.1	Grav.
PHI +6	(1/64 mm)	12.4	% Finer	0.1	Grav.
PHI +7	(1/128 mm)	8.8	% Finer	0.1	Grav.
PHI +8	(1/256 mm)	7.0	% Finer	0.1	Grav.
PHI +9	(1/512 mm)	4.3	% Finer	0.1	Grav.
Gravel		39.9	%	0.1	Wentworth
Sand		44.3	%	0.1	Wentworth
Silt		8.7	%	0.1	Wentworth
Clay		7.0	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

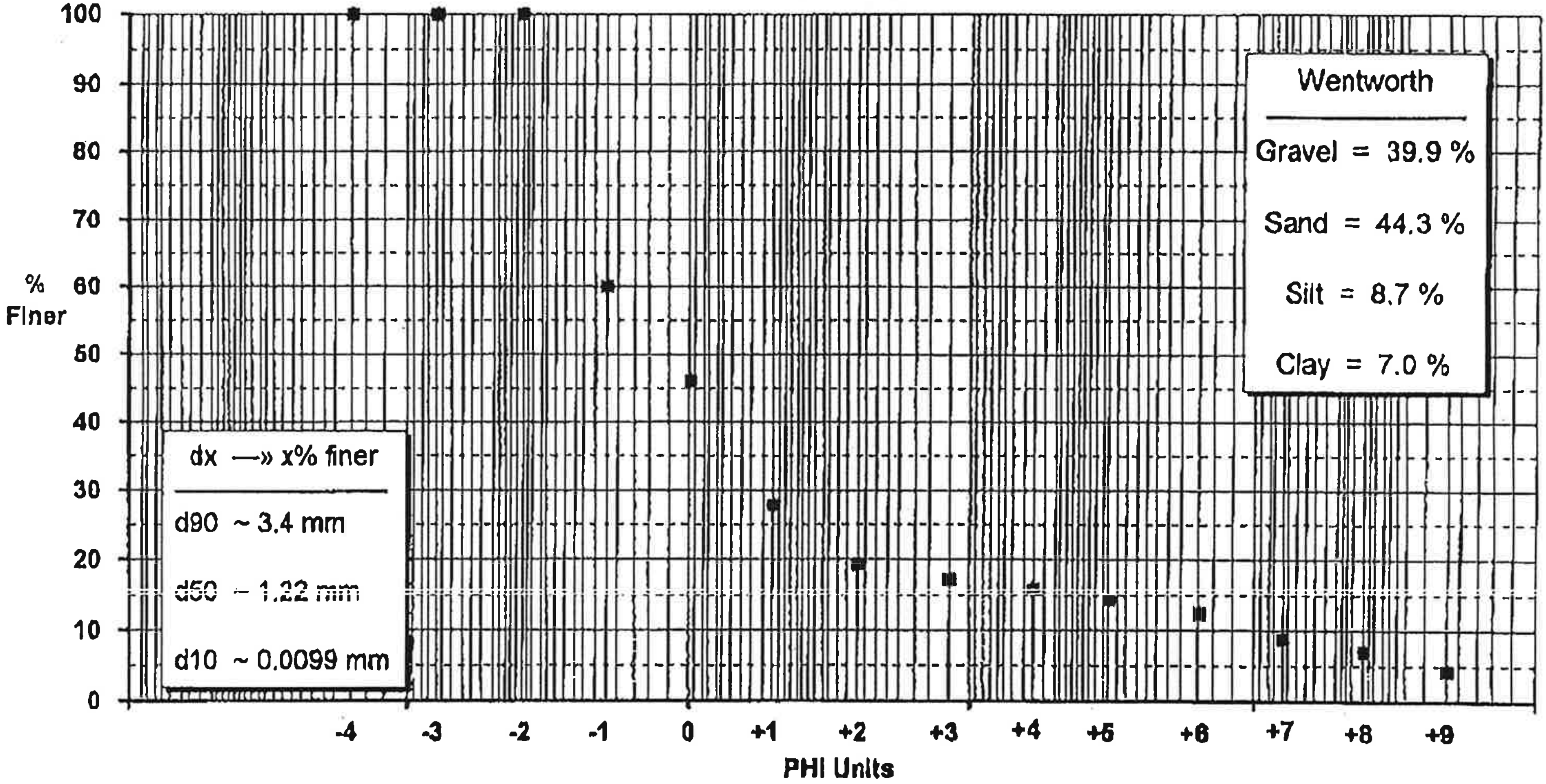
Inorganics Manager
Jerry Arenovich

SO 3C 86385

BL-R-2-2(A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037527



MDS ENVIRONMENTAL SERVICES LIMITED

Sample : 96-H037528
Client ID : SO 3C 86386
Project : 967231
BL-R-2-3 (A+B).

EVS Consultants LImited
ATTENTION: Peter Kiffnney

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	57.4	% Finer	0.1	Grav.
PHI 0 (1 mm)	39.0	% Finer	0.1	Grav
PHI +1 (1/2 mm)	14.9	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	6.2	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	5.0	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	4.5	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	4.2	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	3.7	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	3.0	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	2.5	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	2.1	% Finer	0.1	Grav.
Gravel	42.6	%	0.1	Wentworth
Sand	52.9	%	0.1	Wentworth
Silt	2.0	%	0.1	Wentworth
Clay	2.5	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

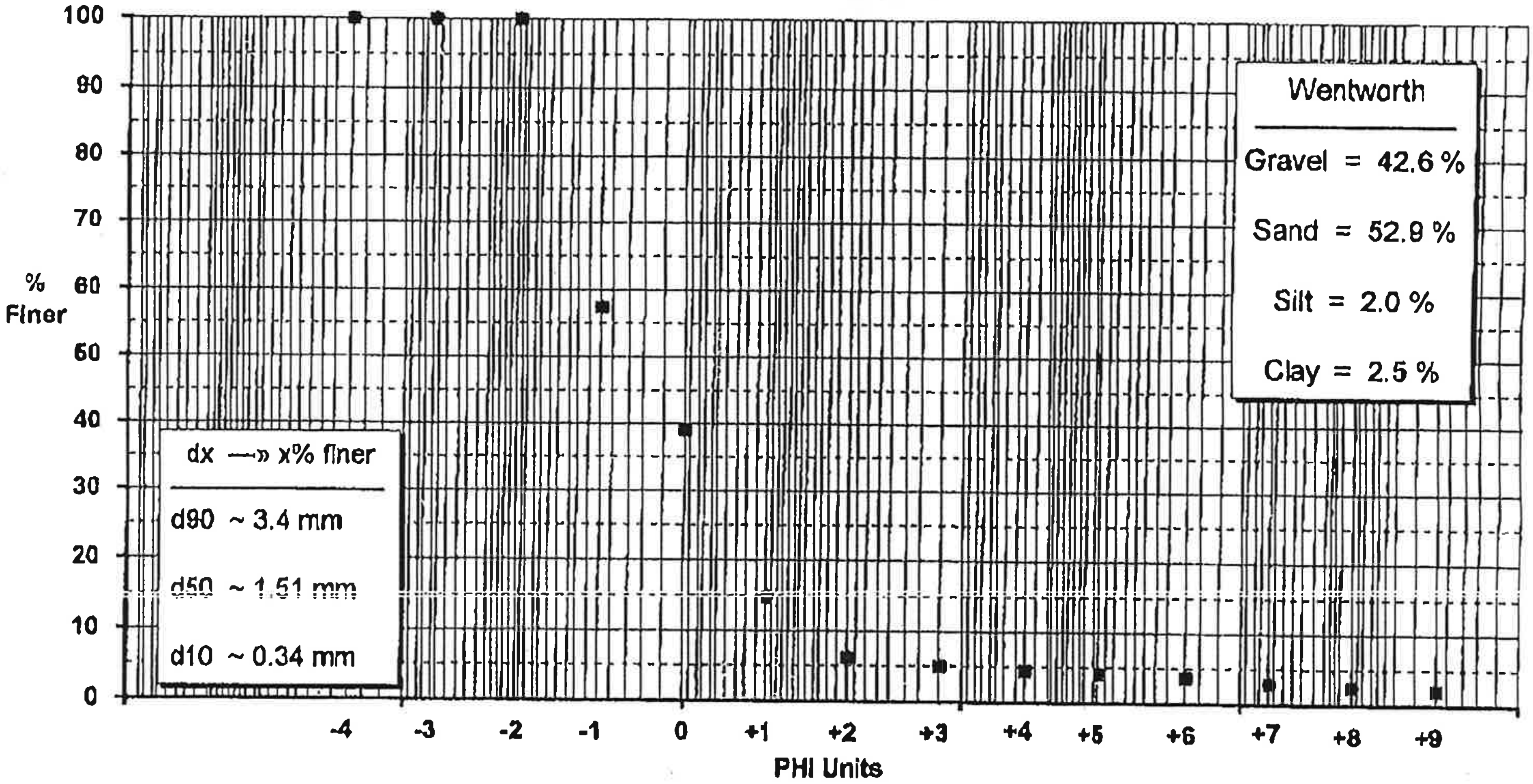
Inorganics Manager
Jerry Aranovich

SO 3C 86386

BL-R-2-3 (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 86-H037628



dx —» x% finer

d90 ~ 3.4 mm

d50 ~ 1.51 mm

d10 ~ 0.34 mm

Wentworth

Gravel = 42.6 %

Sand = 52.9 %

Silt = 2.0 %

Clay = 2.5 %

MDS ENVIRONMENTAL SERVICES LIMITED

EVS Consultants Limited
ATTENTION: Peter Kiffney

Sample : 96-H037529
Client ID : SO 3C 86387
Project : 967231
BL-E-2-3 (A+B).

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	100.	% Finer	0.1	Grav.
PHI 0 (1 mm)	97.5	% Finer	0.1	Grav
PHI +1 (1/2 mm)	95.0	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	92.0	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	88.5	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	82.1	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	76.9	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	62.2	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	40.3	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	32.5	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	20.2	% Finer	0.1	Grav.
Gravel	< 0.1	%	0.1	Wentworth
Sand	17.9	%	0.1	Wentworth
Silt	49.5	%	0.1	Wentworth
Clay	32.5	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valeria Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

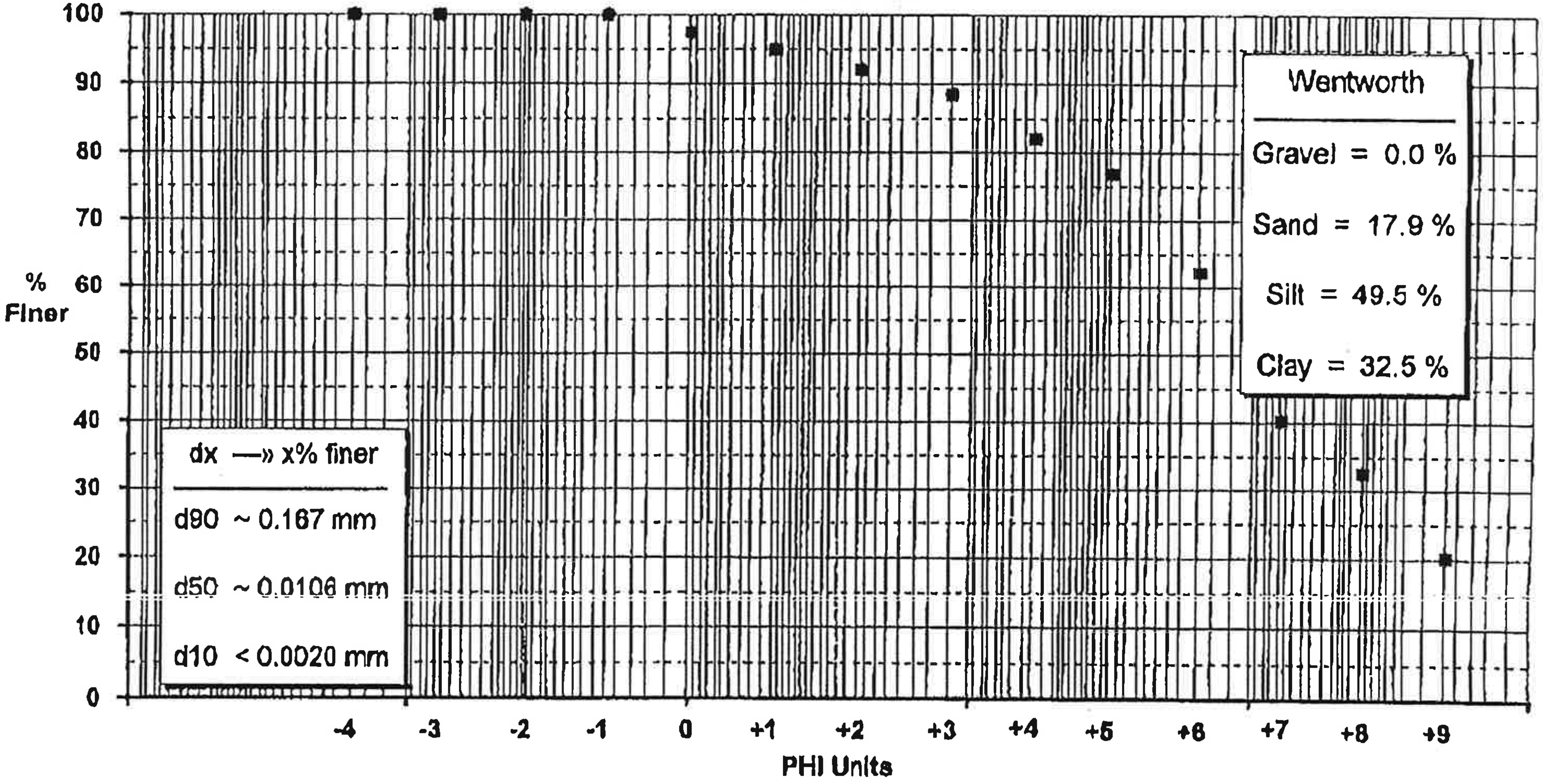
Inorganics Manager Jerry Arenovich

SO 3C 86387

BL-E-2-3 (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 86-H037529



Wentworth	
Gravel	= 0.0 %
Sand	= 17.9 %
Silt	= 49.5 %
Clay	= 32.5 %

dx —» x% finer	
d90	~ 0.167 mm
d50	~ 0.0106 mm
d10	< 0.0020 mm

MDS ENVIRONMENTAL SERVICES LIMITED

Sample : 96-H037530
Client ID : SO 3C 86388
Project : 967231
BL-E-2-4 (A+B)

EVS Consultants LImited
ATTENTION: Peter Kiffney

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	100.	% Finer	0.1	Grav.
PHI 0 (1 mm)	97.4	% Finer	0.1	Grav
PHI +1 (1/2 mm)	94.8	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	92.5	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	89.4	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	83.4	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	79.6	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	68.7	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	48.5	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	39.8	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	26.2	% Finer	0.1	Grav.
Gravel	< 0.1	%	0.1	Wentworth
Sand	16.6	%	0.1	Wentworth
Silt	43.6	%	0.1	Wentworth
Clay	39.8	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 1[illegible], 1996
Date Reported: Nov 18, 1996

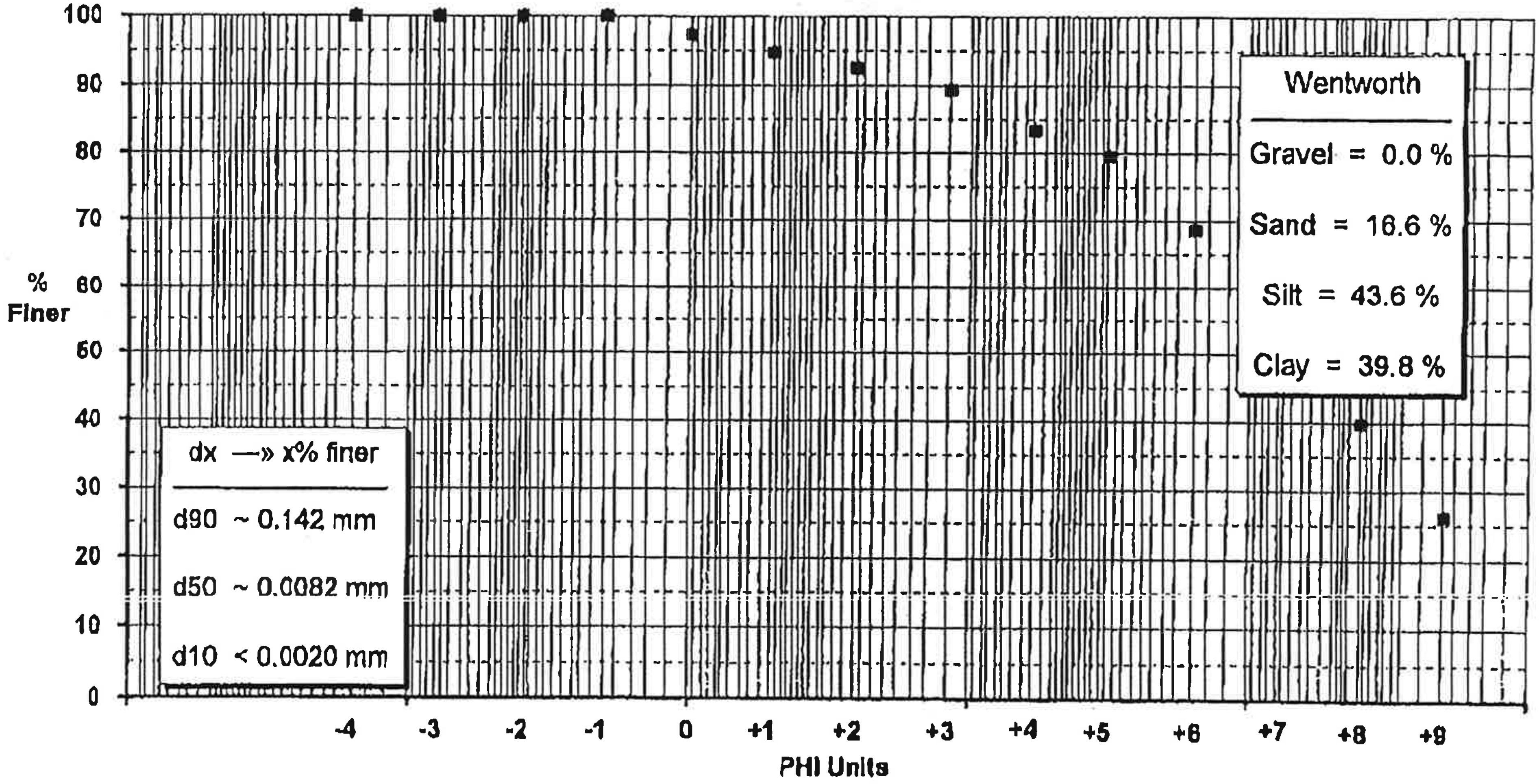
Inorganics Manager
Jerry Arenovich

SO 3C 86388

BL-E-2-4 (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037530



Wentworth	
Gravel	= 0.0 %
Sand	= 16.6 %
Silt	= 43.6 %
Clay	= 39.8 %

dx —» x% finer	
d90	~ 0.142 mm
d50	~ 0.0082 mm
d10	< 0.0020 mm

MDS ENVIRONMENTAL SERVICES LIMITED

Sample : 96-H037531
Client ID : SO 3C 86389
Project : 967231
BL-E-2-5 (A+B)

EVS Consultants Limited
ATTN: Peter Kiffney

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	100.	% Finer	0.1	Grav.
PHI 0 (1 mm)	95.0	% Finer	0.1	Grav
PHI +1 (1/2 mm)	91.7	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	88.9	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	86.4	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	83.9	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	80.9	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	68.4	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	46.4	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	37.1	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	20.6	% Finer	0.1	Grav.
Gravel	< 0.1	%	0.1	Wentworth
Sand	16.1	%	0.1	Wentworth
Silt	46.8	%	0.1	Wentworth
Clay	37.1	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

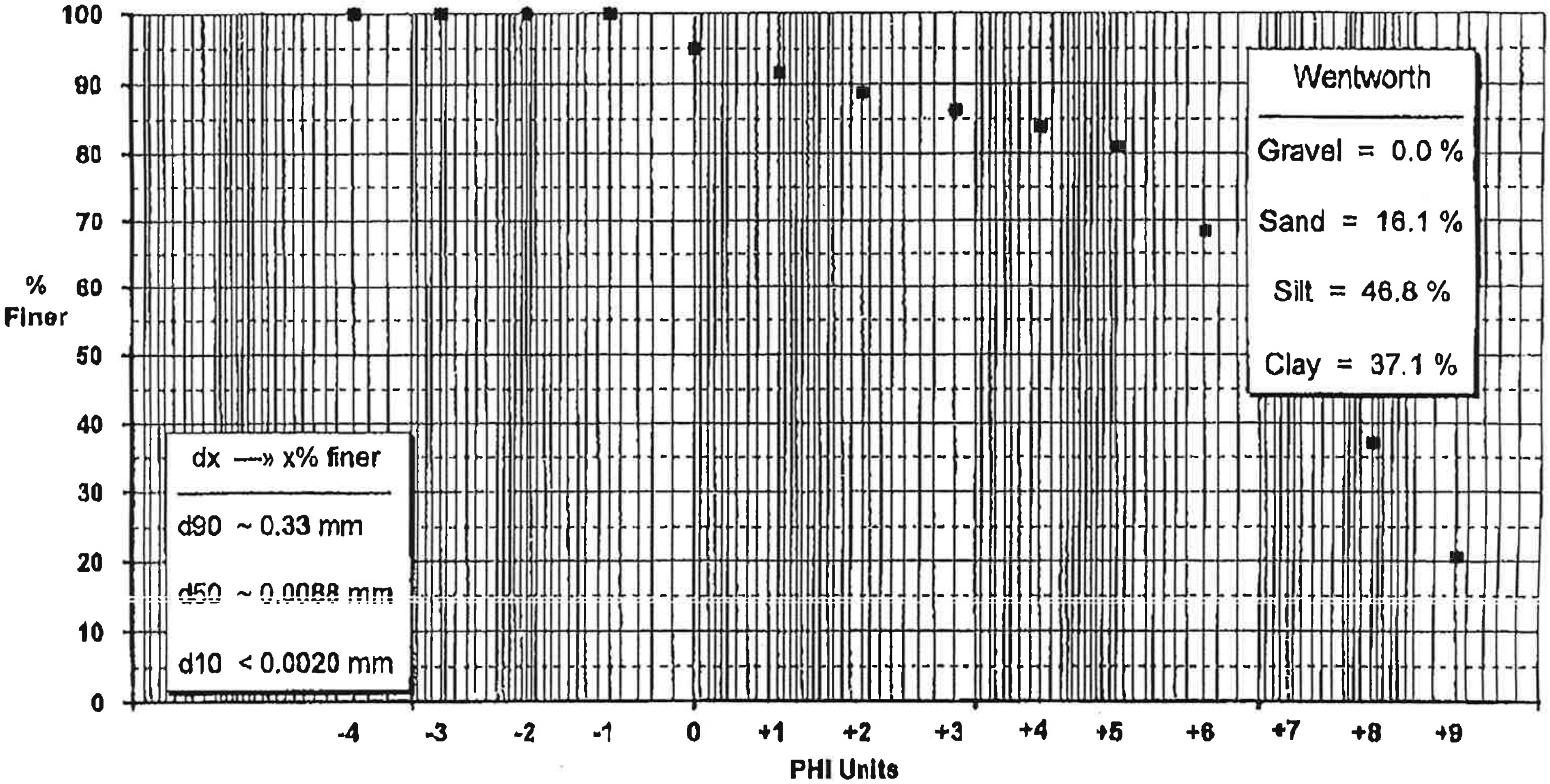
Inorganics Manager
Jerry Arenovich

SO 3C 86389

BL-E-2-5 (A+B)

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037531



Wentworth

Gravel = 0.0 %

Sand = 16.1 %

Silt = 46.8 %

Clay = 37.1 %

dx —» x% finer

d90 ~ 0.33 mm

d50 ~ 0.0088 mm

d10 < 0.0020 mm

MDS ENVIRONMENTAL SERVICES LIMITED

Sample : 96-H037532
Client ID : SO 3C 86390
Project : 967231
BL-E-2-6 (A+B).

EVS Consultants Limited
ATTN: Peter Kiffney

Inorganic Analytes	Value	Units	MDL	Method
12.5 mm	100.	% Finer	0.1	Grav.
9.5 mm	100.	% Finer	0.1	Grav.
4.75 mm	100.	% Finer	0.1	Grav.
PHI -1 (2 mm)	100.	% Finer	0.1	Grav.
PHI 0 (1 mm)	96.9	% Finer	0.1	Grav
PHI +1 (1/2 mm)	93.6	% Finer	0.1	Grav.
PHI +2 (1/4 mm)	90.8	% Finer	0.1	Grav.
PHI +3 (1/8 mm)	87.9	% Finer	0.1	Grav.
PHI +4 (1/16 mm)	85.4	% Finer	0.1	Grav.
PHI +5 (1/32 mm)	83.8	% Finer	0.1	Grav.
PHI +6 (1/64 mm)	75.3	% Finer	0.1	Grav.
PHI +7 (1/128 mm)	51.6	% Finer	0.1	Grav.
PHI +8 (1/256 mm)	41.7	% Finer	0.1	Grav.
PHI +9 (1/512 mm)	23.9	% Finer	0.1	Grav.
Gravel	< 0.1	%	0.1	Wentworth
Sand	14.6	%	0.1	Wentworth
Silt	43.6	%	0.1	Wentworth
Clay	41.7	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

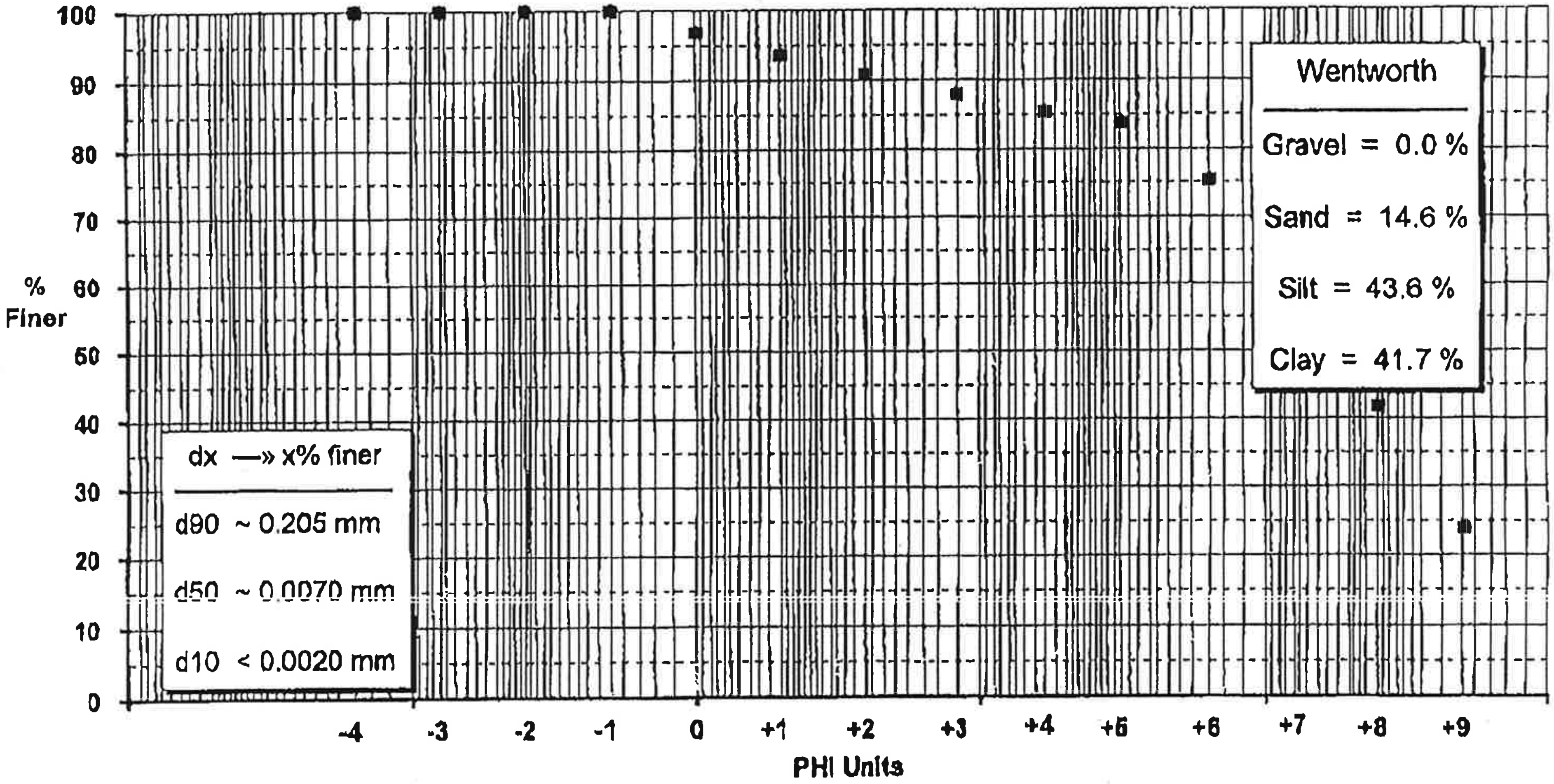
Inorganics Manager
Jerry Arenovich

SO 3C 86390

BL-E-2-6 (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037532



Wentworth

Gravel = 0.0 %

Sand = 14.6 %

Silt = 43.6 %

Clay = 41.7 %

dx —» x% finer

d90 ~ 0.205 mm

d50 ~ 0.0070 mm

d10 < 0.0020 mm

MDS ENVIRONMENTAL SERVICES LIMITED

Sample : 96-H037533
Client ID : SO 3C 86391
Project : 967231
BL-E-2-D(A+B).

EVS Consultants Limited
ATTN: Peter Kiffney

Inorganic Analytes		Value	Units	MDL	Method
12.5 mm		100.	% Finer	0.1	Grav.
9.5 mm		100.	% Finer	0.1	Grav.
4.75 mm		100.	% Finer	0.1	Grav.
PHI -1	(2 mm)	100.	% Finer	0.1	Grav.
PHI 0	(1 mm)	95.8	% Finer	0.1	Grav
PHI +1	(1/2 mm)	92.6	% Finer	0.1	Grav.
PHI +2	(1/4 mm)	89.9	% Finer	0.1	Grav.
PHI +3	(1/8 mm)	87.1	% Finer	0.1	Grav.
PHI +4	(1/16 mm)	84.6	% Finer	0.1	Grav.
PHI +5	(1/32 mm)	81.9	% Finer	0.1	Grav.
PHI +6	(1/64 mm)	73.7	% Finer	0.1	Grav.
PHI +7	(1/128 mm)	50.7	% Finer	0.1	Grav.
PHI +8	(1/256 mm)	39.4	% Finer	0.1	Grav.
PHI +9	(1/512 mm)	24.7	% Finer	0.1	Grav.
Gravel		< 0.1	%	0.1	Wentworth
Sand		15.4	%	0.1	Wentworth
Silt		45.3	%	0.1	Wentworth
Clay		39.4	%	0.1	Wentworth

Note : Results are expressed on a dry weight basis.

Report To:
Valerie Geldart
MDS Laboratories - Toronto
6850 Goreway Drive
Mississauga, ON, L4V 1P1

Date Received: Nov 14, 1996
Date Reported: Nov 18, 1996

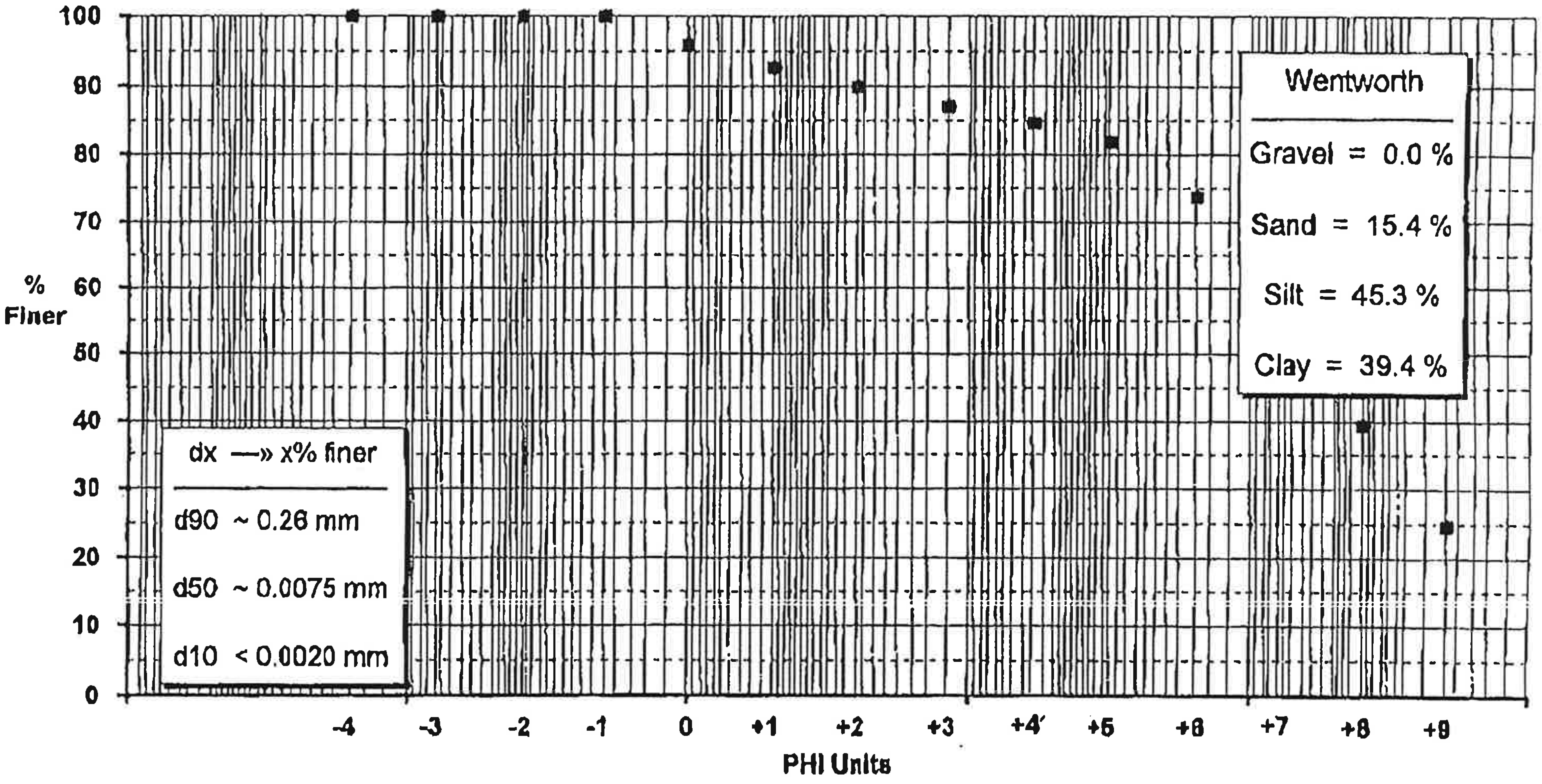
Inorganics Manager
Jerry Arenovich

SO 3C 86391

BL-E-2-D (A+B).

MDS
Environmental Services Ltd.

MDS Sample ID: 96-H037533



APPENDIX E

Benthic Invertebrate Community Structure

ATTACHMENT E.1

Detailed Methods

SAMPLE PROCESSING

All benthos samples were processed and analyzed by Zaranko Environmental Assessment Series (ZEAS), Guelph, ON.

Upon arrival, samples were immediately logged and inspected to ensure adequate preservation to a minimum level of 10% buffered formalin and correct labeling. No problems with preservative or labeling were identified. All benthic samples were sorted with the use of a stereomicroscope. A magnification of 10X was used for macrobenthos (invertebrates > 500 μm) and 20X for meiobenthos (invertebrate size from 200 to 500 μm). To expedite sorting, prior to processing, all samples were stained with a protein dye that is absorbed by aquatic organisms but not by organic material such as detritus and algae. The stain has proven to be extremely effective in increasing sorting accuracy and efficiency.

Prior to sorting, samples were washed free of formalin in a 250 μm sieve. Benthic invertebrates and associated debris were elutriated from any sand and gravel in the sample. Elutriation techniques effectively removed almost all organisms. The remaining sand and gravel fraction was closely inspected for the odd heavier organism such as Pelecypoda, Gastropoda, and Trichoptera with stone cases that may not have all been washed from this fraction. After elutriation, the remaining debris and benthic invertebrates were washed through a series of two sieves, 500μm and 250 μm respectively.

SUBSAMPLING

Benthic samples were sorted entirely (both 500 and 250 μm) except in the instance of large amounts of organic matter and high densities of organisms. Benthic samples containing large amount of organic matter or high densities of organisms can often take days to sort entirely. Thus sorting the whole sample may not be cost effective. In addition, with large quantities of organic matter there comes a point when additional sorting does not yield further ecological information. As such, the following subsampling techniques were employed.

Sample material was distributed evenly on the 500 μm and 250 μm sieves. One half of the material was removed and set aside while the remaining half was distributed evenly on each sieve and again divided in two. A minimum subsample volume of 25% was the criteria set for this study. The same fraction was sorted from the 500 μm and the 250 μm sieve. On average, each sample took between five and six hours to sort in which an average of 300 organisms were removed from the associated debris.

Benthic invertebrates were enumerated and sorted into major taxonomic groups, (i.e., order and family), placed in glass vials and represerved in 70% ethanol for more detailed taxonomic analysis by senior staff. Each vial was labeled with the survey name, date, station, and replicate number. For QA/QC evaluation, sorted sediments and debris were represerved and will be retained for up to a period of six months following the submission of the final report. For those samples that were subsampled, sorted and unsorted fractions were represerved separately.

DETAILED IDENTIFICATION

All invertebrates were identified to the lowest practical level, usually genus, with the exception of bivalves (*Sphaerium*), and oligochaetes which were identified to species. Nematodes were identified to phylum, water mites and harpacticoids to order, and ostracods to class.

Chironomids and oligochaetes were mounted on glass slides in a clearing media prior to identification using a compound microscope. In samples with large numbers of oligochaetes, a random sample of no less than 20% of the picked individuals, up to a maximum of 50, were mounted on slides for identification. Similarly, in samples with a large number of chironomids, individuals that could be identified using a dissecting scope, (e.g., *Cryptochironomus, Chironomus, Monodiamesa, Procladius, Heterotrissocladius*), were enumerated and removed from the sample. The remaining individuals were sorted into sub-families and tribes. A random sample of no less than 20% of the individuals from each group were mounted on slides for identification, up to a maximum of 50 individuals.

VOUCHER COLLECTION

The standard operating procedures for ZEAS's Benthic Ecology Laboratory requires the compilation of a voucher collection for all benthic invertebrate projects. Representative specimens for each taxon are placed in labeled glass vials. Mounted chironomids and oligochaetes remain on the initial slides and representatives of each taxon are circled with a permanent marker. A voucher collection is one way of ensuring continuity in taxonomic identifications if different taxonomists process future samples. The voucher collection is either maintained in our files indefinitely or returned to the client. ZEAS also maintains a master reference collection of all taxa which have been identified by the lab.

QUALITY ASSURANCE AND QUALITY CONTROL MEASURES

ZEAS incorporates the following QA/QC procedures for all benthic studies to ensure reliability of data:

- all samples were stained to facilitate accurate sorting;
- the most updated and widely used taxonomic keys are referenced;
- 10% of all sorted samples were resorted by a second taxonomist to ensure 95% recovery of all invertebrates;
- a voucher collection was compiled and will be kept indefinitely or returned to the client;
- both sorted and unsorted sample fractions were represerved in 10 % formalin and will be maintained for six months after submission of the final report;
- all tabulated benthic data were cross checked against bench sheets by a second person to ensure there have been no data entry errors or incorrect spelling of scientific nomenclature;
- subsampling error was calculated for 10% of the samples requiring subsampling.

REPORTING BENTHIC MACROINVERTEBRATE DATA

Following identification and enumeration, a detailed taxa list was prepared for each station summarizing the total organism density and total number of taxa. The taxa list was prepared using Excel 5.0.

ATTACHMENT E.2

QA/QC

TABLE 1. CALCULATION OF SUBSAMPLING ERROR FOR BENTHIC INVERTEBRATE SAMPLES FROM MYRA FALLS, WESTMIN RESOURCES (1996).

Station	**Number of Animals in Fraction 1**	**Number of Animals in Fraction 2**	**Standard Deviation**	**Coefficient of Variation**
BL-R3-4	128	138	7.07	5.3%
BL-R3-5	509	462	33.23	6.8%
BL-E3-2	140	137	2.12	1.5%

TABLE 2. PERCENTAGE RECOVERY OF BENTHIC INVERTEBRATES FROM SAMPLES FOR MYRA FALLS, WESTMIN RESOURCES (1996).

Station	**Number of Animals Recovered**	**Number of Animals in Re-sort**	**Percent Recovery**
BL-R3-1	603	8	98.7%
BL-E3-2	278	4	98.6%

TABLE 3. SAMPLE FRACTIONS SORTED FOR MYRA FALLS, WESTMIN RESOURCES (1996).

Station	**Fraction Sorted**
MF-R3-1	WHOLE
BL-R3-1	1/4
BL-R3-2	1/4
BL-R3-3	1/4
BL-R3-4	1/4[a]
BL-R3-5	1/2[b]
BL-R3-6	1/2
MF-E3-1	1/8
BL-E3-1	1/4
BL-E3-2	1/2[b]
BL-E3-3	1/4
BL-E3-4	1/8
BL-E3-5	1/4
BL-E3-6	1/8

[a] two eighths sorted for subsampling error calculations

[b] two quarters sorted for subsampling error calculations

ATTACHMENT E.3

Results

Table E3-1a Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 250 µm sieve (densities expressed per sample jar)

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
P. Coelenterata														
Hydra	-	4	12	116	28	12	2	-	-	-	-	-	-	-
P. Nematoda	1	324	156	60	60	8	16	-	100	10	8	80	76	48
P. Platyhelminthes														
Cl. Turbellaria														
F. Tricladida	2	-	-	4	-	-	-	2	-	-	-	-	-	-
P. Nemertea														
Prostoma	-	20	8	84	264	12	96	-	20	-	16	40	20	56
P. Annelida														
Cl. Oligochaeta														
F. Enchytraeidae	-	453	572	180	-	4	-	1253	129	4	4	-	48	696
F. Naididae														
Chaetogaster diaphanus	-	-	23	-	-	-	-	-	21	-	-	-	-	-
Nais communis	8	322	23	-	-	-	4	13123	11	-	4	-	24	-
Nais variabilis	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Pristina leidyi	-	-	-	-	-	-	-	-	64	-	-	-	8	-
Pristinella osborni	-	66	91	644	120	12	23	-	-	-	-	-	-	-
Slavina appendiculata	-	-	23	-	-	-	-	-	-	-	-	-	-	-
Vejdovskyella comata	-	33	-	-	-	-	-	-	-	-	-	-	-	-
F. Tubificidae														
Aulodrilus americanus	-	25	-	-	-	-	-	-	-	-	155	144	-	-
Bothrioneurum vejdovskyanum	-	459	30	-	-	6	2	-	-	-	-	-	-	-
Rhyacodrilus montana	-	1	-	-	-	-	2	-	8	35	61	16	12	16
immatures with hair chaetae	-	-	-	-	-	-	2	-	11	2	8	-	4	-
immatures without hair chaetae	-	-	-	-	-	-	-	-	4	-	-	-	-	8
F. Lumbriculidae														
Stylodrilus heringianus	-	156	59	40	8	136	51	-	-	141	8	-	-	-
P. Arthropoda														
Cl. Arachnida														
O. Hydracarina	5	12	20	164	276	44	54	32	12	20	-	-	4	8
Cl. Maxillopoda														
O. Harpacticoida	-	-	40	40	24	1212	6	-	16	-	-	-	-	16
Cl. Ostracoda	6	4	-	16	88	10	32	-	24	-	188	160	28	24
Cl. Malacostraca														
O. Amphipoda														
F. Hyalellidae														
Hyalella azteca	-	-	-	-	-	-	10	-	4	34	12	-	12	16
Cl. Insecta														
O. Ephemeroptera														
F. Ameletidae														
Ameletus	28	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Baetidae														
indeterminate	-	-	-	-	-	-	-	16	-	-	-	-	-	-
Baetis	3	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Ephemerellidae														
indeterminate	14	-	-	-	-	-	-	16	-	-	-	-	-	-
F. Heptageniidae														
indeterminate	39	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	43	-	-	-	-	-	-	8	-	-	-	-	-	-
Epeorus	25	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	13	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Leptophlebiidae														
Paraleptophlebia	3	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Plecoptera														
F. Capniidae														
indeterminate	120	-	-	-	-	-	-	64	-	-	-	-	-	-
Paracapnia	53	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Chloroperlidae														
indeterminate	19	-	-	-	-	-	-	8	-	-	-	-	-	-
Sweltsa	29	-	-	-	-	-	-	1	-	-	-	-	-	-
F. Nemouridae														
indeterminate	10	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E3-1a **Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 250 µm sieve (densities expressed per sample jar)**

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
?Amphinemura	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Zapada	1	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Taeniopterygidae														
indeterminate	1	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Trichoptera														
indeterminate	-	-	-	-	-	-	-	8	-	-	-	-	-	-
Trichoptera pupae	-	-	-	-	-	-	4	-	-	-	-	-	-	-
F. Lepidostomatidae														
Lepidostoma	50	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Leptoceridae														
indeterminate	-	4	4	40	-	-	-	-	4	2	-	-	-	-
Mystacides	-	-	-	8	-	32	74	-	4	16	24	48	28	-
Oecetis	-	-	-	16	-	2	4	-	-	-	24	8	4	8
F. Limnephilidae														
Ecclisomyia	2	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Rhyacophilidae														
Rhyacophila	1	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Diptera														
F. Ceratopogonidae	-	4	4	8	-	8	6	-	4	4	16	8	12	16
F. Chironomidae														
Chironomid pupae	-	-	-	-	-	-	-	48	-	-	-	-	-	-
S.F. Chironominae														
Cladopelma	-	-	-	-	-	-	-	-	40	-	4	8	-	-
Cladotanytarsus	-	96	12	4	4	200	4	-	16	2	68	88	64	-
Cryptochironomus	-	-	-	-	-	-	-	-	-	-	12	8	4	-
Dicrotendipes	-	112	56	40	-	136	58	-	188	78	28	144	96	32
Micropsectra	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Microtendipes	-	-	-	-	-	-	-	-	36	58	108	158	28	40
Nilothauma	-	-	-	4	4	2	-	-	4	-	4	-	-	-
Pagastiella	-	4	12	-	-	-	2	-	-	2	20	32	184	16
Polypedilum	1	4	-	-	-	-	-	24	-	-	-	16	4	-
Tanytarsus	-	224	8	20	-	32	22	-	116	8	188	160	432	232
S.F. Diamesinae														
Pagastia	1	-	-	-	-	-	-	8	-	-	-	-	-	-
S.F. Orthocladiinae														
Brillia	4	-	-	-	-	-	-	64	-	-	-	-	-	-
?Corynoneura	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus	-	-	-	-	-	-	-	256	-	-	-	-	-	-
Eukiefferiella	-	-	-	-	-	-	-	104	-	-	-	-	-	-
Heterotrissocladius	-	-	-	-	-	-	-	-	4	-	-	16	-	-
Orthocladius	1	-	-	-	-	-	-	344	-	-	-	-	-	-
Parakiefferiella	-	28	20	32	-	40	14	-	44	18	20	128	196	24
Parametriocnemus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Psectrocladius	-	-	-	12	-	10	2	-	56	-	4	-	-	-
Rheocricotopus	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Symposiocladius	1	-	-	-	-	-	-	-	-	-	-	-	-	-
?Thienemanniella	-	-	-	4	-	-	-	-	-	-	-	-	-	-
Tvetenia	-	4	-	-	-	-	-	-	-	-	-	-	-	-
S.F. Tanypodinae														
Ablabesmyia	-	4	-	-	-	8	6	-	20	10	20	16	24	24
Procladius	-	44	4	-	-	2	10	-	316	88	456	296	244	128
Rheopelopia	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Thienemannimyia complex	10	-	-	-	4	-	2	48	8	-	-	-	-	-
Zavrelimyia	1	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Empididae														
indeterminate	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Chelifera	-	4	-	4	12	-	2	-	-	-	4	8	-	-
Oreogeton	-	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Tipulidae														
Dicranota	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Hexatoma	1	-	-	-	-	-	-	-	-	-	-	-	-	-
P. Mollusca														

Table E3-1a **Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 250 µm sieve (densities expressed per sample jar)**

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
Cl. Gastropoda														
F. Ancylidae														
Ferrissia	-	-	-	5	-	-	-	-	-	-	-	-	-	-
F. Lymnaeidae														
indeterminate	-	-	-	-	-	-	4	-	-	-	-	-	-	-
F. Planorbidae														
indeterminate	-	-	-	8	132	6	86	-	-	2	-	-	-	-
Gyraulus	-	-	-	4	16	2	30	-	-	2	-	-	-	-
Menetus	-	-	-	-	16	-	6	-	-	18	-	-	-	-
F. Physidae														
Physella	-	-	-	1	4	-	2	-	-	-	-	-	-	-
Cl. Pelecypoda														
F. Sphaeriidae														
Pisidium	-	4	-	-	-	-	-	-	4	-	164	64	60	-
TOTAL NUMBER OF ORGANISMS	513	2415	1177	1558	1060	1936	638	15453	1288	554	1628	1646	1620	1408
TOTAL NUMBER OF TAXA	36	26	20	25	15	23	30	22	29	20	27	22	25	18

Table E3-1b Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 500 µm sieve
(densities expressed per sample jar)

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
P. Coelenterata														
Hydra	-	-	4	4	-	2	-	-	-	-	-	-	-	-
P. Nematoda	-	12	8	-	-	2	2	-	12	-	-	24	16	8
P. Platyhelminthes														
Cl. Turbellaria														
F. Tricladida	-	-	-	-	-	-	-	2	-	-	-	-	-	-
P. Nemertea														
Prostoma	-	-	4	32	24	-	48	-	-	-	4	-	-	-
P. Annelida														
Cl. Oligochaeta														
F. Enchytraeidae	-	123	207	4	-	-	-	24	-	-	-	-	8	80
F. Naididae														
Chaetogaster diaphanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nais communis	3	25	-	-	-	-	-	8	-	-	-	-	-	-
Nais variabilis	-	-	-	-	-	-	-	-	-	-	-	-	4	-
Pristina leidyi	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pristinella osborni	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slavina appendiculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vejdovskyella comata	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Tubificidae														
Aulodrilus americanus	-	25	-	-	-	-	-	-	-	-	151	136	-	-
Bothrioneurum vejdovskyanum	-	294	30	-	-	-	2	-	-	-	-	-	-	-
Rhyacodrilus montana	-	1	-	-	-	-	2	-	8	29	61	16	12	16
immatures with hair chaetae	-	-	-	-	-	-	-	-	-	-	-	-	-	-
immatures without hair chaetae	-	-	-	-	-	-	-	-	4	-	-	-	-	8
F. Lumbriculidae														
Stylodrilus heringianus	-	123	59	40	8	128	38	-	-	91	-	-	-	-
P. Arthropoda														
Cl. Arachnida														
O. Hydracarina	3	8	-	24	32	8	16	16	4	-	-	-	-	8
Cl. Maxillopoda														
O. Harpacticoida	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cl. Ostracoda	-	-	-	-	-	-	-	-	-	-	84	48	4	8
Cl. Malacostraca														
O. Amphipoda														
F. Hyalellidae														
Hyalella azteca	-	-	-	-	-	-	10	-	4	34	12	-	12	16
Cl. Insecta														
O. Ephemeroptera														
F. Ameletidae														
Ameletus	21	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Baetidae														
indeterminate	-	-	-	-	-	-	-	16	-	-	-	-	-	-
Baetis	3	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Ephemerellidae														
indeterminate	8	-	-	-	-	-	-	16	-	-	-	-	-	-
F. Heptageniidae														
indeterminate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	43	-	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus	9	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	13	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Leptophlebiidae														
Paraleptophlebia	3	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Plecoptera														
F. Capniidae														
indeterminate	4	-	-	-	-	-	-	64	-	-	-	-	-	-
Paracapnia	34	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Chloroperlidae														
indeterminate	1	-	-	-	-	-	-	8	-	-	-	-	-	-
Sweltsa	29	-	-	-	-	-	-	1	-	-	-	-	-	-
F. Nemouridae														
indeterminate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
?Amphinemura	6	-	-	-	-	-	-	-	-	-	-	-	-	-

Table E3-1b	Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 500 µm sieve (densities expressed per sample jar)

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
Zapada	1	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Taeniopterygidae														
indeterminate	1	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Trichoptera														
indeterminate	-	-	-	-	-	-	-	8	-	-	-	-	-	-
Trichoptera pupae	-	-	-	-	-	-	4	-	-	-	-	-	-	-
F. Lepidostomatidae														
Lepidostoma	28	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Leptoceridae														
indeterminate	-	-	4	20	-	-	-	-	-	-	-	-	-	-
Mystacides	-	-	-	8	-	28	52	-	4	14	24	48	24	-
Oecetis	-	-	-	8	-	2	4	-	-	-	24	8	4	8
F. Limnephilidae														
Ecclisomyia	2	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Rhyacophilidae														
Rhyacophila	1	-	-	-	-	-	-	-	-	-	-	-	-	-
O. Diptera														
F. Ceratopogonidae	-	-	-	-	-	2	-	-	-	2	16	-	12	16
F. Chironomidae														
Chironomid pupae	-	-	-	-	-	-	-	48	-	-	-	-	-	-
S.F. Chironominae														
Cladopelma	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Cladotanytarsus	-	-	-	-	-	2	-	-	-	-	-	-	12	-
Cryptochironomus	-	-	-	-	-	-	-	-	-	-	12	-	4	-
Dicrotendipes	-	92	52	36	-	110	50	-	64	16	20	72	32	16
Micropsectra	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Microtendipes	-	-	-	-	-	-	-	-	36	58	108	158	28	40
Nilothauma	-	-	-	4	4	2	-	-	-	-	4	-	-	-
Pagastiella	-	-	-	-	-	-	-	-	-	-	12	24	64	8
Polypedilum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanytarsus	-	40	4	-	-	18	-	-	76	2	160	112	400	160
S.F. Diamesinae														
Pagastia	-	-	-	-	-	-	-	8	-	-	-	-	-	-
S.F. Orthocladiinae														
Brillia	-	-	-	-	-	-	-	32	-	-	-	-	-	-
?Corynoneura	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus	-	-	-	-	-	-	-	88	-	-	-	-	-	-
Eukiefferiella	-	-	-	-	-	-	-	104	-	-	-	-	-	-
Heterotrissocladius	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Orthocladius	-	-	-	-	-	-	-	248	-	-	-	-	-	-
Parakiefferiella	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psectrocladius	-	-	-	-	-	-	-	-	4	-	-	-	-	-
Rheocricotopus	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Symposiocladius	1	-	-	-	-	-	-	-	-	-	-	-	-	-
?Thienemanniella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tvetenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S.F. Tanypodinae														
Ablabesmyia	-	-	-	-	-	-	-	-	-	-	4	-	4	8
Procladius	-	4	-	-	-	2	2	-	120	14	188	136	116	48
Rheopelopia	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Thienemannimyia complex	-	-	-	-	4	-	2	40	4	-	-	-	-	-
Zavrelimyia	1	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Empididae														
indeterminate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chelifera	-	-	-	-	-	-	-	-	-	-	4	8	-	-
Oreogeton	-	-	-	-	-	-	-	8	-	-	-	-	-	-
F. Tipulidae														
Dicranota	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Hexatoma	1	-	-	-	-	-	-	-	-	-	-	-	-	-
P. Mollusca														
Cl. Gastropoda														
F. Ancylidae														

Table E3-1b Benthic invertebrates from Myra Falls, Westmin Resources, 1996: 500 µm sieve (densities expressed per sample jar)

TAXA	REFERENCE							EXPOSURE						
	Myra Creek	Campbell Lake						Myra Creek	Buttle Lake					
	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6	MF-1	BL-1	BL-2	BL-3	BL-4	BL-5	BL-6
Ferrissia	-	-	-	1	-	-	-	-	-	-	-	-	-	-
F. Lymnaeidae														
indeterminate	-	-	-	-	-	-	4	-	-	-	-	-	-	-
F. Planorbidae														
indeterminate	-	-	-	8	100	4	58	-	-	-	-	-	-	-
Gyraulus	-	-	-	4	16	2	30	-	-	2	-	-	-	-
Menetus	-	-	-	-	16	-	6	-	-	18	-	-	-	-
F. Physidae														
Physella	-	-	-	1	4	-	2	-	-	-	-	-	-	-
Cl. Pelecypoda														
F. Sphaeriidae														
Pisidium	-	4	-	-	-	-	-	-	4	-	144	56	60	-
TOTAL NUMBER OF ORGANISMS	218	751	372	194	208	312	332	757	348	280	1032	862	816	448
TOTAL NUMBER OF TAXA	24	12	9	13	8	14	16	20	14	11	18	15	18	15

APPENDIX F

Fisheries

ATTACHMENT F.1

Population Survey

Table F1-1: Fish captured in Buttle Lake, Myra Falls mine: exposure and reference sites

					Lengths		
Date	**Gear**	**Site**	**Species**	**Standard (mm)**	**Forked (mm)**	**Total (mm)**	**Weight (g)**
10/8/06	GN	R	RB	nd	nd	nd	nd
10/8/06	GN	R	RB	nd	nd	nd	nd
10/8/06	GN	R	RB	nd	nd	nd	nd
10/9/96	GN	R	RB	403	412	477	1200
10/9/96	GN	R	RB	376	405	432	800
10/9/96	GN	R	RB	222	240	259	200
10/9/96	GN	R	RB	286	305	320	350
10/9/96	BS	R	unknown	nd	nd	nd	nd
10/9/96	BS	R	unknown	nd	nd	nd	nd
10/9/96	BS	R	unknown	nd	nd	nd	nd
10/9/96	BS	R	350 TSB	nd	nd	nd	nd
10/9/96	BS	R	3 CAS	nd	nd	nd	nd
10/9/96	MT	R	1 CAS	nd	nd	nd	nd
10/9/96	MT	R	1 TSB	nd	nd	nd	nd
10/10/96	GN	E	RB	210	226	242	175
10/10/96	GN	E	RB	204	238	250	200
10/10/96	GN	E	RB	205	214	230	150
10/10/96	GN	E	RB	248	264	285	250
10/10/96	GN	E	RB	215	235	250	175
10/11/96	GN	E	RB	261	285	295	375
10/11/96	GN	E	RB	218	235	252	175
10/11/96	GN	E	RB	260	277	295	325
10/11/96	GN	E	RB	244	264	282	300

nd = no data available

Site Code: E = Exposure
R = Reference

Gear Type: GN = Gillnet
BS = Beach Seine
MT = Minnow Trap
EF = Electrofishing
AN = Angling

Fish Species: LT = Lake Trout
CL = Lake Cisco
BB = Burbot
RW = Round Whitefish
AG = Arctic Grayling

RB = Rainbow Trout
TSB = Threespine Stickleback
CAS = Prickly Sculpin
MW = Mountain Whitefish
NSC = Northern Squawfish
CC = Sculpin (General)