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# Reay Creek Pond Sediment Investigations
# Canora Road Between Northbrook Drive and Bowcott Place

## Sampling and Analysis of Reay Creek Pond Sediments

**May 2015**
**SLR Project No.: 205.03696.00000**

# SAMPLING AND ANALYSIS OF REAY CREEK POND SEDIMENTS

## CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE

**SLR Project No.: 205.03696.00000**

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# EXECUTIVE SUMMARY

Samples of sediments were collected and analysed to assess sediment quality at eight locations and from several depths in the Reay Creek Pond. The locations were selected to represent the areas of the pond between the Canora Rd. end and the dam. The locations were considered representative of Reay Creek Pond sediments. Better understanding of the variation and range of concentrations over the length of the Pond could benefit from more samples, but the current results address the purpose of the investigations.

The specific purpose was to compare analytical results to established regulatory reference values to determine if the sediments would be classified as contaminated. Reference values (i.e., substance concentrations) in the Contaminated Sites Regulation (BC CSR) and national Canadian Council of Minister of the Environment (CCME) guidelines were used.

Sediments were analyzed for two chemical substance groups, metals and polycyclic aromatic hydrocarbons (PAHs). Provincial and national criteria or guidelines have been established and published for metals and PAHs (i.e., BC CSR; and CCME), so comparison of analytical concentrations of these substances with the criteria and guidelines determines whether the sediments should be classified as contaminated. Metals and PAHs commonly occur in sediments and elevated concentrations can reflect impacts from the drainage areas to the water bodies that the sediments underlie.

Review of remediation requirements and options are not included in the purpose of the current investigations and this report. While either numerical concentration criteria or risk-based criteria can be used to determine acceptable remediation according to the CSR in BC, concentration criteria are used to determine if contamination is present.

Metals concentrations in Reay Creek Pond exceeded CSR and CCME reference criteria / guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper in at least one sample also exceeded a criterion / guideline but to a lesser degree than the four other metals noted.

PAH concentrations in Reay Creek Pond exceeded CSR and CCME reference criteria / guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAH substances with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines and six had concentrations below all applicable criteria / guidelines; and
- Two of the 3 samples for which PAH analyses were carried out had relatively low concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, (i.e., TEL / ISQG guidelines) but below the CSR “sensitive” criteria.

Sediments in the Reay Creek Pond would be classified as “contaminated” on account of both metals and PAH concentrations when referenced to both national (CCME) guidelines and BC (CSR) sediment quality criteria.

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# 1.0 INTRODUCTION

## 1.1 Background

The Town of Sidney requires data for sediment quality in the Reay Creek Pond located within the Reay Creek Park. New accounting standards are applicable to the Town of Sidney according to Public Sector Accounting Standards (PSAS). Liability for contamination is an aspect to be considered in accounting by public sector entities. The question of whether sediments in the Reay Creek Pond were contaminated and therefore whether remediation costs should be allowed for was an issue to be addressed.

At about the same time that the need for sediment quality confirmation and potential remediation cost was being considered by the Town of Sidney, others were also investigating sediments and indicating that results had showed concentrations of several substances exceeding national and provincial guidelines.

## 1.2 Objectives

The objectives of the sediment sampling and analysis project carried out by SLR on behalf of the Town of Sidney were to:

- Obtain representative, albeit limited, samples of sediments from the floor of the Reay Creek Pond;
- Describe the methods, procedures used to collect sediment samples and document the locations so any further sampling or sampling by others could be compared and supplemented as appropriate;
- Obtain laboratory analyses of the samples for substances / contaminants of potential concern; and
- Compare the laboratory analysis results to established guidelines, criteria or standards (i.e., National; Provincial) so it could be determined if Reay Creek Pond sediment concentrations exceed these reference values and the sediments would be classified as contaminated, thereby addressing the first two of five PSAS questions.

# 2.0 PREVIOUS INVESTIGATIONS

## 2.1 Camosun College

The Environmental Technology Program at Camosun College conducted studies and prepared a report for the Reay Creek Pond in June 2010.[1] The report prepared by Camosun College was provided to and reviewed by SLR so that sampling and analysis could account for and supplement the information in the Camosun College report.

A number of characteristics and aspects of the pond were investigated and reported on in the Camosun College report, including:

- Water and sediment depth transects (11 transect locations);

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[1] *Reay Creek Pond Study.* Camosun College Environmental Technology Study. Justin Robinson and Rachelle Sarrazin. June 2010.

- Water quality sample analyses (3 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P);
- Water parameter measurements (Field measurements for dissolved oxygen [DO], electrical conductivity [EC], pH, temperature);
- Sediments sample analyses (4 locations; surface grab samples):
    - Extracted pore water (4 samples, in-house analyses; ammonia-N; nitrite-N; nitrate-N; phosphate-P).
    - Sediment five day BOD tests ([BOD5] 5 samples; in-house analyses).
    - Sediment metals (2 samples; Maxxam Analytics Inc. analyses).
- Invertebrates (2 locations, water and surface sediment); and
- Fish (4 locations).

From the information collected in the field and calculations carried out, the Camosun College report provided information regarding:

- Pond water depths;
- Sediment thicknesses;
- Estimated total volumes of sediment; and
- Observations and summaries pertaining to general water conditions, habitat suitability, water quality, flora and fauna, etc.

## 2.2 Peninsula Streams Association

The Peninsula Streams Society collected sediments in the Reay Creek Pond Area in 2013 and following SLR's sampling and analysis of sediments. Additionally, surface sediment grab samples within Reay Creek downstream of the Reay Creek Pond were collected on January 22, 2015. The 2013 sample analytical results have not been provided to SLR. The results of analyses of the January 22, 2015 samples below the Reay Creek Pond have been provided to the Town of Sidney and to SLR. General comments about methods and findings have been indicated to both the Town of Sidney and to SLR.

# 3.0 SITE INFORMATION

## 3.1 Location

Reay Creek Pond is part of the Reay Creek Park, located to the southeast of the Victoria International Airport, just east of Canora Road and between Northbrook and Westbrook Drive on the north and Bowcott Place on the south. Reay Creek Park is within the boundaries of the Town of Sidney in its southwest corner. The Patricia (Pat) Bay Hwy is located about 0.5 km east of the south end of the pond and about 0.6 km in the downstream direction (i.e., southeast) of the south end of the Reay Creek Pond. The Victoria International Airport (YYJ) is located to the west, but mainly to the northwest of the Reay Creek Pond. The length of the pond is about 200 m between Canora Road and the dam.

Reay Creek originates on YYJ property just to the south of the commercial properties in the area of the control tower, flows across non-YYJ property within North Saanich, under Canora Road, through the Reay Creek Pond portion of the Reay Creek Park (Town of Sidney), through Peter Grant Park (Town of Sidney) and then south, again into North Saanich, under the Pat Bay Hwy and thence east-southeast under Lochside Drive to its discharge location into the Bazan Bay portion of Haro Strait. Figure A illustrates the location of Reay Creek, the Reay Creek Park and Pond, as well as YYJ, the Pat Bay Hwy and Haro Strait.

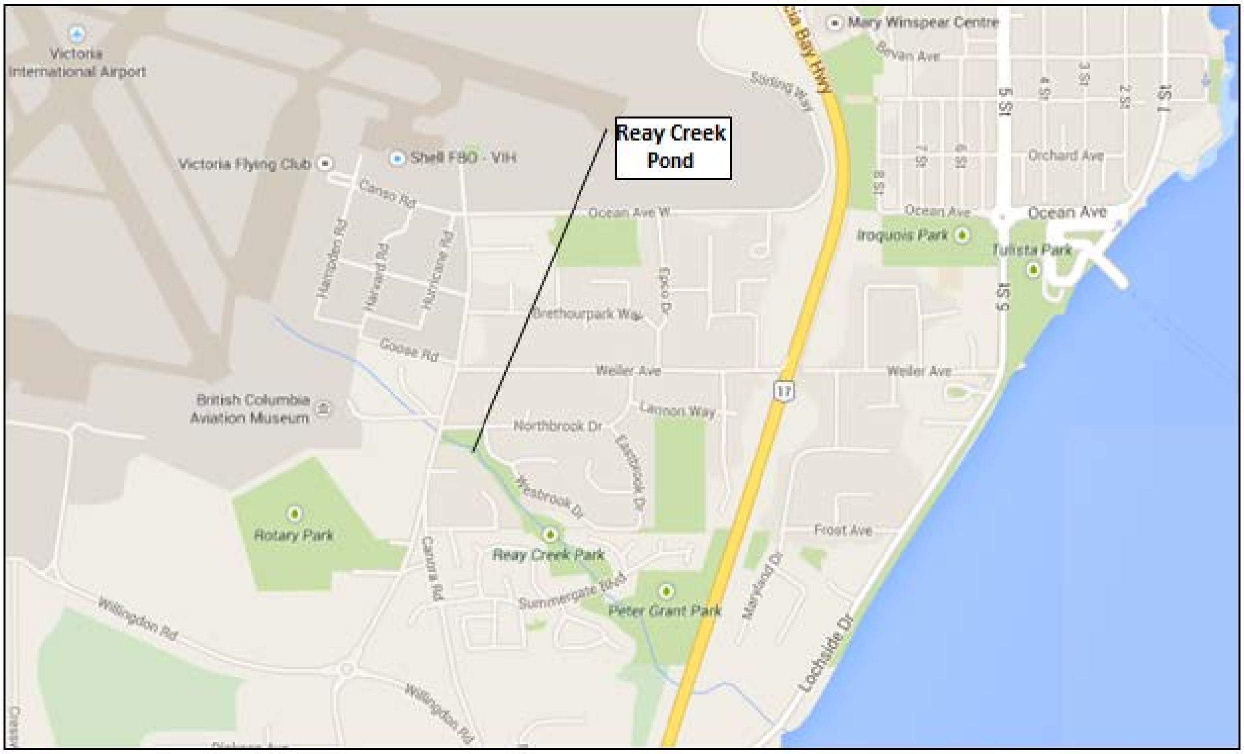

**Figure A**
**Reay Creek Pond Site Location**

### 3.2 Reay Creek Pond

In the past, lands adjacent to Reay Creek in the area of the Pond were owned by many different property owners. SLR understands that a duck farm owner adjacent to the Creek constructed an earthen / mud dam to control water flow and levels. A pond was created above the dam.

In 1998 the dam was reconstructed by the Town of Sidney to prevent failure and better control the flow.

Much effort to restore Reay Creek and a number of stream restoration components have involved many different stakeholders, volunteers, Association and Society members, the Airport and several levels of government.

## 4.0 SEDIMENT SAMPLING AND ANALYTICAL METHODS

Sampling was conducted on Thursday January 15, 2015 and samples were submitted to the laboratory the next day. Sampling locations, methods and procedures, and quality assurance / quality control procedures are outlined in the following sections.

Prior to sampling, SLR prepared a site / project specific Health & Safety Plan (HASP) with attached copies of SLR's:

- Standard Safety Procedure – Working Around Water (SSP 019); and
- Safety Guidance Document – Working Around Water (SGD 09).

The HASP was reviewed prior to the start of work and a copy was on-hand during sampling.

## 4.1 Sampling Locations

Sample locations were selected to represent sediments over the full length of Reay Creek Pond, limited by the numbers of samples proposed and budgeted for. Areas of accumulation of sediments as indicated by cross-sections and sediments depth reported in the previous Camosun College report were considered when selecting locations.

Locations were distributed from near the top (Canora Rd end) of the Pond to near the dam, with depth samples in the areas of greatest sediment deposit as indicated by the Camosun College report. Camosun College transects as reported were located by overlay and plotted on orthophotos that included the Reay Creek Pond area. It was considered that future reference and comparison of results could benefit from sample location selection that could also reference the previous sampling. Drawing 1 illustrates the selected sample locations and also the previous transects for reference.

## 4.2 Sampling Methods and Equipment

Sampling was carried out from a small boat, moved between locations and stabilised at each location with oars. Depth of water at the time of sampling was shallow so no anchors or longer poles were needed. Sampling was completed with assistance of Town of Sidney personnel.

Both surface grab samples and core samples were collected depending on location and expected depth of sediment. Core samples collected so that both shallow (i.e., more recently deposited) and deeper (i.e., older deposit) sediments could be represented. Surface grab samples were collected using a stainless steel Petite Ponar Sampler that is widely used in both fresh and salt water for sediment sampling including from hard bottoms such as sand, gravel, consolidated marl or clay. Core samples were collected using a Wildco stainless steel corer with enclosed ~5 cm (~2 in) sleeve inside the stainless steel sheath attached to the threaded head assembly. Both Petite Ponar and Wildco core sampler were dropped for sampling and retrieved manually using a rope securely attached to each. Figure B illustrates the samplers.

Petite Ponar Grab Sampler

Wildco Stainless Steel Core Sampler

**Figure B**
**Samplers Used for Sediment Sample Collection**

## 4.3 Sample Handling

A portion of the grab samples collected with the Petite Ponar were transferred by hand with single use disposable gloves, to laboratory supplied 120 ml glass jars with Teflon lined lids. Two sample jars were filled where sufficiently large grab samples had been collected. Jars were labelled at the time of sampling. The sampler was cleaned between samples firstly with pond water and then rinsed thoroughly with distilled water between samples.

Cores samples in the sleeves / tubes collected in the Wildco core sampler were removed from the sampler and capped on both ends in the field to fully retain the samples and prevent contamination. Tubes were labelled, the sampler cleaned with pond water and rinsed with distilled water and then a new, clean sleeve re-inserted into the sampler for collecting the next sample.

Grab samples were placed in glass jars in the field and capped sleeves with core samples were stored and transported from the field in coolers.

Sampling of the cores was completed indoors at SLR facilities in Victoria. To allow transferring core samples, caps from corer sleeves were removed and cores were extruded in increments into cleaned stainless steel bowls using a clean, plastic sample container with the same outside diameter as the inside diameter of the sleeves and a stainless steel rod to move the container through the sleeve. Core samples were collected in depth increments either from the stainless steel bowl or directly from the core extruded but suspended from the sleeve.

## 4.4 Sampling Depths and Sub-Samples

Grab samples (3 locations) collected with the Pettite Ponar collected samples from approximately the top 10 cm of sediment. Detritus and organic materials (e.g., twigs, largely undecomposed leaves and grass, or rooted grass) at this site limited the depth of samples to 10 cm and may have limited the depth to even less than 10 cm at one or two of the locations.

Core samples were collected to depths ranging from 25 to 40 cm below the surface of the sediments. Three depth increments (6 locations), or four depth increments (1 location) were segregated for sub-sampling of the cores. Core segments ranged in lengths from 8 cm to 17 cm, depending on the overall core length, but also on the consistency of the materials and feasibility of controlling core extrusion rates. Depth increments obtained were considered suitable as sub-samples.

Grab samples and core sub-samples were selected for analyses. Not all samples and sub-samples could be selected for laboratory analyses. Numbers of samples were limited by budget allowances. As well, a number of samples could be expected to have similar analytical results (e.g., ~10 cm surface increments of core samples and nearby grab samples). Table A summarizes the sample depths selected for one or more laboratory analyses as well as the overall number of samples collected.

**Table A**
**Numbers of Samples Selected for Analysis and Sampled - by Depth Increment**

| Depth | Samples Selected for Analysis | Number of Samples Collected |
|---|---|---|
| Grab (~10 cm) | 1 | 3 |
| Surface (0-8cm; 0-10 cm) | 6 | 7 |

| Depth | Samples Selected for Analysis | Number of Samples Collected |
|---|---|---|
| Mid-core (range, 8-30 cm) | 4 | 7 |
| Deeper (range, 25-40 cm) | 5 | 7 |

## 4.5 Parameters for Analyses

Two groups of substances were selected for analyses, metals and polycyclic aromatic hydrocarbons (PAHs). Additionally, one sample was selected for total organic carbon (TOC) and one for grain size analyses.

Metals and PAH groups are each comprised of numerous individual substances. Typically, about 30 metals (including sub-species of several) and about 20 PAH substances are included in analyses. Metals and PAHs were the focus of analyses because both national and provincial guidelines and criteria have been developed and published for these groups of substances. Also, these groups of substances are most likely to reflect elevated concentrations due to land uses and activities, particularly commercial or industrial, in upland drainage areas contributing to sediment deposited in receiving water bodies.

A number of other groups of substances could be analyzed for and may be present in sediments (e.g., pesticides; polychlorinated biphenyls (PCBs); dioxins and furans) but were not selected for this preliminary sediment characterization project for several reasons, for example:

- Analytical results are often below detection levels or detectable concentrations are very low;
- Costs of analyses of single or small numbers of samples are very high; or
- Guidelines or criteria may not have been developed and published.

## 4.6 Quality Assurance / Quality Control

Field procedures and sample handling methods were implemented to minimize opportunity for contamination and to confirm tracking of samples. Procedures included:

- Using laboratory cleaned and sealed sampling containers;
- Using single use, disposal gloves for each new sample;
- Cleaning and rinsing reusable sampling equipment (e.g., Ponar Sampler; Wildco Core Sampler);
- Labelling all samples in the field to ensure correct tracking;
- Accompanying samples submitted to the laboratory with a completed Chain of Custody document;

All samples were analyzed by ALS Environmental (ALS) of Burnaby, BC, which is accredited by the Canadian Association for Laboratory Accreditation (CALA) for the parameters analyzed and uses MOE recognized methods to conduct analyses. As conveyed by the laboratory, method blanks, control standards samples, certified reference material standards, method spikes, replicates, duplicates, surrogates and instrument blanks are routinely analyzed as part of their QA/QC programs. ALS conducts routine internal laboratory QA/QC analyses to validate the reliability of the analytical results. The results of laboratory internal quality control replicates can be found within the chemical analysis reports included in Appendix C.

## 5.0 REGULATORY REQUIREMENTS AND REFERENCE VALUES

As noted above in Section 1.2, one of the objectives of this project was compare laboratory analysis results for sediment samples to established guidelines, criteria or standards (i.e., National; Provincial) so it could be determined if Reay Creek Pond sediment concentrations exceed these reference values and the sediments would be classified as contaminated, thereby addressing the first two of five PSAS questions.

The sections below provide a summary of Sediment Quality Criteria and National Sediment Quality Guidelines.

### 5.1 Provincial Sediment Quality Criteria

The Contaminated Sites Regulation (CSR), Schedule 9, Generic Numerical Sediment Criteria (SedQC) provides reference values for assessing sediment quality. Concentration criteria for substances of potential concern are provided for freshwater and marine sediments. These criteria are for aquatic life use and are intended to protect sediment-dwelling species from unacceptable effects that may be associated with exposure to contaminated sediments at typical and sensitive sites. The designated use of the aquatic, estuarine, or marine ecosystem portion of a site is used to classify the site as either typical or sensitive (i.e., for Freshwater, or Marine and Estuarine: Sensitive $\text{SedQC}_{\text{SS}}$ and Typical $\text{SedQC}_{\text{TS}}$). “Sensitive sediment use” and “Typical sediment use” are defined in a MOE procedure document.[2]

"Sensitive sediment use" means the use as habitat for sensitive components of freshwater, marine or estuarine aquatic ecosystems of a site containing sediment, which sensitive components include, but are not limited to,

(a) phytoplankton, zooplankton, benthos, macrophytes and fish,
(b) habitats used by endangered or threatened species or species of special concern under the Species at Risk Act (Canada),
(c) watercourses, wetlands, forested riparian areas, mudflats and intertidal zones that are important to the preservation of fish or wildlife,
(d) reaches of aquatic habitats that are important to fish spawning or serve as important rearing habitat for fish,
(e) reaches of aquatic environments that encompass or border habitat compensation or restoration sites or other areas that are intended or designed to create, restore or enhance biological or habitat features, and
(f) areas and aquatic habitat included in wild life management areas designated under the *Wildlife Act*; and

"Typical sediment use" means the use of a site containing sediment for a use that is not a sensitive sediment use.

As implied by the terms sensitive and typical, the sensitive criteria are more stringent (i.e., have lower concentration thresholds) and typical criteria are less stringent (i.e., have higher concentration thresholds).

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[2] *Definitions and Acronyms for Contaminated Sites*. Procedure 8. January 14, 2014. Effective January 14, 2014. BC Ministry of Environment.

Criteria are provided in Schedule 9 for a number of substance / contaminant groups including:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: PCBs, PCDDs (dioxins), and PCDFs (furans);
- Phenolic substances (1 substance, pentachlorophenol);
- Polycyclic aromatic hydrocarbons (PAHs) (13 substances, and total PAHs); and
- Pesticides (8 substances).

Provision also is included in the CSR (Section 11(3)) for considering background concentration standards for sediments; however, requirements for determining background sediment quality have not been specified in an approved Protocol so using alternate numerical standards to those prescribed in Schedule 11 of the CSR is not currently possible.

## 5.2 National Sediment Quality Guidelines

Canadian Council of Ministers of the Environment (CCME) guidelines for sediment quality are derived from the available toxicological information according to the formal protocol established by CCME. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline and is also referred to as the Interim Sediment Quality Guideline (ISQG). The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

Guidelines (i.e., TEL & PEL) are provided by CCME for essentially the same substance / contaminant groups as in the CSR for BC, namely:

- Metals (7 substances);
- Chlorinated hydrocarbons (3 substance groups, including: PCBs, PCDDs (dioxins), and PCDFs (furans);
- Phenolic substances (1 substance, pentachlorophenol);
- Polycyclic aromatic hydrocarbons (PAHs) (13 substances, and total PAHs); and
- Pesticides (8 substances).

As implied by the explanations for the CCME guideline terms TEL / ISQG and PEL, the TEL / ISQG guidelines are more stringent (i.e., have lower concentration thresholds) and PEL guidelines are less stringent (i.e., have higher concentration thresholds).

## 5.3 Applicable Criteria / Guidelines

Both the CSR criteria for BC and the National CCME guidelines include substance concentrations for protection of marine and freshwater aquatic systems. Reay Creek Pond and Reay Creek in the area of the Reay Creek Pond is a freshwater system. The criteria and guideline concentrations for freshwater are considered applicable. Sediment chemistry data tables at the end of the text of this report therefore include only the concentrations for freshwater.

From the definitions for "sensitive sediment use" in then CSR, some elements would apply. Other aspects of the definition for "sensitive" would clearly not apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both "sensitive" and "typical".

From the explanation of the TEL and PEL threshold levels used in the CCME guidelines the objectives for use of, and reference to both the TEL and PEL levels could apply. Sediment chemistry data tables at the end of the text of this report therefore include the concentrations for both TEL and PEL.

### 5.4 Alternate Criteria - Risk-Based

It should be noted that contaminated sites legislation and the Contaminated Sites Regulation in BC define two general types of standards (in the case of sediment, standards are referred to as criteria):

- *Numerical standards* are acceptable concentrations of substances in soil, surface water, groundwater, vapour and sediments.
- *Risk-based standards* are acceptable risk levels from exposure to substances at sites.

At sites under BC jurisdiction, either numerical concentration or risk-based standards or criteria may be applied when considering remediation requirements and options. One option for remediation is to remove contaminants so no sediments exceeding reference concentrations remain. An alternate is to conduct risk assessment to confirm that contaminants managed in-place would not pose unacceptable risks to human health or the environment, or if required, risk management / risk control measures could be implemented so risk would be reduced to acceptable levels.

Despite the options for remediation, numerical concentration standards/criteria must be used to determine whether or not contamination is present at a site and if the site is classified as a contaminated site. The Contaminated Site Regulation. Section 11 states:

> "(1) Subject to section 12 and subsections (2), (3) and (4) of this section, the following substances, standards and conditions are prescribed for the purposes of the definition of "contaminated site" in section 39 of the Act: (a)…; (b)…; (c) the concentration of any substance in sediment at the site is greater than the applicable generic numerical sediment criterion; (d)…;"

## 6.0 SEDIMENT RESULTS

Sediment analytical results are compared below to numerical concentrations criteria / guidelines. Risk assessment has not been carried out so risk-based concentrations as might be considered for remediation, are not discussed.

### 6.1 Field Observations

At the time of sampling in mid-January 2015, SLR noted that Reay Creek Pond water was relatively shallow and exposed grasses, brush and several overhanging trees reduced the area of open water, generally confirming the views from aerial photos. Overflow via the spillway at the dam was relatively low.

Sediment sampling via both the Ponar sampler and the Wildco Core sampler collected in the open water areas, encountered a surface layer of grasses, roots of grasses, some detritus (e.g., leaves, twigs). These materials were included in the Ponar grab samples and limited sediment sample recovery somewhat. Due to these materials, the flexible plastic fluted core catcher in the leading edge of the sleeve / tube inside the sampler, intended to maintain the collected sample inside of the core tube, tended to become blocked, limiting the depth of sampling. This resulted in use of the core catcher being abandoned.

## 6.2 Laboratory Analytical Results

Laboratory analyses reports for sediment samples submitted are included in Appendix C. Summary Tables of the analytical results along with CSR and CCME criteria and guidelines as discussed in Section 5 above are included at the end of the text of this report and are discussed in the following sections.

### *6.2.1 Metals*

Table 2 presents metals analysis results in relation to both CSR criteria and CCME guidelines. Seven of the metal substances for which analyses were completed had published CSR criteria and CCME guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper also exceed at least one criterion / guideline but to a lesser.

Figure C below illustrates the range of concentrations of the four metals noted above and the criteria / guidelines.

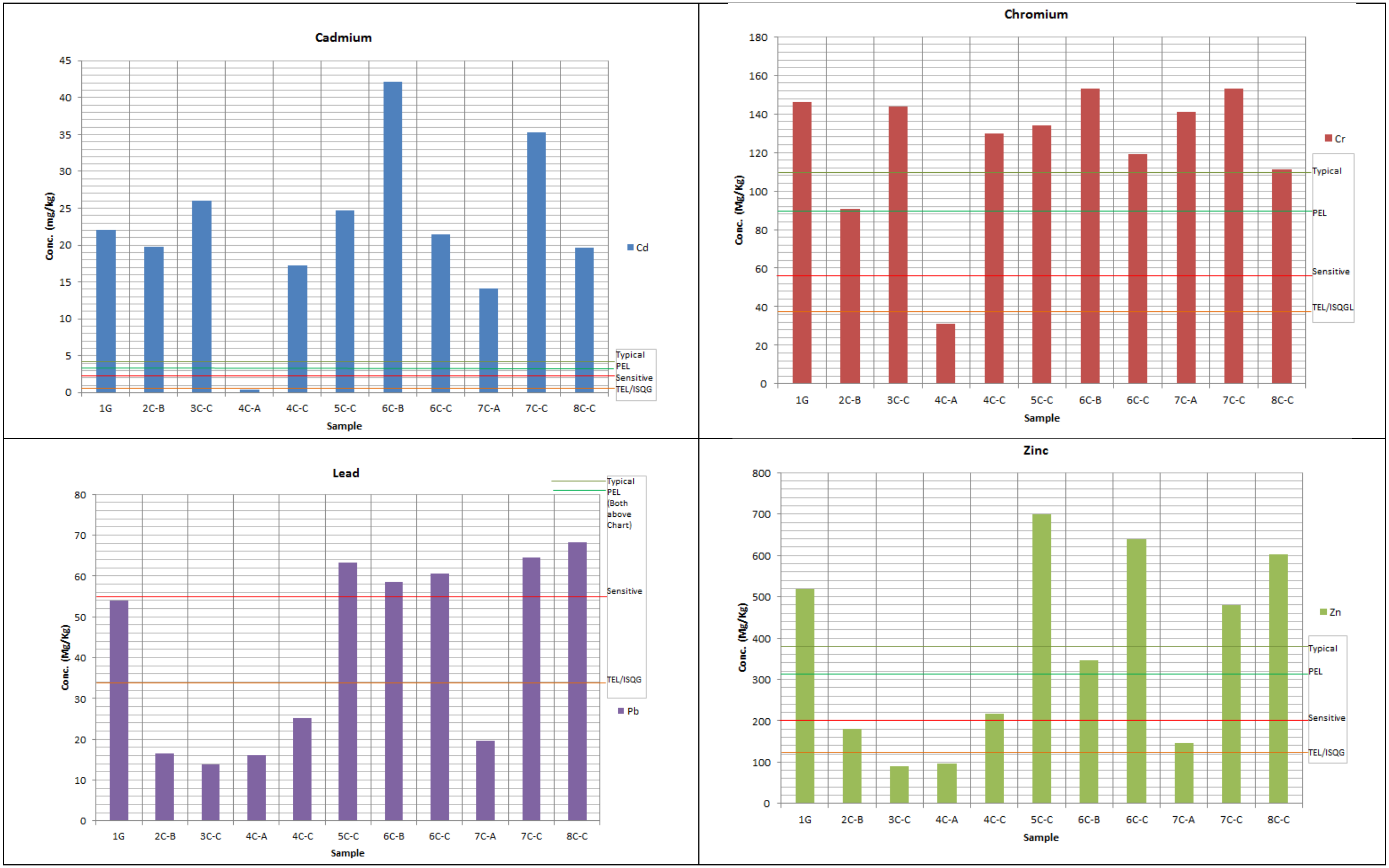

**Figure C**
**Metal Concentrations (Cd, Cr, Pb & Zn) in Relation to CSR Criteria & CCME Guidelines**

Additionally, regarding concentrations of metals, the charts in Figure C indicate:

- Very low threshold concentrations for cadmium and significant exceedances of criteria / guideline for all samples except one deeper sample (4C-A);
- Considerable variability of concentrations between samples, but generally the highest concentrations for surface sediment samples (i.e., samples with labels XC-C (core samples) and XG (surface grab)); and
- No apparent clear trend of higher concentration of the metals at the Canora Rd. end or the end nearest the dam, though slightly higher concentrations for several metals may be suggested closer to the end of the Pond nearest the dam.

### *6.2.2 Polycylic Aromatic Hydrocarbons (PAHs)*

Table 3 presents PAH analysis results for 3 samples in relation to both CSR criteria and CCME guidelines. Thirteen of the 20 PAH substances for which analyses were completed had published CSR criteria and CCME guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAHs with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Six of the 13 PAHs with published criteria / guidelines had concentrations below all applicable criteria / guidelines;
- Two of the 3 samples that had concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, the TEL / ISQG guidelines but below the provincial “sensitive” criteria; and
- Not enough samples were analyzed for PAHs to allow observations regarding variability or trends in concentrations, if any near the Canora Rd. end of the Pond and the end nearest the dam.

Figure D below illustrates the concentrations of four selected PAH substances that had concentrations exceeding one or more published criteria / guidelines. This sample with the highest concentration of a number of the PAHs was for a mid-depth sample (i.e., indicated by the XX-B label vs. the surface sample (XX-C) or the deeper (XX-A) sample).

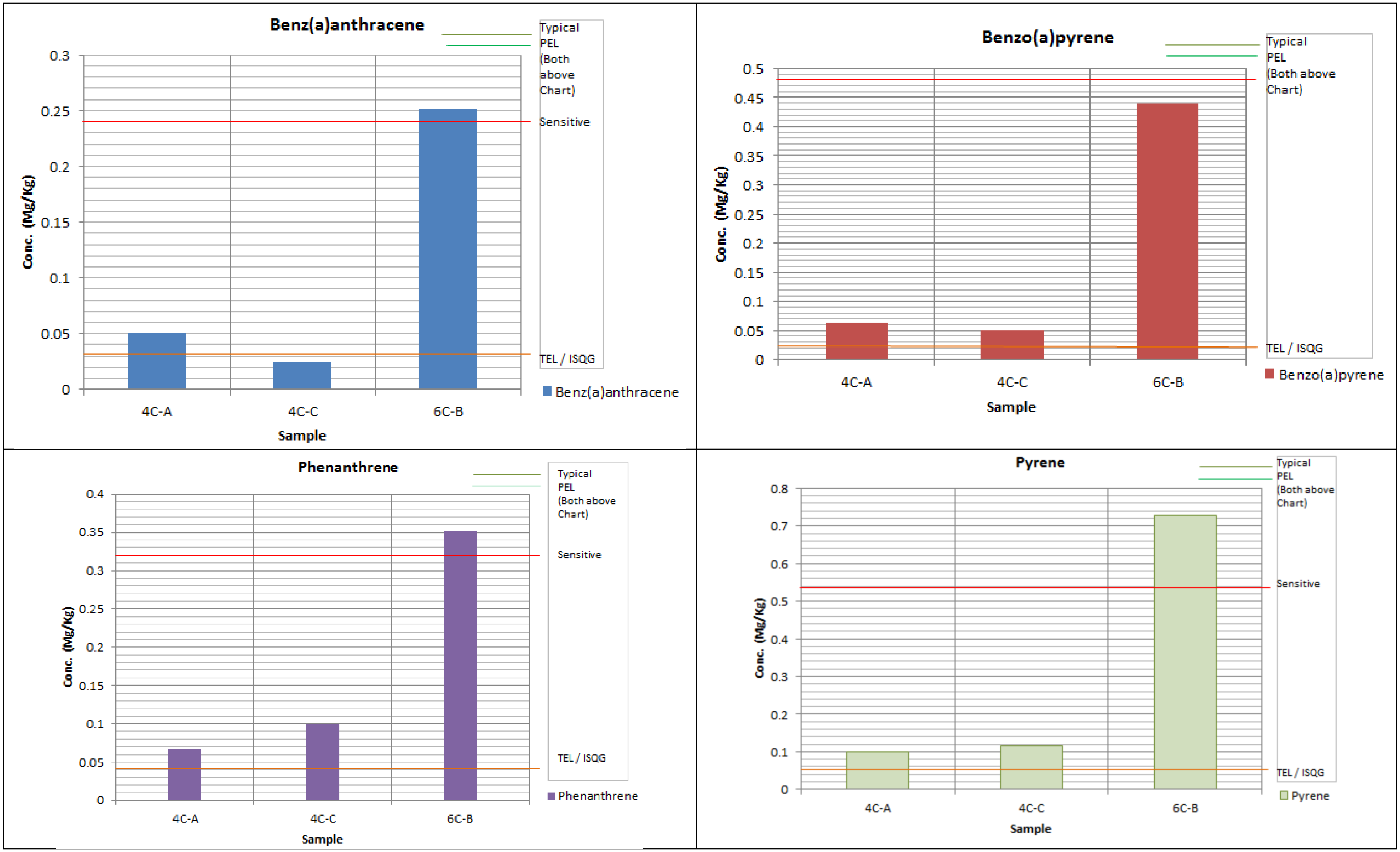

**Figure D**
**Concentrations of Selected PAHs in Relation to CSR Criteria & CCME Guidelines**

### *6.2.3 Representative Characterization Results – TOC and Grain Size*

One sample was analyzed for total organic carbon and one sample for grain size analysis. One sample was analyzed for each to indicate the conditions generally considered representative, from field observations. While considered representative, one sample cannot be indicated as the "average"; however, it does indicate that conditions that are typical of the area and do not represent an unusual or extreme condition. Table 4 includes the results for total organic carbon and the laboratory report with the analytical result is included in Appendix C.

The grain size distribution results are included with the laboratory reports (i.e., near end) in Appendix C. The sample has 95% "fines" less than 0.075 mm and would be classified as a "silt loam".

## 7.0 DISCUSSION

### 7.1 Current Investigation

Samples of sediments at eight locations and several depths in the Reay Creek Pond were collected and submitted to a laboratory for chemical analyses to assess sediment quality. The locations were selected to represent all areas of the pond. The locations were also selected with reference to eleven previous transects across the pond, used by the Environmental Technology Program, Camosun College, to characterize Reay Creek Pond water and sediment depths. The locations were considered representative of Rey Creek Pond sediments. Better understanding of the variation and range of concentrations over the length of the Pond would benefit from more samples, but the results for current samples address the purpose of the investigations.

The specific purpose was to compare analytical results to established regulatory reference values to determine if the sediments would be classified as contaminated. Reference values (i.e., substance concentrations) in the CSR (BC) and CCME Guidelines (National) were used.

Sediments were analyzed for two chemical substance groups, metals and polycyclic aromatic hydrocarbons (PAHs). Provincial and national criteria or guidelines have been established and published for metals and PAHs (i.e., BC CSR; and CCME), so comparison of analytical concentrations of these substances with the criteria and guidelines determines whether the sediments should be classified as contaminated. Metals and PAHs commonly occur in sediments and elevated concentrations typically reflect impacts from the drainage areas, but also direct deposits, if any, to the water bodies that the sediments underlie.

Review of remediation requirements and options are not included in the purpose of the current investigations and this report. As outlined in Section 5.4 above, while either numerical concentration criteria or risk-based criteria can be used to determine acceptable remediation according to the CSR in BC, concentration criteria must be used to determine if contamination is present in sediments (i.e., at this site; or if applicable, in soils, groundwater, surface water or site vapour at a site).

### 7.2 Comparison to Previous Camosun College Results

The Camosun College study included laboratory analyses of metals for two locations, one sample from near the middle of the pond and one sample from near the dam. Chromium and cadmium analytical results were noted in the report discussion as elevated, exceeding CCME

"Probable Effect Levels" (PEL) guidelines at both locations. Reference was not made to zinc concentrations at both locations also exceeding PEL guidelines. Results were not compared to the more stringent TEL / ISQG reference values.

Regarding cadmium and the Camosun College results compared to the SLR concentrations:

- The two cadmium concentrations were within the range of the larger number of SLR concentrations, with the SLR average slightly above the Camosun College average (i.e., 21.5 vs. 19.75mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average cadmium was higher that the Camosun College surface (grab) sample cadmium by slightly more (22.86 vs. 19.75 mg/kg).

Regarding chromium and the Camosun College results compared to the SLR concentrations:

- The two chromium concentrations were also within the range of the larger number of SLR concentrations, with the SLR average slightly above the Camosun College average (i.e., 112.73 vs. 111 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average cadmium was higher that the Camosun College surface (grab) sample cadmium by slightly more (118.06 vs. 111 mg/kg).

Regarding lead and the Camosun College results compared to the SLR concentrations:

- The two lead concentrations were also within the range of the larger number of SLR concentrations, but the SLR average was well below the Camosun College average (i.e., 38.41 vs. 65.35 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average lead was still well below the Camosun College surface (grab) sample (42.51 vs. 65.35 mg/kg).

Regarding zinc and the Camosun College results compared to the SLR concentrations:

- The two zinc concentrations were above the range of the larger number of SLR concentrations, and the SLR average was well below the Camosun College average (i.e., 335.1 vs. 721 mg/kg); and
- If only the surface and mid-depth SLR samples were considered, the SLR sample average lead was still well below the Camosun College surface (grab) sample average ( 337.77 vs. 721 mg/kg).

In summary, cadmium and chromium results are considered to be very similar for the 2010 Camosun College samples as for the SLR samples. The lead and particularly the zinc concentrations were somewhat different, however, and would need to be examined more closely in regard to sample characteristics or analytical method differences, if information is available. Nonetheless, the conclusions regarding classification of the sediments as contaminated would be the same.

## 8.0 CONCLUSIONS AND SUMMARY

Metals concentrations in Reay Creek Pond exceeded CSC and CCME reference criteria / guidelines. In summary regarding metal concentrations in the sediments:

- Six of the 7 metals with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Four of the metals, cadmium (Cd), chromium (Cr), lead (Pb) and zinc (Zn) exceeded the criteria / guidelines to the greatest degree, with Cd exceeding criteria / guidelines by the greatest margin and lead by the lowest margin; and
- Arsenic and copper also exceed at least one criterion / guideline but to a lesser.

PAH concentrations in Reay Creek Pond exceeded CSC and CCME reference criteria / guidelines. In summary regarding PAH concentrations in the sediments:

- Seven of the 13 PAHs with published criteria / guidelines had concentrations exceeding one or more of the criteria / guidelines;
- Six of the 13 PAHs with published criteria / guidelines had concentrations below all applicable criteria / guidelines;
- Two of the 3 samples that had concentrations of PAHs exceeding criteria / guidelines close to the most stringent of the criteria / guidelines, the TEL / ISQG guidelines but below the provincial “sensitive” criteria; and
- Not enough samples were analyzed for PAHs to allow observations regarding variability or trends in concentrations, if any, near the Canora Rd. end of the Pond and the end nearest the dam.

Sediments in the Reay Creek Pond would be classified as “contaminated” on account of both metals and PAH concentrations when referenced to both national (CCME) guidelines and BC (CSR) sediment quality criteria.

## 9.0 PROFESSIONAL STATEMENT

This sediment sampling and analysis report, prepared by SLR for the above-referenced site, was prepared by Benjamin McKinnon, B.I.T. and John Wiens, Ph.D., P.Ag. The authors of the report have over 25 years of combined experience in the assessment and remediation of similar sites and are familiar with the work carried out for the subject site.

## 10.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for the Town of Sidney, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of the Town of Sidney. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of SLR.

This report has been prepared for specific application to this site and site conditions existing at the time work for the report was completed. Any conclusions or recommendations made in this report reflect SLR’s professional opinion based on limited investigations including: visual observation of the site, surface and subsurface investigation at discrete locations and depths, and laboratory analysis of specific chemical parameters. The results cannot be extended to previous or future site conditions, portions of the site that were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters and materials that were not addressed. Substances other than those addressed by the investigation may exist within the site; and substances addressed by the investigation may exist in areas of the site not investigated in concentrations that differ from those reported. SLR does not warranty information from third party sources used in the development of investigations and subsequent reporting.

Nothing in this report is intended to constitute or provide a legal opinion. SLR expresses no warranty to the accuracy of laboratory methodologies and analytical results. SLR makes no representation as to the requirements of compliance with environmental laws, rules, regulations or policies established by federal, provincial or local government bodies. Revisions to the regulatory standards referred to in this report may be expected over time. As a result, modifications to the findings, conclusions and recommendations in this report may be necessary.

## 11.0 REFERENCES

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# TABLES

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

## TABLE 1: SEDIMENT SAMPLE LOG AND RECORD OF ANALYSIS

| Sample Location ID | Sample ID | Sample Depth (cm) | Metals Analysis | PAH Analysis | TOC Analysis | Grain Size Analsis |
|---|---|---|---|---|---|---|
| 1G | 1G | 0-10 | 1 | 0 | 0 | 0 |
| 2C | -C | 0-8 | 0 | 0 | 0 | 0 |
|  | -B | 8-25 | 1 | 0 | 0 | 0 |
|  | -A | 25-35 | 0 | 0 | 0 | 0 |
| 3C | -C | 0-8 | 1 | 0 | 0 | 0 |
|  | -B | 8-25 | 0 | 0 | 0 | 0 |
|  | -A | 25-35 | 0 | 0 | 0 | 0 |
| 4C | -D | 0-10 | 0 | 0 | 0 | 0 |
|  | -C | 10-20 | 1 | 1 | 0 | 0 |
|  | -B | 20-30 | 0 | 0 | 0 | 0 |
|  | -A | 30-40 | 1 | 1 | 0 | 0 |
| 5G | 5G | 0-10 | 0 | 0 | 0 | 0 |
| 5C | -C | 0-10 | 1 | 0 | 0 | 0 |
|  | -B | 10-20 | 0 | 0 | 0 | 0 |
|  | -A | 20-32 | 0 | 0 | 0 | 0 |
| 6C | -C | 0-10 | 1 | 0 | 0 | 0 |
|  | -B | 10-20 | 1 | 1 | 1 | 1 |
|  | -A | 20-30 | 0 | 0 | 0 | 0 |
| 7C | -C | 0-10 | 1 | 0 | 0 | 0 |
|  | -B | 10-20 | 0 | 0 | 0 | 0 |
|  | -A | 20-30 | 1 | 0 | 0 | 0 |
| 8G | 8G | 0-10 | 0 | 0 | 0 | 0 |
| 8C | -C | 0-9 | 1 | 0 | 0 | 0 |
|  | -B | 9-16 | 0 | 0 | 0 | 0 |
|  | -A | 16-25 | 0 | 0 | 0 | 0 |
| Totals |  |  | 11 | 3 | 1 | 1 |

Notes:
G - Grab Sample (Petite Ponar)
C - Core Sample (Wildco Corer)
Sample Depth - From Top of Sediment

## TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [1 of 3]

| **Sample ID** | **1G** | **2C-B** | **3C-C** | **4C-A** | **National - CCME Sediment** | | **Provincial - CSR Sediment** | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **CCME ISQG FW** | **CCME PEL FW** | **CSR SDft** | **CSR SDfs** |
| Depth (cm) | 0-10 | 8-25 | 0-8 | 30-40 | ns | ns | ns | ns |
| pH | 6.44 | 6.53 | 7.07 | 7.16 | ns | ns | ns | ns |
| Aluminum | --- | --- | --- | --- | ns | ns | ns | ns |
| Antimony | 1.19 | 0.29 | 0.47 | 0.40 | ns | ns | ns | ns |
| Arsenic | 5.18 | 4.85 | 7.32 | 11.2 | 5.9 | 17 | 20 | 11 |
| Barium | 105 | 105 | 59.7 | 79.4 | ns | ns | ns | ns |
| Beryllium | 0.45 | 0.33 | 0.29 | 0.33 | ns | ns | ns | ns |
| Bismuth | --- | --- | --- | --- | ns | ns | ns | ns |
| Boron | --- | --- | --- | --- | ns | ns | ns | ns |
| Cadmium | ***22.1*** | ***19.8*** | ***26.0*** | 0.448 | 0.6 | 3.5 | 4.2 | 2.2 |
| Chromium (+3) | --- | --- | --- | --- | ns | ns | ns | ns |
| Chromium (+6) | --- | --- | --- | --- | ns | ns | ns | ns |
| Chromium (total) | ***146*** | ***90.6*** | ***144*** | 31.2 | 37.3 | 90 | 110 | 56 |
| Cobalt | 14.1 | 12.0 | 9.43 | 11.4 | ns | ns | ns | ns |
| Copper | 75.9 | 31.3 | 22.5 | 30.5 | 35.7 | 197 | 240 | 120 |
| Iron | --- | --- | --- | --- | ns | ns | ns | ns |
| Lead | 53.9 | 16.5 | 13.9 | 16.1 | 35 | 91.3 | 110 | 57 |
| Lithium | --- | --- | --- | --- | ns | ns | ns | ns |
| Magnesium | --- | --- | --- | --- | ns | ns | ns | ns |
| Manganese | --- | --- | --- | --- | ns | ns | ns | ns |
| Mercury | 0.100 | < 0.05 | < 0.05 | < 0.05 | 0.17 | 0.486 | 0.58 | 0.3 |
| Molybdenum | 1.78 | 1.16 | 0.40 | 0.57 | ns | ns | ns | ns |
| Nickel | 33.3 | 19.9 | 18.5 | 23.4 | ns | ns | ns | ns |
| Selenium | 0.67 | 0.55 | < 0.2 | 0.27 | ns | ns | ns | ns |
| Silver | 0.25 | < 0.1 | 0.11 | 0.13 | ns | ns | ns | ns |
| Strontium | --- | --- | --- | --- | ns | ns | ns | ns |
| Thallium | 0.085 | 0.064 | 0.097 | 0.053 | ns | ns | ns | ns |
| Tin | 2.2 | < 2 | < 2 | < 2 | ns | ns | ns | ns |
| Titanium | --- | --- | --- | --- | ns | ns | ns | ns |
| Uranium | 1.09 | 0.822 | 0.534 | 0.648 | ns | ns | ns | ns |
| Vanadium | 76.4 | 56.0 | 50.1 | 65.9 | ns | ns | ns | ns |
| Zinc | 519 | 181 | 90.7 | 97.5 | 123 | 315 | 380 | 200 |

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
**Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)**
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

## TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [2 of 3]

| Sample ID | 4C-C | 5C-C | 6C-B | 6C-C | National - CCME Sediment | | Provincial - CSR Sediment | |
|---|---|---|---|---|---|---|---|---|
| **Date** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **CCME ISQG FW** | **CCME PEL FW** | **CSR SDft** | **CSR SDfs** |
| Depth (cm) | 10--20 | 0-10 | 10-20 | 0-10 | ns | ns | ns | ns |
| pH | 6.76 | 6.47 | 6.63 | 6.49 | ns | ns | ns | ns |
| Aluminum | --- | --- | --- | --- | ns | ns | ns | ns |
| Antimony | 0.58 | 1.30 | 0.61 | 1.21 | ns | ns | ns | ns |
| Arsenic | 4.55 | 5.11 | 5.35 | 4.71 | 5.9 | 17 | 20 | 11 |
| Barium | 86.6 | 123 | 126 | 118 | ns | ns | ns | ns |
| Beryllium | 0.33 | 0.49 | 0.50 | 0.56 | ns | ns | ns | ns |
| Bismuth | --- | --- | --- | --- | ns | ns | ns | ns |
| Boron | --- | --- | --- | --- | ns | ns | ns | ns |
| Cadmium | ***17.3*** | ***24.7*** | ***42.1*** | ***21.4*** | 0.6 | 3.5 | 4.2 | 2.2 |
| Chromium (+3) | --- | --- | --- | --- | ns | ns | ns | ns |
| Chromium (+6) | --- | --- | --- | --- | ns | ns | ns | ns |
| Chromium (total) | ***130*** | ***134*** | ***153*** | ***119*** | 37.3 | 90 | 110 | 56 |
| Cobalt | 11.1 | 15.6 | 13.4 | 14.8 | ns | ns | ns | ns |
| Copper | *37.3* | *99.8* | *64.1* | *93.9* | 35.7 | 197 | 240 | 120 |
| Iron | --- | --- | --- | --- | ns | ns | ns | ns |
| Lead | 25.3 | 63.4 | 58.6 | 60.7 | 35 | 91.3 | 110 | 57 |
| Lithium | --- | --- | --- | --- | ns | ns | ns | ns |
| Magnesium | --- | --- | --- | --- | ns | ns | ns | ns |
| Manganese | --- | --- | --- | --- | ns | ns | ns | ns |
| Mercury | 0.056 | 0.128 | 0.098 | 0.129 | 0.17 | 0.486 | 0.58 | 0.3 |
| Molybdenum | 0.91 | 2.05 | 1.49 | 1.98 | ns | ns | ns | ns |
| Nickel | 22.7 | 38.5 | 34.1 | 38.2 | ns | ns | ns | ns |
| Selenium | 0.43 | 0.82 | 0.51 | 0.79 | ns | ns | ns | ns |
| Silver | 0.10 | 0.34 | 0.25 | 0.32 | ns | ns | ns | ns |
| Strontium | --- | --- | --- | --- | ns | ns | ns | ns |
| Thallium | 0.065 | 0.102 | 0.089 | 0.106 | ns | ns | ns | ns |
| Tin | < 2 | < 2 | 2.2 | < 2 | ns | ns | ns | ns |
| Titanium | --- | --- | --- | --- | ns | ns | ns | ns |
| Uranium | 0.810 | 1.17 | 1.02 | 1.12 | ns | ns | ns | ns |
| Vanadium | 55.2 | 77.7 | 81.8 | 78.5 | ns | ns | ns | ns |
| Zinc | *218* | ***700*** | ***347*** | ***639*** | 123 | 315 | 380 | 200 |

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
**Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)**
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

## TABLE 2: SEDIMENT CHEMISTRY RESULTS - METALS PARAMETERS (mg/kg) [3 of 3]

| **Sample ID** | **7C-A** | **7C-C** | **8C-C** | **National - CCME Sediment** | | **Provincial - CSR Sediment** | |
|---|---|---|---|---|---|---|---|
| **Date** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **CCME ISQG FW** | **CCME PEL FW** | **CSR SDft** | **CSR SDfs** |
| Depth (cm) | 20-30 | 0-10 | 0-9 | ns | ns | ns | ns |
| pH | 7.21 | 6.17 | 6.41 | ns | ns | ns | ns |
| Aluminum | --- | --- | --- | ns | ns | ns | ns |
| Antimony | 0.39 | 0.76 | 1.25 | ns | ns | ns | ns |
| Arsenic | 6.17 | 4.51 | 5.53 | 5.9 | 17 | 20 | 11 |
| Barium | 105 | 119 | 133 | ns | ns | ns | ns |
| Beryllium | 0.38 | 0.52 | 0.51 | ns | ns | ns | ns |
| Bismuth | --- | --- | --- | ns | ns | ns | ns |
| Boron | --- | --- | --- | ns | ns | ns | ns |
| Cadmium | ***14.1*** | ***35.3*** | ***19.7*** | 0.6 | 3.5 | 4.2 | 2.2 |
| Chromium (+3) | --- | --- | --- | ns | ns | ns | ns |
| Chromium (+6) | --- | --- | --- | ns | ns | ns | ns |
| Chromium (total) | ***141*** | ***153*** | ***111*** | 37.3 | 90 | 110 | 56 |
| Cobalt | 10.6 | 14.0 | 15.2 | ns | ns | ns | ns |
| Copper | 34.7 | 74.6 | 88.4 | 35.7 | 197 | 240 | 120 |
| Iron | --- | --- | --- | ns | ns | ns | ns |
| Lead | 19.7 | 64.6 | 68.2 | 35 | 91.3 | 110 | 57 |
| Lithium | --- | --- | --- | ns | ns | ns | ns |
| Magnesium | --- | --- | --- | ns | ns | ns | ns |
| Manganese | --- | --- | --- | ns | ns | ns | ns |
| Mercury | 0.055 | 0.112 | 0.124 | 0.17 | 0.486 | 0.58 | 0.3 |
| Molybdenum | 0.70 | 1.30 | 1.94 | ns | ns | ns | ns |
| Nickel | 23.9 | 36.0 | 37.3 | ns | ns | ns | ns |
| Selenium | 0.40 | 0.61 | 0.69 | ns | ns | ns | ns |
| Silver | < 0.1 | 0.33 | 0.35 | ns | ns | ns | ns |
| Strontium | --- | --- | --- | ns | ns | ns | ns |
| Thallium | 0.071 | 0.103 | 0.097 | ns | ns | ns | ns |
| Tin | < 2 | 3.0 | *7.3* | ns | ns | ns | ns |
| Titanium | --- | --- | --- | ns | ns | ns | ns |
| Uranium | 0.972 | 0.961 | 1.34 | ns | ns | ns | ns |
| Vanadium | 62.2 | 76.3 | 80.3 | ns | ns | ns | ns |
| Zinc | 146 | ***480*** | ***603*** | 123 | 315 | 380 | 200 |

Notes:
m - metres
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
**Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)**
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

## TABLE 3: SEDIMENT CHEMISTRY RESULTS - PAH PARAMETERS (mg/kg)

| **Sample ID** | **4C-A** | **4C-C** | **6C-B** | **National - CCME Sediment** | | **Provincial - CSR Sediment** | |
|---|---|---|---|---|---|---|---|
| **Date** | **15-Jan-2015** | **15-Jan-2015** | **15-Jan-2015** | **CCME ISQG FW** | **CCME PEL FW** | **CSR SDft** | **CSR SDfs** |
| Depth (cm) | 30-40 | 10-20 | 10-20 | ns | ns | ns | ns |
| Acenaphthene | < 0.05 | < 0.05 | < 0.05 | 0.00671 | 0.0889 | 0.11 | 0.055 |
| Acenaphthylene | < 0.05 | < 0.05 | < 0.05 | 0.00587 | 0.128 | 0.15 | 0.08 |
| Acridine | --- | --- | --- | ns | ns | ns | ns |
| Anthracene | < 0.05 | < 0.05 | < 0.05 | 0.0469 | 0.245 | 0.29 | 0.15 |
| Benz(a)anthracene | 0.051 | < 0.05 | 0.252 | 0.0317 | 0.385 | 0.46 | 0.24 |
| Benzo(a)pyrene | 0.064 | 0.051 | *0.440* | 0.0319 | 0.782 | 0.94 | 0.48 |
| Benzo(b)fluoranthene | 0.117 | *0.106* | *0.832* | ns | ns | ns | ns |
| Benzo(g,h,i)perylene | 0.051 | < 0.05 | 0.355 | ns | ns | ns | ns |
| Benzo(k)fluoranthene | < 0.05 | < 0.05 | *0.264* | ns | ns | ns | ns |
| Chrysene | 0.087 | 0.075 | 0.507 | 0.0571 | 0.862 | 1 | 0.53 |
| Dibenz(a,h)anthracene | < 0.05 | < 0.05 | 0.056 | 0.00622 | 0.135 | 0.16 | 0.084 |
| Fluoranthene | 0.106 | 0.133 | 0.806 | 0.111 | 2.355 | 2.8 | 1.5 |
| Fluorene | < 0.05 | < 0.05 | < 0.05 | 0.0212 | 0.144 | 0.17 | 0.089 |
| Indeno(1,2,3-c,d)pyrene | 0.053 | 0.052 | *0.398* | ns | ns | ns | ns |
| 1-Methylnaphthalene | --- | --- | --- | ns | ns | ns | ns |
| 2-Methylnaphthalene | < 0.05 | < 0.05 | < 0.05 | 0.0202 | 0.201 | 0.24 | 0.12 |
| Naphthalene | < 0.05 | < 0.05 | < 0.05 | 0.0346 | 0.391 | 0.47 | 0.24 |
| Phenanthrene | 0.067 | 0.099 | 0.352 | 0.0419 | 0.515 | 0.62 | 0.32 |
| Pyrene | 0.101 | 0.116 | 0.728 | 0.053 | 0.875 | 1.1 | 0.54 |
| Quinoline | --- | --- | --- | ns | ns | ns | ns |
| Benzo(a)pyrene Equivalency | --- | --- | --- | ns | ns | ns | ns |
| PAHs, Total | --- | --- | --- | ns | ns | 20 | 10 |

Notes:
m - metres
PAH - polycyclic aromatic hydrocarbons
mg/kg - milligrams per dry kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard/guideline listed
Exceeds CCME ISQG FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Interim Sediment Quality Guidelines (ISQG)
**Exceeds CCME PEL FW: CCME Canadian Environmental Quality Guidelines, Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Freshwater Probable Effect Levels (PEL)**
Exceeds CSR SDft: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Typical
Exceeds CSR SDfs: BC Contaminated Sites Regulation, Schedule 9, Generic Numerical Sediment Criteria, Freshwater Sensitive

## TABLE 4: SEDIMENT CHEMISTRY RESULTS - OTHER PARAMETERS (mg/kg)

| Sample ID | 6C-B | National - CCME Sediment | | Provincial - CSR Sediment | |
|---|---|---|---|---|---|
| **Date** | **15-Jan-2015** | **CCME ISQG FW** | **CCME PEL FW** | **CSR SDft** | **CSR SDfs** |
| Depth (cm) | | | | | |
| Calculated Chloride | --- | ns | ns | ns | ns |
| Calculated Sodium | --- | ns | ns | ns | ns |
| Organic Carbon, Total | 5.33 | ns | ns | ns | ns |

Notes:
mg/kg - milligrams per kilogram
< - less than analytical detection limit indicated
'---' - sample not analyzed for parameter indicated
ns - no standard listed

# DRAWINGS

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

NOTES:
REFERENCED FROM: CAPITAL REGIONAL DISTRICT, REGIONAL COMMUNITY ATLAS

LEGAL DESCRIPTION:
SECTION 8, RANGE 3 EAST, NORTH SAANICH DISTRICT
PID: 000-213-365

LEGEND:

| | |
|---|---|
| — - — | PROPERTY BOUNDARY |
| ● C | CORE SAMPLE LOCATION |
| ◆ G | GRAB SAMPLE LOCATION |
| - - - | APPROXIMATE LOCATION OF 2010 CAMOSUM COLLEGE STUDY TRANSECT (*REAY CREEK POND REMEDIATION STUDY*. ENVIRONMENTAL TECHNOLOGY PROGRAM. JUSTIN ROBINSON & RACHELLE SARRAZIN. JUNE 2010) |

0 5 10 20 30 40 m

SCALE 1:750
WHEN PLOTTED CORRECTLY ON A 11 x 17 PAGE LAYOUT
NAD 1983 UTM Zone 10N

THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.

# TOWN OF SIDNEY
# REAY CREEK POND, REAY CREEK PARK - CANORA ROAD BETWEEN NORTHBROOK DRIVE AND BOWCOTT PLACE SIDNEY, BC

SAMPLING AND ANALYSIS OF REAY CREEK POND SEDIMENTS

SEDIMENT SAMPLING LOCATIONS

| | | |
|---|---|---|
| Date: May 5, 2015 | | Drawing No. |
| Project No. 205.03696.00000 | | 1 |

SLR
global environmental solutions

Cadfile name: S_205-03696-00000-A1.dwg

# PHOTOGRAPHS

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

**Photo 1:** Reay Cr. Pond viewed to the southeast towards the area of the dam, from approximate mid-pond area, Oct. 22, 2014

**Photo 2:** Pond area viewed north from approximately mid-pond area, Oct. 2014

**Photo 3:** Pond area east of Canora Rd. end of Pond, Oct. 2014

**Photo 4:** Pond discharge over dam spillway (left & top of right photo) and valve controlled discharge pipe at dam

**Photo 5:** Open water area of Pond viewed north from about mid-pond area on January 15, 2015

**Photo 6:** Pond area narrowed by vegetation, viewed northeast from approximate mid-pond

**Photo 7:** Petite Ponar (top) sampler used for surface sediment grab sampling

**Photo 8:** Sediment core samples in capped tubes ready for extruding and sampling

# APPENDIX A
# Previous Report Information – Camosun College

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

# Reay Creek Pond Remediation Study

*Produced for Camosun College*
*Environmental Technology Program*

*By Justin Robinson*
*& Rachelle Sarrazin*

*June 2010*

## Executive Summary

Reay Creek is one of the few urban streams in Victoria that supports an established run of Coho Salmon. However, problems upstream have put this run at risk. Reay Creek Pond is a potential contributor to these problems. The pond is situated on the Saanich Peninsula on the border of Sidney, North Saanich and the Victoria International Airport. This anthropogenically created pond, formed by an earthen dam first installed in the early half of the 20th century, has become an overactive sediment deposition zone. These sediments contain the cumulative effect of decades of agricultural use, historic and current run-off from Victoria International Airport and now runoff from residential areas. These factors have caused Reay Creek Pond to contain a build-up of organic sedimentation, agricultural nutrients and heavy metal contamination.

This study aims to determine water quality, with emphasis on eutrophication factors; sediment depth and pond topography; and recommendations for remediation for the Reay Creek Pond.

Reay Creek Pond was divided into 11 transects every 20 m, each transect then had water and total depth measurements taken at 2 m intervals. The difference between these two measurements was the sediment depth. The results were then mapped using ESRI ArcGIS.

Water quality was determined from three points in the pond: near the dam, at the approximate centre and near the inflow culvert. These samples were tested for nitrogen, nitrite-nitrogen, nitrate-nitrogen and phosphate. Additionally, at each sampling location conductivity, dissolved oxygen, temperature and pH were measured.

Sediment samples were collected at the same 3 locations as water quality tests and one additional location 20 m from the dam. The samples were then separated, homogenised and placed in a centrifuge to extract the sediment pore water. The resulting pore water was then tested for the same parameters as surface water. Samples were also collected for lab analysis at Maxxam Analytics. These samples were taken from the 20 m from dam point and the approximate middle of the pond.

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 m$^3$ of non-compacted sediment.

The temperature throughout Reay Creek Pond is very variable (ranging from 12.5 to 21.5 °C) an indicator of poor water quality. The pH was found to fluctuate between 7.22 and 8.46, causing potential stress on fish health. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were exceed testable limits of 2 ppm. Reay Creek Pond sediment displayed relatively normal conditions for freshwater systems. Total phosphorus levels in the sediment were high, potentially causing a eutrophic event if disturbed.

Maxxam laboratory analysis of heavy metals determined that both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Based on these results it is recommended that the sediment from Reay Creek Pond be removed. Remediation is also an option however less attractive considering the pond size, metal contamination, sediment loads and neighbourhood desire of a publicly usable pond.

Sediment removal can be accomplished either through draining and excavation of sediments or suction dredging.

Draining and excavation is a laboriously complex solution, requiring a bypass pipe to be installed to drain the pond before excavation can begin. The process will also require large machinery to gain access to the pond, possibly resulting in destruction of shoreline vegetation.

Suction dredging may be a better solution, utilising a smaller suction raft to remove sediment without requiring heavy machinery or draining the pond. The primary concern with suction dredging will be acquiring the machinery.

Mitigation and remediation of sediments to reduce metal contamination and possible eutrophic events is conceivable, however undesirable as the sediments would continue to build up in the pond.

# Acknowledgements

Special thanks to those who were able to provide assistance for this project: Ian Bruce was an immense help, providing contacts, materials, ideas and a pillar of support; Reg Kirkham for use of his property and local knowledge of Reay Creek Pond; Cindy Wright for her insight and knowledge with sediments and sediment coring; Audrey Dallimore for providing tools for sediment coring; Tony Dorling for providing equipment on short notice; Neil Meanwell for chemistry insight; Steve Gormican for his experience with aquatic environments; Leslie Glover for her assistance with lab work and passionate drive; Dave Thomas for biology technical support; David Wade and Robin Robinson for guest field day appearances and alternative points of view.

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# Methodology

## Sediment and Water Depth Measurements

Reay Creek Pond was divided into 11 transects every 20 meters. The first transect started 5 m away from the dam, as poor sediment levels were found close to the dam. The location of the second transect was determined by measuring 20 m away from the first transect on both shores. Transects 3 and 4 were measured 10 meters away from the last transect on one shore and 20 m away on the opposing shore in order to compensate for a sharp turn. After Transect 4, each transect was measured by connecting a 50 m measuring tape to the center of the previous transect and measuring 20 m while following the contours of the pond. The location of the next transect was visually defined by features on both shores and the addition of red flagging tape. Transect locations can be seen in Figure 2.

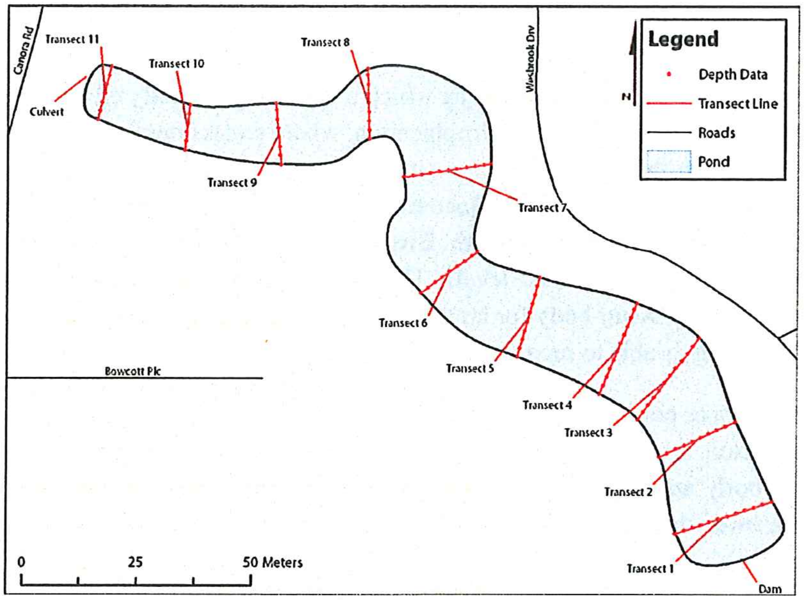

Figure 2 – Map showing transect locations and data collection points for Reay Creek Pond study, June 2010

For each transect, rebar was hammered into opposing shores and rope with flagged 2 m intervals was stretched tightly between both rebar locations. In order to maintain accuracy, the distance between each 2 m marked intervals was measured and corrected for each transect. For correct referencing, the same shore was used for the zero meter mark of each transect. The distance, bearing, and GPS location of each transects start and end points were collected in order to be referenced in Arc Map GIS software.

Sediment and water depth measurements were taken from a boat using several thin bamboo rods at different lengths. The bamboo rods were inserted in the water body until there was a slight resistance, at which time the measurer would mark the water level in regards to the bamboo rod with his or her index and thumb. A 50 m measure tape was pulled tight across the bottom of the bamboo stick to the measurer's index finger where the water to sediment depth is recorded in cm to one decimal place of precision. In order to compensate for increased bending in the bamboo sticks, the measuring tape was stretched tightly across the stick without following its contour. Water to sediment depth measurements were collected simultaneously by both measurers at a selected sample location. The discrepancy between the two measurements were noted and adjusted to maintain accuracy.

The bamboo stick was then inserted into the water at a new location close to the original sampling site location to collect total depth measurements. Strong force was used on the bamboo stick in order to be certain that a hard substrate was reached and was applied multiple times to ensure correct measurement. The measurer then marked the water level on the bamboo stick using his or her index finger and thumb and then gently pulled up the stick while maintaining their grasp location on the stick. The stick was cleaned and then measured using the same 50 m measuring tape. Measurements were recorded in centimetres to one decimal place of precision. Sediment depth was calculated by subtracting the total depth of the sample site by the water to sediment depth.

### Water Quality Sampling

Water samples were collected at the beginning, middle, and end of the pond using 1 litre plastic bottles. Bottles were cleaned three times with pond water and inserted into the pond for several minutes to allow for water flow. Water samples were collected at a depth of one foot in order to prevent contamination of surface water. Bottles were shaken and capped in the water to prevent any bubbles from being collected. Two water samples were collected at the end of pond in order to match the location of sediment samples collected at 20 meters and 5 meters away from the dam.

Water samples were refrigerated between 4 and 6°C for 24 hours following collection. LaMotte's Water Quality Testing Products were used in conjunction with a LaMotte SMART 2 Colorimeter to test for Ammonia Nitrogen (Low Range), Nitrite Nitrogen (Low Range), Nitrate Nitrogen (Low Range), and Phosphate (Low Range). The colorimeter was pre-calibrated by LaMotte for proper use all of their water quality testing kits. Before testing, all tubes, flasks, and graduated cylinders were rinsed with tap water. Testing methods followed LaMotte's Procedure sheets provided with each kit. In order to assess errors associated with sample heterogeneity and sample testing techniques, two replicates were created for each test using the same water sample. Colorimeter results were collected until values were stable. In some cases an average of many colorimeter results was recorded due to fluctuations caused by tube orientation in the colorimeter.

Water parameters were also collected using a Model 85 YSI meter. These parameters included conductivity and dissolved oxygen. A pHTestr 30 was used to collect pH information. Temperature was also recorded using a glass thermometer. These parameters were collected at the same sites as above: beginning, middle, and end.

### Sediment Sample Collection and Pore Water Analysis

Sediment samples were collected at four different sampling locations along Reay Creek using an metal Ekman Grab. Sediment sampling sites were located at the beginning, middle and end of the pond as close to water sampling sites as possible. At the end of the pond, sediment samples were collected at two locations 20 and 5 meters away from the dam. Sediment samples were collected following the RISC protocol for sampling lake sediment on a boat[12]. Once collected, samples were released from the Ekman Grabber into a large plastic container and scooped into a labelled Tupperware container using the container itself. Large organic content was manually removed as the sample was scooped into the Tupperware container. Each sample container was quickly moved to shore and placed into the pond in order to maintain a constant temperature. To prevent contamination of surface water, the lids of the containers were closed tightly and never allowed to be submerged. Sediment samples were refrigerated between 4 and 6°C for 42 hours, following the RISC Preservation and Hold Times for Sediments and Tissues Guidelines[12]. The temperature of the refrigerator was checked twice and adjusted to maintain a constant temperature.

Sediment samples were brought to Camosun College's Microbiology Lab in order to undergo pore water extraction through the use of their centrifuge. A non-analytical balance scale was balanced and tared with an empty 10 ml glass test tube and a test tube holder in order to hold the tubes upright when being weighed. For each sediment sample the sediment was transferred into thirty-two 10 ml glass test tubes using small metal scoopers and 20ml plastic pipettes. Each test tube was weighed to a weight of 10.50 g

# Results

## Sediment Depth Transects & Mapping

From the depths recorded in the field the depth of sediment was determined. The results of this can be found in Table 1 of Appendix A. Transect Locations can be seen in Figure 5. Figure A-1 to Figure A-11 shows the cross-sectional depths of the water and sediment based on this data.

Two maps were produced using the collected depth data (Table 1 of Appendix A). Figure 3 shows the depth of water and Figure 4 shows the depth of sediment in Reay Creek Pond. A third map (Figure 5) was produced to show the thickness of sediment.

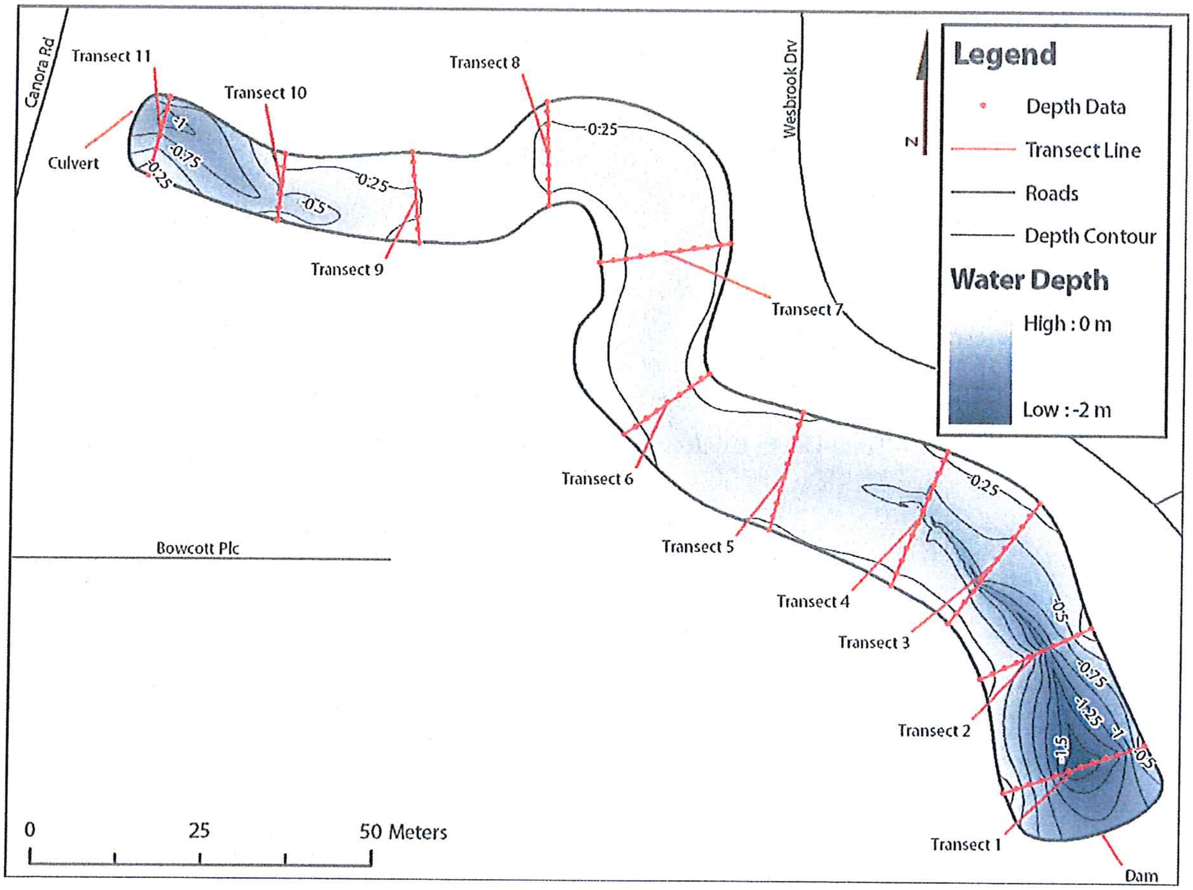

Figure 3 – Water Depth Contour Map of Reay Creek Pond, June 2010

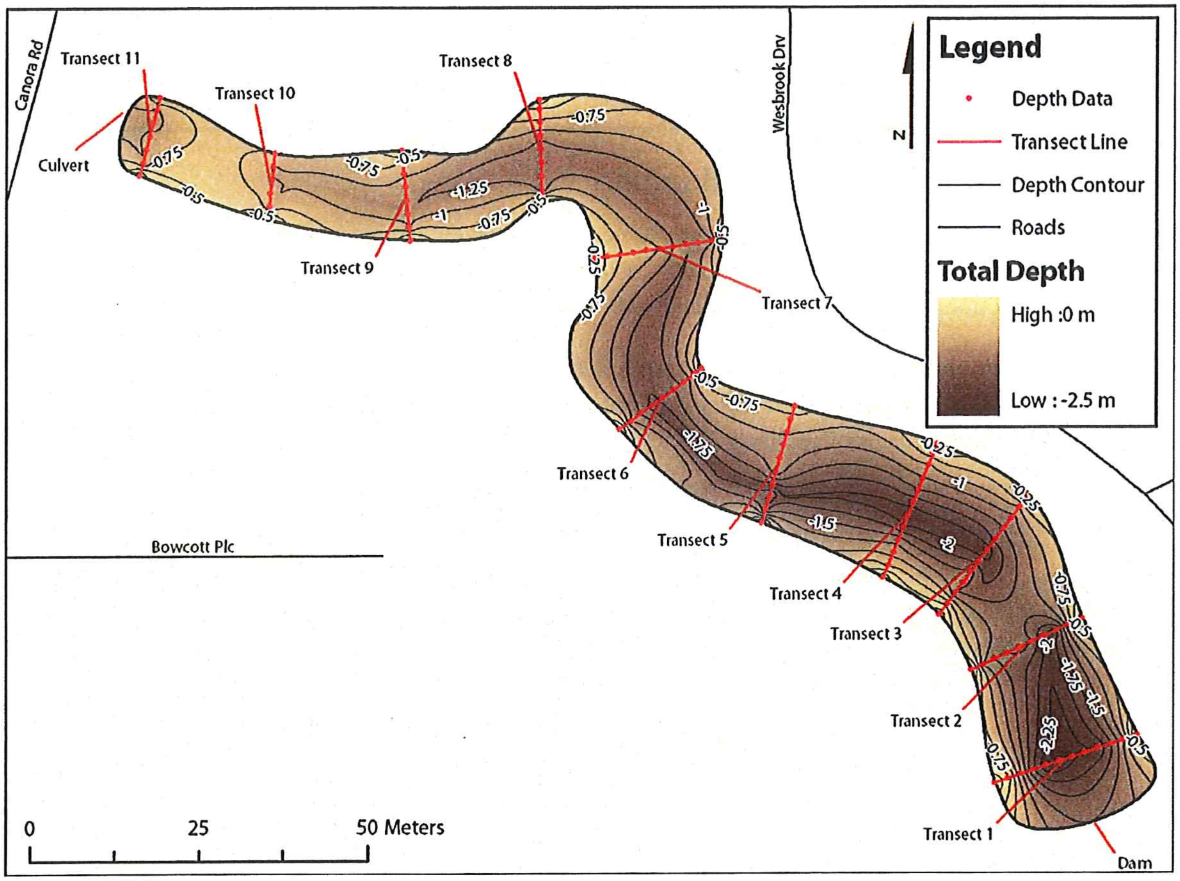

Figure 4 – Total Depth Contour Map of Reay Creek Pond, June 2010

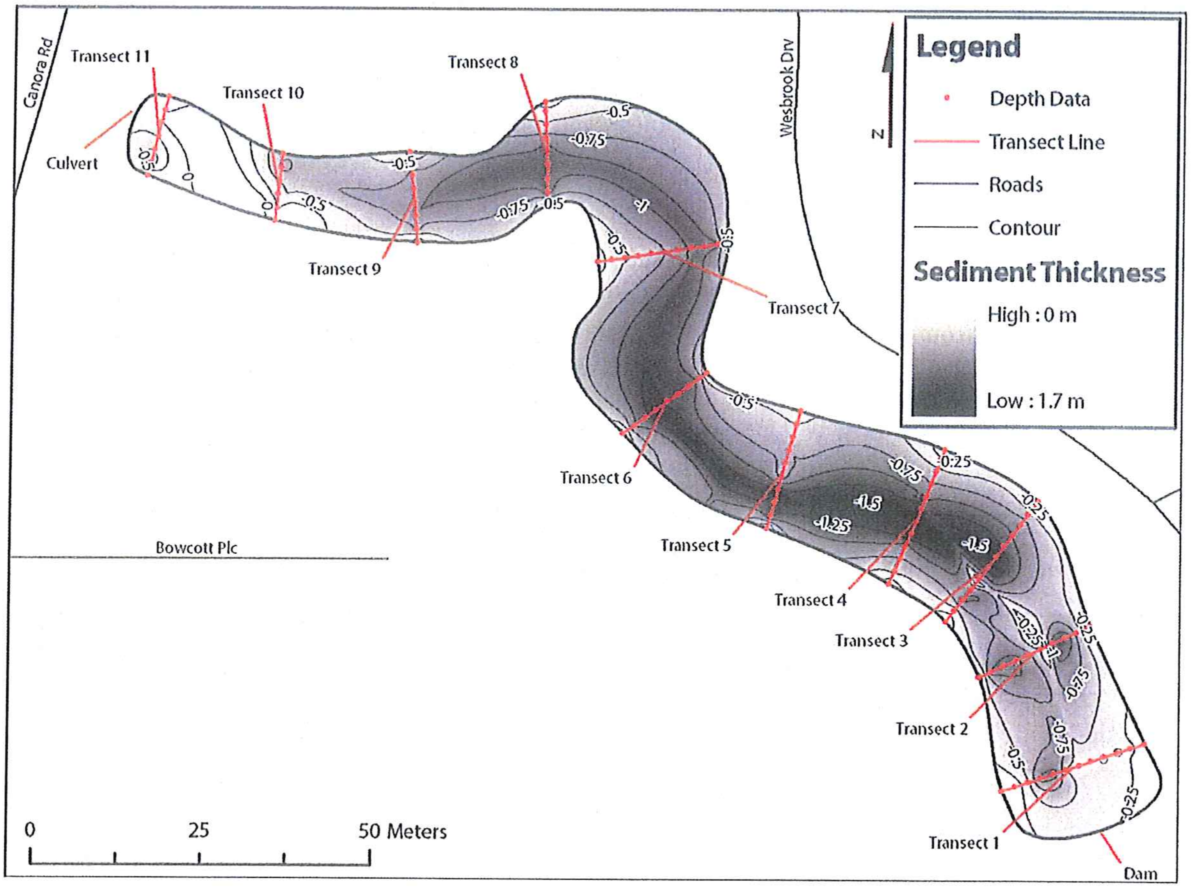

Figure 5 – Thickness of Sediment and Contours Map of Reay Creek Pond, June 2010

Three dimensional analysis was conducted on the sediment and water depth layers, this resulted in a 3 dimensional TIN (triangulated irregular network). Due to the constraints of displaying 3D media in reports the ArcScene files can be found on the accompanying CD-ROM in Appendix B. From the 3D model it was determined that the volume of sediment in the pond is approximately 2569 $m^3$.

## Flora & Fauna

A cursory identification of the dominant aquatic vegetation occurred during depth analysis. It was found the two dominant aquatic plants were *Elodea canadensis* and *Potamogeton robbinsii.*

The only aquatic vertebrate found during the period of study was the three-spined stickleback *(Gasterosteus aculeatus).* Four were captured for identification, one was found floating on the surface already deceased (the largest of the four, approximately 3.5 inches long, with puncture marks near pectoral fin).

## Testing Results

The following sections describe the results obtained from water quality testing "in-house" using individual quality sets as described in the methodology and the results obtained from Maxxam Analytical Laboratories.

### In-House Experiments

In the following tables (Table 1 – Table 3) the results of the individual test packages for water quality is presented. Table 1 shows the water quality of surface water where over the entire pond ammonia concentration ranged from 0.03 to 1.02 ppm, nitrite-nitrogen ranged from 0.0025 to 1.775 ppm, nitrate-nitrogen ranged from 0.002 to 1.69 ppm and phosphate ranged from 0.03 to 0.23 ppm.

Table 1 – Water Quality results of Water Samples from Reay Creek Pond collected June 5 2010, analysed June 6 2010

| Location | Rep | Ammonia-Nitrogen (ppm) | Nitrite-Nitrogen (ppm) | Nitrate-Nitrogen (ppm) | Phosphate (ppm) |
|---|---|---|---|---|---|
| **Culvert** | 1 | 0.165 | 1.775 | 0.0045 | 0.09 |
| | 2 | N/A* | 0.0025 | 1.69 | 0.03 |
| **Middle** | 1 | 1.02 | 0.007 | 0.76 | 0.09 |
| | 2 | 0.915** | 0.009 | 0.76 | 0.09 |
| **20m From Dam** | 1 | 0.03 | 0.052 | 0.315 | 0.07 |
| | 2 | 0.31 | 0.005 | 0.4 | 0.15 |
| | 3 | MAX | 0.005 | 0.33 | 0.155 |
| **3m From Dam** | 1 | 0.25 | 0.31 | 0.005 | 0.23 |
| | 2 | 0.41 | 0.43 | 0.002 | 0.115 |

*Reagents exhausted

**New reagents used

Table 2 shows the results of testing water quality from pore water extracted from sediments. In the pore water ammonia concentration was higher than measureable values except for in one case where the concentration was 0.98 ppm; both nitrite-nitrogen and nitrate-nitrogen measured 0 ppm in all tests; phosphate ranged from 1.3 to 2.13 ppm.

Table 2 – Water Quality results of Pore Water Samples from Reay Creek Pond Sediment collected June 5 2010, analysed June 7 2010

| **Location** | **Rep** | **Ammonia-Nitrogen (ppm)** | **Nitrite-Nitrogen (ppm)** | **Nitrate-Nitrogen (ppm)** | **Phosphate (ppm)** |
|---|---|---|---|---|---|
| **Culvert** | 1 | 0.98 | 0 | 0 | 1.3 |
| | 2 | >2 | 0 | 0 | 1.31 |
| **Middle** | 1 | >2 | 0 | 0 | 2.13 |
| | 2 | >2 | 0 | 0 | 2.06 |
| **20m From Dam** | 1 | >2 | 0 | 0 | 1.91 |
| | 2 | >2 | 0 | 0 | 1.9 |
| **3m From Dam** | 1 | >2 | 0 | 0 | 1.42 |
| | 2 | >2 | 0 | 0 | 1.48 |

Table 3 shows water parameters (dissolved oxygen, conductivity, pH and temperature) taken while in the field. Dissolved oxygen ranged from 6.84 to 16.5 mg/L; conductivity ranged from 266.5 to 302 µS; pH ranged from 7.22 to 8.46 and temperature ranged from 12.5 to 21.5 °C. Surface water alkalinity was later determined to be 160 ppm.

Table 3 – Water Parameters Collected in-field from Reay Creek Pond on June 5 2010

| **Location** | **DO (mg/L)** | **Conductivity (µS)** | **pH** | **Temp (°C)** | **Time** |
|---|---|---|---|---|---|
| **Culvert** | 7.65 | 270.8 | 7.22 | 12.5 | 12:05 |
| **Middle** | 17.5 | 302 | 8.46 | 21.5 | 16:32 |
| **3 m From Dam** | 6.84 | 266.5 | 7.22 | 16.5 | 16:10 |

## Biochemical Oxygen Demand

After three days, the biochemical oxygen demand (BOD) in five of the six BOD bottles was 0 mg/L. At day two the BOD spiked to about 30mg/L for the five BOD bottles, but dropped to zero shortly thereafter. BOD in the third bottle, at a sediment to water dilution ratio of 1:29, continuously increased to 50 mg/L by the third day. After five days the BOD in all bottles was at zero, with the BOD in the third bottle decreasing rapidly after day three. These results are tabulated in Table 4.

Table 4 – Results of Biochemical Oxygen Demand tests for Reay Creek Pond, Analysed June 2 2010

| Sample | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |
|---|---|---|---|---|---|
| BOD Sample 1 | 0 | 30 | 0 | 0 | 0 |
| BOD Sample 2 | 0 | 28 | 0 | 0 | 0 |
| BOD Sample 3 | 0 | 29 | 50 | 0 | 0 |
| BOD Sample 4 | 0 | 24 | 0 | 0 | 0 |
| BOD Sample 5 | 0 | 27 | 0 | 0 | 0 |

### Metal Analysis Results

The following tables show results requested from Maxxam Analytics. Table 5 shows heavy metal results from sediment sampled from the middle and near the dam (approximately 3 m in front of dam) of Reay Creek Pond. Of interest are the concentrations of chromium, with 115 ppm in middle sediment and 107 in dam sediment, and cadmium, with 21.5 ppm in middle sediment and 18 ppm in dam sediment. In addition to total metals, available orthophosphate and total organic carbon (TOC) were also requested. Maxxam reported 60.5 µg/g available orthophosphate and 62 g/kg of TOC.

Table 5 – Total Metal Results from Maxxam Lab for Middle and Near-Dam Sediments

| Metal | Middle Sediment (ppm) | Dam Sediment (ppm) |
|---|---|---|
| **Total Aluminum (Al)** | 20600 | 23700 |
| **Total Antimony (Sb)** | 1.2 | 1.4 |
| **Total Arsenic (As)** | 4.6 | 5.3 |
| **Total Barium (Ba)** | 114 | 138 |
| **Total Beryllium (Be)** | 0.5 | 0.5 |
| **Total Bismuth (Bi)** | 0.1 | 0.2 |
| **Total Cadmium (Cd)** | 21.5 | 18 |
| **Total Calcium (Ca)** | 7560 | 8070 |
| **Total Chromium (Cr)** | 115 | 107 |
| **Total Cobalt (Co)** | 15 | 15.5 |
| **Total Copper (Cu)** | 88.8 | 103 |
| **Total Iron (Fe)** | 29300 | 34400 |
| **Total Lead (Pb)** | 65.7 | 65 |
| **Total Magnesium (Mg)** | 7130 | 8180 |
| **Total Manganese (Mn)** | 474 | 783 |
| **Total Mercury (Hg)** | 0.09 | 0.12 |
| **Total Molybdenum (Mo)** | 1.6 | 2.2 |
| **Total Nickel (Ni)** | 34.5 | 38 |
| **Total Phosphorus (P)** | 882 | 1320 |
| **Total Potassium (K)** | 947 | 1180 |
| **Total Selenium (Se)** | <0.5 | <0.5 |
| **Total Silver (Ag)** | 0.16 | 0.18 |

| Metal | Middle Sediment (ppm) | Dam Sediment (ppm) |
|---|---|---|
| **Total Sodium (Na)** | 453 | 603 |
| **Total Strontium (Sr)** | 51.4 | 52.5 |
| **Total Thallium (Tl)** | 0.08 | 0.1 |
| **Total Tin (Sn)** | 1.4 | 1.5 |
| **Total Titanium (Ti)** | 788 | 685 |
| **Total Vanadium (V)** | 69 | 77 |
| **Total Zinc (Zn)** | 701 | 741 |
| **Total Zirconium (Zr)** | 3.3 | 2.9 |

phosphorous concentration between 882 ppm and 1320 ppm, the pond sediment is over 8000 times greater than the minimum total phosphorous concentration range observed in the surface waters hyper-eutrophic lakes[1] (see Table 5). Due to the fact that inorganic phosphate readily absorbs onto small particulate matter, only a fraction of total phosphorous would be available to mix with surface waters[26]. Although much of the organic phosphate is mineralized within the sediment column into useable inorganic phosphate, much of it would also become absorbed either onto surrounding sediment particles or onto suspended particulates in the water after being stirred[22]. Both the sedimentation and mineralization of organic and inorganic phosphorous would prevent all of the sediment phosphorous from entering the surface waters of Reay Creek Pond during disruption. Unfortunately, the amount of phosphorous tied to particulate matter depends strongly on the concentration of Fe(OOH) and $CaCO_3$, which is unknown in Reay Creek Pond[26]. Even though we do not know how much phosphorous is tied up in sediment, it can be inferred based on the high concentrations of total phosphorous found in our results that only a small fraction of the sediment column would need to be disturbed in order to cause a eutrophication event in the pond[26].

Phosphate levels in the sediment pore water varied little over the extent of the pond. A spike of 0.70 ppm from the culvert to the middle of Reay Creek Pond may have been caused by the increased biotic activity and presence in the area (shown by high levels of photosynthesis) (see Table 2). High biotic activity could result in high decomposition rates where large quantities of inorganic phosphate would be released[26]. The released inorganic phosphate would be transported downward into the sediment by absorbing onto suspended matter entering the pond as a result of erosion[26]. The large difference between phosphate and phosphorous concentrations could be explained by the fact that phosphate decreases as total phosphorous increases[1]. Additionally, the difference between total phosphorous and phosphate values reinforces the fact that phosphate is a poor indicator of phosphorous.

## Flora & Fauna

The two main species of aquatic vegetation in Reay Creek Pond, *Elodea canadensis* and *Potamogeton robbinsii,* form monoculture mats. This is expected as that is the primary life strategy of these two species[27]. However, this does not account for the observed lack of aquatic plant diversity throughout the pond.

There was a resounding lack of amphibious life in this pond, both adult and pre-adult stages. During the time of study amphibious reproduction should have been occurring. This could either be attributed to toxic metal contamination or the possibility that amphibious life has not colonised this anthropogenically created pond.

## Metal Analysis

Due to the proximity to Victoria International Airport one of the primary concerns for this study was the concentration of cadmium and other heavy metals in sediments. When comparing the results of metal analysis (Table 5) to the Canadian Environmental Quality Guidelines produced by the Canadian Council of Ministers of the Environment[1], it was found that both cadmium and chromium were above both Canadian interim sediment quality guidelines (ISQG) and probable effect levels (PEL) established for sediments (for cadmium the ISQG is 0.6 and PEL is 3.5, for chromium the ISQG is 37.3 and PEL is

90.0). Cadmium concentration in the middle sediments was seven times the recommended value (PEL) with 21.5 mg/kg (ppm).

These results indicate that adverse biological effects may occur due to higher than PEL concentrations, especially for benthic organisms. This would reduce mortality, diversity abundance and would result in behavioural changes in aquatic organisms[1]. This would partially explain the lack of aquatic diversity quantitatively observed in the field.

## Biochemical Oxygen Demand

The BOD examination used in this study was ineffective (see Table 4). The methodology used for examining sediments was adopted from a dilution method and did not take into consideration the manometric measuring device used. Incorrect dilutions caused the noticeable crash, even if a value had been reported after 5 days—due to incorrect dilutions—the result would have not been accurate. Measurements from a manometric BOD device are correlated to the volume within each container, and do not require dilution.

## Conclusion

Sedimentation levels in Reay Creek Pond are high, with an average water depth of 38.8 cm and a sediment depth of 129.4 cm. Over the entire pond there is an approximate total volume of 2569 $m^3$ of non-compacted sediment.

Water temperature was too high to sustain many of the various life stages of Cutthroat Trout and Coho Salmon. The temperature throughout Reay Creek Pond is very variable which is a poor indicator of water quality. The dissolved oxygen levels were high enough to sustain aquatic wildlife but were too low to accommodate spawning activities and healthy populations of mayfly. Conductivity was too low to cause toxic effects on aquatic life, specifically Coho Salmon. The pH was found to be under heavy influence of respiration of aquatic vegetation, due to the large growth area provided by shallow conditions. This causes large fluctuations of pH which can stress and damage to fish health, even though overall the pH remains an acceptable neutral value. Ammonia levels fall within the prescribed guidelines set out by the Canadian Council of Ministers of the Environment (CCME) for sustaining aquatic life. Nitrate exceed the same guidelines at two sampling sites but was able to meet Environment Canada's guidelines for freshwater aquatic life. Phosphate was determined to be a limiting nutrient and identified Reay Creek Pond's trophic level to be oligotrophic to meso-eutrophic.

Ammonia concentrations in sediment pore water were found to be very high, exceeding testable limits of 2 ppm. Low levels of nitrate and nitrite were found in the sediment pore water, reflecting normal sediment conditions in a freshwater system. Total phosphorus levels in the sediment were very high. Even though we were unable to measure the amount of phosphorus tied up in the sediment, if the sediments were to be mixed into the water column the resulting phosphorus concentration would not be able to sustain aquatic life. Additionally, if a small fraction of sediment was disrupted, an eutrophication event could occur.

Both cadmium and chromium were higher than probable effect levels (PEL) determined by the Canadian Environmental Quality Guidelines[1]. The tested sediments contained 21.5 ppm and 18 ppm of cadmium in the middle and dam sediment respectively, with a PEL guideline of 3.5 ppm. These sediments also contained 115 ppm (middle sediment) and 107 ppm (dam sediment) of chromium, with a PEL guideline of 90.0 ppm).

Overall the surface water quality of Reay Creek Pond is capable of supporting a low diversity of aquatic life. However, for life to thrive within this system, sediment remediation—in some form—must occur. The water quality of Reay Creek Pond directly affects the downstream ecosystem and the aquatic life residing within. Based on the results of this study, there is a possibility of an eutrophication event disrupting sensitive creek habitat.

# Appendix A– Depth Data

The following appendix contains depth results for field work and transect figures for visualisation.

Table A-1 – Collected depth measurements and sediment depth calculation for Reay Creek Pond, collected May 7 2010 to June 12 2010

| Transect | Distance (m) | Water to Sediment Depth (cm) | Total Depth (cm) | Sediment Depth (cm) | Comments |
|---|---|---|---|---|---|
| 1 | 2 | 31.9 | 35.2 | 3.3 | |
| 1 | 4 | 74.5 | 116.7 | 42.2 | |
| 1 | 6 | 86.8 | 199.1 | 112.3 | |
| 1 | 8 | 138.1 | 251.8 | 113.7 | |
| 1 | 10 | 199.7 | 244.6 | 44.9 | |
| 1 | 12 | 190.3 | 227.2 | 36.9 | |
| 1 | 14 | 184.7 | 223.2 | 38.5 | |
| 1 | 16 | 158.9 | 220.5 | 61.6 | |
| 1 | 18 | 159.8 | 177.8 | 18.0 | Gray clay |
| 1 | 20 | 92.7 | 129.7 | 37.0 | Hit rock substrate |
| 1 | 22 | 0.0 | 0.0 | 0.0 | Shoreline |
| 2 | 2 | 22.2 | 135.1 | 112.9 | |
| 2 | 4 | 39.3 | 151.9 | 112.6 | |
| 2 | 6 | 38.6 | 149.0 | 110.4 | Possible log |
| 2 | 8 | 51.1 | 139.6 | 88.5 | Possible log |
| 2 | 10 | 87.6 | 148.2 | 60.6 | |
| 2 | 12 | 79.5 | 199.5 | 120.0 | |
| 2 | 14 | 79.8 | 211.2 | 131.4 | |
| 2 | 16 | 28.0 | 92.9 | 64.9 | |
| 3 | 2 | 25.9 | 55.6 | 29.7 | A lot of coarse organic debris |
| 3 | 4 | 41.9 | 149.8 | 107.9 | |
| 3 | 6 | 52.8 | 139.4 | 86.6 | |
| 3 | 8 | 56.5 | 142.5 | 86.0 | |
| 3 | 10 | 46.7 | 187.6 | 140.9 | |
| 3 | 12 | 55.0 | 214.5 | 159.5 | |
| 3 | 14 | 53.9 | 164.5 | 110.6 | |
| 3 | 16 | 50.2 | 149.8 | 99.6 | |
| 3 | 18 | 45.1 | 136.2 | 91.1 | |
| 3 | 20 | 35.6 | 100.2 | 64.6 | |
| 3 | 22.38 | | | | Shore |
| 4 | 2 | 27.8 | 85.6 | 57.8 | |
| 4 | 4 | 35 | 107.7 | 72.7 | |
| 4 | 6 | 45.6 | 131.5 | 85.9 | |
| 4 | 8 | 47.2 | 197.7 | 150.5 | |

| Transect | Distance (m) | Water to Sediment Depth (cm) | Total Depth (cm) | Sediment Depth (cm) | Comments |
|---|---|---|---|---|---|
| 4 | 10 | 46.9 | 215.1 | 168.2 | |
| 4 | 12 | 47.4 | 190.9 | 143.5 | |
| 4 | 14 | 50.2 | 148.7 | 98.5 | |
| 4 | 16 | 47.1 | 123.9 | 76.8 | |
| 4 | 18 | 45.6 | 106.2 | 60.6 | |
| 4 | 20 | 30.5 | 59.7 | 29.2 | Woody Debris |
| 4 | 21.5 | | | | Shore |
| 5 | 2 | 46.6 | 183.0 | 136.4 | |
| 5 | 4 | 40.6 | 156.6 | 116.0 | Strong Stratification |
| 5 | 6 | 43.2 | 173.8 | 130.6 | Strong Stratification |
| 5 | 8 | 44.0 | 102.5 | 58.5 | |
| 5 | 10 | 36.6 | 107.0 | 70.4 | |
| 5 | 12 | 37.7 | 112.4 | 74.7 | |
| 5 | 14 | 44.2 | 97.0 | 52.8 | |
| 5 | 16 | 38.3 | 88.8 | 50.5 | |
| 5 | 18 | 11.3 | 54.9 | 43.6 | Shore |
| 6 | 2 | 19.5 | 126.6 | 107.1 | |
| 6 | 4 | 36.5 | 151.7 | 115.2 | |
| 6 | 6 | 37.2 | 184.5 | 147.3 | Strong Stratification |
| 6 | 8 | 46.0 | 165.0 | 119.0 | |
| 6 | 10 | 34.7 | 150.1 | 115.4 | |
| 6 | 12 | 26.9 | 147.7 | 120.8 | |
| 6 | 14 | 6.9 | 105.7 | 98.8 | |
| 6 | 15.345 | | | | Shore |
| 7 | 2 | 20.6 | 67.0 | 46.4 | Sand (~2cm) |
| 7 | 4 | 26.1 | 74.5 | 48.4 | Sand (~3cm) |
| 7 | 6 | 27.8 | 77.4 | 49.6 | Sand (~3cm) |
| 7 | 8 | 30.7 | 90.8 | 60.1 | Sand (~2 cm) |
| 7 | 10 | 25.0 | 99.2 | 74.2 | Sand (~2cm) |
| 7 | 12 | 36.9 | 125.4 | 88.5 | Sand (~1.5 cm) |
| 7 | 14 | 37.7 | 143.0 | 105.3 | Sand (~4 cm) |
| 7 | 16 | 38.6 | 147.2 | 108.6 | Sand (~2.5 cm) |
| 7 | 18 | 25.4 | 141.4 | 116.0 | Sand (~1 cm) |
| 7 | 19.45 | | | | Shore |
| 8 | 2 | 26.7 | 149.7 | 123.0 | Sand (~15cm) |
| 8 | 4 | 32.3 | 144.9 | 112.6 | Sand (~15cm) |
| 8 | 6 | 28.3 | 141.4 | 113.1 | Sand |
| 8 | 8 | 27.5 | 139.0 | 111.5 | Firm sand |
| 8 | 10 | 30.6 | 118.6 | 88.0 | no sand (limted) |
| 8 | 12 | 28.8 | 79.7 | 50.9 | no sand (limted) |

| Transect | Distance (m) | Water to Sediment Depth (cm) | Total Depth (cm) | Sediment Depth (cm) | Comments |
|---|---|---|---|---|---|
| **8** | 14 | 17.5 | 58.8 | 41.3 | Dense Layer (2cm) |
| **8** | 15.4 | | | | Shore |
| **9** | 2 | 18.8 | 102.5 | 83.7 | rocks (holding fence post) |
| **9** | 4 | 26.8 | 109.9 | 83.1 | Partial sand |
| **9** | 6 | 26.3 | 106.5 | 80.2 | Partial sand |
| **9** | 8 | 26.8 | 113.1 | 86.3 | Partial sand |
| **9** | 10 | 16.6 | 96.2 | 79.6 | Stirred sediment |
| **9** | 12 | 12.4 | 82.2 | 69.8 | |
| **9** | 13.5 | | | | Shore |
| **10** | 2 | 68.2 | 98.0 | 29.8 | |
| **10** | 4 | 43.7 | 88.0 | 44.3 | |
| **10** | 6 | 48.1 | 97.9 | 49.8 | Sand (1 cm) |
| **10** | 8 | 21.4 | 102.8 | 81.4 | Sand |
| **10** | 10 | 1.0 | 74.3 | 73.3 | Shore |
| **11** | 2 | 29.0 | 100.3 | 71.3 | Sand |
| **11** | 4 | 48.2 | 93.8 | 45.6 | Sand |
| **11** | 6 | 67.1 | 90.9 | 23.8 | Sand |
| **11** | 8 | 112.5 | 113.5 | 1.0 | Sand (1 cm) |
| **11** | 10 | 106.3 | 106.3 | 0.0 | Dense gravel |
| **11** | 12 | 27.2 | 49.4 | 22.2 | Shore |

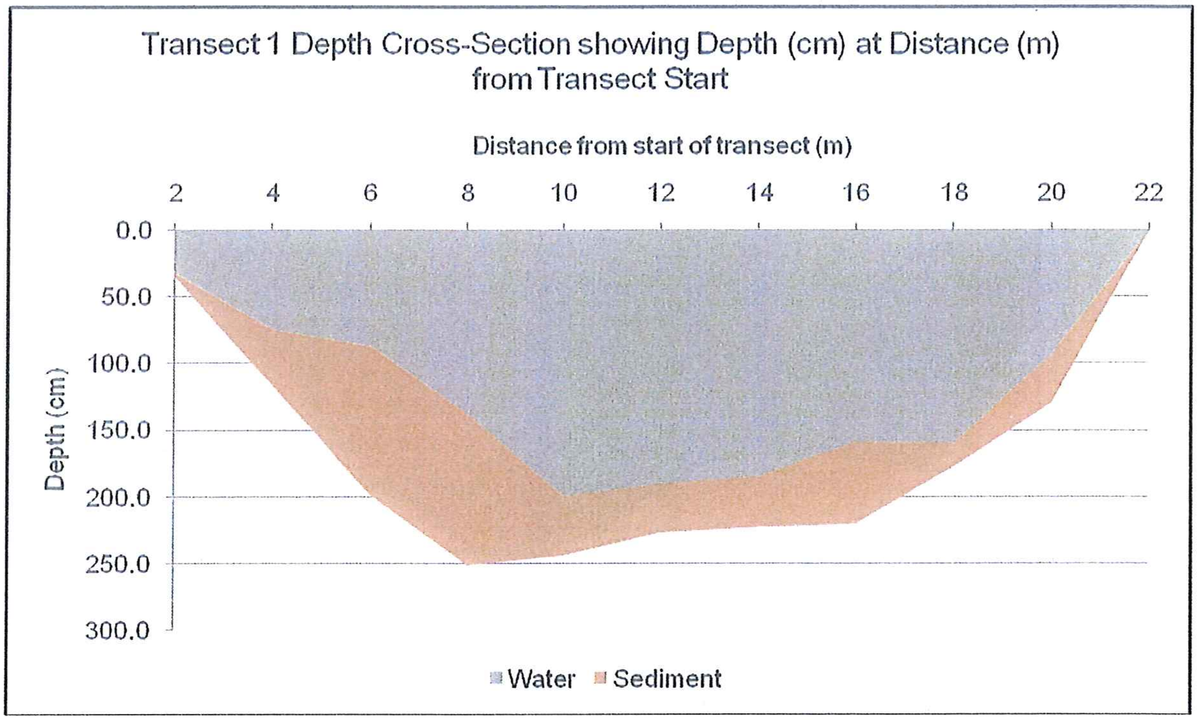

Figure A-1 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 1

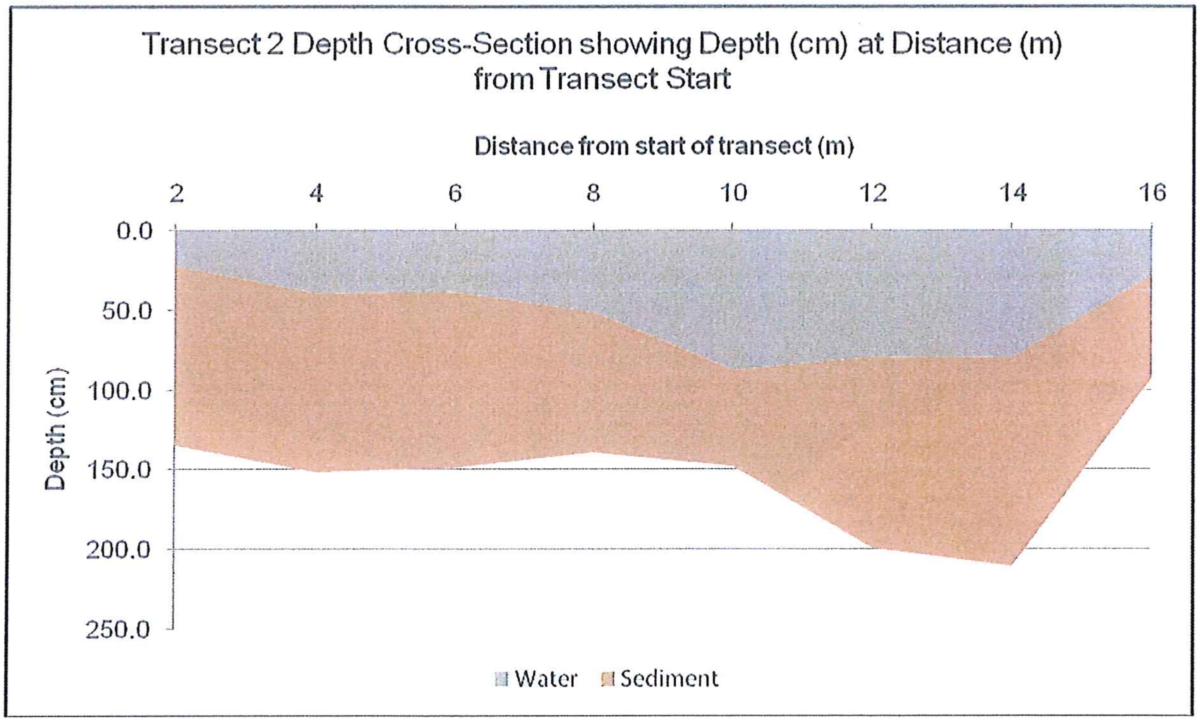

Figure A-2 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 2

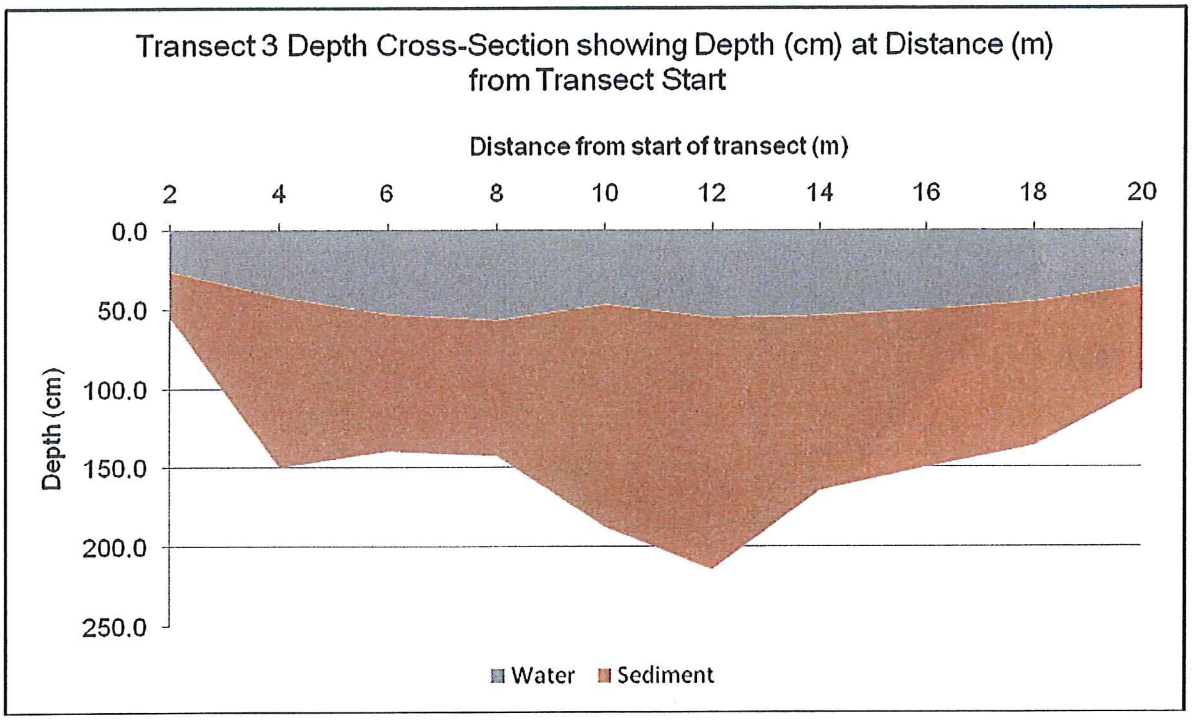

Figure A-3 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 3

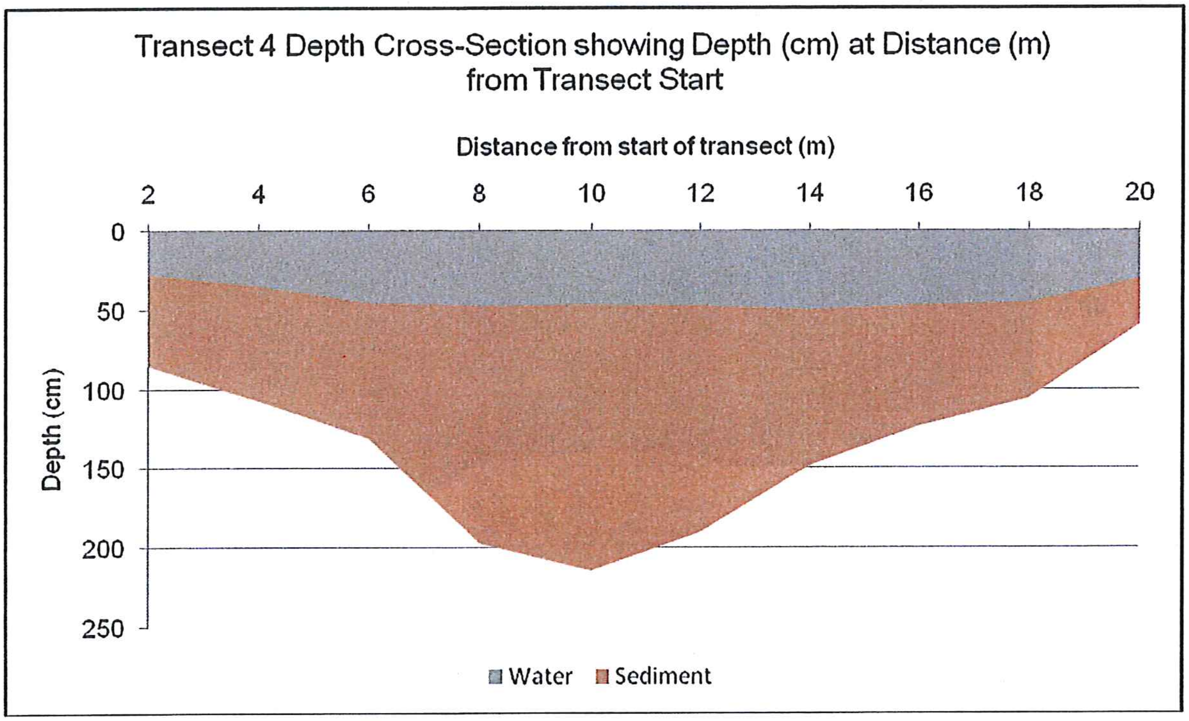

Figure A-4 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 4

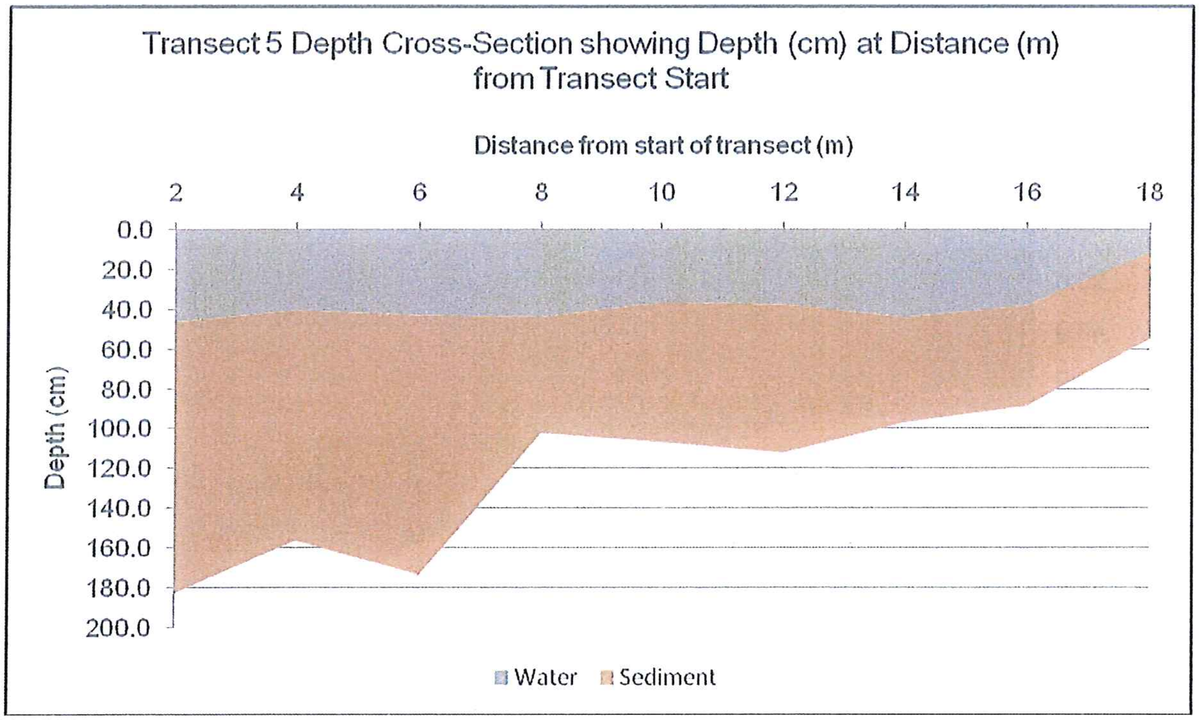

Figure A-5 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 5

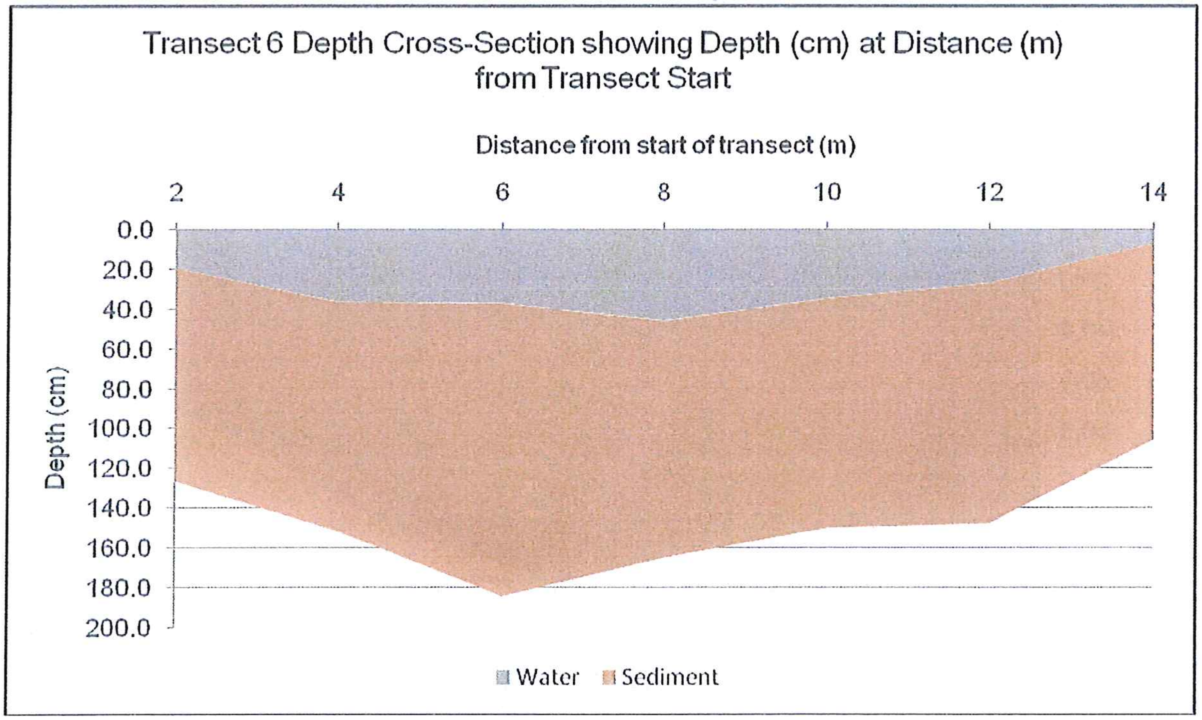

Figure A-6 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 6

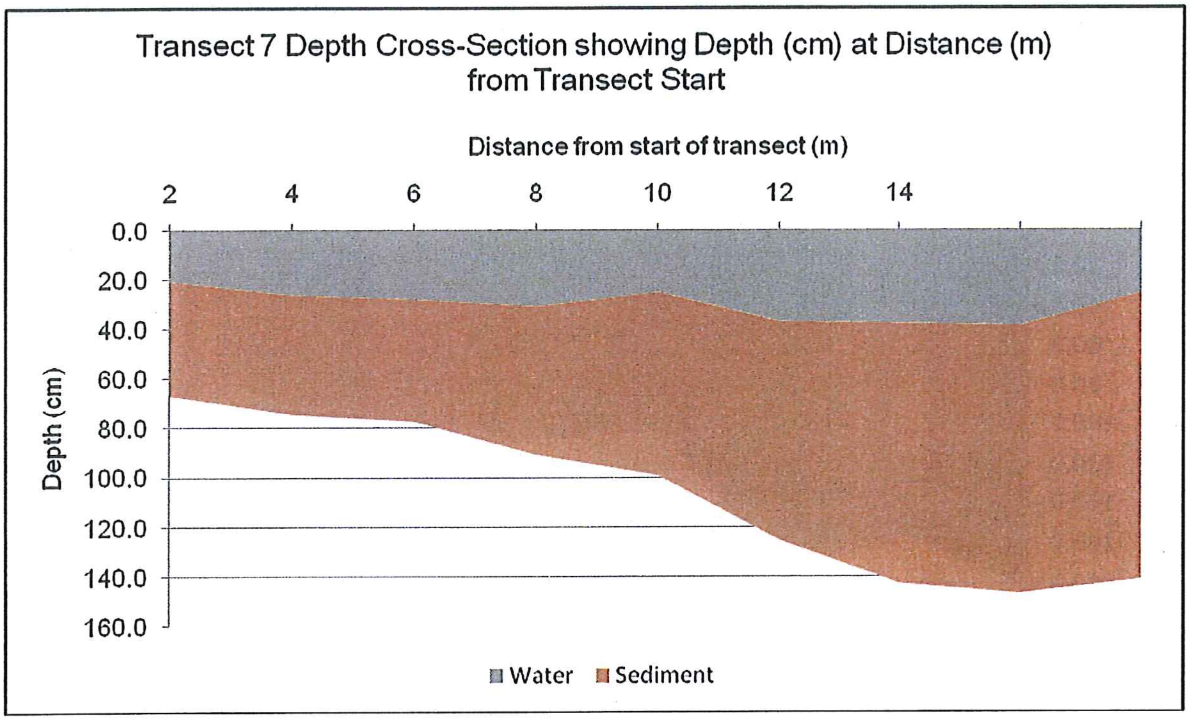

Figure A-7 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 7

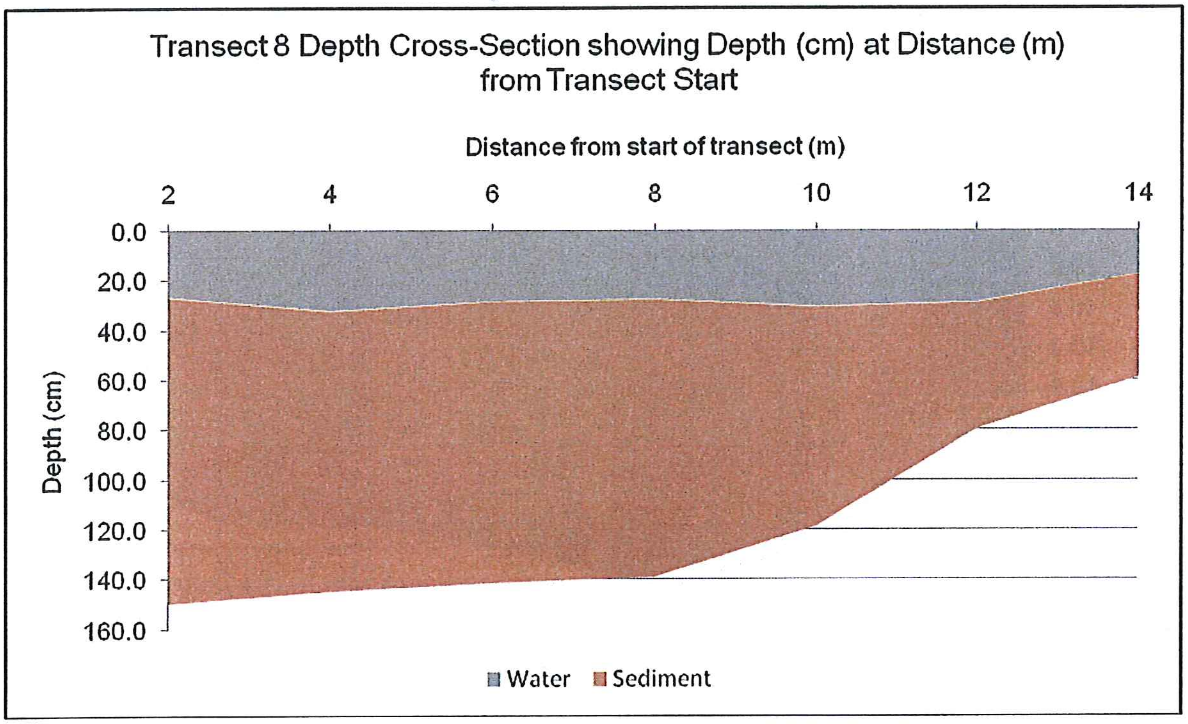

Figure A-8 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 8

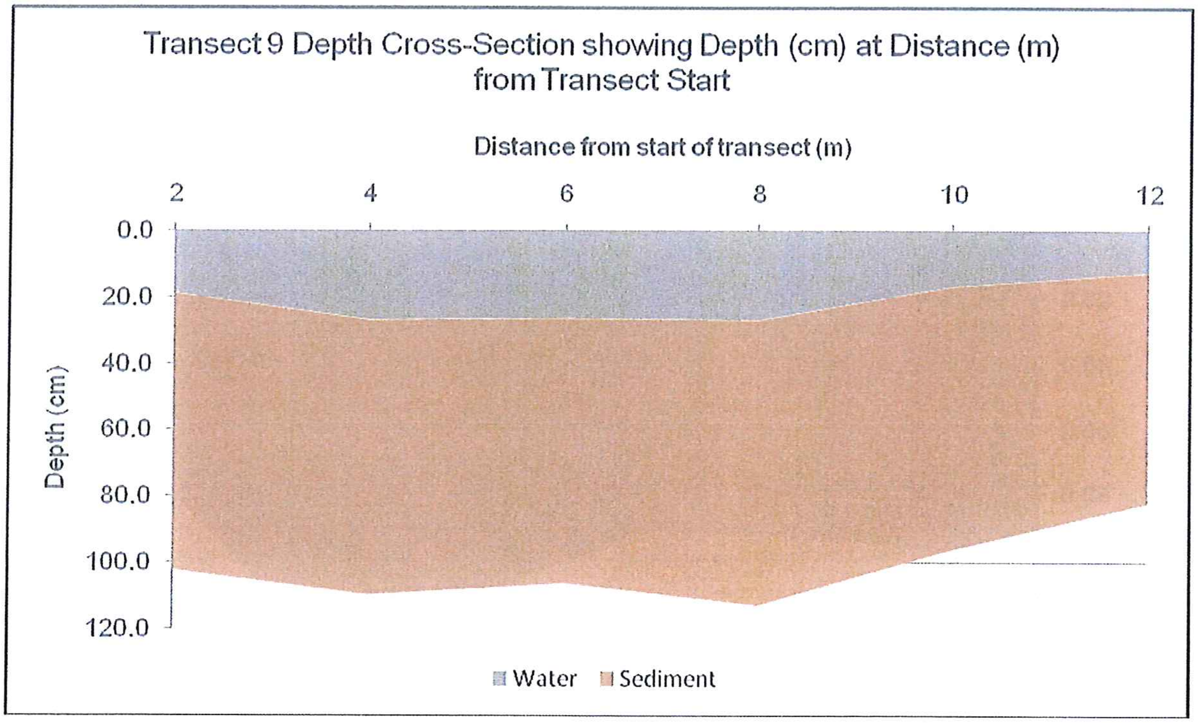

Figure A-9 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 9

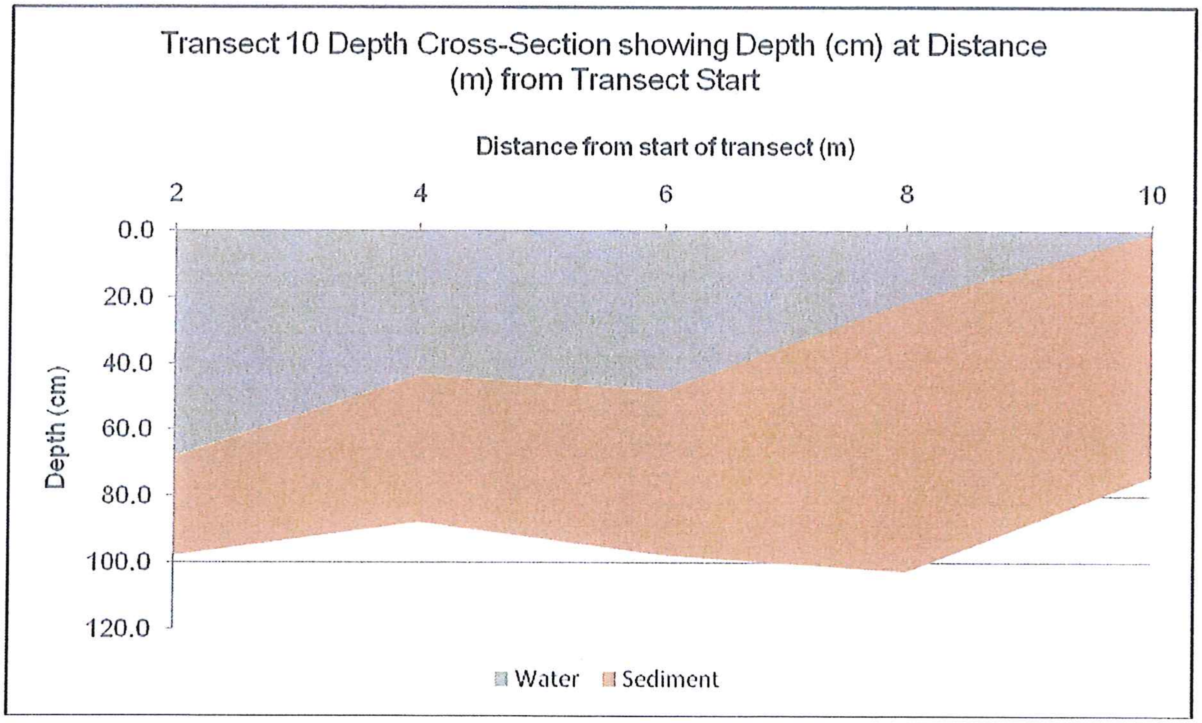

Figure A-10 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

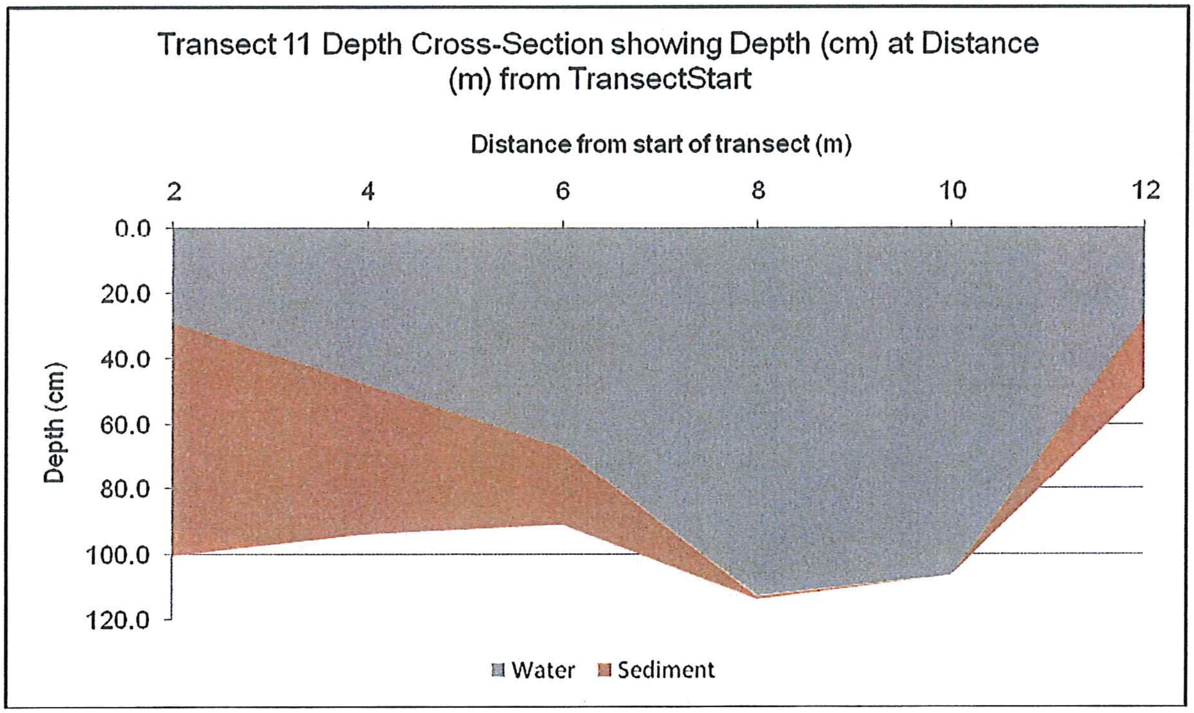

Figure A-11 – Depth cross-section: depth (cm) at distance (m) from transect start for transect 10

# APPENDIX B
# Regulatory Criteria & Guidelines Information

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

B.C. Reg. 375/96
O.C. 1480/96 and M271/2004

Deposited December 16, 1996
effective April 1, 1997

## *Environmental Management Act*

# CONTAMINATED SITES REGULATION

**Note:** Check the Cumulative Regulation Bulletin 2014 and 2015
for any non-consolidated amendments to this regulation that may be in effect.

[includes amendments up to B.C. Reg. 4/2014, January 31, 2014]

**Point in Time**

## Schedule 9

[en. B.C. Reg. 324/2004, s. 70; am. B.C. Regs. 239/2007, s. 9; 343/2008, s. 18.]

### Generic Numerical Sediment Criteria[1]

| COLUMN I Substance | COLUMN II Freshwater Sediment[2] Sensitive[4] ($SedQC_{SS}$) | COLUMN III Freshwater Sediment[2] Typical[5] ($SedQC_{TS}$) | COLUMN IV Marine and Estuarine Sediment[3] Sensitive[4] ($SedQC_{SS}$) | COLUMN V Marine and Estuarine Sediment[3] Typical[5] ($SedQC_{TS}$) |
|---|---|---|---|---|
| **Inorganic Substances** | | | | |
| arsenic | 11.0 | 20.0 | 26.0 | 50.0[6] |
| cadmium | 2.2 | 4.2 | 2.6 | 5.0 |
| chromium (total) | 56.0[6] | 110.0 | 99.0 | 190.0 |
| copper | 120.0 | 240.0 | 67.0 | 130.0 |
| lead | 57.0 | 110.0 | 69.0 | 130.0 |
| mercury | 0.3 | 0.58 | 0.43 | 0.84 |
| zinc | 200.0 | 380.0 | 170.0 | 330.0 |
| **Organic Substances**<br>**Chlorinated Hydrocarbons**<br>*chlorinated aliphatics* | | | | |
| hexachlorocyclohexane[7] | 0.00086[6] | 0.0017[6] | 0.00061 | 0.0012[6] |
| *miscellaneous chlorinated hydrocarbons* | | | | |

| | | | | |
|---|---|---|---|---|
| PCBs[9](total) | 0.17 | 0.33 | 0.12 | 0.23 |
| PCDDs and PCDFs[8] | 0.00013[6] | 0.00026[6] | 0.00013 | 0.00026[6] |
| **Phenolic Substances** | | | | |
| *chlorinated phenols* | | | | |
| pentachlorophenol | 0.4[10] | 0.8[10] | 0.36[11] | 0.69[11] |
| **Polycyclic Aromatic Hydrocarbons (PAHs)** | | | | |
| *alkylated low molecular weight PAHs*<br>2-methylnaphthalene | 0.12 | 0.24 | 0.12 | 0.24 |
| *low molecular weight PAHs* | | | | |
| acenaphthene | 0.055 | 0.11 | 0.055 | 0.11 |
| acenaphthylene | 0.08 | 0.15 | 0.079 | 0.15 |
| anthracene | 0.15 | 0.29 | 0.15 | 0.29 |
| fluorene | 0.089 | 0.17 | 0.089 | 0.17 |
| naphthalene | 0.24 | 0.47 | 0.24 | 0.47 |
| phenanthrene | 0.32 | 0.62 | 0.34 | 0.65 |
| *high molecular weight PAHs* | | | | |
| benz[a]anthracene | 0.24 | 0.46 | 0.43 | 0.83 |
| benzo[a]pyrene | 0.48 | 0.94 | 0.47 | 0.92 |
| chrysene | 0.53 | 1.0 | 0.52 | 1.0 |
| dibenz[a,h]anthracene | 0.084 | 0.16 | 0.084 | 0.16 |
| fluoranthene | 1.5 | 2.8 | 0.93 | 1.8 |
| pyrene | 0.54 | 1.1 | 0.87 | 1.7 |
| *Total PAHs* | | | | |
| PAHs (total) [12] | 10.0 | 20.0 | 10.0 | 20.0 |
| **Pesticides** | | | | |
| chlordane | 0.0055 | 0.011 | 0.003 | 0.0057 |
| DDD (total) [13] | 0.0053 | 0.01 | 0.0048 | 0.0094 |
| DDE (total) [14] | 0.0042 | 0.0081 | 0.23 | 0.45 |
| DDT (total) [15] | 0.003 | 0.0057 | 0.003 | 0.0057 |
| dieldrin | 0.0041 | 0.008 | 0.0027 | 0.0052 |
| endrin | 0.039 | 0.075[6] | 0.039 | 0.075[6] |
| heptachlor and heptachlor epoxide | 0.0017 | 0.0033[6] | 0.0017 | 0.0033 |
| lindane [7] | 0.00086[6] | 0.0017[6] | 0.00061 | 0.0012[6] |

## Footnotes

1. All values are in µg/g dry weight (dwt) unless otherwise stated. Substance must be analyzed using methods specified in a director's protocol or alternate methods acceptable to a director.

2. Criteria to protect freshwater aquatic life.
3. Criteria to protect marine and/or estuarine aquatic life.
4. Sensitive sediment means sediment at a site with sensitive aquatic habitat and for which sensitive sediment management objectives apply. Consult director for further advice.
5. Typical sediment means sediment that is not sensitive sediment. Consult director for further advice.
6. Denotes a sediment quality criteria which is considered less reliable or that could not be fully evaluated.
7. Criteria is specific to gamma isomer.
8. Calculated using data for PCDDs, PCDFs, PCBs and associated PCDD, PCDF and PCB toxicity equivalency factors.
9. Total PCBs includes either the sum of four to seven Arochlor mixtures (i.e. Arochlor 1016, 1221, 1232, 1242, 1248, 1254 and/or 1260) or the sum of ≥ 20 individual PCB congeners. No discrete criterion for Arochlor 1254 was derived, since the existing Canadian Council of Ministers of the Environment interim Probable Effects Level (PEL) for that substance was inconsistent with the PEL provided for total PCBs and the Probable Effects Level (PEL) for Arochlor 1254 was derived using methods different from those used to derive the criterion for total PCBs listed in this schedule.
10. Criterion is set equal to the State of New York, Department of Environmental Conservation, 1994 criterion for the substance.
11. Criterion is set equal to the Washington State, Department of Ecology, 1991 criterion for the substance.
12. Total PAHs includes:
    2-methylnaphthalene,
    acenaphthalene,
    acenaphthene,
    anthracene,
    benz[a]anthracene,
    benzo[a]pyrene,
    chrysene,
    dibenz[a,h]anthracene,
    fluorene,
    fluoranthene,
    naphthalene,
    phenanthrene, and
    pyrene.
13. DDD is 2,2-bis(p-chlorophenyl)-1,1-dichloroethane
14. DDE is 2,2-bis(p-chlorophenyl)-1,1-dichloroethylene
15. DDT is 2,2-bis(p-chlorophenyl)-1,1,1-trichloroethane

**Contents | Parts 1 to 18 | Schedule 1 | Schedule 1.1 | Schedule 2 | Schedule 3 | Schedule 4 | Schedule 5 | Schedule 6 | Schedule 7 | Schedule 8 | Schedule 9 | Schedule 10 | Schedule 11**

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# Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

# INTRODUCTION

As chemicals or substances are released into the environment through natural processes or human activities, they may enter aquatic ecosystems and partition into the particulate phase. These particles may be deposited into the bed sediments where the contaminants may accumulate over time. Sediments may therefore act as long-term reservoirs of chemicals to the aquatic environment and to organisms living in or having direct contact with sediments. Because sediments comprise an important component of aquatic ecosystems, providing habitat for a wide range of benthic and epibenthic organisms, exposure to certain substances in sediments represents a potentially significant hazard to the health of the organisms. Effective assessment of this hazard requires an understanding of relationships between concentrations of sediment-associated chemicals and the occurrence of adverse biological effects. Sediment quality guidelines are scientific tools that synthesize information regarding the relationships between the sediment concentrations of chemicals and any adverse biological effects resulting from exposure to these chemicals.

This chapter provides information regarding the derivation and implementation of Canadian sediment quality guidelines. In addition, detailed chemical-specific fact sheets have been developed for those chemicals for which national guidelines have been derived.

Sediment quality guidelines provide scientific benchmarks, or reference points, for evaluating the potential for observing adverse biological effects in aquatic systems. The guidelines are derived from the available toxicological information according to the formal protocol established by the Canadian Council of Ministers of the Environment (CCME 1995). The protocol, reprinted in this chapter for reference, includes general guidance on the implementation of sediment quality guidelines, in conjunction with other relevant information, in order to prioritize and focus sediment quality assessments. The formal protocol used to derive sediment quality guidelines relies on both a modification of the National Status and Trends Program (modified NSTP) approach and the spiked-sediment toxicity test (SSTT) approach.

To derive sediment quality assessment values, the modified NSTP approach uses data from North American field-collected sediments that contain chemical mixtures (Long and Morgan 1990; Long 1992; Long and MacDonald 1992; MacDonald 1994; CCME 1995; Long et al. 1995). Synoptically collected chemical and biological data ("co-occurrence data") are evaluated from numerous individual studies to establish an association between the concentration of each chemical measured in the sediment and any adverse biological effect observed.

The co-occurrence data are compiled in a database referred to as the Biological Effects Database for Sediments (BEDS) in order to calculate two assessment values. The lower value, referred to as the threshold effect level (TEL), represents the concentration below which adverse biological effects are expected to occur rarely. The upper value, referred to as the probable effect level (PEL), defines the level above which adverse effects are expected to occur frequently. By calculating TELs and PELs according to a standard formula, three ranges of chemical concentrations are consistently defined: (1) the minimal effect range within which adverse effects rarely occur (i.e., fewer than 25% adverse effects occur below the TEL), (2) the possible effect range within which adverse effect occasionally occur (i.e., the range between the TEL and PEL), and (3) the probable effect range within which adverse biological effects frequently occur (i.e., more than 50% adverse effects occur above the PEL). The definitions of these ranges are based on the assumption that the potential for observing toxicity resulting from exposure to a chemical increases with increasing concentration of the chemical in the sediment (Long et al. 1995). The definition of the TEL is consistent with the definition of a Canadian sediment quality guideline. The PEL is recommended as an additional sediment quality assessment tool that can be useful in identifying sediments in which adverse biological effects are more likely to occur.

The SSTT approach involves an independent evaluation of information from spiked-sediment toxicity tests for estimating the concentration of a chemical below which adverse effects are not expected to occur. In this approach, an SSTT value is derived using data from controlled laboratory tests in which organisms are exposed to sediments spiked with known concentrations of a chemical or specific mixture of chemicals. Such studies provide quantifiable cause-and-effect relationships between the concentration of a chemical in sediments and the observed biological response (e.g., survival, reproductive success, or growth). Spiked-sediment toxicity tests may also be used to determine the extent to which environmental conditions modify the bioavailability of a chemical, and ultimately the response of organisms exposed to the spiked sediments.

Minimum toxicological data requirements have been set for the SSTT approach to ensure that the derived SSTT values provide adequate protection to aquatic organisms. Spiked-sediment toxicity tests that meet the minimum data requirements are currently available only for cadmium in marine (and estuarine) sediments. In addition, concerns regarding spiked-sediment toxicity testing methodology limit the degree to which these values may be used as the scientific basis for recommending sediment quality guidelines at this time.

Subsequent to an evaluation of the toxicological information, Canadian sediment quality guidelines are recommended if information exists to support both the modified NSTP and the SSTT approaches. (These are referred to as *full* sediment quality guidelines.) Generally, the lower of the two values derived using either approach is recommended as the Canadian sediment quality guideline. Interim sediment quality guidelines (ISQGs) are recommended if information is available to support only one approach.

The guidelines may also be derived to reflect predictive relationships that have been established between the concentration of the chemical in sediments, and any environmental factor or condition that may influence the toxicity of a specific chemical (e.g., sediment characteristics, such as total organic carbon content [TOC] or acid volatile sulphides [AVS]; or water column characteristics, such as hardness). Consideration of these relationships will increase the applicability of guidelines to a wide variety of sediments throughout Canada.

If insufficient information exists to derive interim guidelines using either the modified NSTP approach or the SSTT approach, guidelines from other jurisdictions are evaluated and may be provisionally adopted in the short term as ISGQs. Further details on the derivation and evaluation of Canadian ISQGs and PELs for both freshwater and marine sediments are outlined in the protocol (CCME 1995, reprinted in this chapter).

Canadian ISQGs are recommended for total concentrations of chemicals in freshwater and marine surficial sediments (i.e., top 5 cm), as quantified by standardized analytical protocols for each chemical. For the analytical quantification of metals in sediments, the choice of digestion method is dependent on the intended use of the results (e.g., for quantification of the bioavailable fraction or for geochemical evaluation). Because ISQGs are intended to be used for evaluating the potential for biological effects, "near-total" trace metal extraction methods that remove the biologically available fraction of metals and not residual metals (i.e., those metals held within the lattice framework of the sediment) are recommended for determining sediment metal concentrations. A strong extraction method using hydrofluoric acid would remove both the bioavailable and residual fractions of metals in the sediment. Therefore in this chapter, the concentration of "total" metal refers to the concentration of metal recovered using a near-total (mild digestion; e.g., aqua regia, nitric acid, or hydrochloric acid) method.

To date, spiked-sediment toxicity data are limited; therefore, ISQGs, which are derived using only the modified NSTP approach (i.e., the TEL), are reported instead of full sediment quality guidelines. Currently, ISQGs and PELs are recommended for 31 chemicals or substances (7 metals, 13 PAHs, and 11 organochlorine compounds). Tables 1 and 2 list the chemicals and corresponding ISQGs and PELs that are recommended for freshwater and marine (including estuarine) sediments as well as the percentages of adverse biological effects found within concentration ranges surrounding the ISQGs and PELs. Although these sediment quality guidelines are considered interim at this time, they should not be used differently than if they were full sediment quality guidelines. During their application, it should however be recognized that these values reflect associative information only because insufficient reliable spiked-sediment toxicity data currently exist to evaluate cause-and-effect relationships.

Sediment quality guidelines have a broad range of potential applications, as do other environmental quality guidelines. They can serve as goals or interim targets for national and regional toxic chemical management programs, as benchmarks or targets in the assessment and remediation of contaminated sites, or as the basis for the development of site-specific objectives. They may also be used as environmental benchmarks for international discussions on emission reductions, as environmental guidelines on trade agreements, in reports on the state of regional or national sediment quality, in the assessment of the efficacy of environmental regulations, in evaluations of potential impacts of developmental activities, and in the design, implementation, and evaluation of sediment quality monitoring programs. Despite the variety of potential uses, sediment quality guidelines are likely to be routinely applied as screening tools in the site-specific assessment of the potential risk of exposure to chemicals in sediment and in formulating initial management decisions (e.g., acceptability for open-water disposal, required remediation, further site investigation, and prioritization of sites).

In the application of the existing framework for assessing sediment quality, it is important to recognize that

Canadian ISQGs are intended to be used in conjunction with other supporting information. Such information includes site-specific background concentrations and concentrations of other naturally occurring substances, biological assessments, environmental quality guidelines for other media (e.g., water, tissue, and soil), and Canadian ISQGs and PELs (or other relevant sediment quality assessment values) for other chemicals. It should also be noted that the ISQGs and PELs are developed using scientific information only. Socioeconomic (e.g., cost) or technological (e.g., remedial technology) factors that may influence their application are not considered in the development process, but may play a varying role in their application (and/or in the development of site-specific sediment quality objectives) within the decision-making framework of different jurisdictions and programs.

It is widely recognized that no single sediment quality assessment tool should be used to predict whether adverse biological effects will occur as a result of exposure to chemicals in sediments. Rather, the appropriate use of different tools will provide the most useful information (Luoma and Carter 1993; Chapman 1995). The use of ISQGs to the exclusion of other supporting information can lead to erroneous conclusions or predictions about sediment quality. Decisions are more defensible if they are administered in a manner that acknowledges scientific uncertainties and allows for management modifications as scientific knowledge improves (Luoma and Carter 1993). In the framework discussed above, Canadian ISQGs and PELs provide nationally consistent benchmarks with which to evaluate the ecological significance of concentrations of sediment-associated chemicals and determine the relative priority of sediment quality concerns. Canadian ISQGs should be used along with all other relevant information in making practical and informed decisions regarding sediment quality. These considerations are equally important whether the focus is to maintain, protect, or improve sediment quality conditions at a particular site in Canada.

## References

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MacDonald, D.D. 1994. Approach to the assessment of sediment quality in Florida coastal waters. Vol. I. Prepared for the Florida Department of Environmental Protection. MacDonald Environmental Sciences, Ltd., Ladysmith, BC.

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Canadian Council of Ministers of the Environment. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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Aussi disponible en français.

Canadian Council
of Ministers
of the Environment
CCME
Le Conseil canadien
des ministres
de l'environnement

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| 2-Methylnaphthalene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 20.2 | 201 | 1998 | 20.2 | 201 | 1998 |
| Acenaphthene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 6.71 | 88.9 | 1998 | 6.71 | 88.9 | 1998 |
| Acenaphthylene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 5.87 | 128 | 1998 | 5.87 | 128 | 1998 |

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Anthracene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 46.9 | 245 | 1998 | 46.9 | 245 | 1998 |
| Aroclor 1254<br>PCBs | Organic<br>Polyaromatic compounds<br>Polychlorinated biphenyls | 60 | 340 | 2001 | 63.3 | 709 | 2001 |
| Arsenic<br>CASRN none | Inorganic | 5900 | 17 000 | 1998 | 7240 | 41 600 | 1998 |
| Benz(a)anthracene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 31.7 | 385 | 1998 | 74.8 | 693 | 1998 |

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| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Benzo(a)pyrene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 31.9 | 782 | 1998 | 88.8 | 763 | 1998 |
| Beryllium | Inorganic | No data | No data | 2015-02-23 | No data | No data | 2015-02-23 |
| Cadmium<br>CASRN 7440439 | Inorganic | 600 | 3500 | 1997 | 700 | 4200 | 1997 |
| Chlordane | Organic<br>Pesticides<br>Organochlorine compounds | 4.5 | 8.87 | 1998 | 2.26 | 4.79 | 1998 |
| Chromium (total)<br>CASRN 7440-47-3 | Inorganic | 37 300 | 90 000 | 1998 | 52 300 | 160 000 | 1998 |
| Chrysene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 57.1 | 862 | 1998 | 108 | 846 | 1998 |

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Copper | Inorganic | 35 700 | 197 000 | 1998 | 18 700 | 108 000 | 1998 |
| Dibenz(a,h)anthracene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 6.22 | 135 | 1998 | 6.22 | 135 | 1998 |
| Dichloro diphenyl dichloroethane, 2,2-Bis (p-chlorophenyl)-1,1-dichloroethane<br>DDD | Organic<br>Pesticides<br>Organochlorine compounds | 3.54 | 8.51 | 1998 | 1.22 | 7.81 | 1998 |
| Dichloro diphenyl ethylene, 1,1-Dichloro-2,2-bis(p-chlorophenyl)-ethene<br>DDE | Organic<br>Pesticides<br>Organochlorine compounds | 1.42 | 6.75 | 1998 | 2.07 | 374 | 1998 |
| Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane<br>DDT (total) | Organic<br>Pesticides<br>Organochlorine compounds | 1.19 | 4.77 | 1998 | 1.19 | 4.77 | 1998 |
| Dieldrin | Organic<br>Pesticides<br>Organochlorine compounds | 2.85 | 6.67 | 1998 | 0.71 | 4.3 | 1998 |

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Endrin | Organic<br>Pesticides<br>Organochlorine compounds | 2.67 | 62.4 | 1998 | 2.67 | 62.4 | 1998 |

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Fluoranthene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 111 | 2355 | 1998 | 113 | 1494 | 1998 |
| Fluorene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 21.2 | 144 | 1998 | 21.2 | 144 | 1998 |

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| Chemical name | Chemical groups | ISQG | PEL | | ISQG | PEL | |
| Heptachlor<br>Heptachlor epoxide | Organic<br>Pesticides<br>Organochlorine compounds | 0.6 | 2.74 | 1998 | 0.6 | 2.74 | 1998 |
| Hexachlorocyclohexane<br>Lindane | Organic<br>Pesticides<br>Organochlorine compounds | 0.94 | 1.38 | 1998 | 0.32 | 0.99 | 1998 |
| Lead | Inorganic | 35 000 | 91 300 | 1998 | 30 200 | 112 000 | 1998 |
| Mercury<br>CASRN 7439976 | Inorganic | 170 | 486 | 1997 | 130 | 700 | 1997 |
| Naphthalene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 34.6 | 391 | 1998 | 34.6 | 391 | 1998 |

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| **Chemical name** | **Chemical groups** | **ISQG** | **PEL** | | **ISQG** | **PEL** | |
| Nonylphenol and its ethoxylates<br>CASRN 84852153 | Organic<br>Nonylphenol and its ethoxylates | 1400 | *No data* | 2002 | 1000 | *No data* | 2002 |
| Phenanthrene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 41.9 | 515 | 1998 | 86.7 | 544 | 1998 |
| Polychlorinated biphenyls<br>PCBs | Organic<br>Polyaromatic compounds<br>Polychlorinated biphenyls | 34.1 | 277 | 2001 | 21.5 | 189 | 2001 |
| Polychlorinated dibenzo-p-dioxins/dibenzo furans<br>PCDDs, PCDFs | Organic<br>Polyaromatic compounds<br>Polychlorinated dioxins and furans | 0.85 ng TEQ/kg dry weight | 21.5 ng TEQ/kg dry weight | 2001 | 0.85 ng TEQ/kg dry weight | 21.5 ng TEQ/kg dry weight | 2001 |
| Pyrene<br>PAHs | Organic<br>Polyaromatic compounds<br>Polycyclic aromatic hydrocarbons | 53 | 875 | 1998 | 153 | 1398 | 1998 |

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

| | | Sediment Quality Guidelines for the Protection of Aquatic Life | | | | | |
|---|---|---|---|---|---|---|---|
| | | Freshwater | | | Marine | | |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| **Chemical name** | **Chemical groups** | **ISQG** | **PEL** | | **ISQG** | **PEL** | |
| | | | | | | | |
| | | Concentration | Concentration | Date | Concentration | Concentration | Date |
| **Chemical name** | **Chemical groups** | **ISQG** | **PEL** | | **ISQG** | **PEL** | |
| Sodium adsorption ratio<br>SAR | | *No data* | *No data* | *No data* | *No data* | *No data* | *No data* |
| | | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date | Concentration (µg/kg dry weight) | Concentration (µg/kg dry weight) | Date |
| **Chemical name** | **Chemical groups** | **ISQG** | **PEL** | | **ISQG** | **PEL** | |
| Toxaphene | Organic<br>Pesticides<br>Organochlorine compounds | 0.1 | No PEL derived | 2002 | 0.1 | No PEL derived | 2002 |
| Zinc | Inorganic | 123 000 | 315 000 | 1998 | 124 000 | 271 000 | 1998 |

| Chemical name | Chemical groups |
|---|---|

| Chemical name | Chemical groups |
|---|---|
| Sodium adsorption ratio<br>SAR | |

# APPENDIX C
# Laboratory Analytical Report

Sampling and Analysis of Reay Creek Pond Sediments
Canora Road Between Northbrook Drive and Bowcott Place
SLR Project No.: 205.03696.00000

SLR CONSULTING (CANADA) LTD.
ATTN: John Wiens
# 6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2

| | |
|---|---|
| Date Received: | 17-JAN-15 |
| Report Date: | 27-JAN-15 10:44 (MT) |
| Version: | FINAL |

Client Phone: 250-475-9595

# Certificate of Analysis

| | |
|---|---|
| **Lab Work Order #:** | **L1568180** |
| Project P.O. #: | NOT SUBMITTED |
| Job Reference: | 205.03696.00000 |
| C of C Numbers: | 10-192650, 10-192652 |
| Legal Site Desc: | |

**Comments:** Please note that the pH ratio was changed to 1:4 for samples L1568180-12,18.

Erin Bolster, B.Sc.
Account Manager

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | | | | | | |
|---|---|---|---|---|---|---|
| | **Sample ID** | L1568180-1 | L1568180-3 | L1568180-5 | L1568180-7 | L1568180-9 |
| | **Description** | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT |
| | **Sampled Date** | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 |
| | **Sampled Time** | | | | | |
| | **Client ID** | 1G | 2C-B | 3C-C | 4C-C | 4C-A |
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Physical Tests** | Grain Size Curve | | | | | |
| | Moisture (%) | | | | 48.8 | 39.5 |
| | pH (1:2 soil:water) (pH) | 6.44 | 6.53 | 7.07 | 6.76 | 7.16 |
| **Organic / Inorganic Carbon** | Total Organic Carbon (%) | | | | | |
| **Metals** | Antimony (Sb) (mg/kg) | 1.19 | 0.29 | 0.47 | 0.58 | 0.40 |
| | Arsenic (As) (mg/kg) | 5.18 | 4.85 | 7.32 | 4.55 | 11.2 |
| | Barium (Ba) (mg/kg) | 105 | 105 | 59.7 | 86.6 | 79.4 |
| | Beryllium (Be) (mg/kg) | 0.45 | 0.33 | 0.29 | 0.33 | 0.33 |
| | Cadmium (Cd) (mg/kg) | 22.1 | 19.8 | 26.0 | 17.3 | 0.448 |
| | Chromium (Cr) (mg/kg) | 146 | 90.6 | 144 | 130 | 31.2 |
| | Cobalt (Co) (mg/kg) | 14.1 | 12.0 | 9.43 | 11.1 | 11.4 |
| | Copper (Cu) (mg/kg) | 75.9 | 31.3 | 22.5 | 37.3 | 30.5 |
| | Lead (Pb) (mg/kg) | 53.9 | 16.5 | 13.9 | 25.3 | 16.1 |
| | Mercury (Hg) (mg/kg) | 0.100 | <0.050 | <0.050 | 0.056 | <0.050 |
| | Molybdenum (Mo) (mg/kg) | 1.78 | 1.16 | 0.40 | 0.91 | 0.57 |
| | Nickel (Ni) (mg/kg) | 33.3 | 19.9 | 18.5 | 22.7 | 23.4 |
| | Selenium (Se) (mg/kg) | 0.67 | 0.55 | <0.20 | 0.43 | 0.27 |
| | Silver (Ag) (mg/kg) | 0.25 | <0.10 | 0.11 | 0.10 | 0.13 |
| | Thallium (Tl) (mg/kg) | 0.085 | 0.064 | 0.097 | 0.065 | 0.053 |
| | Tin (Sn) (mg/kg) | 2.2 | <2.0 | <2.0 | <2.0 | <2.0 |
| | Uranium (U) (mg/kg) | 1.09 | 0.822 | 0.534 | 0.810 | 0.648 |
| | Vanadium (V) (mg/kg) | 76.4 | 56.0 | 50.1 | 55.2 | 65.9 |
| | Zinc (Zn) (mg/kg) | 519 | 181 | 90.7 | 218 | 97.5 |
| **Polycyclic Aromatic Hydrocarbons** | Acenaphthene (mg/kg) | | | | <0.050 | <0.050 |
| | Acenaphthylene (mg/kg) | | | | <0.050 | <0.050 |
| | Anthracene (mg/kg) | | | | <0.050 | <0.050 |
| | Benz(a)anthracene (mg/kg) | | | | <0.050 | 0.051 |
| | Benzo(a)pyrene (mg/kg) | | | | 0.051 | 0.064 |
| | Benzo(b)fluoranthene (mg/kg) | | | | 0.106 | 0.117 |
| | Benzo(g,h,i)perylene (mg/kg) | | | | <0.050 | 0.051 |
| | Benzo(k)fluoranthene (mg/kg) | | | | <0.050 | <0.050 |
| | Chrysene (mg/kg) | | | | 0.075 | 0.087 |
| | Dibenz(a,h)anthracene (mg/kg) | | | | <0.050 | <0.050 |
| | Fluoranthene (mg/kg) | | | | 0.133 | 0.106 |
| | Fluorene (mg/kg) | | | | <0.050 | <0.050 |

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| Grouping | Analyte | L1568180-10 | L1568180-12 | L1568180-13 | L1568180-15 | L1568180-16 |
|---|---|---|---|---|---|---|
| | **Sample ID** | L1568180-10 | L1568180-12 | L1568180-13 | L1568180-15 | L1568180-16 |
| | **Description** | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT |
| | **Sampled Date** | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 |
| | **Sampled Time** | | | | | |
| | **Client ID** | 5C-C | 6C-C | 6C-B | 7C-C | 7C-A |
| **SOIL** | | | | | | |
| **Physical Tests** | Grain Size Curve | | | SEE ATTACHED | | |
| | Moisture (%) | | | 63.3 | | |
| | pH (1:2 soil:water) (pH) | 6.47 | 6.49 | 6.63 | 6.17 | 7.21 |
| **Organic / Inorganic Carbon** | Total Organic Carbon (%) | | | 5.33 | | |
| **Metals** | Antimony (Sb) (mg/kg) | 1.30 | 1.21 | 0.61 | 0.76 | 0.39 |
| | Arsenic (As) (mg/kg) | 5.11 | 4.71 | 5.35 | 4.51 | 6.17 |
| | Barium (Ba) (mg/kg) | 123 | 118 | 126 | 119 | 105 |
| | Beryllium (Be) (mg/kg) | 0.49 | 0.56 | 0.50 | 0.52 | 0.38 |
| | Cadmium (Cd) (mg/kg) | 24.7 | 21.4 | 42.1 | 35.3 | 14.1 |
| | Chromium (Cr) (mg/kg) | 134 | 119 | 153 | 153 | 141 |
| | Cobalt (Co) (mg/kg) | 15.6 | 14.8 | 13.4 | 14.0 | 10.6 |
| | Copper (Cu) (mg/kg) | 99.8 | 93.9 | 64.1 | 74.6 | 34.7 |
| | Lead (Pb) (mg/kg) | 63.4 | 60.7 | 58.6 | 64.6 | 19.7 |
| | Mercury (Hg) (mg/kg) | 0.128 | 0.129 | 0.098 | 0.112 | 0.055 |
| | Molybdenum (Mo) (mg/kg) | 2.05 | 1.98 | 1.49 | 1.30 | 0.70 |
| | Nickel (Ni) (mg/kg) | 38.5 | 38.2 | 34.1 | 36.0 | 23.9 |
| | Selenium (Se) (mg/kg) | 0.82 | 0.79 | 0.51 | 0.61 | 0.40 |
| | Silver (Ag) (mg/kg) | 0.34 | 0.32 | 0.25 | 0.33 | <0.10 |
| | Thallium (Tl) (mg/kg) | 0.102 | 0.106 | 0.089 | 0.103 | 0.071 |
| | Tin (Sn) (mg/kg) | <2.0 | <2.0 | 2.2 | 3.0 | <2.0 |
| | Uranium (U) (mg/kg) | 1.17 | 1.12 | 1.02 | 0.961 | 0.972 |
| | Vanadium (V) (mg/kg) | 77.7 | 78.5 | 81.8 | 76.3 | 62.2 |
| | Zinc (Zn) (mg/kg) | 700 | 639 | 347 | 480 | 146 |
| **Polycyclic Aromatic Hydrocarbons** | Acenaphthene (mg/kg) | | | <0.050 | | |
| | Acenaphthylene (mg/kg) | | | <0.050 | | |
| | Anthracene (mg/kg) | | | <0.050 | | |
| | Benz(a)anthracene (mg/kg) | | | 0.252 | | |
| | Benzo(a)pyrene (mg/kg) | | | 0.440 | | |
| | Benzo(b)fluoranthene (mg/kg) | | | 0.832 | | |
| | Benzo(g,h,i)perylene (mg/kg) | | | 0.355 | | |
| | Benzo(k)fluoranthene (mg/kg) | | | 0.264 | | |
| | Chrysene (mg/kg) | | | 0.507 | | |
| | Dibenz(a,h)anthracene (mg/kg) | | | 0.056 | | |
| | Fluoranthene (mg/kg) | | | 0.806 | | |
| | Fluorene (mg/kg) | | | <0.050 | | |

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | | | | | | |
|---|---|---|---|---|---|---|
| | **Sample ID** | L1568180-18 | | | | |
| | **Description** | SEDIMENT | | | | |
| | **Sampled Date** | 15-JAN-15 | | | | |
| | **Sampled Time** | | | | | |
| | **Client ID** | 8C-C | | | | |
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Physical Tests** | Grain Size Curve | | | | | |
| | Moisture (%) | | | | | |
| | pH (1:2 soil:water) (pH) | 6.41 | | | | |
| **Organic / Inorganic Carbon** | Total Organic Carbon (%) | | | | | |
| **Metals** | Antimony (Sb) (mg/kg) | 1.25 | | | | |
| | Arsenic (As) (mg/kg) | 5.53 | | | | |
| | Barium (Ba) (mg/kg) | 133 | | | | |
| | Beryllium (Be) (mg/kg) | 0.51 | | | | |
| | Cadmium (Cd) (mg/kg) | 19.7 | | | | |
| | Chromium (Cr) (mg/kg) | 111 | | | | |
| | Cobalt (Co) (mg/kg) | 15.2 | | | | |
| | Copper (Cu) (mg/kg) | 88.4 | | | | |
| | Lead (Pb) (mg/kg) | 68.2 | | | | |
| | Mercury (Hg) (mg/kg) | 0.124 | | | | |
| | Molybdenum (Mo) (mg/kg) | 1.94 | | | | |
| | Nickel (Ni) (mg/kg) | 37.3 | | | | |
| | Selenium (Se) (mg/kg) | 0.69 | | | | |
| | Silver (Ag) (mg/kg) | 0.35 | | | | |
| | Thallium (Tl) (mg/kg) | 0.097 | | | | |
| | Tin (Sn) (mg/kg) | 7.3 | | | | |
| | Uranium (U) (mg/kg) | 1.34 | | | | |
| | Vanadium (V) (mg/kg) | 80.3 | | | | |
| | Zinc (Zn) (mg/kg) | 603 | | | | |
| **Polycyclic Aromatic Hydrocarbons** | Acenaphthene (mg/kg) | | | | | |
| | Acenaphthylene (mg/kg) | | | | | |
| | Anthracene (mg/kg) | | | | | |
| | Benz(a)anthracene (mg/kg) | | | | | |
| | Benzo(a)pyrene (mg/kg) | | | | | |
| | Benzo(b)fluoranthene (mg/kg) | | | | | |
| | Benzo(g,h,i)perylene (mg/kg) | | | | | |
| | Benzo(k)fluoranthene (mg/kg) | | | | | |
| | Chrysene (mg/kg) | | | | | |
| | Dibenz(a,h)anthracene (mg/kg) | | | | | |
| | Fluoranthene (mg/kg) | | | | | |
| | Fluorene (mg/kg) | | | | | |

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | Sample ID<br>Description<br>Sampled Date<br>Sampled Time<br>Client ID | L1568180-1<br>SEDIMENT<br>15-JAN-15<br><br>1G | L1568180-3<br>SEDIMENT<br>15-JAN-15<br><br>2C-B | L1568180-5<br>SEDIMENT<br>15-JAN-15<br><br>3C-C | L1568180-7<br>SEDIMENT<br>15-JAN-15<br><br>4C-C | L1568180-9<br>SEDIMENT<br>15-JAN-15<br><br>4C-A |
|---|---|---|---|---|---|---|
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | Indeno(1,2,3-c,d)pyrene (mg/kg) | | | | 0.052 | 0.053 |
| | 2-Methylnaphthalene (mg/kg) | | | | <0.050 | <0.050 |
| | Naphthalene (mg/kg) | | | | <0.050 | <0.050 |
| | Phenanthrene (mg/kg) | | | | 0.099 | 0.067 |
| | Pyrene (mg/kg) | | | | 0.116 | 0.101 |
| | Surrogate: Acenaphthene d10 (%) | | | | 92.7 | 95.0 |
| | Surrogate: Chrysene d12 (%) | | | | 107.5 | 111.7 |
| | Surrogate: Naphthalene d8 (%) | | | | 85.2 | 88.9 |
| | Surrogate: Phenanthrene d10 (%) | | | | 109.0 | 107.8 |

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | **Sample ID** | L1568180-10 | L1568180-12 | L1568180-13 | L1568180-15 | L1568180-16 |
|---|---|---|---|---|---|---|
| | **Description** | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT | SEDIMENT |
| | **Sampled Date** | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 | 15-JAN-15 |
| | **Sampled Time** | | | | | |
| | **Client ID** | 5C-C | 6C-C | 6C-B | 7C-C | 7C-A |
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | Indeno(1,2,3-c,d)pyrene (mg/kg) | | | 0.398 | | |
| | 2-Methylnaphthalene (mg/kg) | | | <0.050 | | |
| | Naphthalene (mg/kg) | | | <0.050 | | |
| | Phenanthrene (mg/kg) | | | 0.352 | | |
| | Pyrene (mg/kg) | | | 0.728 | | |
| | Surrogate: Acenaphthene d10 (%) | | | 92.8 | | |
| | Surrogate: Chrysene d12 (%) | | | 105.4 | | |
| | Surrogate: Naphthalene d8 (%) | | | 85.0 | | |
| | Surrogate: Phenanthrene d10 (%) | | | 103.7 | | |

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

# ALS ENVIRONMENTAL ANALYTICAL REPORT

| | Sample ID | L1568180-18 | | | | |
|---|---|---|---|---|---|---|
| | Description | SEDIMENT | | | | |
| | Sampled Date | 15-JAN-15 | | | | |
| | Sampled Time | | | | | |
| | Client ID | 8C-C | | | | |
| **Grouping** | **Analyte** | | | | | |
| **SOIL** | | | | | | |
| **Polycyclic Aromatic Hydrocarbons** | Indeno(1,2,3-c,d)pyrene (mg/kg) | | | | | |
| | 2-Methylnaphthalene (mg/kg) | | | | | |
| | Naphthalene (mg/kg) | | | | | |
| | Phenanthrene (mg/kg) | | | | | |
| | Pyrene (mg/kg) | | | | | |
| | Surrogate: Acenaphthene d10 (%) | | | | | |
| | Surrogate: Chrysene d12 (%) | | | | | |
| | Surrogate: Naphthalene d8 (%) | | | | | |
| | Surrogate: Phenanthrene d10 (%) | | | | | |

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

# Reference Information

**QC Samples with Qualifiers & Comments:**

| QC Type Description | Parameter | Qualifier | Applies to Sample Number(s) |
|---|---|---|---|
| Duplicate | Chromium (Cr) | DUP-H | L1568180-18 |

**Qualifiers for Individual Parameters Listed:**

| Qualifier | Description |
|---|---|
| DUP-H | Duplicate results outside ALS DQO, due to sample heterogeneity. |

## Test Method References:

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **C-TOT-ORG-LECO-SK** | Soil | Organic Carbon by combustion method | SSSA (1996) p. 973 |

Total Organic Carbon (C-TOT-ORG-LECO-SK, C-TOT-ORG-SK)

Total C and inorganic C are determined on separate samples. The total C is determined by combustion and thermal conductivity detection, while inorganic C is determined by weight lass after addition of hydrochloric acid. Organic C is calculated by the difference between these two determinations.

Reference for Total C:
Nelson, D.W. and Sommers, L.E. 1996. Total Carbon, organic carbon and organic matter. P. 961-1010 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

Reference for Inorganic C:
Loeppert, R.H. and Suarez, D.L. 1996. Gravimetric Method for Loss of Carbon Dioxide. P. 455-456 In: J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **GRAIN SIZE-SK** | Soil | Grain Size Analysis | SSIR-51 METHOD 3.2.1 |

Particle size distribution is determined by a combination of techniques. Dry sieving is performed for coarse particles, wet sieving for sand particles and the pipette sedimentation method for clay particles.

Reference:

Burt, R. (2009). Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 5. Method 3.2.1.2.2. United States Department of Agriculture Natural Resources Conservation Service.

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **HG-200.2-CVAF-VA** | Soil | Mercury in Soil by CVAFS | EPA 200.2/1631E (mod) |

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CVAFS.

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **MET-200.2-CCMS-VA** | Soil | Metals in Soil by CRC ICPMS | EPA 200.2/6020A (mod) |

Soil samples are digested with nitric and hydrochloric acids, followed by analysis by CRC ICPMS.

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. This method does not dissolve all silicate materials and may result in a partial extraction. depending on the sample matrix, for some metals, including, but not limited to Al, Ba, Be, Cr, Sr, Ti, Tl, and V.

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **MOISTURE-VA** | Soil | Moisture content | ASTM D2974-00 Method A |

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **PAH-TMB-H/A-MS-VA** | Soil | PAH - Rotary Extraction (Hexane/Acetone) | EPA 3570/8270 |

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3570 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

| ALS Test Code | Matrix | Test Description | Method Reference** |
|---|---|---|---|
| **PH-1:2-VA** | Soil | pH in Soil (1:2 Soil:Water Extraction) | BC WLAP METHOD: PH, ELECTROMETRIC, SOIL |

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the dried (at <60°C) and sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water. The pH of the solution is then measured using a standard pH probe.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

*The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:*

# Reference Information

| Laboratory Definition Code | Laboratory Location |
|---|---|
| SK | ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA |
| VA | ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA |

**Chain of Custody Numbers:**

10-192650 10-192652

**GLOSSARY OF REPORT TERMS**

*Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.*
*mg/kg - milligrams per kilogram based on dry weight of sample.*
*mg/kg wwt - milligrams per kilogram based on wet weight of sample.*
*mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.*
*mg/L - milligrams per litre.*
*< - Less than.*
*D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).*
*N/A - Result not available. Refer to qualifier code and definition for explanation.*

*Test results reported relate only to the samples as received by the laboratory.*
*UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.*
*Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.*

# Quality Control Report

Client: SLR CONSULTING (CANADA) LTD.
# 6 - 40 Cadillac Avenue
Victoria BC V8Z 1T2
Contact: John Wiens

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **C-TOT-ORG-LECO-SK** | **Soil** | | | | | | | |
| **Batch R3137083** | | | | | | | | |
| **WG2029212-2 IRM** | | **08-109_SOIL** | | | | | | |
| Total Organic Carbon | | | 0.98 | | % | | 0.77-1.43 | 22-JAN-15 |
| **WG2029212-3 MB** | | | | | | | | |
| Total Organic Carbon | | | <0.10 | | % | | 0.1 | 22-JAN-15 |
| **HG-200.2-CVAF-VA** | **Soil** | | | | | | | |
| **Batch R3138207** | | | | | | | | |
| **WG2030529-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Mercury (Hg) | | | 104.0 | | % | | 70-130 | 24-JAN-15 |
| **WG2030529-5 CRM** | | **VA-CANMET-TILL1** | | | | | | |
| Mercury (Hg) | | | 102.6 | | % | | 70-130 | 24-JAN-15 |
| **WG2030529-3 LCS** | | | | | | | | |
| Mercury (Hg) | | | 98.2 | | % | | 70-130 | 24-JAN-15 |
| **WG2030529-1 MB** | | | | | | | | |
| Mercury (Hg) | | | <0.0050 | | mg/kg | | 0.005 | 24-JAN-15 |
| **Batch R3138336** | | | | | | | | |
| **WG2030545-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Mercury (Hg) | | | 102.3 | | % | | 70-130 | 25-JAN-15 |
| **WG2030545-5 CRM** | | **VA-CANMET-TILL1** | | | | | | |
| Mercury (Hg) | | | 101.1 | | % | | 70-130 | 25-JAN-15 |
| **WG2030545-3 LCS** | | | | | | | | |
| Mercury (Hg) | | | 96.2 | | % | | 70-130 | 25-JAN-15 |
| **WG2030545-1 MB** | | | | | | | | |
| Mercury (Hg) | | | <0.0050 | | mg/kg | | 0.005 | 25-JAN-15 |
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138038** | | | | | | | | |
| **WG2030529-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Antimony (Sb) | | | 99.0 | | % | | 70-130 | 23-JAN-15 |
| Arsenic (As) | | | 99.9 | | % | | 70-130 | 23-JAN-15 |
| Barium (Ba) | | | 93.0 | | % | | 70-130 | 23-JAN-15 |
| Beryllium (Be) | | | 103.0 | | % | | 70-130 | 23-JAN-15 |
| Cadmium (Cd) | | | 101.0 | | % | | 70-130 | 23-JAN-15 |
| Chromium (Cr) | | | 101.1 | | % | | 70-130 | 23-JAN-15 |
| Cobalt (Co) | | | 99.3 | | % | | 70-130 | 23-JAN-15 |
| Copper (Cu) | | | 99.4 | | % | | 70-130 | 23-JAN-15 |
| Lead (Pb) | | | 101.9 | | % | | 70-130 | 23-JAN-15 |
| Molybdenum (Mo) | | | 97.1 | | % | | 70-130 | 23-JAN-15 |
| Nickel (Ni) | | | 99.1 | | % | | 70-130 | 23-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138038** | | | | | | | | |
| **WG2030529-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Selenium (Se) | | | 96.2 | | % | | 70-130 | 23-JAN-15 |
| Silver (Ag) | | | 94.6 | | % | | 70-130 | 23-JAN-15 |
| Thallium (Tl) | | | 107.9 | | % | | 70-130 | 23-JAN-15 |
| Tin (Sn) | | | 95.4 | | % | | 70-130 | 23-JAN-15 |
| Vanadium (V) | | | 102.2 | | % | | 70-130 | 23-JAN-15 |
| Zinc (Zn) | | | 98.5 | | % | | 70-130 | 23-JAN-15 |
| **WG2030529-5 CRM** | | **VA-CANMET-TILL1** | | | | | | |
| Antimony (Sb) | | | 102.0 | | % | | 70-130 | 23-JAN-15 |
| Arsenic (As) | | | 106.8 | | % | | 70-130 | 23-JAN-15 |
| Barium (Ba) | | | 101.6 | | % | | 70-130 | 23-JAN-15 |
| Beryllium (Be) | | | 0.52 | | mg/kg | | 0.34-0.74 | 23-JAN-15 |
| Cadmium (Cd) | | | 102.0 | | % | | 70-130 | 23-JAN-15 |
| Chromium (Cr) | | | 110.7 | | % | | 70-130 | 23-JAN-15 |
| Cobalt (Co) | | | 105.4 | | % | | 70-130 | 23-JAN-15 |
| Copper (Cu) | | | 100.9 | | % | | 70-130 | 23-JAN-15 |
| Lead (Pb) | | | 95.3 | | % | | 70-130 | 23-JAN-15 |
| Molybdenum (Mo) | | | 0.70 | | mg/kg | | 0.24-1.24 | 23-JAN-15 |
| Nickel (Ni) | | | 105.2 | | % | | 70-130 | 23-JAN-15 |
| Selenium (Se) | | | 0.30 | | mg/kg | | 0.12-0.52 | 23-JAN-15 |
| Silver (Ag) | | | 0.22 | | mg/kg | | 0.12-0.32 | 23-JAN-15 |
| Thallium (Tl) | | | 0.137 | | mg/kg | | 0.075-0.175 | 23-JAN-15 |
| Tin (Sn) | | | 1.1 | | mg/kg | | 0-3 | 23-JAN-15 |
| Uranium (U) | | | 111.4 | | % | | 70-130 | 23-JAN-15 |
| Vanadium (V) | | | 111.2 | | % | | 70-130 | 23-JAN-15 |
| Zinc (Zn) | | | 103.4 | | % | | 70-130 | 23-JAN-15 |
| **WG2030529-3 LCS** | | | | | | | | |
| Antimony (Sb) | | | 98.2 | | % | | 70-130 | 23-JAN-15 |
| Arsenic (As) | | | 98.8 | | % | | 70-130 | 23-JAN-15 |
| Barium (Ba) | | | 94.9 | | % | | 70-130 | 23-JAN-15 |
| Beryllium (Be) | | | 96.0 | | % | | 70-130 | 23-JAN-15 |
| Cadmium (Cd) | | | 97.9 | | % | | 70-130 | 23-JAN-15 |
| Chromium (Cr) | | | 96.8 | | % | | 70-130 | 23-JAN-15 |
| Cobalt (Co) | | | 96.1 | | % | | 70-130 | 23-JAN-15 |
| Copper (Cu) | | | 94.6 | | % | | 70-130 | 23-JAN-15 |
| Lead (Pb) | | | 99.1 | | % | | 70-130 | 23-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138038** | | | | | | | | |
| **WG2030529-3 LCS** | | | | | | | | |
| Molybdenum (Mo) | | | 94.8 | | % | | 70-130 | 23-JAN-15 |
| Nickel (Ni) | | | 97.4 | | % | | 70-130 | 23-JAN-15 |
| Selenium (Se) | | | 100.1 | | % | | 70-130 | 23-JAN-15 |
| Silver (Ag) | | | 95.7 | | % | | 70-130 | 23-JAN-15 |
| Thallium (Tl) | | | 98.7 | | % | | 70-130 | 23-JAN-15 |
| Tin (Sn) | | | 97.1 | | % | | 70-130 | 23-JAN-15 |
| Uranium (U) | | | 100.1 | | % | | 70-130 | 23-JAN-15 |
| Vanadium (V) | | | 97.4 | | % | | 70-130 | 23-JAN-15 |
| Zinc (Zn) | | | 93.7 | | % | | 70-130 | 23-JAN-15 |
| **WG2030529-1 MB** | | | | | | | | |
| Antimony (Sb) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Arsenic (As) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Barium (Ba) | | | <0.50 | | mg/kg | | 0.5 | 23-JAN-15 |
| Beryllium (Be) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Cadmium (Cd) | | | <0.020 | | mg/kg | | 0.02 | 23-JAN-15 |
| Chromium (Cr) | | | <0.50 | | mg/kg | | 0.5 | 23-JAN-15 |
| Cobalt (Co) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Copper (Cu) | | | <0.50 | | mg/kg | | 0.5 | 23-JAN-15 |
| Lead (Pb) | | | <0.50 | | mg/kg | | 0.5 | 23-JAN-15 |
| Molybdenum (Mo) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Nickel (Ni) | | | <0.50 | | mg/kg | | 0.5 | 23-JAN-15 |
| Selenium (Se) | | | <0.20 | | mg/kg | | 0.2 | 23-JAN-15 |
| Silver (Ag) | | | <0.10 | | mg/kg | | 0.1 | 23-JAN-15 |
| Thallium (Tl) | | | <0.050 | | mg/kg | | 0.05 | 23-JAN-15 |
| Tin (Sn) | | | <2.0 | | mg/kg | | 2 | 23-JAN-15 |
| Uranium (U) | | | <0.050 | | mg/kg | | 0.05 | 23-JAN-15 |
| Vanadium (V) | | | <0.20 | | mg/kg | | 0.2 | 23-JAN-15 |
| Zinc (Zn) | | | <2.0 | | mg/kg | | 2 | 23-JAN-15 |
| **Batch R3138770** | | | | | | | | |
| **WG2030545-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Antimony (Sb) | | | 102.3 | | % | | 70-130 | 25-JAN-15 |
| Arsenic (As) | | | 99.7 | | % | | 70-130 | 25-JAN-15 |
| Barium (Ba) | | | 98.3 | | % | | 70-130 | 25-JAN-15 |
| Beryllium (Be) | | | 102.8 | | % | | 70-130 | 25-JAN-15 |
| Cadmium (Cd) | | | 93.6 | | % | | 70-130 | 25-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138770** | | | | | | | | |
| **WG2030545-4 CRM** | | **VA-NRC-STSD1** | | | | | | |
| Chromium (Cr) | | | 99.0 | | % | | 70-130 | 25-JAN-15 |
| Cobalt (Co) | | | 99.0 | | % | | 70-130 | 25-JAN-15 |
| Copper (Cu) | | | 98.0 | | % | | 70-130 | 25-JAN-15 |
| Lead (Pb) | | | 99.1 | | % | | 70-130 | 25-JAN-15 |
| Molybdenum (Mo) | | | 94.8 | | % | | 70-130 | 25-JAN-15 |
| Nickel (Ni) | | | 98.2 | | % | | 70-130 | 25-JAN-15 |
| Selenium (Se) | | | 99.0 | | % | | 70-130 | 25-JAN-15 |
| Silver (Ag) | | | 98.1 | | % | | 70-130 | 25-JAN-15 |
| Thallium (Tl) | | | 98.4 | | % | | 70-130 | 25-JAN-15 |
| Tin (Sn) | | | 98.6 | | % | | 70-130 | 25-JAN-15 |
| Vanadium (V) | | | 101.7 | | % | | 70-130 | 25-JAN-15 |
| Zinc (Zn) | | | 98.9 | | % | | 70-130 | 25-JAN-15 |
| **WG2030545-5 CRM** | | **VA-CANMET-TILL1** | | | | | | |
| Antimony (Sb) | | | 99.6 | | % | | 70-130 | 25-JAN-15 |
| Arsenic (As) | | | 102.2 | | % | | 70-130 | 25-JAN-15 |
| Barium (Ba) | | | 100.5 | | % | | 70-130 | 25-JAN-15 |
| Beryllium (Be) | | | 0.51 | | mg/kg | | 0.34-0.74 | 25-JAN-15 |
| Cadmium (Cd) | | | 93.3 | | % | | 70-130 | 25-JAN-15 |
| Chromium (Cr) | | | 98.0 | | % | | 70-130 | 25-JAN-15 |
| Cobalt (Co) | | | 97.4 | | % | | 70-130 | 25-JAN-15 |
| Copper (Cu) | | | 95.4 | | % | | 70-130 | 25-JAN-15 |
| Lead (Pb) | | | 87.4 | | % | | 70-130 | 25-JAN-15 |
| Molybdenum (Mo) | | | 0.64 | | mg/kg | | 0.24-1.24 | 25-JAN-15 |
| Nickel (Ni) | | | 99.3 | | % | | 70-130 | 25-JAN-15 |
| Selenium (Se) | | | 0.29 | | mg/kg | | 0.12-0.52 | 25-JAN-15 |
| Silver (Ag) | | | 0.23 | | mg/kg | | 0.12-0.32 | 25-JAN-15 |
| Thallium (Tl) | | | 0.111 | | mg/kg | | 0.075-0.175 | 25-JAN-15 |
| Tin (Sn) | | | 1.0 | | mg/kg | | 0-3 | 25-JAN-15 |
| Uranium (U) | | | 107.8 | | % | | 70-130 | 25-JAN-15 |
| Vanadium (V) | | | 98.9 | | % | | 70-130 | 25-JAN-15 |
| Zinc (Zn) | | | 95.4 | | % | | 70-130 | 25-JAN-15 |
| **WG2030545-1 MB** | | | | | | | | |
| Antimony (Sb) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Arsenic (As) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Barium (Ba) | | | <0.50 | | mg/kg | | 0.5 | 25-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138770** | | | | | | | | |
| **WG2030545-1 MB** | | | | | | | | |
| Beryllium (Be) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Cadmium (Cd) | | | <0.020 | | mg/kg | | 0.02 | 25-JAN-15 |
| Chromium (Cr) | | | <0.50 | | mg/kg | | 0.5 | 25-JAN-15 |
| Cobalt (Co) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Copper (Cu) | | | <0.50 | | mg/kg | | 0.5 | 25-JAN-15 |
| Lead (Pb) | | | <0.50 | | mg/kg | | 0.5 | 25-JAN-15 |
| Molybdenum (Mo) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Nickel (Ni) | | | <0.50 | | mg/kg | | 0.5 | 25-JAN-15 |
| Selenium (Se) | | | <0.20 | | mg/kg | | 0.2 | 25-JAN-15 |
| Silver (Ag) | | | <0.10 | | mg/kg | | 0.1 | 25-JAN-15 |
| Thallium (Tl) | | | <0.050 | | mg/kg | | 0.05 | 25-JAN-15 |
| Tin (Sn) | | | <2.0 | | mg/kg | | 2 | 25-JAN-15 |
| Uranium (U) | | | <0.050 | | mg/kg | | 0.05 | 25-JAN-15 |
| Vanadium (V) | | | <0.20 | | mg/kg | | 0.2 | 25-JAN-15 |
| Zinc (Zn) | | | <2.0 | | mg/kg | | 2 | 25-JAN-15 |
| **Batch R3138832** | | | | | | | | |
| **WG2030545-3 LCS** | | | | | | | | |
| Antimony (Sb) | | | 96.9 | | % | | 70-130 | 26-JAN-15 |
| Arsenic (As) | | | 100.1 | | % | | 70-130 | 26-JAN-15 |
| Barium (Ba) | | | 106.1 | | % | | 70-130 | 26-JAN-15 |
| Beryllium (Be) | | | 93.5 | | % | | 70-130 | 26-JAN-15 |
| Cadmium (Cd) | | | 97.7 | | % | | 70-130 | 26-JAN-15 |
| Chromium (Cr) | | | 95.1 | | % | | 70-130 | 26-JAN-15 |
| Cobalt (Co) | | | 99.2 | | % | | 70-130 | 26-JAN-15 |
| Copper (Cu) | | | 97.9 | | % | | 70-130 | 26-JAN-15 |
| Lead (Pb) | | | 97.0 | | % | | 70-130 | 26-JAN-15 |
| Molybdenum (Mo) | | | 94.1 | | % | | 70-130 | 26-JAN-15 |
| Nickel (Ni) | | | 99.1 | | % | | 70-130 | 26-JAN-15 |
| Selenium (Se) | | | 99.8 | | % | | 70-130 | 26-JAN-15 |
| Silver (Ag) | | | 102.2 | | % | | 70-130 | 26-JAN-15 |
| Thallium (Tl) | | | 90.0 | | % | | 70-130 | 26-JAN-15 |
| Tin (Sn) | | | 96.8 | | % | | 70-130 | 26-JAN-15 |
| Uranium (U) | | | 90.1 | | % | | 70-130 | 26-JAN-15 |
| Vanadium (V) | | | 100.8 | | % | | 70-130 | 26-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **MET-200.2-CCMS-VA** | **Soil** | | | | | | | |
| **Batch R3138832** | | | | | | | | |
| **WG2030545-3 LCS** | | | | | | | | |
| Zinc (Zn) | | | 91.2 | | % | | 70-130 | 26-JAN-15 |
| **MOISTURE-VA** | **Soil** | | | | | | | |
| **Batch R3137528** | | | | | | | | |
| **WG2030532-2 LCS** | | | | | | | | |
| Moisture | | | 100.0 | | % | | 90-110 | 22-JAN-15 |
| **WG2030532-1 MB** | | | | | | | | |
| Moisture | | | <0.25 | | % | | 0.25 | 22-JAN-15 |
| **PAH-TMB-H/A-MS-VA** | **Soil** | | | | | | | |
| **Batch R3138053** | | | | | | | | |
| **WG2030531-4 IRM** | | **ALS PAH1 RM** | | | | | | |
| Acenaphthene | | | 95.3 | | % | | 60-130 | 24-JAN-15 |
| Acenaphthylene | | | 100.3 | | % | | 60-130 | 24-JAN-15 |
| Anthracene | | | 98.4 | | % | | 60-130 | 24-JAN-15 |
| Benz(a)anthracene | | | 95.4 | | % | | 60-130 | 24-JAN-15 |
| Benzo(a)pyrene | | | 96.2 | | % | | 60-130 | 24-JAN-15 |
| Benzo(b)fluoranthene | | | 103.0 | | % | | 60-130 | 24-JAN-15 |
| Benzo(g,h,i)perylene | | | 108.4 | | % | | 60-130 | 24-JAN-15 |
| Benzo(k)fluoranthene | | | 103.2 | | % | | 60-130 | 24-JAN-15 |
| Chrysene | | | 107.9 | | % | | 60-130 | 24-JAN-15 |
| Dibenz(a,h)anthracene | | | 97.8 | | % | | 60-130 | 24-JAN-15 |
| Fluoranthene | | | 99.3 | | % | | 60-130 | 24-JAN-15 |
| Fluorene | | | 89.3 | | % | | 60-130 | 24-JAN-15 |
| Indeno(1,2,3-c,d)pyrene | | | 102.5 | | % | | 60-130 | 24-JAN-15 |
| 2-Methylnaphthalene | | | 96.4 | | % | | 60-130 | 24-JAN-15 |
| Naphthalene | | | 94.2 | | % | | 50-130 | 24-JAN-15 |
| Phenanthrene | | | 103.5 | | % | | 60-130 | 24-JAN-15 |
| Pyrene | | | 98.4 | | % | | 60-130 | 24-JAN-15 |
| **WG2030531-1 MB** | | | | | | | | |
| Acenaphthene | | | <0.0050 | | mg/kg | | 0.005 | 24-JAN-15 |
| Acenaphthylene | | | <0.0050 | | mg/kg | | 0.005 | 24-JAN-15 |
| Anthracene | | | <0.0040 | | mg/kg | | 0.004 | 24-JAN-15 |
| Benz(a)anthracene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Benzo(a)pyrene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Benzo(b)fluoranthene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |

| Test | Matrix | Reference | Result | Qualifier | Units | RPD | Limit | Analyzed |
|---|---|---|---|---|---|---|---|---|
| **PAH-TMB-H/A-MS-VA** | **Soil** | | | | | | | |
| **Batch R3138053** | | | | | | | | |
| **WG2030531-1 MB** | | | | | | | | |
| Benzo(g,h,i)perylene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Benzo(k)fluoranthene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Chrysene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Dibenz(a,h)anthracene | | | <0.0050 | | mg/kg | | 0.005 | 24-JAN-15 |
| Fluoranthene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Fluorene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Indeno(1,2,3-c,d)pyrene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| 2-Methylnaphthalene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Naphthalene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Phenanthrene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Pyrene | | | <0.010 | | mg/kg | | 0.01 | 24-JAN-15 |
| Surrogate: Naphthalene d8 | | | 94.7 | | % | | 50-130 | 24-JAN-15 |
| Surrogate: Acenaphthene d10 | | | 94.3 | | % | | 60-130 | 24-JAN-15 |
| Surrogate: Phenanthrene d10 | | | 96.5 | | % | | 60-130 | 24-JAN-15 |
| Surrogate: Chrysene d12 | | | 93.3 | | % | | 60-130 | 24-JAN-15 |

# Quality Control Report

**Legend:**

| | |
|---|---|
| Limit | ALS Control Limit (Data Quality Objectives) |
| DUP | Duplicate |
| RPD | Relative Percent Difference |
| N/A | Not Available |
| LCS | Laboratory Control Sample |
| SRM | Standard Reference Material |
| MS | Matrix Spike |
| MSD | Matrix Spike Duplicate |
| ADE | Average Desorption Efficiency |
| MB | Method Blank |
| IRM | Internal Reference Material |
| CRM | Certified Reference Material |
| CCV | Continuing Calibration Verification |
| CVS | Calibration Verification Standard |
| LCSD | Laboratory Control Sample Duplicate |

**Sample Parameter Qualifier Definitions:**

| Qualifier | Description |
|---|---|
| DUP-H | Duplicate results outside ALS DQO, due to sample heterogeneity. |
| J | Duplicate results and limits are expressed in terms of absolute difference. |
| RPD-NA | Relative Percent Difference Not Available due to result(s) being less than detection limit. |

**Hold Time Exceedances:**

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

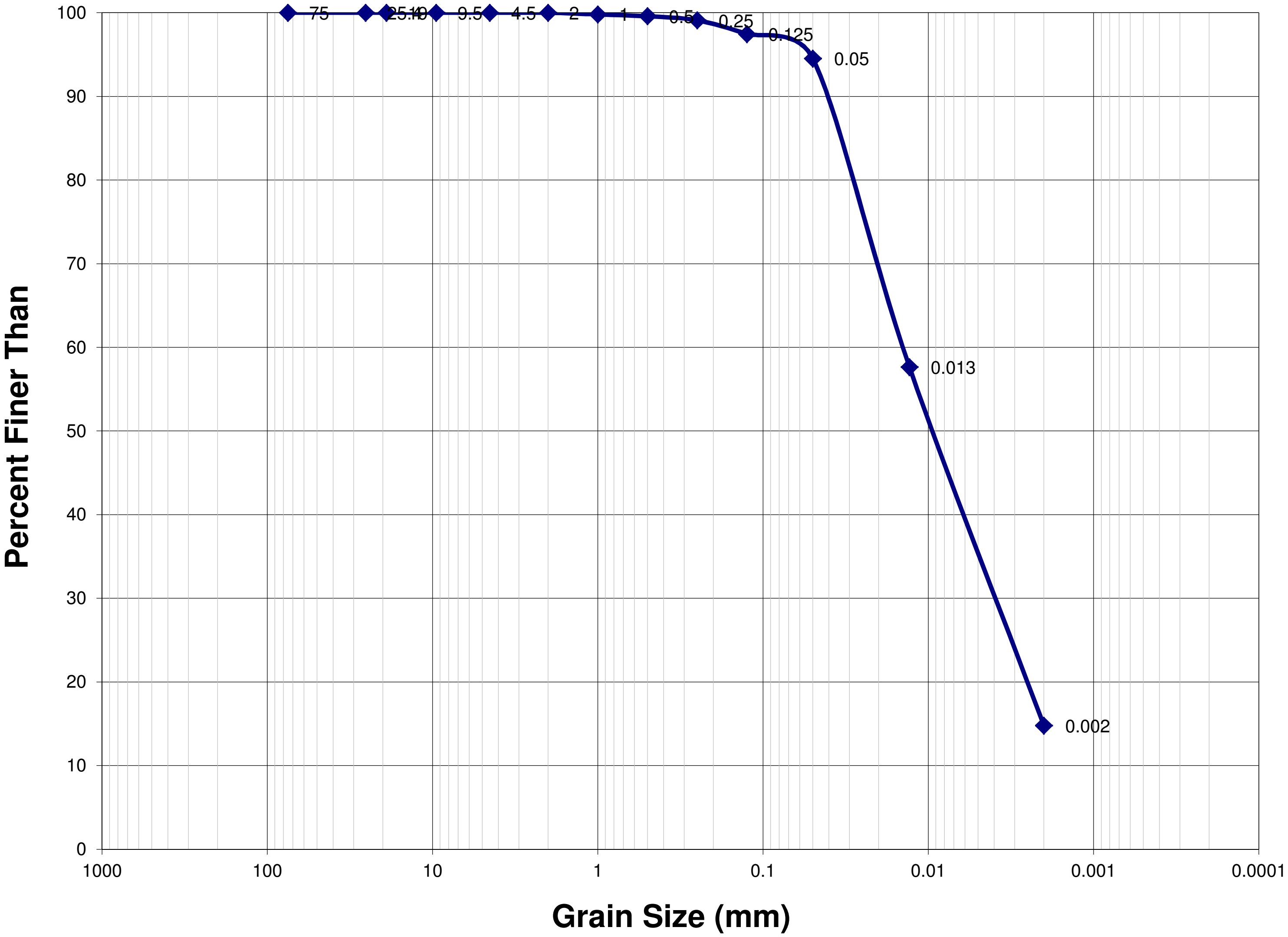
Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

**ALS Laboratory Group**
ANALYTICAL CHEMISTRY & TESTING SERVICES
**Environmental Division**

819-58th Street, Saskatoon, SK  S7K 6X5

**Client Name:** SLR CONSULTING (CANAD
**Project:**
**Sample ID:** 6C-B
**Lab ID:** L1568180-13

# Particle Size Distribution Curve



## Summary of Results

**Unified Soil Classification System (USCS)**

| Size Class | Size Range | Wt. (%) |
|---|---|---|
| Cobbles | > 3" | 0 |
| Gravel | 4.75mm - 3" | 0 |
| Coarse Sand | 2.0mm - 4.75mm | 0 |
| Medium Sand | 0.425mm - 2.0mm | 0 |
| Fine Sand | 0.075mm - 0.425mm | 4 |
| Fines | < 0.075mm | 95 |

**Canadian Soil Survey Committee (CSSC)**

| Size Class | Size Range | Wt. (%) |
|---|---|---|
| Cobbles | > 3" | 0 |
| Gravel | 2mm - 3" | 0 |
| Sand | 0.05mm - 2mm | 5 |
| Silt | 0.002mm - 0.05mm | 80 |
| Clay | < 0.002mm | 15 |

Texture   Silt loam

Method Reference: Can. Soc. Soil Sci. (1993) Method 47.2

**10-** 192650

ALS Environmental

# Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878
www.alsglobal.com

Page 1 of 2

**Report To** John Wiens
Company: SLR Consulting (Canada) Ltd
Contact: John Wiens
Address: 6-40 Cadillac Ave, Victoria, B.C. V8Z1T2, CANADA
Phone: 250-475-9595 Fax: 250-475-9596

**Report Format / Distribution**
Standard: X Other (specify):
Select: PDF X Excel X Digital Fax
Email 1: jwiens@slrconsulting.com
Email 2: bmckinnon@slrconsulting.com

**Service Request:** (Rush subject to availability - Contact ALS to confirm TAT)
☒ Regular (Standard Turnaround Times - Business Days)
☐ Priority (2-4 Business Days)-50% surcharge - Contact ALS to confirm TAT
☐ Emergency (1-2 Business Days)-100% Surcharge - Contact ALS to confirm TAT
☐ Same Day or Weekend Emergency - Contact ALS to confirm TAT

**Invoice To** Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No
Company:
Contact:
Address:
Phone:

L1568180-COFC

**Lab Work Ord**

**Client / Project Information**
Job #: 205.03696.00000
PO / AFE:
LSD:
Quote #:
**ALS Contact:** Erin Bolster
**Sampler:** BAM

**Analysis Request**
(Indicate Filtered or Preserved, F/P)

| Sample # | Sample Identification (This description will appear on the report) | Date (dd-mmm-yy) | Time (hh:mm) | Sample Type | Metals | PAH | Total Organic Carbon (TOC) | Grain Size (GS) | HOLD | Number of Containers |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1G | 15-Jan-15 | — | Sediment | X | | | | | 3 |
| | 2C-C | ↓ | — | ↓ | | | | | X | 2 |
| | 2C-B | | — | | X | | | | | 2 |
| | 2C-A | | — | | | | | | X | 2 |
| | 3C-C | | — | | X | | | | | 2 |
| | 3C-~~B~~A | | — | | | | | | X | 2 |
| | 4C-C | | — | | X | X | | | | 1 |
| | 4C-B | | — | | | | | | X | 2 |
| | 4C-A | | — | | X | X | | | | 2 |
| | 5C-C | | — | | X | | | | | 2 |
| | 5C-A | | — | | | | | | X | 2 |
| | 6C-C | ↓ | — | ↓ | X | | | | | 2 |

**Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details**

**Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.**

**By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.**

| SHIPMENT RELEASE (client use) | | | SHIPMENT RECEPTION (lab use only) | | | | SHIPMENT VERIFICATION (lab use only) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Released by: Ben McKinnon | Date: 16-01-15 | Time: 1600 | Received by: Doren | Date: Jan 17 | Time: 1155 | Temperature: 4 °C | Verified by: | Date: | Time: | Observations: Yes / No ? If Yes add SIF |

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

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**10-** 192652

ALS Environmental

## Chain of Custody / Analytical Request Form

Canada Toll Free: 1 800 668 9878

www.alsglobal.com

Page 2 of 2

**Report To** John wiens
Company: SLR Consulting (Canada) Ltd
Contact: John wiens
Address: 6-40 Cadillac Ave, Victoria, BC.
V8Z 1T2, CANADA
Phone: 250-475-9595 Fax: 250-475-9596

**Invoice To** Same as Report ? (circle) [✓ Yes] or No (if No, provide details)
Copy of Invoice with Report? (circle) [✓ Yes] or No
Company:
Contact:
Address:
Phone:

L1568180-COFC

**Lab Work Orde**

**Report Format / Distribution**
Standard: ☒ Other (specify):
Select: PDF ☒ Excel ☒ Digital Fax
Email 1: jwiens@slrconsulting.com
Email 2: bmckinnon@slrconsulting.com

**Client / Project Information**
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LSD:
Quote #:

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**Sampler:** BAM

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**Analysis Request**

(Indicate Filtered or Preserved, F/P)

| Sample # | Sample Identification (This description will appear on the report) | Date (dd-mmm-yy) | Time (hh:mm) | Sample Type | Metals | PAH | Total Organic Carbon (TOC) | Grain Size (GS) | Hold | | | | | | | | Number of Containers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6C-B | 15-Jan-15 | — | Sediment. | X | X | X | X | | | | | | | | | 2 |
| | 6C-A | ↓ | — | ↓ | | | | | X | | | | | | | | 2 |
| | 7C-C | | — | | X | | | | | | | | | | | | 2 |
| | 7C-A | | — | | X | | | | | | | | | | | | 2 |
| | 8G | | — | | | | | | X | | | | | | | | 4 |
| | 8C-C | | — | | X | | | | | | | | | | | | 2 |
| | 8C-B | | — | | | | | | X | | | | | | | | 2 |
| | | | | | | | | | | | | | | | | | |
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**Special Instructions / Regulation with water or land use (CCME- Freshwater Aquatic Life/BC CSR-Commercial/AB Tier 1-Natural/ETC) / Hazardous Details**

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|---|---|---|---|---|---|---|---|---|---|---|
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REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

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**Calgary, AB**
134-12143 40 Street SE
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Fax:  (403) 263-7906

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Fax:  (902) 420-9703

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Canada
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Fax:  (250) 374-8656

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Kelowna, BC  V1Y 2A3
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Fax:  (250) 763-7303

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Fax:  (905) 415-1019

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Fax:  (250) 390-5042

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Fax:  (250) 562-4458

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Fax   (306) 525-4691

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Saskatoon, SK  S7P 0B6
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Fax:  (306) 374-6077

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122-45 Wabana Court
Sydney, NS  B1P 6J1
Canada
Tel:   (902) 564-7911
Fax:  (902) 564-7910

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Fax:  (604) 738-2508

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Fax:  (250) 475-9596

**Winnipeg, MB**
Unit D, 1420 Clarence Avenue
Winnipeg, MB  R3T 1T6
Canada
Tel:   (204) 477-1848
Fax:  (204) 475-1649

**Whitehorse, YT**
6131 6 Avenue
Whitehorse, YT  Y1A 1N2
Canada
Tel:   (867) 689-2021

**Yellowknife, NT**
Unit 44, 5022 49 Street
Yellowknife, NT  X1A 3R8
Canada
Tel:   (867) 765-5695


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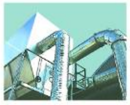
Waste Management


Planning & Development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Mining & Minerals


Infrastructure