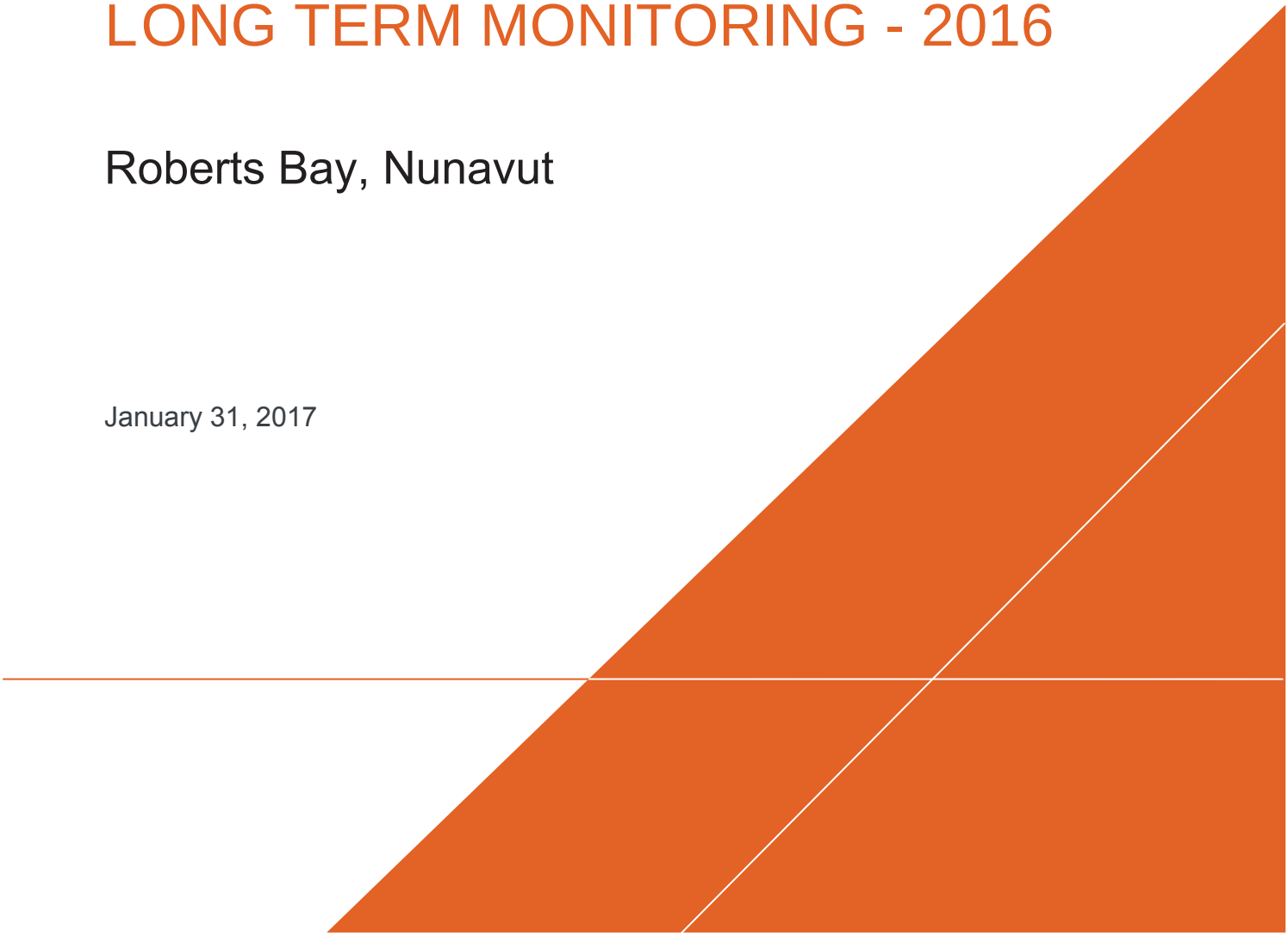
ARCADIS Design & Consultancy for natural and built assets

Indigenous and Northern Affairs Canada – Nunavut Regional Office

LONG TERM MONITORING - 2016

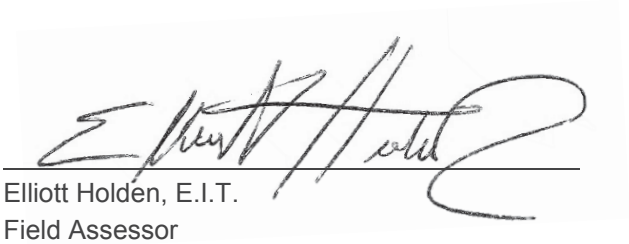
Roberts Bay, Nunavut

January 31, 2017



LONG TERM MONITORING - 2016

Roberts Bay, Nunavut



Elliott Holden, E.I.T.
Field Assessor

Prepared for:

Jean Allen

Contaminants Specialist

Indigenous and Northern Affairs Canada – Nunavut Regional Office

969 Qimugjuk Building, 2nd Floor

Iqaluit, Nunavut X0A 0H0

Gino Dalla Colletta, M.Sc., MPM, P.Geo. (ON)
Senior Reviewer

Prepared by:

Arcadis Canada Inc.

329 Churchill Avenue North

Suite 200

Ottawa, Ontario K1Z 5B8

Tel 613 721 0555

Fax 613 721 0029

Stephanie Joyce, M.Sc., C.Chem.
Project Manager

Our Ref.:

100347-001

Date:

January 31, 2017

CONTENTS

TABLES (in report)

TABLES (at end of report)

FIGURES

APPENDICES

Appendix A: Site Photographs (7 pages)

Appendix B: Thermistor Data (9 pages)

Appendix C: Field Notes

Appendix D: Laboratory Analytical Reports

Appendix E: Health and Safety Plan

ATTACHMENT

DVD Labelled “2016 Long Term Monitoring – Roberts Bay”

ACRONYMS AND ABBREVIATIONS

AMSRP	Abandoned Military Site Remediation Protocol
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CALA	Canadian Association for Laboratory Accreditation
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guidelines
DEW	Distant Early Warning
EC	Environment Canada
FCSAP	Federal Contaminated Sites Action Plan
FIGQG	Federal Interim Groundwater Quality Guidelines
GIS	Geographic Information System
GPS	Global Positioning System
HASP	Health and Safety Plan
INAC	Indigenous and Northern Affairs Canada
LTM	Long Term Monitoring
NHWL	Non-Hazardous Waste Landfill
PCBs	Polychlorinated Biphenyls
PHCs	Petroleum Hydrocarbons
POL	Petroleum, Oil and Lubricants
QA/QC	Quality Assurance/Quality Control
RDL	Reportable Detection Limit
RPD	Relative Percent Difference
ULA	Upper Limit of Acceptability

EXECUTIVE SUMMARY

Arcadis Canada Inc. (Arcadis) was retained by Indigenous and Northern Affairs Canada - Nunavut Regional Office (INAC) to conduct long-term monitoring (LTM) activities in 2016 at the former silver mine at Roberts Bay, Nunavut. The site is located on crown land approximately 115 km southwest of the hamlet of Cambridge Bay, south of Melville Sound on the north coast of mainland Nunavut, and approximately 1 km north of Roberts Lake.

The Roberts Bay site was an active silver mine in the early 1970s. Remedial activities were conducted between 2008 and 2010 and included the disposal of non-hazardous waste and contaminated soils in an on-site facility, the Solid Waste Management Facility landfill (SWMF). The SWMF was outfitted with three thermistors (string A, B and C) to monitor below grade temperatures.

The 2016 site visit by Arcadis is the fourth long-term monitoring event to take place since the completion of remediation activities. Visual and physical observations suggest that there has been little change at the site since the previous site visit in 2014. The SWMF is performing as designed and continues to contain the enclosed waste.

The dataloggers at thermistor string A, B and C were replaced during the 2016 site visit. The replacement dataloggers were installed with new batteries and desiccants. To access the dataloggers, the locks on the three datalogger housings had to be cut off. New locks were installed on the datalogger housings; however, the new locks were not of the model standard to INAC sites (i.e., 40 mm Guard universal-key padlocks, No. 834, key number 102). Arcadis recommends the locks on the three datalogger housings be replaced with the standard Guard locks during the next scheduled monitoring event.

Arcadis assessed that the data stored on the datalogger installed at string B was corrupt and recorded faulty temperatures on multiple beads at seemingly random timeframes. Corrupted data from string B was also encountered during the previous monitoring event in 2014. Arcadis was able to extract and assess non-corrupted data from the 2014, 2015 and 2016 data sets. Replacement of the datalogger at string B is expected to prevent further issues with corrupt data at thermistor string B in the future.

The most recent thermal monitoring data from thermistor strings indicates the waste in the SWMF continues to remain frozen year round. The maximum depth of the active layer remains less than the depth to the waste material contained within the SWMF. Thermal monitoring data has shown that the maximum depth of the active layer was decreasing from 2010 to 2014, however, this decreasing trend was broken in 2015 by a slight increase in the maximum active layer. Further thermal monitoring is required to assess if the increase in thickness of the active layer in 2015 is the beginning of a trend.

Historical thermistor data suggest that the maximum active layer depth often occurs in September at the SWMF. It was therefore assumed that the 2016 maximum active layer depth was not achieved by the time of the site visit.

In addition to physical and temperature observations, Arcadis collected surface water samples to assess the performance of the SWMF. Aluminum, cadmium, copper and/or iron concentrations reported in the surface water samples collected from one or more of the monitoring locations exceeded the Water License criteria and/or the Canadian Council of Ministers of the Environment (CCME) Freshwater Aquatic Life (FWAL) guidelines. To determine if these elevated metal concentrations are a natural occurrence or a result of leaching from the SWMF, further monitoring of surface water is required. Cobalt concentrations in sample ROB-6 also exceeded the upper limit of acceptability (ULA); however, this exceedance is likely a result of limited data available for the ULA calculation. The surface water sample collected from monitoring locations ROB-6 also reported colour results that exceeded the ULA. As sample ROB-6 was collected from a very shallow and vegetated waterbody, a high colour result is not unexpected. All other chemical parameters were measured at concentrations either below the laboratory reportable detection limit or below the calculated ULAs. At this time, the reported exceedances noted are not considered indicative of any deterioration in the integrity of the SWMF.

1 INTRODUCTION

Arcadis Canada Inc. (Arcadis) was retained by Indigenous and Northern Affairs Canada (INAC) to complete the fourth monitoring event (Year 7) of the Roberts Bay Mine Long Term Monitoring (LTM) Plan. This project was completed under INAC Standing Offer Number 4600000861, Order Number 4500352890.

This report describes the monitoring activities completed in 2016 at the former Roberts Bay silver mine, located on crown land approximately 115 km southwest of the Hamlet of Cambridge Bay, south of Melville Sound in the central Kitikmeot Region of Nunavut (Figure 1, located at the end of this report). It was prepared in accordance with the Arcadis proposal Number 566661-000, dated June 23, 2016.

Throughout this report the abandoned silver mine site at Roberts Bay, Nunavut, will be referred to as "the site".

1.1 Project Objectives

The objective of the 2016 LTM program was to complete Year 7 monitoring activities as described in the *Roberts Bay and Ida Bay Long Term Monitoring Plan* (INAC, 2009; referred to as the LTM Plan). The overall objective of the LTM plan is to assess whether the Solid Waste Management Facility (SWMF) landfill constructed at the site is performing as designed and continues to contain the waste placed within it during the remediation.

The program included visual observations, chemical analyses (where useful and possible), thermal monitoring and interviews with members of the nearby community knowledgeable about local activities at the site. The purpose of the program was to assess the condition of the natural environment and whether the site infrastructure is performing as designed.

1.2 Scope of Work

The scope of long term monitoring work as described in the Roberts Bay and Ida Bay Long-Term Monitoring Plan (INAC, 2009) was as follows:

1. Visual monitoring of the SWMF, including:
    - Checking the physical integrity of the SWMF and observing evidence of erosion, ponding, frost action, settlement and lateral movement and completing a visual monitoring checklist.

- Taking photographs to document the condition of the SWMF to substantiate the recorded observations.

2. Monitoring of surface water in the vicinity of the SWMF, including:

   - Collection of surface water samples from the designated upgradient and downgradient surface water sampling locations.
   - Examination and analyses of the surface water samples for colour, odour, hardness, pH, conductivity, temperature, total and dissolved metals, polychlorinated biphenyls (PCBs), petroleum hydrocarbon (PHCs), major ions, total dissolved solids (TDS) and total suspended solids (TSS).

3. Soil Monitoring (as required):

   - Soil sampling was to be limited to locations where seepage or staining was identified as part of the visual inspection.

4. Thermal monitoring of the SWMF, including:

   - Collection of data from automatic dataloggers attached to each of the three thermistor strings installed at the SWMF.
   - Analysis of the thermal data to provide ground temperature profiles at various locations within the SWMF.
   - Servicing the dataloggers, as required.

5. Natural environment monitoring:

   - Documentation of observations and evidence of human and wildlife activity present at the site.
   - Making observations regarding the re-vegetation of disturbed areas.
   - Interview with member(s) of the local Hunters and Trappers Organization or other persons knowledgeable of the site; collection of anecdotal information.

6. Preparation of a report documenting the 2016 monitoring program.

To fulfill the scope of work as described above, Arcadis, Along with INAC, devised a work plan that included the following tasks:

a. Preparation of a health and safety plan;

b. Preparation of a sampling plan for surface water;
c. Acquisition of surface water samples for chemical analysis;
d. Inspection of thermistor installations and collection of datalogger information;
e. Interpretation of analytical data;
f. Visual inspection and photo documentation of the site;
g. Observation and investigation of wildlife trends; and
h. Preparation of this report.

2 BACKGROUND INFORMATION

2.1 Site Description

Roberts Bay and nearby Ida Bay are two abandoned silver mines located approximately 115 kilometres southwest of Cambridge Bay on the north coast of mainland Nunavut in the central Kitikmeot region of the territory. The Roberts Bay site is located approximately 1 km north of Roberts Lake while the Ida Bay mine site is located adjacent to Melville Sound about 6 km north of the Roberts Bay site.

These two sites were explored between 1965 and 1972 and operated from 1972 to 1975, after which, they were abandoned. Further explorations continued throughout the 1980s and 1990s. Evidence of recent mineral exploration (abandoned drilling equipment and empty drums) was observed near the dock at Roberts Lake during the 2012 monitoring visit; however, during the 2014 site visit all equipment and the dock had been removed.

A remediation project was conducted at the sites between 2008 and 2010. The remediation involved the demolition and disposal of buildings, structures and other debris, as well as the clean-up of hazardous materials. Contaminated soil was excavated and either shipped off-site or placed in the SWMF landfill constructed at the Roberts Bay site. All impacted materials were removed from Ida Bay and placed in the SWMF landfill at Roberts Bay as well; therefore, no remediation infrastructure requiring monitoring was constructed there. Site visits to Ida Bay are thus not a part of the Roberts Bay long term monitoring program.

The Roberts Bay mine site had been in a state of abandonment for nearly 30 years when remediation activities commenced in 2008. Residual mine-related infrastructure present at the site prior to remediation included a tailings pond, waste rock piles, abandoned equipment and buildings, non-hazardous wastes and debris (e.g. scrap metal, wood, mill equipment, appliances and burlap bags), hazardous wastes (e.g. petroleum products, batteries, propane tanks, assay lab reagents and some unknown chemicals) and petroleum and metals impacted soil.

Historically, the Roberts Bay mine site also contained two mine openings (one adit and one vertical shaft) and a vent raise. The adit was located approximately 70 m east of the SWMF. The vertical shaft and vent raise were located on the side of a basaltic ridge approximately 200 m northeast of the SWMF. The two former mine openings and vent raise were fully sealed and re-graded during the remediation; they are no longer visible from the surface. A geochemical assessment conducted on the waste rock and the tailings at the site suggested that these materials are non-acid generating.

Constructed during remediation in the summer of 2009, the SWMF is a non-hazardous waste landfill built over the former tailings pond, as seen on Figures 1 and 2 (also refer to Photos 1 to 3, Appendix A). Monitoring procedures adopted by INAC for this site are similar to those defined in the Abandoned Military Site Remediation Protocol (AMSRP), with some modifications as applicable to mine sites.

The SWMF was designed to contain non-hazardous contaminated soils and debris, and to encapsulate and stabilize tailings water remaining at the site. The SWMF was constructed over the former tailings pond, covered by a woven geotextile and then covered with 2 m of compacted waste rock which had been assessed as non-metal leaching and non-acid generating. The waste was placed in lifts and sequentially covered with granular fill. On the basis of survey work, a total of 109 m^3 of debris and 742 m^3 of debris and waste rock intermediate cover were placed into the SWMF.

The design was based on the characteristics of the contaminants in the soil and the local geothermal and permafrost properties. The design uses permafrost as the primary containment barrier with both the contents and perimeter berms remaining in a frozen state. It was projected that the SWMF would reach a frozen state within a few years of construction. To monitor the freeze back of the contents and berms, three ground temperature sensor strings (thermistors) and dataloggers were installed along a transect of the facility. The thickness of the cover material was calculated to exceed the maximum depth of active layer thawing using modelled climate data; this was to ensure impacted materials within the SWMF remain frozen throughout the year.

2.2 Previous Monitoring Programs

Prior to the field program, Arcadis reviewed the following reports pertaining to the Roberts Bay abandoned mine site, some of which include previous site investigations and remedial activities:

- Arcadis Franz Canada Inc., March 13, 2015, Long Term Monitoring 2014, SWMF Landfill, Roberts Bay, Nunavut;
- Franz Environmental Inc., January 2013, 2012 Monitoring Program SWMF Landfill, Roberts Bay, Nunavut;
- Franz Environmental Inc., November 19, 2010, 2010 Monitoring Program SWMF Landfill, Roberts Bay, Nunavut;
- Indian and Northern Affairs Canada. February 9, 2009. Roberts Bay and Ida Bay Long-Term Monitoring Plan;

- Nunavut Water Board (NWB)'s Water License, August 8, 2008. License No. 1BR-ROB0813 issued to Indian and Northern Affairs Canada;
- SENES Consultants Limited, February, 2010. 2009 Inter-Seasonal Report for Roberts Bay and Ida Bay Mine Sites Site Remediation Program, Nunavut;
- AMEC Earth & Environmental for Public Works and Government Services Canada, January 2007, Roberts Bay and Ida Bay Abandoned Mine Sites Remediation Plan; and
- Indian and Northern Affairs Canada, Contaminated Sites Program, March 2009, Abandoned Military Site Remediation Protocol.

The 2016 monitoring program was the fourth of eight, scheduled over a 25 year period for the Site. Information from previous investigations was incorporated into this year's sampling plan. Data collected in subsequent years will be combined with the complete data set, as well as that from pre-landfill construction in 2008 and 2009, and analyzed.

As part of the investigation, information regarding land use by both humans and wildlife was gathered though interviews with members of the Ekaluktutiak Hunters and Trappers Association in the nearby community of Cambridge Bay.

3 REGULATORY REVIEW

3.1 Guideline Review

Where guidelines were developed, criteria presented in the Nunavut Water Board (NWB)'s Water Licence No. 1BR-ROB0813 (NWB, 2008) were used to compare surface water analytical results. These criteria were developed during a human health and ecological risk assessment which determined site-specific remedial objectives prior to remediation of the site. The water license expired in 2013; however, the criteria presented in Table 1 in Appendix A of the Water License were still used for comparison (see Tables 1 and 2 at the end of this report).

The Roberts Bay abandoned mine site is a federal site, and is therefore exempt from territorial regulation; however, the possibility of future disposition of the site may make it subject to territorial environmental guidelines. Because the Nunavut environmental guidelines are based on the work of the Canadian Council of Ministers of the Environment (CCME), the federal and territorial guidelines often coincide.

3.2 Soil

The governing guideline for soil at contaminated sites in Nunavut is the *Environmental Guideline for Contaminated Site Remediation* (EGCSR), published by the Government of Nunavut in March, 2009. The criteria for petroleum hydrocarbon compounds (PHCs) in soil are found in Section 3.4, and are adapted from the CCME's "Canada-Wide Standard for Petroleum Hydrocarbons in Soil" (CCME, 2008; CWS-PHC). The criteria for other compounds in soil are found in Table A-4 of Appendix 4 of the EGCSR, and are obtained from the CSQGs, published in the *Canadian Environmental Quality Guidelines* (CCME, 1999, updated online). The criteria are numerical limits intended to maintain, improve or protect environmental quality and human health at contaminated sites.

3.3 Surface Water

There are no surface water guidelines provided in the Roberts Bay LTM Plan. In the absence of site-specific guidelines, the AMSRP guidance on post-construction landfill monitoring indicates that "comparison to background and baseline values is recommended." The AMSRP provides the following table (Table 3-1) for the assessment of analytical data in groundwater; a similar approach has been used for the assessment of surface water analytical data.

Table 3-1: Groundwater Chemical Assessment Approach

Geochemical Assessment	Acceptable	Marginal	Significant	Unacceptable
Groundwater concentrations within average ± three standard deviations or within analytical variability	Performing as expected	-	-	-
Increasing trend in contaminant data over 2 or more successive monitoring events (variation in excess of average ± three standard deviations or analytical variability)	-	Low risk of failure	-	-
Groundwater concentrations in excess of three times average baseline concentrations in more than one monitoring event	-	-	Moderate risk of failure	-
Where applicable, surface water concentrations in excess of surface water quality guidelines for the protection of aquatic life	-	-	-	Failure
Required Actions	Monitor as per schedule	Increase monitoring frequency. Monitor surface water quality, if applicable, in downgradient water bodies within 300 m.	Assess causes of increasing contaminant concentrations. Evaluate whether remediation is required.	Assess cause of contaminant concentrations. Develop remedial plan. Implement remedial plan.

This table is reproduced from AMSRP Chapter 11, Table 4.2

Arcadis has used historical data presented in previous reports to obtain mean and standard deviation of analytical results from monitoring activities conducted in 2010, 2012 and 2014 in order to establish statistical upper limits of acceptability (ULAs). These limits are calculated as mean plus three standard deviations, and are used for comparison with analytical results from the 2016 field program. The calculated ULA values are included in surface water analytical tables presented at the end of this report. This is a very limited data set and therefore standard deviations for some parameters are quite high; additional data will help to create more realistic limits.

For some parameters, sufficient data to calculate mean and standard deviation were not available. This is primarily due to the high frequency of results reported to be below the laboratory reportable detection limit (RDL).

In these instances, and for purposes of comparison with the calculated ULA, the following CCME guidelines are included in this report:

- Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FWAL) (CCME, updated online), Summary Table.

Canadian water quality guidelines are intended to provide protection of freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical conditions

At the site, neither surface water nor groundwater is used for drinking water or agricultural uses. The landfill is greater than one kilometre from the nearest water body, Roberts Lake. Where ULAs were not calculated, the CCME FWAL water quality guidelines were applied to the surface waters at the site.

3.4 Soil

No soil samples were collected in 2016. Soil samples have only been collected during the 2010 monitoring event, which can serve as background samples for future soil sampling, laboratory analysis and analytical data comparison (if needed). Soil guidelines used for comparison in previous monitoring programs included the following:

- AMSRP, Volume I – Main Report (INAC, 2009).
- *CSQGs for the Protection of Environmental and Human Health* (CCME, 1999, with updates) for residential/parkland use, including fact sheets for BTEX. Non-potable groundwater is stipulated and coarse-grain material is assumed based on a 2009 grain-size analysis, field observation (generally sandy material) as well as for conservative reasons – being that coarse-grain criteria are more stringent than those applied to fine grain.
- *Canada-Wide Standard (CWS) for Petroleum Hydrocarbons in Soil* (CCME, 2008a) - Tier 1 Residential/Parkland, coarse-grained soil, non-potable groundwater.

These can be referenced in future monitoring events, should soil samples be collected.

4 INVESTIGATIVE METHODOLOGY

The site visit to Roberts Bay was carried out on August 19, 2016. During the field investigation, weather conditions were sunny, with a few clouds. Temperatures ranged from 7 to 8°C. The monitoring program included the following tasks:

- Completing a Health and Safety Plan;
- Visually observing and photographically documenting the physical integrity of the landfill and the reporting on the observable conditions over the rest of the site;
- Natural environment monitoring and gathering information from knowledgeable persons regarding local wildlife and human activity;
- Collecting landfill temperature data from previously installed thermistor strings;
- Measuring various physical parameters in the water samples; and
- Collection and submission of surface water samples, including duplicates, for applicable laboratory analysis.

The field investigation procedures are described below.

4.1 Health and Safety Plan

Before commencing with site activities, a site-specific health and safety plan (HASP) was developed. The HASP identified and provided mitigative actions for potential physical and chemical hazards associated with the work required to complete the site monitoring program. Emergency provisions such as extra food and shelter were included given the site's remoteness. A wildlife monitor with a valid firearm license was also hired and present on site for the duration of the site visit. The HASP contained a listing of emergency contact numbers and provided protocols to follow in the event of an emergency. A copy of the HASP is located in Appendix E.

A copy of the HASP was presented to INAC for their review and approval before activities at the site began. Prior to conducting any work at the site, the HASP was distributed and discussed with all personnel involved in the monitoring program. A copy of the HASP has been retained on file with Arcadis.

4.2 Visual Inspection

The physical integrity of the SWMF and immediate surrounding areas were assessed using systematic visual observations and empirical measurements to record evidence of erosion, ponding, frost action,

settlement and lateral movement of the landfills. Definitions for completing the checklist are found in Table 4-1 (below). A visual monitoring checklist, presented in the Roberts Bay LTM Plan, was completed for the landfill and is found in Tables 5-1 and 5-2 in Section 5.3. A photographic record was completed to document the condition of the structures and substantiate the visual observations (Appendix A).

Table 4-1: Preliminary Visual Inspection Report SWMF - Definitions

Performance / Severity Rating	Description
Acceptable	Noted features are of little consequence. The landfill is performing as designed. Minor deviations in environmental or physical performance may be observed, such as isolated areas of erosion, settlement.
Marginal	Physical/environmental performance appears to be deteriorating with time. Observations may include an increase in size or number of features of note, such as differential settlement, erosion or cracking. No significant impact on landfill stability to date, but potential for failure is assessed as low or moderate.
Significant	Significant or potentially significant changes affecting landfill stability, such as significant changes in slope geometry, significant erosion or differential settlement; scarp development. The potential for failure is assessed as imminent.
Unacceptable	Stability of landfill is compromised to the extent that ability to contain waste materials is compromised. Examples may include: • Debris exposed in erosion channels or areas of differential settlement. • Liner exposed. • Slope failure.
Extent	**Description**
Isolated	Singular feature
Occasional	Features of note occurring at irregular intervals/locations
Numerous	Many features of note, impacted less than 50% of the surface area of the landfill
Extensive	Impacting greater than 50% of the surface area of the landfill

The 2016 visual inspection was conducted with the aid of a Trimble Pro XRT GPS unit (real-time accuracy of 1-2 m and corrected accuracy of 10-30 cm while connected to OmniSTAR). The Trimble Pro XRT GPS was preloaded with the 2014 logged GPS data file enabling Arcadis field personnel to accurately locate features of note. However, changes to features observed in 2016 and new photograph viewpoints could not be captured on the GPS unit due to operational difficulties. The 2014 SSF format file is still the most up-to-date version of the spatial data gathered at the site. Use of the Trimble Pro XRT

GPS to facilitate observation and documentation of any changes to the condition of the SWMF in future site monitoring visits is still recommended.

4.3 Wildlife Survey

Arcadis made observations of the natural environment at the time of the site visit and recorded these observations in field notes. Observations included direct sightings of wildlife, other evidence of wildlife (e.g., droppings, tracks, feathers/fur), wildlife activities (migrating, nesting, etc.), numerical estimates of wildlife, and vegetation observations. Where possible, observations by Arcadis have been compared to previously recorded observations.

As part of the investigation, information regarding land use by both humans and wildlife at the site was gathered though the wildlife monitor, Mr. Jimmy Evalik, a member of the Ekaluktutiak Hunters and Trappers Organization. Additional information was gathered from other persons from the nearby community of Cambridge Bay knowledgeable of the site and surrounding area.

A discussion of the recorded observations and information obtained is presented in Section 7 of this report.

4.4 Thermal Monitoring

Three thermistor strings were initially installed along a transect of the SWMF in the late summer of 2009. Thermistor installation records with details concerning the number of beads and bead depths were not available to Arcadis. Based on the data collected in August, 2010, Arcadis concluded that the number of beads at Thermistors A, B and C is 9, 11 and 9, respectively. Assumptions regarding bead depth are discussed in detail in Section 5.4. Each thermistor string is connected to a Lakewood Systems Ultra-Logger datalogger that is programmed to record values twice daily – at 0h00 and 12h00 – on a continual basis.

During the site visit, the resistance at each bead was measured manually at each thermistor string. This data was converted to temperature values which were compared to the values logged by the dataloggers. The manual resistance check confirms the functionality of each bead, and the comparison with the logged data confirms that the analog data channels of the datalogger are operating correctly. All manually collected data had close agreement with the data collected by the dataloggers. The manual resistance check data is presented in Table B-2, Appendix B.

Thermistor data for the period from August 2014 to August 2016 were downloaded from all three dataloggers using a laptop with Lakewood Systems' Prolog2 (v.2.226) software. While in the field,

datasets from each datalogger were inspected to ensure completeness and data validity. Datalogger battery voltages, memory usage, and programming were noted and a visual inspection of the housing equipment was performed. All three dataloggers were replaced. The replacement dataloggers were reset and installed with new batteries and desiccants.

The SWMF ground temperature record was compiled and trends were highlighted. A discussion, along with plots of temperature versus depth and time, is presented in Section 5.4. The annual maintenance report, which also contains a basic description of the datalogger systems, can be found in Table B-1, Appendix B. Raw data is provided in the attached DVD.

4.5 Surface Water Sample Collection

The surface water sampling methodology conformed to guidance provided in the following documents:

- CCME EPC-NCS62E Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites - Volume I: Main Report, Dec 93 (CCME catalogue - http://www.ccme.ca/assets/pdf/pn_1101_e.pdf);
- CCME EPC-NCS66E Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites - Volume II: Analytical Method Summaries, Dec 93 (CCME catalogue - http://www.ccme.ca/assets/pdf/pn_1103_e.pdf);
- INAC Roberts Bay and Ida Bay Long-Term Monitoring Plan (INAC, 2009); and
- INAC Abandoned Military Site Remediation Protocol, Contaminated Sites Program (INAC, 2009).

Surface water was sampled at five locations: four in proximity to the SWMF and one distant, background reading collected from Roberts Lake. Water samples submitted for total metals analyses were preserved and not field-filtered. Water samples submitted for dissolved metals analyses were not preserved and were not filtered in the field. Filtration of these samples was conducted in the lab prior to analysis.

Samples were successfully collected from previously established surface water monitoring locations ROB-6, ROB-7, ROB-8 and ROB-10. The surface water sample at monitoring location ROB-7 was collected in duplicate, and a background sample was collected from Roberts Lake (surface water monitoring location ROB-9). A summary of the samples that were collected and submitted for laboratory analysis during the surface water sampling activities is provided in Table 4-2, below. Additional information is provided in the surface water sampling field notes included in Appendix C.

Table 4-2: Summery of Surface Water Samples from near the SWMF

SWMF Area	Sample	Description	Analytical Parameters
Downgradient	ROB-6	Surface water to southeast of SWMF that may at times flow South to Roberts Lake	• Total and dissolved metals • PCBs • PHC fractions F1 to F4 and BTEX • Inorganics (major ions, TDS, TSS, colour, pH, conductivity)
	ROB-7 and Duplicate	Southwest of the SWMF	
	ROB-8	Northeast of SWMF (to detect possible leachate and runoff)	
	ROB-10	Southeast of SWMF (to detect possible leachate and runoff)	
Background	ROB-9	Roberts Lake (for background and control)	

All samples were stored immediately in laboratory prepared sample bottles. As soon as was possible, samples were placed on ice and remained chilled until delivery to the laboratory.

4.6 Soil Sample Collection

If required, soil sampling was to be completed by manual excavation. Baseline soil data were collected during the 2010 site visit. Subsequent soil samples are only to be collected should physical or other chemical evidence of landfill deterioration be observed. No such evidence was observed during the 2016 site visit; therefore, no soil samples were collected.

4.7 Quality Assurance/Quality Control

Field personnel employed Arcadis' Quality Assurance/Quality Control (QA/QC) protocols, including appropriate techniques for soil sampling, sample storage, shipping and handling, as well as collection of duplicates.

4.7.1 Field

Surface water samples were collected by hand and placed in appropriately sized and prepared laboratory vessels. Sample numbers were clearly marked on the containers. The water bottles were filled to

capacity with minimum headspace and stored in coolers with ice to moderate temperature fluctuations during transport to the laboratory.

As a quality control measure, one surface water blind field duplicate sample was collected and analyzed for identical parameters (total and dissolved metals, PCBs, PHCs, BTEX, suspended and dissolved solids, major ions, hardness, pH and conductivity).

The samples, accompanied by a Chain of Custody form, were shipped via Canadian North to Maxxam in Yellowknife. There, the samples were re-packaged and shipped by Maxxam to the appropriate analytical laboratory in either Edmonton or Calgary (as a function of the analysis to be performed). Copies of the Chain of Custody forms are provided in Appendix D.

Analytical results from these samples were compared with the analytical results from previous annual monitoring events.

4.7.2 Laboratory

The selected laboratory, Maxxam Analytics (Maxxam), is certified by the Canadian Association for Laboratory Accreditation, Inc. (CALA) and has an internal QA/QC protocol. The internal QA/QC protocol includes the analysis of matrix spikes, spike blanks and method blanks. The laboratory QA/QC documentation is provided with the analytical report and was reviewed by Arcadis as part of the QA/QC protocol.

4.8 Analytical Program

Surface water samples were sent to Maxxam Analytics in Yellowknife, NWT and ultimately on to Edmonton or Calgary, Alberta for chemical analyses of the target compounds previously identified. Maxxam is certified by the Canadian Association for Laboratory Accreditation, Inc. (CALA) and has an internal QA/QC protocol. The laboratory QA/QC documentation is provided with the analytical report and was reviewed by Arcadis as part of the QA/QC protocol. The certificates of analysis and associated chain of custody forms are presented in Appendix D.

5 SOLID WASTE MANAGEMENT FACILITY

5.1 Area Summary

The SWMF, composed of both a dry and a wet cell, is located to the west of the two former adits, and is built on the same location as the former mine tailings pond. Monitoring of the SWMF consisted in part of a visual inspection to assess its physical integrity by collecting evidence of erosion, ponding, frost action, settlement and lateral movement. Surface water samples were also collected at locations downgradient of the SWMF and a background surface water sample was collected from Roberts Lake.

The SWMF surface water sample locations and photographic viewpoints can be seen in Figure 1 and Figure 2 at the end of this report. The visual inspection report is presented in Section 5.3.

5.2 Photographic Record

The photographic record of the SWMF was completed as per Terms of Reference for the monitoring program. A selection of photos is presented in Appendix A, where photograph captions provide the landfill viewpoint numbers (as seen in Figure 2). Full resolution digital copies of all photographs are contained in the attached DVD. Note that in this report, photo numbers refer to the selection photos in Appendix A and viewpoint numbers refer to the photos on the DVD.

5.3 Visual Inspection Report

The visual inspection of the SWMF and surrounding area was conducted on August 19, 2016. The visual monitoring checklist shown in Table 5-1 was completed using the format provided in the *Roberts Bay and Ida Bay Long-Term Monitoring Plan* (INAC, 2009). Features observed to date have been summarized in Table 5-2. Field notes relating to the visual inspection are included in Appendix C.

Table 5-1: Roberts Bay SWMF Visual Inspection Checklist

Date:	August 19,2016
Landfill:	Solid Waste Management Facility Landfill (SWMF)

1. Erosion	**Answer**
a) Is erosion occurring on the surface or berms of the landfill?	No
i) Are there preferred drainage channels?	No
ii) Is there sloughing of material?	No
b) What is the extent of the erosion? *(percentage of surface area)*	–
i) Is it localized or continuous?	–
c) Where is the erosion occurring? N/A	
d) Explanation: N/A.	

2. Settlement	**Answer**
a) Is there differential settlement occurring on the surface?	No
i) Are there low areas or depressions?	Yes
ii) Are voids forming?	No
b) What is the extent of the settlement? *(percentage of surface area)*	< 1%
i) Is it localized or continuous?	Localized
ii) How deep is it?	< 0.3 m
c) Where is the settlement occurring? Three very small areas identified at surface of SWMF (refer to viewpoint numbers 27 to 32 on Figure 2). Minor settlement areas remain unchanged since 2014. One new area of settlement observed during the 2016 site visit	
d) Explanation: No obvious cause, but appears to be a result of mechanical processes (i.e. grading and compaction of landfill surface during construction).	

3. Frost Action	**Answer**
a) Is there frost action/damage to the landfill?	No
i) Is there exposed debris due to uplift?	No
ii) Is there tension cracking along the berms?	No
iii) Is there sorting of granular fill?	No
b) What is the extent of the frost action? *(percentage of surface area)*	–
i) Is it localized or continuous?	–
c) Where is the heaving/cracking occurring? No frost action observed on any surface of the SWMF.	
d) Explanation: No apparent signs of frost action on any surface of the SWMF.	

4. Monitoring Instruments
a) What is the condition of the monitoring wells and thermistor strings? There are no monitoring wells present at this site. Thermistor housing units were in good condition. In order to access the dataloggers, the locks securing the lid of each thermistor housing had to be cut off. These locks were stanadard Guard locks (40 mm universal-key padlocks, No. 834, key number 102) found at other INAC sites and Arcadis field personnel did have the necessary keys; however, the locks were not opening likely due to damage incurred by exposure to local environmental conditions. After downloading the data and installing replacement dataloggers, each thermistor housing was secured with a new Master VLINE lock. The locks should be replaced by the standardized Guard locks during the next monitoring event.
5. Others
Animal Burrows: No animal burrows were observed in or on the SWMF. **Vegetation**: No vegetation growth was observed on the SWMF. Due to elevation, drainage, regional climate, and the type of material (large angular cobble) used to cap the SWMF, the establishment of vegetation is not anticipated. The wildlife monitor (Jimmy Evalik) noted that vegetation on the access road had increased. **Staining**: No staining was observed at the SWMF. **Vegetation stress**: None observed. **Seepage points**: None observed. **Exposed debris**: No debris was exposed from the SWMF.
6. Sketch
See Figure 2
7. General Comments
The physical condition of the SWMF remains unchanged from that observed in 2014. It is considered acceptable and appears to be performing as designed.

Settlement

Four areas of possible settlement were identified on the top of the SWMF during the 2016 site visit (refer to Figure 2). Three areas were observed in 2014, and one new area was observed in 2016. These four isolated areas were reported to be small (less than a few square metres) and shallow (less than 30 cm). Previous reports have indicated that these areas appear to be a result of mechanical processes and may

simply represent minor variation in the final grading and compaction of the surface of the landfill. These settlement areas have not previously been labelled. To facilitate consistency and accuracy, they have been designated Features A through D, as noted in Figure 2.

There was no evidence of water infiltration observed and no ponding was observed on top of the landfill. After visual observations and comparison to the 2014 photographs, these areas of settlement remain unchanged in 2016.

Similar to 2014, no ponded water was observed in the immediate vicinity of the SWMF during the 2016 site visit. Surface water was present to the northeast, southeast and southwest (sampling points ROB-6, ROB-7, ROB-8 and ROB-10) of the landfill (refer to Figure 2).

Erosion

No evidence of erosion or preferred drainage channels was observed during the 2016 site visit.

Frost Action

Similar to previous observations, no evidence of heaving or cracking was observed on the top or berms of the SWMF, and no frost action was observed at any of the thermistor housing units during the 2016 site visit.

Evidence of Burrowing Animals

No animal burrows were observed on the SWMF during the 2016 site visit. As in previous site visits, indications of burrowing animals (Arctic ground squirrels, commonly known as sik siks) were prevalent throughout the undisturbed areas of the site, specifically along the banks of the trail to Roberts Lake. One was spotted south of the SWMF during the site visit.

Staining

No evidence of staining was observed on or near the SWMF during the 2016 site visit.

Seepage Points

There was no evidence of seepage from the SWMF observed during the 2016 site visit.

Debris

No exposed debris was observed at the SWMF during the 2016 site visit.

Discussion

Based on the minimal to non-existent erosion, settlement, frost action, burrowing, staining and seepage observed, the performance of the SWMF, with respect to containment, was rated as satisfactory because the evidence observed suggests the structure is performing as designed.

Table 5-2 summarizes the features observed during the visual inspection.

Table 5-2: Features Observed during Visual Inspection - Roberts Bay

Checklist Item	Feature Letter	Relative Location	Length* (m)	Width* (m)	Depth* (m)	Extent	Description (Change)	Additional Comments	Viewpoint Reference
Settlement	A	Top of SWMF, between thermistors A and B	0.2	0.3	0.4	<1%	Minor area of settlement	Observed in 2014	28 and 29
Settlement	B	Southeast of Feature A, 15 m east of thermistor B	0.02	0.05	3	<1%	Minor area of settlement	Observed in 2014	31 and 32
Settlement	C	South side of SWMF, 5 m southwest of thermistor C	0.02	0.05	3	<1%	Minor area of settlement	Observed in 2014	27
Settlement	D	Top of SWMF, 6 m west of Feature A	0.03	0.05	1.5	<1%	Minor area of settlement	First observed in 2016	37

5.4 Thermal Monitoring Data

As generally described in the site remediation report (SENES, 2010), three thermistor strings (A, B and C) were installed in the SWMF. Thermistor string installation records were not available; however, site remediation specifications (INAC Project No. 416829) recommended that temperature sensing beads be placed at 500 mm intervals from thermistor bore bottoms to the landfill surface. Based on the elevations of the thermistor borehole bottoms, casing tops and the landfill surface provided by the SWMF construction drawings, it was assumed that thermistor beads were placed from the borehole bottom to the top at the recommended 500 mm spacing. The top bead appears to coincide with the landfill surface in the case of thermistor string A. Thermistor string B has the top bead positioned above the ground surface, while string C has the top two beads positioned above the ground surface. These conclusions are drawn based on observation of the thermistor string cables within the housings, and are supported by the magnitude of diurnal temperature fluctuations observed at the upper beads. Larger diurnal temperature fluctuations are apparent when the bead is positioned above the ground surface and is measuring air temperature. The inferred bead depths are presented in Table B-2, Appendix B.

Arcadis performed a complete memory download on the dataloggers installed at all three strings. A manual verification of the data downloaded from the dataloggers was performed in the field using a sensitive resistance meter available from the datalogger manufacturer. Results indicate all temperature sensing beads of the three thermistor strings were performing well.

During data processing, Arcadis assessed that the data from string B was corrupt and recorded faulty temperatures on multiple beads at seemingly random timeframes (i.e., no noticeable pattern). Corrupted data from string B were also encountered during the previous monitoring event in 2014. The data sets collected in 2014 were sent to Lakewood Systems for review, however, the corrupted data could not be corrected. For data sets collected in 2016, Arcadis removed manually corrupted data in order to assess quality and quantity of the remaining data. A complete annual data set contains 730 unique data points. After corrupted data was removed, the 2014 and 2015 data sets contained 609 and 589 unique data points of reasonable quality, respectively. The reduced data set size of the 2014 and 2015 should be considered when reviewing the statistical values. The datalogger at thermistor string B (serial no. 0507003) was likely the cause of the corrupted data sets as the manually measured resistance values indicate all the beads on strings B are performing well. The replacement of the datalogger at string B with another datalogger (serial no. 05070020) in 2016 is expected to prevent further issues with corrupt data at thermistor string B in the future.

All thermistor beads positioned below the ground surface were found to yield temperatures within the standard ± 0.2 ºC margin of error when compared to field resistance readings, with the exception of bead 2 on string A (discrepancy of 0.3 ºC) and bead 3 on string C (discrepancy of 0.4 ºC). The discrepancies noted in string A are very close to the acceptable margin of error; the data from these beads were considered useable and were retained. A larger margin of error between manually and automatically recorded temperatures is considered acceptable for beads positioned above or near the ground surface, as is the case for bead 1 of string A, beads 1 and 2 of string B, and beads 1 and 2 for string C. The larger margin of error is attributable to fluctuation in atmospheric temperature over the duration of the test period. Additional details of the manual verification test are presented in Table B-2, Appendix B.

The position of the 0°C isotherm was calculated at each location from ground temperatures recorded by the dataloggers in August, refer to Table 5-3. Plots of depth versus temperature (at each thermistor bead) for each year and temperature versus time over the previous two years are presented in Figure B-1 through Figure B-6, Appendix B.

Table 5-3: Summary of SWMF Active Layer Thickness

Parameter	Thermistor String		
	A	B	C
Depth to 0º isotherm (m) on Aug 7, 2012	1.38	1.79 (2)	1.71
Depth to 0º isotherm (m) on Aug 7, 2013	1.73	N/A (1)	1.59
Depth to 0º isotherm (m) on Aug 7, 2014	1.49	1.53	1.50
Depth to 0º isotherm (m) on Aug 7, 2015	1.54	1.56	1.52
Depth to 0º isotherm (m) on Aug 7, 2016	1.61	1.60	1.56
Maximum depth to permafrost 2009	Permafrost trend not yet established		
Maximum depth to permafrost 2010 (m) (Jan 1 to Dec 31)	2.95	N/A (1)	2.31
Maximum depth to permafrost 2011 (m) (Jan 1 to Dec 31)	2.53	N/A (1)	2.07
Maximum depth to permafrost 2012 (m) (Jan 1 to Dec 31)	2.09	N/A (1)	2.00
Maximum depth to permafrost 2013 (m) (Jan 1 to Dec 31)	1.86	1.80 (2)	1.86
Maximum depth to permafrost 2014 (m) (Jan 1 to Dec 31)	1.65	1.62 (3)	1.61

Parameter	Thermistor String		
	A	B	C
Maximum depth to permafrost 2015 (m) (Jan 1 to Dec 31)	1.72	1.69 (3)	1.70
Maximum depth to permafrost 2016	Permafrost trend not yet established		

Notes:

(1) Insufficient data to calculate a depth
(2) Interpolated from manually recorded temperature data
(3) Data set reduced due to corrupted data. A complete annual data set contains 730 unique data points. After corrupted data was removed, the 2014 and 2015 data set size was 609 and 589, respectively.

At the locations of thermistor string A and C, thermal monitoring indicates the maximum active layer depth has progressively decreased from 2010 to 2014. In 2015, the maximum active layer depth increased an average of 8 cm compared to its depth in 2014. Further thermal monitoring is required to assess if the increase in thickness of the active layer in 2015 is the beginning of a trend. Historical thermistor data suggest that the maximum active layer depth often occurs in September at the SWMF, as such, the 2016 maximum active layer depth was likely not achieved by the time of the 2016 site visit. In general, it can be concluded that the waste contained within the SWMF, reported to be at a depth of ≥ 3 m bgs has remained frozen year round since the fall of 2010.

Thermistor details can be found in the annual maintenance monitoring report (Table B-1, Appendix B).

5.5 Analytical Results – Surface Water

As described in Section 4.5, a total of five surface water samples (four samples plus one blind duplicate) were submitted to Maxxam for analyses of PHCs, metals, PCBs and inorganic parameters. Obtained analytical results are discussed below.

PHCs

Laboratory analytical results for PHCs are presented in Table 1, at the end of this report. As shown in the table, concentrations of all PHC parameter were below laboratory RDLs. As previously-reported PHC concentrations have been, for the most part, below RDLs, no ULAs were calculated for PHCs in surface water.

Metals

Laboratory analytical results, NWB Water License criteria, selected federal guidelines and calculated site-specific ULAs for dissolved and total metals are presented in Table 2. Site-specific ULAs were calculated for total and dissolved metals parameters as detailed in Section 3.3.

The following exceedances were reported in comparing analytical results to the NWB Water license criteria:

- Total aluminum concentrations exceeded the Water License criteria of 0.1 mg/L in the surface water sample collected from monitoring location ROB-6 and ROB-9;
- Total cadmium concentrations in the surface water sample collection from monitoring location ROB-6 and dissolved cadmium concentrations in the surface water samples collected form monitoring location ROB-6 and ROB-9 exceeded the Water License criterion of 0.017 µg/L. Note that the RDL for this analysis is 0.020 µg/L, which also exceeds the Water License criterion;
- Total copper concentrations exceeded the Water License criteria of 0.002 mg/L to 0.004 mg/L (assumed to be dependent on hardness as is the CCME FWAL guideline, but this is not explicitly indicated in the Water License) in surface water samples collected from monitoring location ROB-6, ROB-7 (and duplicate), ROB-9 and ROB-10. Dissolved copper concentrations were reported in excess of the criteria in surface water samples collected from monitoring location ROB-6, ROB-7 (and duplicate) and ROB-10; and
- Total iron concentrations exceeded the Water License criterion of 0.3 mg/L in surface water samples collected from monitoring location ROB-6, ROB-8 and ROB-9. Dissolved iron concentrations were reported in excess of the guideline in surface water samples collected from monitoring location ROB-6 only.

The following exceedances were reported in comparing analytical results to the CCME FWAL guidelines:

- Total aluminum concentrations exceeded the CCME FWAL guideline of 0.1 mg/L in the surface water sample collected from monitoring location ROB-6 and ROB-9;
- Total copper concentrations exceeded the calculated CCME FWAL guideline (dependent on hardness and calculated to be 0.004 mg/L for samples collected from ROB-6, ROB-7 and ROB-10, and 0.002 mg/L for the sample collected from ROB-9) in surface water samples

collected from monitoring location ROB-6, ROB-7 (and duplicate), ROB-9 and ROB-10. Dissolved copper concentrations were reported in excess of the guideline in surface water samples collected from monitoring location ROB-6, ROB-7 (and duplicate) and ROB-10; and

- Total iron concentrations exceeded the CCME FWAL guideline of 0.3 mg/L in surface water samples collected from monitoring location ROB-6, ROB-8 and ROB-9. Dissolved iron concentrations were reported in excess of the guideline in surface water samples collected from monitoring location ROB-6 only.

All other analyzed parameters reported concentrations below RDLs or below CCME FWAL guidelines.

The following exceedances of the calculated ULAs were reported:

- Dissolved cobalt concentrations reported in the surface water sample collected from monitoring location ROB-6 exceeded the ULA (calculated from 2010, 2012 and 2014 data); and
- The surface water sample collected from monitoring location ROB-6 reported a colour value greater than the ULA (calculated from 2010, 2012 and 2014 data).

Copper has previously been detected above guidelines in surface water in at least one of the samples collected from monitoring location ROB-06, ROB-9 and/or ROB-10 during the 2010, 2012 and 2014 site visits, indicating that elevated copper concentrations are common at these locations. The maximum total copper concentration reported to date has been 0.0063 mg/L at monitoring location ROB-10 in 2012. Higher values were reported in 2016 (e.g. concentrations of approximately 0.009 mg/L at monitoring location ROB-6 and ROB-7). This should be monitored in future years, to assess if this is a natural occurrence or a result of leaching from the SWMF.

Cobalt concentrations in samples collected at monitoring location ROB-6 have been below detection limits in all previous LTM events. The dissolved concentration reported in 2016 is 0.0015 mg/L, which exceeded the ULA. The total cobalt concentration was reported to be 0.0020 mg/L in 2016, which did not exceed the ULA. The ULA exceedance may be attributed to the limited data available for its calculation.

The colour results obtained in 2016 from the sample collected from monitoring location ROB-6 was considerably higher than previous year's results. The sample was collected from a very shallow and vegetated waterbody and a high colour result is not unexpected.

PCBs

Laboratory analytical results for PCBs are shown in Table 3. The 2016 analytical results and all previous analytical results for PCBs in surface water at the site are all below RDLs. As such, a site-specific ULA cannot be calculated for PCBs in surface water. In addition, there are no CCME recommended guidelines for PCBs in surface water because environmental exposure to PCBs is predominantly via sediment, soil, or tissue (CCME, 2007).

Inorganic Parameters

Laboratory analytical results for inorganic parameters are presented in Table 4. CCME FWAL guidelines exist for some of the parameters under this heading; these are noted in Table 4 for reference purposes. Using the methodology detailed in Section 3.3, site-specific upper limits of acceptability were successfully calculated for several other parameters under this heading. These site-specific limits are used to determine the acceptability of the 2016 surface water monitoring analytical results. One ULA exceedance was noted:

- The sample collected from monitoring location ROB-6 reported colour results that exceeded the ULA of 118 PtCo units. The location where sample ROB-6 was collected was very shallow, with significant vegetation (see Photo 10). A high colour result is not unexpected for this type of water body;

One exceedance of the CCME FWAL guidelines was reported:

- The chloride concentration in the sample collected from ROB-8 exceeded the guideline of 120 mg/L.

Various exceedances of these parameters (colour and chloride) have been previously reported; however, the colour result (ROB-6) is higher than previous concentrations. The reported chloride concentration in the surface water sample collected from monitoring location ROB-8 is similar to previous concentrations (as evidenced by no ULA exceedance). These parameters are often influenced by natural phenomena (e.g. quantity of water, amount of vegetation, sample location) and may not be a result of SWMF deterioration. The next scheduled LTM event for Roberts Bay will be in 2019 (Year 10) and these parameters should be monitored closely.

Laboratory certificates of analyses for the 2016 surface water samples are provided in Appendix D.

5.6 QA/QC

In order to obtain the required minimum of 20% duplicate samples, as stipulated in Long Term Monitoring Plan, one duplicate surface water sample was collected during the 2016 monitoring activities. Analytical results for submitted samples and their duplicate pairs were compared to provide an indication of the precision of both the field sampling and laboratory analysis methods.

As a quality control check, a Relative Percent Difference (RPD) was calculated when analytical results from both samples were greater than five times the reportable detection limit (RDL). RPD values are presented along with analytical results in Tables 1 through 4. As per CCME Guidance (Guidance Manual for Environmental Site Characterization in Support of Human and Health Risk Assessment, Volume I Guidance Manual, CCME, 2016), the RPDs for parameters of duplicate groundwater samples should not exceed 40%.

Duplicate evaluations of surface water samples for PHCs, dissolved metals, PCBs and inorganic parameters all fell within limits of acceptability, with one exception. Total suspended solids did not meet the duplicate evaluations criteria. Although care was taken to collect as similar samples as possible, differing amounts of suspended material could have entered each jar. Error associated with the sampling procedures could account for this difference. As both values are within the ULA, this is not a concern at this time.

6 SURROUNDING AREAS

The surrounding areas of the SWMF at Roberts Bay, including the borrow areas, locations of former adits and re-graded areas were also inspected during the 2016 site visit. The area surrounding the SWMF was found to be clean and in good order, with no significant change observed since the last site visit.

7 NATURAL ENVIRONMENT

Information regarding the natural environment was gathered directly, through observation, and indirectly, through consultation with knowledgeable local persons in order to better understand the presence and temporal change of wildlife. The Roberts Bay LTM Plan recommends monitoring the following parameters:

- Wildlife sightings;
- Other evidence of recent presence of wildlife (e.g. droppings, tracks);
- Wildlife activity (e.g. nesting, migration);
- Qualitative assessment of relative numbers versus previous years; and
- Revegetation of disturbed areas versus previous years.

Information regarding these parameters was either gathered directly, through personal observation while on site or indirectly, through the wildlife monitor, a member of the Ekaluktutiak Hunters and Trappers Association in the nearest community of Cambridge Bay, NU.

Wildlife and Human Activity

During the 2016 site visit, the following signs of wildlife were observed on site:

- One ground squirrel (commonly known as a sik sik) was observed south of the SWMF;
- A loon was heard to the south of the SWMF; and
- Polar bear scat was observed 400 m northeast of the SWMF.

After discussion with the wildlife monitor, it was reported that the site has been used for hunting and fishing in the past. Caribou, muskox, rabbits, foxes, seals, whales and arctic hare are hunted in the area. Arctic char and trout are also fished. The wildlife monitor also reported that the number of animals seen this year during hunting trips has gone down, especially for caribou.

Evidence of fish survey equipment and weirs that had been installed into a nearby creek flowing into Roberts Lake was present. It was reported in 2012 that a floating dock was present in Roberts Lake at the pathway leading to the SWMF and abandoned exploration drilling equipment adjacent to the dock, however, this has since been removed.

Re-establishment of Vegetation

Major site remedial work, which comprised excavation and construction activities, was completed in the summer of 2009. According to the wildlife monitor, increased vegetation was observed on the access road during the 2016 site visit. Given the regional setting of the Roberts Bay SWMF landfill and growth observed at other, similar sites in the Nunavut region, it is reasonable to assume that it will take some time for native vegetation to become re-established at the site. Due to the type of material used to cap the landfill (large angular cobble), re-vegetation of the surface of the SWMF is considered to be very minimal within the time-frame of the long-term monitoring program at the site.

8 CONCLUSIONS

The most recent thermal monitoring data from thermistor strings indicates the waste in the SWMF continues to remain frozen year round. The maximum depth of the active layer remains less than the depth to the waste material contained within the SWMF. Thermal monitoring data has shown that the maximum depth of the active layer was decreasing from 2010 to 2014, however, this decreasing trend was broken in 2015 by a slight increase in the maximum active layer. Further thermal monitoring is required to assess if the increase in thickness of the active layer in 2015 is the beginning of a trend. Historical thermistor data suggest that the maximum active layer depth often occurs in September at the SWMF. It was therefore assumed that the 2016 maximum active layer depth was not achieved by the time of the site visit.

The dataloggers at thermistor string A, B and C were replaced during the 2016 site visit. The replacement dataloggers were installed with new batteries and desiccants. To access the dataloggers, the locks on the three datalogger housings had to be cut off. New locks were installed on the datalogger housings; however, the new locks were not of the model standard to INAC sites (i.e. 40 mm Guard universal-key padlocks, No. 834, key number 102). Arcadis recommends the locks on the three datalogger housings be replaced with the standard Guard locks during the next scheduled monitoring event.

Arcadis assess that the data stored on the datalogger installed at string B was corrupt and recorded faulty temperatures on multiple beads at seemingly random timeframes. Corrupted data from string B was also encountered during the previous monitoring event in 2014. Arcadis was able to extract and assess non-corrupted data from the 2014, 2015 and 2016 data sets. Replacement of the datalogger at string B is expected to prevent further issues with corrupt data at thermistor string B in the future.

In addition to physical and temperature observations, Arcadis collected surface water samples to assess the performance of the SWMF. Copper concentrations reported in the surface water samples collected from monitoring location ROB-6 and ROB-7 exceeded the ULA. To determine if elevated copper concentrations are a natural occurrence or a result of leaching from the SWMF, further monitoring of copper concentrations is required. Cobalt concentrations in surface water sample ROB-6 also exceeded the ULA, however, this exceedance is likely a result of limited data available for the ULA calculation. The surface water sample collected from monitoring location ROB-6 also reported colour results that exceeded the ULA. As surface water sample ROB-6 was collected from a very shallow and vegetated waterbody, a high colour result is not unexpected. Surface water samples ROB-6, ROB-7, ROB-8, ROB-9 and ROB-10 all had exceedances of NWB Water Board criteria and/or the CCME FWAL guidelines for one of more of the following parameters: total aluminium, total copper, total iron, and chloride. All other

chemical parameters were measured at concentrations either below the laboratory RDL or below the calculated upper limits of acceptability. At this time, the reported exceedances noted are not considered indicative of any deterioration in the integrity of the SWMF.

As a result of the physical observations and analytical results of the 2016 field program, Arcadis believes that the site has undergone little change from the last monitoring event (August 2014) and that the SWMF continues to operate as designed.

9 LIMITATIONS

This report has been prepared exclusively for Indigenous and Northern Affairs Canada. Any other person or entity may not rely upon the report without the express written consent from Indigenous and Northern Affairs Canada.

Any use, which a third party makes of this report, or any reliance on decisions made based on it, is the responsibility of such third parties. Arcadis Canada Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Some of the information presented in this report was provided through existing documents and interviews. Although attempts were made, whenever possible, to obtain a minimum of two confirmatory sources of information, Arcadis Canada Inc., in certain instances, has been required to assume that the information provided is accurate.

The conclusions presented represent the best judgment of the assessors based on current environmental standards and on the site conditions observed on August 19, 2016. Due to the nature of the investigation and the limited data available, the assessors cannot warrant against undiscovered environmental liabilities.

Should additional information become available, Arcadis Canada Inc. requests that this information be brought to our attention so that we may re-assess the conclusions presented herein.

There is no warranty, expressed or implied that the work reported herein has uncovered all potential environmental liabilities, nor does the report preclude the possibility of contamination outside of the areas of investigation. The findings of this report were developed in a manner consistent with a level of care and skill normally exercised by members of the environmental science and engineering profession currently practicing under similar conditions in the area.

A potential remains for the presence of unknown, unidentified, or unforeseen surface and sub-surface contamination. Any evidence of such potential site contamination would require appropriate surface and sub-surface exploration and testing.

If new information is developed in future work (which may include excavations, borings, or other studies), Arcadis Canada Inc. should be requested to re-evaluate the conclusions of this report, and to provide amendments as required.

10 REFERENCES

AMEC Earth & Environmental, January 2007. Roberts Bay and Ida Bay Abandoned Mine Sites Remediation Plan.

Canadian Council of Ministers of the Environment. 2016. Guidance Manual for Environmental Site Characterization in Support of Human and Health Risk Assessment, Volume I Guidance Manual.

Canadian Council of Ministers of the Environment. 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health, updated online.

Canadian Council of Ministers of the Environment, 2007. Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FWAL), updated online.

Canadian Council of Ministers of the Environment. 2008a. Canada-Wide Standards for Petroleum Hydrocarbons in Soil.

Canadian Council of Ministers of the Environment. 2008b. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale Supporting Technical Document.

Canadian Council of Ministers of the Environment. 2008c. Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: User Guidance.

Franz Environmental Inc., 2010. Monitoring Program Solid Waste management Facility Landfill Roberts Bay, Nunavut, Final Report.

Franz Environmental Inc., 2012. Monitoring Program Solid Waste management Facility Landfill Roberts Bay, Nunavut, Final Report.

Indian and Northern Affairs Canada. March 2009. *Abandoned Military Site Remediation Protocol*, Contaminated Sites Program.

Indian and Northern Affairs Canada. February 9, 2009. *Roberts Bay and Ida Bay Long-Term Monitoring Plan*.

Indian and Northern Affairs Canada, Specification, Project No. 416829, Roberts Bay/Ida Bay, Section 31 70 02 Site Remediation.

Ministry of the Environment, Ontario, 1994. Water Management - Policies, Guidelines, Provincial Water Quality Objectives.

Nunavut Water Board (NWB)'s Water Licence, August 8, 2008. License No. 1BR-ROB0813 issued to Indian and Northern Affairs Canada.

SENES Consultants Limited. February, 2010. 2009 Inter-Seasonal Report for Roberts Bay and Ida Bay Mine Sites Site Remediation Program, Nunavut.

TABLES

Table 1
PHC Analytical Results for Surface Water Samples
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

PARAMETER	Units	Guidelines			RDL	ROB-6	ROB-7		RPD	ROB-8	ROB-9	ROB-10
Sample ID		NWB Water License[1]	CCME FWAL[2]	Upper Limit of Acceptability[3]								
Date						19/08/2016	19/08/2016	19/08/2016		19/08/2016	19/08/2016	19/08/2016
BTEX & F1 Hydrocarbons							Duplicate					
Benzene	ug/L	370	370	Not Available	0.4	<0.40	<0.40	<0.40	NC	<0.40	<0.40	<0.40
Toluene	ug/L	2	2	Not Available	0.4	<0.40	<0.40	<0.40	NC	<0.40	<0.40	<0.40
Ethylbenzene	ug/L	90	90	Not Available	0.4	<0.40	<0.40	<0.40	NC	<0.40	<0.40	<0.40
o-Xylene	ug/L	NC	NC	Not Available	0.4	<0.80	<0.80	<0.80	NC	<0.80	<0.80	<0.80
p+m-Xylene	ug/L	NC	NC	Not Available	0.8	<0.40	<0.40	<0.40	NC	<0.40	<0.40	<0.40
Total Xylenes	ug/L	180	NC	Not Available	0.8	<0.80	<0.80	<0.80	NC	<0.80	<0.80	<0.80
F1 (C6-C10)-BTEX	ug/L	NC	NC	Not Available	100	<100	<100	<100	NC	<100	<100	<100
F1 (C6-C10)	ug/L	NC	NC	Not Available	100	<100	<100	<100	NC	<100	<100	<100
F2-F4 Hydrocarbons												
F2 (C10-C16 Hydrocarbons)	mg/L	NC	NC	Not Available	0.1	<0.10	<0.10	<0.10	NC	<0.10	<0.10	<0.10
F3 (C16-C34 Hydrocarbons)	mg/L	NC	NC	Not Available	0.2	<0.20	<0.20	<0.20	NC	<0.20	<0.20	<0.20
F4 (C34-C50 Hydrocarbons)	mg/L	NC	NC	Not Available	0.2	<0.20	<0.20	<0.20	NC	<0.20	<0.20	<0.20
Reached Baseline at C50	mg/L	NC	NC	Not Available	N/A	Yes	Yes	Yes	NC	Yes	Yes	Yes

Notes:

1 = Nunavut Water Board License, License No. 1BR-ROB0813, Remediation Criteria in Table 1, Appendix A

2 = CCME (2007) Canadian Environmental Quality Guidelines Summary Table. Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life (FWAL).

3 = Upper Limit of Acceptability is determined as described in Report Section 3.2. Upper limits of acceptability are calculated using mean of previous sampling rounds +3 standard deviations.

* = See Quality Assurance and Quality Control section for scenario rationale.

NC = No Criteria

RDL= Reportable Detection Limit

20 = Exceeds selected guideline.

Table 2
Metals Analytical Results for Surface Water Samples
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

PARAMETER		Guidelines				Lowest RDL	ROB-6		ROB-7						ROB-8		ROB-9		ROB-10	
Sample ID		NWB Water Licesnse[1]	CCME FWAL[2]	Upper Limit of Acceptability[3]																
Date							19/08/2016	19/08/2016	19/08/2016			19/08/2016			19/08/2016	19/08/2016	19/08/2016	19/08/2016	19/08/2016	19/08/2016
Metals	Units		Total	Total	Dissolved		Total	Dissolved	Total	Duplicate	RPD	Dissolved	Duplicate	RPD	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum (Al)	mg/L	0.005-0.1	0.1	NC	NC	0.003	0.16	0.098	0.073	0.055	28%	0.014	0.013	NC	0.011	0.0059	0.47	0.077	0.034	0.013
Antimony (Sb)	mg/L	NG	NG	NC	NC	0.00060	<0.00060	<0.00060	<0.00060	<0.00060	NC	<0.00060	<0.00060	NC	<0.00060	<0.00060	<0.00060	<0.00060	0.0017	<0.00060
Arsenic (As)	mg/L	0.005	0.005	0.046	0.010	0.0002	0.0039	0.0015	0.00035	0.00042	NC	0.00027	0.00034	NC	0.0024	0.0022	0.00036	0.00021	0.0014	0.00034
Barium (Ba)	mg/L	NG	NG	NC	NC	0.01	0.044	0.028	0.026	0.026	NC	0.025	0.025	NC	0.068	0.066	<0.010	<0.010	0.049	0.025
Beryllium (Be)	mg/L	NG	NG	NC	NC	0.001	<0.0010	<0.0010	<0.0010	<0.0010	NC	<0.0010	<0.0010	NC	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Boron (B)	mg/L	NG	1.5	NC	NC	0.02	<0.020	<0.020	<0.020	<0.020	NC	<0.020	<0.020	NC	0.050	0.049	0.021	<0.020	0.048	<0.020
Cadmium	ug/L	0.017	0.09	0.11	0.053	0.02	0.031	0.026	<0.020	<0.020	NC	<0.020	<0.020	NC	<0.020	<0.020	<0.020	0.02	<0.020	<0.020
Calcium (Ca)	mg/L	NG	NG	NC	NC	0.3	29	31	34	34	0%	35	35	0%	140	140	8.5	9.3	79	35
Chromium (Cr)	mg/L	0.0089	0.0089	0.003	NC	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	NC	<0.0010	<0.0010	NC	<0.0010	<0.0010	0.0011	<0.0010	<0.0010	<0.0010
Chromium VI (6+)	mg/L	NG	0.001	NC	NC	0.0010	<0.0010	NA	<0.0010	<0.0010	NC	NA	NA	NC	<0.0010	NA	<0.0010	NA	<0.0010	NA
Cobalt (Co)	mg/L	NG	NG	0.006	0.0009	0.0003	0.0020	0.0015	<0.00030	<0.00030	NC	<0.00030	<0.00030	NC	0.00044	0.00035	<0.00030	<0.00030	<0.00030	<0.00030
Copper (Cu)	mg/L	0.002-0.004	0.002-0.004[4]	0.022	0.0089	0.0002	0.0086	0.0085	0.0093	0.01	7%	0.0077	0.0077	0%	0.00064	0.00040	0.0022	0.0016	0.0072	0.0077
Iron (Fe)	mg/L	0.3	0.3	NC	NC	0.060	2.9	0.66	0.14	0.088	NC	<0.060	<0.060	NC	0.53	0.29	0.59	0.083	<0.060	<0.060
Lead (Pb)	mg/L	0.001-0.007	0.001-0.007[4]	0.016	0.001	0.0002	0.0023	0.00032	<0.00020	<0.00020	NC	<0.00020	<0.00020	NC	<0.00020	<0.00020	<0.00020	<0.00020	0.00064	<0.00020
Lithium (Li)	mg/L	NG	NG	NC	NC	0.02	<0.020	<0.020	<0.020	<0.020	NC	<0.020	<0.020	NC	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Magnesium (Mg)	mg/L	NG	NG	NC	NC	0.2	4.7	4.9	12	12	0%	13	13	NC	110	110	6.6	7.0	27	13
Manganese (Mn)	mg/L	NG	NG	NC	NC	0.004	0.032	0.028	0.0062	<0.0040	NC	<0.0040	<0.0040	NC	0.69	0.59	0.017	0.011	0.0045	<0.0040
Mercury (Hg)	ug/L	0.026	0.026	NC	NC	0.002	<0.020	0.0045	<0.020	<0.020	NC	<0.0020	<0.0020	NC	<0.020	<0.0020	<0.020	<0.0020	<0.020	<0.0020
Molybdenum (Mo)	mg/L	0.073	0.073	NC	NC	0.0002	0.00037	0.00057	0.0005	0.0006	NC	0.00048	0.00049	NC	0.0014	0.0014	<0.00020	<0.00020	0.0018	0.00049
Nickel (Ni)	mg/L	0.025-0.150	0.025-0.15[4]	0.01	0.005	0.0005	0.0023	0.0017	0.0006	<0.00050	NC	<0.00050	<0.00050	NC	0.00081	0.00072	0.0012	0.00052	0.00064	<0.00050
Phosphorus (P)	mg/L	NG	NG	NC	NC	0.1	<0.10	<0.10	<0.10	<0.10	NC	<0.10	<0.10	NC	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Potassium (K)	mg/L	NG	NG	NC	NC	0.3	<0.30	<0.30	1.3	1.3	NC	1.3	1.3	NC	9.6	10	2.2	2.3	4.3	1.3
Selenium (Se)	mg/L	0.001	0.001	NC	NC	0.0002	0.00042	0.00034	<0.00020	<0.00020	NC	<0.00020	<0.00020	NC	<0.00020	<0.00020	<0.00020	<0.00020	0.00034	<0.00020
Silicon (Si)	mg/L	NG	NG	NC	NC	0.1	2.5	2.8	2	1.9	5%	1.8	1.8	0%	1.1	1.1	1.4	0.57	2.5	1.8
Silver (Ag)	mg/L	0.0001	0.00025	NC	NC	0.0001	<0.00010	<0.00010	<0.00010	<0.00010	NC	<0.00010	<0.00010	NC	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Sodium (Na)	mg/L	NG	NG	NC	NC	0.50	7.2	8.2	12	12	0%	12	12	0%	660	650	33	35	60	12
Strontium (Sr)	mg/L	NG	NG	NC	NC	0.020	0.035	0.035	0.032	0.032	NC	0.033	0.033	NC	0.63	0.66	0.049	0.056	0.14	0.033 (2)
Sulphur (S)	mg/L	NG	NG	NC	NC	0.20	4.7	5.1	3.2	3.2	0%	3	3	0%	49	45	1.9	1.8	44	3.0
Thallium (Tl)	mg/L	0.0008	0.0008	NC	NC	0.0002	<0.00020	<0.00020	<0.00020	<0.00020	NC	<0.00020	<0.00020	NC	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tin (Sn)	mg/L	NG	NG	NC	NC	0.0010	<0.0010	<0.0010	<0.0010	<0.0010	NC	<0.0010	<0.0010	NC	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Titanium (Ti)	mg/L	NG	NG	NC	NC	0.0010	0.0039	0.0013	0.0027	0.0021	NC	<0.0010	<0.0010	NC	<0.0010	<0.0010	0.026	0.0031	<0.0010	<0.0010
Uranium (U)	mg/L	NG	0.015	NC	NC	0.0001	0.00014	<0.00010	0.00021	0.00025	NC	0.0002	0.00021	NC	0.0018	0.0018	<0.00010	<0.00010	0.0038	0.00021
Vanadium (V)	mg/L	NG	NG	NC	NC	0.0010	0.0014	<0.0010	<0.0010	<0.0010	NC	<0.0010	<0.0010	NC	<0.0010	<0.0010	0.0017	<0.0010	<0.0010	<0.0010
Zinc (Zn)	mg/L	0.03	0.03	0.026	0.011	0.0030	0.0056	0.0068	<0.0030	<0.0030	NC	<0.0030	<0.0030	NC	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

Notes:

1 = Nunavut Water Board License, License No. 1BR-ROB0813, Remediation Criteria in Table 1, Appendix A

2 = CCME (2007) Canadian Environmental Quality Guidelines Summary Table. Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life (FWAL).

3 = Upper Limit of Acceptability is determined as described in Report Section 3.3. Upper limits of acceptability are calculated using mean of previous sampling rounds +3 standard deviations.

4 = Guideline depends on hardness, guideline calcuated for each sample and compared to result

NC: Not calculated

NG: No guideline

NA: Not Analyzed

RDL: Reportable Detection Limit

20 = Exceeds NWB Water License criteria

20 = Exceeds CCME FWAL guideline.

20 = Results exceeds ULA

Table 3
PCB Analytical Results for Surface Water Samples
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

PARAMETER	Guidelines		RDL	ROB-6	ROB-7		RPD	ROB-8	ROB-9	ROB-10
Sample ID	CCME FWAL[1]	Upper Limit of Acceptability[2]								
Date				19/08/2016	19/08/2016			19/08/2016	19/08/2016	19/08/2016
PCBs (mg/L)						Duplicate				
Aroclor 1016	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1221	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1232	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1242	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1248	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1254	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1260	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1262	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Aroclor 1268	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050
Total PCB	NG	NC	0.000050	<0.000050	<0.000050	<0.000050	NC	<0.000050	<0.000050	<0.000050

Notes:

1 = CCME (2007) Canadian Environmental Quality Guidelines Summary Table. Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life (FWAL).

2 = Upper Limit of Acceptability is determined as described in Report Section 3.3. Upper limits of acceptability are calculated using mean of previous sampling rounds +3 standard deviations.

NG: No guideline

NC: Not calculated

RDL: Reportable Detection Limit

Table 4
Inorganic Parameter Analytical Results for Surface Water Samples
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

PARAMETER		Guidelines		Lowest RDL	ROB-6	ROB-7		RPD	ROB-8	ROB-9	ROB-10
Sample ID		CCME FWAL[1]	Upper Limit of Acceptability[2]								
Date					19/08/2016	19/08/2016	19/08/2016		19/08/2016	19/08/2016	19/08/2016
Calculated Parameters						Duplicate					
Anion Sum	meq/L	NG	NC	N/A	1.9	3.2	3.1	3%	41	2.5	9
Cation Sum	meq/L	NG	NC	N/A	2.3	3.4	3.3	3%	45	2.6	9.5
Hardness ($CaCO_3$)	mg/L	NG	1329	0.5	98	140	140	0%	820	52	330
Ion Balance	N/A	NG	NC	0.01	1.3	1.1	1.1	0%	1.1	1	1.1
Dissolved Nitrate (NO_3)	mg/L NO_3	13	NC	0.044	<0.044	0.24	0.25	4%	<0.044	<0.044	9.9
Nitrate plus Nitrite (N)	mg/L	NG	NC	0.02	<0.020	0.054	0.057	NC	<0.020	<0.020	2.2
Dissolved Nitrite (NO_2)	mg/L NO_2	0.06	NC	0.033	<0.033	<0.033	<0.033	NC	<0.033	<0.033	<0.033
Misc. Inorganics											
Conductivity	uS/cm	NG	5930	1.0	190	300	310	3%	4400	280	890
pH	pH	6.5-9.0	6.0 < 8.7	N/A	7.01	7.91	7.97	1%	7.83	7.51	7.71
Colour	PtCo units	NG	108	2	170	47	45	4%	80	24	25
Total Dissolved Solids	mg/L	NG	4541	10	180	190	200	5%	2500	170	540
Total Suspended Solids	mg/L	NG	391	1.0	120	97	12	**156%**	8.7	24	85
Anions											
Alkalinity (PP as CaCO3)	mg/L	NG	NC	0.5	<0.50	<0.50	<0.50	NC	<0.50	<0.50	<0.50
Alkalinity (Total as CaCO3)	mg/L	NG	NC	0.5	68	130	130	0%	290	28	180
Bicarbonate (HCO3)	mg/L	NG	NC	0.5	83	150	150	0%	360	34	210
Carbonate (CO3)	mg/L	NG	NC	0.5	<0.50	<0.50	<0.50	NC	<0.50	<0.50	<0.50
Hydroxide (OH)	mg/L	NG	NC	0.5	<0.50	<0.50	<0.50	NC	<0.50	<0.50	<0.50
Dissolved Sulphate (SO4)	mg/L	NG	319	1	9.7	8.7	8.8	1%	140	4.4	140
Dissolved Chloride (Cl)	mg/L	120	1855	1	11	16	16	0%	**1100**	66	90
Nutrients											
Dissolved Nitrite (N)	mg/L N	NG	NC	0.01	<0.010	<0.010	<0.010	NC	<0.010	<0.010	<0.010
Dissolved Nitrate (N)	mg/L N	NG	5.1	0.01	<0.010	0.054	0.057	5%	<0.010	<0.010	2.2

Notes:

1 = CCME (2007) Canadian Environmental Quality Guidelines Summary Table. Canadian Water Quality Guidelines for the protection of Freshwater Aquatic Life (FWAL).

2 = Upper Limit of Acceptability is determined as described in Report Section 3.3. Upper limits of acceptability are calculated using mean of previous sampling rounds +3 standard deviations; significant figures of results are factored in the calculation.

NC = No Criteria

RDL= Reportable Detection Limit

20 : CCME FWAL guideline exceeded

20 : ULA exceeded

Table 5
Calculation of ULAs for Metal Parameters
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

Sample #	Location	Date	Diss. As [mg/L]	As [mg/L]	Diss. Cd [ug/l]	Cd [ug/l]	Diss. Co [mg/L]	Co [mg/L]	Diss. Cr [mg/L]	Cr [mg/L]	Diss. Cu [mg/L]	Cu [mg/L]	Diss. Ni [mg/L]	Ni [mg/L]	Diss. Pb [mg/L]	Pb [mg/L]	Diss. Zn [mg/L]	Zn [mg/L]
Surface Water Samples																		
ROB-6	SE of SWMF	2010	0.0005	0.0023	0.012	0.079	<0.0003	0.0047	<0.001	0.003	0.0042	0.0220	0.0008	0.0045	<0.0002	0.0092	0.005	0.017
ROB-7	W of SWMF	2010	0.01	0.050	0.008	0.087	<0.0003	0.0041	<0.001	<0.001	0.001	0.0048	0.0047	0.01	<0.0002	0.014	<0.003	0.021
ROB-8	NE of SMWF	2010	0.002	0.005	<0.005	0.05	<0.0003	<0.0003	<0.001	<0.001	<0.001	0.0020	<0.0005	<0.0005	<0.0002	<0.0002	<0.003	<0.003
ROB-9	Robert's Lake	2010	0.0002	0.0003	0.005	<0.005	<0.0003	<0.0003	<0.001	<0.001	0.001	0.0020	<0.0005	0.0008	<0.0002	<0.0002	<0.003	<0.003
ROB-10	E of SWMF	2010	0.0016	0.0022	0.052	0.048	<0.0003	0.0005	<0.001	<0.001	0.0027	0.0051	0.0019	0.0032	0.0008	0.0048	0.010	0.014
ROB-6	SE of SWMF	2012	0.00041	0.00048	0.0072	<0.005	<0.0003	<0.0003	<0.0010	<0.0010	0.005	0.006	0.00065	0.00057	<0.0002	<0.0002	<0.003	<0.003
ROB-8	NE of SMWF	2012	0.0017	0.0015	<0.013	0.017	0.00097	0.001	<0.0025	<0.0025	0.00053	<0.00050	<0.0013	0.0015	<0.0005	<0.0005	<0.0075	<0.0075
ROB-9	Robert's Lake	2012	<0.0002	0.00031	<0.005	<0.005	<0.0003	<0.0003	<0.001	<0.001	0.0016	0.0013	<0.0005	<0.0005	<0.0002	<0.0002	<0.003	<0.003
ROB-10	E of SWMF	2012	0.0012	0.0012	0.0069	0.0093	<0.00030	<0.00030	<0.0010	<0.0010	0.0057	0.0063	<0.0005	<0.0005	<0.0002	0.00023	<0.003	<0.003
ROB-6	SE of SWMF	2014	0.00036	0.00046	<0.02	<0.02	<0.00030	<0.00030	<0.0010	<0.0010	0.0045	0.0049	0.00051	0.00061	<0.0002	<0.0002	0.0034	<0.003
ROB-8	NE of SMWF	2014	0.0023	0.0026	<0.02	<0.02	0.00032	0.00036	<0.0010	<0.0010	0.00072	0.0004	0.00079	0.00071	<0.0002	<0.0002	<0.003	<0.003
ROB-9	Robert's Lake	2014	0.00023	0.00035	<0.02	<0.02	<0.00030	<0.00030	<0.0010	<0.0010	0.0019	0.0023	0.00053	<0.0005	<0.0002	<0.0002	<0.003	<0.003
ROB-10	E of SWMF	2014	0.00083	0.0012	<0.02	<0.02	<0.00030	<0.00030	<0.0010	<0.0010	0.0057	0.0059	<0.0005	<0.0005	<0.0002	<0.0002	<0.003	<0.003
ROB-6	SE of SWMF	2016	0.0015	0.0039	0.026	0.031	0.0015	0.002	<0.0010	<0.0010	0.0085	0.0086	0.0017	0.0023	0.00032	0.0023	0.0068	0.0056
ROB-7	SW of SWMF	2016	0.00027	0.00035	<0.020	<0.020	<0.00030	<0.00030	<0.0010	<0.0010	0.0077	0.0093	<0.00050	0.0006	<0.00020	<0.00020	<0.0030	<0.0030
ROB-8	NE of SMWF	2016	0.0022	0.0024	<0.020	<0.020	0.00035	0.00044	<0.0010	<0.0010	0.0004	0.00064	0.00072	0.00081	<0.00020	<0.00020	<0.0030	<0.0030
ROB-9	Robert's Lake	2016	0.00021	0.00036	0.02	<0.020	<0.00030	<0.00030	<0.0010	0.0011	0.0016	0.0022	0.00052	0.0012	<0.00020	<0.00020	<0.0030	<0.0030
ROB-10	E of SWMF	2016	0.00034	0.0014	<0.020	<0.020	<0.00030	<0.00030	<0.0010	<0.0010	0.0077	0.0072	<0.00050	0.00064	<0.00020	0.00064	<0.0030	<0.0030
Statistics																		
N Value			18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
N Value [2010 -2014 only]			13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Average			0.001	0.004	0.017	0.028	0.000	0.001	<0.0025	0.001	0.003	0.005	0.001	0.002	0.000	0.002	0.004	0.006
Average [2010-2014 only]			0.002	0.005	0.015	0.030	0.000	0.001	<0.0025	0.001	0.003	0.005	0.001	0.002	0.000	0.002	0.004	0.007
Minimum			0.0002	0.0003	0.005	0.005	0.0003	0.0003	<0.001	0.001	0.0004	0.0004	0.0005	0.0005	0.0002	0.0002	0.003	0.003
Maximum			0.01	0.05	0.052	0.087	0.0015	0.0047	<0.0025	0.003	0.0085	0.022	0.0047	0.01	0.0008	0.014	0.01	0.021
Standard Deviation (s)* [2010 - 2014 only]			0.0026	0.0135	0.0128	0.0278	0.0002	0.0015	NC	0.0007	0.0020	0.0056	0.0012	0.0027	0.0002	0.0044	0.0022	0.0064
Acceptable Range (Average +/- 3s) [2010-2014 only]			0 < 0.0095	0 < 0.046	0 < 0.053	0 < 0.113	0 < 0.0009	0 < 0.006	NC	0 < 0.003	0 < 0.0089	0 < 0.022	0 < 0.005	0 < 0.01	0 < 0.001	0 < 0.016	0 < 0.011	0 < 0.026

Detection limits are converted to results to calculate average and standard deviation
Zero is substituted for negative values where average minus 3s is less than zero
NC: Not calculated. Where there are no values other than "non-detect," no standard deviation is calculated. The acceptable range for these samples should be close to the detection limit.

Table 6
Calculation of ULAs for PHC, PCB and Inorganic Parameters
Indigenous and Northern Affairs Canada

ARCADIS Design & Consultancy for natural and built assets

Sample #	Location	Date	PCBs [ug/L]	TPH Identity								Inorganic Parameters											
				Benzene [ug/L]	Toluene [ug/L]	Ethyl-benzene [ug/L]	Total Xylene [ug/L]	F1 [ug/L]	F2 [ug/L]	F3 [ug/L]	F4 [ug/L]	Conductivity [µmho/cm]	pH	Colour [PtCo]	Hardness [mg/L]	Total Dissolved Solids [mg/L]	Total Suspended Solids [mg/L]	Dissolved Fluoride [mg/L]	Dissolved sulphate [mg/L]	Dissolved Chloride [mg/L]	Ortho-phosphate [mg/L]	Nitrite [mg/L]	Nitrate [mg/L]
Surface Water Samples																							
ROB-6	SE of SWMF	2010	<0.05	<0.2	<0.2	<0.2	<0.4	<100	<100	<100	<100	1500	7.66	34	590	1500	420	0.060	150	280	<0.003	<0.003	1.4
ROB-7	W of SWMF	2010	<0.05	<0.2	<0.2	<0.2	<0.4	<100	<100	<100	<100	950	7.60	20	415	970	80	0.060	120	90	<0.003	<0.003	<0.003
ROB-8	NE of SMWF	2010	<0.05	<0.2	<0.2	<0.2	<0.4	<100	<100	<100	<100	4000	7.84	59	871	3400	11	0.140	230	1000	0.004	<0.003	<0.003
ROB-9	Robert's Lake	2010	<0.05	<0.2	<0.2	<0.2	<0.4	<100	<100	<100	<100	250	7.45	11	40.3	180	11	0.070	5	58	0.004	<0.003	<0.003
ROB-10	E of SWMF	2010	<0.05	<0.2	<0.2	<0.2	<0.4	<25	<100	<100	<100	1900	7.62	15	582	1700	57	0.050	170	380	<0.003	<0.003	3.6
ROB-6	SE of SWMF	2012	<0.05	<0.2	<0.2	<0.2	<0.4	<25	<100	<100	<100	590	7.97	41	260	370	<1.0	0.072	61	59	0.007	<0.003	0.73
ROB-8	NE of SMWF	2012	<0.05	<0.2	<0.2	<0.2	<0.4	<25	<100	<100	<100	4100	7.74	74	780	2400	<1.0	0.150	130	1100	0.005	<0.003	0.005
ROB-9	Robert's Lake	2012	<0.05	<0.4	<0.4	<0.4	<0.8	<100	<100	<100	<100	240	7.64	8.8	40	130	1.0	0.055	5	58	0.003	<0.003	0.008
ROB-10	E of SWMF	2012	<0.05	<0.4	<0.4	<0.4	<0.8	<100	<100	<100	<100	850	7.74	10	290	490	<1.0	0.060	110	100	0.013	<0.003	3.1
ROB-6	SE of SWMF	2014	<0.05	<0.4	<0.4	<0.4	<0.8	<100	<100	<100	<100	562	6.93	43		420	5.3	0.053	98	76	<0.003	<0.01	0.81
ROB-8	NE of SMWF	2014	<0.05	<0.4	<0.4	<0.4	<0.8	<100	<100	<100	<100	3710	7.78	80		2900	15	0.150	160	1500	0.003	<0.01	<0.01
ROB-9	Robert's Lake	2014	<0.05	<0.4	<0.4	<0.4	<0.8	<100	<100	<100	<100	194	6.74	16		120	4	0.050	5	61	<0.003	<0.01	<0.01
ROB-10	E of SWMF	2014	<0.05	<0.4	0.41	<0.4	<0.8	<100	<100	<100	<100	535	6.82	15		420	1.3	0.050	150	61	<0.003	<0.01	4.3
ROB-6	SE of SWMF	2016	<0.05	<0.4	<0.40	<0.40	<0.80	<100	<0.10	<0.20	<0.20	190	7.01	170	98	180	120		9.7	11		<0.010	<0.010
ROB-7	SW of SWMF	2016	<0.05	<0.4	<0.40	<0.40	<0.80	<100	<0.10	<0.20	<0.20	300	7.91	47	140	190	97		8.7	16		<0.010	0.054
ROB-8	NE of SMWF	2016	<0.05	<0.4	<0.40	<0.40	<0.80	<100	<0.10	<0.20	<0.20	4400	7.83	80	820	2500	8.7		140	1100 (3)		<0.010	<0.010
ROB-9	Robert's Lake	2016	<0.05	<0.4	<0.40	<0.40	<0.80	<100	<0.10	<0.20	<0.20	280	7.51	24	52	170	24		4.4	66		<0.010	<0.010
ROB-10	E of SWMF	2016	<0.05	<0.4	<0.40	<0.40	<0.80	<100	<0.10	<0.20	<0.20	890	7.71	25	330	540	85		140	90		<0.010	2.2
Statistics																							
N Value			18	18	18	18	18	18	18	18	18	18	18	18	14	18	18	13	18	18	13	18	18
N Value [2010 -2014 only]			13	13	13	13	13	13	13	13	13	13	13	13	9	13	13	13	13	13	13	13	13
Average			<0.05	<0.4	0.29	<0.4	<0.8	<100	<100	<100	<100	1490.8	7.50	32.8	429.8	1153.8	46.8	0.08	107.2	371.0	0.0044	<0.01	1.08
Average [2010 - 2014 only]			<0.05	<0.4	0.29	<0.4	<0.8	<100	<100	<100	<100	1490.8	7.50	32.8	429.8	1153.8	46.8	0.08	107.2	371.0	0.0044	<0.01	1.08
Minimum			<0.05	<0.2	0.2	<0.2	<0.4	<25	<100	<100	<100	194	6.74	8.8	40	120	1.000	0.05	4.8	58	0.003	<0.003	0.003
Maximum			<0.05	<0.4	0.41	<0.4	<0.8	<100	<100	<100	<100	4100	7.97	80	871	3400	420	0.15	230	1500	0.013	<0.01	4.3
Standard Deviation (s)* [2010-2014 only]			NC	NC	0	NC	NC	NC	NC	NC	NC	1480	0	25	300	1129	115	0	71	495	0	NC	2
Acceptable Range (Average +/- 3s) [2010-2014 only]			NC	NC	0 < 0.607	NC	NC	NC	NC	NC	NC	0 < 5930	6 < 8.72	0 < 108	0 < 1329	0 < 4541	0 < 391	0 < 0.197	0 < 319	0 < 1855	0 < 0.013	NC	0 < 5.75

Detection limits are converted to results to calculate average and standard deviation
Zero is substituted for negative values where average minus 3s is less than zero
NC: Not calculated. Where there are no values other than "non-detect," no standard deviation is calculated. The acceptable range for these samples should be close to the detection limit.

FIGURES

N

50m

ROB-8
ROB-8
ROB-8

BORROW AREA 5

BORROW AREA 4

BORROW AREA 1

FORMER ADIT

FORMER MILL BUILDING

ROB-10
ROB-10
ROB-10

BORROW AREA 2

ROB-7
ROB-7

FORMER OLD CAMP & LANDFILL

ROB-6
ROB-6
ROB-6

70m

Background Surface Water Sample "ROB-9" taken 763m south of this point

Trail from Robert's Lake to the SWMF Landfill

80m

70m

34

20m

35

36

FISH WEIR AND STUDY AREA

ROB-9
ROB-9

10m

20m

ROBERT'S LAKE

LEGEND

- Solid Waste Management Facility Landfill
- Trail
- Surface water Sample Location (FRANZ, 2012 & 2014)
- Surface water Sample Location (FRANZ, 2010)
- Surface water Sample Location (FRANZ, 2016)
- Viewpoint Photograph not taken in 2016

Title: SITE PLAN

ARCADIS

Project: LONG TERM MONITORING PROGRAM, SWMF LANDFILL, ROBERTS BAY, NUNAVUT

Date: October 2010

Updated: November 2016

Client: INAC

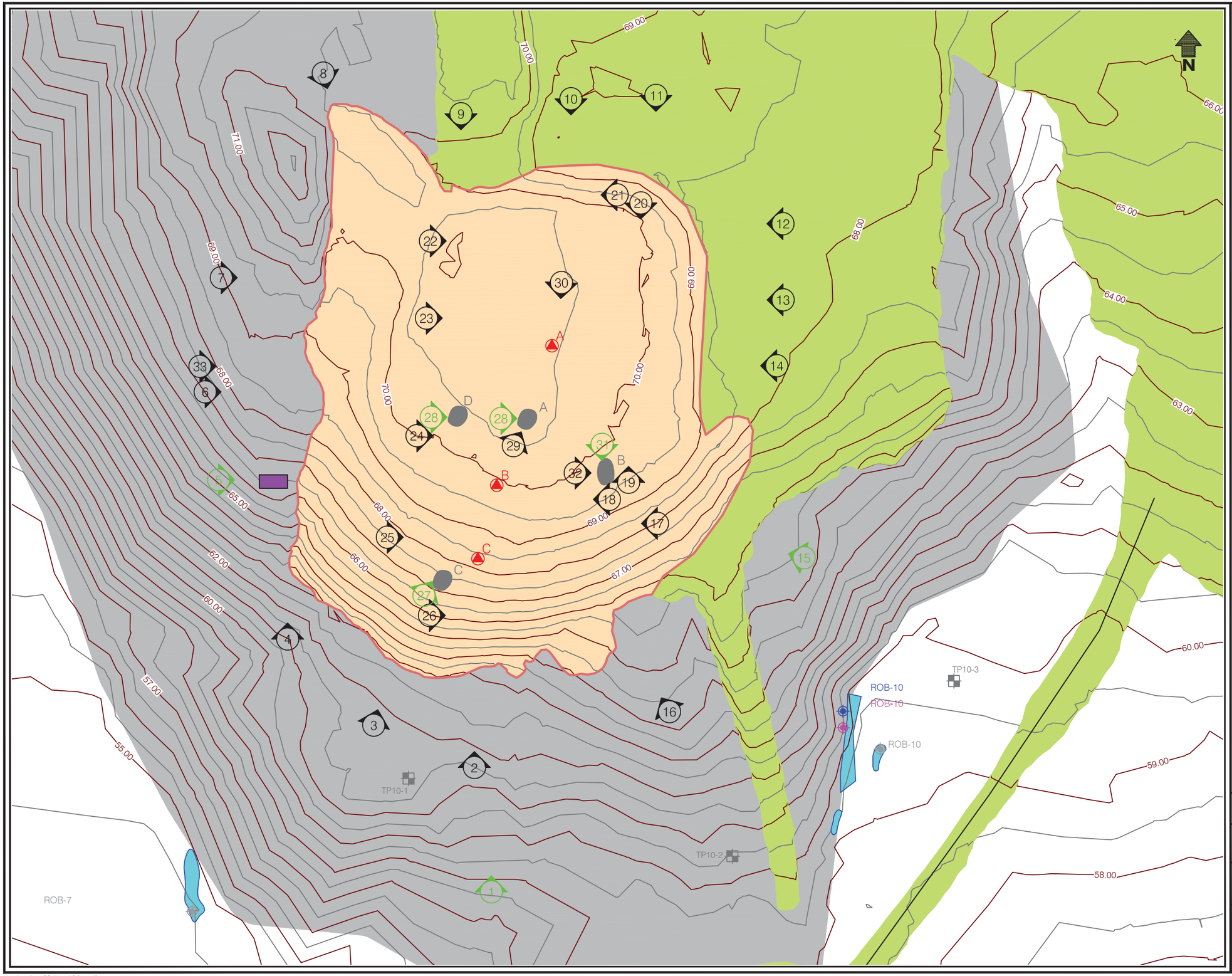
Metres
50 0 50 100
1:3250

FIGURE 1

TO BE PRINTED IN COLOUR ON 8.5"X11" PAPER ONLY - DO NOT SCALE

updated on: 30-Jan-17 by eholden

Z:\Projects\2016\100347-001 INAC DEW Line LTM\Individual Sites\Roberts Bay\Figures\1-CAD\100347-001 Roberts_Bay_Final_2016.dwg(layout)



LEGEND

- 68.00 — Ground surface Contour
- Outcrop
- Waste Rock Area
- Pond/Surface water
- Blast Hole (2 m deep) - not visible (covered)
- Solid Waste Management Facility Landfill
- A — Possible Settlement Area
- 1 — Viewpoint Photograph
- 27 — Picture Viewpoint Photograph provided in Appendix A
- A — Thermistor
- Soil Sample Location (FRANZ, 2010)
- Surface water Sample Location (FRANZ, 2012 & 2014)
- Surface water Sample Location (FRANZ, 2010)
- Surface water Sample Location (FRANZ, 2016)

REFERENCE:

1. PUBLIC WORKS AND GOVERNMENT SERVICES CANADA, PROJECT N° : 416829, SHEET 2 of 2
2. FIGURE BASED ON AMEC LAND SURVEYS LIMITED DRAWINGS: ROBERTS BAY AND IDA BAY MINE SITE REMEDIATION, SHEETS 1-4, SEPTEMBER 2005

NOTE:

1. SEE ATTACHED DVD FOR VIEWPOINT PICTURES
2. SURFACE WATER SAMPLED IN THE SAME LOCATIONS IN 2012 AND 2014.

Metres
10 0 10 20
1:500

Title: **SOLID WASTE MANAGEMENT FACILITY LANDFILL**

Project: **LONG TERM MONITORING PROGRAM, SWMF LANDFILL, ROBERTS BAY, NUNAVUT**

Client: **INAC**

ARCADIS

Date: October 2010
Updated: November 2016

FIGURE 2

TO BE PRINTED IN COLOUR ON 8.5"X11" PAPER ONLY - DO NOT SCALE

updated on:29-Nov-16 by dlogan

Z:\Projects\2016\100347-001 INAC DEW Line LTM\Individual Sites\Roberts Bay\Figures\1-CAD\100347-001 Roberts_Bay.dwg(layout)

APPENDIX A

Site Photographs

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

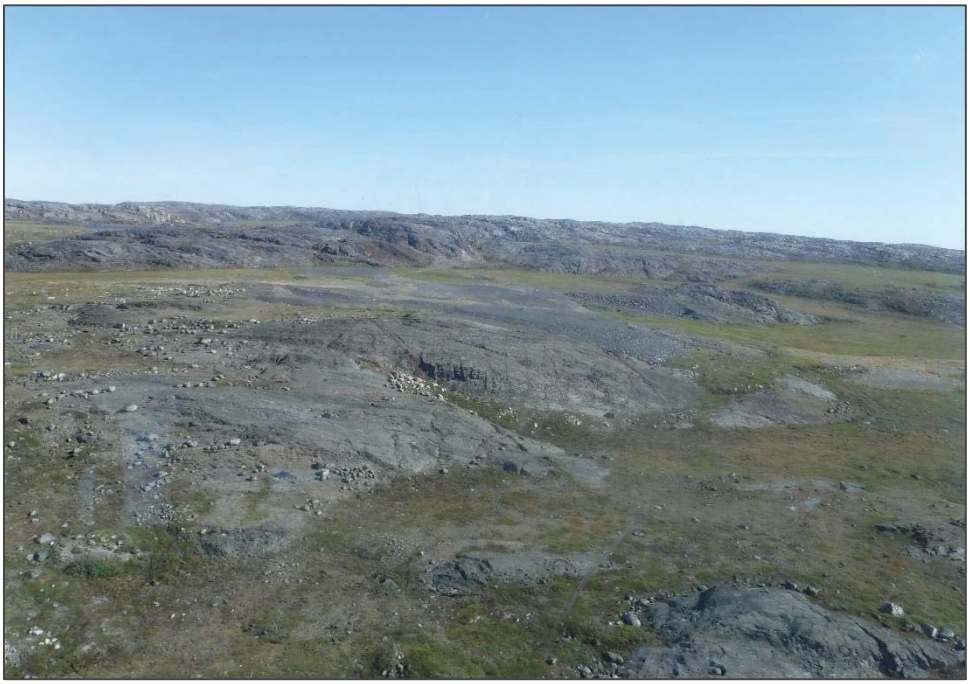


Photo: 1

Date:
August 19, 2016

Description:
Aerial View of SWMF

Location:
Roberts Bay SWMF

Photo: 2

Date:
August 19, 2016

Description:
South side of SWMF

Location:
Viewpoint 1

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

Photo: 3

Date:
August 19, 2016

Description:
Blast hole on west side of SWMF

Location:
Viewpoint 5

Photo: 4

Date:
August 19, 2016

Description:
Looking south at north edge of SWMF

Location:
Viewpoint 9

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

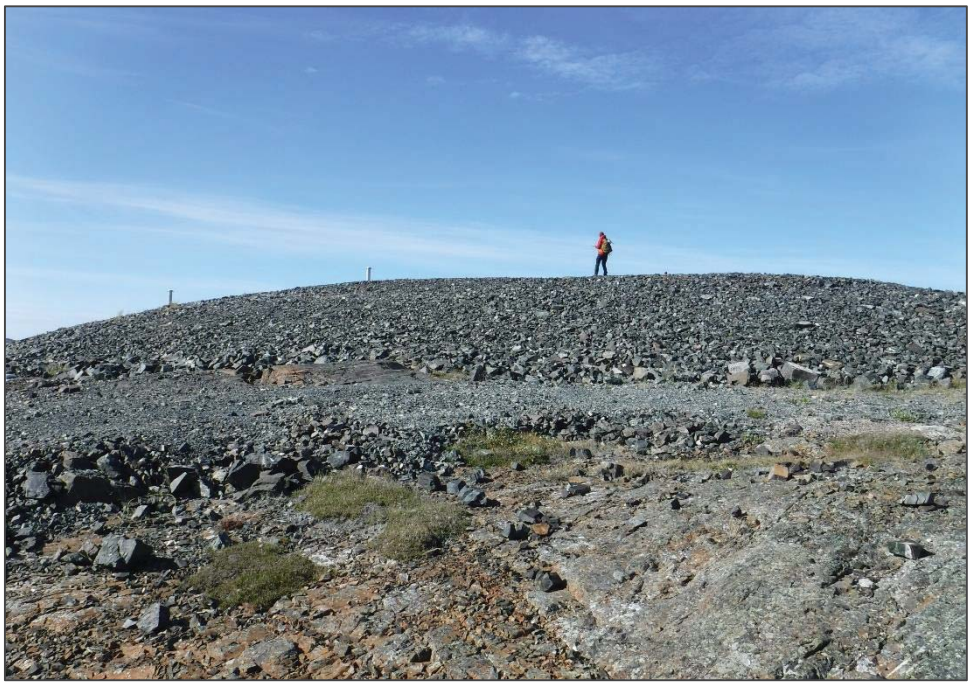


Photo: 5

Date:
August 19, 2016

Description:
Looking northwest at southeast side of SWMF

Location:
Viewpoint 15

Photo: 6

Date:
August 19, 2016

Description:
Area of settlement (Feature C)

Location:
Viewpoint 27

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

Photo: 7

Date:
August 19, 2016

Description:
Area of settlement (Feature A)

Location:
Viewpoint 28

Photo: 8

Date:
August 19, 2016

Description:
Area of settlement (Feature B)

Location:
Viewpoint 31

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

Photo: 9

Date:
August 19, 2016

Description:
New area of settlement observed in 2016 (Feature D)

Location:
Viewpoint 37

Photo: 10

Date:
August 19, 2016

Description:
Monitoring location ROB-6, southeast of SWMF

Location:
Roberts Bay

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

Photo: 11

Date:
August 19, 2016

Description:
Monitoring location ROB-7, southwest of SWMF

Location:
Roberts Bay

Photo: 12

Date:
August 19, 2016

Description:
Monitoring location ROB-8, northeast of SWMF

Location:
Roberts Bay

Project Photographs

Long Term Monitoring
Roberts Bay, Nunavut

Photo: 13

Date:
August 19, 2016

Description:
Monitoring location ROB-10, southeast of SWMF

Location:
Roberts Bay

Photo: 14

Date:
August 19, 2016

Description:
Looking N across top of SWMF at thermistor string casings

Location:
Roberts Bay

APPENDIX B

Thermistor Data

Table B-1: Thermistor Annual Maintenance Report

Contractor name: Arcadis Canada Inc.		**Inspection date:** 2016-08-19	
Prepared by: Elliott Holden, B. Eng.			
Thermistor Information			
Thermistor Number	**String-A site 1**	**String-B site 2**	**String-C site 3**
Install date	2009	2009	2009
Location	Roberts Bay (SWMF)	Roberts Bay (SWMF)	Roberts Bay (SWMF)
Inclination	Vertical	Vertical	Vertical
Cable length (m)	N/A	N/A	N/A
Cable length (m) above ground	2.5	3.3	3.1
No. of beads*	9	11	9
Bead type	44007	44007	44007
Coordinates (m)	N:7563819 E: 435359	N:7563800 E: 435351	N:7563790 E: 435349
Elevation: casing top (masl)	71.80	71.29	69.53
Elevation: bottom bore (masl)	66.67	65.76	65.11
Serial no. of datalogger installed in 2016	05070006	05070020	09100147
Serial no. of datalogger removed in 2016	07060503	05070003	07060500
Logger model	Lakewood Systems Ultra-Logger (RX-16 Revision J-C)		
*determined indirectly from thermistor logger data.			
Thermistor inspection			
Thermistor Number	**String-A site 1**	**String-B site 2**	**String-C site 3**
Casing	Good condition	Good condition	Good condition
Cover	Good condition	Good condition	Good condition
Dataloggers Installed in 2016	Good condition	Good condition	Good condition
Dataloggers Removed in 2016	Good condition	To be determined	Good condition
Cable	Good condition	Good condition	Good condition
Beads	Operational	Operational	Operational
Memory Used	80%	80%	80%
Battery installation date	Aug. 19, 2016	Aug. 19, 2016	Aug. 19, 2016
Battery change date (recommended)	2019	2019	2019
Main battery (V)	11.34	11.34	11.34
Aux battery (V)	13.87	13.75	13.50

Observations and proposed maintenance

- To access the dataloggers, the locks securing the lid of each thermistor housing were cut. After downloading the data and installing new dataloggers, each thermistor housing was secured with a new Master VLINE lock. The locks should be replaced by the standardized Guard locks (40 mm universal-key padlocks, No. 834, key number 102) during the next monitoring event

- New dataloggers with new batteries and desiccants were installed at all strings.

- A Lakewood resistance meter and switchbox were employed to compare manual (taken directly from thermistor beads) and logged readings. It was assessed that all of the beads were functioning correctly.

Table B-2: Manual Thermistor Readings and Inferred Bead Elevations

Analog Channel		Approx. Elevation (masl)*	Approx. Depth (mbgs)*	Thermistor R (Ohms)	Temperature (ºC)		
					Manual	Logged	Difference
String-A	1	70.5	0	8970	12.2	10.9	1.3
	2	70.17	0.33	10924	8.1	7.8	0.3
	3	69.67	0.83	12020	6.1	6.0	0.1
	4	69.17	1.33	14988	1.7	1.8	0.1
	5	68.67	1.83	16795	-0.5	-0.5	0.1
	6	68.17	2.33	17715	-1.5	-1.5	0.0
	7	67.67	2.83	18859	-2.8	-2.7	0.0
	8	67.17	3.33	19860	-3.7	-3.8	0.0
	9	66.67	3.83	20860	-4.7	-4.7	0.1
				maximum	--	--	***1.3***
String-B	1	70.76	-0.5	5579	22.5	19.2	3.3
	2	70.26	0	6902	17.8	14.2	3.6
	3	69.76	0.14	10833	8.2	8.2	0.1
	4	69.26	0.64	11870	6.4	6.5	0.2
	5	68.76	1.14	14002	3.1	3.1	0.1
	6	68.26	1.64	16323	0.0	0.1	0.1
	7	67.76	2.14	17295	-1.1	-1.0	0.1
	8	67.26	2.64	18092	-2.0	-1.9	0.0
	9	66.76	3.14	19069	-3.0	-3.0	0.0
	10	66.26	3.64	19950	-3.8	-3.9	0.0
	11	65.76	4.14	20710	-4.5	-4.6	0.1
				maximum	--	--	***3.6***
String-C	1	68.61	-0.5	5393	23.2	20.5	2.7
	2	68.61	-0.41	6464	19.2	15.1	4.1
	3	68.11	0.09	10812	8.3	7.9	0.4
	4	67.61	0.59	11804	6.5	6.5	0.1
	5	67.11	1.09	13918	3.2	3.2	0.0
	6	66.61	1.59	16306	0.1	0.1	0.0
	7	66.11	2.09	17211	-1.0	-1.0	0.0
	8	65.61	2.59	18025	-1.9	-1.9	0.0
	9	65.11	3.09	18968	-2.9	-2.9	0.0
				maximum	--	--	***4.1***

Temperature difference attributable to greater variability in air temperature measured by surface beads and time difference between logging time and manual resistance reading

Established elevation of borehole bottom (from as-built drawings)

Established elevation of landfill surface (from as-built drawings)

* Inferred elevation and depth based on design recommendations of 500 mm bead spacing from borehole bottom

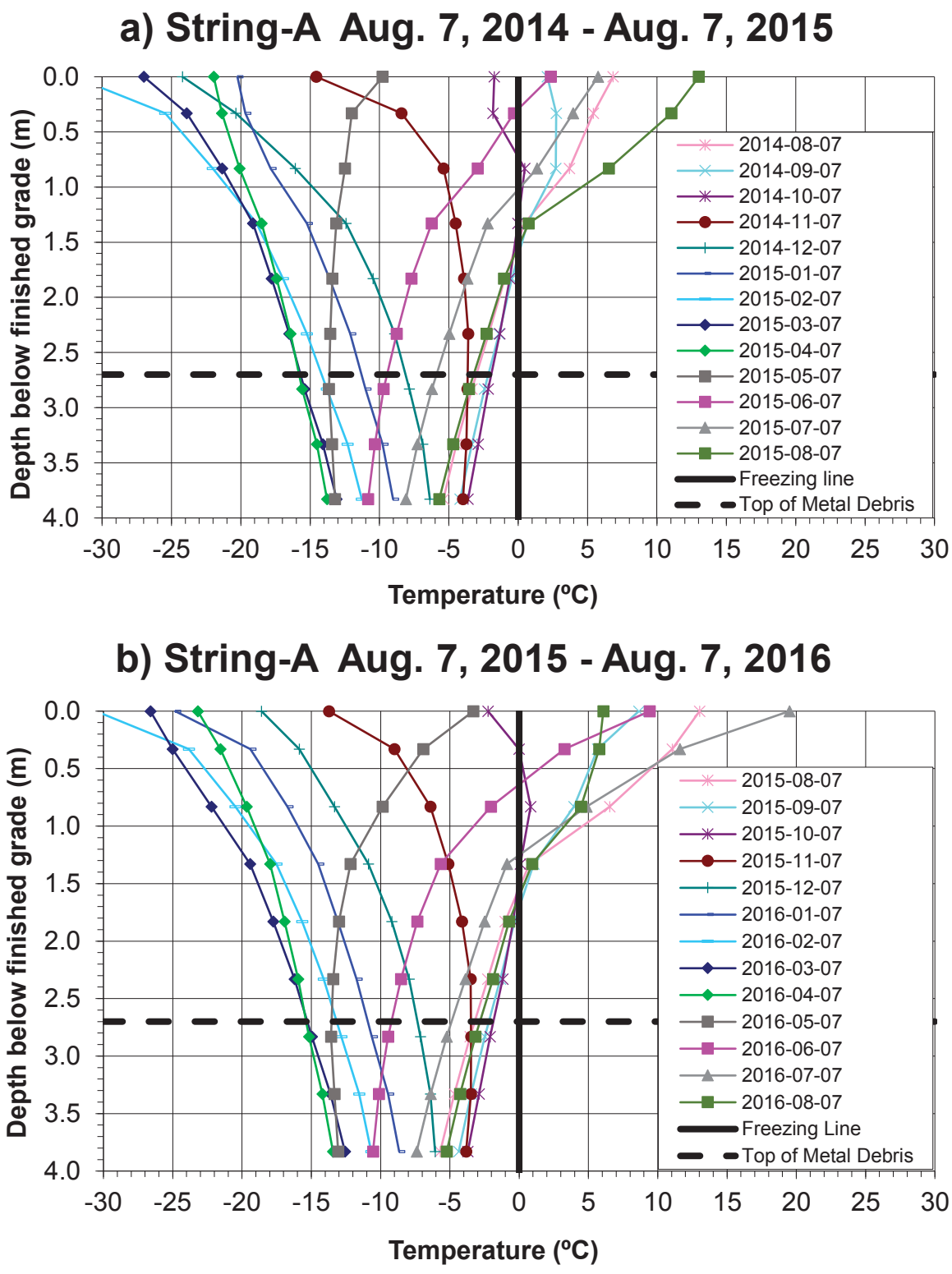


Figure B-1: Monthly ground temperature profiles at thermistor string A: a) 2014-2015, b) 2015-2016

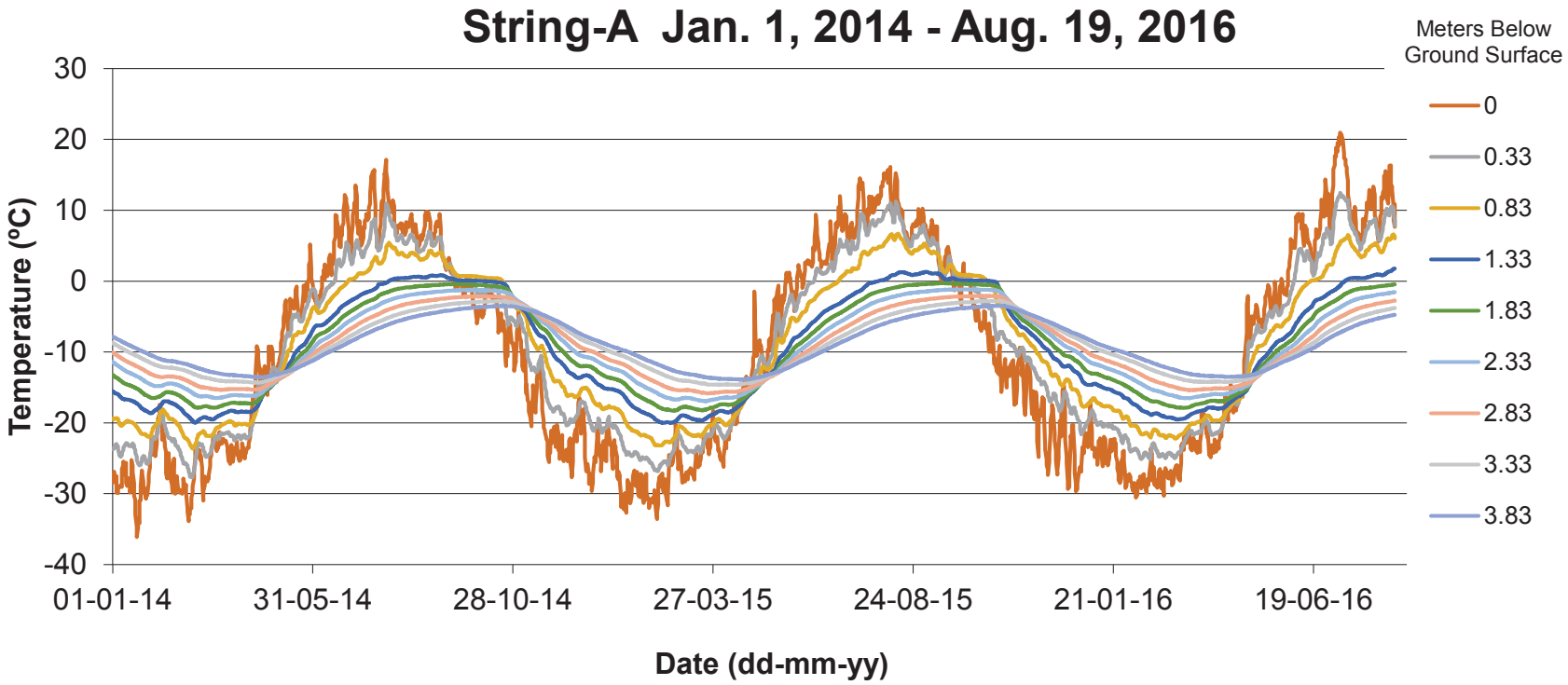


Figure B-2: Temperature vs. time at thermistor string A: (January 2014-August 2015)

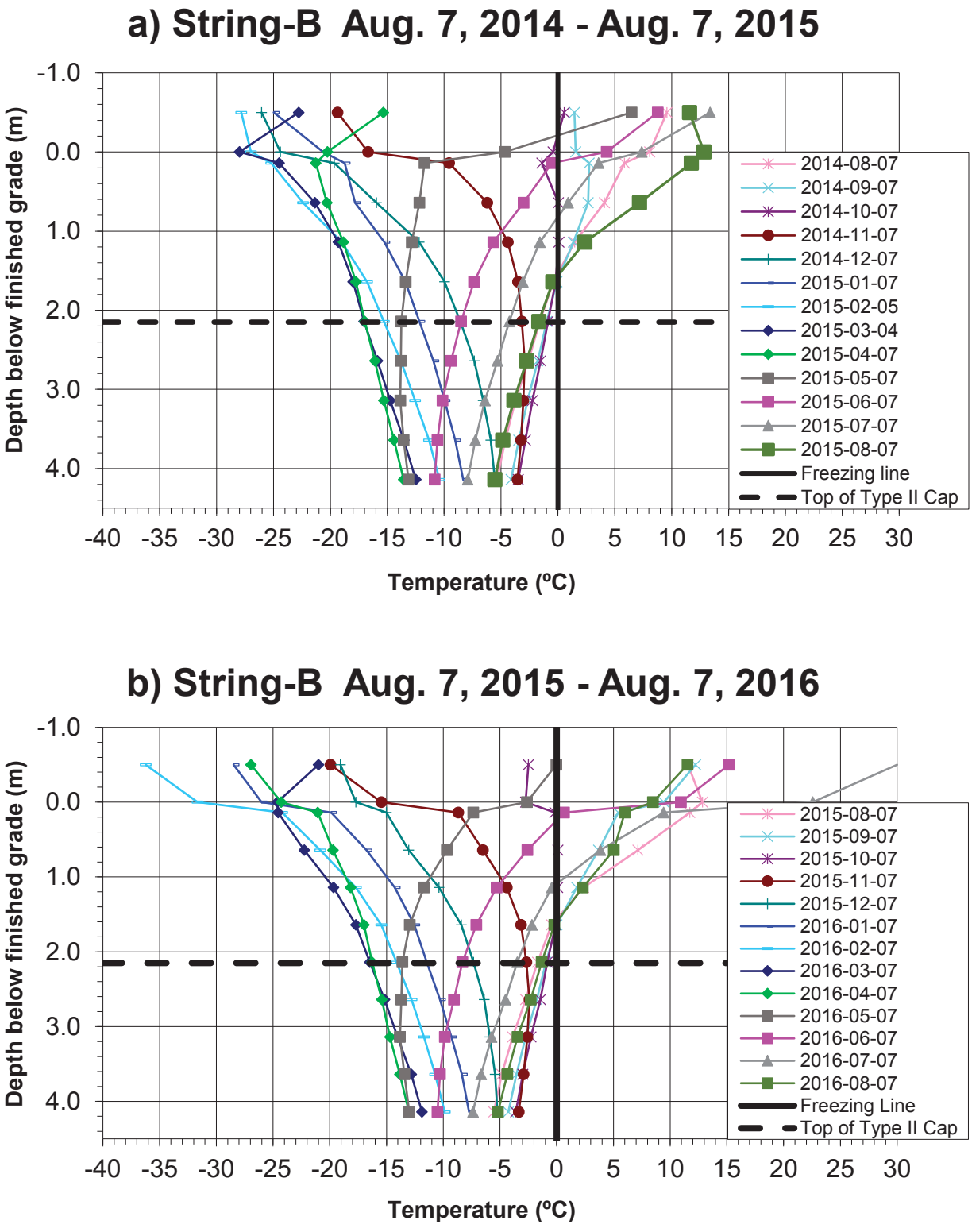


Figure B-3: Monthly ground temperature profiles at thermistor string B: a) 2014-2015, b) 2015-2016

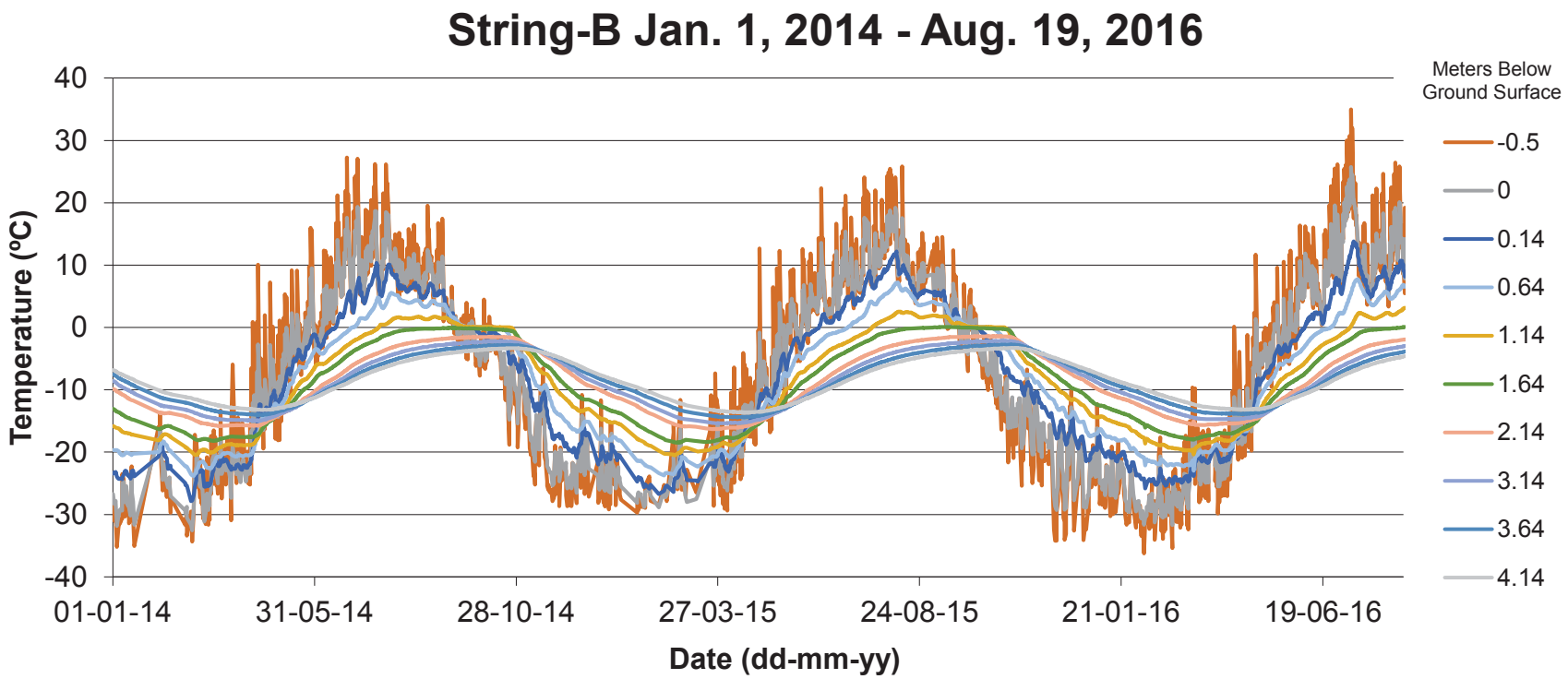


Figure B-4: Temperature vs. time at thermistor string B: (January 2014-August 2015)

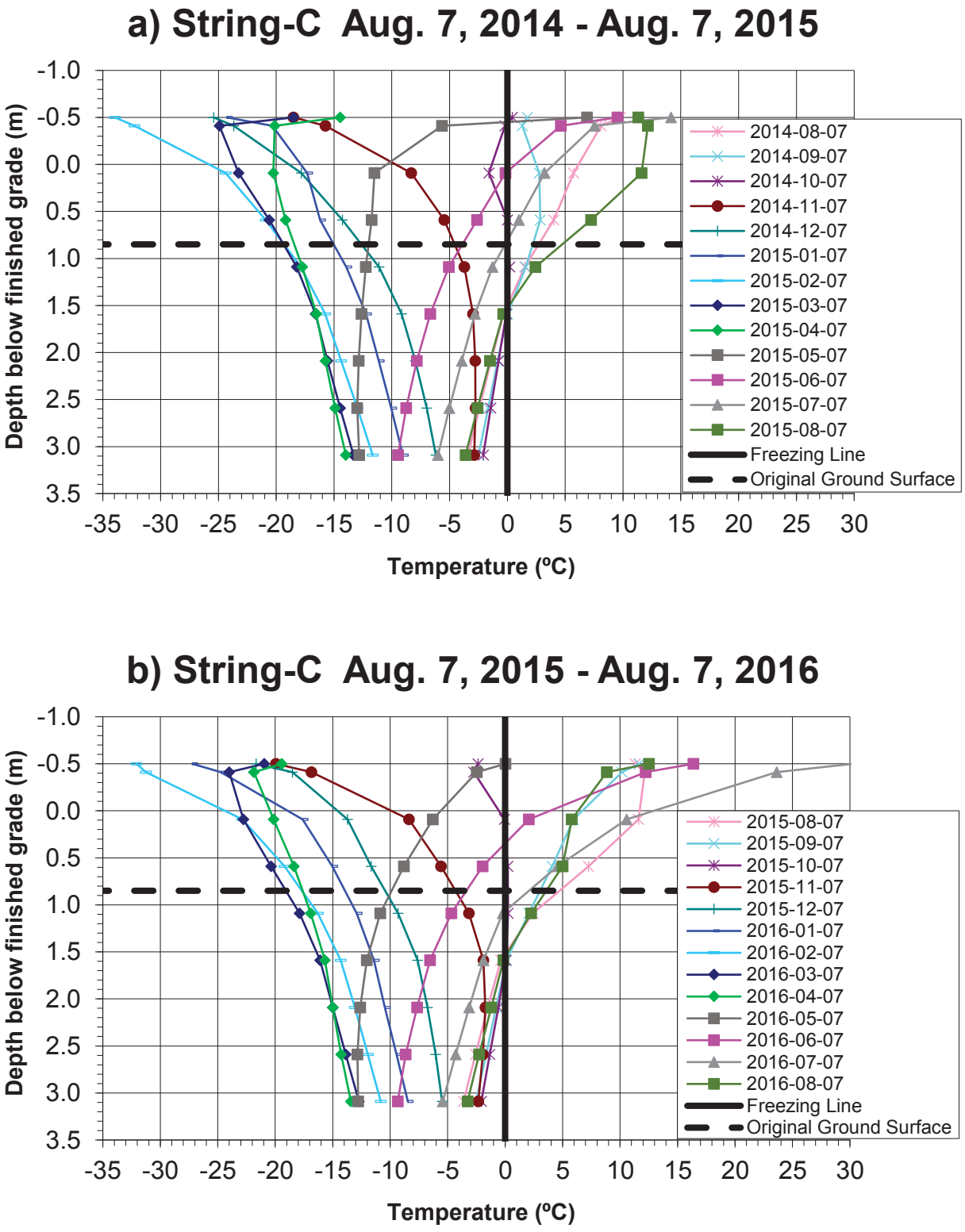


Figure B-5: Monthly ground temperature profiles at thermistor string C: a) 2014-2015, b) 2015-2016

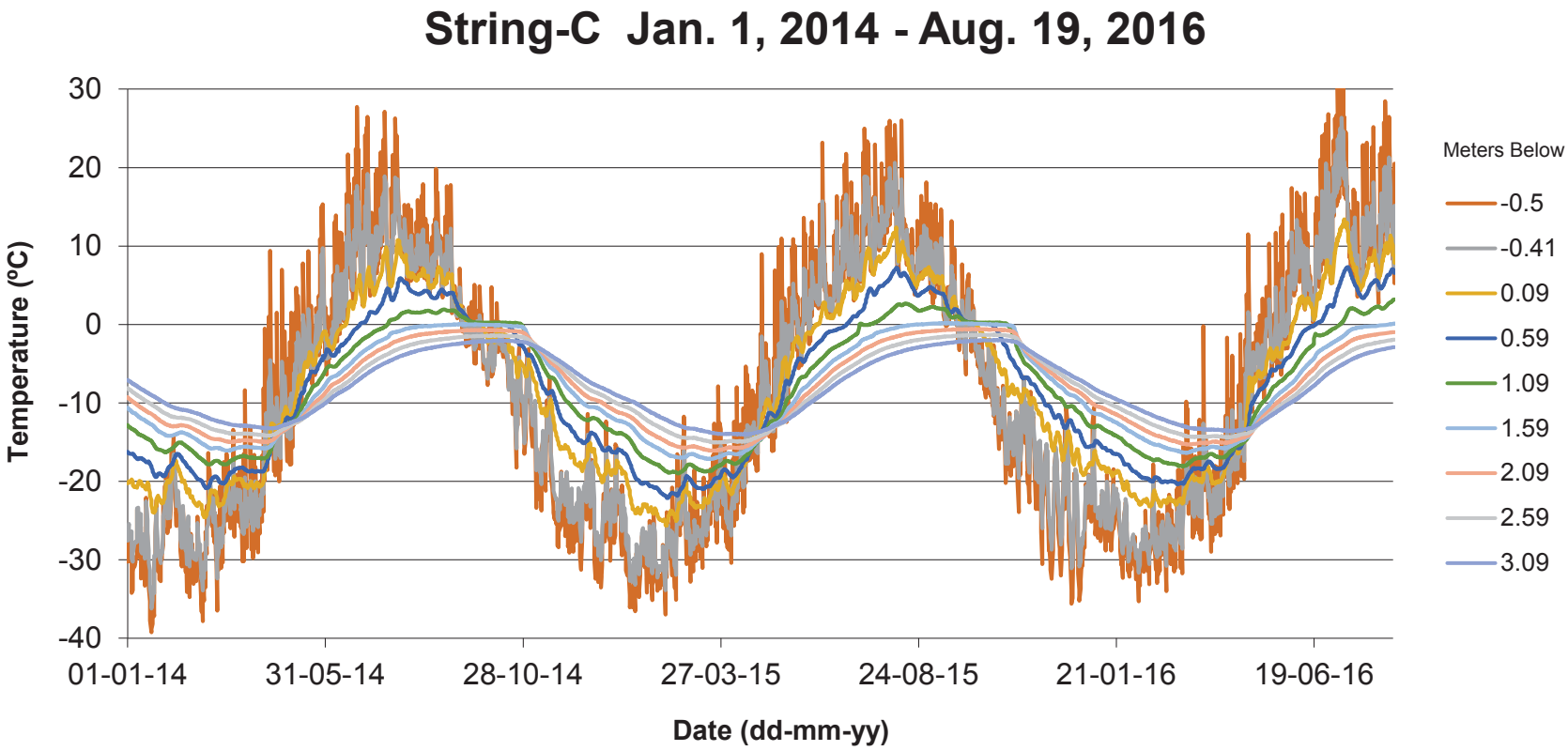


Figure B-6: Temperature vs. time at thermistor string C: (January 2014-August 2015)