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Mallik 7-Year Drilling Waste Sump Monitoring Program: Summary Report

O. Piraux, M.M. Côté, S. Akagawa, T. Kawamoto, P. Seccombe-Hett and S.R. Dallimore

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Mallik 7-Year Drilling Waste Sump Monitoring Program: Summary Report

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2016

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Mallik 7-Year Drilling Waste Sump Monitoring Program

Summary Report

FINAL

June 2015

Prepared for:
Aurora Research Institute

Prepared by:
KAVIK-Stantec Inc.

Project Number: 110219284

KAVIK-STANTEC

KAVIK-STANTEC

Executive Summary

The Mallik L-38 lease area in the outer Mackenzie Delta has been the site of three historical gas hydrate drilling programs, Mallik 2L-38 conducted in 1998, and Mallik 3L/4L/5L-38 conducted in 2002 and the Mallik gas hydrate production program conducted in the winters of 2007 and 2008. The 1998 and 2002 programs utilized conventional drilling sumps to dispose of drill cuttings and fluids. Of note, an additional drill sump constructed in the winter of 1973 is also at the Mallik site. This sump, which was part of the Mallik L-38 discovery well, was constructed by Imperial Oil Ltd. and is not part of the undertakings described in this report. In 1998 the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC), Natural Resources Canada (NRCan) collaborated to complete a gas hydrate research program (Dallimore et al. 1999). With JAPEX Canada Ltd. (JAPEX) acting as the operator, the JAPEX/JNOC/GSC Mallik 2L-38 well was drilled and a drilling waste disposal sump, approximately 45 m x 50 m in size was constructed on the lease. This sump is referred as the Mallik 2L-38 Sump.

In 2002, a seven-party participant group also led by JNOC and GSC, with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 wells. JAPEX Canada Ltd. acted as the operator for this program, constructing a drill sump, approximately 50 m x 55 m in size, was constructed to dispose of the drilling waste generated during drilling of the three wells. This sump is referred as the Mallik 3L/4L/5L-38 Sump.

In the winters of 2007 and 2008 a third gas hydrate research program at the Mallik site was led by Japan Oil, Gas and Metals National Corporation (JOGMEC), NRCan and the Aurora Research Institute (ARI) called the JOGMEC/NRCan/ARI Mallik 2007-2008 Gas Hydrate Production Research Well Program. ARI acted as the operator of this program with the Japan Oil Gas and Metals National Corporation and Natural Resources Canada as participants. This program re-entered the 2L-38 and 3L-38 wells without construction of the sumps. All drilling waste material was removed from site and disposed of at an approved facility (Dallimore et al, 2013). As a condition of Water Board License No. N7L1-1817, ARI was required to undertake a 7-year monitoring program at the Mallik 2L-38 and Mallik 3L/4L/5L-38 sumps.

The information provided in the annual sump monitoring submissions to the Water Board satisfies the conditions assumed by ARI under Part H of the Northwest Territories Water Board License No. N7L1-1817: Conditions Applying to Abandonment and Restoration, specifically section H 2 which states ‘The Licensee shall monitor the existing drilling Waste Sumps 2L-38 and 3L/4L/5L- 38 after closure for a period of at least seven (7) years in accordance with the Northwest Territories Water board Publication ‘Protocol for the Monitoring of Drilling-Waste Disposal Sumps, October, 2006’.

This summary report is provided to the Water Board on behalf of ARI as a courtesy to assemble all of the pertinent monitoring observations during this period.

Table of Contents

1 INTRODUCTION 1
1.1 GENERAL 1
1.2 PROJECT LOCATION AND ENVIRONMENTAL SETTING 1

2 HISTORY OF DEVELOPMENT AND RESEARCH AT THE MALLIK L-38 LEASE AREA 5
2.1 MALLIK L-38 DISCOVERY WELL – 1971 5
2.2 JAPEX/JNOC/GSC MALLIK 2L-38 RESEARCH PROGRAM - 1998 5
2.3 CONSTRUCTION OF MALLIK 2L-38 DRILLING WASTE SUMP 6
2.4 THE JAPEX/JNOC/GSC ET AL. MALLIK 3L/4L/5L-38 RESEARCH PROGRAM - 2002 7
2.5 CONSTRUCTION OF MALLIK 3L/4L/5L-38 DRILLING WASTE SUMP 7
2.6 JOGMEC/NRCAN/AURORA MALLIK 2007-2008 GAS HYDRATE PRODUCTION RESEARCH WELL PROGRAM 11
2.7 THERMISTOR CABLE INSTALLATION AT MALLIK SITE – APRIL 2007 11
2.8 THERMISTOR CABLE INSTALLATION IN 2L-38 DRILLING WASTE SUMP – SEPTEMBER 2012 12

3 SUMMARY OF MONITORING PROGRAM 14
3.1 VISUAL ASSESSMENT 16
3.1.1 Topography 16
3.1.2 Drainage 21
3.1.3 Vegetation and wildlife 22
3.2 AIR TEMPERATURE 22
3.3 ACTIVE LAYER MEASUREMENTS 23
3.4 GROUND TEMPERATURE 26
3.5 ELECTROMAGNETIC SURVEYS 30
3.6 SOIL AND WATER SAMPLING 35
3.6.1 Water sampling 35
3.6.2 Soil sampling 35

4 SUPPLEMENTARY ACTIVITY - APPLICATION OF UAV TECHNOLOGY TO DRILLING WASTE SUMP MONITORING 37

5 CONCLUSION 43

6 CHALLENGES RELATED TO IMPLEMENTING THE DRILLING WASTE SUMP MONITORING PROGRAM AT THE MALLIK SITE 45

7 CLOSURE 46

8 REFERENCES 47

Appendices

APPENDIX A Summary of Wells Drilled at Mallik Site in 1998, 2001 and 2002
APPENDIX B Annual Site Monitoring Reports
APPENDIX C Annual Site Inspection Report
APPENDIX D Site Photographs
APPENDIX E Thermistor Data
APPENDIX F Drilling Waste Sump Monitoring and Retrofit Program, Project Description
APPENDIX G Drilling Waste Sump Monitoring and Retrofit Program, ARI License

Abbreviations

ARI ..... Aurora Research Institute, Aurora College
CCME ..... Canadian Council of Ministers of the Environment
DEM ..... Digital Elevation Model
EM ..... Electromagnetic
EISC ..... Environmental Impact Screening Committee
GSC ..... Geological Survey of Canada
IOL ..... Imperial Oil Ltd.
ISR ..... Inuvialuit Settlement Region
JAPEX ..... JAPEX Canada Ltd.
JNOC ..... Japan National Oil Corporation
JOGMEC ..... Japan Oil, Gas and Metals National Corporation
NWT ..... Northwest Territories
NRCan ..... Natural Resources Canada
SDL ..... Significant Discovery Licence
UAV ..... Unmanned Aerial Vehicle

1 INTRODUCTION

1.1 GENERAL

This summary report has been produced by KAVIK-Stantec, in collaboration with Natural Resources Canada (NRCan) and Japan Oil, Gas and Metals National Corporation (JOGMEC), and is provided to the Inuvialuit Water Board on behalf of Aurora Research Institute (ARI).

The report provides a summary of the seven-year drilling waste sump monitoring activities conducted at the Mallik L-38 site between 2008 and 2014. The report is organized in three main sections consisting of:

- Project location and environmental setting
- History of development and research at the Mallik L-38 lease area
- Summary of monitoring program

The report concludes with a discussion on the current sump conditions and a brief discussion on the challenges related to implementing the drilling waste sump monitoring program at the Mallik site. A series of documents are provided in Appendices as follows:

- Summary of wells drilled at Mallik site in 1998, 2001 and 2002 (Appendix A)
- Annual Site Monitoring Reports (Appendix B)
- Annual Site Inspection Report (Appendix C)
- Site Photographs (Appendix D)
- Thermistor Data (Appendix E)
- Drilling waste sump Monitoring and Retrofit Program. Project Description (Appendix F)
- Drilling waste sump Monitoring and Retrofit Program. ARI License (Appendix G)

Digital files and raw data collected during the monitoring activities have been submitted to the Inuvialuit Water Board and are presented on a DVD contained at the end of this report.

1.2 PROJECT LOCATION AND ENVIRONMENTAL SETTING

The Mallik L-38 site is located on Richards Island in the outer region of the Mackenzie Delta bordering the Beaufort Sea. The site is located within the Inuvialuit Settlement Region (ISR) of the Northwest Territories (Figure 1-1). The site coordinates are approximately 69°27’38”N, 134°39’42”W. The Mallik lease is located on Crown land within the Imperial Oil Resources Ltd. (IOL) Significant Discovery License (SDL) 060.

The area lies adjacent to the Beaufort Sea in the extreme northeastern extent of the Mackenzie River Delta (Ecosystem Classification Group 2012). The site consists of low-lying nearshore floodplains on the west coast of Mallik Bay. The ground surface topography is mostly flat with only a few short gentle slopes located along the edges of the water bodies. Numerous shallow lakes and ponds, some partially drained,

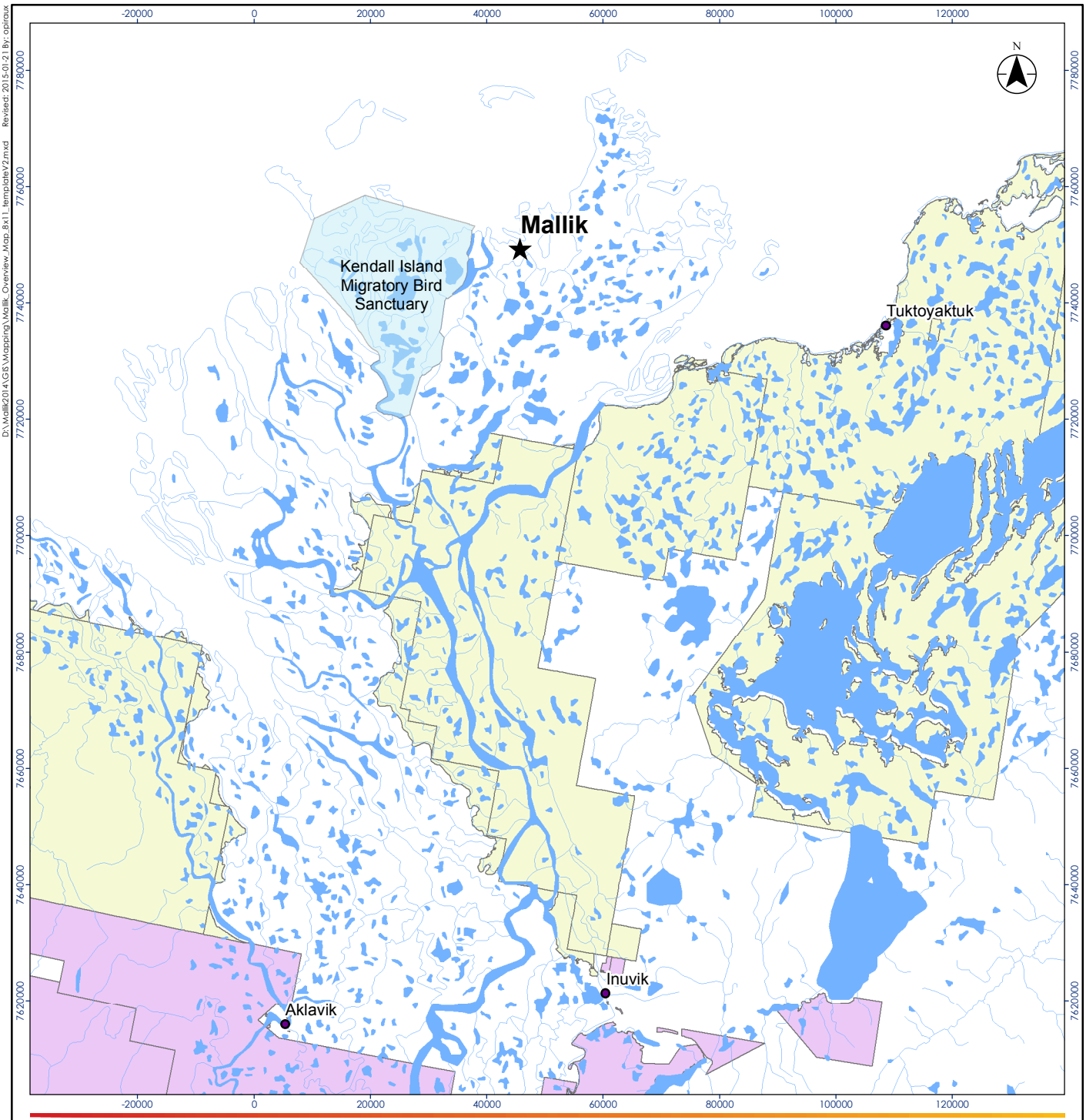
are located at the site. Surficial materials consist of modern deltaic sediments with coarse grained silt being the dominant material and texture.

The site is located within the continuous permafrost zone, with a temperature regime characterized by long cold winters and short cool summers. The mean annual air temperature during the climate normal period (1980-2010) was -10.1°C at Tuktoyaktuk, the nearest meteorological station[1]. Near surface ground temperatures range between -5°C and -7°C in the outer Mackenzie Delta area (Burn and Kokelj 2009; Morse et al. 2012).

Syngenetic ice-wedge polygons are common features in the area (Morse and Burn 2013). A well-developed network of low-centered polygons is visible at Mallik, with some of the polygons intersecting the limits of the sumps. The base of ice-bonded permafrost in the Mallik L-38 well is estimated at 640 m below ground level (Dallimore and Collett 1999).

The locations of the sumps and other site features are presented on Figure 1-2.

1 Data available at: http://climate.weather.gc.ca/climate_normals/index_e.html



D:\Mallik2014\GIS\Mapping\Mallik_Overview_Map_8x11_templateV2.mxd Revised: 2015-01-21 By: opiraux

- Project Location
- Communities
- Migratory Bird Sanctuary
- Watercourse
- Waterbody
- Inuvialuit Settlement Lands
- Gwichin Settlement Lands

0 10,000 20,000 metres

1:1,000,000 (at original document size of 8.5x11)

KAVIK-STANTEC

Project Location 123456789

Northwest Territories

Prepared by OP on 2014-12-05
Technical Review by ABC on 2014-01-16
Independent Review by ABC on 2014-01-16

Client/Project

Aurora Research Institute
Mallik Sump Monitoring Project

Figure No.

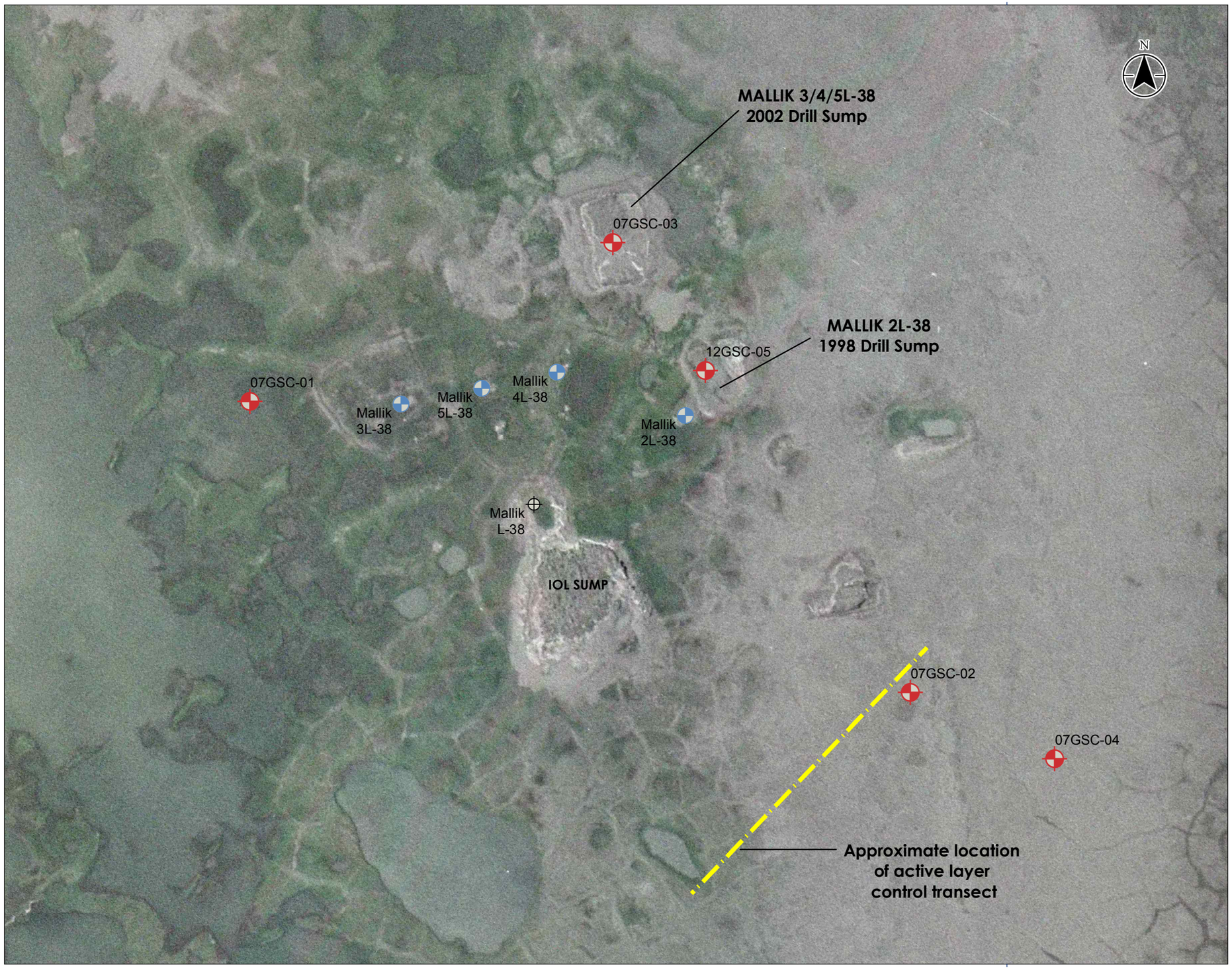
1-1

Title

Project Location

Notes

1. Coordinate System: NAD 1983 UTM Zone 10N
2. Digital base data from Natural Resources Canada (accessed via the Geogratis web site http://geogratis.cgdi.gc.ca)



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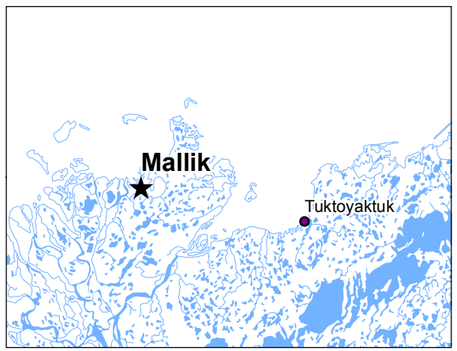
AURORA RESEARCH INSTITUTE
AURORA COLLEGE

Legend

- Mallik Exploration Well
- Mallik Discovery Well
- Thermistor Cable

0 40 80 metres
1:2,000 (At original document size of 11x17)

Notes
1. Coordinate System: Canada Lambert Conformal Conic
2. Orthophoto from the Mackenzie Valley Air Photos (MVAP), Property of the NWT Centre for Geomatics, 2011.



Client/Project

Aurora Research Institute
Mallik Sump Monitoring Project

Figure No.
1-2

Title
Overview Map
Mallik Site

D:\Mallik\2014\GIS\Mapping\Mallik_Overview_Map_11x17_V2.mxd Revised: 2015-02-02 By: dpiteux

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2 HISTORY OF DEVELOPMENT AND RESEARCH AT THE MALLIK L-38 LEASE AREA

2.1 Mallik L-38 Discovery Well – 1971

The Mallik L-38 exploration well, drilled to 8310 ft (2532 m) by IOL in winter 1971-72, was part of the rapidly paced oil and gas exploration, which took place both in the onshore and offshore of the Mackenzie-Beaufort Basin during the 1970s and 1980s. One drilling waste sump was constructed during this exploration activity. IOL is responsible for this drilling waste sump and this sump is outside the scope of this drilling waste sump monitoring program.

2.2 JAPEX/JNOC/GSC Mallik 2L-38 Research Program - 1998

In February and March of 1998, an 1150 m deep gas hydrate research well, Mallik 2L-38, was completed at the site. This project brought together researchers from North America and Japan to undertake the first investigation of a natural gas hydrate occurrence beneath permafrost that included extensive dedicated coring and associated engineering and scientific studies. Natural gas hydrate occurrences are known to represent a significant hydrocarbon reservoir in many arctic basins; however, prior to Mallik 2L-38, almost no field research had been undertaken to evaluate their in situ properties.

Two fundamental objectives were established for the Mallik 2L-38 research-well program. The Japan National Oil Corporation (JNOC), the Japan Petroleum Exploration Company (JAPEX) and other participating organizations from Japan sought to undertake a variety of verification studies in preparation for exploration drilling in 1999 of gas hydrate deposits in the Nankai Trough, offshore of Japan's eastern coast. These included the evaluation of technologies related to gas hydrate drilling, geophysics, casing, and production at an onshore site with known gas hydrate occurrences. In addition, a long-standing interest in gas hydrate occurrences in permafrost settings led the Geological Survey of Canada (GSC) and the United States Geological Survey (USGS) to propose a comprehensive science program to quantify the geological, geophysical, geochemical and engineering properties of an arctic gas hydrate occurrence. Following a long review process, a site for the gas hydrate research well was selected near the IOL Mallik L-38 industry exploration well.

The Mallik 2L-38 well was completed in 39 days using a conventional arctic exploration drill rig. Surface logistics were established by a winter ice road that was constructed along channels of the Mackenzie River. Initially, a surface hole was drilled to a depth of 687 m and eight coring runs were successfully conducted within the permafrost interval (0-640 m). Subsequently, a 219 mm casing was installed and the main hole was advanced to the target depth of 1150 m. The results of the JAPEX/JNOC/GSC Mallik 2L-38 well were published in Geological Survey of Canada Bulletin 544, which included an interactive CD-ROM which includes all field and post-field data (Dallimore et al. 1999).

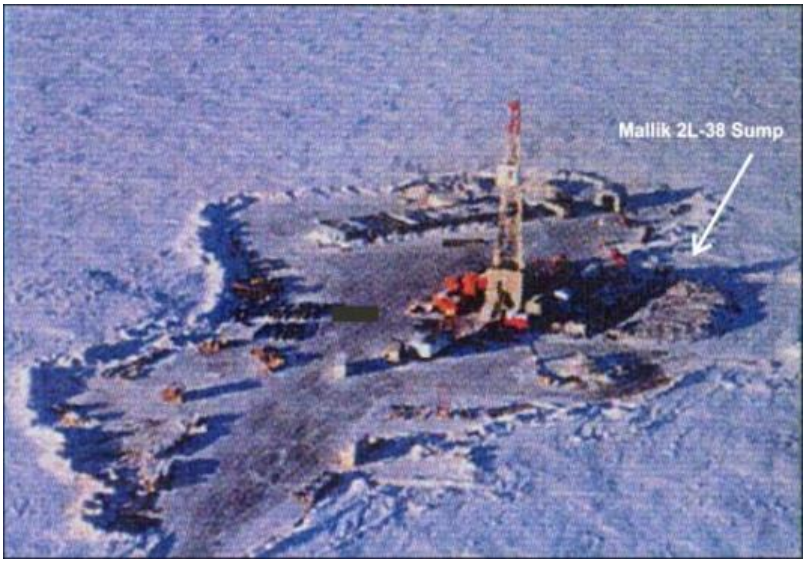


Figure 2-1 Mallik site during the winter 1998 research program.

2.3 Construction of Mallik 2L-38 Drilling Waste Sump

The JAPEX/JNOC/GSC Mallik 2L-38 research program constructed and utilized a sump to dispose of drilling waste. JAPEX Canada was the designated operator for this well program and retained the Land Use permits for the drilling activities and the sump. The sump was constructed using the standard practice of excavating a pit adjacent to the well-head by blasting into the frozen ground. The excavated material was then retained and used as back-fill and cap material over the drilling waste. This design allows for the permafrost to aggrade into the unfrozen drill waste and back-fill, allowing the drilling waste to maintain a solid (frozen), immobile state. The seasonal active layer is intended to only penetrate into the sump cap material.

The Mallik 2L-38 drilling waste sump was blasted at the end of January 1998. The drilling waste sump measured approximately 45 m x 50 m. No record of the depth of the drilling waste sump has been located but is estimated to be approximately 5 m based on historical photographs and interpretation of the results of the EM surveys. The sump was used for a total of 35 days (February 16 to March 22, 1998). The drilling waste mud consisted primarily of a bentonite clay drilling mud with potassium chloride (KCl) used to suppress the freezing point. Minor amounts of additional drilling additives were also used including weighting material such as barite (BaSO4). Prior to closure, the sumps were inspected by the Water Resources Officer from Inuvik, NT. The drilling waste sump was closed at the end of March 1998 using heavy equipment to redistribute the native soil material as backfill and sump cap. It is estimated from historical photographs that the cap extended a minimum of two meters beyond the edges of the sump walls.

A camp sump was excavated on site in 1998. The 1998 camp sump is located 35 m west from the 2L-38 sump. The camp sump is much smaller in size, measuring approximately 15 m by 25 m. Its exact depth is unknown but estimated to range between 3 m and 4 m. The sump was capped with previously excavated

material at the closure of the 2008 drilling program. This sump does not contain drilling waste and therefore was not required to be monitored as part of the program.

2.4 The JAPEX/JNOC/GSC et al. Mallik 3L/4L/5L-38 Research Program - 2002

The Mallik 2002 field program was a complex undertaking designed to enable more than 50 separate research studies. Main goals of this program were to advance research pertaining to gas hydrate production and to assess the environmental implications of terrestrial gas hydrate deposits, including geohazard and climate-change considerations.

The base program called for the completion of three research wells, gas hydrate coring, production testing and an extensive geophysics program that included borehole and surface surveys. Field activities were undertaken in the winter when the ground surface was frozen and access to the site could be gained by ice roads along river channels. As described in detail by Takahashi et al. (2005), considerable logistical effort was devoted to extending the winter operational season to provide sufficient time for the planned fieldwork. The drill rig and much of the drilling-support equipment were staged to a location near the drill site by river barge in the summer of 2001. Sprayed-ice roads were constructed in late November and early December to allow the equipment to be set up at the drill site. The first research well was spudded on December 25, 2001, and the entire field program was completed on March 14, 2002.

Two 1188 m deep observation wells, JAPEX/JNOC/GSC et al. Mallik 3L-38 and 4L-38, were drilled first. These wells were drilled coplanar with, and offset 40 m from, the main production research well to enable a number of monitoring studies before, during and after gas hydrate production testing. The main production research well, JAPEX/JNOC/GSC et al. Mallik 5L-38, was completed to a depth 1166 m. Science activities included open-hole permafrost well logging and continuous wireline coring from 885 to 1151 m, which extended through the main gas hydrate intervals and below the expected base of the gas hydrate stability zone at about 1100 m.

The scientific results from the Mallik 2002 gas hydrate production research were published in Geological Survey of Canada Bulletin 585, which included an interactive CD-ROM which includes all field and post-field data (Dallimore and Collett 2005).

2.5 Construction of Mallik 3L/4L/5L-38 Drilling Waste Sump

The JAPEX/JNOC/GSC et al. Mallik 3L/4L/5L-38 research programs constructed and utilized a sump for its drilling waste. Figure 2-2 shows the lay-out of the Mallik site in winter 2002, including the location of the drilling waste sump. The drilling waste sump was constructed in the same manner as the previous sumps at site. On December 15, 2001 the drilling waste sump area was drilled and loaded with explosives. The surface material was then blasted and heavy equipment excavated the material to form a pit. The drilling waste sump was constructed in two stages. The original excavation was estimated to be 28 m x 38 m x 3.5 m deep with a potential volume of 3,724 m^3.

During the course of the drilling program more drilling waste material was produced than expected. It was therefore deemed necessary to enlarge the original excavation. JAPEX Canada submitted an application

to expand the existing drilling waste to Indian and Northern Affairs Canada. On February 18, 2002 they received approval to expand the drilling waste sump by approximately 4 m x 11 m, as per Part E, Conditions Applying to Modifications, of Water Licence N7L1-1769 was granted. The expansion was achieved by blasting adjacent to the original sump and connecting the two sumps to form one. The size of the enlarged sump was approximately 50 m x 55 m x 3.5 m.

The expanded drilling waste sump was used for a total of 62 days (December 25, 2001 to February 24, 2002). Drilling operations discharge was estimated based on daily averages for three periods with varying levels of activity plus additional discharge on specific days. A photo of the Mallik drilling waste sump on March 4, 2002 is presented in Figure 2-3. As with the Mallik 2L-38 sump, the drilling waste mud consisted primarily of a bentonite clay drilling mud with potassium chloride (KCl) used to suppress the freezing point. Minor amounts of additional drilling additives were also used including weighting material such as Barite (BaSO4).

On March 10, 2002, drilling waste samples were taken for lab analysis before abandonment of the sump, as per regulations. Results were submitted to the NWT Water Board in an analytical report by Canada Petroleum Engineering Inc. on March 25, 2002. Based on this report and an on-site inspection from Indian and Northern Affairs Canada, permission was granted to properly abandon their drill sump on March 26, 2002. The drilling waste sump was closed at the end of March 2002 using heavy equipment to redistribute the native soil material as backfill and sump cap. The cap extended a minimum of 2 m beyond the edges of the sump walls.

A camp sump was also constructed during the 2002 winter drilling season. The 2002 camp sump is located 350 m southeast from the 3L/4L/5L-38 drilling sump. The camp sump is approximately 30 m by 10 m. Its exact depth is unknown but estimated to range between 3 m and 4 m. The sump was capped with previously excavated material at the closure of the 2002 drilling program. This second sump does not contain drilling waste and therefore was not required to be monitored as part of the program.

Figures 2-4 and 2-5 show the condition of the sump cap in the first thaw season following construction of the 3L/4L/5L-38 drilling waste sump. The June 2002 photo shows the well-contoured sump cap (Figure 2-4), while the August 2002 photo shows the sump cap after a recent storm surge event (Figure 2-5).

A summary of wells drilled at Mallik site during the winter 1998 program and the winter 2002 programs in presented in Appendix A.

Figure 2-2 Photo of Mallik site on March 8, 2002.

Figure 2-3 Photo of Mallik drilling waste sump on March 4, 2002.

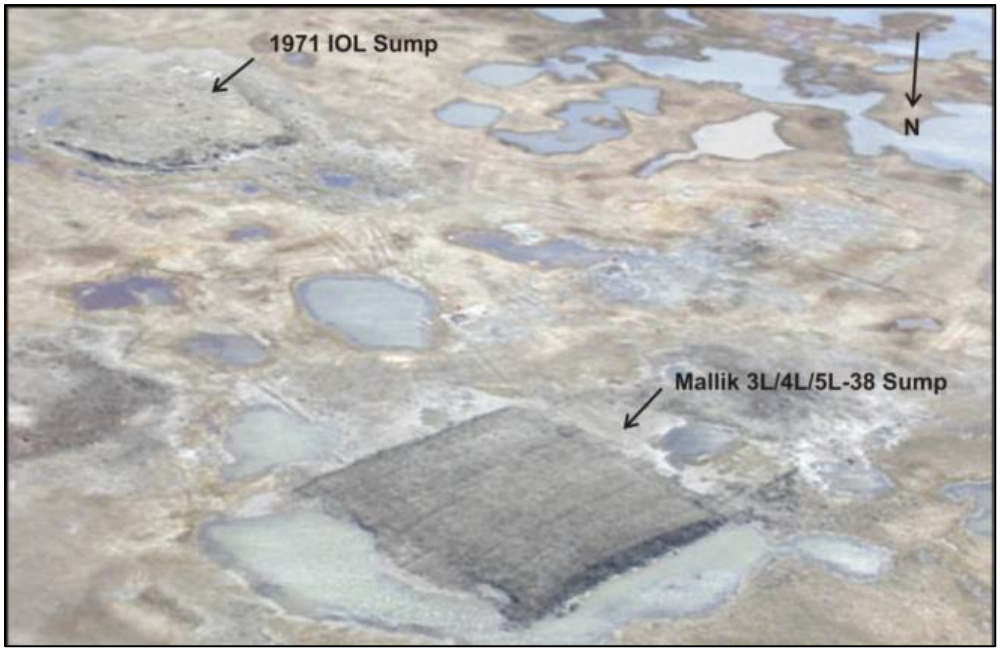


Figure 2-4 Photo of capped 3L/4L/5L-38 Mallik drilling waste sump, June 25, 2002.

Figure 2-5 Photo of capped 3L/4L/5L-38 Mallik drilling waste sump after storm surge event, end of August, 2002.

2.6 JOGMEC/NRCan/Aurora Mallik 2007-2008 Gas Hydrate Production Research Well Program

In 2005, NRCan and the JOGMEC (formerly JNOC) began planning for the third phase of research and development at the Mallik site. The primary goal of this program was to conduct a full-scale depressurization production test. The research and development program was designed to be conducted over two successive winter seasons due to the short winter drilling season in the Mackenzie Delta. The first season (winter 2007) was devoted to the installation of well infrastructure consisting of a main production well (reopening and deepening of Mallik 2L-38 drilled in 1998) and a water-injection well (reopening and deepening of Mallik 3L-38 drilled in 2002). A short-term (24-hr) depressurization test was undertaken during the first winter to evaluate gas- and water –flow rates, and sand mobility, prior to undertaking a long-term test the following winter.

In the second field season (winter 2008), the Mallik 2L-38 well was reopened and recompleted to support a longer duration production test, incorporating required modifications developed as a result of the short-term test. The Mallik 3L-38 well was also reopened and equipped as a produced-water disposal well. Continuous methane production from gas hydrate was achieved over a 6-day period from March 10-16, 2008, demonstrating the proof of concept that sustained gas production can be achieved by simple depressurization of a gas hydrate reservoir using conventional oil and gas drilling, completion, and production methods.

The scientific results from this gas hydrate production program were published in Geological Survey of Canada Bulletin 601, which included an interactive CD-ROM which includes all field and post-field data (Dallimore et al. 2012).

It is important to note that this was a sumpless program and no sumps were constructed during these two winters. All drilling and camp waste was removed from the site and disposed of at an approved facility. The existing Mallik 2L-38 drilling sump was in close proximity to the production wellbore for this Program. Thus, the facilities associated with the rigs (i.e., rig buildings, catwalk, mud tanks, etc.) positioned around the wellbore were close to the sump during the Program. Encroachment onto this sump was unavoidable, therefore a substantial ice pad (minimum 30 cm thickness) was built to protect the sump, and time spent on the sump area was minimized.

2.7 Thermistor Cable Installation at Mallik Site – April 2007

At the end of the 2007 Mallik Program, a rathole rig (Figure 2-6) was mobilized to the site to drill five boreholes for the installation of thermistor cables for the Drilling Waste Sump Monitoring Program (Figure 1-2). Borehole 07GSC-01 was located in an undisturbed area approximately 200 m southwest of all Mallik sumps. At the time of installation, the site was snow covered, and the 07GSC-01 was located on the edge of a large but shallow pond. Three thermistors cables (07GSC-02, 07GSC-04, 07GSC-05) were installed along a transect ~50 m apart towards the coast to represent undisturbed, very low vegetation, coastal conditions. Unfortunately borehole 07GSC-05 was damaged beyond repair soon after installation and was therefore removed. Borehole 07GSC-03 was drilled at the center of the Mallik 3L/4L/5L-38 sump.

Figure 2-6 Installation of thermistor cables with rathole rig in April 2007.

2.8 Thermistor Cable Installation in 2L-38 Drilling Waste Sump – September 2012

In September 2012, KAVIK-Stantec coordinated the drilling and installation of a thermistor cable in the centre of the Mallik 2L-38 drilling waste sump to allow for monitoring of the temperature conditions.

The drilling was done by Clean Harbors, a company with extensive experience in the Mackenzie Delta region. The drilling equipment was shipped by truck from Grande Prairie, Alberta then was transported by sling to site in two separate pieces using a 412 model helicopter (Figure 2-7).

Figure 2-7 Mobilization of drilling equipment in 2012.

The drill was moved to site on September 19th and the drilling was done the following day. The Mallik site was much wetter than during the monitoring visit on September 4th and 5th. There were clear signs of a recent storm surge. Recent water marks were present high up the IOL sump, indicating that the 1998 and

2002 sumps were likely completely submerged approximately a week before the drilling took place. The groundwater table was still quite high but did not affect the drilling. A series of large wood beams were used to stabilize the drill to avoid potential shifting and sinking in the soft silt of the sump cap. The drilling was very consistent and no sharp contact corresponding to the base of the sump was noted. A coarse stratigraphy was observed as follows:

- Active layer: 1.2 m
- Thickness of the sump cap: unknown
- Base of the sump: 4.5 m to 5.5 m
- Mostly silt from 5.5 m to 7.5 m
- Silt with some gravels from 7.5 m to 12.5 m

Thermistor cable 12GSC-05 was installed following the same technique employed for the other four cables on site (i.e. the cable inserted into a series of glued PVC pipes). The data logger was programmed to record temperatures on an hourly basis (Figure 2-8).

Figure 2-8 Casing installed over the thermistor cable 12GSC-05.

3 SUMMARY OF MONITORING PROGRAM

As part of its responsibilities as operator of the Mallik 2007/08 field programs, ARI was required to conduct a Drilling Waste Sump Monitoring Program at the JAPEX/JNOC/GSC Mallik 2L-38 and the JAPEX/JNOC/GSC et al. 3L/4L/5L-38 sumps for a period of seven years (i.e., 2008 to 2014) as stipulated under NWT Water Board License No. N7L1-1817 issued to the Aurora Research Institute for December 1, 2006 until November 30, 2008. Table 3-1 presents the general timeframe associated with the development and permitting of the Drilling Waste Sump Monitoring Program at Mallik.

Table 3-1 Timeframe of development and permitting of the Drilling Waste Sump Monitoring Program at Mallik

Date	Item	Objective/Milestone
Sept 7, 2006	Presentation to EISC on Mackenzie Delta Gas Hydrate Research and Development Project, by JOGMEC, Schlumberger, GSC and ARI.	Provided an update on the status of Mallik Program and address questions from EISC. Following this meeting discussion ensued about the merits of completing the Mallik 2007 field activities without a drill sump and the desirability to conduct a sump monitoring program of the 1998 and 2002 sumps constructed by JAPEX Canada Ltd on behalf of past programs.
April 2 and 3, 2007	Consultation with Inuvik, Tuktoyaktuk and Aklavik Hunters and Trappers Committees on the Mallik 2L-38 and 3L/4L-5L-38 Drilling Waste Sump Monitoring Program by Kavik-Axys (now KAVIK-Stantec) on behalf of project proponents.	Presented the proposed Drilling Waste Sump Monitoring Program at the Mallik site to the communities and addressed any questions, issues or concerns they may have about the proposed work.
April 7, 2007	While 2007 field operations were underway, boreholes were drilled with a rat-hole rig for installation of thermistor cables for Drilling Waste Sump Monitoring Program.	Installed of 07GSC-01, 07GSC-02, 07GSC-03, 07GSC-04, 07GSC-05 for Drilling Waste Sump Monitoring Program.
June 22, 2007	Consultation with Tuktoyaktuk and Inuvik Hunters and Trappers Committees on Mackenzie Delta Gas Hydrate Research and Development Project - Mallik Update and Drilling Waste Sump Monitoring Consultation by Kavik-Axys on behalf of project proponents.	Presented the Drilling Waste Sump Monitoring Program at the Mallik site to the communities and addressed any questions, issues or concerns they may have about the proposed work.
July 3, 2007	Consultation with Aklavik Hunters and Trappers Committee on Mackenzie Delta Gas Hydrate Research and Development Project - Mallik Update and Drilling Waste Sump Monitoring Consultation by Kavik-Axys on behalf of project proponents.	Presented the Drilling Waste Sump Monitoring Program at the Mallik site to the communities and addressed any questions, issues or concerns they may have about the proposed work.
July 5, 2007	Consultation with EISC on Mackenzie Delta Gas Hydrate Research and Development Project - Mallik Update and Drilling Waste Sump Monitoring consultation by Schlumberger, Kavik-Axys and ARI.	Present the Drilling Waste Sump Monitoring Program at the Mallik site to the communities and addressed any questions, issues or concerns they may have about the proposed work.

Date	Item	Objective/Milestone
February 2008	Aurora Research Institute Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program Project Description submitted to the Environmental Impact Screening Committee for approval.	Project description submitted.
March 2008	EISC screened the submission and approved the Drilling Waste Sump Monitoring Program.	EISC Decision Letter received.

The main objectives of the monitoring program were to assess the local site conditions and to provide data on the performance of the sumps. The monitoring protocol[2] included annual surveys of the following parameters:

- The visual assessment of the site with an emphasis on sump cap conditions
- The measurements of the active layer thickness on the sump caps and around their perimeter, as well as in an undisturbed area adjacent to the sumps
- The downloading and acquisition of temperature data from the sumps and various background locations
- Electromagnetic (EM) surveys (EM31 and 38) on both sumps and surrounding areas
- The sampling of surface material present in areas showing elevated electromagnetic conductivities, as deemed appropriate
- The sampling of ponded water located on the sump caps and in an undisturbed area immediately adjacent to the sumps, as deemed appropriate

The timing of the various monitoring site visits is documented in Table 3-2.

Table 3-2 Timeframe implementation of Drilling Waste Sump Monitoring Program at Mallik

Year	Site visit date	Site visit participants	Annual Water Board report
1	August 5, 12 & 13, 2008	GSC	Prepared and submitted by Aurora Research Institute
2	August 9 to 15, 2009 August 16, 2009	JOGMEC and JAPEX GSC and ARI	Prepared and submitted by Aurora Research Institute
3	September 29 and 30, 2010	KAVIK-Stantec	Prepared and submitted by KAVIK-Stantec
4	August 20 & 22, 2011	KAVIK-Stantec and GSC	Prepared and submitted by KAVIK-Stantec
5	September 4 & 5, 2012	KAVIK-Stantec, JOGMEC and GSC	Prepared and submitted by KAVIK-Stantec
5	September 20, 2012	KAVIK-Stantec and Clean Harbors	Installation of thermistor 12GSC-05
6	September 10 & 11, 2013	KAVIK-Stantec	Prepared and submitted by KAVIK-Stantec

[2] NWT Water Board. 2006. Protocol for the Monitoring of Drilling-Waste Disposal Sumps. Yellowknife, Northwest Territories. Available online at: http://www.nwtwb.com/Downloads/Drilling_Waste_Disposal_Sumps_2005.pdf

7	August 12 & 13, 2014	KAVIK-Stantec, JOGMEC and GSC	Prepared and submitted by KAVIK-Stantec

The following section summarizes the results of each main components of the monitoring program.

3.1 VISUAL ASSESSMENT

3.1.1 Topography

Topographic information is available for the Mallik site from topographic surveys conducted in the summer of 2006 by Inukshuk Geomatics Inc. (Figure 3-1).

It can be seen from the 2006 topographic data and from the various field photographs included in the annual monitoring reports (see Figure 3-2 and 3-3 as well as additional site photographs in Appendix D) that the surface of the majority of the two drill sumps are raised above the surrounding terrain. This is consistent with one of the design goals of sumps, which is to raise the ground elevation and lower the mean annual ground surface temperature regime.

The 2006 contour data indicates that the surface of the 3L/4L/5L-38 sump cap rises above the surrounding ground surface by approximately 40 cm to 100 cm, with the highest point being located at the center of the sump. The contour data indicates that a small depression approximately 40 cm deep is located along the southwest perimeter of the sump. The center of the 2L-38 sump also rises above the surrounding ground surface (by approximately 40 cm to 80 cm), however, the east portion of the sump is characterized by a 60 to 80 cm depression. No topographic surveys were conducted during the 2007 to 2013 annual site monitoring visits; however field notes and site photographs were taken each year to document the depressions at the surface or perimeter of the sumps (see the annual monitoring reports in Appendix).

Based on visual observations only, the subsidence areas on the eastern and western sides of the 2L-38 sump cap appear to have increased slightly since the beginning of the monitoring program in 2008. The two depressions are now connecting with each other along the northern perimeter of the sump cap, with a small and narrow depression also visible along the southern perimeter (visible on Figure 3-3).The depressions on the east and west side of the sumps are approximately 1.2 m (±20 cm) lower than the surrounding topography.

Shallow depressions are present along the southwest and northeast sides of the 3L/4L/5L-38 sump. The depression along the southwest portion of this sump covers the full width of the sump (i.e. approximately 50 m) while three interconnected depressions are present on northeast portion. The deepest depression is located at the south corner of the sump and is approximately 80 cm (±20 cm) in depth. Note that the limits of the two sumps are not clearly defined and that some of the subsidence might be located along the outside perimeter of the sumps (i.e., the sump caps are believe to overlap the sides of sump by at least 2 m).

Additional notes and field photographs of the conditions of the sump caps are presented in the annual sump monitoring reports.

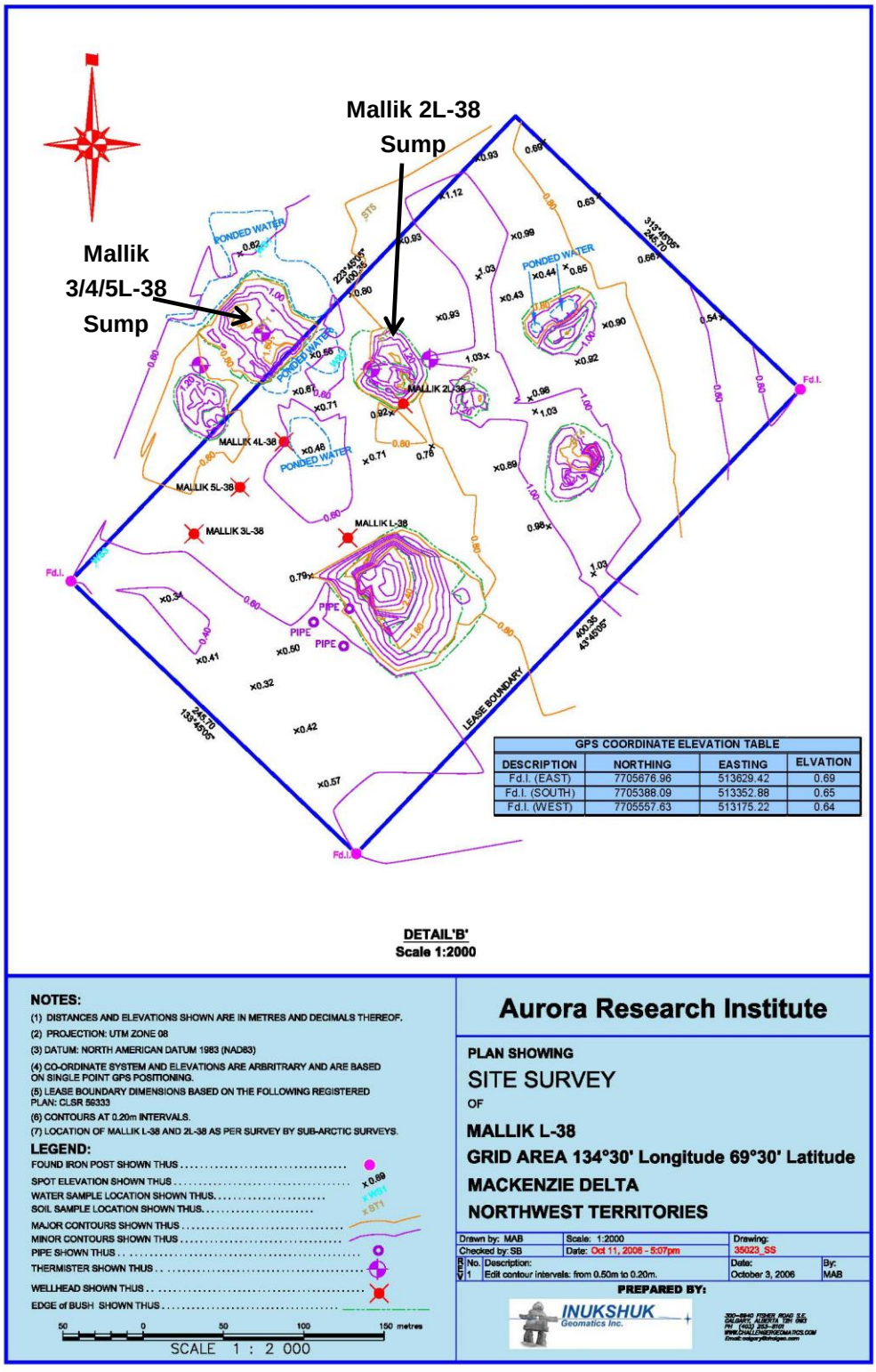


Figure 3-1 Topographic survey of the Mallik site conducted in 2006.

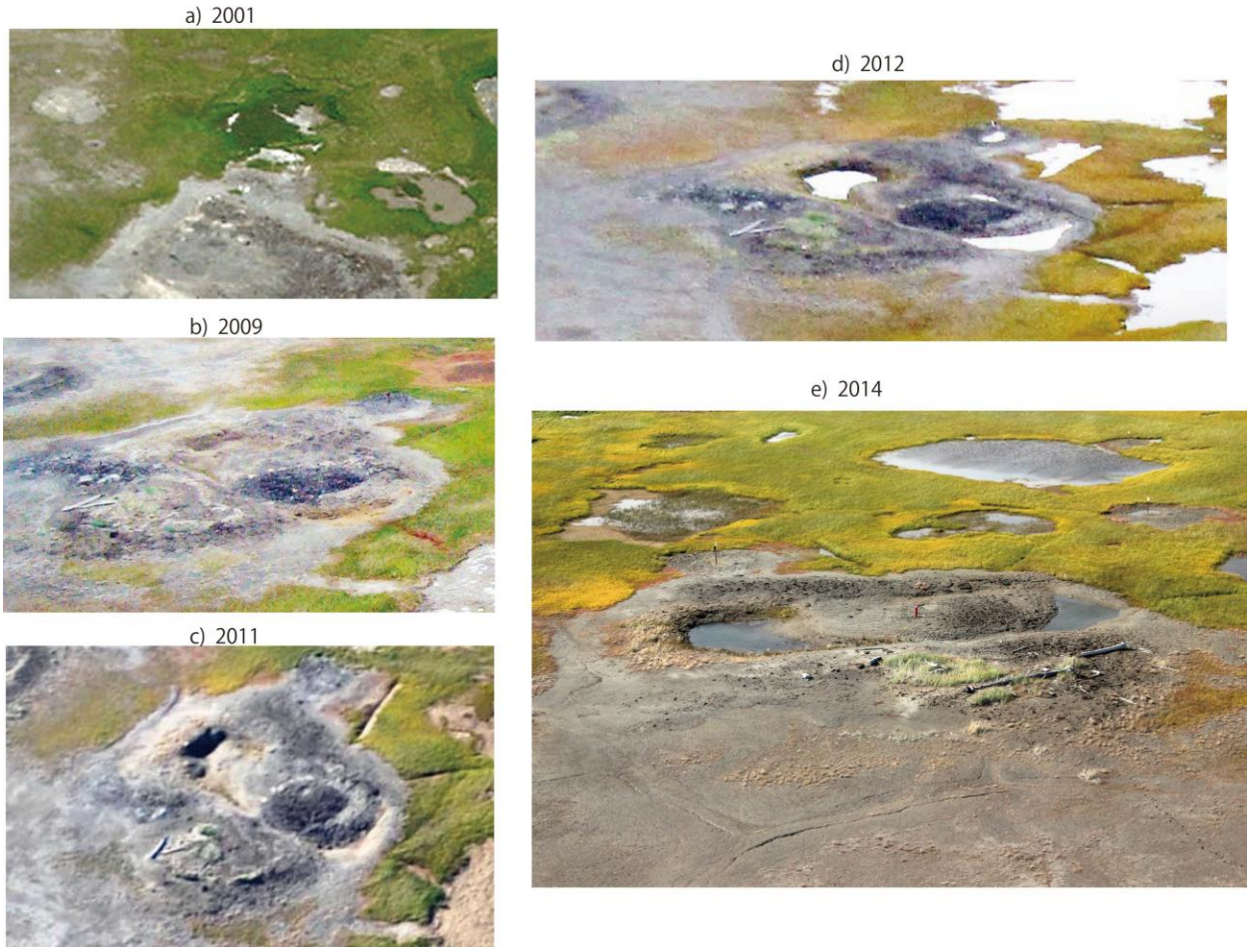


Figure 3-2 Selected aerial photographs from the 2L-38 Sump between 2001 and 2014.

Figure 3-3 Selected aerial photographs from the 3L/4L/5L-38 Sump between 2002 and 2014.

3.1.2 Drainage

The relief in the vicinity of the Mallik site is very low and the general land surface elevation is close to sea level. As a consequence, the area is subject to storm surges which inundate the low-lying terrestrial environment with sea water. Surface water is common in small and large ponds and water levels change throughout the thaw period in response to both precipitation and storm surges. The sumps have therefore been constructed in an environment where there is variability in surface water from precipitation and run-off as well as occasional inundation from the sea. As the storm surge recedes and the ponded sea water evaporates, there is some natural buildup of salt precipitate in the near surface soils. The fact that the site is located in continuous permafrost terrain also limits the downward drainage and contributes to keeping soils wet for a longer period of time.

The surface drainage conditions were carefully noted during every site inspection. A summary of drainage conditions observed during site visits is presented in Table 3-3.

Table 3-3 Summary of site drainage conditions, 2008 to 2014

Survey Date	Summary of site drainage[1] condition at the time of visit
2008	• Imperfect to poorly drained, saturated soils and some areas with surface water • High water level in most ponds • Some water ponding at both ends of the 2L-38 Sump and along the western limit of the 3L/4L/5L-38 sump
2009	• Imperfect to poorly drained, saturated soils and some areas with surface water • Moderate to high water level in most ponds • Some water ponding at both ends of the 2L-38 Sump and along the western limit of the 3L/4L/5L-38 sump
2010	• Approximately 15 to 20 cm of snow present at the site at the time of visit • Some water ponding at both ends of the 2L-38 Sump and along the western limit of the 3L/4L/5L-38 sump
2011	• Moderate to well drained • Several shallow natural ponds were dry • Some water ponding at both ends of the 2L-38 Sump and along the western limit of the 3L/4L/5L-38 sump • Soil salinization present at the ground had since evaporated
2012	• Imperfect to poorly drained, saturated soils and some areas with surface water • High water level in most ponds • Some water ponding at both ends of the 2L-38 sump and along the western limit of the 3L/4L/5L-38 sump • Indicators of a recent storm surge (e.g., ripple marks and presence of new wood debris at the ground surface) that occurred sometime between the September 5 and September 20 field visits
2013	• Imperfect to poorly drained, saturated soils and some areas with surface water • Moderate to high water level in all ponds • Some water ponding in the depressions of the 2L-38 and the 3L/4L/5L-38 sumps • Sump indicators of a storm surge (e.g., ripple marks and presence of high water mark along the edge of the IOL sump)

Survey Date	Summary of site drainage[1] condition at the time of visit
2014	• Moderate to imperfect, some area characterized by saturated soils • Some water present in most natural ponds but the water level present in the depression located within the sump perimeters was lower
[1]Drainage classes from Agriculture and Agri-Food Canada. http://sis.agr.gc.ca/cansis/nsdb/soil/v2/snt/drainage.html	

3.1.3 Vegetation and wildlife

The Mallik site is located in proximity to Mallik Bay, just alongside the boundary between the vegetated floodplain and the unvegetated tidal flat. Vegetation present at the site is predominantly composed of a variety of graminoid species, such as sedges and cottongrasses, with a few sporadic low shrubs and mosses.

It is estimated that less than 10% of the total sump caps are currently covered by vegetation. The Mallik sump caps were never seeded. Annual field observations and the comparison of field photographs showed only very minor variations in vegetation conditions over the monitoring period. The absence of vegetation at the surface of the sump is seen as positive as it limits the quantity of snow that accumulates at the surface of the sump as it has been noted in past studies that snow accumulation around the edges of the sump and enhanced snow cover associated with revegetation of sump caps may affect the thermal regime of a sump (Kokelj and GeoNorth 2002).

Several signs of wildlife were noted at the site during annual site visits. Bird tracks and droppings are the most common signs of wildlife on site, followed by ungulate tracks. The remains of a young reindeer calf (cause of death unknown) were found near to the 07GSC-02 thermistor in 2012. Remains of old fox dens are present near the IOL sump but no signs of recent activity were noted during the annual site visits. Bear tracks, most likely a juvenile bear, were noted on site during the 2014 visit.

3.2 AIR TEMPERATURE

Air temperature was recorded hourly at the Mallik site beginning on October 1, 2010. The air temperature sensor was installed at approximately 1.5 m above the ground surface. The sensor was mounted within a radiation shield to minimize the heating effects of solar radiation and direct exposure to sun, rain and snow. The average monthly air temperatures are presented in Table 3-4. Daily mean air temperatures are presented in Figure 3-4.

Table 3-4 Average monthly air temperatures

	Mean Air Temperature (°C)			
	2010/2011	2011/2012	2012/2013	2013/2014
September	-	4.1	5.8	2.9
October	-5.3	-3.9	-2.8	-0.3
November	-13.1	-20.4	-15.4	-13.3
December	-25.7	-22.7	-26.7	-23.2

	Mean Air Temperature (°C)			
	2010/2011	**2011/2012**	**2012/2013**	**2013/2014**
January	-25.9	-27.6	-28.4	-24.0
February	-23.2	-23.1	-29.2	-25.1
March	-23.0	-30.0	-26.0	-21.6
April	-19.0	-14.5	-18.9	-13.7
May	-3.2	-4.3	-5.6	-0.9
June	4.6	8.1	5.5	5.8
July	12.1	15.3	9.9	10.8
August	10.2	12.4	10.5	10.1*
Annual	**-**	**-8.9**	**-10.1**	**-8.5**
*Based on the first 12 days of August only				

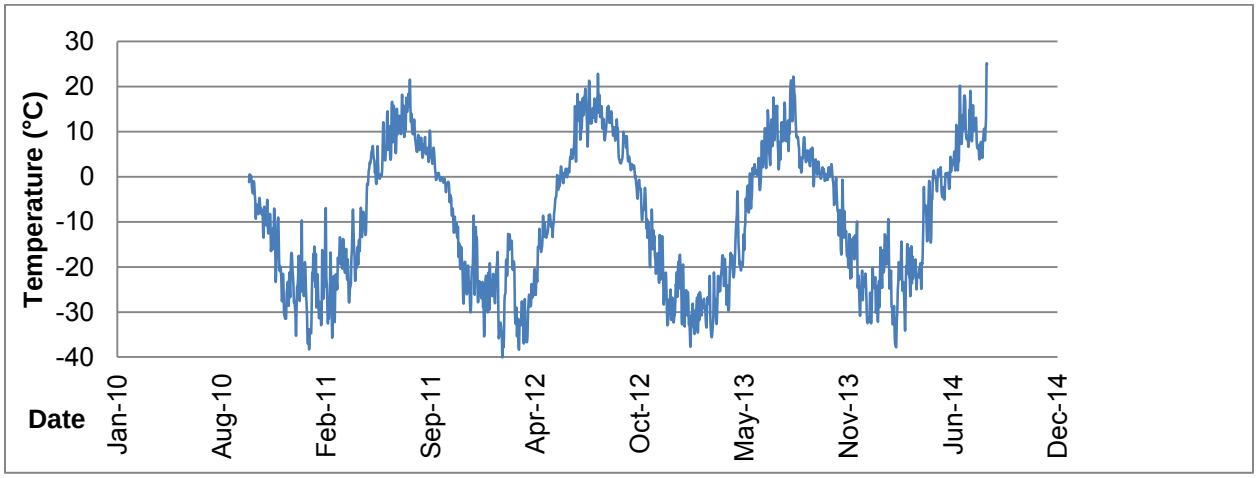


Figure 3-4 Daily mean air temperatures recorded at Mallik, October 2010 to August 2015.

3.3 ACTIVE LAYER MEASUREMENTS

The active layer is defined as the near surface section of sediment or organic material subject to annual freezing and thawing. Generally, active layer thickness varies in response to air temperature, snow cover, summer rainfall, soil characteristics and vegetation (Nelson et al. 1998). It is also influenced by differential thermal conductivity, ground moisture content and meteorological events (Romanovsky and Osterkamp 1995).

Active layer depths were measured during each annual site visit by inserting a graduated steel probe into the soil until the point of refusal. Measurements were collected on the sump caps and along the perimeter of the sump caps (i.e., within 2 m of the assumed interface between the sump cap and the surrounding undisturbed area). Additional measurements were taken along a control transect located in an undisturbed area located approximately 200 m south from the sumps.

Maximum, minimum and average active layer thicknesses measured during each site visit for the 2008/2014 period are summarized in Table 3-4. Note that the 2009 survey was limited to ground temperature monitoring and that no active layer data were collected.

Although active layer depths were recorded on different dates each year, some general comments can still be made. Active layer measurements collected over the 7-year monitoring period show only minor variations in active layer thickness (Figure 3-5). No clear trend exists between the average thaw depth of the sump caps when compared to the sump perimeters. The annual average thaw depths measured along the control transect are generally slightly lower than the values measured at the sumps and around their perimeters. Average thaw depth of the sump caps have slightly increased from 2008 to 2011, but decreased from 2012 to 2014. This is likely due to various factors such as air temperature, soil moisture, duration and thickness of snow cover.

Table 3-5 Summary of active layer data, 2008 to 2014

		2L-38 Sump		3L/4L/5L-38 Sump		Control Transect
		Sump Cap	Perimeter	Sump Cap	Perimeter	
08/13/2008	Number of measurements	2	8	5	7	[1]N.D.
	Minimum thawing depth (cm)	114	92	104	92	N.D.
	Maximum thawing depth (cm)	116	118	121	124	N.D.
	Average thawing depth (cm)	**115**	**111**	**113**	**106**	**N.D.**
09/29/2010	Number of measurements	5	8	5	8	8
	Minimum thawing depth (cm)	100	105	111	115	105
	Maximum thawing depth (cm)	132	122	123	126	121
	Average thawing depth (cm)	**119**	**113**	**118**	**121**	**113**
08/20/2011	Number of measurements	30	44	22	36	35
	Minimum thawing depth (cm)	90	94	111	108	84
	Maximum thawing depth (cm)	151	150	196	153	142
	Average thawing depth (cm)	**121**	**114**	**133**	**117**	**113**
09/04/2012	Number of measurements	25	18	22	20	20
	Minimum thawing depth (cm)	116	125	124	124	108
	Maximum thawing depth (cm)	178	148	145	144	145
	Average thawing depth (cm)	**140**	**136**	**132**	**131**	**128**
09/11/2013	Number of measurements	17	16	25	21	22
	Minimum thawing depth (cm)	110	113	109	108	100
	Maximum thawing depth (cm)	140	140	152	145	125
	Average thawing depth (cm)	**123**	**125**	**121**	**123**	**113**
08/13/2014	Number of measurements	17	20	26	20	20
	Minimum thawing depth (cm)	100	105	90	105	90
	Maximum thawing depth (cm)	137	130	138	121	138
	Average thawing depth (cm)	**114**	**114**	**115**	**111**	**110**

[1]N.D. – Not determined

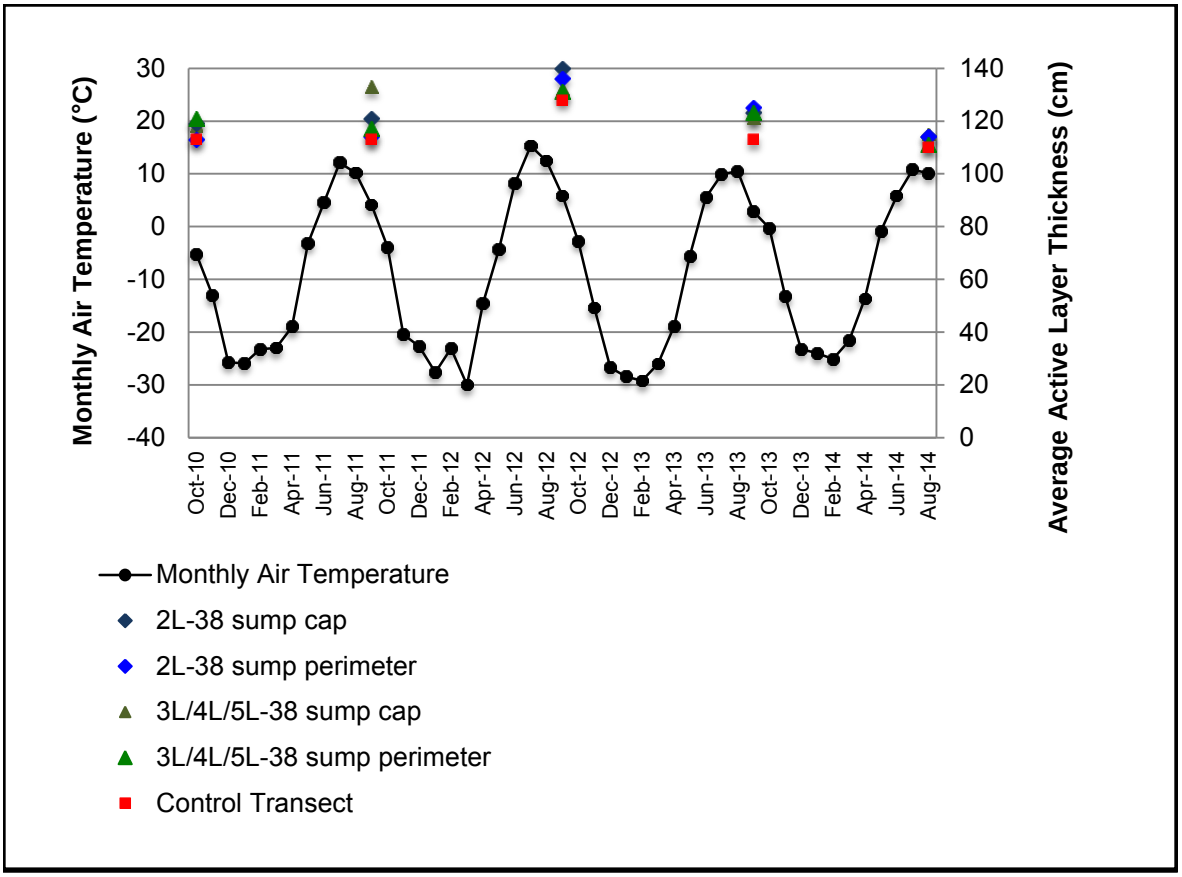


Figure 3-5 Comparison of average monthly air temperature and average active layer thickness.

3.4 GROUND TEMPERATURE

Ground thermal monitoring has been conducted at the Mallik site since April 2007. The thermistor sensor depths ranged from just below ground surface to a maximum depth of 12 m with data loggers set up to record temperatures hourly. Table 3-6 presents the depth of each thermistor in meters. Annual average ground temperatures for each thermistor cable are presented in Figure 3-6. Daily average temperatures for each cable are presented in Appendix E.

Table 3-6 Depth below ground surface of thermistors

Thermistor Sensors	Thermistor Depths (m)				
	07GSC-01[1]	07GSC-02[1]	07GSC-03[1]	07GSC-04	12GSC-05[2]
1	-	1.0	1.0	1.0	0.25
2	0.35	1.5	1.5	1.5	0.50
3	0.85	2.0	2.0	2.0	0.75
4	1.35	2.5	2.5	2.5	1.5
5	2.35	4.5	4.5	3.5	3
6	4.35	6.5	6.5	5.5	6
7	6.85	10.5	10.5	8.0	9
8	4.28	5.65	5.65	10.5	12

NOTES:
[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e., the depth of the sensor #8 is above the sensor #6).
[2] New thermistor cable installed on September 20, 2012

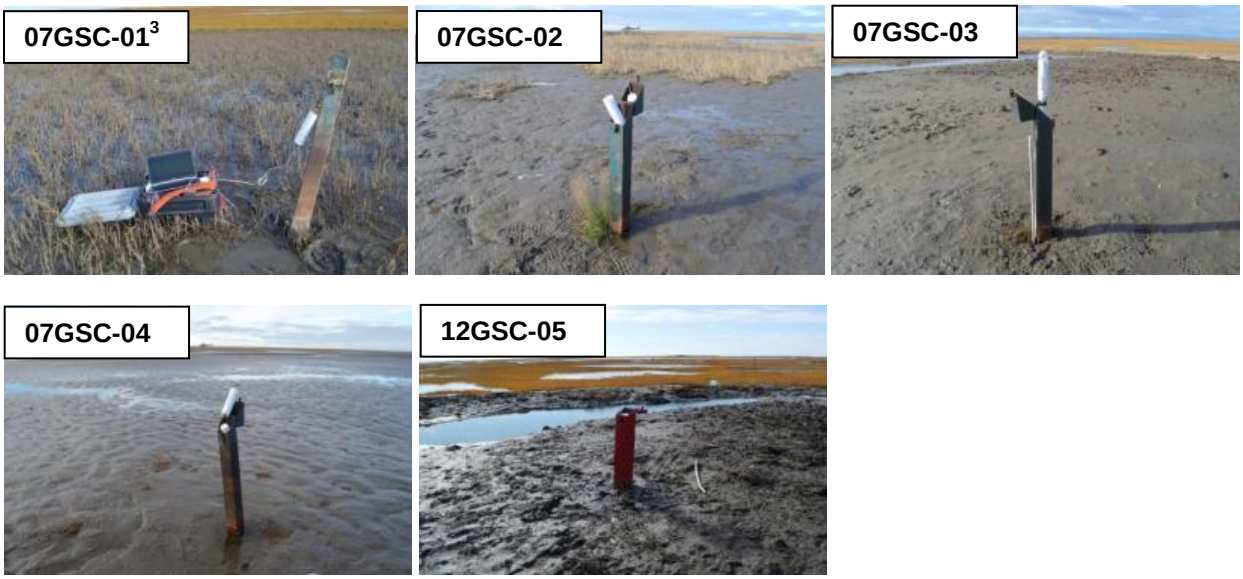
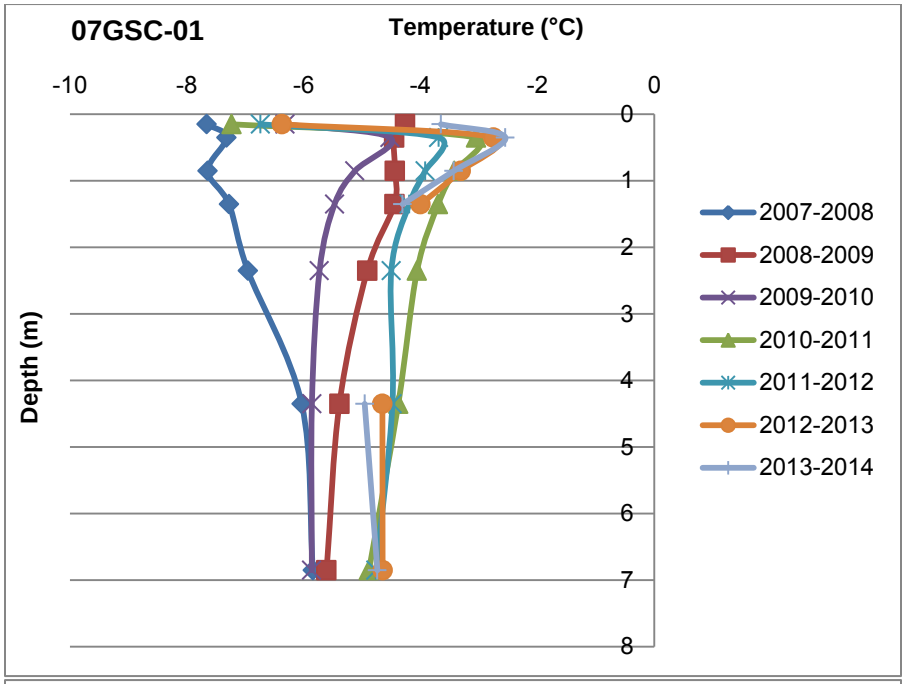
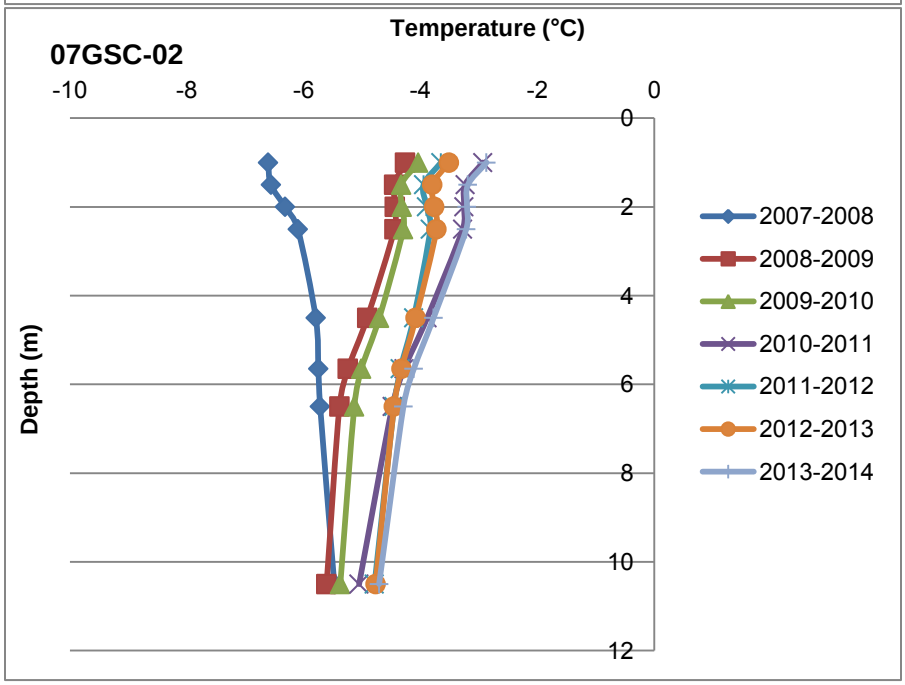
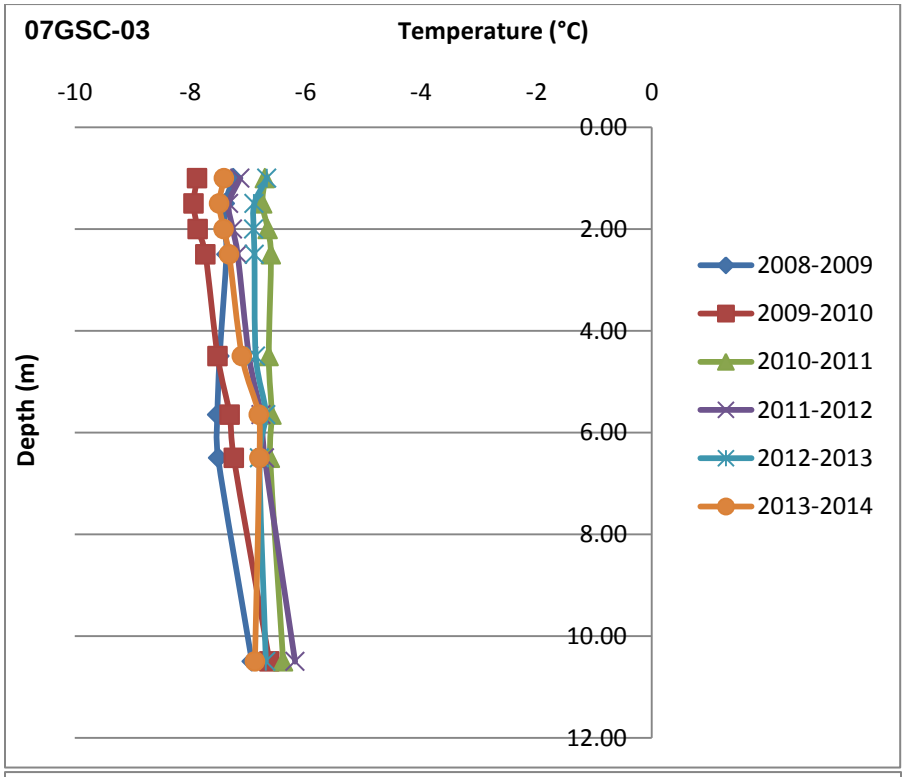


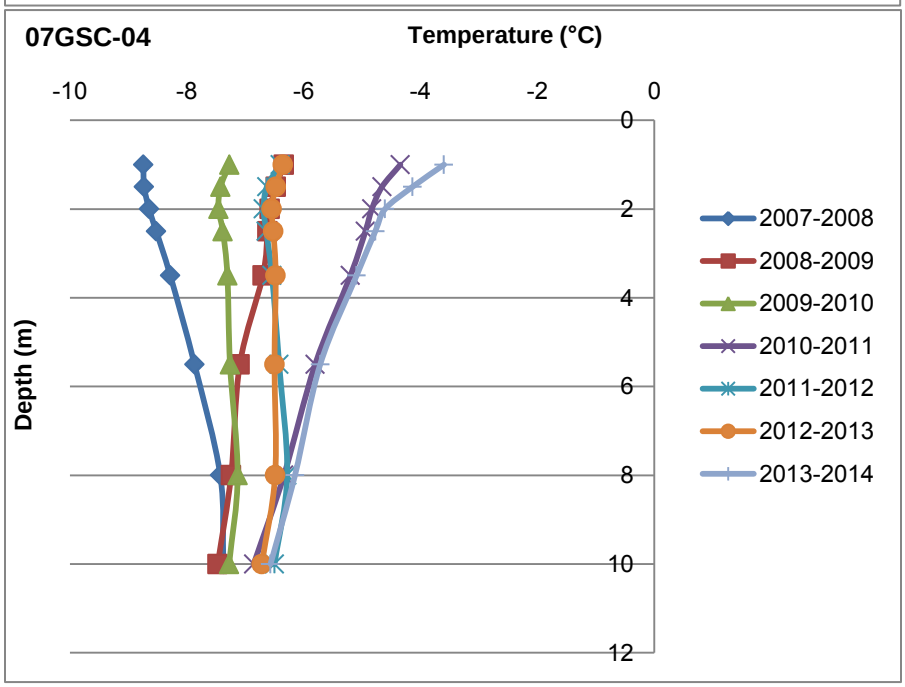
Figure 3-6 Ground surface conditions at the thermistor cables (12/08/2014)

NOTE: [3]Approximately 30 cm of water was present in the pond at 07GSC-01 between 2007 and 2012. No surface water was present in the pond during the site visits in 2013 and 2014.


07GSC-01
Temperature (°C)
-10
-8
-6
-4
-2
0
0
1
2
3
4
5
6
7
8
Depth (m)
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014


Temperature (°C)
07GSC-02
-10
-8
-6
-4
-2
0
0
2
4
6
8
10
12
Depth (m)
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014


07GSC-03
Temperature (°C)
-10
-8
-6
-4
-2
0
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (m)
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014


07GSC-04
Temperature (°C)
-10
-8
-6
-4
-2
0
0
2
4
6
8
10
12
Depth (m)
2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014

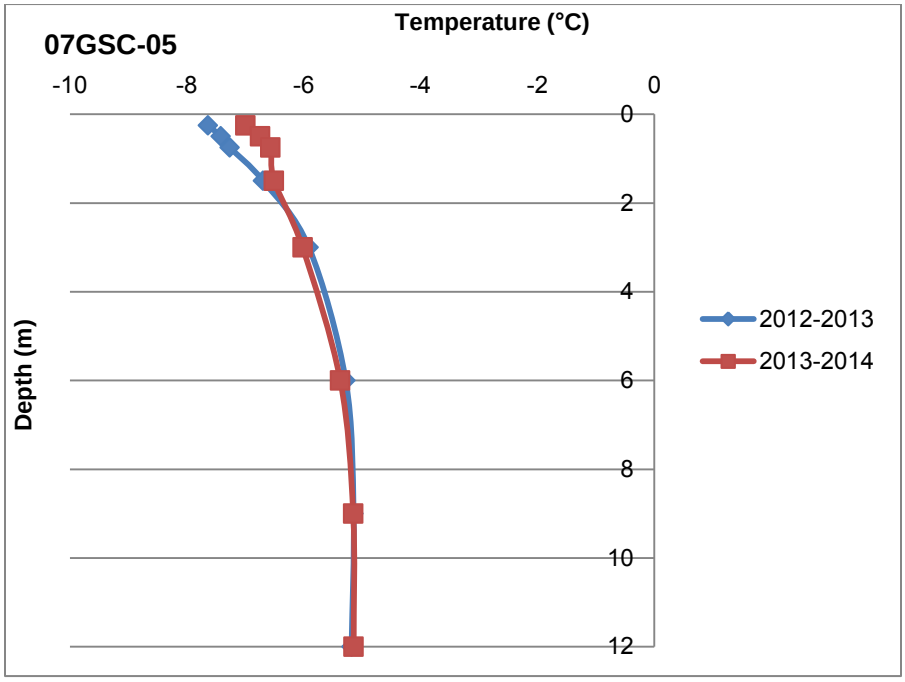


Figure 3-7 Average ground temperature data for each thermistor cable, 2007 to 2012.

Ground temperature monitoring data demonstrates that the thermal regime recorded at the site appears to primarily fluctuate with seasonal temperature variations, regardless of whether the thermistor is located within the sump or outside the sump. Variances in temperature are also assumed to be a function of several secondary factors such as local site conditions, material texture and drainage, presence or absence of vegetation, annual thickness of snow cover, etc.

The comparison of the mean annual ground temperatures profiles for September 2013 to August 2014 (Figure 3-8) indicates that the ground temperature in the upper portion (i.e. between 0 and 5 m) of the two sumps are colder than the three control locations.

Thermistor cable 07GSC-03 is located in the 3L/4L/5L-38 sump and measures temperatures at depths ranging from 1 m to 10.5 m. The thermistor cable has recorded the coldest and most stable temperature profile of all 5 thermistors. The 1 m depth thermistor at 07GSC-03 indicates that the material at that depth was unfrozen from July 25th, 2014 and reached a daily maximum temperature of 0.5°C on August 11th, 2014 (i.e. the last few day of data recording before the site visit). The thermistor located at 1.5 m indicates that the material remained frozen for the last 12 months period, with an annual average temperature of -7.8°C. The data are in accordance with the active layer measured at the thermistor during the site visit (i.e. 129 cm).

Thermistor cable 12GSC-05 is located at the center of 2L-38 sump and measures temperature at depth ranging from 0.25 m to 12 m. The thermistor at 0.75 m indicates that the material at that depth was unfrozen from July 13th, 2014, reached a daily maximum temperature of 2.5°C on July 24th, 2014 and was beginning to freeze-back (0.3°C) at the survey date on August 12th, 2014. The thermistor located at

1.5 m indicates that the material remained frozen for the last 12 months period, with an annual average temperature of -6.7°C.

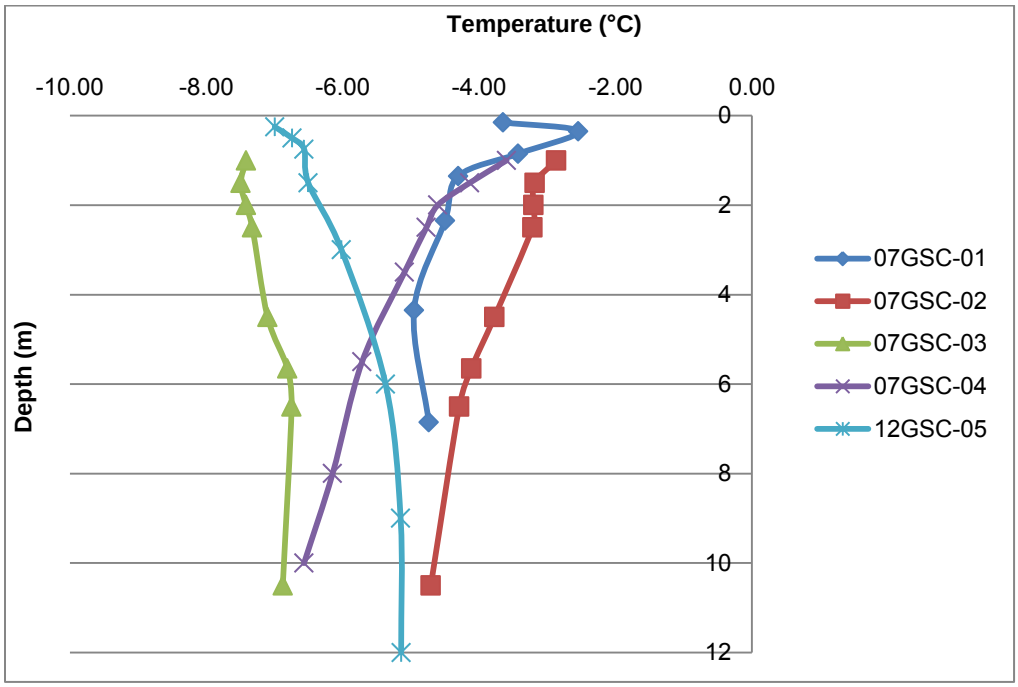


Figure 3-8 Annual mean temperature profiles at the various monitoring locations for the 2013-2014 period. Temperature in the upper portion (i.e. between 0 and 5 m) of the two sumps are colder than the three control locations.

3.5 ELECTROMAGNETIC SURVEYS

Electromagnetic surveys (EM-31 and EM-38) are geophysical tools used to indicate the spatial distribution of conductive materials (anions, cations, metals, etc.) for subsurface materials.

Changes in the distribution of conductive materials may indicate lateral migration of saline drilling fluids and problems with the sump integrity. The main variables which could be affecting the material conductivity are salinity, soil moisture, soil temperature and active layer thickness.

Interpreting inductive electromagnetic (EM) geophysical data in this dynamic permafrost setting is quite challenging. Critical factors to consider when interpreting EM data from permafrost environment are the depth of the active layer and the surface moisture conditions. The presence of numerous shallow ponds and the inundation of the area by storm surges should also be considered. At this site identifying potential anthropogenic impacts is complicated by seasonal variations in active layer and standing water from year to year as well as naturally occurring sediment salts. Differentiating anthropogenic from naturally occurring terrain variability in apparent EM anomalies is thus complex and interpretations should be considered as such.

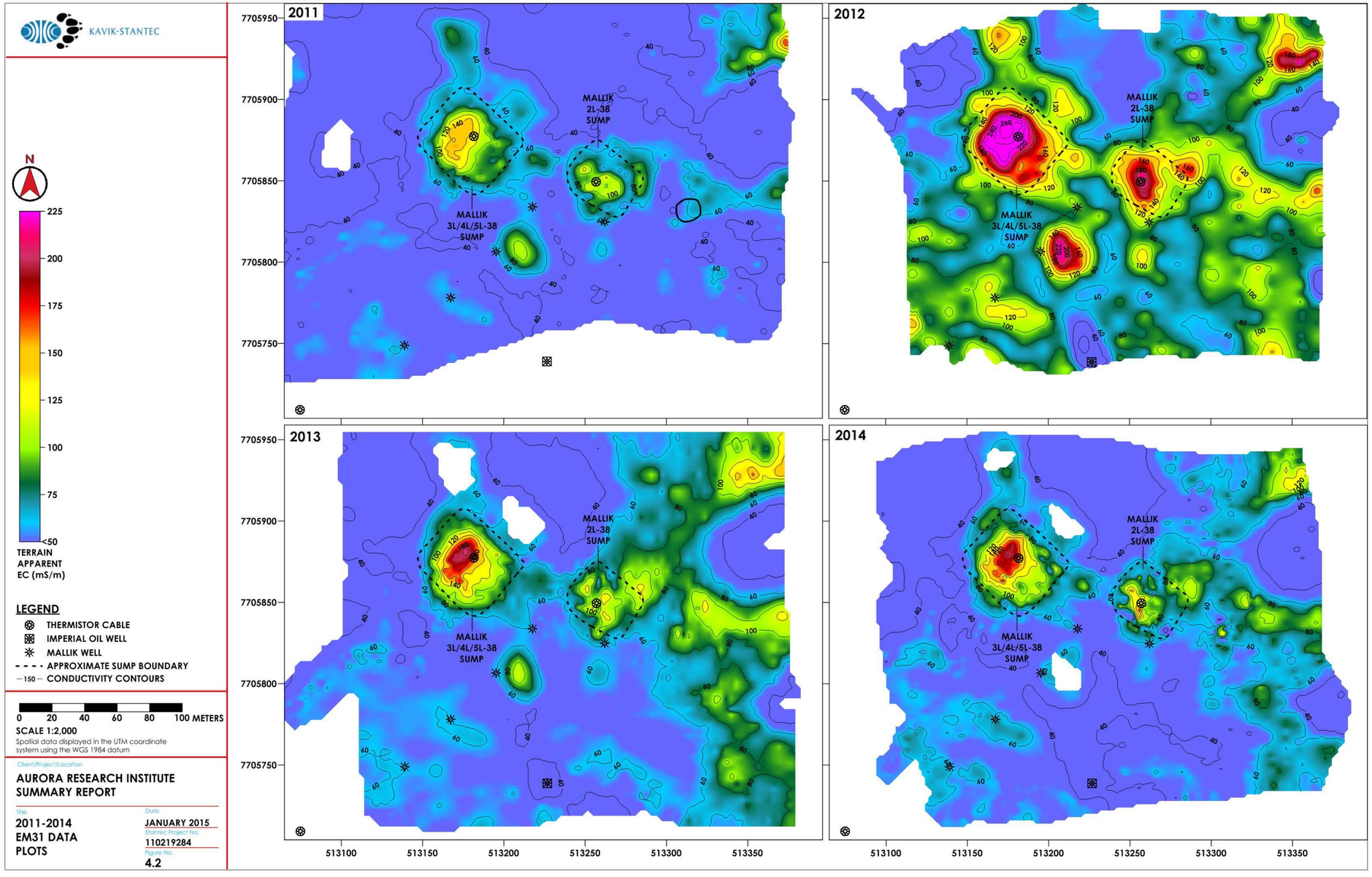
The patterns of EM distribution at the Mallik site are generally very similar from year to year, with only minor differences that are most probably related to variations in the main variable mentioned above (i.e., salinity, soil moisture, soil temperature and active layer thickness).

The shallow EM38 survey (i.e., an effective ground penetration of approximately 1.5 m) and the deeper EM31 survey (i.e., an effective ground penetration of approximately 5 m) both identified areas of elevated apparent conductivity for the Mallik 2L-38 and Mallik 3L/4L/5L-38 sumps which is interpreted to correspond to the presence of saline drill cuttings within the sumps (see Figure 3-9 and 3-10).

The EM31 and EM38 surveys also indicate that there is elevated apparent conductivity at several areas outside the sumps perimeters.

The eastern portion of the Mallik site (i.e. east of the 2L-38 sump) is characterized by elevated electrical conductivity (EC) that is especially pronounced in the EM38 data. This implies that the source of elevated EC is primarily within the upper 1.5 m of the soil profile. Several natural factors could explain this elevated EC. The fact that the area is slightly lower in elevation than the western portion of the site suggest that it is more subject to annual inundation and subsequent evaporation of sea water raising the EC of the surface soils. In addition, this area is bare of any vegetation and the active layer is generally thicker than the rest of the site.

Elevated EC measurements each year have been observed to correspond with several natural ponds. These are most evident as areas of moderately elevated terrain apparent EC in the EM38 data. Using water analysis results from the site (section 3.6.1 and Appendix C), indications that the high conductivity is most likely related to the evaporation of trapped sea water from the annual storm surges and is not indicative of sump seepage.


KAVIK-STANTEC
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175
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75
<50
TERRAIN APPARENT EC (mS/m)
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IMPERIAL OIL WELL
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150 CONDUCTIVITY CONTOURS
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SCALE 1:2,000
Spatial data displayed in the UTM coordinate system using the WGS 1984 datum
Client/Project/Location
AURORA RESEARCH INSTITUTE
SUMMARY REPORT
Title
2011-2014
EM31 DATA
PLOTS
Date
JANUARY 2015
Stantec Project No.
110219284
Figure No.
4.2
2011
2012
2013
2014
MALLIK 2L-38 SUMP
MALLIK 3L/4L/5L-38 SUMP
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7705900
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Figure 3-9 Comparison of the EM 31 (effective ground penetration of approximately 5 m) survey data for the last four years of the monitoring program

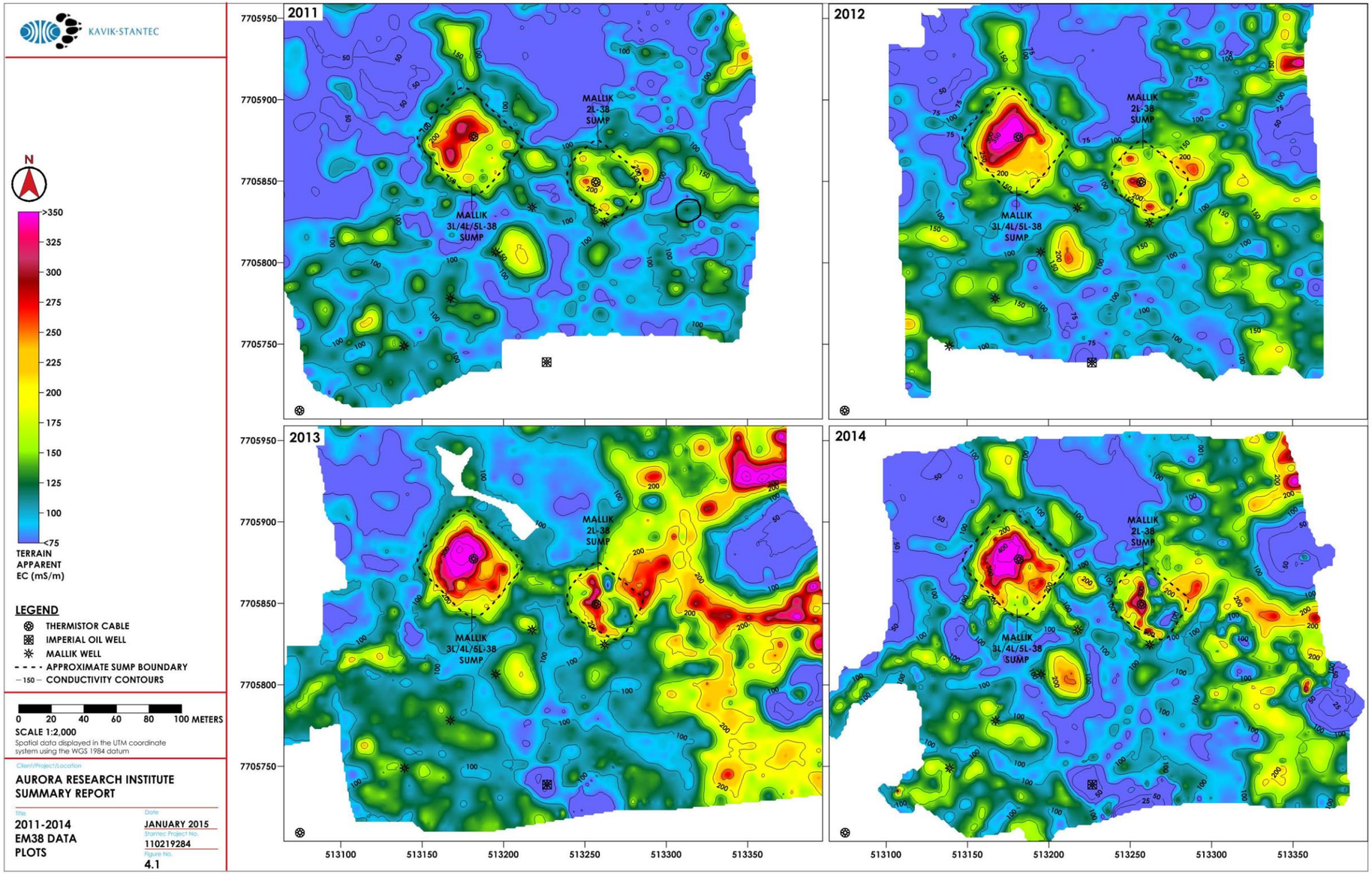

Figure 3-10 Comparison of the EM 38 (effective ground penetration of approximately 1.5 m) survey data for the last four years of the monitoring program.

3.6 SOIL AND WATER SAMPLING

3.6.1 Water sampling

Surface water was sampled during the 2010 to 2014 annual surveys from subsidence areas located either within the sump caps or adjacent to the sump's perimeters. Surface water samples were also taken from ponded water in undisturbed locations. The samples were collected at arm's reach within the deepest area of the ponded water and stored in laboratory-issued 500 ml plastic jars. Samples were submitted to specialized laboratory for routine water chemistry analysis.

Numerous water samples were taken each year of the monitoring program. The number of samples varied each year based on the amount of ponded water. The only areas were elevated unnatural cations were observed was in the depressions on the sump caps. Details on the locations and chemical analysis results of the 2010 to 2014 samples are included in the annual monitoring reports located in Appendix C. A summary of selected water samples taken from the localized depressions at the surface of both drilling sumps is presented in Table 3.7.

The concentrations of sodium, potassium and chloride measured from the ponded water located in both the 2L-38 and the 3L/4L/5L-38 area varied considerably over the summer 2010 to summer 2014 sampling period. The results do not suggest increased seepage of seasonally unfrozen drill mud contaminants into the depressions. The variations in concentration are most likely due to the inputs of water from precipitation events as well as water coming from the storm surges. Similarly there is a possibility that some of the impacted water is washed away from the depressions during the most active storm surge events.

Of the seven water samples collected in 2014, the samples showing the most elevated potassium levels were taken from the pools located within the ponding surrounding both sumps perimeters (i.e. sample W2 with 720 mg/L and W4 with 510 mg/L). In comparison, the potassium levels measured in samples located outside the sumps areas varied from 35 to 71 mg/L. The water samples showing the highest concentrations of chloride were also measured from samples taken within the sumps perimeters (i.e. sample W2 with 2,700 mg/L and W4 with 2,800 mg/L). Water samples W2 and W4 were also showing the highest levels of calcium of all water samples (i.e. sample W2 with 250 mg/L and W4 with 410 mg/L). These high concentrations of potassium and chloride suggest that some seasonally unfrozen drill mud contaminants may be present in the water pooling within the subsiding portions of the sump caps.

3.6.2 Soil sampling

A series of soil samples was also collected during the 2010 to 2014 annual surveys. Details on sample locations and chemical analysis results are included in the annual monitoring reports. The purpose of the soil sampling program was to investigate potential migration of drilling materials outside the sump perimeters. Using results from the EM surveys, samples were taken from areas displaying elevated apparent conductivity. The vast majority of soils samples analyzed over the 2010 to 2014 period have shown normal soil conditions. High sodium contents have been measured in several samples and are believed to result from the evaporation of sea water.

A soil sample taken in 2014 from an area of elevated apparent conductivity located immediately east from the Mallik 2L-38 Sump (sample # MALLIK-2014-S1) suggest that some material used during the drilling process is present at the ground surface in that specific area. The chemical analysis result shows much higher potassium content than the control sample (1,700 mg/kg for sample MALLIK-2014-S1 versus 28 mg/kg for sample MALLIK-2014-S2) while the pH, conductivity and chloride values are fairly similar between both samples.

A distinct white colored and fine textured material was observed on the ground surface during the 2013 and 2014 site visits. A sample of this material taken in 2013 (MALLIK-2013-S3) indicates high levels of potassium, chloride and sodium that could correspond to drilling fluid material. A comparison of the EM31 and EM38 data suggest that the contaminant is mostly present at the near surface and therefore not related to the seepage of drilling contaminants from the sump.

Table 3-7 Summary of water and soil samples taken from the depressions at the surface of the drilling sumps.

Sample number	pH value	Electrical Conductivity (dS/m)	Dissolved Sodium mg/L	Dissolved Potassium mg/L	Dissolved Chloride mg/L
2L-38 Sump (east depression)					
MALLIK-2010-W01	7.74	7.9	300	950	1900
MALLIK-2011-S02*	7.15	3.1	2700	3300	9800
MALLIK-2012-W02	7.55	5.6	280	600	1100
MALLIK-2013-W01	7.99	1.6	200	28	360
MALLIK-2014-W01	8.41	3.6	390	110	No data
2L-38 Sump (west depression)					
MALLIK-2010-W02	7.93	14	1900	680	4100
MALLIK-2011-S03*	7.00	7.6	930	580	2300
MALLIK-2012-W01	7.61	14	1600	820	3800
MALLIK-2013-W02	8.07	4.1	300	330	1100
MALLIK-2014-W02	8.05	9.1	800	720	2700
3/4/5L-38 (SW corner depression)					
MALLIK-2012-W01	7.81	26	1800	2800	7700
MALLIK-2013-W05	7.99	3.9	380	210	1000
MALLIK-2014-W04	7.92	9.6	850	510	2800
*Soil sample					

4 SUPPLEMENTARY ACTIVITY - APPLICATION OF UAV TECHNOLOGY TO DRILLING WASTE SUMP MONITORING

An Unmanned Aerial Vehicle (UAV) survey was conducted by KAVIK-Stantec on August 13, 2014. This technology is used for low level aerial image acquisition and 3D Digital Elevation Model (DEM) generation. The use of the UAV technology allowed for the acquisition of high-resolution (3 to 5 cm pixel resolution) digital images of the site from which a digital elevation model (DEM) can be generated. The various images are then geometrically corrected (i.e. orthorectified) such that the scale of the photograph is uniform. The resulting image consists of a mosaic of colored orthophotos. A DEM is a continuous 3D representation of a terrain surface area that has been geometrically corrected, so it can be used to measure distances and heights. The accuracy of the elevation data acquired using the UAV is of approximately ±35cm horizontally and ±20cm vertically. The main advantages of UAV system acting as a photogrammetric sensor platform over more traditional manned airborne system are the high flexibility that allows image acquisition from unconventional viewpoints, the low cost in comparison with classical aerial photogrammetry, and the high resolution images obtained (Perez et al. 2013).

The use of the UAV survey technique was tested at the Mallik site to investigate the utility of this technology in the assessment of the topography of the sumps and surrounding terrain. Ground subsidence is known to occur at the 2L-38 and 3L/4L/5L-38 sumps, and the acquisition of time-specific orthophoto and DEM data could be used as a reference against future UAV surveys for inter-annual change detection.

A graphic visualization of the aerial mosaic and UAV elevation data acquired at Mallik are presented in Figure 4-1 and Figure 4-2. Cross-sections intersecting the sump areas provide some information on the depth of the various depressions. Based on the 2014 field observations and on the delineation of the depressions using the UAV data, approximately 60 percent of the 2L-38 sump cap and approximately 10 percent of 3L/4L/5L-38 sump caps are exhibiting surface subsidence.

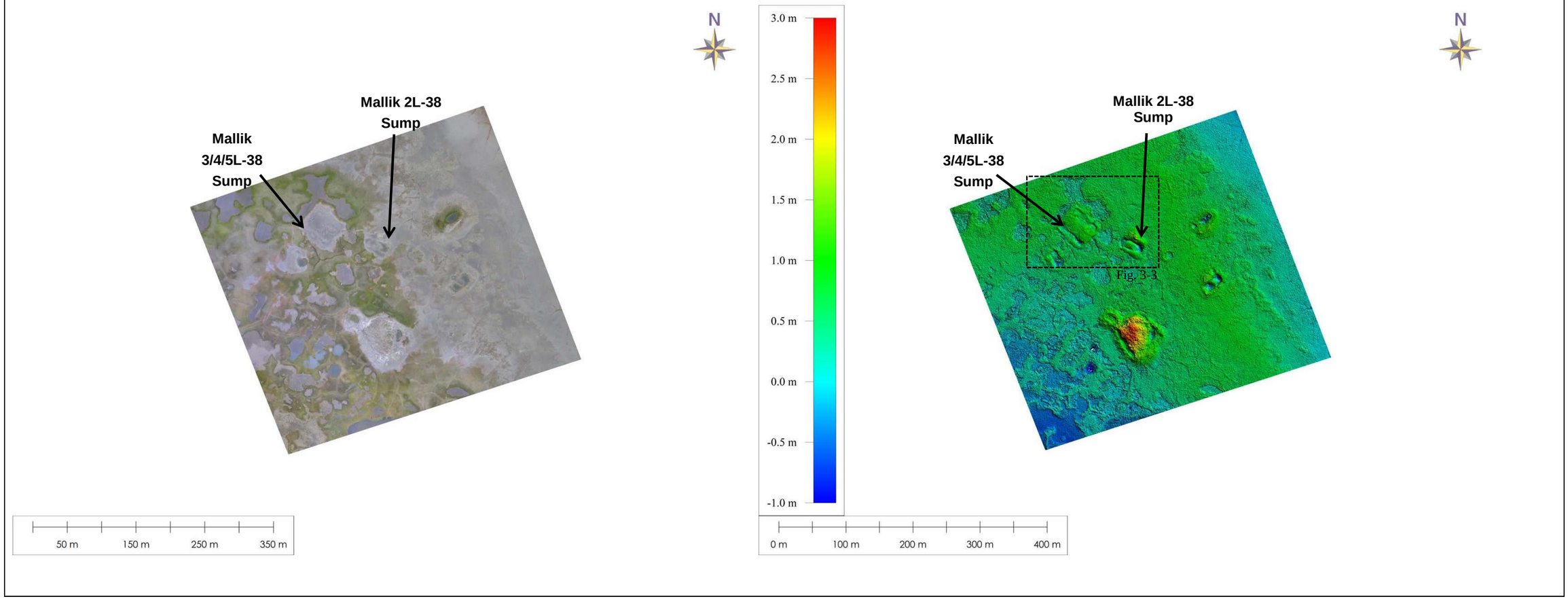

Figure 4-1 Orthomosaic and DEM data from the 2014 UAV survey.

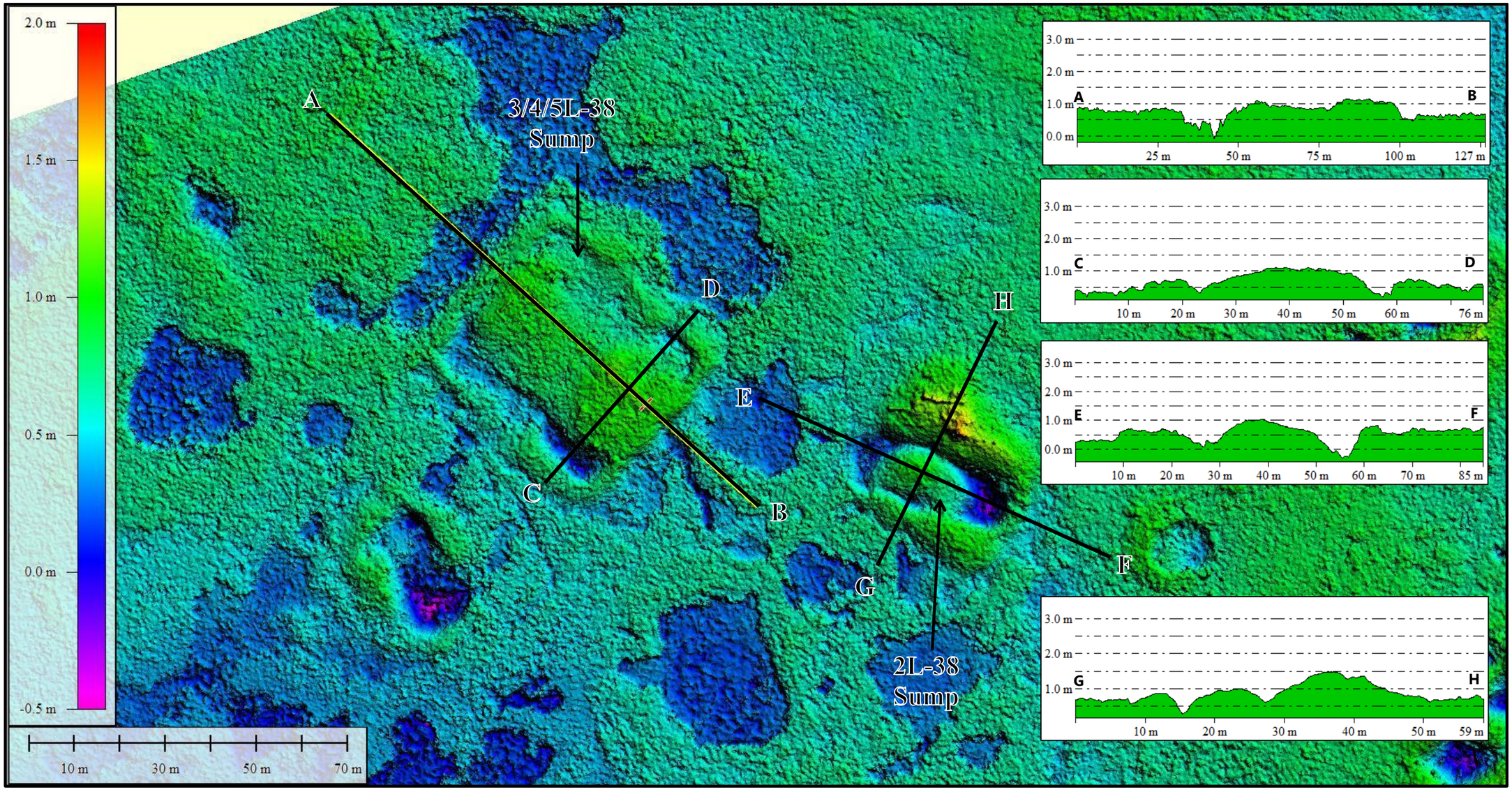

Figure 4-2 Topographic data from the 2014 UAV survey

5 CONCLUSION

The location of the Mallik site along the low-lying coastal terrain of the Mackenzie Delta, only a few hundred meters from the Beaufort Sea is particularly susceptible to storm surges. This element, in conjunction with the area being underlain by thick continuous permafrost and substantial variability in surface water from precipitation and run-off result in site drainage conditions that are generally poor.

Vegetation, where present, consists mainly of variety of graminoid species, such as sedges and cottongrasses, with a few sporadic low shrubs and mosses. No vegetation was seeded as the surface of the two sumps following the various drilling programs and only very localized patches of grass have re-established at the surface of the 3L/4L/5L-38 sump cap (the 2L-38 sump cap remains bare of any vegetation).

The presence of localized depressions within the sump perimeters was reported in the annual sump monitoring reports since the first year of the monitoring program in 2008. Visual observation and site photographs suggest that the depressions have slightly increased in size and depth, particularly over the first three years of the program.

New topographic data was acquired for the Mallik site in August of 2014 using UAV surveying technology. Although not required as part of the Drilling Waste Sump Monitoring Protocol, this survey provides the most useful data to date on the ground surface topography of the two sumps and surrounding areas.

Active layer measurements conducted over the 7-year monitoring period show only minor variations in active layer thickness. Air temperature was recorded at the site since from October 2010 to August 2014. The data indicates average monthly air temperature above 0°C for the month of June to September inclusively, with an annual average temperature of -9°C.

Ground thermal monitoring has been conducted at the Mallik site since April 2007. Thermistor 07GSC-03 located at the center of the 3L/4L/5L-38 sump has the coldest and most stable temperature profile of all thermistors located on site. The thermistor located at 1.5 m indicates that the material remained frozen for the last 6-year period, with an annual average temperature of -7.3°C. Annual ground temperature variations recorded at the various thermistor cables are likely a function of natural factors such as annual weather regime, soil moisture, duration and thickness of snow cover. An additional thermistor cable was installed at the center of the 2L-38 Mallik sump in September of 2012.

Electromagnetic surveys (EM) have been conducted at the Mallik site during the monitoring program. Each of the surveys has indicated elevated apparent conductivity at the two sump areas in relation with the presence of saline drill cuttings within the sumps. The surveys also indicate elevated apparent conductivity at several areas outside the sumps perimeters, which are related to natural factors such as variable soil moisture regime, variable active layer thickness and the presence of salt concentrations issued from the evaporation of sea water.

Soil and water samples were taken at various locations during the monitoring program in order to investigate potential contamination outside the sumps. Water sampled from the depressions located within the sumps perimeters showed elevated concentration of potassium and chloride when compared to

water sampled from natural depressions located outside the sumps. These elevated levels of potassium and chloride are believed to originate from the sump material buried below. Soil and water sampled in the undisturbed area outside the sump perimeters do not indicate any seepage or migration of the drilling material outside the sumps.

6 CHALLENGES RELATED TO IMPLEMENTING THE DRILLING WASTE SUMP MONITORING PROGRAM AT THE MALLIK SITE

The monitoring of capped drilling sumps in remote locations has a number of challenges. Some obvious challenges are related to the remoteness of the Mallik site and its coastal Beaufort Sea floodplain location, which is susceptible to storm surges. The following is a short discussion of some of the main challenges related to monitoring the Mallik 2L-38 and 3L/4L/5L-38 sumps.

- Limited information on the size of the sumps
- Difficulties in estimating ground subsidence
- Difficulties related to the interpretation of EM data

The first challenge that we faced during the Drilling Waste Sump Monitoring Program was the limited documentation related to the construction, use and closure of the two sumps. A review of historical reports, documents and photos showed small discrepancies in the dimensions of the sumps. The general location and extend of the sumps are evident from the site microtopography, however it is not possible to accurately identify the contact between the edges of the sumps and the undisturbed terrain. This is mainly due to the fact that the sump caps extend beyond the actual sumps. Knowing the exact dimensions and locations of the sumps would have helped in assessing if waste drilling fluids have migrated into the undisturbed soils outside of the sumps, as well as assessing if the subsidence affecting the sump caps is extending to the undisturbed terrain surrounding the sumps.

The occurrence of ground subsidence at the 2L-38 sump and 3L/4L/5L-38 sump is indicated by the presence of several depressions at the surface of the sump caps. The review of historical reports and site photographs indicate that these depressions were not present at the sump closure and that they have formed subsequently. Visual inspections conducted during the seven year monitoring program suggest that the depressions have increased in size and depth, however this is based solely on descriptive observations and no numerical data are available. Furthermore, the ponded water conditions vary from year to year, making visual comparisons difficult. The results of the 2014 UAV survey and subsequent generation of an orthomosaic image and a DEM for the site, demonstrate the potential of UAV technology in conducting quantitative inter-annual comparisons of features such as sumps. This quantitative assessment of elevation change may also help in differentiating between ground subsidence due to the thawing of ice rich materials and a decrease in elevation due to erosion caused by storm surges.

As previously mentioned, the interpretation of EM data is quite challenging at the Mallik site. This is due to a number of factors including the presence of permafrost, the annual variation in soil moisture and active layer thickness, the natural occurrence of salt in the local soils as well as the recurrent storm surges and subsequent evaporation of sea water. All of these elements affect the EM reading in some ways and makes the interpretation of moderate to elevate EM readings in areas located outside of the sump areas a challenge.

7 CLOSURE

The August 2014 field visit marked the last year of the seven-year Monitoring Program. The air temperature thermistor that was mounted on the 2L-38 well head location marker was removed from the site. Special attention was given to collect any plastic and/or metal fragments that were present on the site. The only object and/or scientific instrumentation remaining at the Mallik site associated with the Program are the five thermistor cables, the five dataloggers and metal protective casings.

ARI has discussed the Mallik ground temperature monitoring equipment with the permafrost scientists from the Northwest Territories Geoscience Office. This instrumentation continues to function well and provides data of great scientific value which could contribute to gaining additional knowledge and understanding if the permafrost ground condition is this unique coastal environment. The on-going collection of ground temperature data at the Mallik site would be complementary to their current NWT wide ground temperature monitoring program and would be a significant contribution to their monitoring program. The equipment should be transferred to the NWT Geoscience Office to support on-going research in the NWT.

Respectfully Submitted,

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APPENDIX A

Summary of Wells Drilled at Mallik Site in 1998, 2001 and 2002

Table A-1 Summary of wells drilled at Mallik site during JAPEX/JNOC/GSC Mallik 2L-38 in winter 1998 and JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 during winter 2001-02

	Mallik 2L-38	Mallik 3L-38	Mallik 4L-38	Mallik 5L-38
Well name	JAPEX/JNOC/GSC Mallik 2L-38	JAPEX/JNOC/GSC et al. Mallik 3L-38	JAPEX/JNOC/GSC et al. Mallik 4L-38	JAPEX/JNOC/GSC et al. Mallik 5L-38
Authority to drill well number	9311-J31-1-1	93311- J31-2-1	93311- J31-2-2	93311- J31-2-3
WID number	1827	1919	1920	1921
Grid Area	69-30-134-30	69-30-134-30	69-30-134-30	69-30-134-30
Classification	Research Well	Research Well	Research Well	Production Well
Well coordinates	Lat. 69.461174 Long. -134.661359	Lat. 69.460514 Long. -134.664573	Lat. 69.461027 Long. -134.662965	Lat. 69.460758 Long. -134.663744
Operator	JAPEX Canada Ltd	JAPEX Canada Ltd	JAPEX Canada Ltd	JAPEX Canada Ltd
Water License number	N3L1-1702	N3L1-1769	N3L1-1769	N3L1-1769
Land Use Permit number	N97A769	N2001A0016	N2001A0016	N2001A0016
NEB Well Identification	302L386930134300	303L386930134300	304L386930134300	305L386930134300
Total depth	1150 m KB	1188 m KB	1188 m KB	1166 m KB
Spud date	February 16, 1998	December 25, 2001	December 21, 2001	December 25, 2001
Last drilling date	March 22, 1998	January 5, 2002	December 23, 2001	February 20, 2002

APPENDIX B

Annual Site Monitoring Reports

Mallik Gas Hydrate Production Research Project:

Aurora Research Institute Mallik 2L-38 and 3L/ 4L/ 5L-38 Sump Monitoring and Retrofit Program

Prepared by
Kevin Martin PMP
IOFS Project Manager

27, November 2008

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Table of Contents

1. Executive Summary: 6
   - 1.1 Recap of Mallik History: 7
   - 1.2 Site Location and Sump Identification 8
   - 1.3 General Data: 12
2. 1998 Mallik 2L-38 Operations 13
   - 2.1 Site Identification and Location 13
   - 2.2 Site History and Local Environmental Conditions 13
     - 2.2.1.1 Purpose of well drilled at the lease: 13
     - 2.2.1.2 Site survey plan: 14
     - 2.2.1.3 Project Team: 17
   - 2.3 Site Development 18
     - 2.3.1.1 Timeline: 18
     - 2.3.1.2 Method of preparing the Sump: 19
     - 2.3.1.3 Reclamation methods: 20
   - 2.4 Sump Details- Sump construction and contents: 20
   - 2.5 Environmental Setting 22
     - 2.5.1.1 Surface conditions 22
     - 2.5.1.2 Soils and ground – ice conditions. 22
   - 2.6 Site conditions after closure – Sump characteristics 23
3. 2002 Mallik 3L, 4L and 5L-38 Operations 24
   - 3.1 Site Identification and Location 24
   - 3.2 Site History and Local Environmental Conditions 25
     - 3.2.1.1 Purpose of well drilled at the lease: 25
     - 3.2.1.2 Site survey plan: 25
     - 3.2.1.3 Project team: 28
   - 3.3 Site Development 29
     - 3.3.1.1 Timeline: 29
     - 3.3.1.2 Method of preparing the Sump: 30

3.3.1.3 Reclamation methods: 31

3.4 Sump Details- Sump construction and contents: 32

3.5 Environmental Setting 33

3.5.1.1 Surface conditions 33

3.5.1.2 Soils and ground – ice conditions 33

3.6 Site conditions after closure – Sump characteristics 34

3.6.1 2002 Sump pictures: 35

4. Active Layer and Ground Temperature Monitoring 39

4.1 Summary: 39

4.2 Active Layer Measurements: 40

4.2.1 1998 Mallik 2L-38 Drill Sump 41

4.2.2 2002 Mallik 3L/ 4L/ 5L-38 Drill Sump 42

4.2.3 2002 Mallik 3L/ 4L/ 5L-38 Camp Sump 42

4.3 AL Thickness in Sump cap depressions: 42

4.3.1 1998 Mallik 2L-38 Drill Sump 42

4.3.2 2002 Mallik 3L/ 4L/ 5L-38 Camp Sump 42

4.4 Summary of Air and Ground temperature: 43

5. References: 53

6. Appendices: 54

6.1 Appendix 1: Mallik 2L-38 and 3L/ 4L/ 5L-38 Sump Monitoring and Retrofit Programme as submitted to the Environmental Impact Screening Committee- February 2008 54

6.2 Appendix 2: Protocol for the Monitoring of Drilling- Waste Disposal Sumps; Inuvialuit Settlement Region – Northwest Territories Water Board - October 2005 55

6.3 Appendix 3: Canadian Petroleum Engineering Inc Letter: Water Use License Number N3L1-1702 dated 18,August 1998. 56

6.4 Appendix 4: Drilling Waste in the Mackenzie Delta (Inuvialuit Settlement Region): Drilling Waste Management Recommended Best Practices: March 2004. 57

6.5 Appendix 5: JOGMEC Mallik L-38 Site: Geophysical and subsurface environmental Site investigation; 2005; Kiggiak-EBA Consulting Ltd. 58

6.6 Appendix 6: September 15, 2006 Mallik Site Survey: Kavik Axys Inc, September 2006. 59

6.7 Appendix : 7 2002 Sump correspondence: 60

6.8 Appendix 8: Canadian Petroleum Engineering Inc Letter: dtd 5,November, 2005 – Final Report for JAPEX/JNOC/GSC et al Mallik 3L-38, 4L-38 & 5L-38. 61

6.9 Appendix 9: Canadian Petroleum Engineering Inc Letter: dtd 25,March 2002 – Water Board for closure of 2002 sump caps. 62

1. Executive Summary:

The purpose of this report is to document the sump monitoring activities for the NWT Water Board Protocol as collected from the field activities and provided to the board as stated in the Mallik 2L and Mallik 3L/ 4L/ 5L-38 Sump Monitoring and Retrofit Programme. **(Appendix 1).**

This report follows the information as mentioned in the Northwest Territories Water Board Protocol for the Monitoring of Drilling Waste Disposal Sumps. **(Appendix 2)**

There are a total of 6 sumps (3 drilling sumps, 2 camp sumps and one flare sump) that have been constructed on the Mallik site year to date. The oldest is the Imperial Oil Ltd sump which was constructed during their drilling campaign back in 1971-1972 for the Mallik L-38 well. This sump is not covered within this file note.

This file note will only cover the five (5) sumps that were constructed during the Gas Hydrate Production Research Programme that took place in the winter campaigns of 1998 and 2002. During the 2006-2008 Mallik Gas Hydrate Production Research Project Mallik wells 2L-38 and 3L-38 were deepened and the casing conductor of Mallik well 6L-38 was run. These operations were preformed “sumpless”, ie no sumps were constructed or added to as all drill cuttings and camp effluent was trucked off site and disposed of through registered waste centres.

During the winter campaign of 1998 a camp sump and drilling sump was constructed when Mallik well 2L-38 was drilled. A flare sump was also constructed to accommodate the planned well test. The research goals for the 1998 campaign were to evaluate the engineering technologies used to drill and core gas hydrate bearing strata and perform a production flow test. Delays caused by adverse weather and mechanical problems caused the cancellation of the planned production test. **(ref *1)**

During the 2002 winter campaign, a further camp sump and drill sump was constructed for Mallik wells 3L-38, 4L-38 and 5L-38. The major goal of the 2002 Mallik programme was to conduct the first modern production test of a gas hydrate deposit **(ref *2)** and continue the quest for more knowledge on gas hydrates. During this campaign the drill sump area was increased to accommodate the additional drill fluids when losses occurred in drilling the production well, Mallik 5L-38. **(Appendix 3)**

The documentation reviewed in compiling this file note was taken from the activities as performed on the site, documented well data files, the environmental site investigation and papers as written by the scientists during those campaigns. A list can be found in the reference towards the rear of this note.

Future reports to be submitted will only cover the drill sumps from the Mallik 2L and Mallik 3L/4L/5L -38 as stated in the Sump Monitoring and Retrofit Programme. **(Appendix 1)**

1.1 Recap of Mallik History:

Imperial Oil Ltd with their Mallik L-38 discovery well drilled in 1971-72, identified gas hydrate formations **(ref*3)**. In 1998 to further investigate this original discovery and as the initiative for a new international gas hydrate research campaign, Canada and Japan established a joint research and development program to study gas hydrates. Led by the Japan National Oil Corporation (JNOC) and Geological Society of Canada (GSC) scientists and engineers, they drilled JAPEX/JNOC/GSC Mallik 2L-38 research well with JAPEX Canada Ltd as the operator. Several cores and samples were taken for further analysis both in a field laboratory at the Aurora Research Institute (Inuvik) and at home institutions. Extensive downhole geophysical well logging was also carried out prior to final abandonment of the well at a total depth of 1150m - just below the base of the hydrate layers. The scientific results and a comprehensive project data base were published as a compendium volume of the Geological Survey of Canada (GSC) of Natural Resources Canada **(ref *4)**.

A second multidisciplinary research and development program was undertaken in 2001/2002 were three more wells were drilled, JAPEX/JNOC/GSC 3L-38, 4L-38 and 5L-38. Mallik 5L-38 was the production well with Mallik 3L-38 and 4L-38 being observation wells. All the wells were drilled vertically in the same plane and spaced approximately 40 metres apart with the production well in the middle.

These R&D studies were led by the GSC and JNOC with JAPEX again acting as the operator. Additional participants included GeoForschungZentrum Potsdam, the U.S. Geological Survey, the U.S. Department of Energy, BP/Chevron Joint Venture and the India National Gas Hydrate program **(ref *2).**

The cuttings from the wells drilled during these campaigns along with the discharge from the camp were placed in their respective sumps built adjacent to the rig and camp respectively. **(see Figure 2.)**

During the 2006-2008 Gas Hydrate Production Research Project, a new configuration of the main players immerged, Japan Oil and Gas Metals Corporation (JOGMEC), replacement for the JNOC corporation, and Natural Resources Canada (NRCan), department in which GSC is situated, supplied the scientists and lead engineers whilst Aurora Research Institute (ARI) out of Inuvik took on the role as operator. Mallik wells 2L-38 and 3L-38 were accessed and deepened. This was to enable a production test to be carried out on Mallik 2L-38 with the produced water being reinjected into Mallik 3L-38. For this campaign all drill cuttings and camp affluent was trucked offsite for disposal – a “sumpless” operation.

1.2 Site Location and Sump Identification

The Mallik Gas Hydrate Production Research Project is located at the existing Mallik L-38 drill site on the western side of Richards Island in the Mackenzie Delta, Northwest Territories. **(Figure 1).**

The site is near the floodplain on the western side of Mallik Bay, on Crown land in the Inuvialuit Settlement region within Imperial Oil Resources Ltd significant discovery license (SDL) 060.

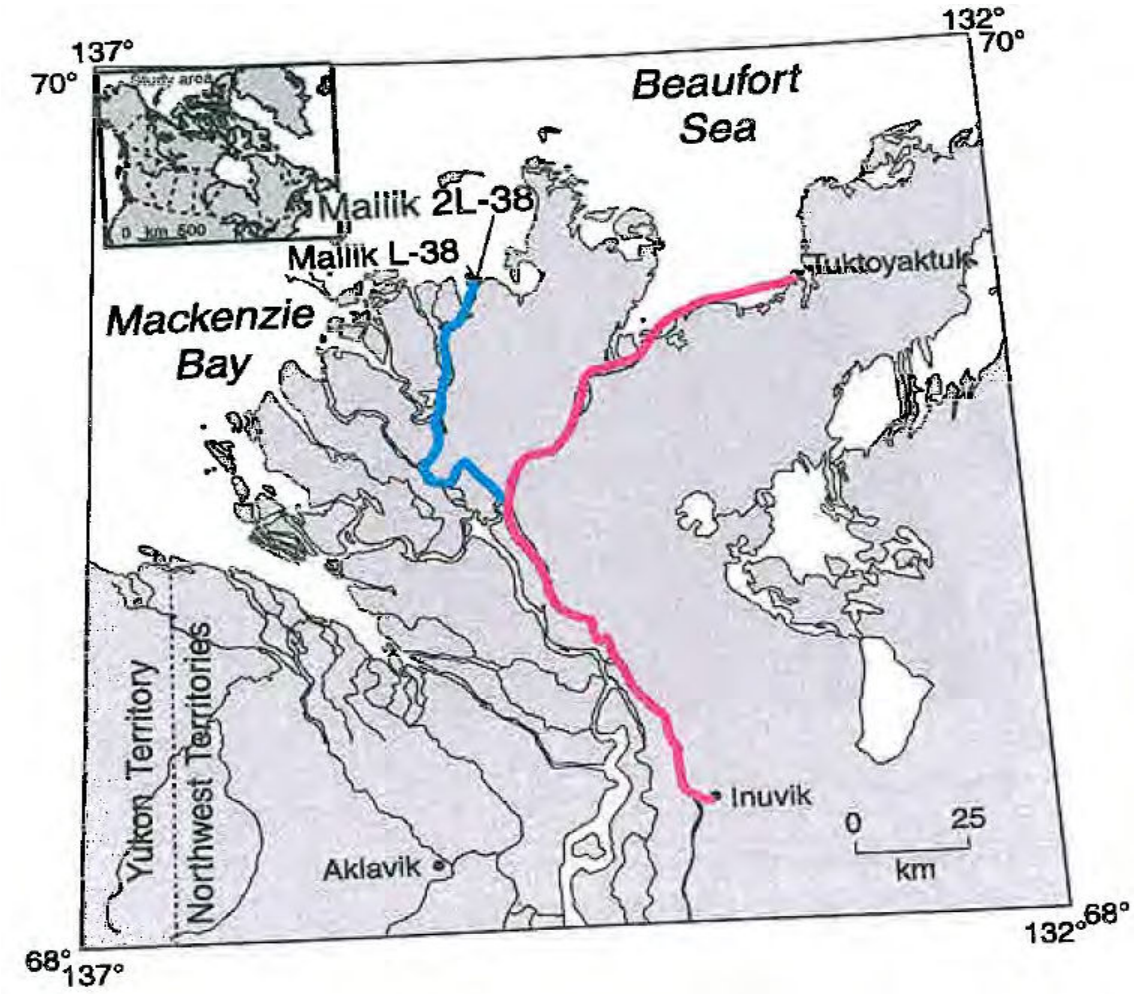


Figure 1: Location map showing the Mallik Site and the routes of ice road – pink is the government road and blue is the drill road as used in 1998 and 2002 campaigns. In 2006/8 campaign access route entailed going out onto Beaufort Sea.

The site map of Mallik Drill site.

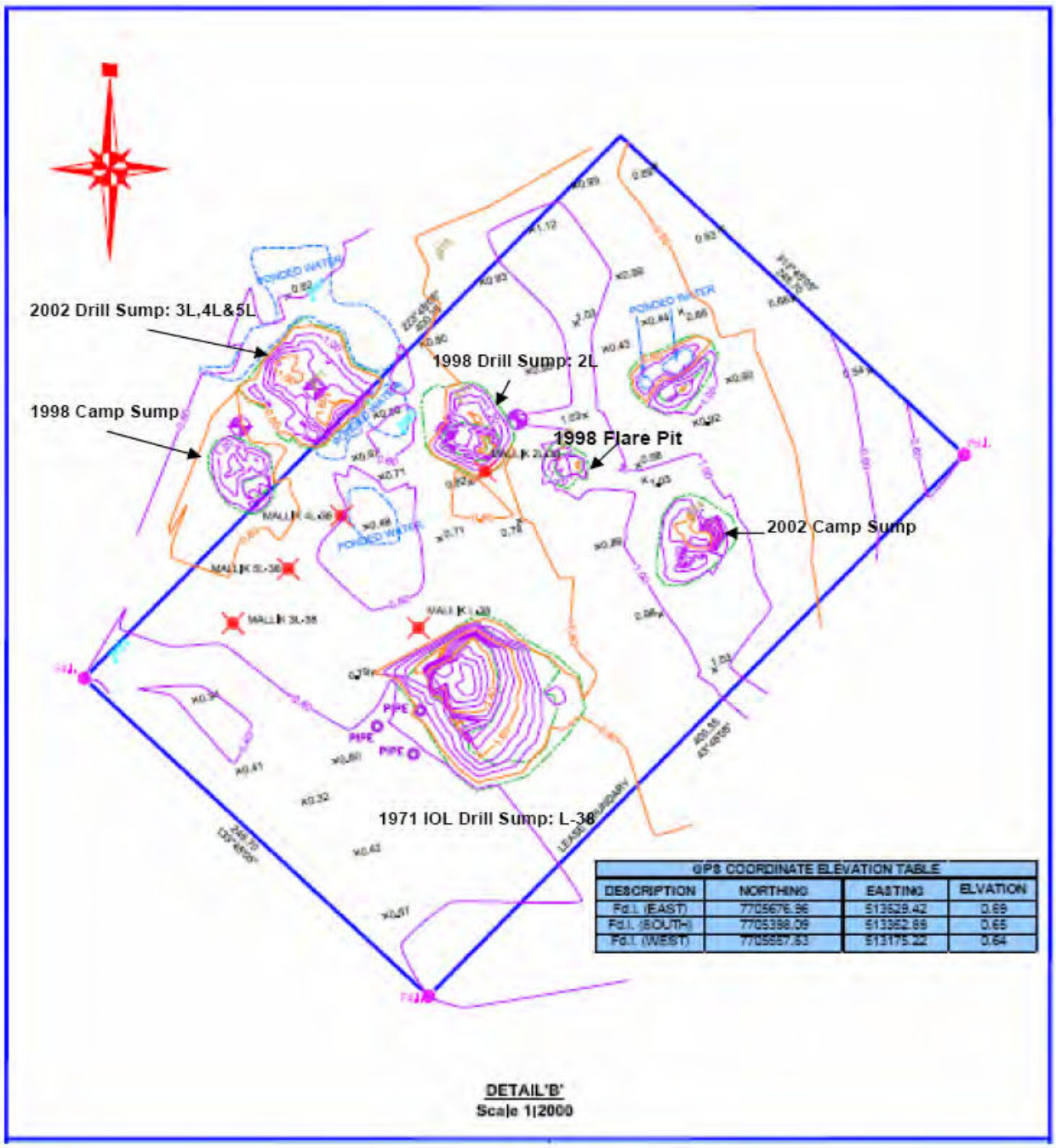
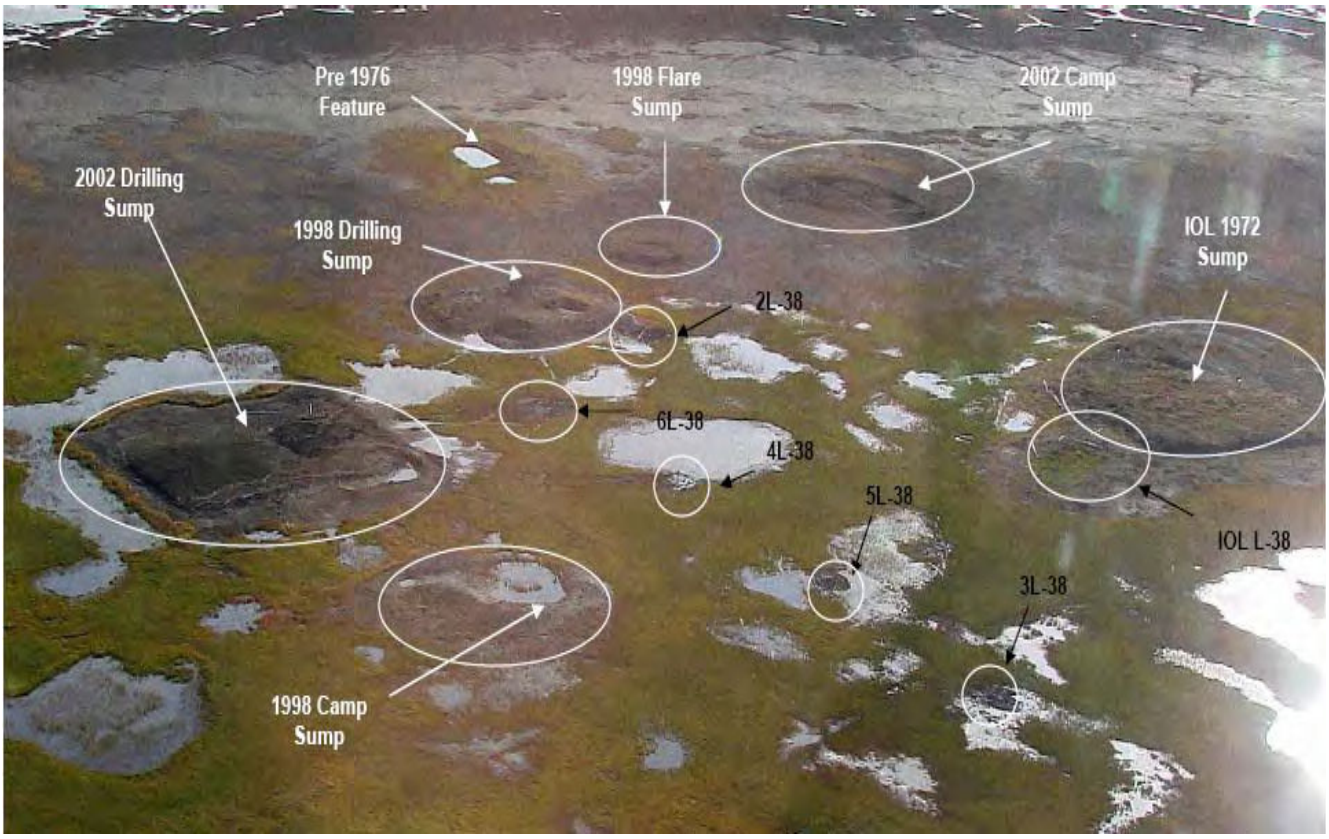
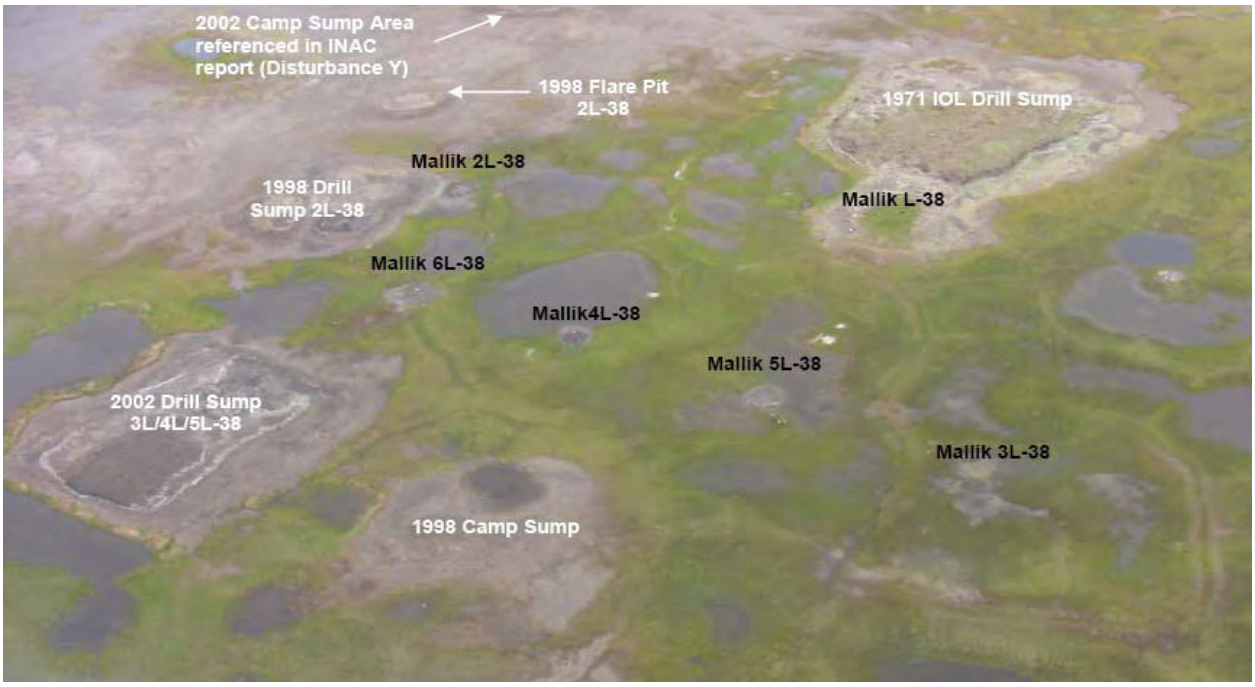


Figure 2: Mallik L-38 site with locations of drill sumps, camp sumps, flare pit and well head locations. Map drawn summer 2006 by Inukshuk Geomatic Inc.

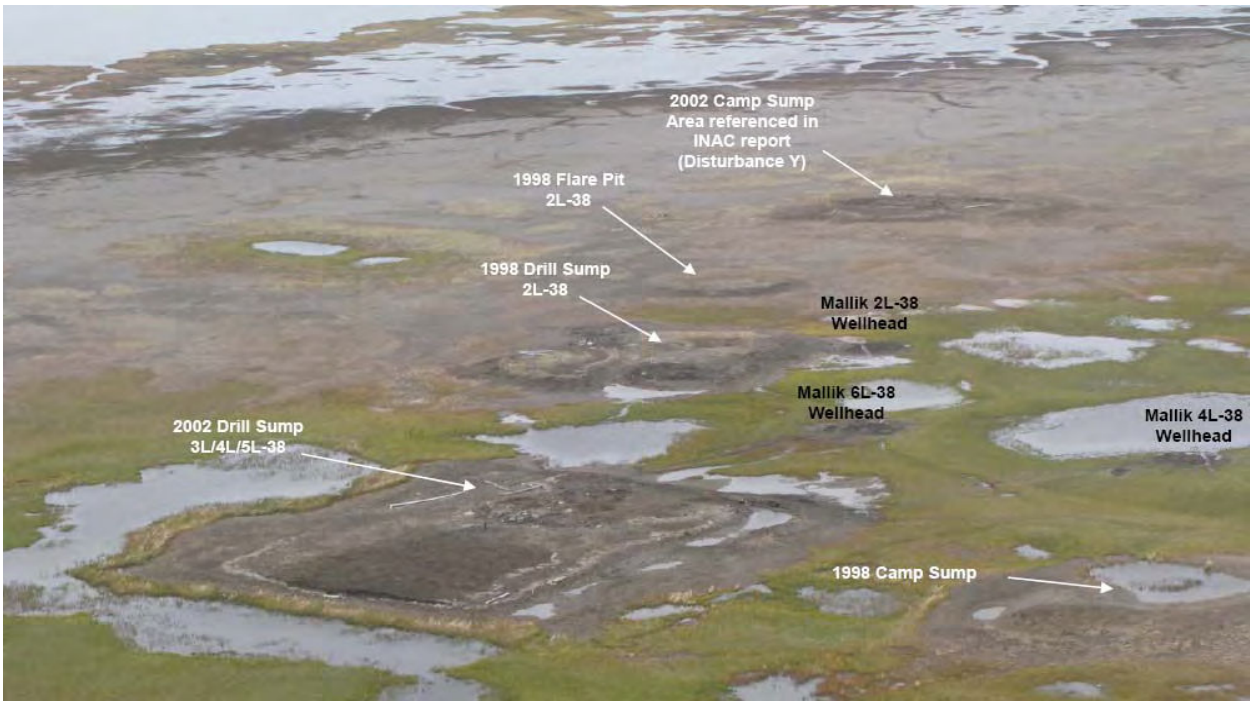
The below photos were taken in summer of 2008 of the Mallik Site.



Picture 1: Taken 15th.Aug.2008 showing whole Mallik site of sump locations and well heads.



Picture 2: Taken 5th.Aug.2008 showing sump location and well heads.



Picture 3 Taken 5th.Aug.2008 showing sump location and well heads.

1.3 General Data:

Description	Mallik Well 2L-38	Mallik Well 3L-38	Mallik Well 4L-38	Mallik Well 5L-38
Well name	JAPEX/JNOC/GSC Mallik 2L-38 (*)	JAPEX/JNOC/GSC Mallik 3L-38	JAPEX/JNOC/GSC Mallik 4L-38	JAPEX/JNOC/GSC Mallik 5L-38
Authority to Drill well #	9311-J31-1-1	93311- J31-2-3	93311- J31-2-3	93311- J31-2-3
WID #	1827	1919	1920	1921
Grid Area	6930-13430	6930-13430	6930-13430	6930-13430
Classification	Research Well	Research Well	Research Well	Production Well
Well location coordinates	Lat: 69_27'_40.71" N Long:134_39'_30.37" N	Lat:69_27'_38.316" N Long: 134_39'_41.614"N	Lat:69_27'_40.288" N Long:134_39'_36.181"N	Lat: 69_27'_39.302" N Long: 134_39'_38.898" N
Operator	Japex Canada Ltd	Japex Canada Ltd	Japex Canada Ltd	Japex Canada Ltd
Water License #	N3L1-1702	N3L1-1769	N3L1-1769	N3L1-1769
Land Use Permit #	N97A769	N2001A0016	N2001A0016	N2001A0016
NEB Well Identification	302L386930134300 (**)	303L386930134300	303L386930134300	303L386930134300

(*)NOTEs: Well names are as per the documentation during their date the drilling of well and sump construction/ capping took place.

Nomenclatures of initials used in the well names are as follows:

JAPEX: Japan Petroleum Exploration Company (Operator)
JNOC: Japan National Oil Corporation (Partner)
GSC: Geological Society of Canada (Partner and coordinator of scientific studies)

(**): As informed by NEB.

2. 1998 Mallik 2L-38 Operations

2.1 Site Identification and Location

Well number and operator	JAPEX/JNOC/GSC Mallik 2L-38: Japan Canada Ltd.
National Energy Board ID	302L386930134300
Water License #	N3L1-1702
Lat. / UTM	69_27'_ 40.71" N
Long./ UTM	134_39'_30.37" N

2.2 Site History and Local Environmental Conditions

2.2.1.1 Purpose of well drilled at the lease:

In 1998 to further investigate the original discovery of gas hydrates found by Imperial Oil Limited on their Mallik L-38 drill site, and as the initiative for a new international gas hydrate research campaign, Canada and Japan established a joint research and development program to study gas hydrates. Led by the Japan National Oil Corporation (JNOC) and Geological Society of Canada (GSC) scientists and engineers, JAPEX/JNOC/GSC Mallik 2L-38 Research Well was drilled with JAPEX Canada Ltd as the operator.

The objective of this well was to core and test the gas hydrate formations as well as evaluate specially designed coring tools. Open hole, cased and a VSP log was also to be run to measure geological parameters. The cores and samples were taken for further analysis both in a field laboratory at the Aurora Research Institute (Inuvik) and at home institutions. Extensive downhole geophysical well logging was also carried out prior to final abandonment of the well at a total depth of 1150m - just below the base of the hydrate layers. The scientific results and a comprehensive project data base were published as a compendium volume of the Geological Survey of Canada (GSC) of Natural Resources Canada **(ref *4).** The testing of the Gas hydrate formations was not undertaken as planned due to lack of time.

2.2.1.2 Site survey plan:

A total of three (3) sumps were constructed on site, i) the main drill sump for the drill cuttings from the well, ii) the camp sump for the camp discharge, iii) the sump for the test flare pit. All of these sumps were inspected by Scott Gallupe, the Water Resources Officer, out of the Inuvik office prior to undertaking the restoration of these sumps as mentioned in Canadian Petroleum Engineering Inc letter dated 18,August 1998 **(Appendix 3).** The sumps were then closed and capped with the cap extending two metres plus beyond the edges of the sump walls with the insitu materials that had been removed during construction as per the Drilling Waste Management Recommended Best Practices. **(Appendix 4)**

Figure 3 below shows the site survey plan showing location of the sump in relation to the drill rig and camp equipment area.

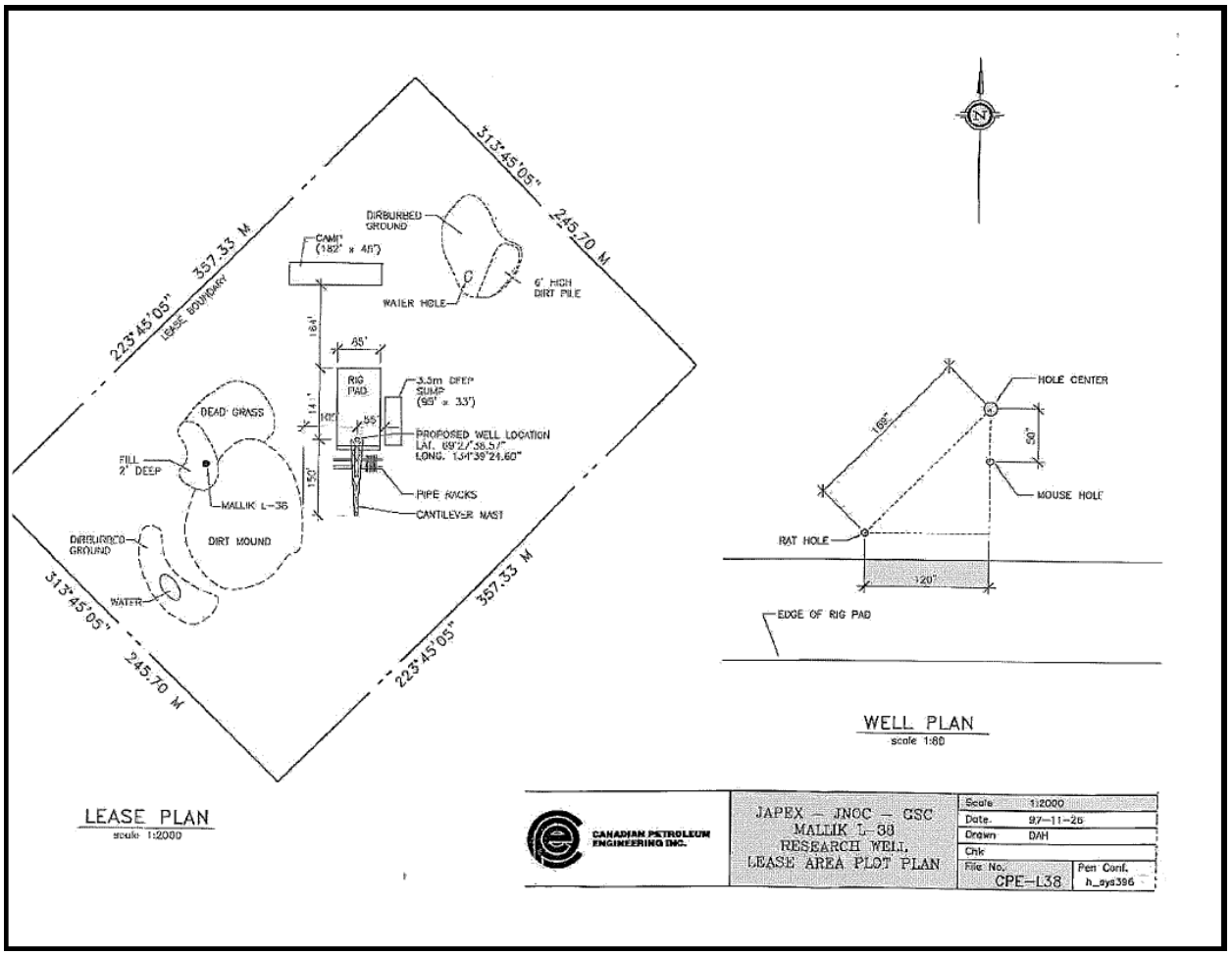


Figure 3: Mallik site survey plan showing location of the drill rig, well head, drill sump and camp location as surveyed by CPE Inc prior to the 1998 campaign.

Upon completion of the 1998 campaign, figure 4 below shows where the camp sump and flare pit had been placed in relation to the drilling rig and camp locations.

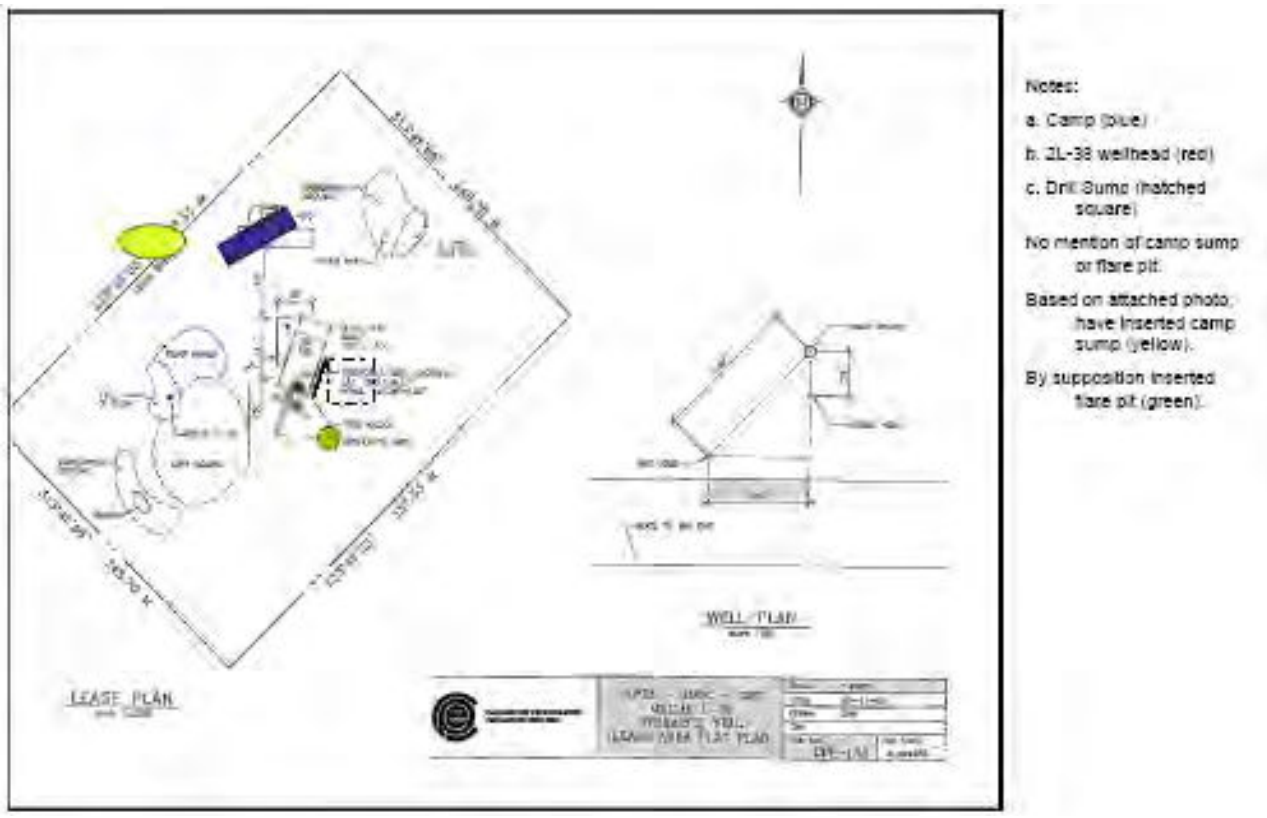
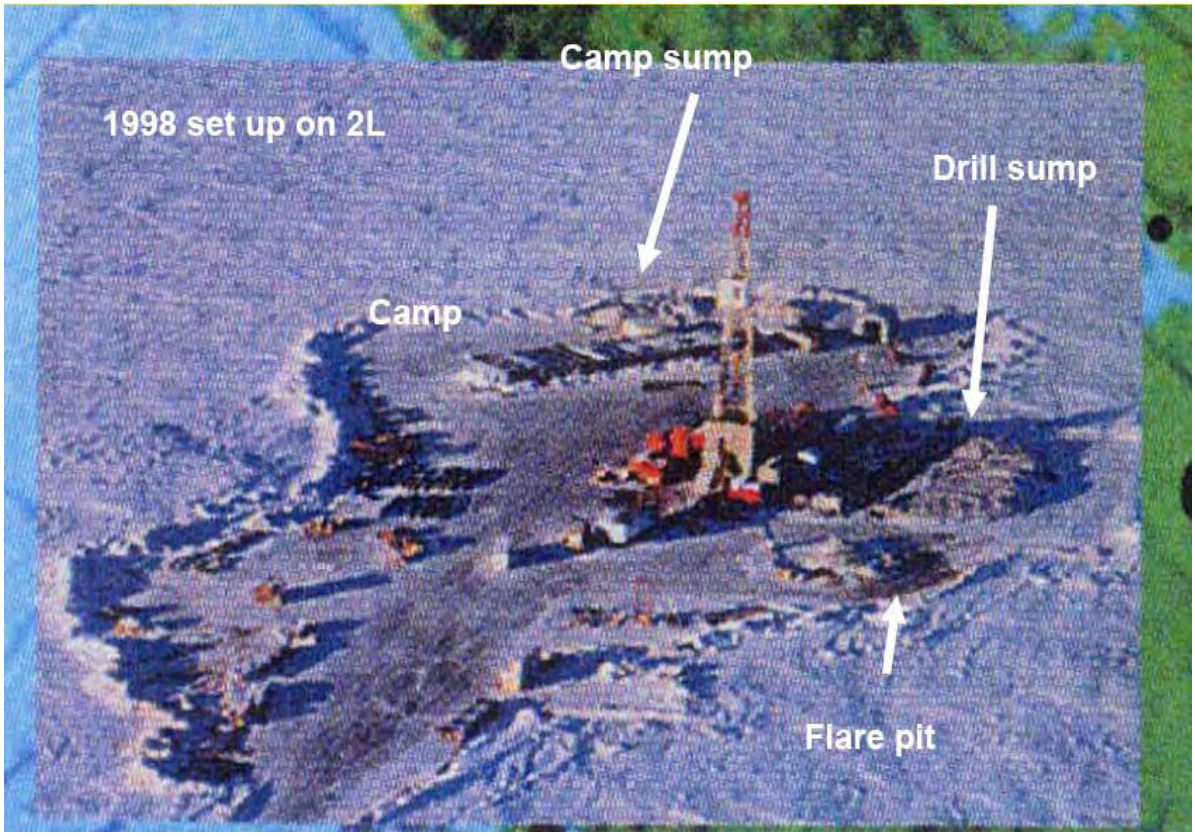


Figure 4: Mallik site for 1998 showing location of Camp sump (yellow), Drill sump (grey) and flare pit (green) n relationship to drill rig and Mallik 2L-38 wellhead.



Picture 4: Picture from a press release showing the 1998 Mallik Site with drilling rig, camp and sump locations.

2.2.1.3 Project Team:

Company	Responsibilities	Contact Info
JAPEX Canada Ltd	Designated well operator and lead drilling operations. Day-to day programme direction from field office in Inuvik.	JAPEX Canada Ltd, 2300 Standard Life Building, 639-5th Avenue SW, Calgary, Alberta, T2P 0M9.
Canadian Petroleum Eng. Inc	Project management for planning, engineering, procurement, permit approvals, and on site supervision.	Canadian Petroleum Eng. Inc. 1900, 717-7th Avenue SW, Calgary, Alberta, T2P 0Z3
JNOC	Steering committee, provide scientist at site to supervise core studies and downhole and surface	Japan National Oil Co., 1-2-2 Hamada, Mihama-ku, Chiba, 261-0025, Japan.

	geophysical programmes.	
GSC	Steering committee, provide scientist at site to supervise core studies and downhole and surface geophysical programmes.	Geological Society of Canada, Box 6000, 9860 West Saanich Road, Sidney, BC, V8L 4B2
Sheetah Drilling Ltd, Northwest Territories.	Supply drilling rig and all associated personnel to operate it.	Sheetah Drilling Ltd., suite 277, 200 Rivercrest Drive SE, Calgary, Alberta, T2C 2X5

2.3 Site Development

2.3.1.1 Timeline:

The following was extracted from the Mallik 2L – 38 End of well report as submitted by Canadian Petroleum Engineering Inc.

1-4/ Feb/98: Staging of light loads from Taglu to Mallik Site

5-15/Feb/98: Rig up of camp, rig and spot all equipment. **(NOTE: Sumps were constructed during this period.)**

16/Feb/98: Well spudded at 2245 hrs

16/Feb – 5/Mar/98: Well drilled and cased to 687 m with cores taken and well logged.

6 – 22/Mar/09: BOP rigged up, tested and drilling continues to 1150m TD. Cores taken.

22-23/Mar/98: Ran Casing logs.

24-25/Mar/98: Vertical Seismic Profiling (VSP) Log ran.

35-27/Mar/98: Abandon well as per requirements.

28/Mar/98: Rig released.

28-31/Mar/98: Deconstruct camp and load out all equipment. NOTE: 30.Mar – DIAND inspection of lease.

1-3/Apr/98: Clean lease and finish capping sumps. All equipment off site.

2.3.1.2 Method of preparing the Sump:

The methodology used to construct the sumps during the 1998 campaign was that as used by the oil and gas industry within the Artic region and in compliance to the recommended practices. Before the winter drilling activity starts, the sump area is selected by being as far from a water source as possible and in proximity to the drilling rig. The sump is excavated by first drilling holes and blasting. Mechanised diggers are then used to extract the soil and stock pile nearby. The excavations depth has been recorded as being approximately 3 – 3.5m deep for the Mallik 2L-38 drill and camp sumps. The flare sump was approximately 3m deep.

Figure 5: Excavation of sump.

During the drilling operations, the drill cuttings were placed within the sumps. A centrifuge was used in removing the drilled fine solids from the active drilling fluid system, the total drilled solids removed was +/- 62 m3. No analysis was conducted on the discharged as no oil bearing formations were encountered.

For the camp sump, the effluent fluid from the sewage treatment plant was placed in the sump.

The cuttings and effluent fluids filled the sumps up to approximately 1.2 m below ground level.

Figure 6: Filling of sump.

2.3.1.3 Reclamation methods:

Before the reclamation of the ground took place, an inspector came to site to verify all is OK be fore the stockpiled soil can be replaced.

The stock piled soil is placed to overlap on the 4 sides by a minimum of 2 m and the height above the ground was measured to be approximately 1.6- 2m. The cap soil is compacted with the mechanized equipment. The slopes of the cap are angled by the mechanized equipment.

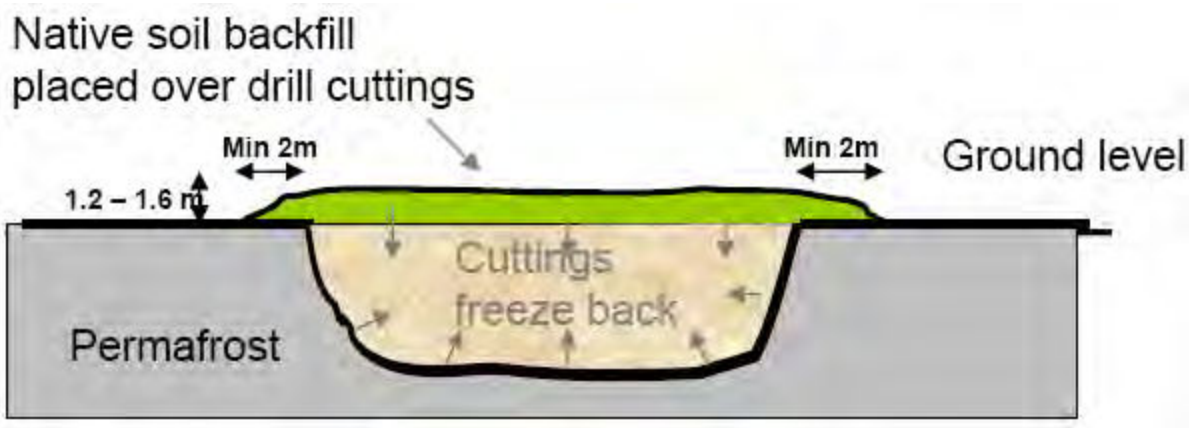


Figure 7: Capping of Sump.

2.4 Sump Details- Sump construction and contents:

Description	Drill Sump	Camp Sump	Flare Pit
1). Date of exaction	6- 8,February 1998	7-9, February 1998	10, February 1998
2). Total days open	56 days	55 days	53 days
3). Date of closure	3.April 1998	3, April 1998	2, April 1998
4). Sump dim.: (l x w x depth) metres	50 x 45 x 3.5	25 x 20 x 3.5	15 x 15 x 3
5).Max./Min./Mean Daily Temp	-14.9/ -23.6/ -19.3	-14.9/ -23.6/ -19.3	-14.9/ -23.6/ -19.3

6). Problems encountered	None	None	None
7). Drilling mud used	See below (1)	Treated Grey Water	See below (2)
8). Min vertical distance to native ground.	Approximately 1.4-1.6	Approximately 1.2-1.4	Approximately 1.2
9). Timing and method of backfill.	3 days- 1-3.April, Native soil as extracted.	2 days- April 2-3, Native soil as extracted.	1 day- April 1, Native soil as extracted.
10). Other reclamation activities.	Site clean up	Site clean up	Site Clean up

Notes:

(1) Drill Sump: The drilling products used to make up the drilling mud are as follows. **(Appendix 3).**

Citric Acid ----------1, 000 kg
2 Ethyl Hexanol ----------340 L
Dextric Lt----------2, 452 kg
Drilltreat ----------1, 860 L
Drispac Superlo----------1, 158 kg
Kelzan XCD----------1, 125 kg
Caustic Potash ----------1, 625 kg
Sawdust---------- 798 kg
Soda Ash---------- 750 kg
Sodium Bicarbonate---------- 681 kg
Starpak DP ---------- 795 kg
XL Defoamer---------- 800 L
Barite---------- 11,600 kg
KCL (Potassium Choloride)---------- 30,600 kg

(2) Flare Pit: The flare was excavated so as to accommodate the flaring of any produced methane gas. Due to drilling difficulties encountered the well test was canceled due to lack of time and flare pit not used. It was refilled with stock piled soil and capped.

2.5 Environmental Setting

2.5.1.1 Surface conditions

Description	**Drill Sump**	**Camp Sump**	**Flare Pit**
1). Terrain Type	Coastal flats	Coastal flats	Coastal flats
2). Slope Gradient	Flats- 0.6- 1.0m above seal level.	Flats- 0.6- 1.0m above seal level.	Flats- 0.6- 1.0m above seal level.
3). Prox. to nearest water and type.	~ 120m to Beluga Bay NE, ~ 40m to large water body SW.	~ 120m to Beluga Bay NE, ~ 40m to large water body SW.	~ 120m to Beluga Bay NE, ~ 40m to large water body SW.
4). Ephermeral drainage ponds	Localized ponds in area draining to SW	Localized ponds in area draining to SW	Localized ponds in area draining to SW
5). Frequency and ave. during flooding.	Annual flooding of 0.5 -1.0m .	Annual flooding of 0.5 -1.0m .	Annual flooding of 0.5 -1.0m .
6). Natural vegetation cover.	Sparse grass.	Sparse grass.	Sparse grass.

2.5.1.2 Soils and ground – ice conditions.

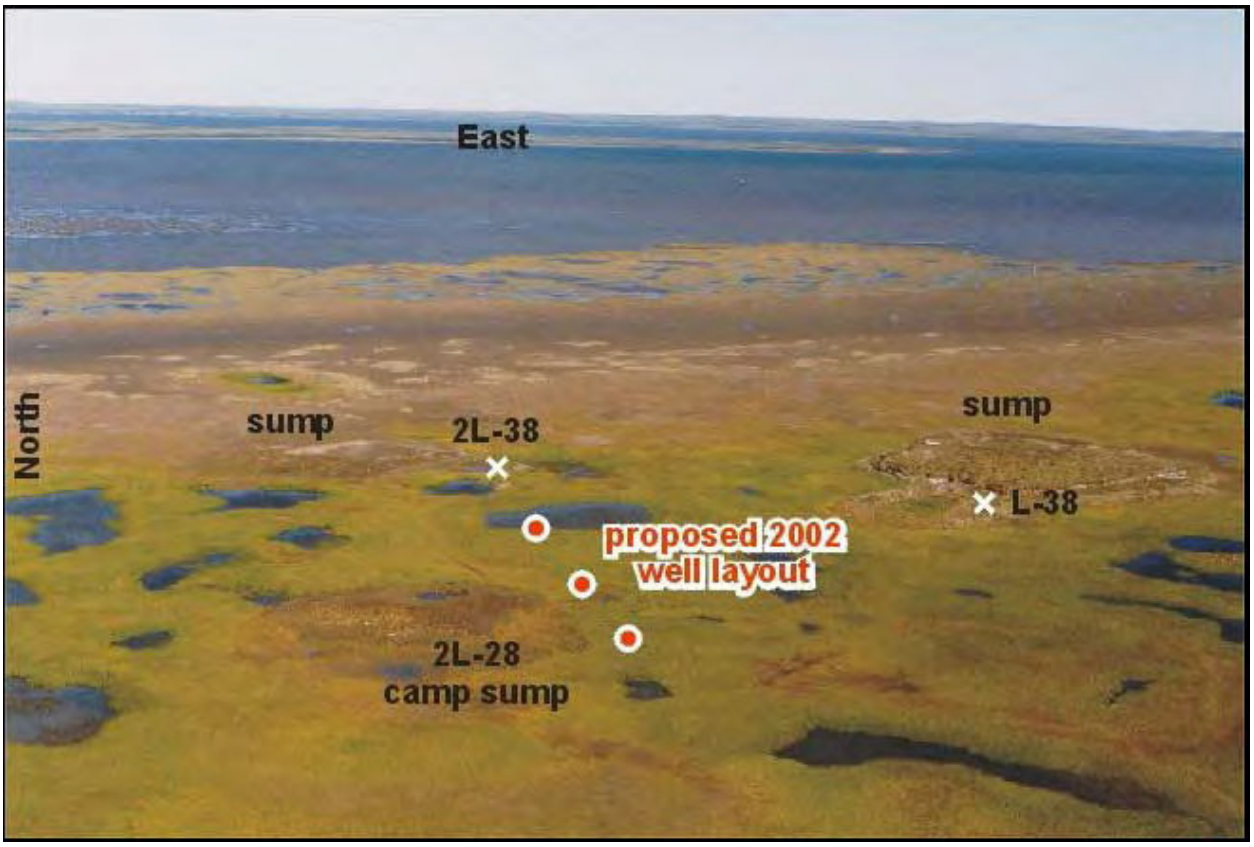
The following was extracted from Kiggiak EBA : Geophysical and Subsurface Environmental Site Investigation : 2005. **(Appendix 5)**

Description	**Drill Sump**	**Camp Sump**	**Flare Pit**
1). Describe each major soil unit	Native soil consisting of silt with trace of clay and fine sands.	Native soil consisting of silt with trace of clay and fine sands.	Native soil consisting of silt with trace of clay and fine sands.
2). Photos	Enclosed in attached report	Enclosed in attached report	Enclosed in attached report

2.6 Site conditions after closure – Sump characteristics

In September 2006, Kavik Axys was retained on conduct a site survey and make a general assessment of the Drill Sumps located on the Mallik L-38 site, excluding the Imperial Oil Ltd L-38 drill sump. The report can be found in **Appendix 6** attached.

Description	**Drill Sump**	**Camp Sump**	**Flare Pit**
1). Dimensions of sump	55 x 46 x 3.5	30 x 25 x 3.5	20 x 20 x 3
2). Height of cap	Approximately 1.6m	Approximately 1.4m	Approximately 1.2m
3). Cap material	Granular soil from sump	Granular soil from sump	Granular soil from sump
4). Slumping of settlement of cap material.	Settlement noted sides	Settlement noted in middle.	OK.
5). Nature of vegetation	None	None	None
6). Soil state adjacent to sump.	Good - undisturbed	Good - undisturbed	Good - undisturbed
7). Ponding on sump	None	Pond in middle of camp sump.	None
8). % of sump that has collapsed.	15%	20%	0%



Picture 5: Picture of Mallik Site taken in 2001 showing existing sumps and proposed 2002 well layout.

3. 2002 Mallik 3L, 4L and 5L-38 Operations

Note: During the 2002 campaign, 3 wells were drilled, completed and abandoned. Only one camp sump and one drill sump was required. The below information is for all three wells and the two sumps.

3.1 Site Identification and Location

Well number and	**JAPEX/JNOC/GSC Mallik 3L-38**	**JAPEX/JNOC/GSC Mallik 4L-38**	**JAPEX/JNOC/GSC Mallik 5L-38**
Operator	JAPEX Canada Ltd.	JAPEX Canada Ltd.	JAPEX Canada Ltd.
National Energy Board ID	303L386930134300	303L386930134300	303L386930134300

Water License #	N3L1-1769	N3L1-1769	N3L1-1769
Lat. / UTM	69_27'_38.316" N	69_27'_40.288" N	69_27'_39.302" N
Long./ UTM	134_39'_41.614"N	134_39'_36.181" N	134_39'_38.898"N

3.2 Site History and Local Environmental Conditions

3.2.1.1 Purpose of well drilled at the lease:

In 2001/2002 a second multidisciplinary research and development program was undertaken were three wells were drilled, JAPEX/JNOC/GSC 3L-38, 4L-38 and 5L-38. The major goal of the 2002 Mallik programme was to conduct the first modern production test of a gas hydrate deposit **(ref *2)** and continue the quest for more knowledge on gas hydrates.

Mallik 5L-38 was the production well with Mallik 3L-38 and 4L-38 being observation wells. All the wells were drilled vertically in the same plane and spaced approximately 40 metres apart with the production well in the middle.

These R&D studies were led by the GSC and JNOC with JAPEX again acting as the operator. Additional participants included GeoForschungZentrum Potsdam, the U.S. Geological Survey, the U.S. Department of Energy, BP/Chevron Joint Venture and the India National Gas Hydrate program **(ref *2)**.

The cuttings from the wells drilled during these campaigns along with the discharge from the camp were placed in their respective sumps built adjacent to the lease and camp respectively. **(see Figure 2.)** During this campaign the drill sump area was increased to accommodate the additional drill fluids when losses occurred. **(Appendix 7)**

3.2.1.2 Site survey plan:

Figures 8,9 and 10 below show the site surveys on the location of the drill sump in relation to the drill rig and camp equipment area, camp sump and location of camp and drill sump.

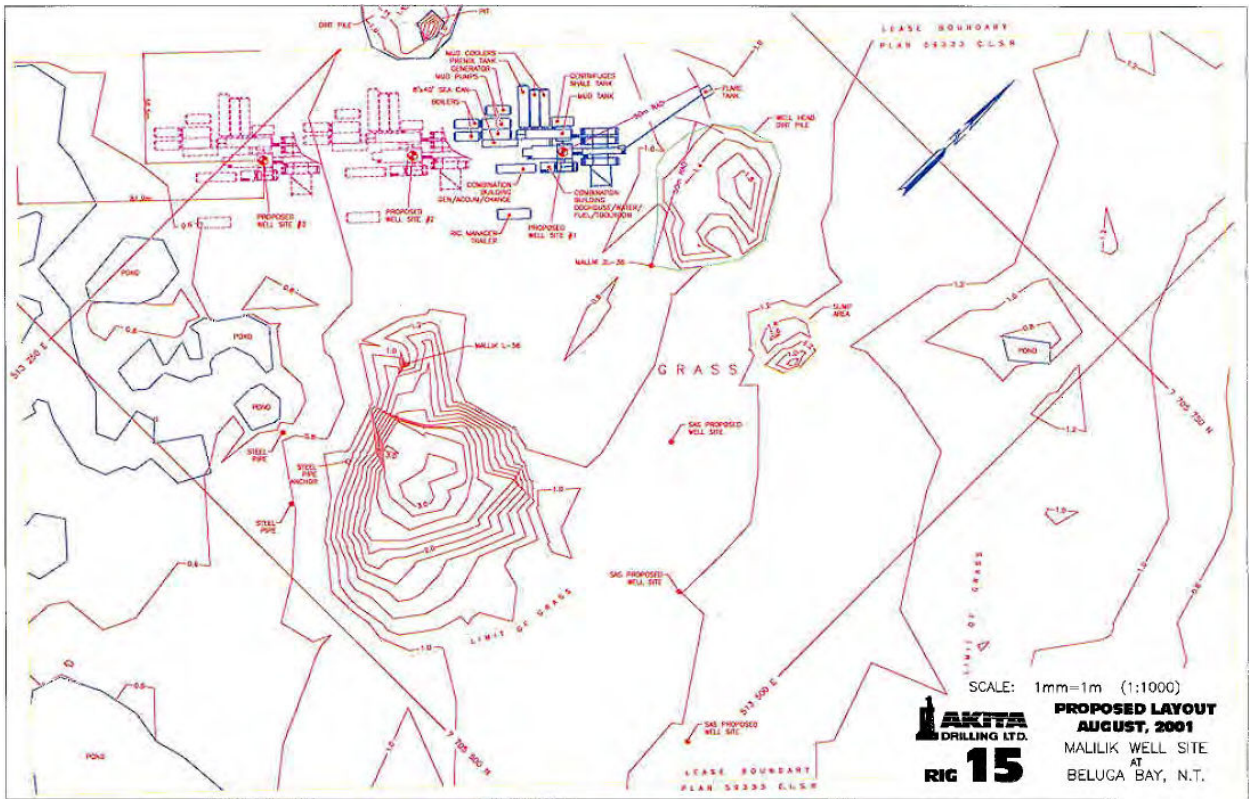


Figure 8: Mallik site survey plan showing location of the Akita #15 drill rig and well heads for the Mallik 3L, 4L, and 5L-38 wells.

Figure 9 below shows the site survey plan showing location of the sumps in relation to the camp along with the access road. Please note this drawing was included within the Canadian Petroleum Engineering Inc. Final Report dtd 5,November 2003. **(Appendix 8).**

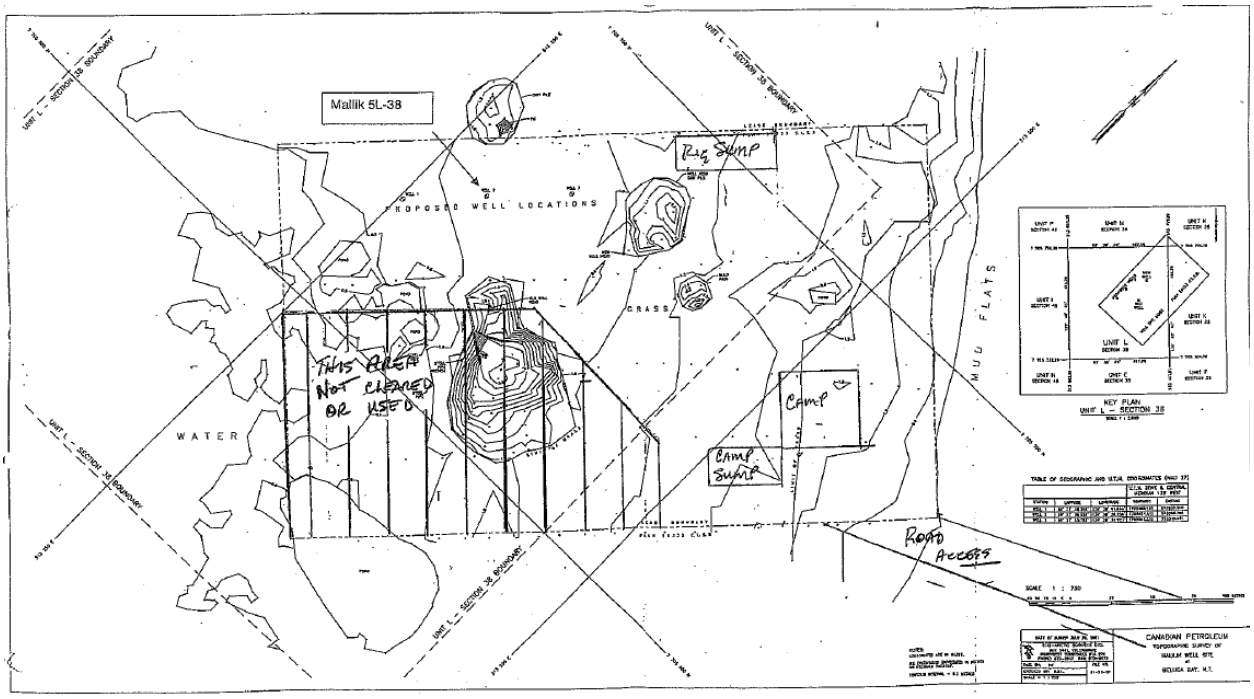


Figure 9: Mallik site showing location of Camp sump, Rig (Drill) sump, camp and road access to site along with the proposed well locations. NOTE: Mallik L5-38 has been marked.

Figure 10 below is a topographic survey of the Mallik Well Site as surveyed by SAS on 30,July 2001 showing the areas in which the Camp and the Rig(Drill) sump areas are to be located. This map shows the proposed lease boundary and the lease boundary for the Mallik Site.

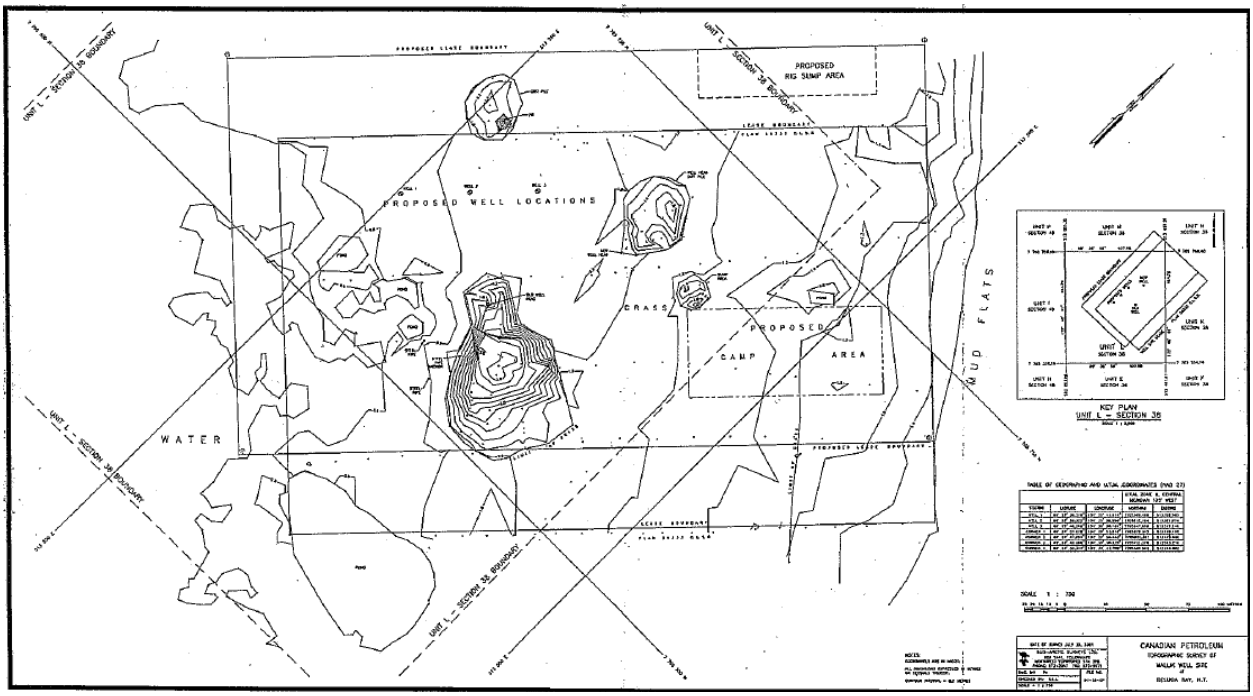


Figure 10: Topographic Survey of Mallik Well Site as surveyed by SAS on 30,July 2001 showing the proposed sites for the Drill Sump and the location of the camp – tying in with Figure 6 above.

3.2.1.3 Project team:

Company	Responsibilities	Contact Info
JAPEX Canada Ltd	Designated well operator and lead drilling operations. Day-to day programme direction from field office in Inuvik.	JAPEX Caada Ltd, 2300 Standard Life Building, 639-5th Avenue SW, Calgary, Alberta, T2P 0M9.
Canadian Petroleum Eng. Inc	Project management for planning, engineering, procurement, permit approvals, and on site supervision.	Canadian Petroleum Eng. Inc. 1900, 717-7th Avenue SW, Calgary, Alberta, T2P 0Z3
JOGMEC	Steering committee, provide scientist at site to supervise core studies and downhole and surface geophysical programmes.	Japan Oil and Gas Metals National Oil Co., 1-2-2 Hamada, Mihama-ku, Chiba, 261-0025, Japan.
NRCan	Steering committee, provide scientist at site to supervise core	Geological Society of Canada, Box 6000, 9860

	studies and downhole and surface geophysical programmes.	West Saanich Road, Sidney, BC, V8L 4B2
Akita Equitak Drilling Ltd	Supply drilling rig and all associated personnel to operate it.	Akita Equitak Drilling Ltd., Box 2637, Inuvik, Northwest territories, X0E 0T0

3.3 Site Development

3.3.1.1 Timeline:

The following timeline of the major activities was extracted from the Mallik 3L, 4L and 5L – 38 Final Well Reports as submitted by Canadian Petroleum Engineering Inc on behalf of Japex Canada Ltd for Mallik wells 3L-38 (dated- 20.Jun.02), 4L-38 (dated 24.Jun.02) and 5L- 38 (dated 25.Jun.02).

20/Nov/01: Personnel fly to Taglu to set up temporary camp and start road construction from staged equipment.

5/Dec/01: Road complete from Taglu to Mallik site

11-13 /Dec/01: Drilled, blast holes and construct camp sump.

13-15/Dec/01: Drill, blast and construct drill sump.

22/Dec/01: Rig moved to location (Akita Rig # 15)

25/Dec/01 to 7/Jan/02: : Spud, drill, compete and plug well. Hole depth 1188m.

7/Jan/02: Rig released with Malik 3L well abandoned.

8-10 /Jan/02: Rig up over Mallik 4L-38

11- 23/Jan/02: Spud, drill, complete and plug well. Hole depth 1188m.

23/Jan/02: Rig released with Malik 4L well abandoned.

24-25/Jan/02: Rig up over Mallik 5L-38

25/Jan to 11/Feb: Spud and drill down to 876m.

12-18/Feb/02: Cut cores from 885 to 1151 metres.

19-20/Feb/02: Drill to TD of 1166 metres.

21-22/Feb/02: Run open hole logs.

22-25/Feb/02: Case and cement well.

26/Feb to 3/Mar/02: Run cased logs, perforate and complete well.

5-10/Mar/02: Conduct thermal test on well.

11 -14/Mar/02: Kill and abandon well.

14/Mar/02: Rig released from Mallik 5L-38.

NOTE: no other daily reports could be located which details the camp rig down, clean up and vacating of the Mallik site.

NOTE: In discussion with Canadian Petroleum Engineering Inc. (Mr E. Fercho: President, 24.November 2008) informed that the sumps were closed in on the 22-25.March 2002 . The day before the inspection from INAC.

3.3.1.2 Method of preparing the Sump:

The methodology used to construct the sumps during the 2002 campaign was that as used by the oil and gas industry within the Artic region and in compliance to the recommended practices. Before the winter drilling activity starts, the sump area is selected by being as far from a water source as possible and in proximity to the drilling rig. The sump is excavated by first drilling holes and blasting. Mechanised diggers are then used to extract the soil and stock pile nearby. The excavations depth has been recorded as being approximately 3- 3.5m deep for the Mallik 3L/ 4L 5L-38 drill and camp sumps.

Figure 11: Excavation of sump.

Figure 12: Filling of sump.

3.3.1.3 Reclamation methods:

Analysis's were conducted on the discharged sump material and reviewed by INAC Water Resources Officer before the cap was placed on sump. **(Appendix 9)** The drill sump cuttings filled the sump to approximately 1.5m below ground level.

For the camp sump, the bulk of the effluent fluid from the sewage treatment plant was placed in the sump. Some of it was also hauled away by truck to Inuvik plant. **(Appendix 8)** The cuttings and effluent fluids filled the sumps up to approximately 2.0m below ground level.

The stock piled soil was positioned to overlap on the 4 sides by a minimum of 2 m and the height above the ground was measured to be approximately 1.6- 2m. The cap soil was compacted with the mechanized equipment. The slopes of the cap are angled by the mechanized equipment.

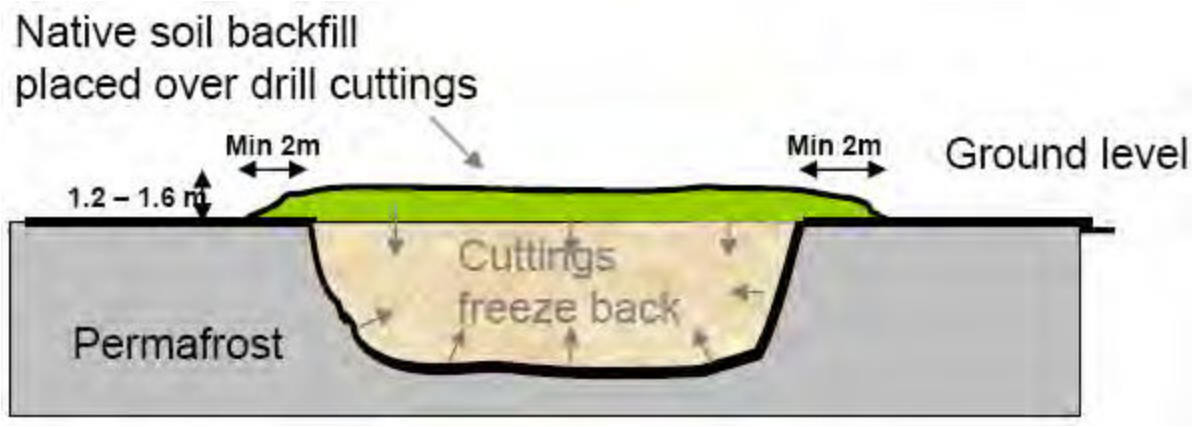


Figure 13: Capping of Sump.

3.4 Sump Details- Sump construction and contents:

Description	Drill Sump	Camp Sump
1). Date of exaction	13.Dec.2001	11.Dec.2001
2). Total days open	101	100
3). Date of closure	24.Mar.2002	23.Mar.2002
4). Sump dimensions: (l x w x depth) metres	45 x 35 x 3.5 (total) see 6) below.	40 x 12 x3.5
5).Max./Min./Mean Daily Temp	-17/ -40/ -22 C	-17/ -40/ -22 C
6). Problems encountered	Sump had to be enlarged to accommodate increased drill cuttings from well. Expansion of sump granted by INAC. **(Appendix 7.**	The treated camp effluent was more than anticipated due to number of personnel on site. Permission to expand sump was declined and excess effluent was trucked back to Inuvik for disposal. **(Appendix 7)**
7). Drilling mud used	See table below (*)	Treated grey water
8). Min vertical distance to native ground.	Approximately 1.4- 1.6	Approximately 1.2-1.4
9). Timing and method of backfill.	3 days: 22-24.Mar with native soil originally extracted.	2 days: 22-23.Mar with native soil as originally extracted
10). Other reclamation activities.	Site clean up	Site clean up

(*) Drill Sump: The drilling products used to make up the drilling mud are as follows.

		3L-38		4L-38		5L-38			
Products	Unit vol	Actual	Tot vol(3L	Actual	Tot vol(4L	Actual	Tot vol(5L	Total volume	
Kelzan XCD	25	55	1375	50	1250	72	1800	**4425**	kg
Prima Seal	18.2	12	218.4	0	0	0	0	**218.4**	kg
2 Ethyl Hexanol	20	9	180	10	200	31	620	**1000**	ltrs
Soda Ash	25	18	450	0	0	16	400	**850**	kg
KOH	25	12	300	15	375	8	200	**875**	kg
KCl	25	717	17925	1272	31800	1425	35625	**85350**	kg
Citric Acid	25			5	125	23	575	**700**	kg
Sawdust	18.2			60	1092	260	4732	**5824**	kg
Sodium Bicarb	25			10	250	32	800	**1050**	kg
Alkapam A1103	25					1	25	**25**	kg
Barite	40					143	5720	**5720**	kg
Soya lecithin	20					17	340	**340**	ltrs
Starpak DP	22.7					60	1362	**1362**	kg
Starflo Exlo	22.7					8	181.6	**181.6**	kg

3.5 Environmental Setting

3.5.1.1 Surface conditions

Description	**Drill Sump**	**Camp Sump**
1). Terrain Type	Coastal flats	Coastal flats
2). Slope Gradient	Flats- 0.6- 1.0m above seal level.	Flats- 0.6- 1.0m above seal level.
3). Prox. to nearest water and type.	~ 120m to Beluga Bay NE, ~ 40m to large water body SW.	~ 120m to Beluga Bay NE, ~ 40m to large water body SW.
4). Ephermeral drainage ponds	Localized ponds in area draining to SW	Localized ponds in area draining to SW
5). Frequency and ave. during flooding.	Annual flooding of 0.5 - 1.0m .	Annual flooding of 0.5 -1.0m .
6). Natural vegetation cover.	Sparse grass.	Sparse grass.

3.5.1.2 Soils and ground – ice conditions

The following was extracted from Kiggiak EBA : Geophysical and Subsurface Environmental Site Investigation : 2005. **(Appendix 5)**

Description	Drill Sump	Camp Sump
1). Describe each major soil unit	Native soil consisting of silt with trace of clay and fine sands.	Native soil consisting of silt with trace of clay and fine sands.
2). Photos	Enclosed in attached report	Enclosed in attached report

3.6 Site conditions after closure – Sump characteristics

Prior to closure of the 2002 Mallik 3L/ 4L 5L-38 Drill Sump and Camp Sump an inspector was on site to grant approval before the sump caps were installed. The drill sump was maintained at 1.5m below ground level and the camp sump was lowered to 2.0m below ground level by hauling the effluent off site to Inuvik Sewage lagoon. **(Ref appendices 7 and 8)**

Samples from the Drill sump were collected and analysed and relayed to the INAC Water Resources officer confirming that all drill products placed into the drill sump were within the permissible limits. **(Appendix 9)**

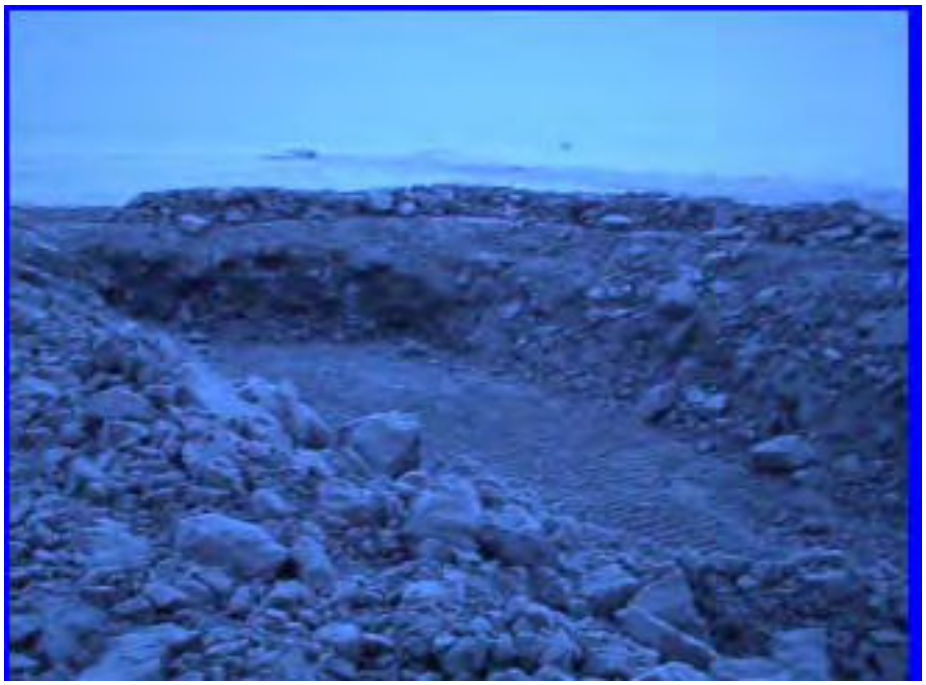
Description	Drill Sump	Camp Sump
1). Dimensions of sump	100 x 85 x 2.0m height	45 x 24 x 2.0m height
2). Height of cap	Approximately 2.0m	Approximately 2.0m
3). Cap material	Granular soil from sump	Granular soil from sump
4). Slumping of settlement of cap material.	Settlement noted sides	Settlement noted in middle.
5). Nature of vegetation	None	None
6). Soil state adjacent to sump.	Good - undisturbed	Good - undisturbed
7). Ponding on sump	None, but subsidence on south side. Sump is surrounded by ponds	Ponding on first 1/4 and 1/4 of sump.

8). % of sump that has collapsed.	15%	50%

In September 2006, Kavik Axys was retained on conduct a site survey and make a general assessment of the Drill Sumps located on the Mallik L-38 site, excluding the Imperial Oil Ltd L-38 drill sump. The report can be found in **Appendix 6** attached.

3.6.1 2002 Sump pictures:

Picture 6: Drill sump construction: 14.December 2001

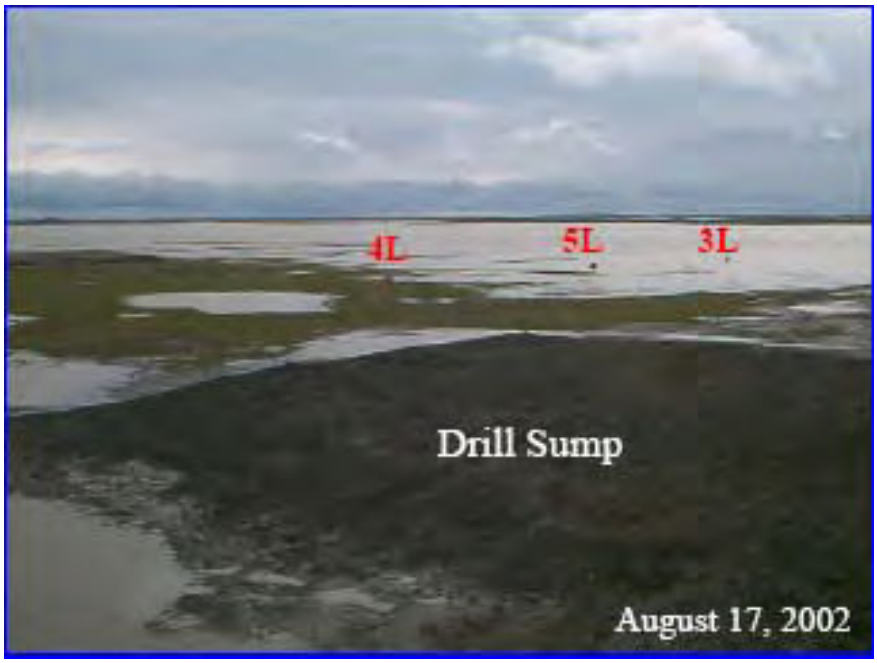


Picture 7: Camp sump construction: 13.December 2001

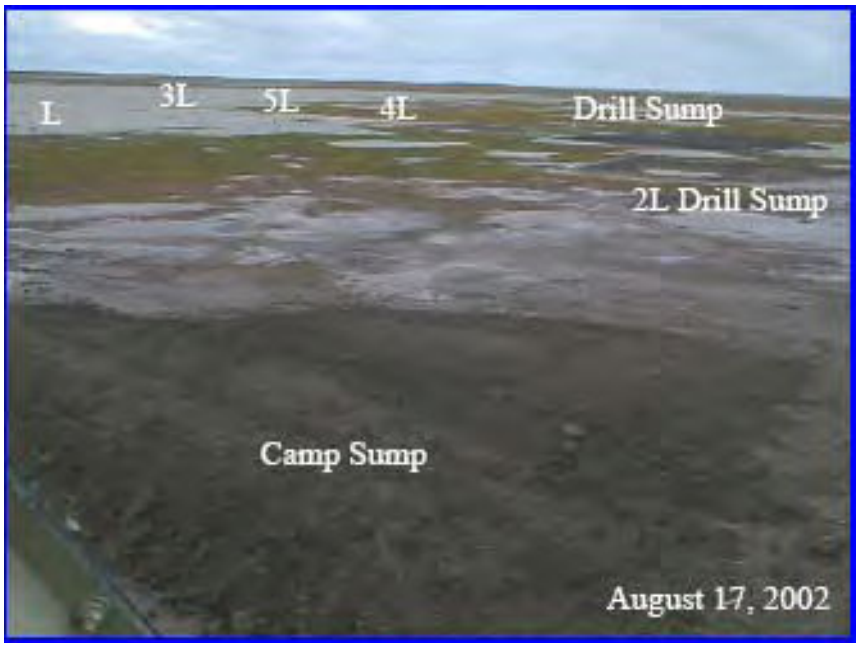
Picture 8: Camp sump with haulage truck extracting effluent. 16. March 2002

Picture 9: Drill sump awaiting approval before capping. 24. March 2002.

Picture 10: Mallik site clean up. 24. March 2002.



Picture 11: Mallik 3L/4L/5L-38 drill Sump, 17.August 2002.



Picture 12: Mallik 2002 Camp Sump 17.August 2002.

4. Active Layer and Ground Temperature Monitoring

Given below is a preliminary review of the site observations as taken.

Monitoring sump performance

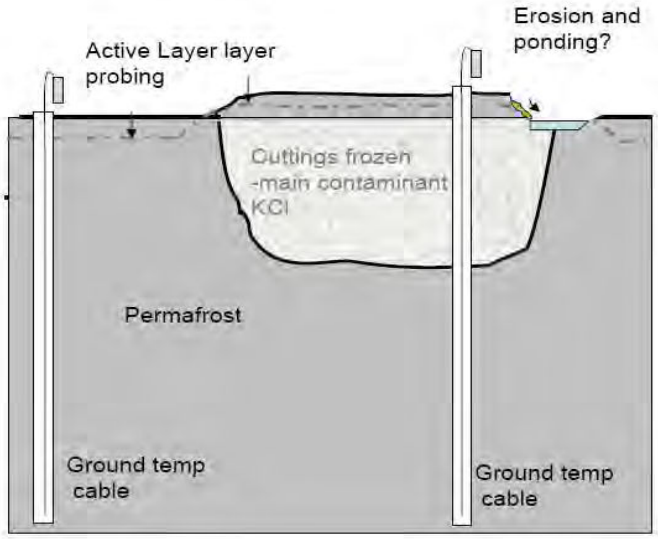
Active layer
-verify by probing for frost line that

active layer is not intersecting cuttings

Ground temperature surveys
-verify by measuring ground temperatures that permafrost is preserved beneath sumps

Surface observations
-verify that no erosion or settlement is occurring that might allow movement of contaminants
-sample any disturbance that appears suspect

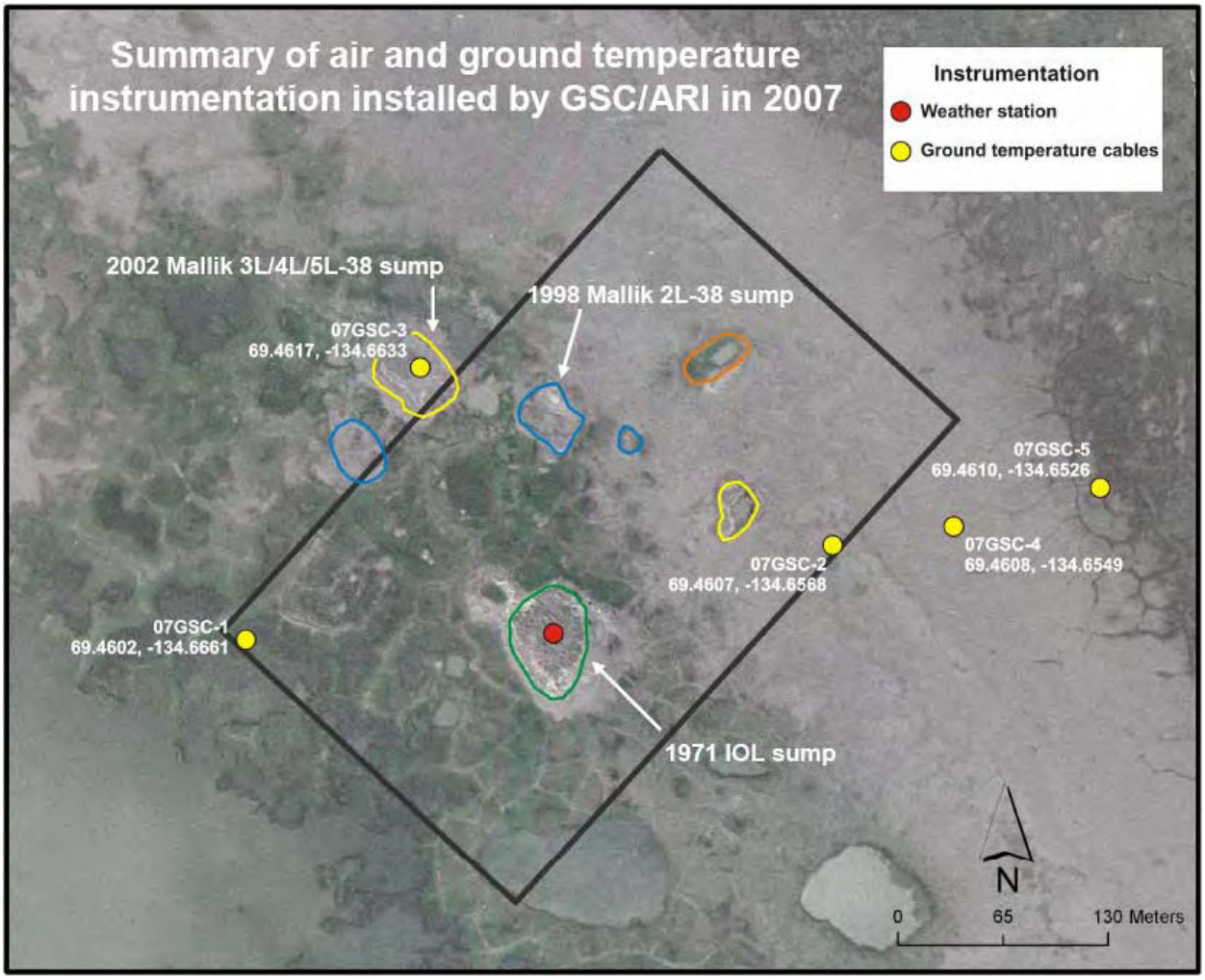
EM survey
-verify that conductive materials in sump are not spreading away from sumps



4.1 Summary:

The following is a summary of field observations of the Mallik sumps as constructed during the 1998 and 2002 Methane Gas Hydrate Production research project.

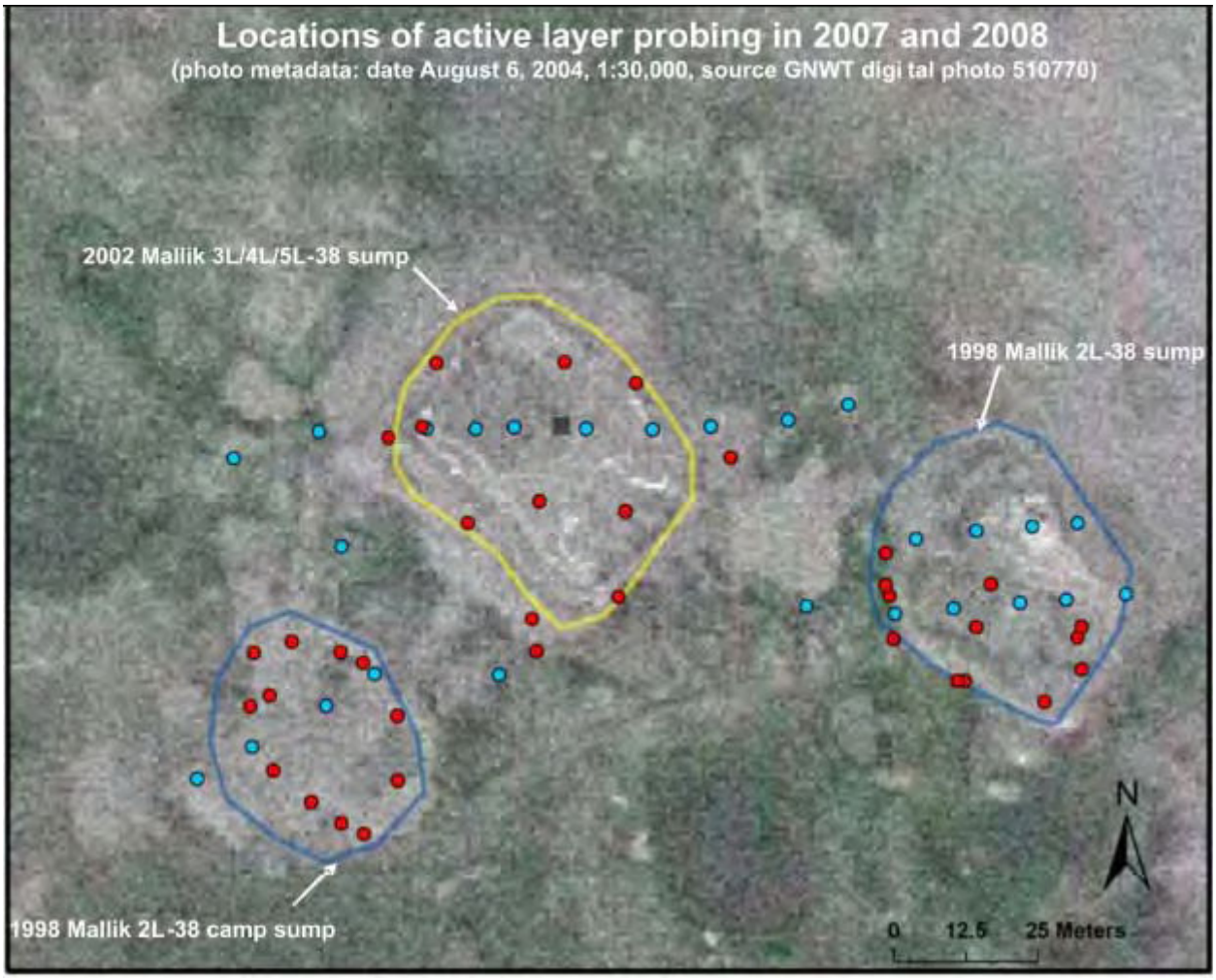
1. August 2005: Contract survey by EBA for EM (Electromagnetic) surveys and site observations **(Appendix 5).**
2. March 2007: GSC/ARI field installations of ground temperature cables.
3. August 2007: GSC/ARI ground temperatures, active layer probing and site observations.
4. August 2008: Feasibility study by GSC/ARI to advance monitoring programme (ground temperatures, active layer probing, EM survey and site observations).



Picture 13: 2004 Aerial photo of Mallik site showing location of sumps.

4.2 Active Layer Measurements:

The flowing are the AL measurements for the 2007 and 2008 site visits taken from the locations as shown in the aerial photo in picture 14.



Picture 14: Locations of active layer probing in 2007 and 2008.

4.2.1 1998 Mallik 2L-38 Drill Sump

	Mean AL on disturbed sump cap (cm)	**Mean AL undisturbed adjacent terrain (cm)**
9th, August 2007	109 (n=13)	100 (n=12)
13th, August 2008	114 (n=9)	100 (n=3)

4.2.2 2002 Mallik 3L/ 4L/ 5L-38 Drill Sump

	Mean AL on disturbed sump cap (cm)	**Mean AL undisturbed adjacent terrain (cm)**
9th, August 2007	106 (n=13)	101 (n=10)
13th, August 2008	115 (n=6)	101 (n=7)

4.2.3 2002 Mallik 3L/ 4L/ 5L-38 Camp Sump

	Mean AL on disturbed sump cap (cm)	**Mean AL undisturbed adjacent terrain (cm)**
9th, August 2007	106 (n=13)	101 (n=10)
13th, August 2008	115 (n=6)	101 (n=7)

4.3 AL Thickness in Sump cap depressions:

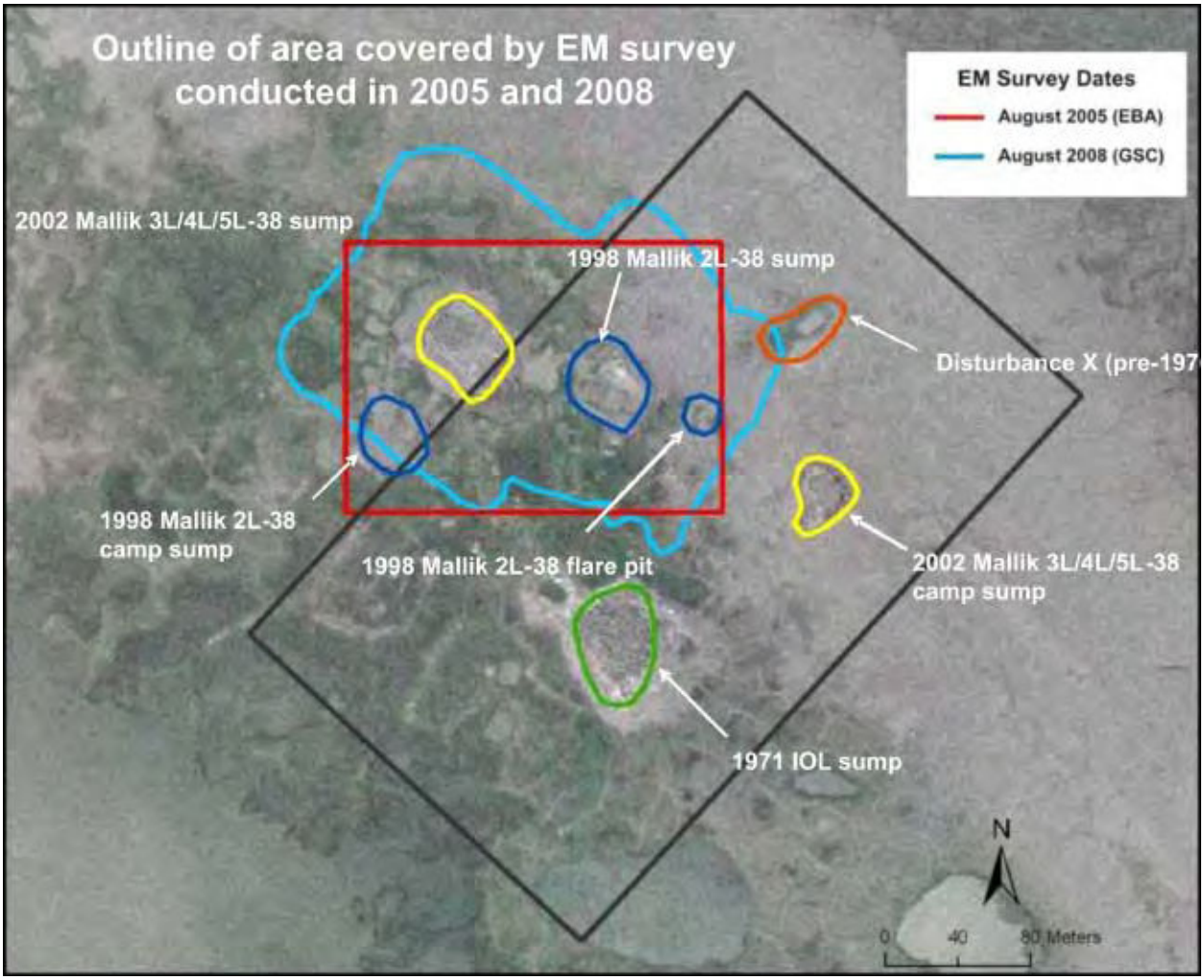
4.3.1 1998 Mallik 2L-38 Drill Sump

	Location 1	**Location 2**
Depression in cap	91 cm	110 cm
Sump Cap	104 cm	>120 cm
Undisturbed terrain	84 cm	109 cm

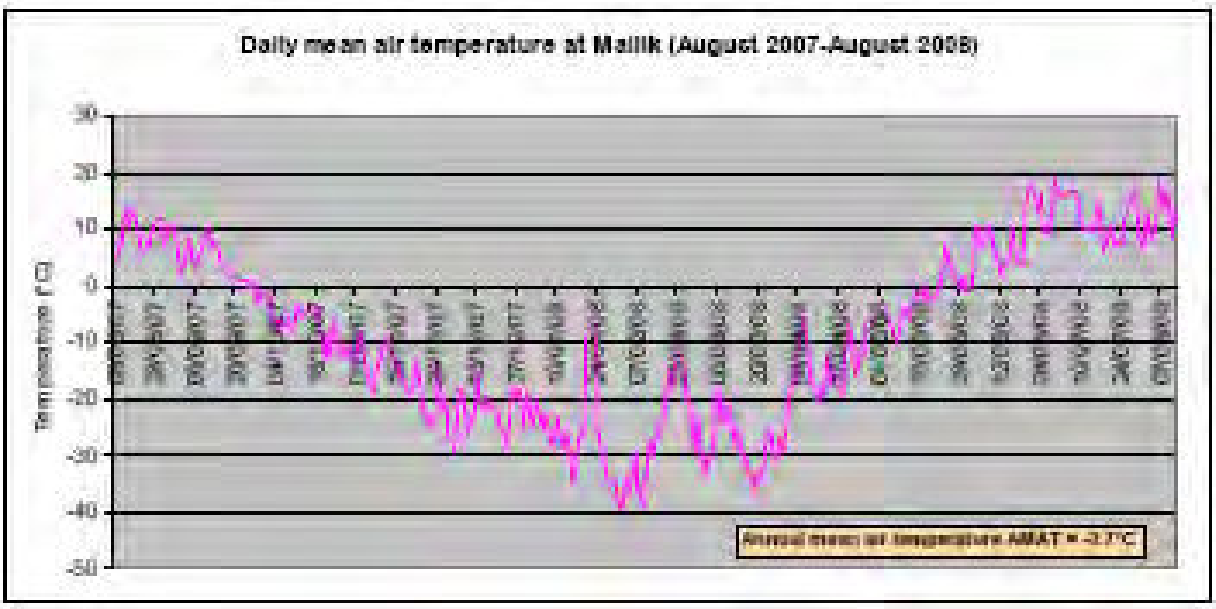
4.3.2 2002 Mallik 3L/ 4L/ 5L-38 Camp Sump

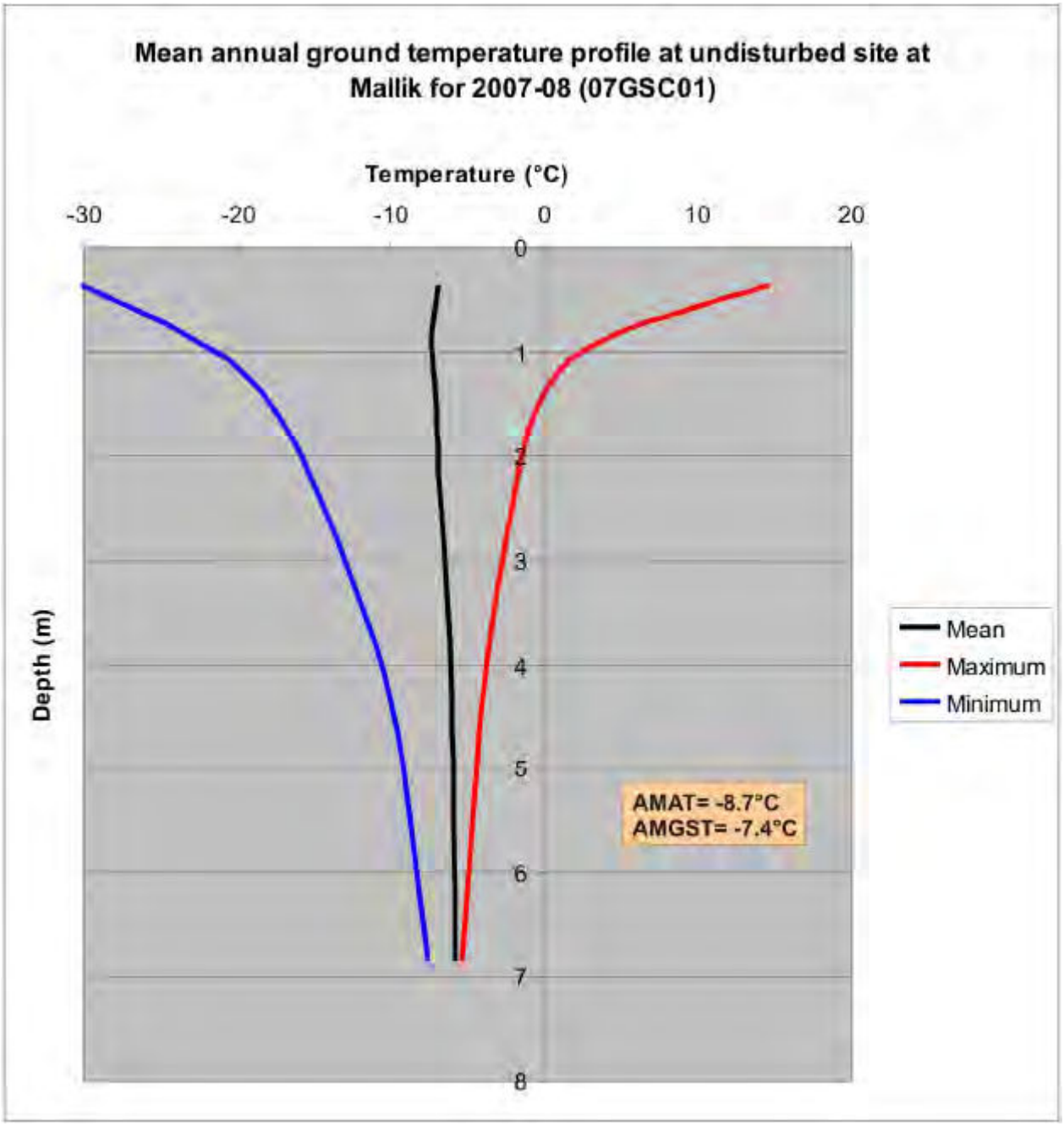
	Location 1
Depression in cap	97 cm
Sump Cap	109 cm
Undisturbed terrain	104 cm

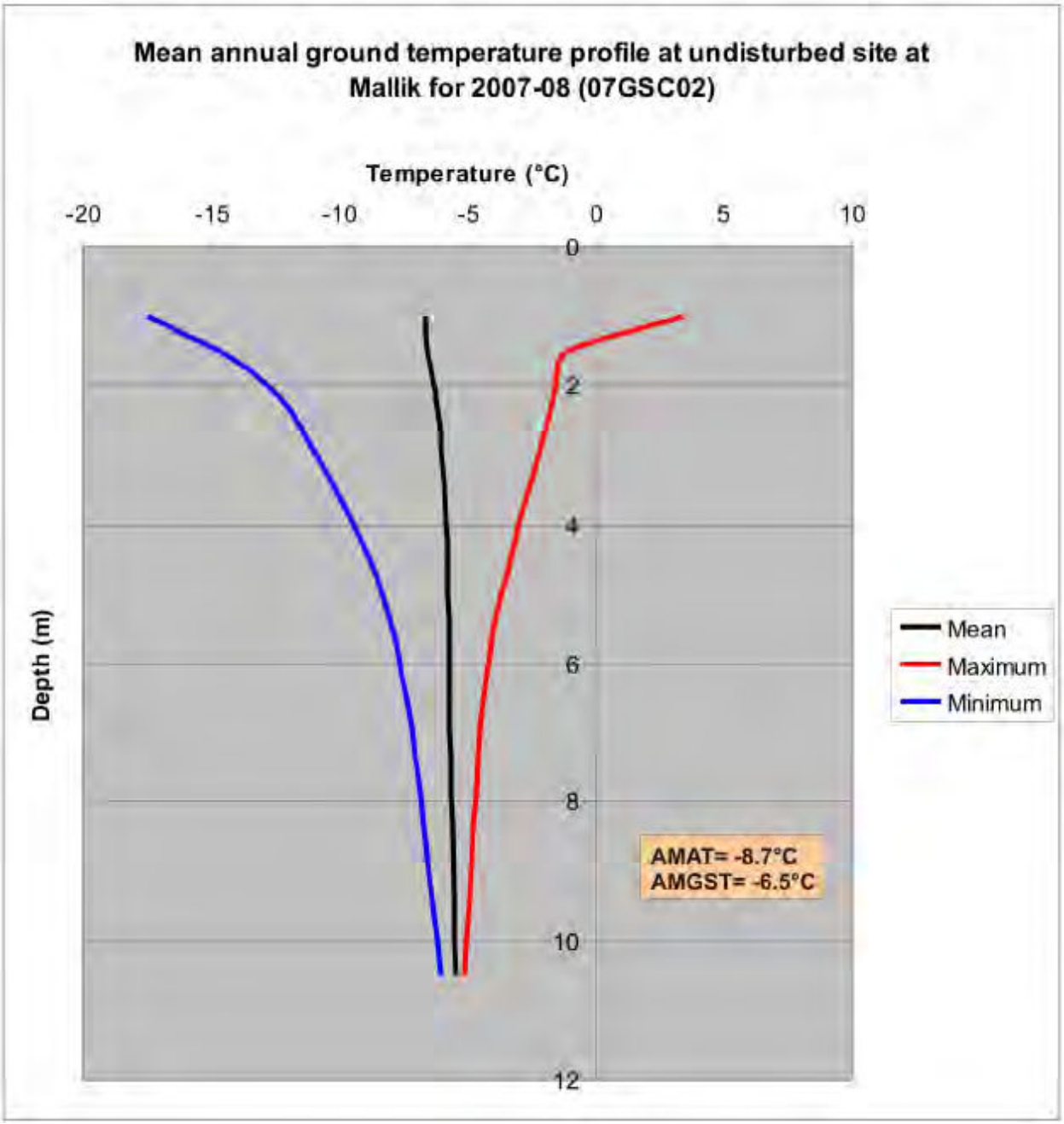
4.4 Summary of Air and Ground temperature:

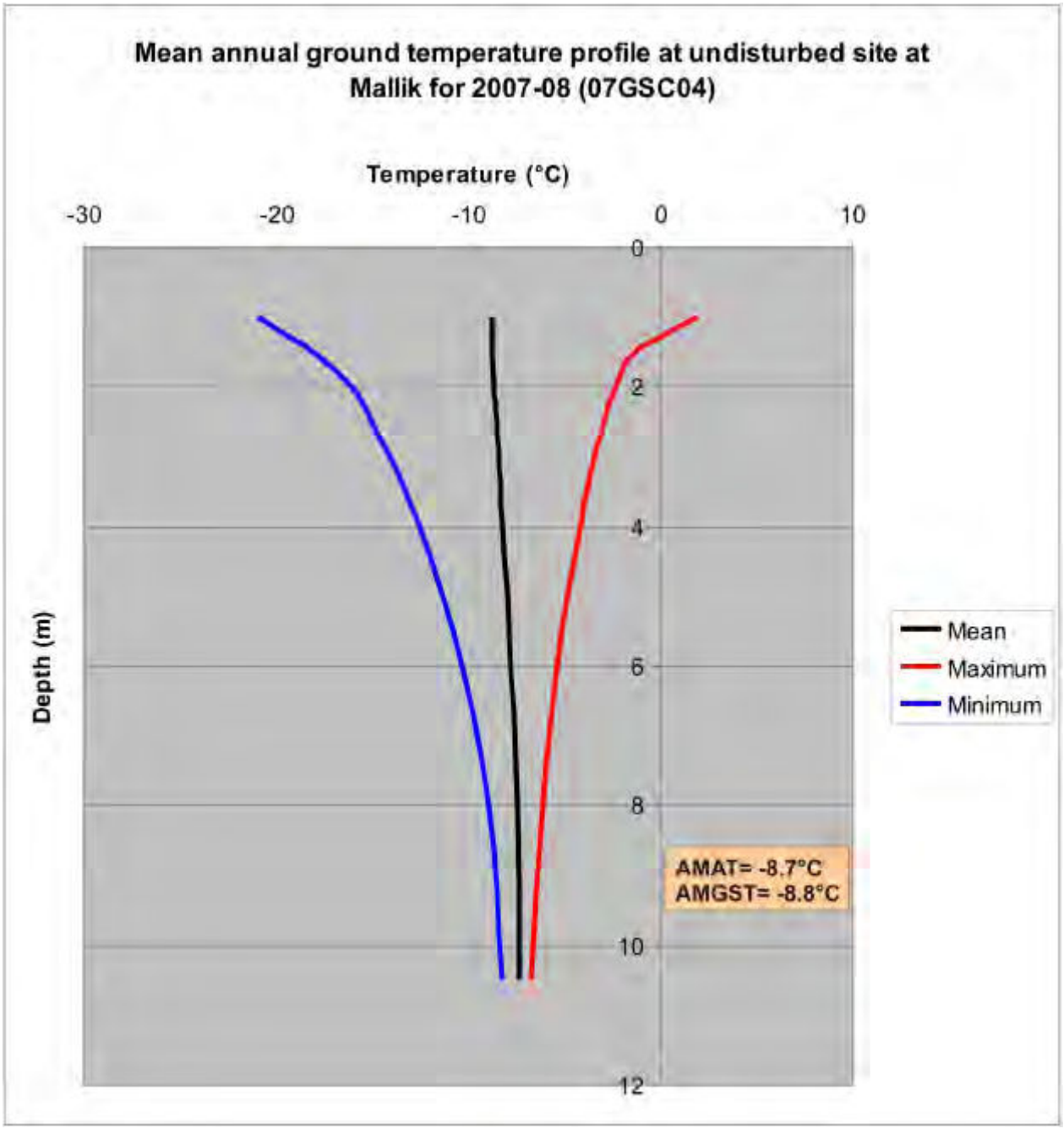


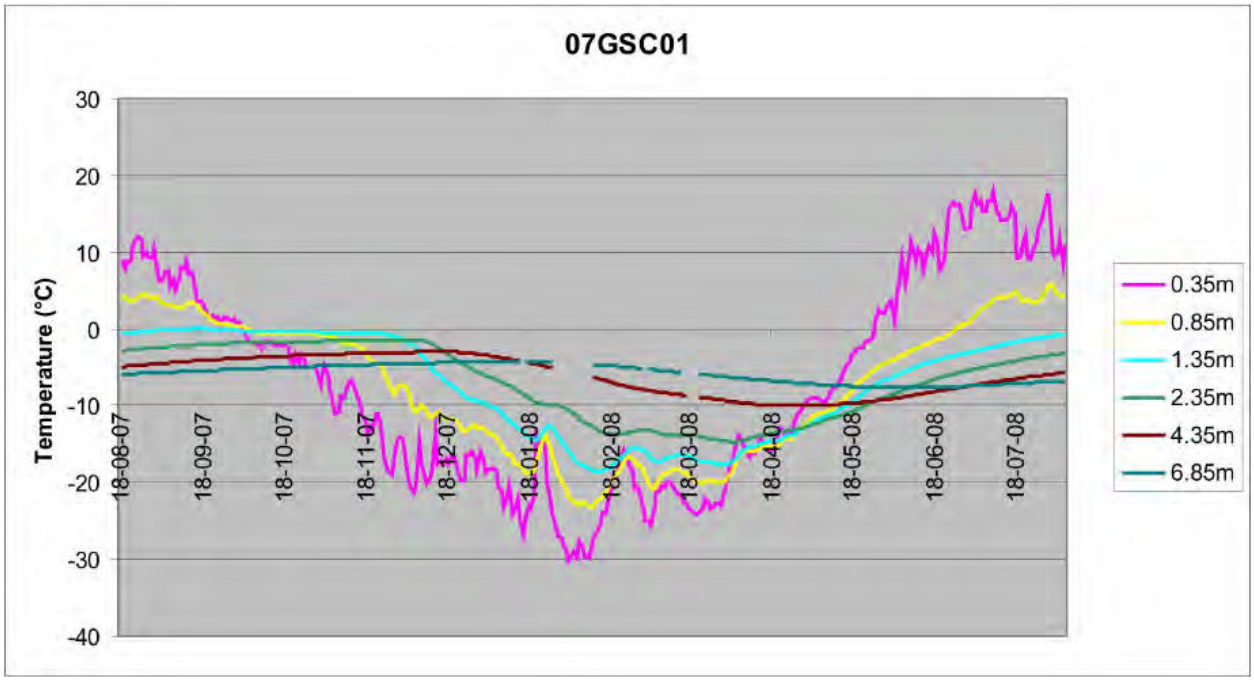
Picture 15: 2004 Aerial photo of Mallik site showing location of electro magnetic survey dates.


Daily mean air temperature at Mallik (August 2007-August 2008)
Temperature (°C)
30
20
10
0
-10
-20
-30
-40
-50

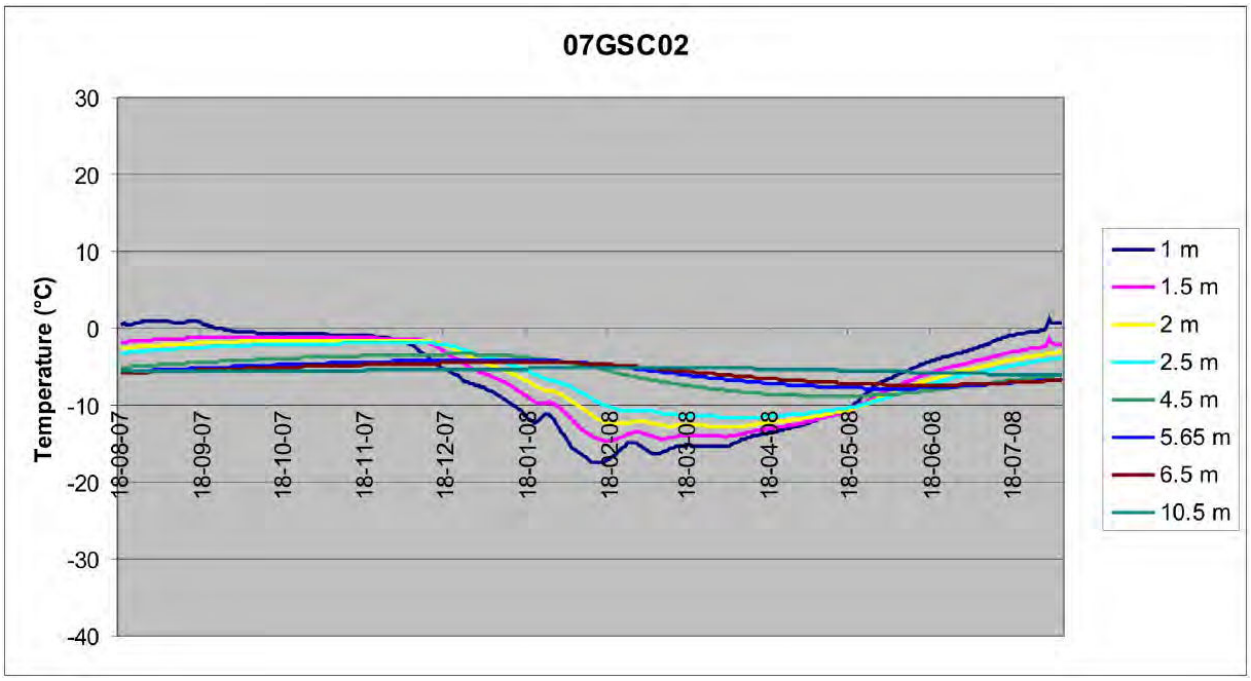

Mean annual ground temperature profile at undisturbed site at Mallik for 2007-08 (07GSC01)
Temperature (°C)
-30
-20
-10
0
10
20
Depth (m)
0
1
2
3
4
5
6
7
8
AMAT= -8.7°C
AMGST= -7.4°C
Mean
Maximum
Minimum


Mean annual ground temperature profile at undisturbed site at Mallik for 2007-08 (07GSC02)
Temperature (°C)
-20
-15
-10
-5
0
5
10
Depth (m)
0
2
4
6
8
10
12
AMAT= -8.7°C
AMGST= -6.5°C
Mean
Maximum
Minimum

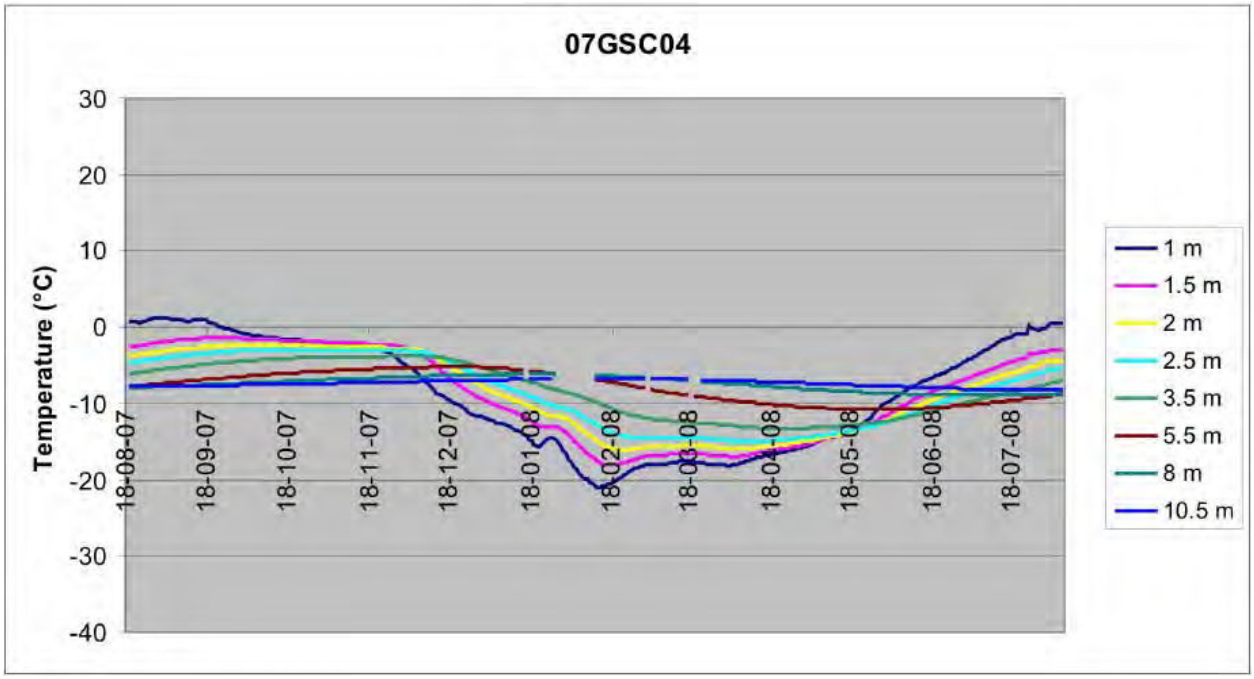

Mean annual ground temperature profile at undisturbed site at Mallik for 2007-08 (07GSC04)
Temperature (°C)
-30
-20
-10
0
10
Depth (m)
0
2
4
6
8
10
12
Mean
Maximum
Minimum
AMAT= -8.7°C
AMGST= -8.8°C



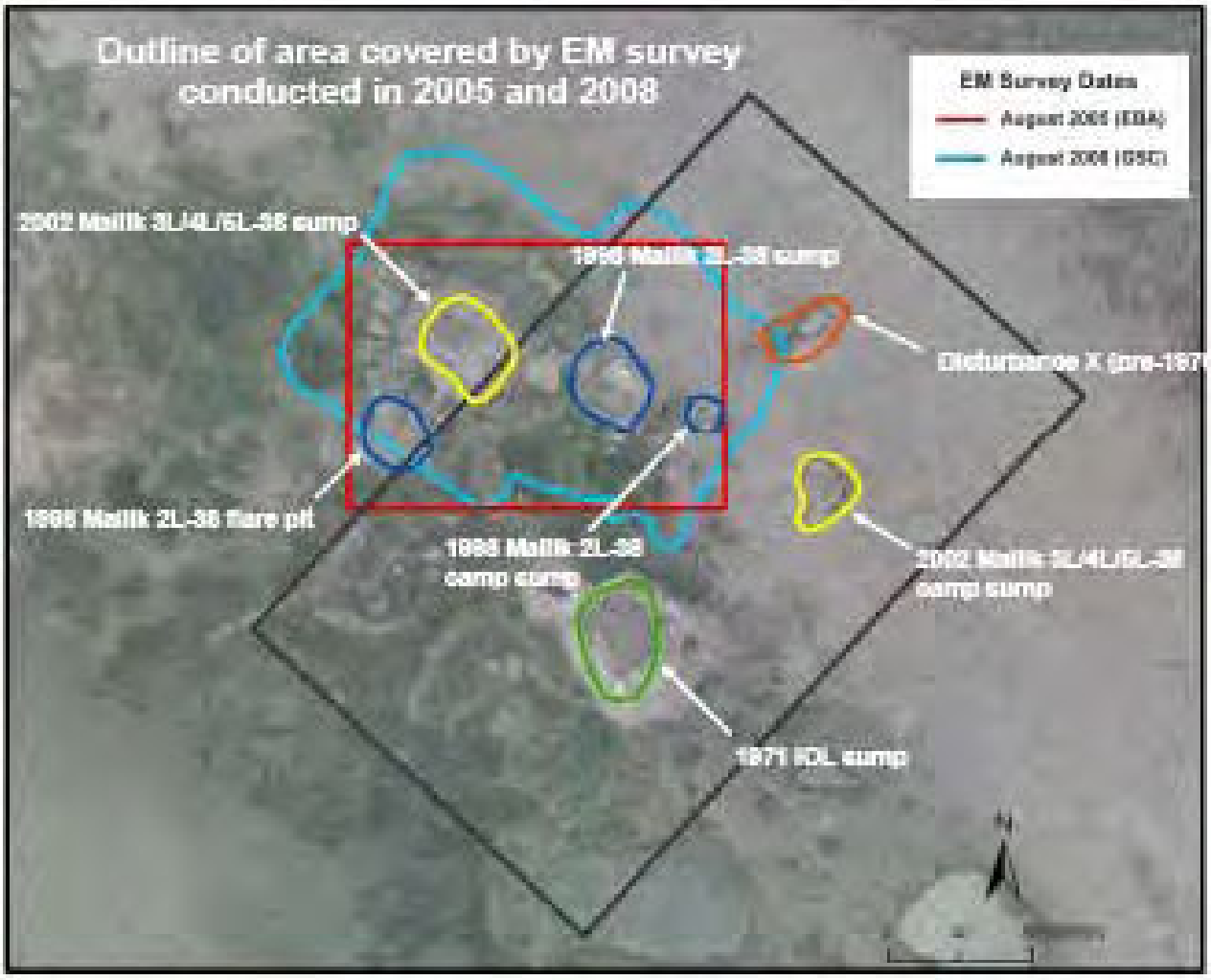
Active layer in Area on August 9, 2007: 86cm, 97cm 88 cm.



Active layer in area on August 9, 2007: 101cm, 103 cm, 117cm.



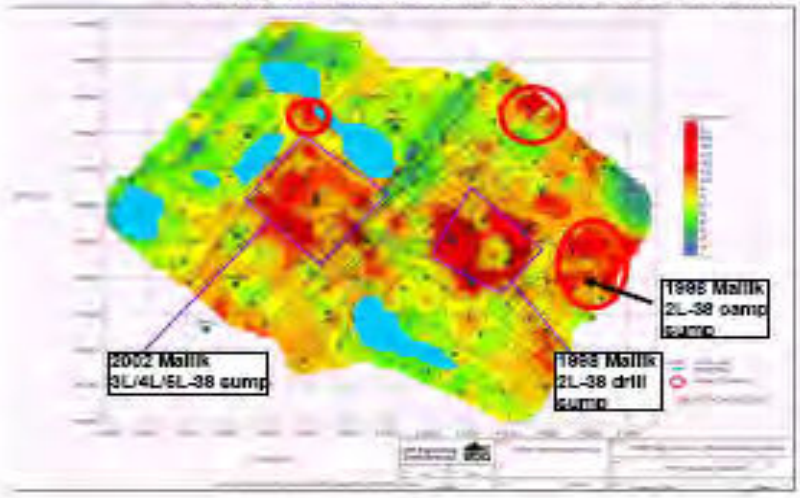
Active layer in Area on August 9, 2007: .120 cm.



Mallik Site showing locations where Electromagnetic surveys were taken in August 2005 and August 2008.

2005 EBA EM-38 survey of near-surface (~1-1.5 m) conductivity

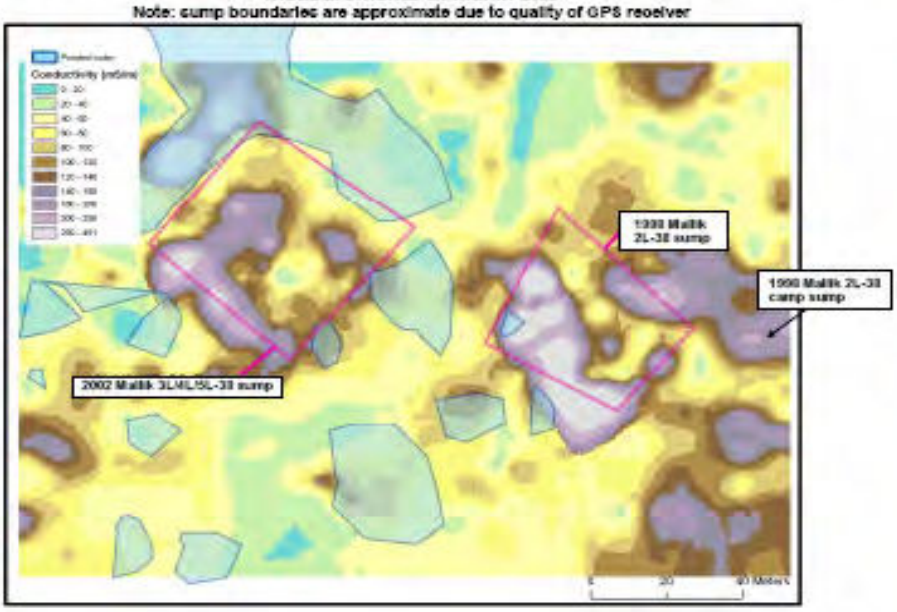
- Information primarily of active layer therefore expect significant seasonal variability
- May be useful to delineate active layer contaminant movement but the signal is also affected by active layer condition itself



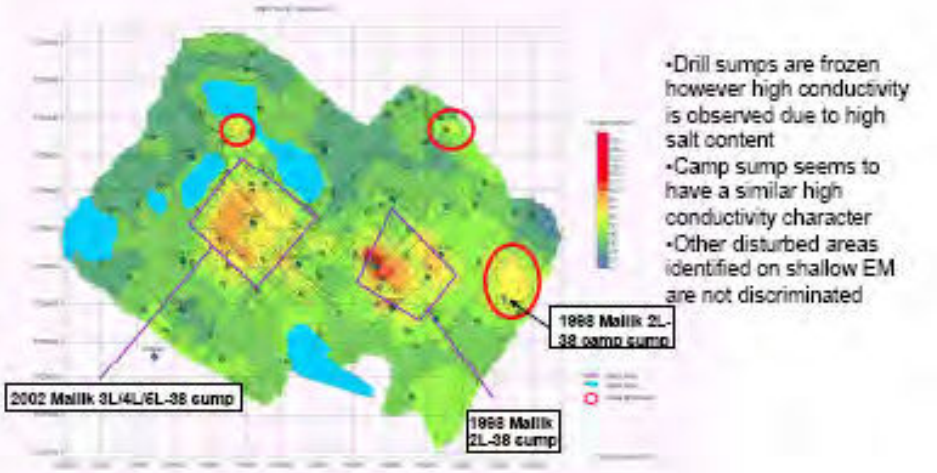
- As expected high conductivity observed beneath 1998 and 2002 drill sumps
- Three areas of concern identified where high conductivity areas were observed outside of immediate sump area
- The largest of these has now been confirmed as the 1998 camp sump

2008 GSC preliminary EM-38 survey of near-surface (~1-1.5 m) conductivity measurements at Mallik site

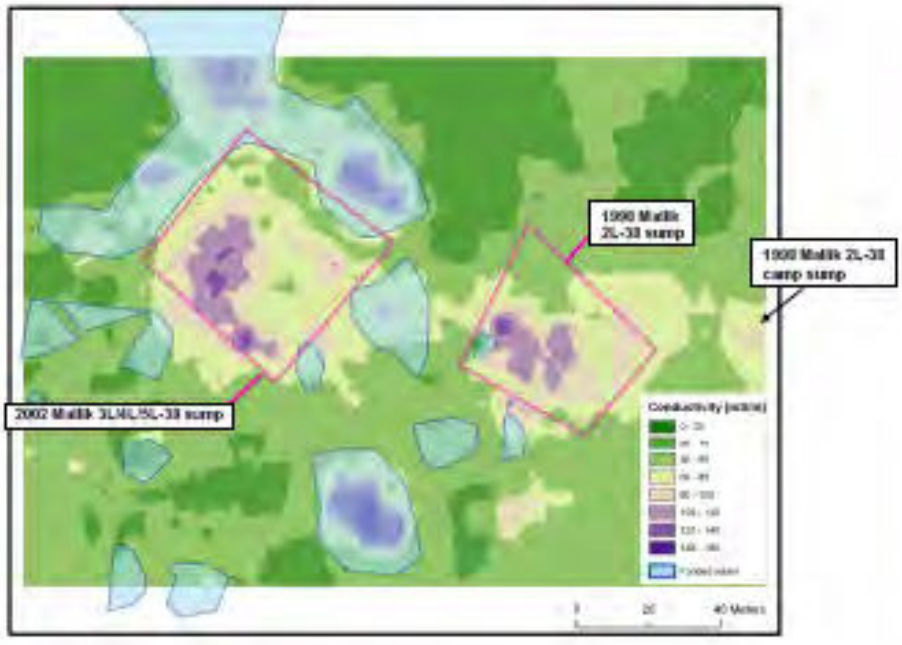
Note: sump boundaries are approximate due to quality of GPS receiver



2005 EBA EM-31 survey of deeper (~1-6 m) conductivity
•Useful for looking at permafrost interval beneath active layer



2008 GSC preliminary EM-31 survey of deeper (~1-6 m) conductivity measurements at Mallik site
Note: sump boundaries are approximate due to quality of GPS receiver



5. References:

*1: Drilling Operations: JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research.

T Ohara, SR Dallimore, and E Fercho: 1999

*2: Drilling and Operations Overview of the Mallik 2002 Production Research Well Program.

H Takahashi, E Fercho, SR Dallimore: 2005

*3: Naturally occurring gas hydrates in the Mackenzie Delta, NWT; - Bulletin of Canadian Petroleum Geology, v 22, no 3, p 340-352.

C Bily and JWL Dick: 1974

*4: GSC Bulletin 544: Overview of Science Programme; JAPEX/JNOC/GSC Mallik 2L-38 Gas Hydrate Research Well.

SR Dallimore, TS Collett, T Uchida: 1999

6. Appendices:

6.1 Appendix 1: Mallik 2L-38 and 3L/ 4L/ 5L-38 Sump Monitoring and Retrofit Programme as submitted to the Environmental Impact Screening Committee- February 2008

6.2 Appendix 2: Protocol for the Monitoring of Drilling-Waste Disposal Sumps; Inuvialuit Settlement Region – Northwest Territories Water Board - October 2005

6.3 Appendix 3: Canadian Petroleum Engineering Inc Letter: Water Use License Number N3L1-1702 dated 18,August 1998.

6.4 Appendix 4: Drilling Waste in the Mackenzie Delta (Inuvialuit Settlement Region): Drilling Waste Management Recommended Best Practices: March 2004.

6.5 Appendix 5: JOGMEC Mallik L-38 Site: Geophysical and subsurface environmental Site investigation; 2005; Kiggiak-EBA Consulting Ltd.

6.6 Appendix 6: September 15, 2006 Mallik Site Survey: Kavik Axys Inc, September 2006.

6.7 Appendix : 7 2002 Sump correspondence:

1). Canadian Petroleum Engineering Inc: Letter dtd 14, February 2002 – Request to enlarge the drilling sump and camp sump.

2). INAC: Response Letter dtd 18, February 2002 – Approval to expand drilling sump…

3). Town of Inuvik: Letter dtd 15, February 2002 – JAPEX Camp Affluent

6.8 Appendix 8: Canadian Petroleum Engineering Inc Letter: dtd 5,November, 2005 – Final Report for JAPEX/JNOC/GSC et al Mallik 3L-38, 4L-38 & 5L-38.

6.9 Appendix 9: Canadian Petroleum Engineering Inc Letter: dtd 25,March 2002 – Water Board for closure of 2002 sump caps.

Mallik Gas Hydrate Production Research Project:

Aurora Research Institute Mallik 2L-38 and 3L/4L/5L- 38 Sump Monitoring and Retrofit Program

Prepared by
Aurora Research Institute

November 25, 2009

OVERVIEW

The purpose of this letter report is to document 2009 monitoring activities undertaken as part of NWT Water Board Water License N7L1-1817 issued to Aurora College on December 1, 2006, in their capacity as the operator of the 2007/08 Aurora/JOGMEC/NRCan Production Research Well program.

The report documents monitoring related to separate activities, each conducted with different project histories and operator responsibilities. These include

1. surface activities related to re-entry and production operations conducted as part of the 2007 and 2008 Aurora/JOGMEC/NRCan Mallik 2L-38, 3L-38 and 6 L-38 field programs (Aurora College as operator), and
2. monitoring activities related to the Japex/JNOC/GSC Mallik 2L-38 drill sump constructed in 1998 (Japex Canada Limited as operator) and the Japex/JNOC/GSC et al. Mallik 3L/ 4L/ 5L-38 drill sump constructed in 2002 (Japex Canada Limited as operator).

MONITORING PROGRAM 2009

1) Site History and Status

The history of well site activities conducted at the Mallik site has been complex (see report by K. Martin submitted by Aurora College to the NWT Water Board as part of the 2008 monitoring report). Site features, as we understand them are summarized in Figure 1 and Figure 2.

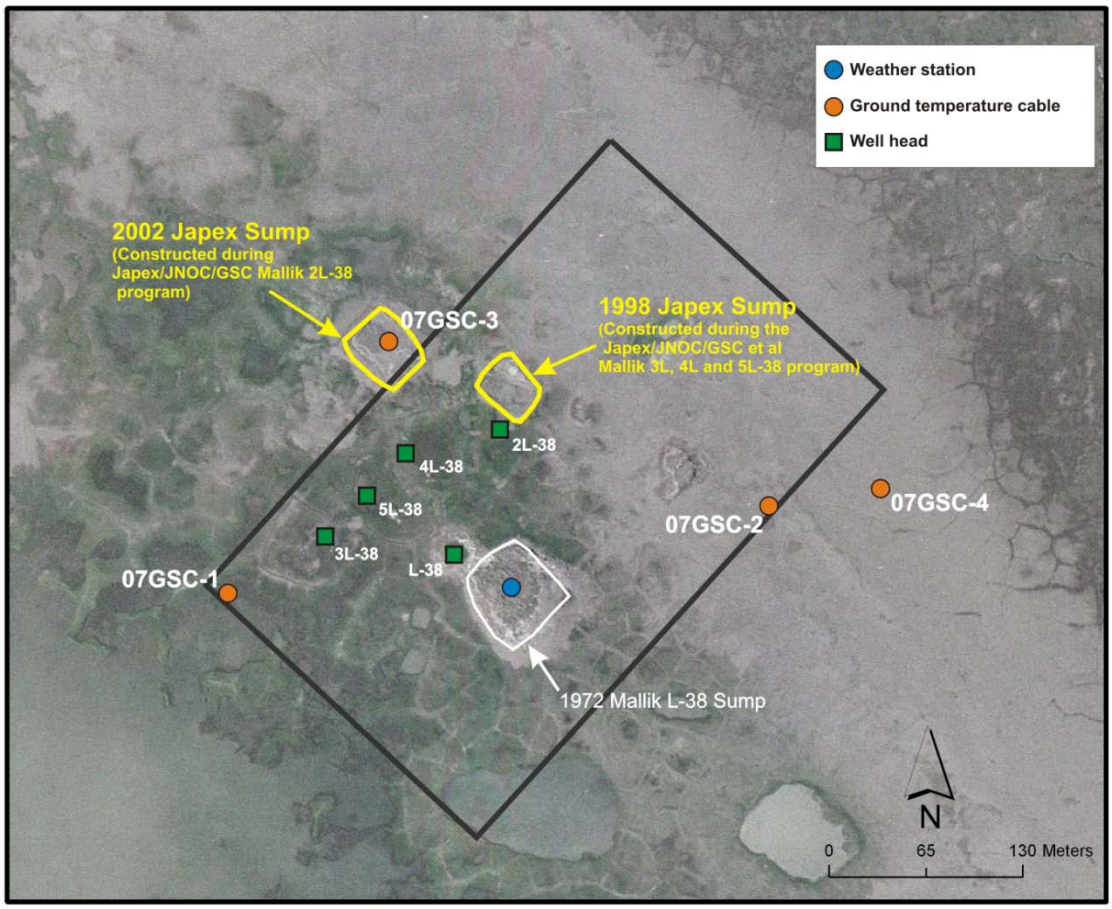


Figure 1: Vertical aerial photo from August 2004 showing location of surface features at Mallik site. Monitoring activities reported here refer to temperature observations at the GSC wells shown in orange and observed site conditions the vicinity of Aurora/JNOC/NRCan Mallik 2L, 3L 5L.

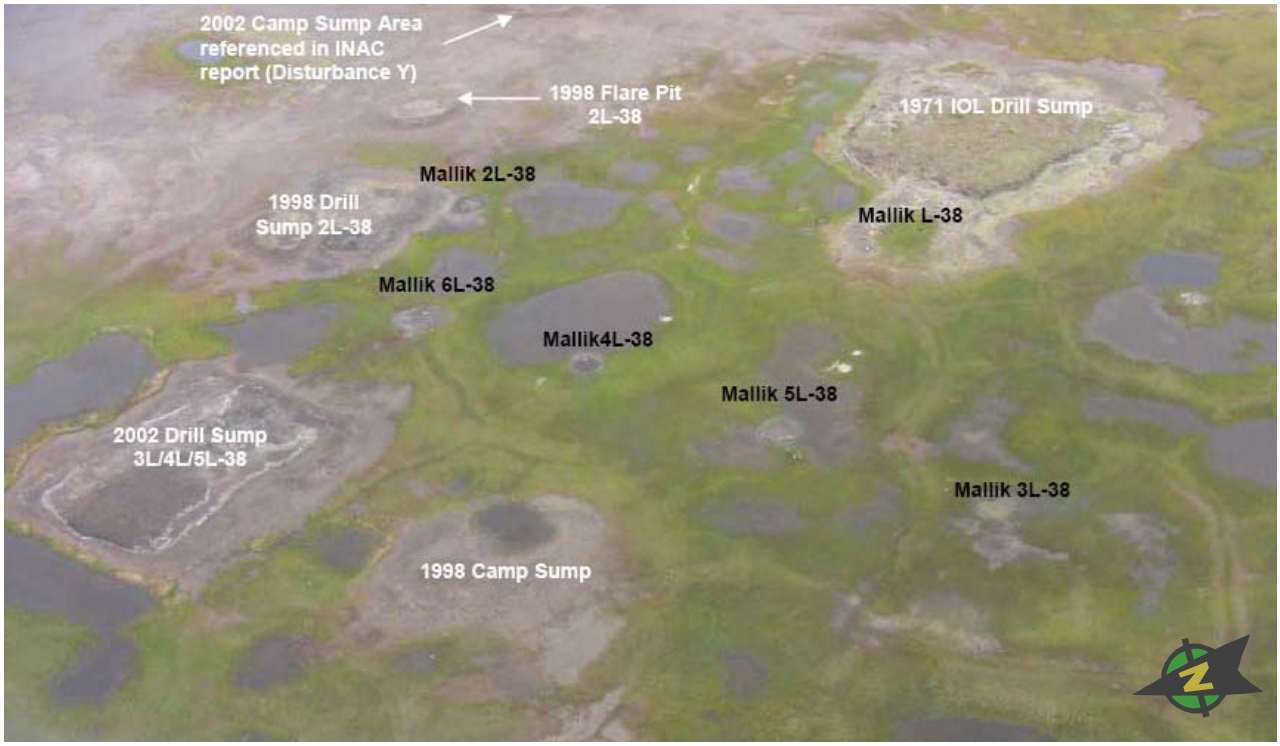


Figure 2: Oblique aerial photograph taken in summer 2008 showing features at Mallik site. No new site photos were taken in 2009.

2) Review of Surface Conditions at Aurora/JOGMEC/NRCan Mallik 2L-38, 3L-38 and 6 L-38

Pippa Seccombe-Hett and Scott Dallimore visited the Mallik site on August 16, 2009 to assess surface conditions in the vicinity of the 2007/08 surface operations. Their observations and notes are summarized on the attached photographs.

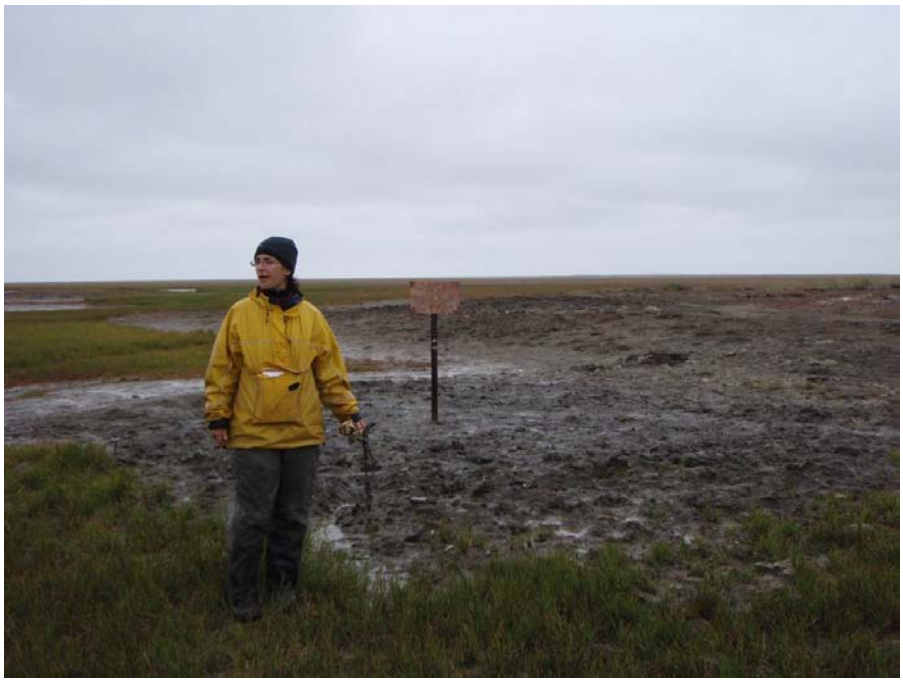


Figure 3: Aurora/JOGMEC/NRCan Mallik 2L-38, August 16, 2009 (photo credit S.R. Dallimore). As detailed by K. Martin in the Aurora College 2008 monitoring report, fill was placed at the surface of this well head in the summer of 2008. Site conditions on August 16th were found to be stable with no evidence of settlement or contamination. Grasses and sedges are beginning to colonize in the disturbed area.

Figure 4: Aurora/JOGMEC/NRCan Mallik 3L-38, August 16, 2009 (photo credit S.R. Dallimore). As detailed by K. Martin in the Aurora 2008 monitoring report, fill was placed at the surface of this well head in the summer of 2008. Site conditions on August 16th were found to be stable with no evidence of settlement or contamination. Site conditions on August 16th were quite wet however, with standing water and encroachment of a small pond. Grasses and sedges are beginning to colonize in the disturbed area and it is expected that the standing water only occurs after storm surges or after heavy rain.

Figure 5: Japex/JNOC/GSC et al Mallik4L-38, August 16, 2009 (photo credit S.R. Dallimore). Site conditions on August 16th were found to be stable with no evidence of settlement or contamination.

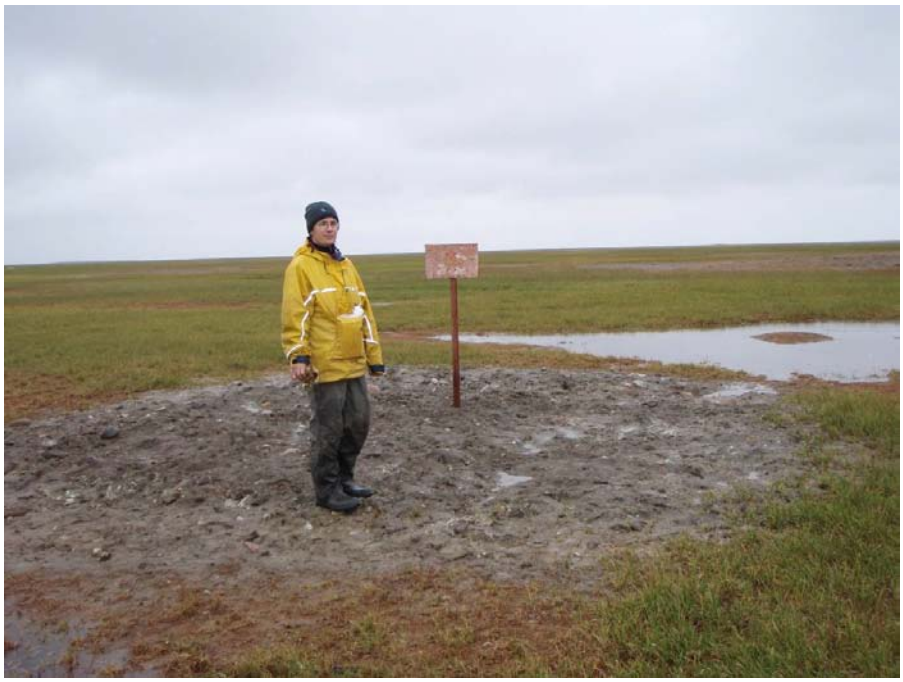


Figure 6: Japex/JNOC/GSC et al Mallik 5L-38, August 16, 2009 (photo credit S.R. Dallimore). Site conditions on August 16th were found to be stable with no evidence of settlement or contamination.

Figure 7: Aurora/JOGMEC/NRCan Mallik 6L-38, August 16, 2009 (photo credit S.R. Dallimore). As detailed by K. Martin in the Aurora College 2008 monitoring report, fill was placed at the surface of this well head in the summer of 2008. Site conditions on August 16th were found to be stable with no evidence of settlement or contamination. Grasses and sedges are beginning to colonize in the disturbed area.

3) Monitoring activities related to the 1998 Japex/JNOC/GSC Mallik 2L-38 drill sump and 2002Japex/JNOC/GSC et al. Mallik 3L/ 4L/ 5L-38 drill sump

The NWT Protocol for the Monitoring of Drilling Waste Disposal Sumps calls for annual monitoring to include measurements of active layer depth, ground temperatures and electromagnetic profiling. In addition, surface observations are required and if any evidence of contamination is observed samples of sediment or water should be taken. Unfortunately, because Japex Canada Ltd., the owner of the sumps, limited Aurora College's access to them, the monitoring activities during 2009 were limited to ground temperature observations in GSC boreholes installed to measure the subsurface temperatures of the 2002 sump and three background locations in areas unaffected by surface operations.

A summary of the 2009 ground temperature conditions is given in Figures 8-15. The estimated mean annual ground surface temperature at the Mallik 2002 sump was -7°C which is colder than the estimated mean annual temperature at the undisturbed sites that varied from -4 to -6°C. This is consistent with the design goals of a sump which are to raise the ground elevation and lower the mean annual ground surface temperature regime. A comparison of the 2008/2009 air and ground temperature at the index site is shown in Figure 16.

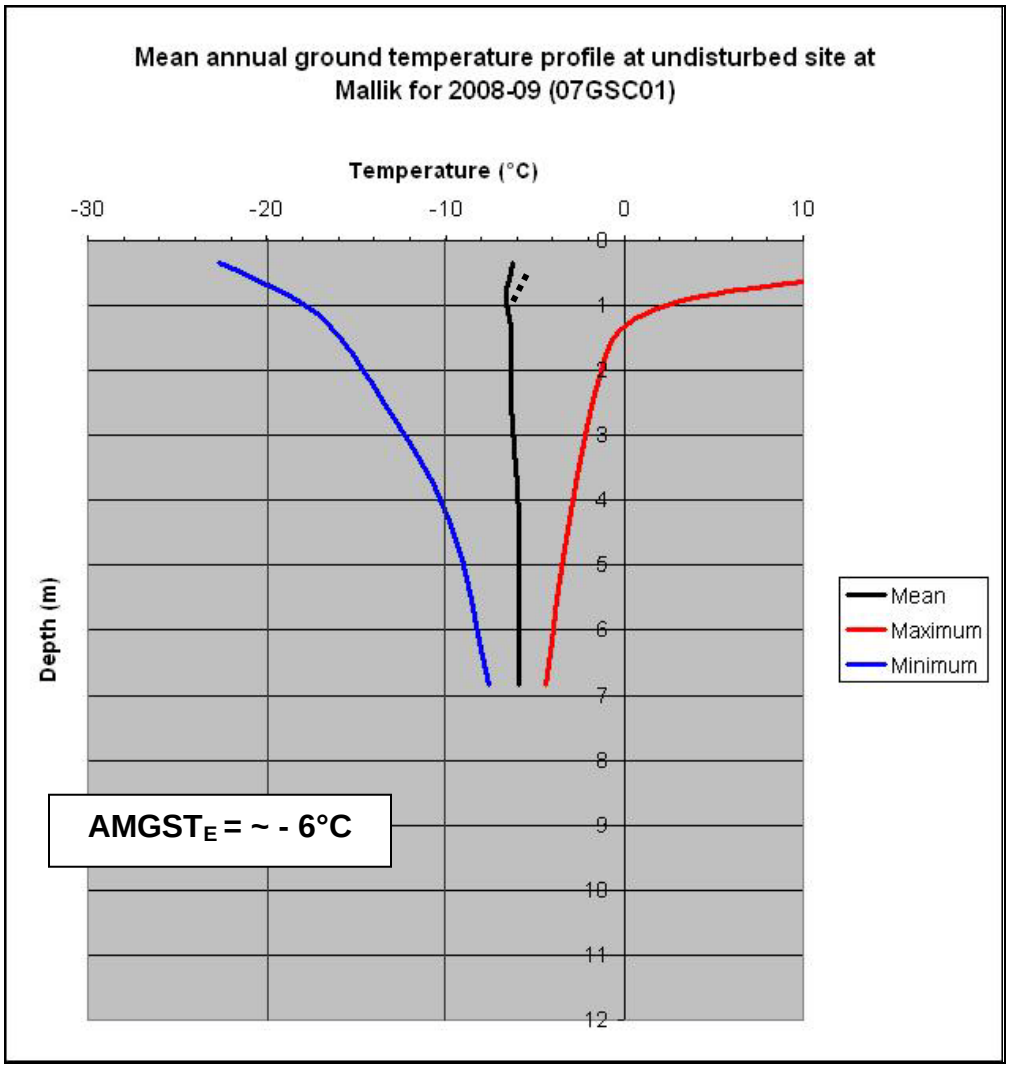


Figure 8: Trumpet curve of permafrost temperatures for 07GSC01 site. Mean annual ground surface temperature at this undisturbed site at the edge of a pond with approximately 10cm of standing water is approximately -6°C.

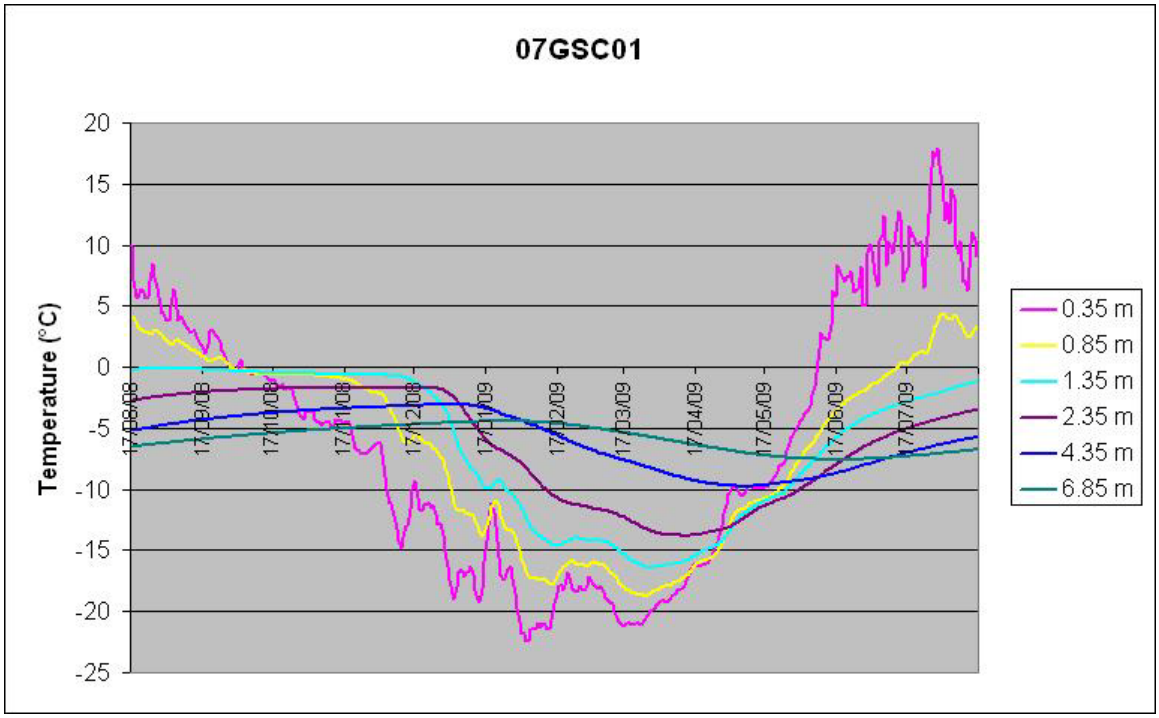


Figure 9: Record of annual temperatures at each measured depth below ground surface in 07GSC01 showing that surface thawing at this site was less than 1.35m.

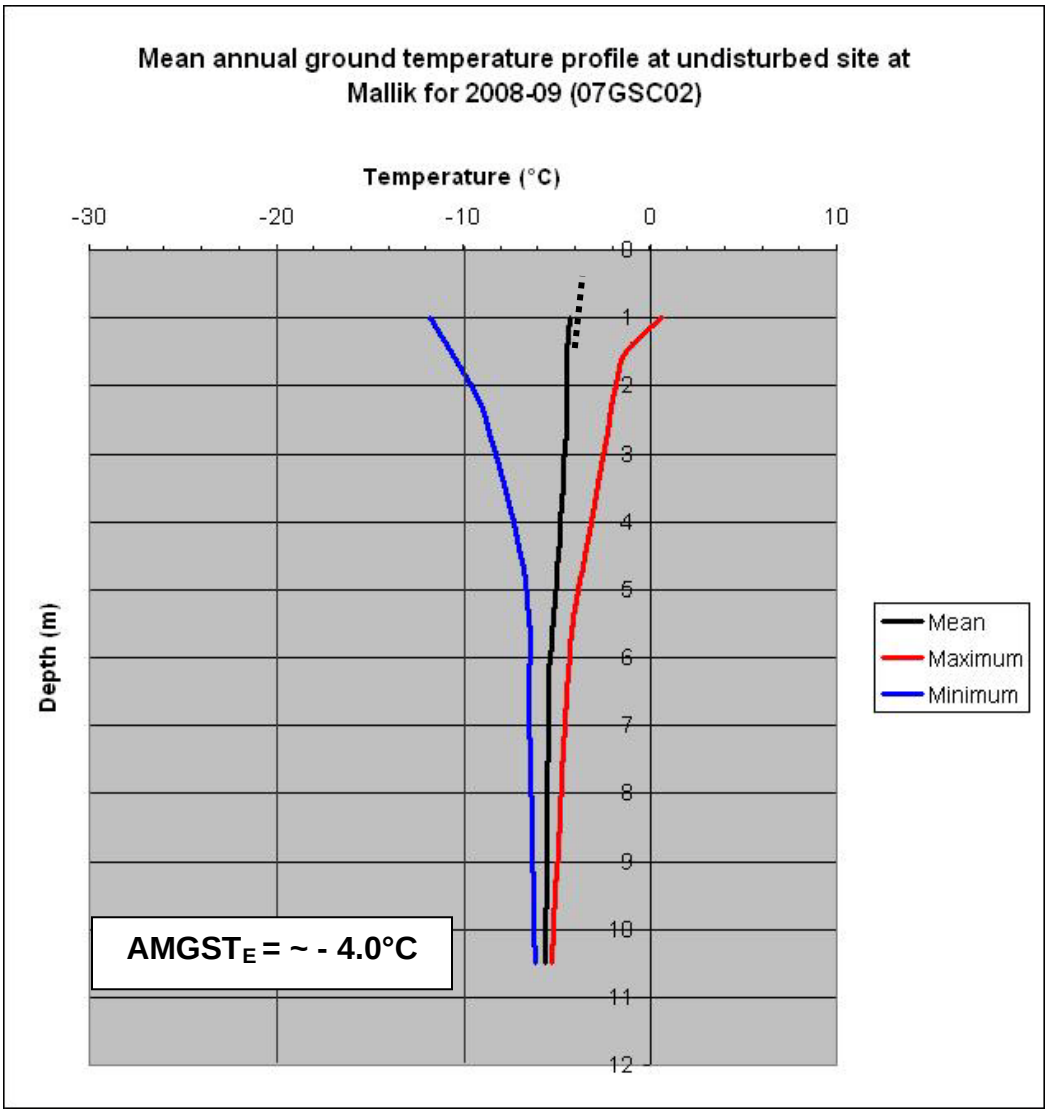


Figure 10: Trumpet curve of permafrost temperatures for 07GSC02 site located in an undisturbed site with low sedge and grass ground cover. Mean annual ground surface temperature at this site is approximately -4°C.

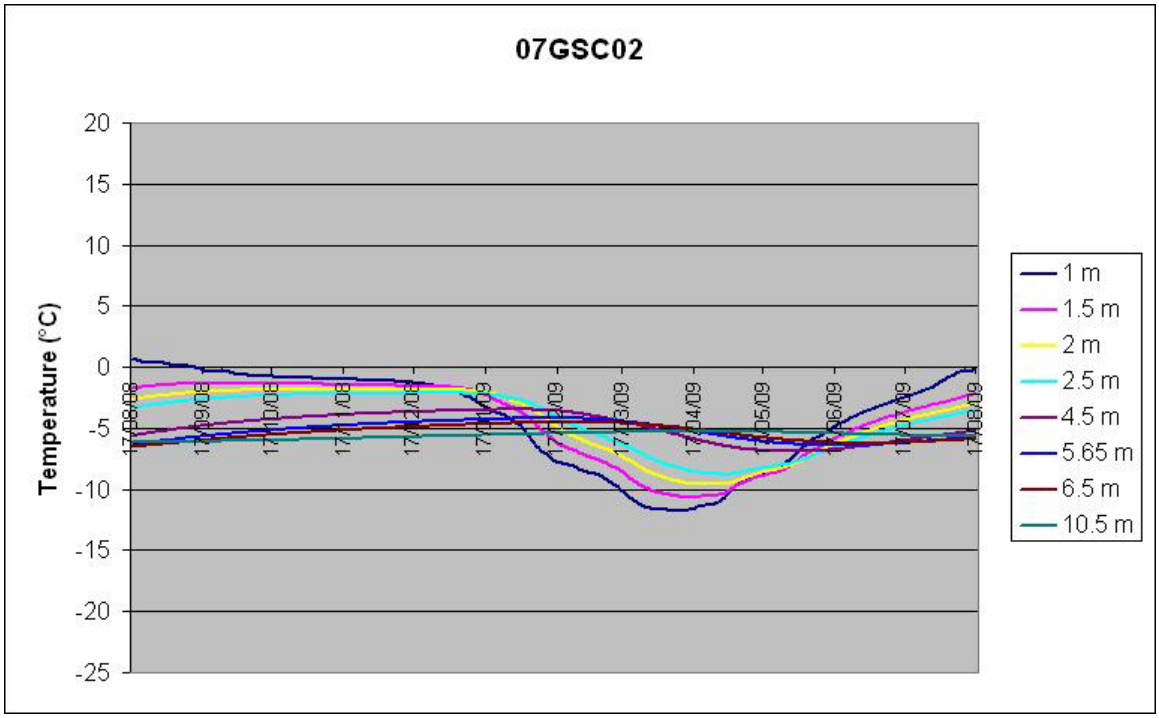


Figure 11: Record of annual temperatures at each measured depth below ground surface in 07GSC02 showing that surface thawing at this site was less than 1.5m.

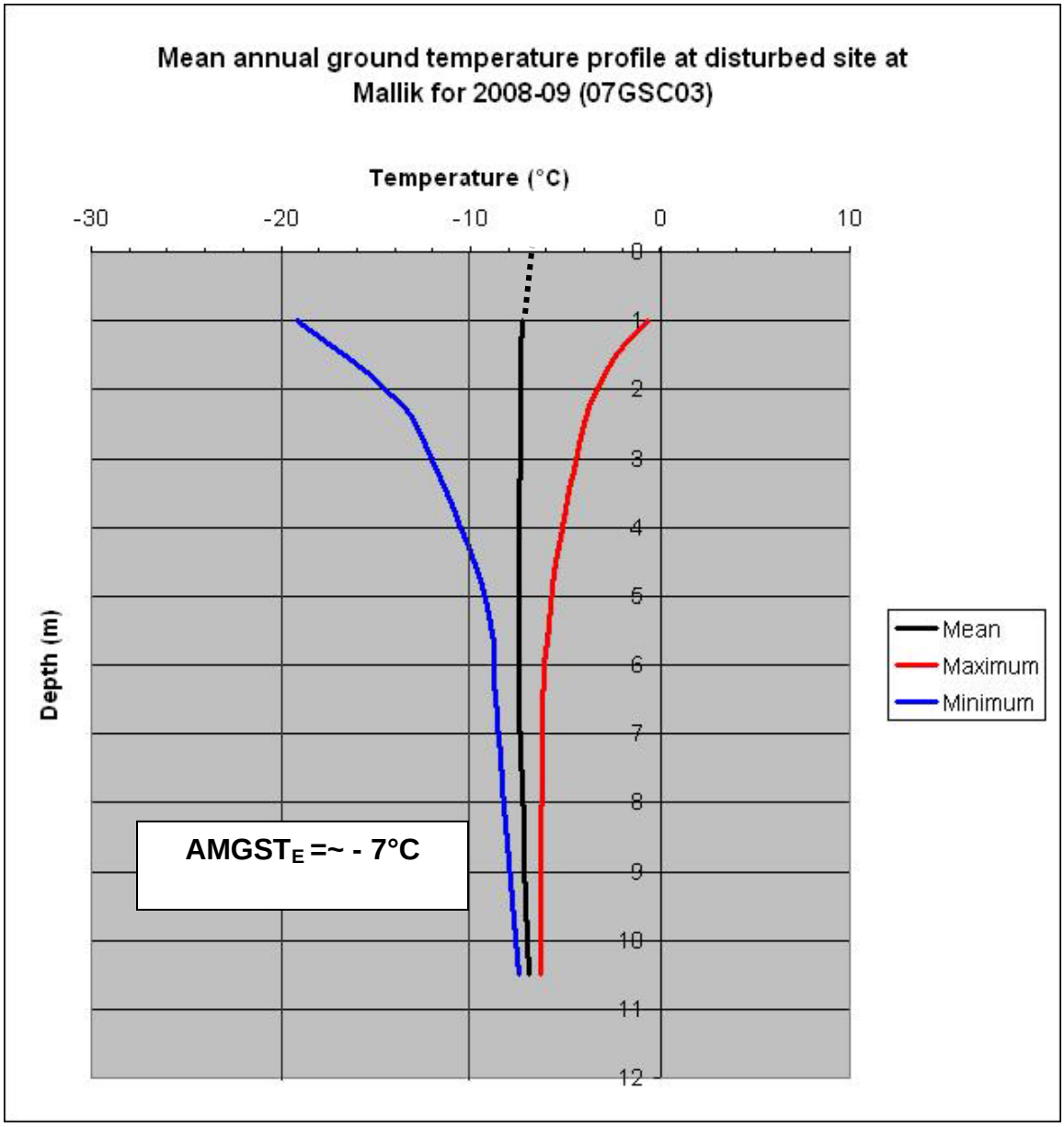


Figure 12: Trumpet curve of permafrost temperatures for 07GSC03 site located in Mallik 2002 sump. Mean annual ground surface temperature at this site is approximately -7°C.

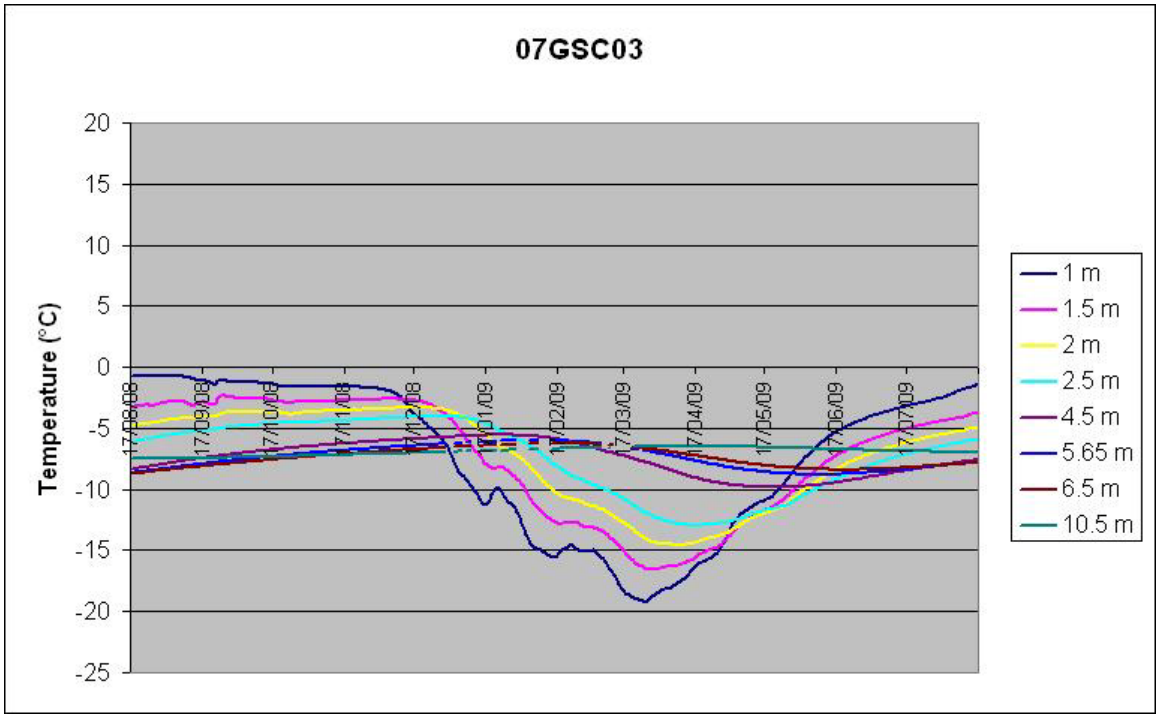


Figure 13: Record of annual temperatures at each measured depth below ground surface in 07GSC03 showing that surface thawing at this site was less than 1.0m.

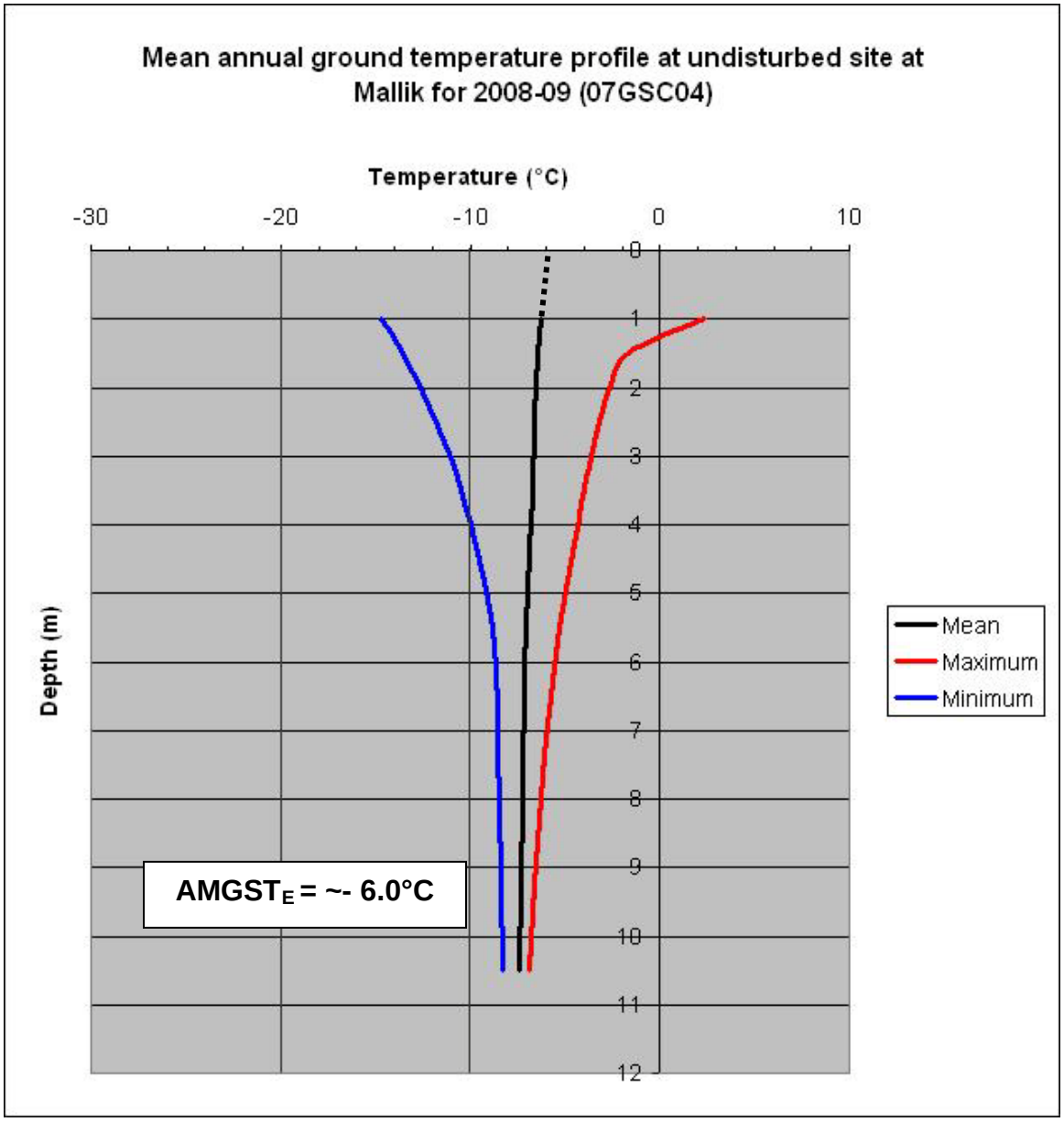


Figure 14: Trumpet curve of permafrost temperatures for 07GSC04 site located in an undisturbed site with sparse to bare ground cover. Mean annual ground surface temperature at this site is approximately -6°C.

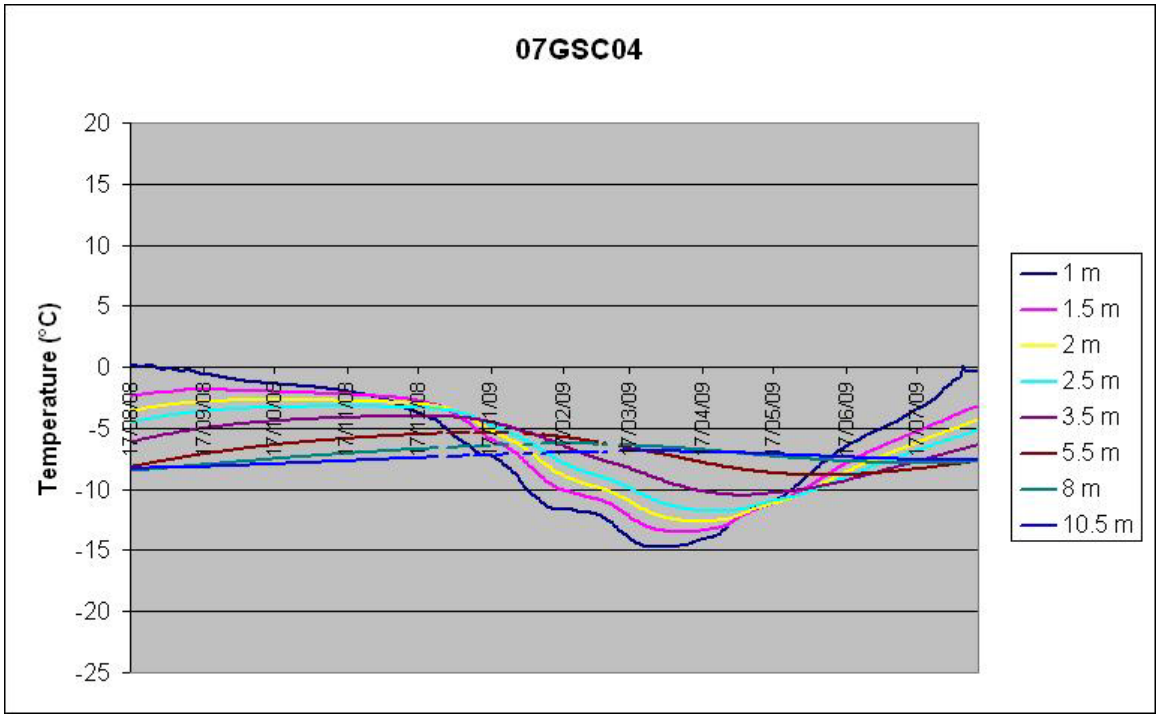


Figure 15: Record of annual temperatures at each measured depth below ground surface in 07GSC04 showing that surface thawing at this site was less than 1.5m.

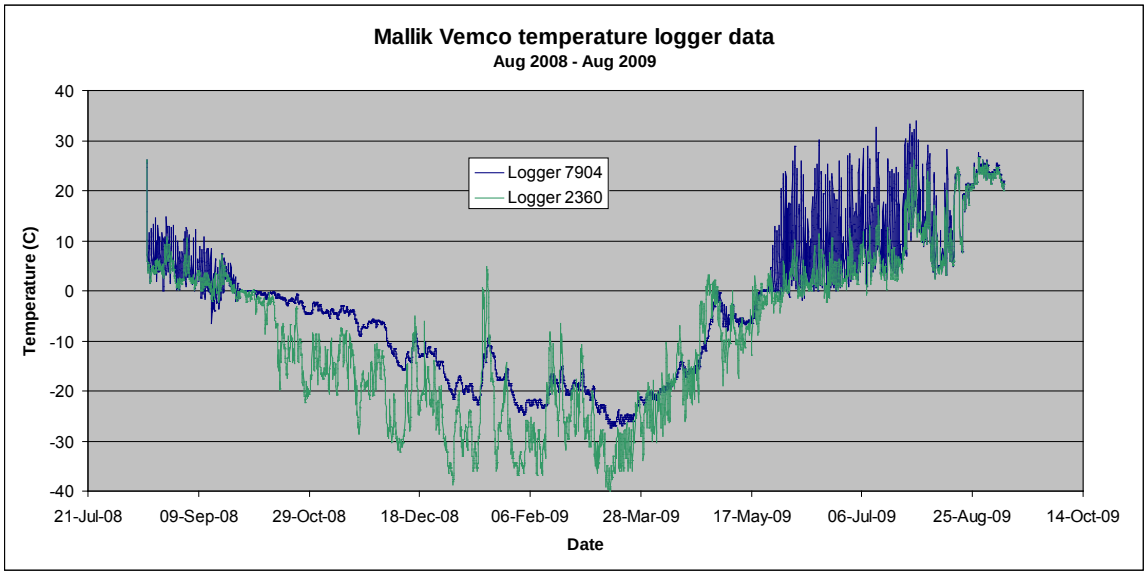


Figure 16: Air temperature record (green) and ground temperature data (blue) for the index site. Note the air temperature station was knocked down during the field season. By the change in the trend of the two records it is likely this occurred near the beginning of April.

2010 Mallik Annual Sump Monitoring Report

For Submission To The Northwest Territories Water Board Under Water License N7L1-1817

Prepared for:

Prepared by:

KAVIK-AXYS Inc.

November 2010
110218287

Table of Contents

1 Introduction 1-1
2 Site Location 2-1
3 Methods 3-1
3.1 Visual Assessment 3-1
3.2 Active-Layer Depth Measurements 3-1
3.3 Ground Temperature Monitoring 3-2
3.4 Electromagnetic Surveys 3-4
3.5 Soil Sampling 3-5
3.6 Water Sampling 3-5
4 Results 4-1
4.1 Visual Assessment 4-1
4.2 Active Layer Depth Measurements 4-4
4.3 Ground Temperature Monitoring 4-6
4.4 Electromagnetic Surveys 4-11
4.5 Soil Sampling 4-12
4.6 Water Sampling 4-15
5 Conclusion 5-1
6 References 6-1
Appendix A Thermistor Temperature Graphs A-1
Appendix B Electromagnetic Surveys B-1
Appendix C Laboratory Analyses C-1

List of Tables

Table 3-1 Current Depths of Thermistor Sensors....3-2
Table 4-2 Soil sampling depth....4-12
Table 4-3 Soil Sampling Results – Salinity....4-13
Table 4-4 Soil Sampling Results – Salinity....4-14
Table 4-5 Water Sampling Results – Routine Water....4-16
Table 4-6 Water Sampling Results – Regulated Metals (CCME/AT1) -Total....4-17

List of Figures

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories....2-2
Figure 2-2 Sumps Locations (photo taken on Sept. 29th, 2010)....2-3
Figure 2-3 Thermistor Locations....2-4
Figure 3-1 Weather Station Thermistor....3-3
Figure 3-2 Electromagnetic Survey (EM31)....3-4
Figure 3-3 Soil and water sample locations....3-5
Figure 4-1 Aerial view of the area looking west (September 28th, 2010)....4-1
Figure 4-2 Aerial view of Mallik 2L-38 (1998 sump)....4-2
Figure 4-3 Aerial view of Mallik 3L/4L/5L-38 (2002 sump)....4-2
Figure 4-4 View of a subsidence area at the east and west limits of the 1998 drilling sump. Water was sampled from both ponds for analysis (Mallik_water_01 and Mallik_water_02)....4-3
Figure 4-5 Location of Active-Layer Transects....4-4
Figure 4-6 Ground temperature at Thermistor 07GSC-01....4-7
Figure 4-7 Ground temperature at Thermistor 07GSC-02....4-8
Figure 4-8 Ground temperature at Thermistor 07GSC-03....4-9
Figure 4-9 Ground temperature at Thermistor 07GSC-04....4-10
Figure 4-10 Depression characterized by high apparent conductivity values (from the EM38 survey)....4-11
Figure A-1 Thermistor 07GSC-01 – Average Monthly Ground Temperatures (August 2009 to August 2010)....A-3
Figure A-2 Thermistor 07GSC-02 – Average Monthly Ground Temperatures (August 2009 to August 2010)....A-4
Figure A-3 Thermistor 07GSC-03 – Average Monthly Ground Temperatures (August 2009 to August 2010)....A-5
Figure A-4 Thermistor 07GSC-04 – Average Monthly Ground Temperatures (August 2009 to August 2010)....A-6

Abbreviations

ARI..... Aurora Research Institute, Aurora College
CCME..... Canadian Council of Ministers of the Environment
GSC .....Geological Survey of Canada
EM..... Electromagnetic
ESSIS..... Environmental SubSurface Imaging Solutions Ltd.
IORL..... Imperial Oil Resources Ltd.
ISR.....Inuvialuit Settlement Region
JAPEX..... JAPEX Canada Ltd.
JNOC..... Japan National Oil Corporation
mbg.....meters below ground
NWT..... Northwest Territories
SDL ..... Significant Discovery Licence

1 Introduction

The Mallik L-38 lease area has been the site of three historical drilling programs (1972, 1998, and 2002), during which a total of three conventional drilling sumps were constructed to dispose of drill cuttings and fluids. Imperial Oil Ltd. (IOL) drilled the original IOL Mallik L-38 discovery well during the winter of 1971-1972, and constructed a large drilling waste disposal sump (approximately 80 m x 95 m). In 1998, the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore *et al*. 1999). With JAPEX Canada Ltd. (JAPEX) as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a drilling waste disposal sump (approximately 45 m x 50 m). In 2002, a seven-party participant group, again led again by JNOC and GSC with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC *et al.* Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste associated with the three wells. In the 2007-2008 Mallik program the 2L- and 3L-38 wells were re-entered and the drilling waste was removed from site (sumpless program).

The 2010 Annual Sump Monitoring Report by Kavik-AXYS Inc. (Kavik-AXYS) details the third year of a seven year monitoring program to monitor the stability of the Mallik 2L-38 and 3L/4L/5L/-38 drilling waste sumps. The monitoring program started in 2008 and is scheduled to conclude in 2014. The information in this report is required under *Part H: Conditions Applying to Abandonment and Restoration of the Northwest Territories Board Licence No. N7L1-1817*.

The 2010 site visit was conducted on September 29th and 30th and included the following:

- a visual assessment of the sump caps conditions
- the measurement of the active layer thickness beneath the sumps, around their perimeter, as well as in an undisturbed area adjacent to the sumps
- the maintenance and replacement of some of the monitoring equipment on site
- the downloading of temperature data at four thermistor locations (07GSC-01 to 07GSC-04)
- electromagnetic (EM) surveys (EM 31 and 38) conducted by a representative from Environmental SubSurface Imaging Solutions Ltd. (ESSIS) on both sumps and surrounding areas
- soil sampling on the sump caps and in one undisturbed area adjacent to the sumps
- surface water sampling of ponded water located on the sumps and in an undisturbed area adjacent to the sumps

This report herein documents the results of this site visit and presents the data gathered from the monitoring activities.

2 Site Location

The Mallik L-38 site is located at the western side of the Richards Island, at the edge of the Mackenzie Delta and the Beaufort Sea, in the Inuvialuit Settlement Region (ISR) of the Northwest Territories (Figure 2-1). The area consists of the nearshore floodplain on the western side of the Mallik Bay. The site coordinates are approximately 69°27'38"N, 134°39'42"W. The area is located on Crown land in the ISR, within the IORL Significant Discovery License (SDL) 060. The locations of the sumps are showed on Figure 2-2 and 2-3.

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories

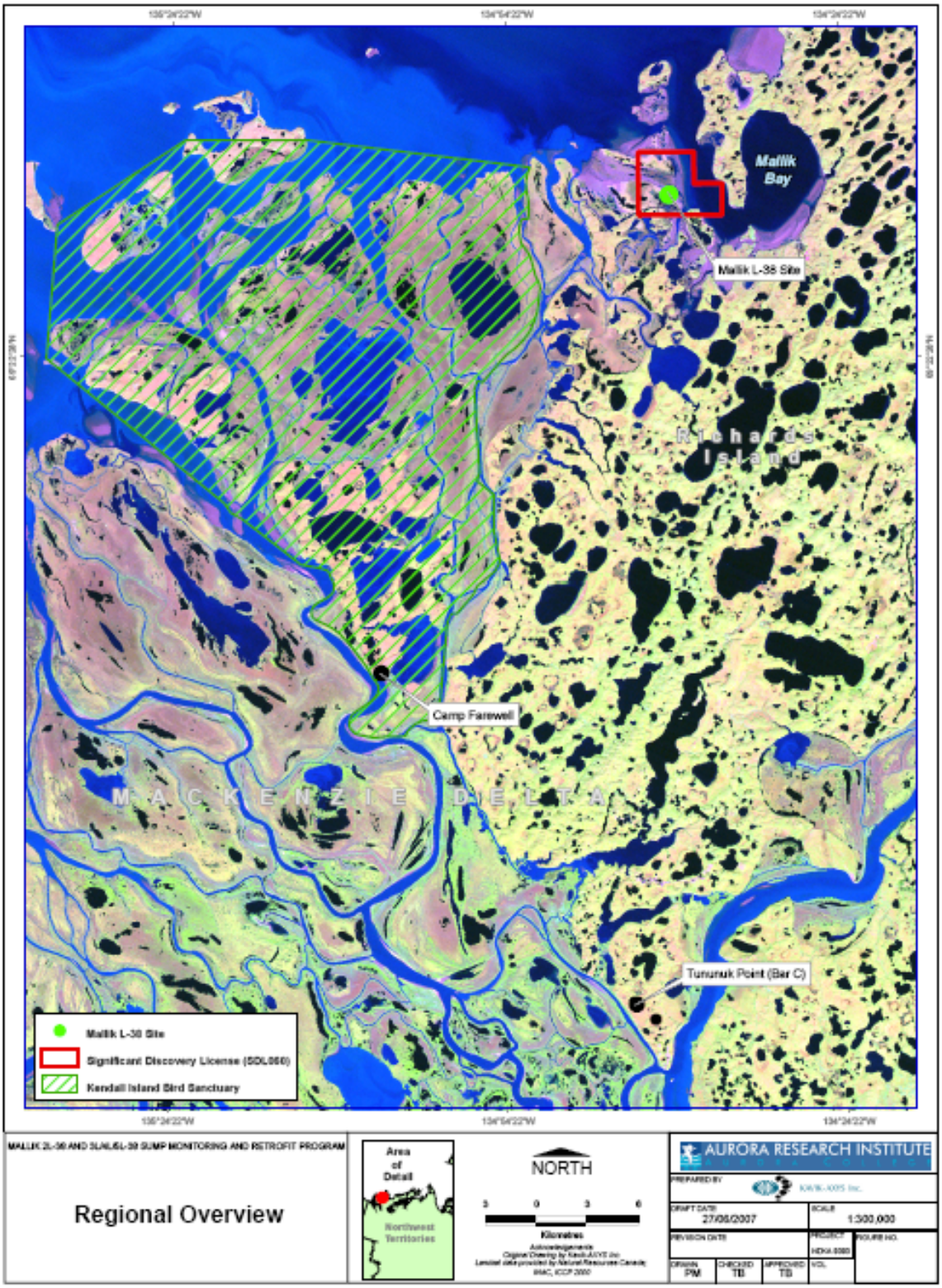


Figure 2-2 Sumps Locations (photo taken on Sept. 29th, 2010)

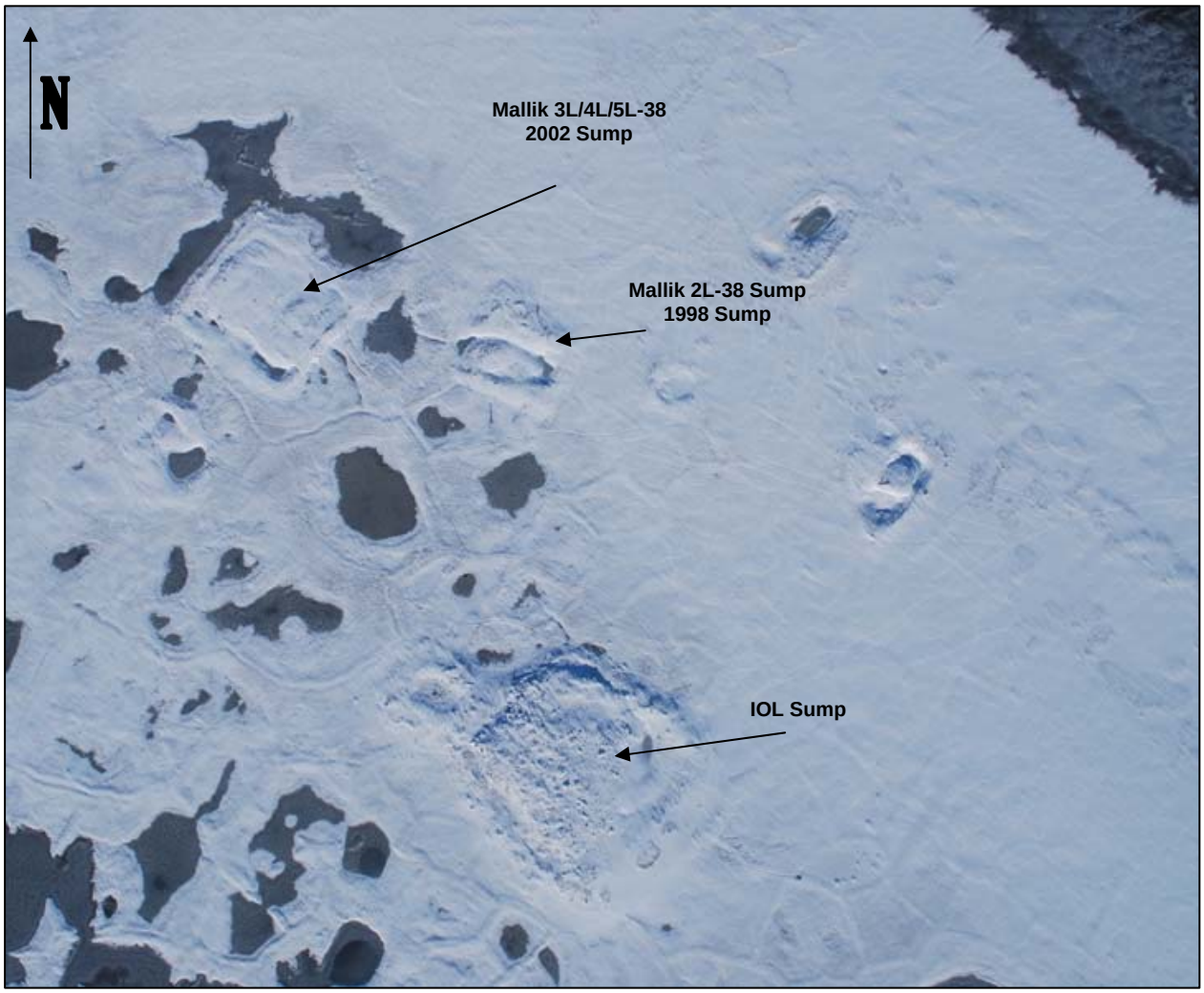
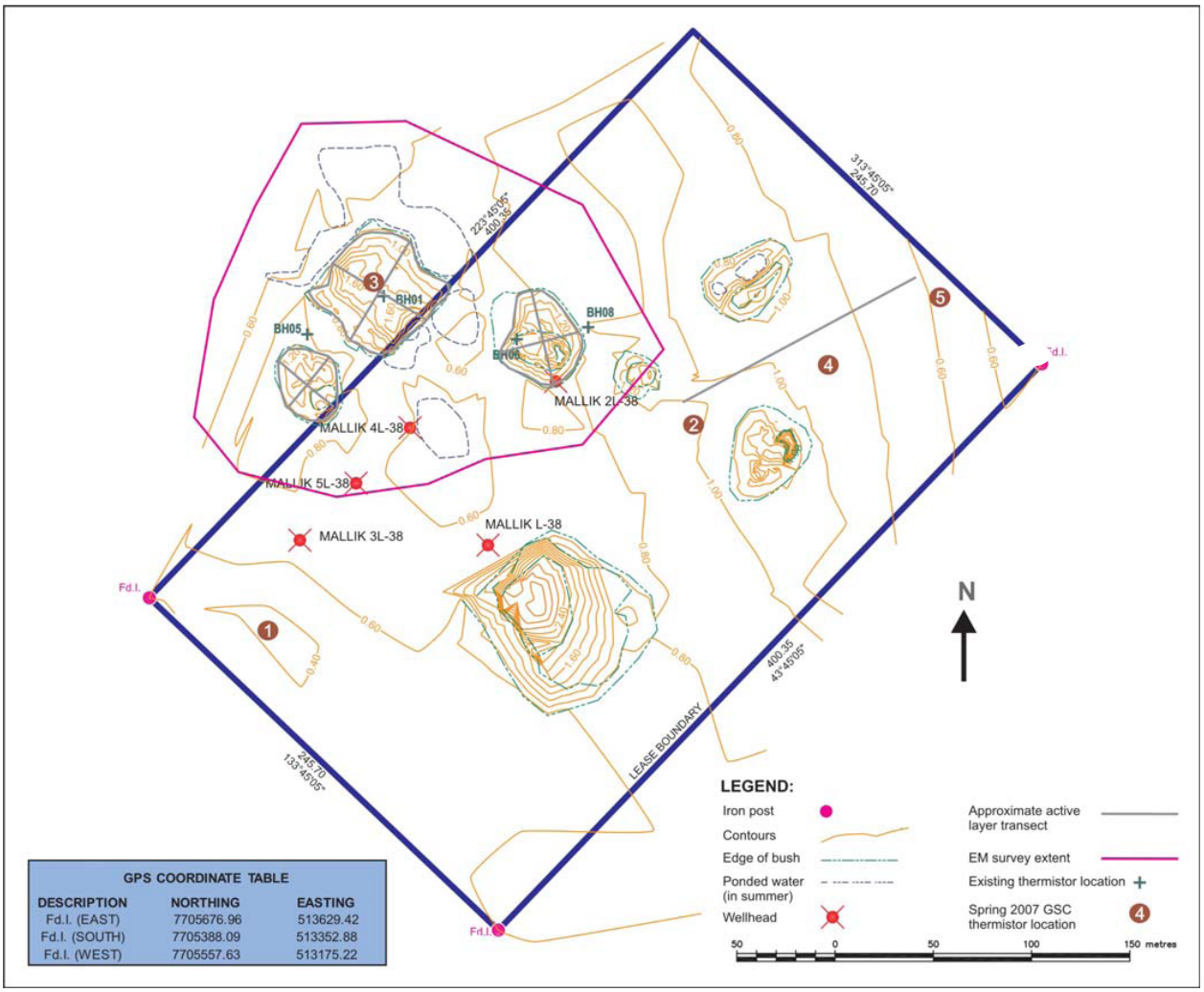


Figure 2-3 Thermistor Locations



3 Methods

The methods for monitoring the Mallik sumps were developed using the following documents:

- Water License No. N7L1-1817 (NWT Water Board, 2004)
- Previous requests and requirements from the NWT Water Board (NWT Water Board, 2006)
- *Protocol for the Management of Drilling Waste Disposal Sumps* – Inuvialuit Settlement Region NWT (NWT Water Board, 2006a)

The following section outlines the methodology followed throughout each component of the monitoring program, including: visual assessment; active layer depth measurements; ground temperature monitoring; electromagnetic surveys; and soil and water sampling.

3.1 Visual Assessment

Visual assessments were completed by Kavik-AXYS representatives during the late-September 2010 visit to document physical conditions of the sumps and sump caps including:

- settlement or subsidence
- presence or absence of ponding
- damage to existing monitoring facilities (thermistors and/or dataloggers)
- erosion, stress or tension cracks
- vegetation health and establishment on the sump cap or surrounding area

Visual assessments were performed from both the air and ground. Due to the presence of snow cover on the site, a detail visual assessment of the vegetation couldn't be realized. Site photographs taken from both the ground and from the air can be reviewed in Appendix A.

3.2 Active-Layer Depth Measurements

Using a specially designed probe, active-layer depths were measured during the September 2010 site assessment. Methodology and locations of measurement points were as per the *Protocol for the Monitoring of Drilling-Waste Disposal Inuvialuit Settlement Region Northwest Territories* (NWT Water Board 2006). Active-layer depths were monitored at a control area, on the sump caps and at the perimeter of the sump caps. The following active-layer measurements were obtained for each sump:

- **Control** – 8 active-layer measurements were collected along a transect north of the control thermistor, paralleling the sump on the east side
- **Sump Cap** – 5 active-layer measurements were collected within the centre and perimeter of the sump cap
- **Sump Perimeter** – 8 active-layer measurements were collected on the undisturbed area surrounding the sump cap within 2 meters (m) of the interface between the sump cap and the surrounding undisturbed area

3.3 Ground Temperature Monitoring

In 2007, four thermistors were installed in and surrounding the Mallik sumps, as specified in *Part H: Conditions Applying to Abandonment and Restoration under NWT Water Licence No. N7L1-1817.* The thermistors were installed to a maximum depth of 10 m, with sensors located at various levels below grade as required under the Licence. See Figure 2-2 for thermistors locations and Table 3-1 for logging depth.

Table 3-1 Current Depths of Thermistor Sensors

Thermistor Sensor	Logging Depths (mbg)			
	Thermistor 07GSC-01[1]	Thermistor 07GSC-02[1]	Thermistor 07GSC-03[1]	Thermistor 07GSC-04
1	-	1.0	1.0	1.0
2	0.35	1.5	1.5	1.5
3	0.85	2.0	2.0	2.0
4	1.35	2.5	2.5	2.5
5	2.35	4.5	4.5	3.5
6	4.35	6.5	6.5	5.5
7	6.85	10.5	10.5	8.0
8	4.28	5.65	5.65	10.5

[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e. the depth of the sensor #8 is above the sensor #6).

Two new thermistors and dataloggers were installed during the September 2010 field visits in order to replace the weather station and ground temperature materials that were damage during the previous season. The new thermistors have been set up on the 2L-38 well head location marker and will record hourly ground surface and air temperatures (see Figure 3-1). Data for those new thermistors will be presented in the 2011 report.

Figure 3-1 Weather Station Thermistor

3.4 Electromagnetic Surveys

ESSIS conducted EM surveys (EM31 and EM38) on September 30th, 2009 using Geonics EM31 and EM38 ground conductivity meters. These instruments were used to identify the lateral extents of ion-rich regions, which might reflect ion migration from the sump to the surrounding areas and help identify the requirement for additional sampling. The survey measures apparent conductivity of the soil around the sump site to determine if salts in the drilling waste are migrating through the soil from the sump. The EM38 meter measures between about 0.0 and 1.5 m (shallow) while the EM31 meter measures between about 0.0 and 5.0 m (deep).

Figure 3-2 Electromagnetic Survey (EM31)

3.5 Soil Sampling

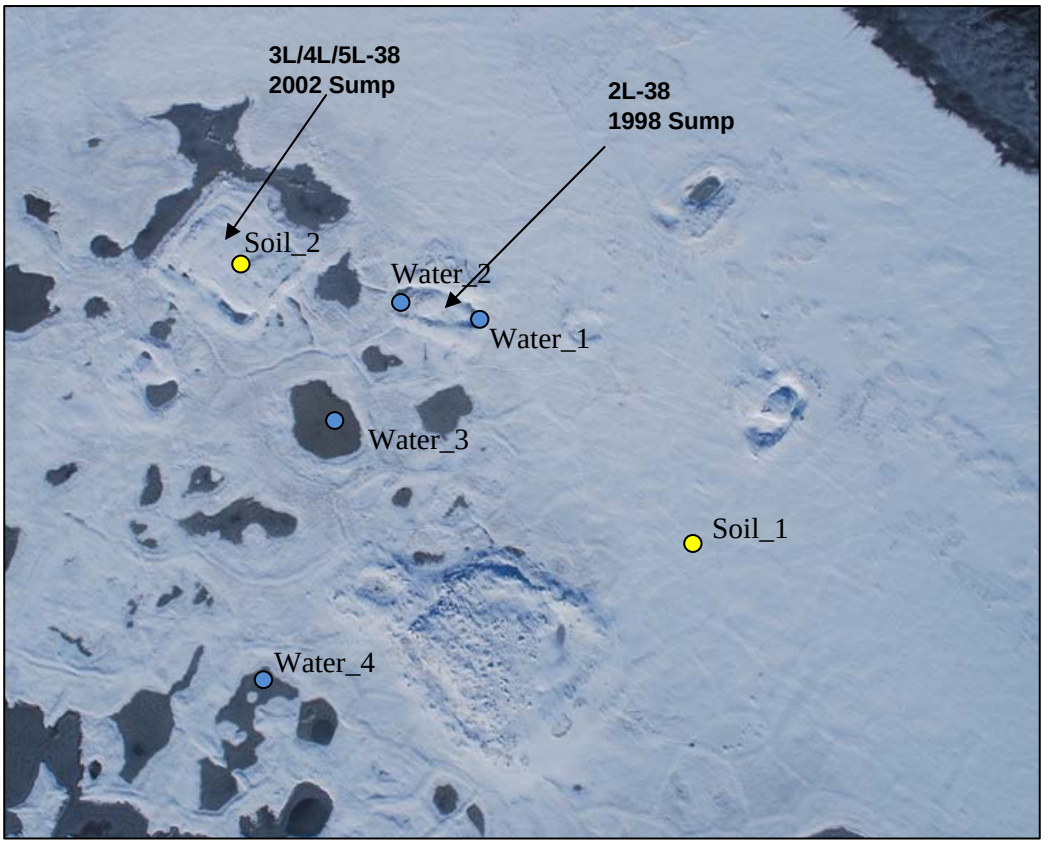
The purpose of the soil investigation was to investigate the lack of vegetation on one area of the 3L/4L/5L-38 2002 sump cap. Soil samples from the surface, middle, and bottom of the active-layer were obtained in this area (Mallik_soil_02). Additional samples from an undisturbed control area were collected (Mallik_soil_01). See Figure 3-3 for the location of the soil samples in 2010.

The soil samples were obtained using a hand-driven Dutch auger. The samples were removed from the auger by hand using clean latex gloves. The samples were retained for analysis in laboratory-issued zip-lock containers and submitted to Maxxam Analytics Inc. Laboratory (Maxxam). See Appendix C for the certified laboratory results from Maxxam.

3.6 Water Sampling

Surface water was sampled from both natural ponding (i.e. a control area away from the sumps) and in an area related to previous ground disturbance (i.e. in the sump area). Sampling was completed following standard water sampling protocol. Samples were collected at arm's length (about 1 m) from the edge of the ponding areas, and then stored in a laboratory-issued 500 mL plastic jar and two 250 mL amber glass jars. Samples were submitted to Maxxam Analytical in Edmonton, AB for salinity analysis. The certified laboratory results are located in Appendix C. The guidelines used to compare the results from the water sampling program are the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for Freshwater and Aquatic Life*.

Figure 3-3 Soil and water sample locations



4 Results

4.1 Visual Assessment

Visual assessment during the 2010 was limited due to extensive snow cover (15-20 cm of fresh snow on site). Although the revegetation of the sump caps couldn't be evaluated, a general overview of the site topography and main features was realized (Figure 4-2 to 4-4).

The Mallik site is characterized by several water ponding areas. These ponding areas are generally shallow (about 30 cm of water) and their extent range from a few square meters (m^2) to about 250 m^2. The presence and extent of each pond is similar to observations during previous field visits. Small shallow depressions were observed on both east and west limits of the 1998 sump. These depressions, approximately 50 to 60 cm below the ground surface, were filled up with water at the time of visit (Figure 4-4). Two samples were collected for water analysis (see section 4.5 Water Analysis). Observations for evidence of settlement, erosion or instability were limited due to snow cover. A detailed visual assessment of the vegetation will be undertaken during the 2011 field visit.

Figure 4-1 Aerial view of the area looking west (September 28th, 2010)

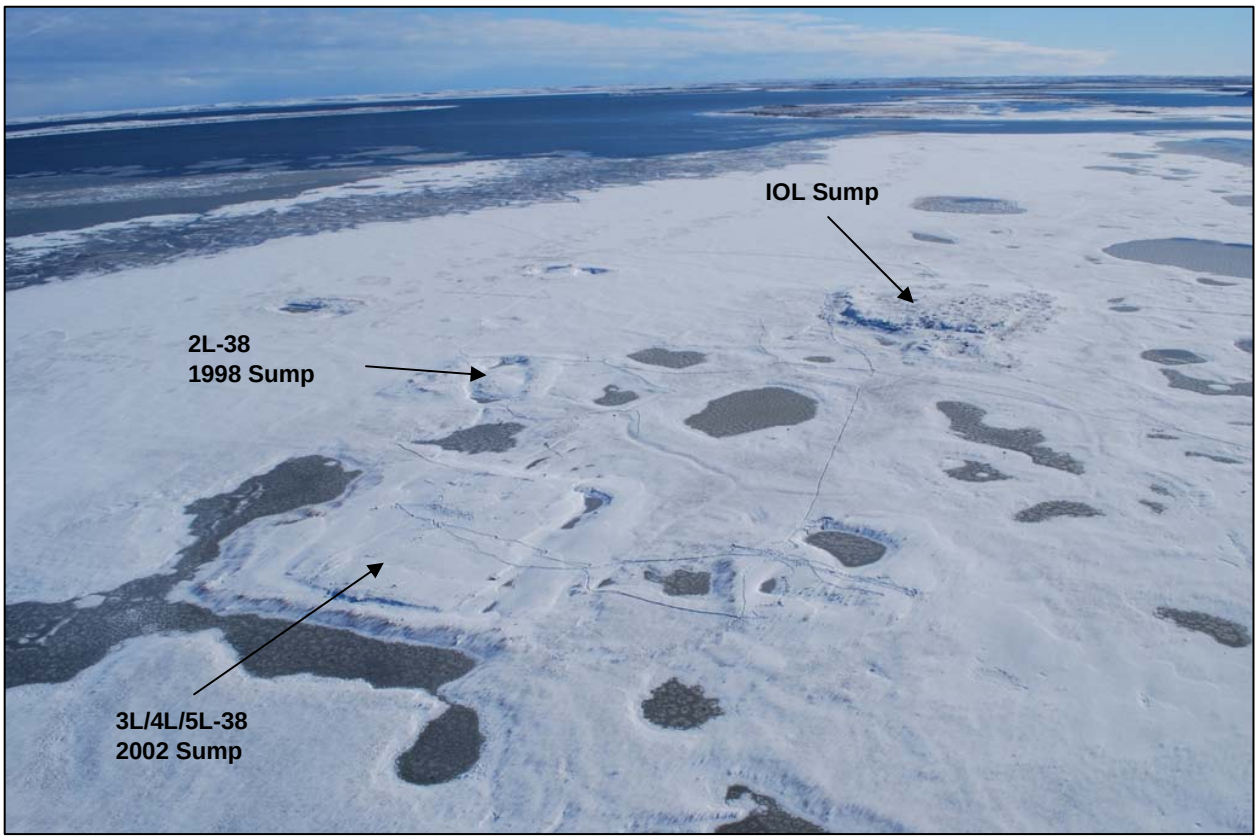


Figure 4-2 Aerial view of Mallik 2L-38 (1998 sump)

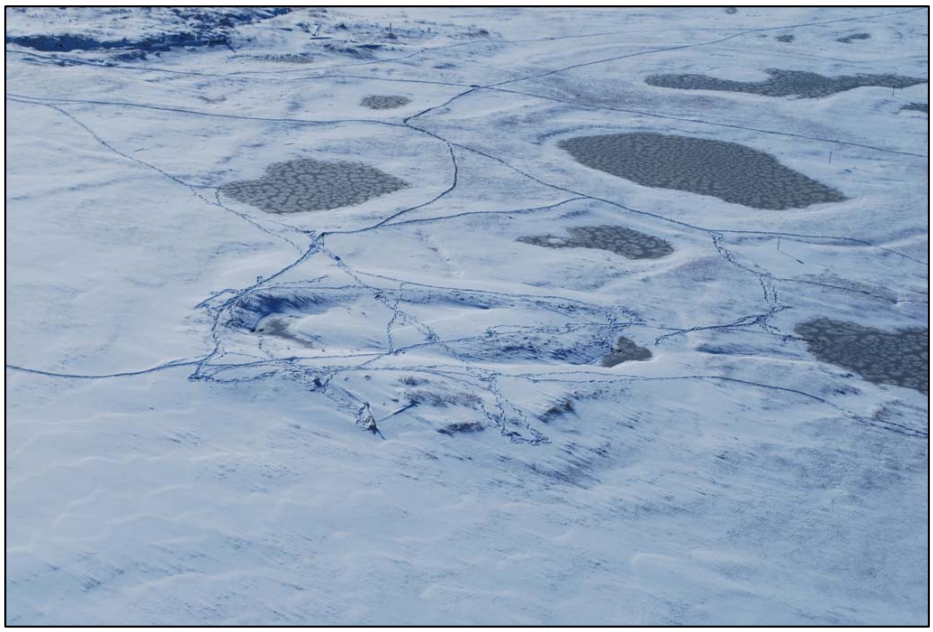


Figure 4-3 Aerial view of Mallik 3L/4L/5L-38 (2002 sump)

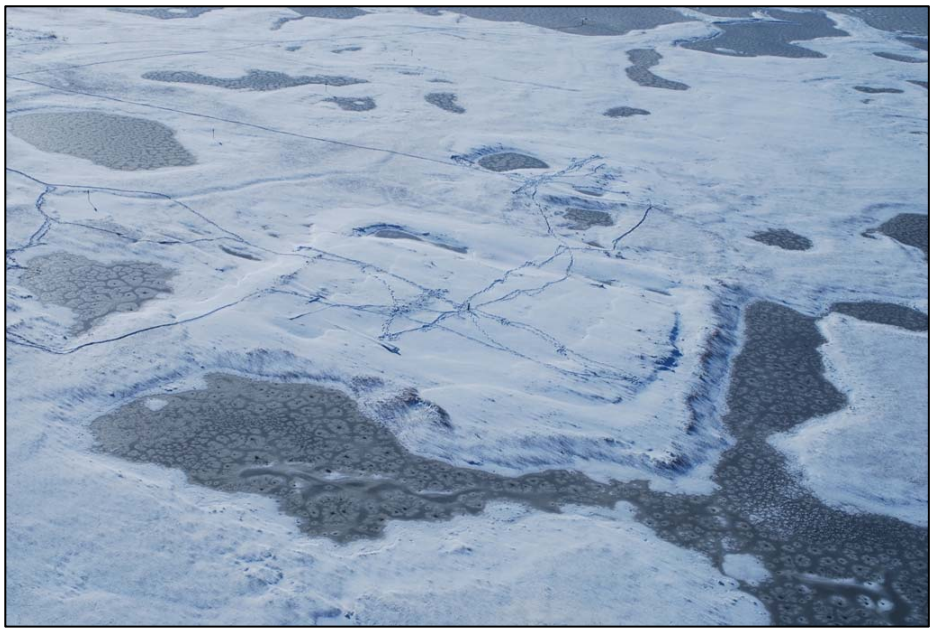


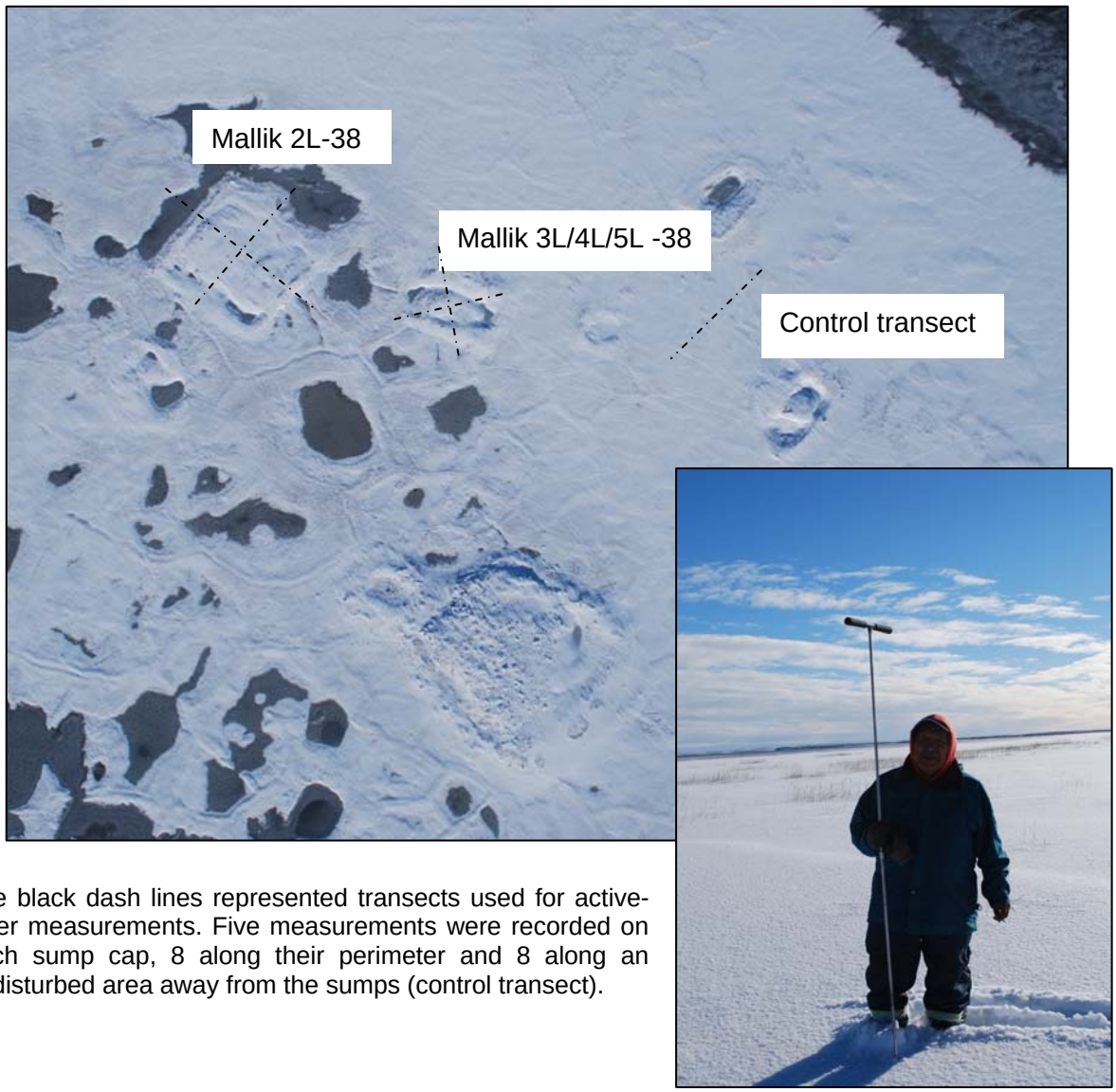
Figure 4-4 View of a subsidence area at the east and west limits of the 1998 drilling sump. Water was sampled from both ponds for analysis (Mallik_water_01 and Mallik_water_02).

4.2 Active Layer Depth Measurements

Active layer depths were measured on September 28th, 2010. The locations of the different transects are displayed on Figure 4-5. See Table 4-1 for the corresponding depths.

The active layer depth on both sump caps range from 100 to 132 cm (Table 4-1). The average active layer depth for each sump is consistent and range from 118 to 119 cm. Active layer depths around the perimeter of the sump caps ranged between 105 and 126 cm and respectively average averaged 110 cm (1998 camp sump), 113 cm (1998 drilling sump) and 121 cm (2002 drilling sump). Active layer depths along the controlled transect ranged from 105 cm to 121 cm and averaged 113 cm. The control transect is located in an undisturbed area located about 150 m east from the Mallik 3L/4L/5L-38 sump.

Figure 4-5 Location of Active-Layer Transects



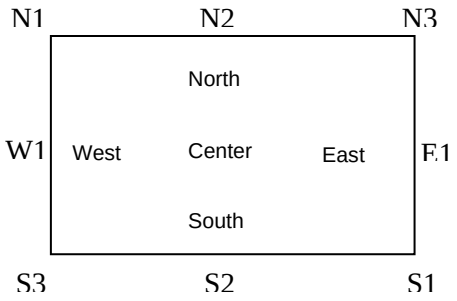
The black dash lines represented transects used for active-layer measurements. Five measurements were recorded on each sump cap, 8 along their perimeter and 8 along an undisturbed area away from the sumps (control transect).

Table 4-1 Active-Layer Measurements

Mallik 2L-38 (1998 Drilling Sump)			
Sump cap		**Sump perimeter**	
Id.	**Thaw depth (cm)**	**Id.**	**Thaw depth (cm)**
1.North	125	1. N1	110
2.East	120	2. N2	107
3.South	132	3. N3	122
4.West	100	4. E1	108
5.Center	120	5. S1	105
		6. S2	109
		7. S3	120
		8. W1	122
Average	119	Average	113

Mallik 3L/4L/5L-38 (2002 Drilling Sump)			
Sump cap		**Sump perimeter**	
Id.	**Thaw depth (cm)**	**Id.**	**Thaw depth (cm)**
1.North	123	1. N1	120
2.East	121	2. N2	118
3.South	111	3. N3	116
4.West	118	4. E1	125
5.Center	116	5. S1	115
		6. S2	120
		7. S3	126
		8. W1	125
Average	118	Average	121

Control Transect	
Waypoint Id.	**Thaw depth (cm)**
23	110
24	105
25	112
26	110
27	110
28	121
29	120
30	119
Average	113



4.3 Ground Temperature Monitoring

Automated ground temperature monitoring is conducted at the Mallik L-38 site since April 2007. The thermistors depth ranged from just below ground surface (i.e. 40 cm) to a maximal depth of 10.5 m. Thermistors are set up to record hourly temperature. The following sections present a summary of the ground temperature conditions recorded at 4 thermistors locations (07GSC-01 to 07GSC-04) for the August 2009 to August 2010 period. The locations of the thermistors are shown on Figure 2-3.

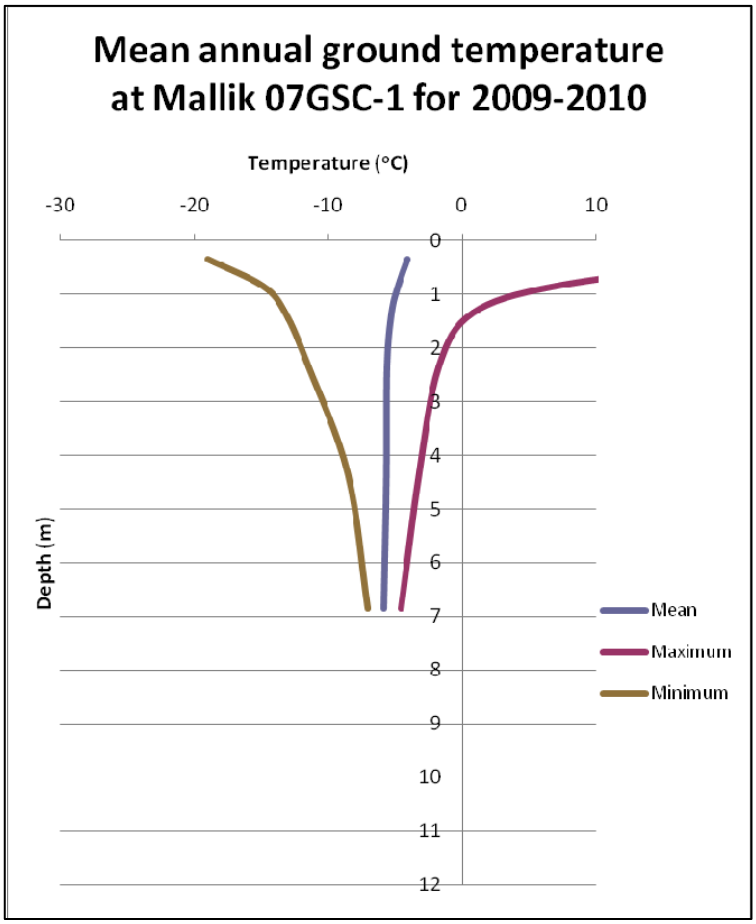
Figures 4-6 to 4-9 show the mean, maximum and minimum annual ground temperature for each sensor depth. See Appendix A for diagrams showing annual variation of the ground temperature at each sensor depth.

Air and ground surface temperature were not recorded at the Mallik site (weather station) during the 2009-2010 due to equipment malfunction (damage by wildlife). Replacement thermistors and dataloggers have been installed.

Thermistor 07GSC-01 is located in an undisturbed area located approximately 200 m southwest of the Mallik sumps. The thermistor is located at the edge of a large pond, characterised by approximately 30 cm of water at the time of visit (Figure 4-6). The mean annual ground temperature recorded at this site is of -5.2 ^{o}C. The maximum surface thawing (i.e. maximum active layer depth) ranged between 1.35 m and 2.35 m.

Figure 4-6 Ground temperature at Thermistor 07GSC-01

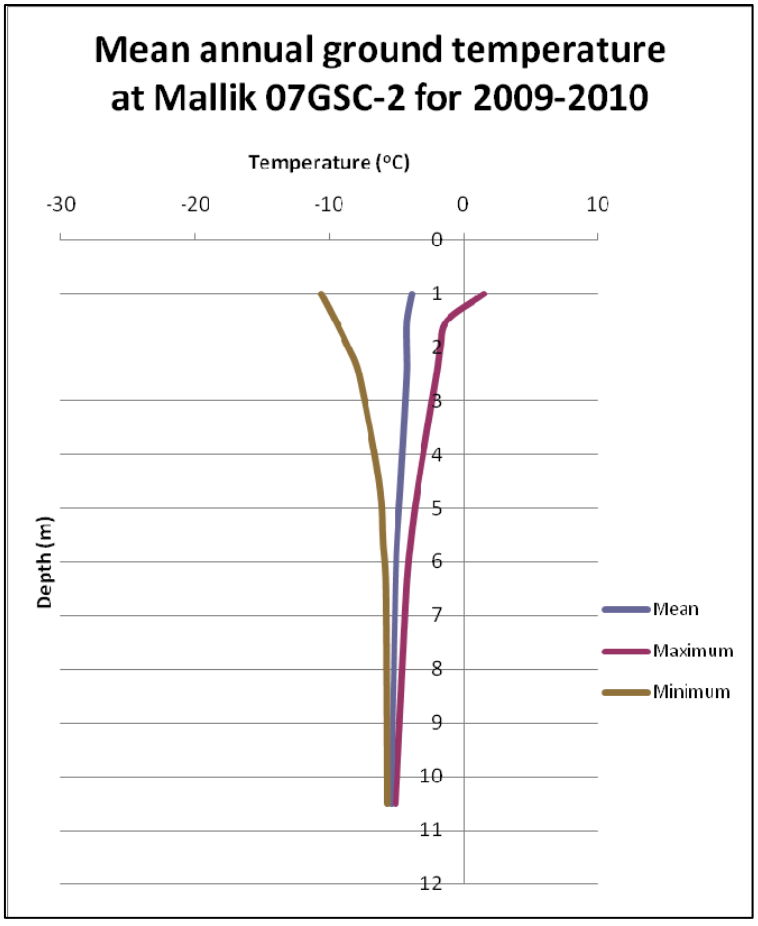
Sensor depth (m)	Mean	Maximum	Minimum
0.35	-4.1	21.7	-19.0
0.85	-4.8	7.0	-14.9
1.35	-5.3	0.7	-13.2
2.35	-5.6	-1.8	-11.5
4.35	-5.7	-3.3	-8.5
6.85	-5.9	-4.6	-7.0



Thermistor 07GSC-02 is located in an undisturbed site with low sedge and grass cover. The mean annual ground temperature recorded at this site corresponds to -4.6 ^{o}C. The maximum surface thawing depth ranged between 1 m and 1.5 m.

Figure 4-7 Ground temperature at Thermistor 07GSC-02

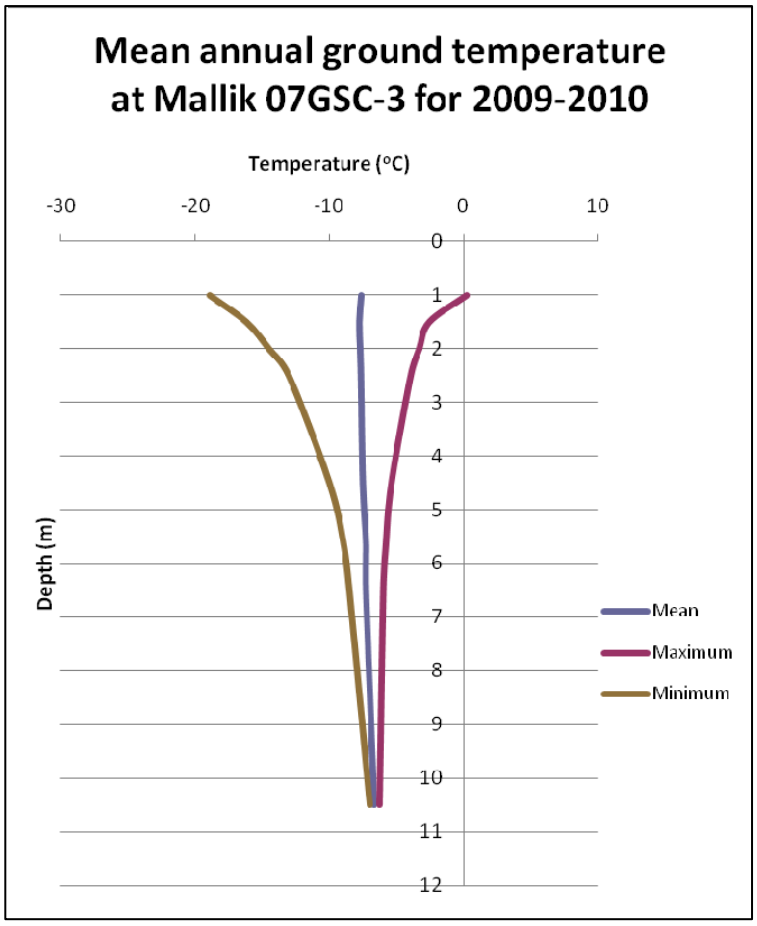
Sensor depth (m)	Mean	Maximum	Minimum
1	-3.9	1.5	-10.6
1.5	-4.2	-1.3	-9.5
2	-4.3	-1.8	-8.6
2.5	-4.2	-2.1	-7.8
4.5	-4.7	-3.4	-6.3
5.65	-5.0	-4.0	-6.0
6.5	-5.1	-4.3	-5.8
10.5	-5.4	-5.1	-5.7



Thermistor 07GSC-03 is the only one located within disturbed material and is installed at the center of the Mallik 3L/4L5L-38 sump (2002 drilling sump). The mean annual ground temperature recorded at this site is of -7.4°C. The maximum active layer thickness ranged between 1 m and 1.5 m.

Figure 4-8 Ground temperature at Thermistor 07GSC-03

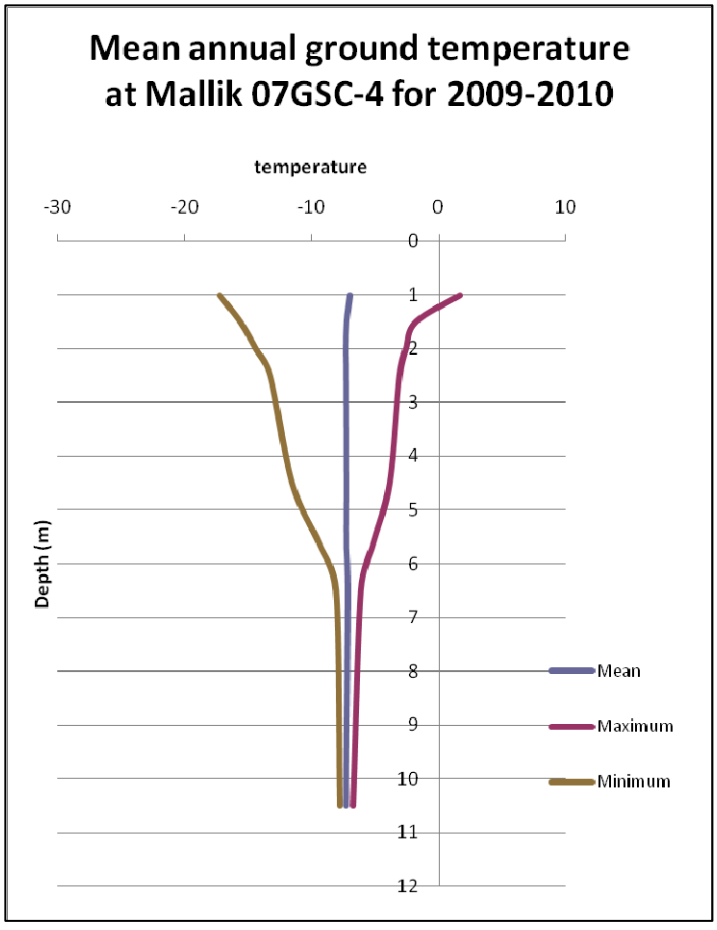
Sensor depth (m)	Mean	Maximum	Minimum
1	-7.6	0.2	-18.9
1.5	-7.8	-2.6	-16.2
2	-7.7	-3.3	-14.5
2.5	-7.7	-3.9	-13.0
4.5	-7.5	-5.4	-10.0
5.65	-7.3	-5.8	-8.9
6.5	-7.3	-6.0	-8.5
10.5	-6.6	-6.3	-7.0



Thermistor 07GSC-04 is located at an undisturbed site approximately 150 m west of Mallik 2L-38 (1998 drilling sump). The mean annual ground temperature recorded at this site is of -7.2°C. Maximum depth of the active layer ranged between 1 m and 1.5 m.

Figure 4-9 Ground temperature at Thermistor 07GSC-04

Sensor depth (m)	Mean	Maximum	Minimum
1.0	-7.0	1.7	-17.2
1.5	-7.3	-1.8	-15.6
2.0	-7.3	-2.6	-14.4
2.5	-7.3	-3.1	-13.3
4.5	-7.3	-3.9	-11.5
5.7	-7.3	-5.2	-9.4
6.5	-7.2	-6.1	-8.1
10.5	-7.3	-6.8	-7.8



4.4 Electromagnetic Surveys

Detailed electromagnetic survey results are presented in Appendix B. As expected, both the EM38 Survey (0 to 1.5 m) and the EM31 Survey (0 to 5 m) have identified areas of high apparent conductivity values on both the Mallik 2L-38 sump (1998 sump) and on the 3L/4L/5L-38 sump (2002 sump) when compared to the surrounding areas. These elevated responses confirm the presence of saline drill cuttings within the sumps, as they have been corrected for the salinity due to sea water infiltration.

The EM38 Survey (0 to 1.5 m) reveals the presence of an additional area of high apparent conductivity located approximately 60 m from the southern edge of the 3L/4L/5L-38 sump (2002 sump). The area consists of a depression filled by water (see Figure 4-10). The depression is approximately 30 m x 35 m and about 60 cm deep. A water sample was collected for analysis (sample Mallik_Water_3). Soil samples will be collected from this area during the 2011 field visit to assess if this high apparent conductivity area is an effect of free standing water of possible saline source (i.e. sea water).

Modestly elevated conductivity measurement values can be seen in some areas beyond the sumps boundaries. Those readings are most likely the results of natural variations and /or drill site activities and are not necessarily indicative of sump seepage. Most of those values correspond to shallow water ponds and are likely related to the evaporation of seawater from previous annual storm surges.

Figure 4-10 Depression characterized by high apparent conductivity values (from the EM38 survey)

4.5 Soil Sampling

Soils from two different locations were collected during the 2010 field visit. See Figure 3-2 for sampling locations and Table 4-2 for sampling depth. Soil samples were collected from the surface, middle and bottom of the active layer for both locations. The first series of sample collected (Mallik_soil_1.1 to 1.3) correspond to a control or undisturbed area located approximately 200 m southwest of the Mallik 2L-38 sump. The second series of sample was collected from the 2002 sump (Mallik_soil_2.1 to 2.3).

Table 4-2 Soil sampling depth

Soil sample	Sampling depth
Mallik_soil_1.1	0-10 cm
Mallik_soil_1.2	45-55 cm
Mallik_soil_1.3	100-110 cm
Mallik_soil_2.1	105-115 cm
Mallik_soil_2.2	50-60 cm
Mallik_soil_2.3	0-10 cm

All samples consist of silt (>70%) with very minor fine sand and clay. The control soil sampled (Mallik_soil_1.1 to 1.3) have electrical conductivity concentrations ranging between 9.3 and 9.7. In comparison, the soils sampled on the 2002 sump have electrical conductivity (EC) ranging from 9.8 to 11. pH of both sample series ranged from 7.8 (surface sample) to 7.89 (bottom sample). Samples from the control site display a high amount of sodium (Na) in comparison with the amount of potassium (K). This is a good indicator of natural salinity, as sea water influenced soils will be Na rich. The soil samples from the 2002 sump display a much higher amount of K and Chloride (Cl) presence in the samples, which is likely the migration of potassium rich drilling wastes being displaced from the sump to the soils above. Sample Mallik_soil_2.1 from the depth of 105-115 cm, resulted in 9900 mg/L for soluble Cl and the EC ration was 11. As the thickness of the cap is uncertain prior to this survey, this suggests the sample may have contained contents of the sump and minimum migration of the saline waters from the sump is migrating upwards into the active layer. Full soil analysis results are presented in table 4-3 and 4-4.

Table 4-3 Soil Sampling Results – Salinity

Maxxam ID		X44159	X44206	X44207		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970	A012970		
	Units	**MALLIK SOIL 1.1**	**MALLIK SOIL 1.2**	**MALLIK SOIL 1.3**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	45	51	45	N/A	4313417
Cation Sum	meq/L	47	53	47	N/A	4313417
Cation/EC Ratio	N/A	9.3	9.7	9.5	0.1	4313411
Ion Balance	N/A	1.1	1.0	1.1	0.01	4313416
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	1400 (1)	1600 (1)	1400 (1)	10	4320611
Soluble Conductivity	dS/m	5.1	5.5	5.0	0.02	4317205
Soluble (CaCl2) pH	N/A	7.80	7.82	7.89	N/A	4317308
Sodium Adsorption Ratio	N/A	13	13	10	0.1	4313418
Soluble Calcium (Ca)	mg/L	170	210	220	1.5	4320837
Soluble Magnesium (Mg)	mg/L	60	73	70	1.0	4320837
Soluble Sodium (Na)	mg/L	770	840	690	2.5	4320837
Soluble Potassium (K)	mg/L	18	15	12	1.3	4320837
Saturation %	%	52.2	48.9	51.5	N/A	4316813
Soluble Sulphate (SO4)	mg/L	300	350	210	5.0	4320837
Theoretical Gypsum Requirement	tons/ac	<0.1	<0.1	<0.1	0.1	4313420

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Table 4-4 Soil Sampling Results – Salinity

Maxxam ID		X44208		X44209	X44210		
Sampling Date		2010/09/28 12:00		2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970		A012970	A012970		
	Units	**MALLIK SOIL 2.1**	**RDL**	**MALLIK SOIL 2.2**	**MALLIK SOIL 2.3**	**RDL**	**QC Batch**
Calculated Parameters							
Anion Sum	meq/L	310	N/A	94	110	N/A	4313417
Cation Sum	meq/L	320	N/A	96	110	N/A	4313417
Cation/EC Ratio	N/A	11	0.1	9.9	9.8	0.1	4313411
Ion Balance	N/A	1.0	0.01	1.0	0.99	0.01	4313416
Soluble Parameters							
Soluble Chloride (Cl)	mg/L	9900 (1)	50	2800 (1)	3100 (1)	30	4320611
Soluble Conductivity	dS/m	30	0.02	9.7	11	0.02	4317205
Soluble (CaCl2) pH	N/A	7.80	N/A	7.85	7.89	N/A	4317308
Sodium Adsorption Ratio	N/A	9.9	0.1	4.3	4.9	0.1	4313418
Soluble Calcium (Ca)	mg/L	2000	1.5	830	840	1.5	4320837
Soluble Magnesium (Mg)	mg/L	900	1.0	170	190	1.0	4320837
Soluble Sodium (Na)	mg/L	2100	2.5	520	610	2.5	4320837
Soluble Potassium (K)	mg/L	2300	1.3	700	940	1.3	4320837
Saturation %	%	52.4	N/A	44.5	45.0	N/A	4316813
Soluble Sulphate (SO4)	mg/L	1700	5.0	780	1000	5.0	4320837
Theoretical Gypsum Requirement	tons/ac	<0.1	0.1	<0.1	<0.1	0.1	4313420

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

4.6 Water Sampling

Surface water samples were collected at four locations (see Figure 3-2):

- A depression along the eastern edge of the 1998 drilling sump (Mallik_water_01)
- A depression along the western edge of the 1998 drilling sump (Mallik_water_02)
- A shallow pond between the 2002 drilling sump and the 1998 drilling sump (Mallik_water_03)
- This electromagnetic survey revealed that this area is characterized by high apparent conductivity (see section 4.4)
- A large pond located west of thermistor 07GSC-01 (Mallik_water_04), a location not anticipated to be affected by the sumps (control sample)

Of the four surface water samples taken, two samples (Mallik_water_02 and _03) have higher values than the control sample. Of most notable concern would be the conductivity levels at these locations. The control sample was analyzed at 8800 uS/cm, whereas _02 and _03 were analyzed at 14000 and 11000 uS/cm respectively. As well for both these samples the dissolved Cl was elevated and the total dissolved solids for sample _02 was almost double the value of the control.

The elevation of the salinity for sample Mallik_water_02 could be explained in part by the fact that the site is located within the storm surge area and that it is flooded annually with seawater; however it is likely there is also influence from migration of sump contents, as indicated by the level of Cl in the sample combined with the EM38 results. The elevation of the salinity for sample Mallik_water_03 can also be explained by the annual seawater infiltration, however other unnatural influences cannot be ruled out and should be investigated further. Water analysis results are presented in Table 4-5 and 4-6.

Table 4-5 Water Sampling Results – Routine Water

Sample Id.		MALLIK_WATER_1		MALLIK_WATER_2		MALLIK_WATER_3		MALLIK_WATER_4		
Date sampled		9/28/2010		9/28/2010		9/28/2010		9/28/2010		
Calculated Parameters	**Units**		**RDL**		**RDL**		**RDL**		**RDL**	**QC Batch**
Anion Sum	meq/L	77	N/A	130	N/A	100	N/A	86	N/A	4315308
Cation Sum	meq/L	74	N/A	130	N/A	97	N/A	77	N/A	4315308
Hardness (CaCO3)	mg/L	1820	0.5	1800	0.5	1290	0.5	921	0.5	4315306
Ion Balance	N/A	0.96	0.01	1.0	0.01	0.95	0.01	0.89	0.01	4315307
Dissolved Nitrate (NO3)	mg/L	0.35	0.01	0.09	0.01	<0.1	0.1	<0.1	0.1	4315310
Nitrate plus Nitrite (N)	mg/L	0.078	0.003	0.020	0.003	<0.03	0.03	<0.03	0.03	4315312
Dissolved Nitrite (NO2)	mg/L	<0.01	0.01	<0.01	0.01	<0.1	0.1	<0.1	0.1	4315310
Total Dissolved Solids	mg/L	4850	10	8030	10	5750	10	4720	10	4315315
Misc. Inorganics										
Conductivity	uS/cm	7900	1	14000	1	11000	1	8800	1	4314303
pH	N/A	7.74	N/A	7.93	N/A	7.96	N/A	8.08	N/A	4314302
Anions										
Alkalinity (PP as CaCO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Alkalinity (Total as CaCO3)	mg/L	240	0.5	300	0.5	230	0.5	270	0.5	4314288
Bicarbonate (HCO3)	mg/L	290	0.5	360	0.5	280	0.5	320	0.5	4314288
Carbonate (CO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Hydroxide (OH)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Dissolved Sulphate (SO4)	mg/L	900 (1)	30	650 (1)	20	420 (1)	2	260 (1)	10	4320487
Dissolved Chloride (Cl)	mg/L	1900 (1)	10	4100 (1)	50	3100 (1)	30	2700 (1)	30	4320480
Nutrients										
Dissolved Nitrite (N)	mg/L	<0.003	0.003	<0.003	0.003	<0.03 (2)	0.03	<0.03 (2)	0.03	4317728
Dissolved Nitrate (N)	mg/L	0.078	0.003	0.020	0.003	<0.03 (2)	0.03	<0.03 (2)	0.03	4317728
Elements										
Dissolved Calcium (Ca)	mg/L	570 (3)	3	330	0.3	200	0.3	110	0.3	4323296
Dissolved Iron (Fe)	mg/L	0.07	0.06	0.18	0.06	0.09	0.06	0.07	0.06	4323296
Dissolved Magnesium (Mg)	mg/L	95	0.2	240	0.2	190	0.2	160	0.2	4323296
Dissolved Manganese (Mn)	mg/L	0.078	0.004	0.12	0.004	0.006	0.004	<0.004	0.004	4323296
Dissolved Potassium (K)	mg/L	950 (1)	3	680 (3)	3	84	0.3	45	0.3	4323296
Dissolved Sodium (Na)	mg/L	300	0.5	1900 (1)	5	1600 (1)	5	1300 (1)	5	4323296

RDL = Reportable Detection Limit
EDL = Estimated Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to matrix interference
(3) Detection limits raised due to dilution to bring analyte within the calibrated range.
Dissolved greater than total. Results within acceptable limits of precision.

Table 4-6 Water Sampling Results – Regulated Metals (CCME/AT1) -Total

Sample Id.		MALLIK_WATER_1		MALLIK_WATER_2		MALLIK_WATER_3	MALLIK_WATER_4		
Date sampled		9/28/2010		9/28/2010		9/28/2010	9/28/2010		
Low Level Elements	**Units**		**RDL**		**RDL**			**RDL**	**QC Batch**
Total Cadmium (Cd)	ug/L	0.11	0.03	0.11	0.03	<0.03	0.09	0.03	4315608
Elements									
Total Aluminum (Al)	mg/L	0.019	0.001	0.090	0.001	0.069	0.33	0.001	4322615
Total Antimony (Sb)	mg/L	0.0021	0.0002	<0.0002	0.0002	<0.0002	<0.0002	0.0002	4322615
Total Arsenic (As)	mg/L	0.0017	0.0002	0.0020	0.0002	0.0024	0.0023	0.0002	4322615
Total Barium (Ba)	mg/L	0.14	0.01	0.16	0.01	0.13	0.40	0.01	4323306
Total Beryllium (Be)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	<0.001	0.001	4322615
Total Boron (B)	mg/L	0.08	0.02	0.34	0.02	0.40	0.50	0.02	4323306
Total Calcium (Ca)	mg/L	560 (1)	3	340	0.3	210	120	0.3	4323306
Total Chromium (Cr)	mg/L	0.001	0.001	0.002	0.001	0.001	0.002	0.001	4322615
Total Cobalt (Co)	mg/L	0.0008	0.0003	0.0010	0.0003	0.0005	0.0007	0.0003	4322615
Total Copper (Cu)	mg/L	0.0033	0.0002	0.0051	0.0002	0.0039	0.0067	0.0002	4322615
Total Iron (Fe)	mg/L	0.28	0.06	0.87	0.06	0.58	1.3	0.06	4323306
Total Lead (Pb)	mg/L	0.0002	0.0002	0.0003	0.0002	0.0002	0.0010	0.0002	4322615
Total Lithium (Li)	mg/L	0.04	0.02	0.07	0.02	0.03	0.02	0.02	4323306
Total Magnesium (Mg)	mg/L	98	0.2	240	0.2	200	170	0.2	4323306
Total Manganese (Mn)	mg/L	0.098	0.004	0.15	0.004	0.025	0.053	0.004	4323306
Total Molybdenum (Mo)	mg/L	0.0025	0.0002	0.0018	0.0002	0.0013	0.0030	0.0002	4322615
Total Nickel (Ni)	mg/L	0.0079	0.0005	0.010	0.0005	0.0068	0.0053	0.0005	4322615
Total Phosphorus (P)	mg/L	<0.1	0.1	<0.1	0.1	<0.1	0.2	0.1	4323306
Total Potassium (K)	mg/L	960 (1)	3	670 (1)	3	88	50	0.3	4323306
Total Selenium (Se)	mg/L	0.0004	0.0002	0.0010	0.0002	0.0008	0.0006	0.0002	4322615
Total Silicon (Si)	mg/L	2.6	0.1	0.3	0.1	0.2	0.5	0.1	4323306
Total Silver (Ag)	mg/L	<0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001	4322615
Total Sodium (Na)	mg/L	320	0.5	1900 (1)	5	1700 (1)	1300 (1)	5	4323306
Total Strontium (Sr)	mg/L	2.5	0.02	2.5	0.02	1.7	1.2	0.02	4323306
Total Sulphur (S)	mg/L	280	0.2	200	0.2	130	79	0.2	4323306
Total Thallium (Tl)	mg/L	<0.0002	0.0002	<0.0002	0.0002	<0.0002	<0.0002	0.0002	4322615
Total Tin (Sn)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	0.001	0.001	4322615
Total Titanium (Ti)	mg/L	0.001	0.001	0.003	0.001	0.002	0.007	0.001	4322615
Total Uranium (U)	mg/L	0.0069	0.0001	0.0052	0.0001	0.0021	0.0010	0.0001	4322615
Total Vanadium (V)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	0.001	0.001	4322615
Total Zinc (Zn)	mg/L	0.009	0.003	0.009	0.003	0.003	0.008	0.003	4322615

RDL = Reportable Detection Limit EDL = Estimated Detection Limit (1) Detection limits raised due to dilution to bring analyte within the calibrated range.

5 Conclusion

The visual assessment of the site was made difficult by the presence of a continuous snow cover (approximately 15 cm at the time of visit). The 2011 field visit will be conducted earlier (most likely in August) in order to avoid the presence of snow. Two small depressional areas were noted on each end of the 2L-38 sump (1998 sump). No other major signs of settlement, erosion or instability were observed in other sump areas.

Active layer measurements showed some consistent values throughout the site. The average active layer depth on the sump caps is of 118.5 cm, 116.5 cm on the cap perimeters and 113 cm along a control transect. These active layer depths are consistent with other data gathered from monitoring sites located within the Mackenzie Delta (Tarnocai et al. 2004). The ground temperatures recorded on site reveal slight variations between the different thermistors. These variations can be explained by factors such as local climatic factors, variations in vegetation covers, variations in material type and size, compactions, etc... Ground temperature data for the thermistor located in the 3L/4L/5L-38 sump (2002 sump) revealed that maximum thaw depth is inferior to 1.5 m, which should allow the sump material to stay frozen all year long.

The results of the electromagnetic survey reveal the presence of a high response area located about 60 m from the southern edge of the 3L/4L/5L-38 sump (2002 sump). The area consists of a depression (belived to be natural) filled up by about 30 cm of water. The high conductivity is most probably explained by the annual input of sea water rather than by any form of seepage from one of the sumps. An increase thaw depth cause by the presence of free standing water could also explain this high response. Soil samples will be collected at this site during the 2011 field visit.

Soil and water sampling have revealed high salinity parameters, and for the most part they are consistent with samples collected outside of the influence of the sumps. The water sample taken from the NW ponding water of the 1998 sump revealed evidence of sump contents migration and further sampling for both water and soil should be conducted in this location.

6 References

Canadian Council of Ministers of the Environment (CCME). 1999 (Update 2007). *Canadian Environmental Quality Guidelines: Summary Table.* Winnipeg, Manitoba.

Dallimore, S.R. Uchilda, T., and Collett T.S. 1999. Scientific Results from JAPEX/JNOC/GSC 2L-38 Gas Hydrate Research Well, Mackenzie Delta, Northwest Territories, Canada. Geological Survey of Canada, Ottawa. Geological Survey of Canada Bulletin 544.

Dallimore, S.R and Collett T.S. 2005. Scientific Results from Mallik 2002 Gas Hydrate Production Research Well Program, Mackenzie Delta, Northwest Territories, Canada. Geological Survey of Canada, Ottawa. Geological Survey of Canada Bulletin 585.

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NWT Water Board. 2006a. *Protocol for the Monitoring of Drilling-Waste Disposal Sumps.* Yellowknife, Northwest Territories.

Tarnocai, C. Nixon, F.M and les Kutny. 2004. Circumpolar-Active-layer-Monitoring (CALM) Sites in the Mackenzie Valley, Northwestern Canada. Permafrost and Periglacial Processes, 15: 141-153.

Appendix A Thermistor Temperature Graphs

Figure A-1 Thermistor 07GSC-01 – Average Monthly Ground Temperatures (August 2009 to August 2010)

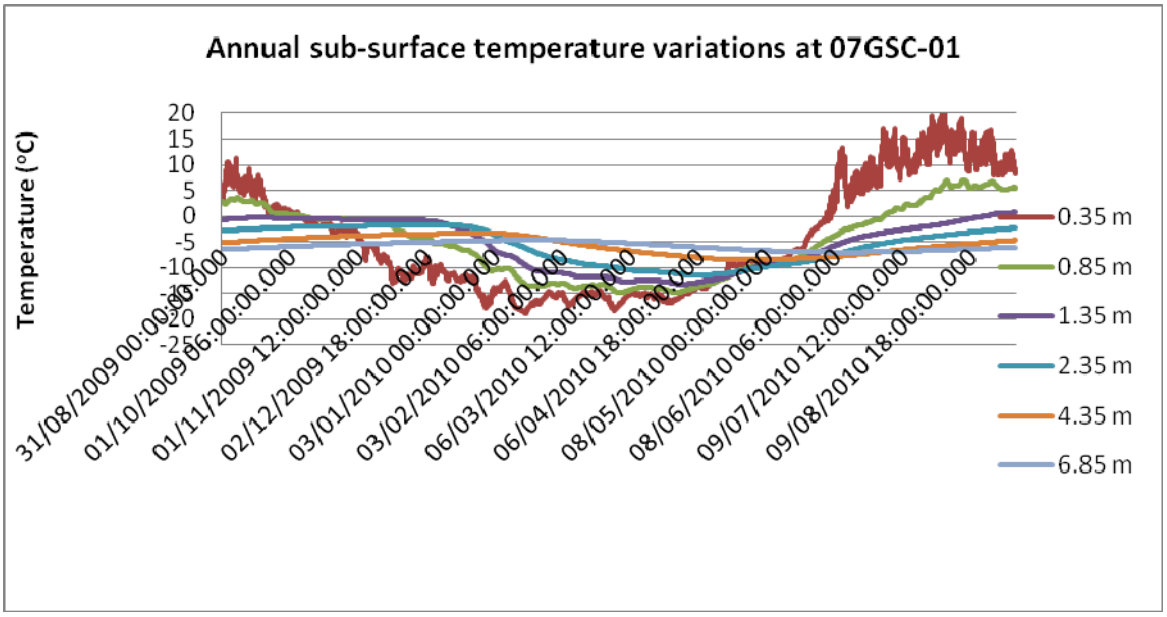


Figure A-2 Thermistor 07GSC-02 – Average Monthly Ground Temperatures (August 2009 to August 2010)

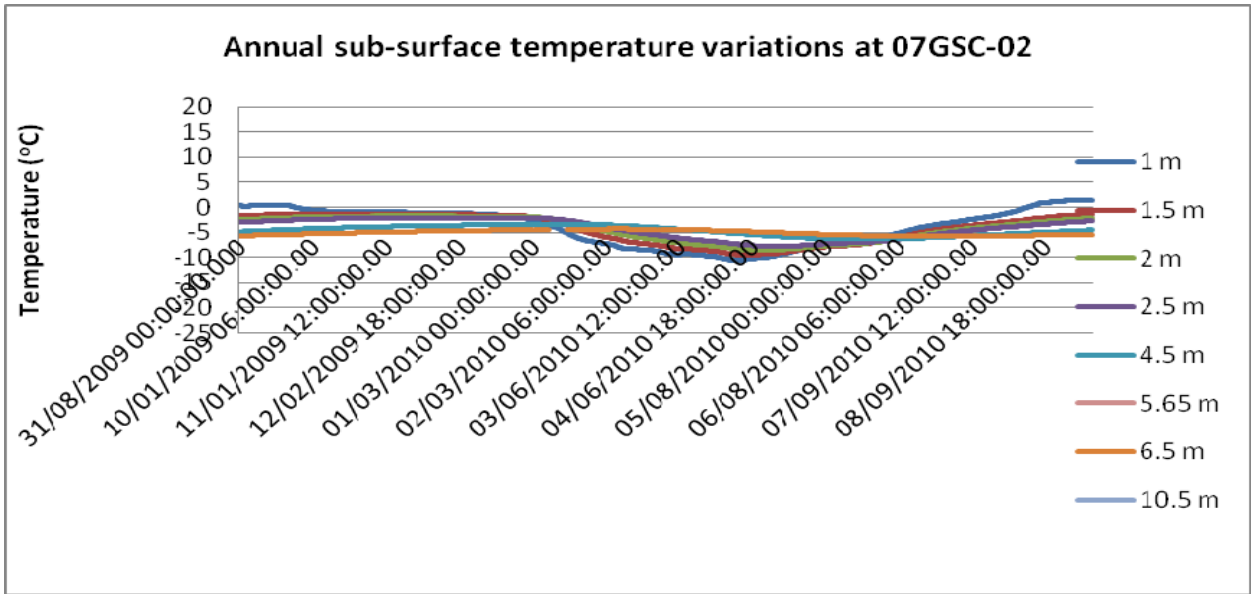


Figure A-3 Thermistor 07GSC-03 – Average Monthly Ground Temperatures (August 2009 to August 2010)

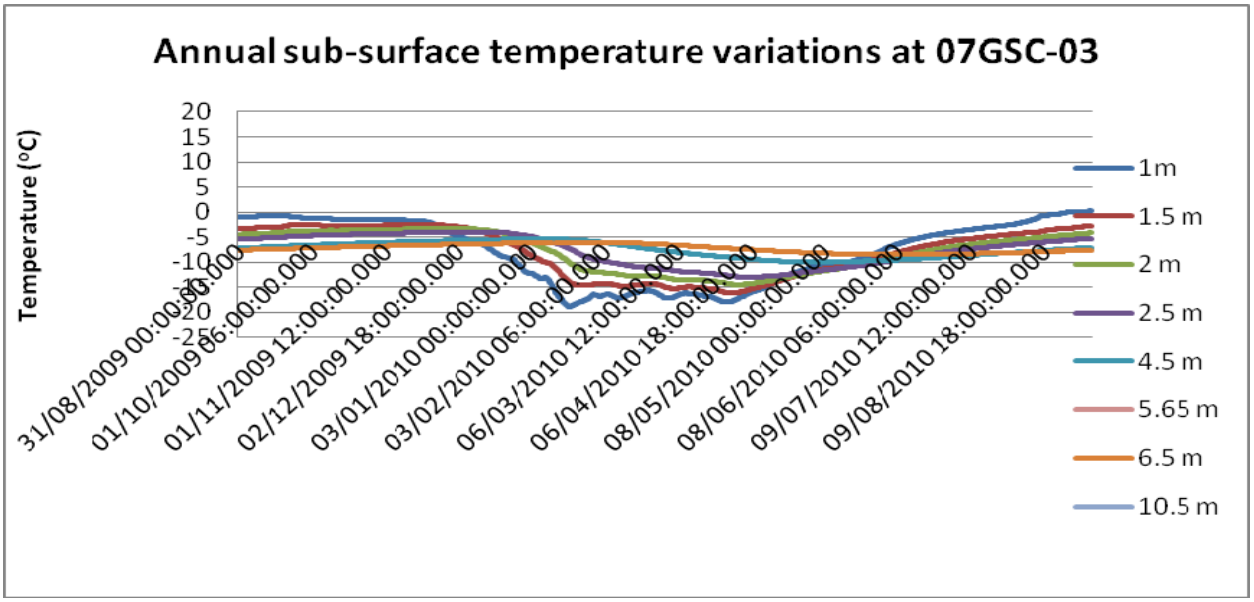
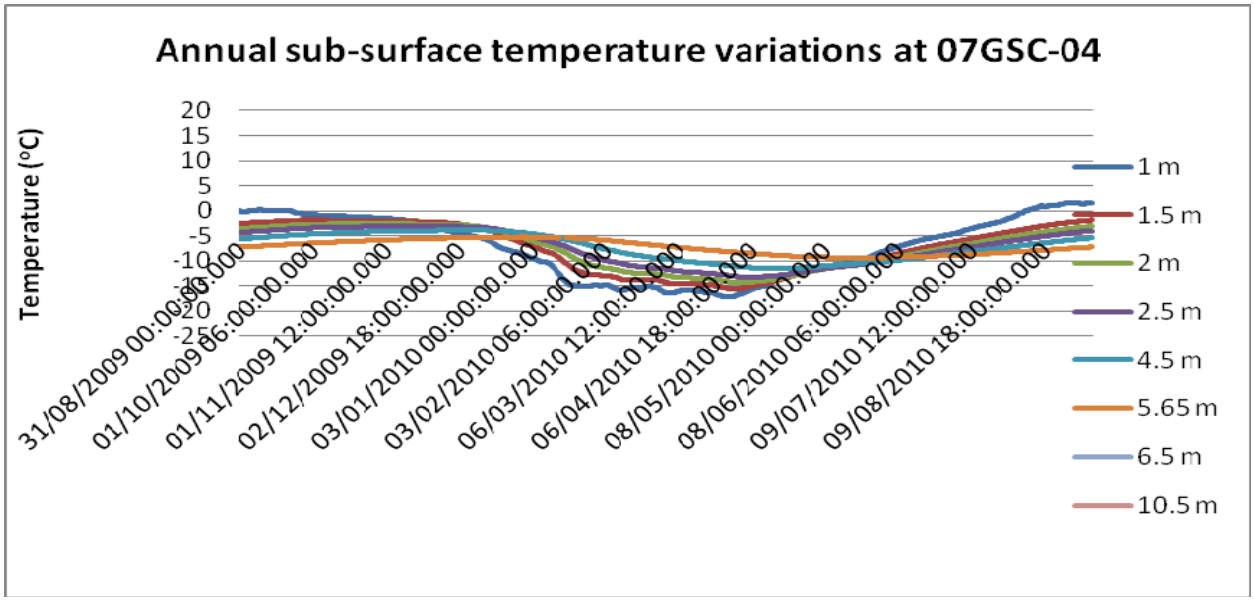
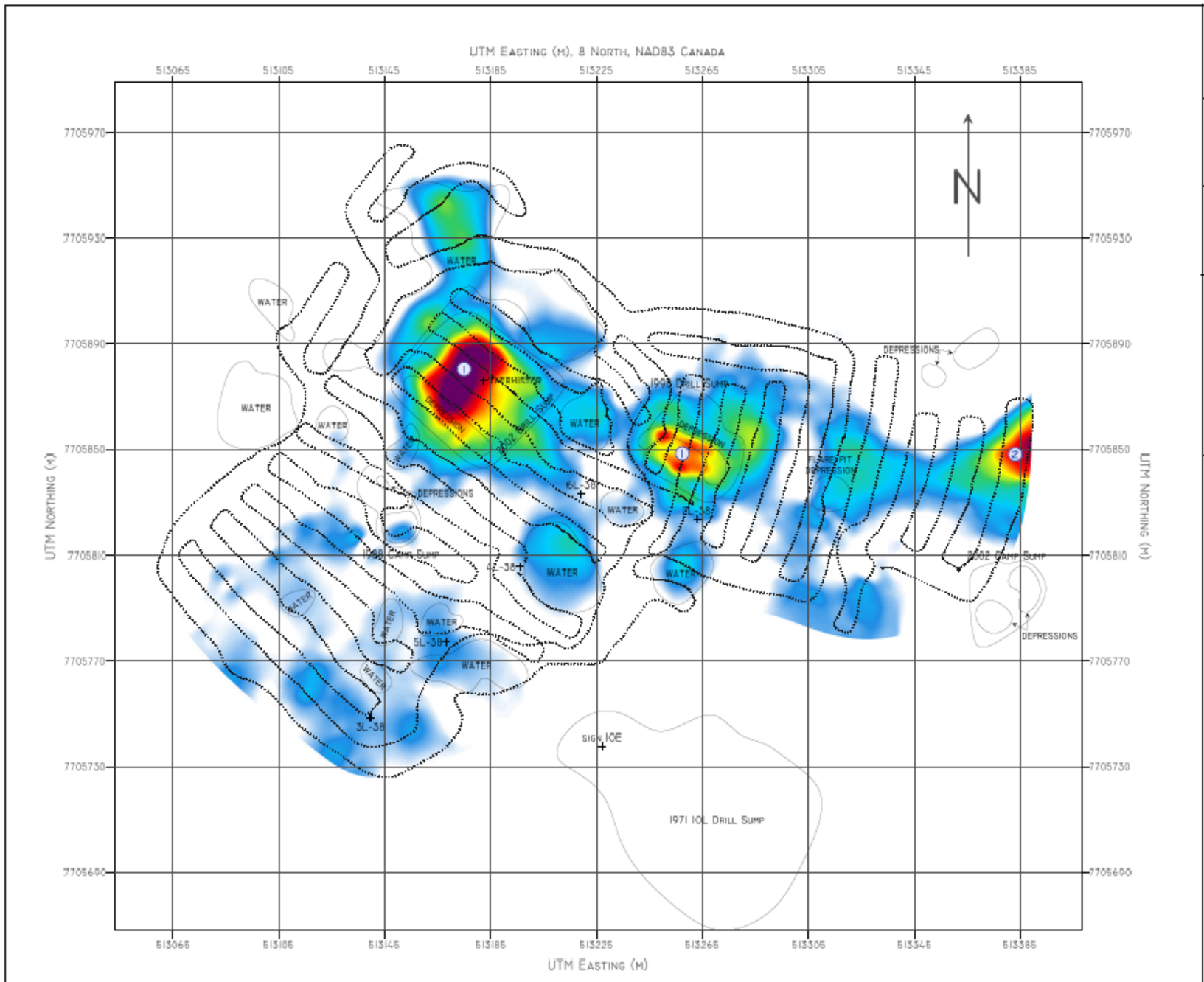


Figure A-4 Thermistor 07GSC-04 – Average Monthly Ground Temperatures (August 2009 to August 2010)



Appendix B Electromagnetic Surveys



Apparent Conductivity (EM31)

Mallik Sump

Directed by:

KAVIK-AXYS Inc.

Produced by:

Essis

Job 2056

Legend

- Point Feature (Sign, Pole, Rock, etc.)
- Area Feature (Slough, Shed, etc.)
- Line Feature (Road, Trees, etc.)
- Fence, Rail, etc.
- Interpreted / Located Buried Line
- Geophysical Measurement Station

50 60 70 80 90 100 110 120 130 140
Apparent Conductivity (mS/m)

Interpretation

The colour image reveals the 'Apparent Conductivity' distribution on site. The term 'Apparent Conductivity' implies that presented conductivities do not linearly relate to actual soil conductivities, being a function in part of the following theoretical constraints:

Skindepth - EM waves travel deeper in resistive soil than conductive soil. The EM31 & EM38 typically reach depths near 5m & 1.5m respectively.

Equivalence - A mean/small conductor at shallow depth yields the same response as a strong/large conductor that is buried deeply.

Thickness • Conductivity Product - A thin conductor is visible only with large conductivity contrast to surrounding soil. A thick conductor can be seen with smaller conductivity contrast.

Instrument Linearity - The Geonics EM31/38 maintain instrument linearity to just before 100 mS/m. Past 100 mS/m, instrument measurements increase at a lesser rate than true soil conductivities.

In general, fine-grained soils are higher in moisture and ionic content than coarse-grained ones, resulting in higher electrical conductivities.

Response trend and locale suggest that elevated response zones, particularly in areas of standing water, but also across the site, are influenced by ion-concentrations issuing from nearby ocean waters.

Suspected naturally occurring ion-concentrations from ocean water may mask and/or mimic ionic occurrences related to the sumps.

Depth - This EM31 map reveals an overall 'lower-than-EM38' response suggesting shallower conductive occurrences.

① Anomalous response locale suggests ionic occurrence related to the sump.

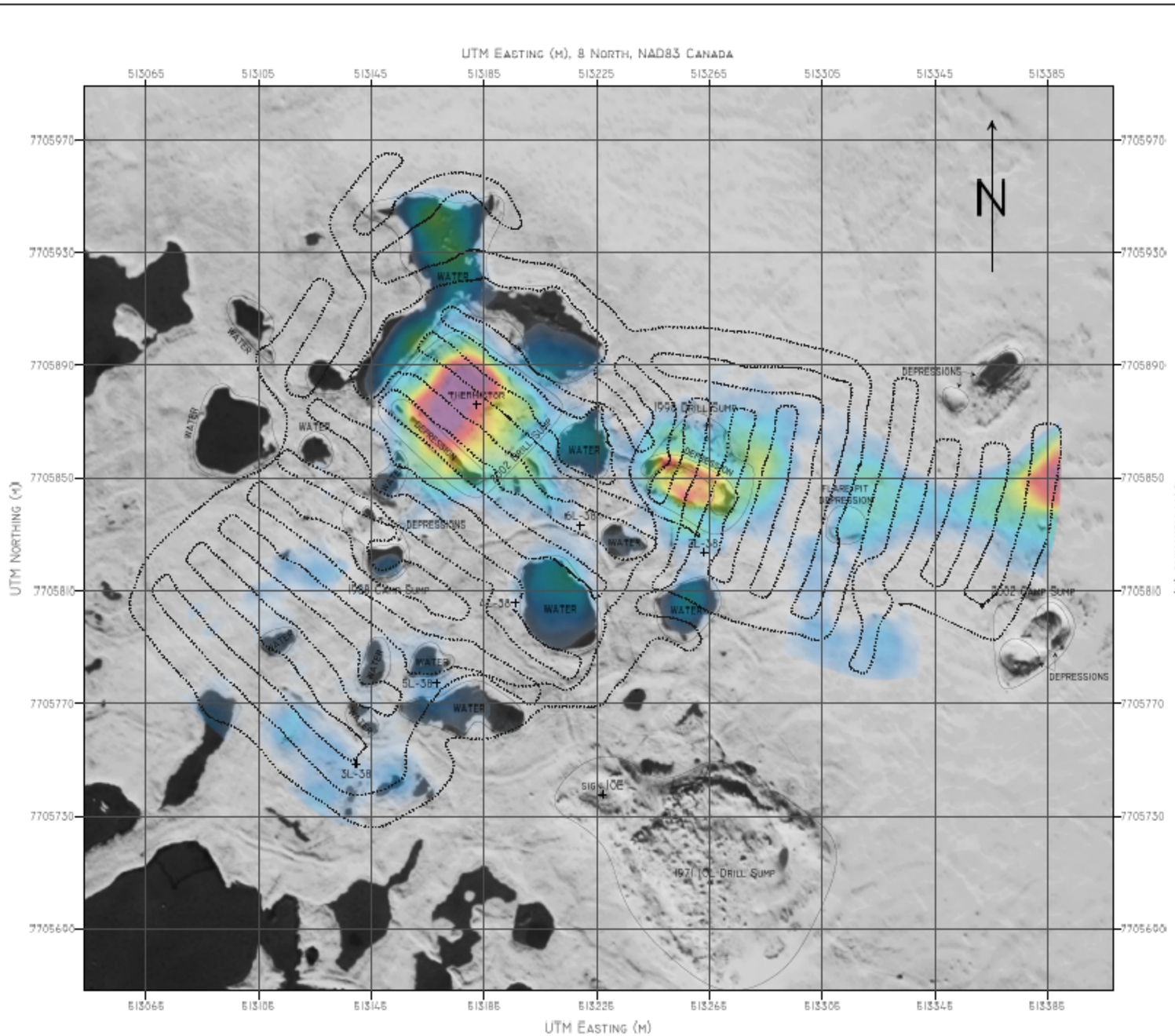
② Anomalous response is considered out of scope for this project. Response related to ion-concentrations, possibly natural in origin.

This EM image was interpreted within various theoretical constraints and should be truthed using soil samples and laboratory analysis.

PERMIT TO PRACTICE
ESSIS LTD.
Signature
Date September 29, 2010
PERMIT NUMBER: P 6825
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Approved:
Created:

Essis Ltd • Box 1419, Okotoks, Alberta, T1S 1B4 • (403) 276-7100



Apparent Conductivity (EM31)

Mallik Sump

Directed by:

KAVIK-AXYS Inc.

Produced by:

Essis

Job 2036

Legend

- Point Feature (Sign, Pole, Riser, etc.)
- Area Feature (Slough, Shed, etc.)
- Line Feature (Road, Trees, etc.)
- Fence, Rail, etc.
- Interpreted / Located Buried Line
- Geophysical Measurement Station

50 60 70 80 90 100 110 120 130 140

Apparent Conductivity (mS/m)

Interpretation

The colour image reveals the 'Apparent Conductivity' distribution on site. The term 'Apparent Conductivity' implies that presented conductivities do not linearly relate to actual soil conductivities, being a function in part of the following theoretical constraints:

Skindepth - EM waves travel deeper in resistive soil than conductive soil. The EM31 & EM38 typically reach depths near 5m & 1.5m, respectively.

Equivalence - A weak/small conductor at shallow depth yields the same response as a strong/large conductor that is buried deeply.

Thickness • Conductivity Product - A thin conductor is visible only with large conductivity contrast to surrounding soil. A thick conductor can be seen with smaller conductivity contrast.

Instrument Linearity - The Geonics EM31/38 maintain instrument linearity to just before 100 mS/m. Past 100 mS/m, instrument measurements increase at a lesser rate than true soil conductivities.

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Date September 29, 2010
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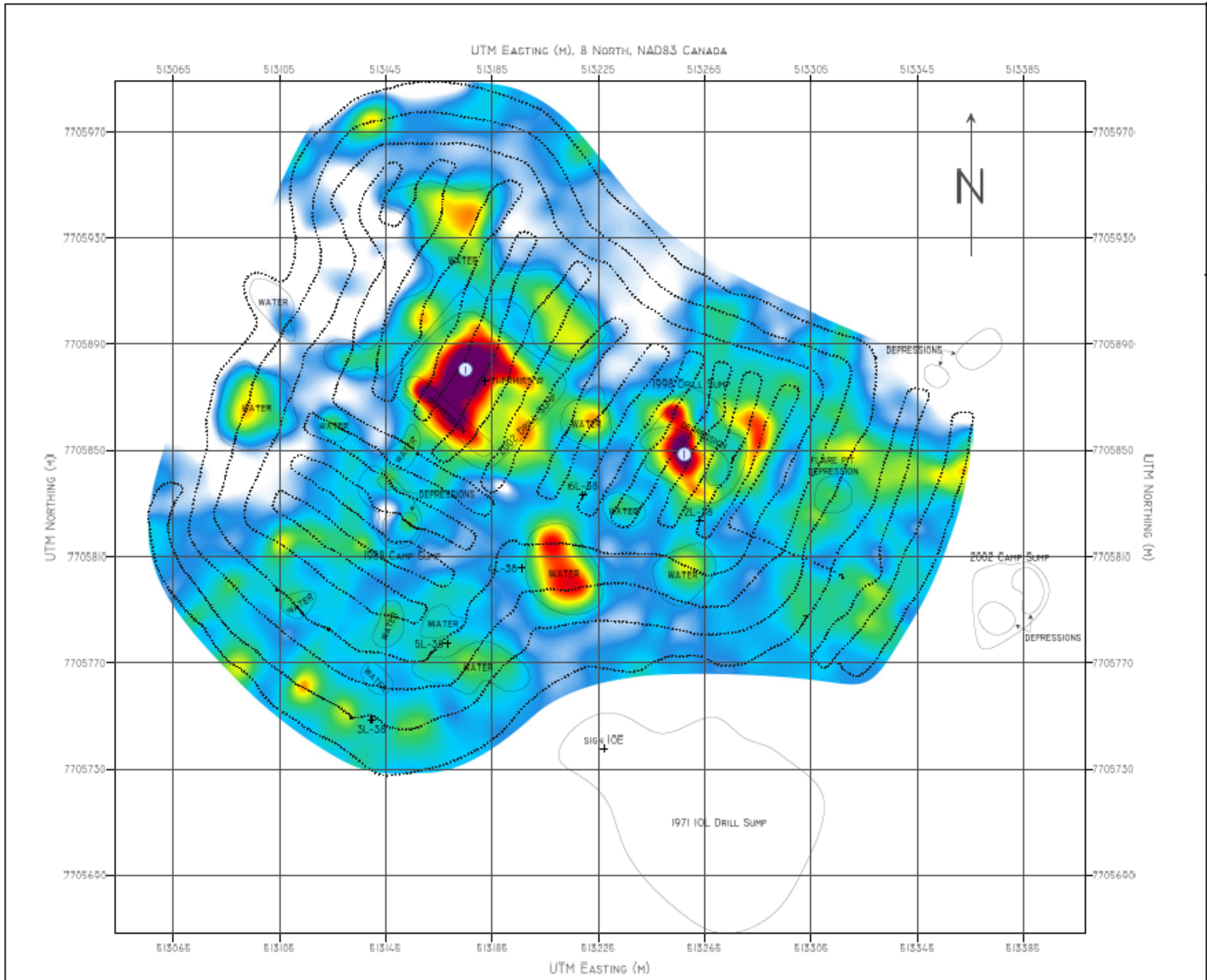

Apparent Conductivity (EM38)

Mallik Sump

Directed by: KAVIK-AXYS Inc.

Produced by: Essis

Job 2036

Legend

- Point Feature (Sign, Pole, Riser, etc.)
- Area Feature (Slough, Shed, etc.)
- Line Feature (Road, Trees, etc.)
- Fence, Rail, etc.
- Interpreted / Located Buried Line
- Geophysical Measurement Station

50 75 100 125 150 175 200 225
Apparent Conductivity (mS/m)

Interpretation

The colour image reveals the 'Apparent Conductivity' distribution on site. The term 'Apparent Conductivity' implies that presented conductivities do not linearly relate to actual soil conductivities, being a function in part of the following theoretical constraints:

Skindepth - EM waves travel deeper in resistive soil than conductive soil. The EM31 & EM38 typically reach depths near 5m & 1.5m, respectively.

Equivalence - A mean/small conductor at shallow depth yields the same response as a strong/large conductor that is buried deeply.

Thickness • Conductivity Product - A thin conductor is visible only with large conductivity contrast to surrounding soil. A thick conductor can be seen with smaller conductivity contrast.

Instrument Linearity - The Geonics EM31/38 maintain instrument linearity to just before 100 mS/m. Past 100 mS/m, instrument measurements increase at a lesser rate than true soil conductivities.

In general, fine-grained soils are higher in moisture and ionic content than coarse-grained ones, resulting in higher electrical conductivities.

Response trend and locale suggest that elevated response zones, particularly in areas of standing water, but also across the site, are influenced by ion-concentrations issuing from nearby ocean waters.

Suspected naturally occurring ion-concentrations from ocean water may mask and/or mimic ionic occurrences related to the sumps.

Depth - This EM38 map reveals an overall 'higher-than-EM31' response suggesting shallower conductive occurrences within first 1.5 m of soil.

ⓘ Anomalous response locale suggests ionic occurrence related to the sump.

This EM image was interpreted within various theoretical constraints and should be truthed using soil samples and laboratory analytics.

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Signature
Date September 29, 2010
PERMIT NUMBER: P 6825
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

Approved:
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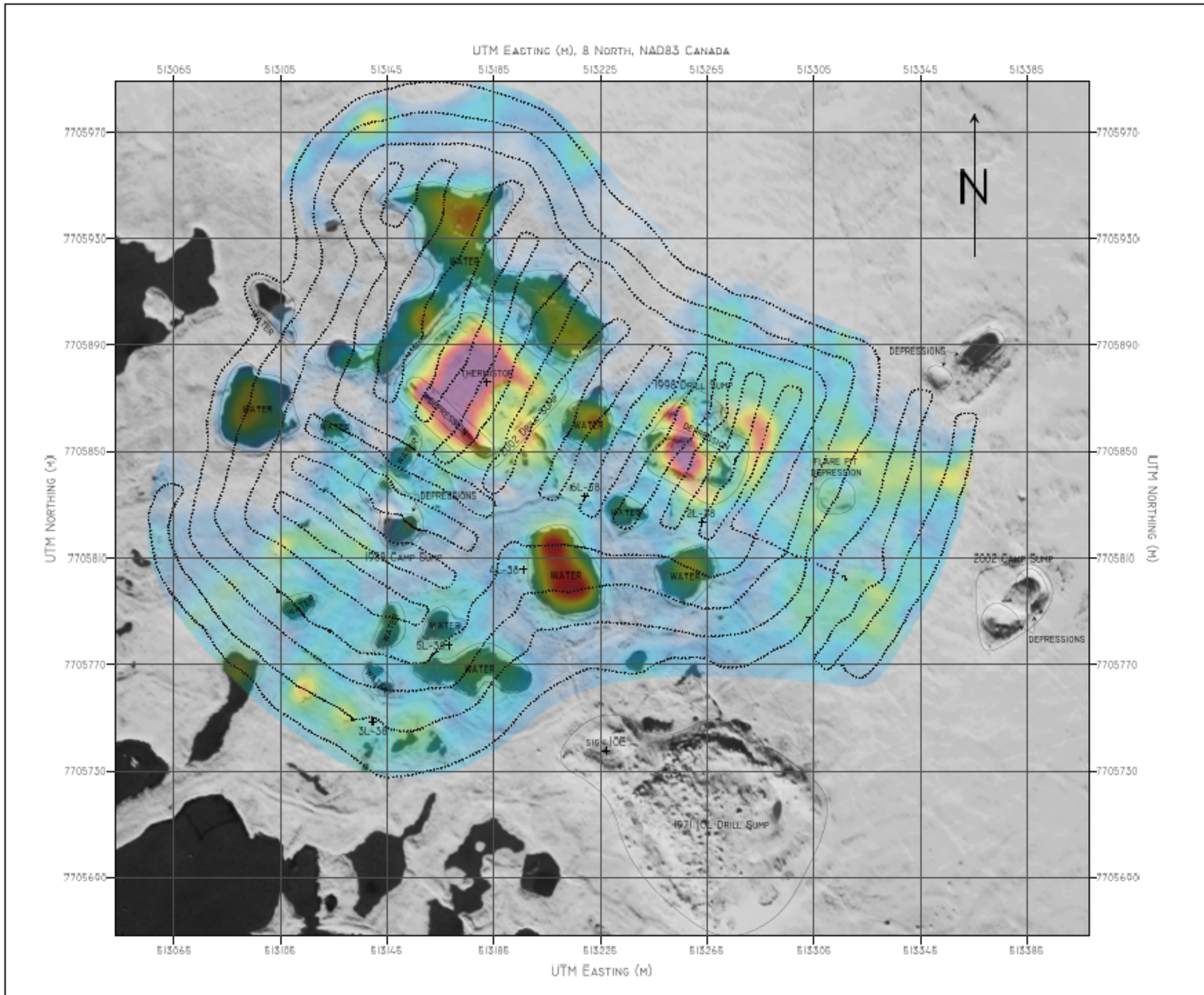

Apparent Conductivity (EM38)

Mallik Sump

Directed by: KAVIK-AXYS Inc.

Produced by: Essis

Job 2036

Legend

- Point Feature (Sign, Pole, Riser, etc.)
- Area Feature (Slough, Shed, etc.)
- Line Feature (Road, Trees, etc.)
- Fence, Rail, etc.
- Interpreted / Located Buried Line
- Geophysical Measurement Station

50 75 100 125 150 175 200 225
Apparent Conductivity (mS/m)

Interpretation

The colour image reveals the 'Apparent Conductivity' distribution on site. The term 'Apparent Conductivity' implies that presented conductivities do not linearly relate to actual soil conductivities, being a function in part of the following theoretical constraints:

Skindepth - EM waves travel deeper in resistive soil than conductive soil. The EM31 & EM38 typically reach depths near 5m & 1.5m, respectively.

Equivalence - A deep/small conductor at shallow depth yields the same response as a strong/large conductor that is buried deeply.

Thickness • Conductivity Product - A thin conductor is visible only with large conductivity contrast to surrounding soil. A thick conductor can be seen with smaller conductivity contrast.

Instrument Linearity - The Geonics EM31/38 maintain instrument linearity to just before 100 mS/m. Past 100 mS/m, instrument measurements increase at a lesser rate than true soil conductivities.

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Date September 29, 2010
PERMIT NUMBER: P 6825
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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Essis Ltd • Box 1419, Okotoks, Alberta, T1S 1B4 • (403) 276-7100

Appendix C Laboratory Analyses

Your P.O. #: 16300R-40
Your Project #: 110218287 MALLIK SUMP ASSESSME
Site: MALLIK, NWT
NSD # 16300R
Your C.O.C. #: A012970

Attention: ELAINE LITTLE
STANTEC CONSULTING LTD
EDMONTON-NATIONAL CONTRACT
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2010/10/12

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B095141
Received: 2010/10/04, 18:34

Sample Matrix: Soil
Samples Received: 6

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Boron (Hot Water Soluble)	6	2010/10/07	2010/10/07	AB SOP-00042	EPA 200.7
Cation/EC Ratio	6	N/A	2010/10/08	Calc	
Chloride (soluble)	3	2010/10/06	2010/10/07	EENVSOP-00055	SM 4110-B
Chloride (soluble)	3	2010/10/06	2010/10/08	EENVSOP-00055	SM 4110-B
Hexavalent Chromium	6	2010/10/06	2010/10/06	EENVSOP-00131	SM 3500-Cr B
Conductivity (Soluble)	6	2010/10/06	2010/10/06	AB SOP-00004	SSMA 15.3
Elements by ICPMS - Soils	1	2010/10/08	2010/10/08	AB SOP-00043	EPA 200.8
Elements by ICPMS - Soils	5	2010/10/08	2010/10/09	AB SOP-00043	EPA 200.8
Ion Balance	6	N/A	2010/10/08	CAL WI-00053	SM 1030E
Sum of Cations, Anions	6	N/A	2010/10/08	Calc	
Moisture	6	N/A	2010/10/06	EENVSOP-00139	Carter SSMA 51.2
pH (1:2 Calcium Chloride Extract)	6	2010/10/06	2010/10/07	AB SOP-00005	Method 4500-H+B
Particle Size by Sieve (75 micron)	6	N/A	2010/10/08	EENVSOP-00077	SSMA 55.4
Sodium Adsorption Ratio	6	N/A	2010/10/08	Calc	
Ca,Mg,Na,K,SO4 (Soluble)	6	2010/10/07	2010/10/07	AB SOP-00042	EPA 200.7
Soluble Paste	6	2010/10/06	2010/10/06	AB SOP-00033	SSMA 15.2
Texture by Hydrometer	6	N/A	2010/10/07	EENVSOP-00076	MMFSPA Ch9
Texture Class	6	N/A	2010/10/08	EENVSOP-00076	MMFSPA Ch9
Theoretical Gypsum Requirement	6	N/A	2010/10/08	CAL WI-00087	SSMA 18.4.4
Organic Carbon and Organic Matter @	6	N/A	2010/10/07	CAL SOP-00035	MMFSPA Ch6

Sample Matrix: Water
Samples Received: 4

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity (pp, total), CO3,HCO3,OH	4	N/A	2010/10/05	AB SOP-00005	SM 2320-B
Cadmium - low level CCME (Total)	4	2010/10/05	2010/10/12	AB SOP-00043	EPA 200.8
Chloride by Automated Colourimetry	4	N/A	2010/10/07	AB SOP-00020	EPA 325.2
Conductivity	4	N/A	2010/10/05	AB SOP-00005	SM 2510-B
Hardness	4	N/A	2010/10/10	CAL WI-00053	AEMM, Method 423
Elements by ICP - Dissolved	4	N/A	2010/10/08	AB SOP-00042	EPA 200.7
Elements by ICP - Total	4	2010/10/07	2010/10/08	AB SOP-00042	EPA 200.7
Elements by ICPMS - Total	3	2010/10/07	2010/10/08	AB SOP-00043	EPA 200.8
Elements by ICPMS - Total	1	2010/10/07	2010/10/12	AB SOP-00043	EPA 200.8
Ion Balance	4	N/A	2010/10/10	CAL WI-00053	SM 1030E

../2

Your P.O. #: 16300R-40
Your Project #: 110218287 MALLIK SUMP ASSESSME
Site: MALLIK, NWT
NSD # 16300R
Your C.O.C. #: A012970

Attention: ELAINE LITTLE
STANTEC CONSULTING LTD
EDMONTON-NATIONAL CONTRACT
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2010/10/12

CERTIFICATE OF ANALYSIS

Sample Matrix: Water
Samples Received: 4

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Sum of cations, anions	4	N/A	2010/10/10	Calc	
Nitrate and Nitrite	4	N/A	2010/10/07	Calc	
Nitrate + Nitrite-N (calculated)	4	N/A	2010/10/07	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC	4	N/A	2010/10/07	AB SOP-00023	SM 4110-B
pH (Alkalinity titrator)	4	N/A	2010/10/05	AB SOP-00005	SM 4500-H+B
Sulphate by Automated Colourimetry	4	N/A	2010/10/07	AB SOP-00018	EPA 375.4
Total Dissolved Solids (Calculated)	4	N/A	2010/10/10		SM 1030E

(1) This test was performed by Maxxam Calgary

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

ALAINA HUNTER, Project Manager
Email: AHunter@maxxam.ca
Phone# (780) 577-7100

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 2

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		X44253		X44300		X44301		
Sampling Date		2010/09/28 12:40		2010/09/28 12:40		2010/09/28 12:45		
COC Number		A012970		A012970		A012970		
	Units	**MALLIK_WATER_1**	**RDL**	**MALLIK_WATER_2**	**RDL**	**MALLIK_WATER_3**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	77	N/A	130	N/A	100	N/A	4315308
Cation Sum	meq/L	74	N/A	130	N/A	97	N/A	4315308
Hardness (CaCO3)	mg/L	1820	0.5	1800	0.5	1290	0.5	4315306
Ion Balance	N/A	0.96	0.01	1.0	0.01	0.95	0.01	4315307
Dissolved Nitrate (NO3)	mg/L	0.35	0.01	0.09	0.01	<0.1	0.1	4315310
Nitrate plus Nitrite (N)	mg/L	0.078	0.003	0.020	0.003	<0.03	0.03	4315312
Dissolved Nitrite (NO2)	mg/L	<0.01	0.01	<0.01	0.01	<0.1	0.1	4315310
Total Dissolved Solids	mg/L	4850	10	8030	10	5750	10	4315315
Misc. Inorganics								
Conductivity	uS/cm	7900	1	14000	1	11000	1	4314303
pH	N/A	7.74	N/A	7.93	N/A	7.96	N/A	4314302
Anions								
Alkalinity (PP as CaCO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Alkalinity (Total as CaCO3)	mg/L	240	0.5	300	0.5	230	0.5	4314288
Bicarbonate (HCO3)	mg/L	290	0.5	360	0.5	280	0.5	4314288
Carbonate (CO3)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Hydroxide (OH)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	4314288
Dissolved Sulphate (SO4)	mg/L	900 (1)	30	650 (1)	20	420 (1)	2	4320487
Dissolved Chloride (Cl)	mg/L	1900 (1)	10	4100 (1)	50	3100 (1)	30	4320480
Nutrients								
Dissolved Nitrite (N)	mg/L	<0.003	0.003	<0.003	0.003	<0.03 (2)	0.03	4317728
Dissolved Nitrate (N)	mg/L	0.078	0.003	0.020	0.003	<0.03 (2)	0.03	4317728
Elements								
Dissolved Calcium (Ca)	mg/L	570 (3)	3	330	0.3	200	0.3	4323296
Dissolved Iron (Fe)	mg/L	0.07	0.06	0.18	0.06	0.09	0.06	4323296
Dissolved Magnesium (Mg)	mg/L	95	0.2	240	0.2	190	0.2	4323296
Dissolved Manganese (Mn)	mg/L	0.078	0.004	0.12	0.004	0.006	0.004	4323296
Dissolved Potassium (K)	mg/L	950 (1)	3	680 (3)	3	84	0.3	4323296
Dissolved Sodium (Na)	mg/L	300	0.5	1900 (1)	5	1600 (1)	5	4323296

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to matrix interference
(3) Detection limits raised due to dilution to bring analyte within the calibrated range.
Dissolved greater than total. Results within acceptable limits of precision.

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		X44302		
Sampling Date		2010/09/28 12:40		
COC Number		A012970		
	Units	**MALLIK_WATER_4**	**RDL**	**QC Batch**
Calculated Parameters				
Anion Sum	meq/L	86	N/A	4315308
Cation Sum	meq/L	77	N/A	4315308
Hardness (CaCO3)	mg/L	921	0.5	4315306
Ion Balance	N/A	0.89	0.01	4315307
Dissolved Nitrate (NO3)	mg/L	<0.1	0.1	4315310
Nitrate plus Nitrite (N)	mg/L	<0.03	0.03	4315312
Dissolved Nitrite (NO2)	mg/L	<0.1	0.1	4315310
Total Dissolved Solids	mg/L	4720	10	4315315
Misc. Inorganics				
Conductivity	uS/cm	8800	1	4314303
pH	N/A	8.08	N/A	4314302
Anions				
Alkalinity (PP as CaCO3)	mg/L	<0.5	0.5	4314288
Alkalinity (Total as CaCO3)	mg/L	270	0.5	4314288
Bicarbonate (HCO3)	mg/L	320	0.5	4314288
Carbonate (CO3)	mg/L	<0.5	0.5	4314288
Hydroxide (OH)	mg/L	<0.5	0.5	4314288
Dissolved Sulphate (SO4)	mg/L	260 (1)	10	4320487
Dissolved Chloride (Cl)	mg/L	2700 (1)	30	4320480
Nutrients				
Dissolved Nitrite (N)	mg/L	<0.03 (2)	0.03	4317728
Dissolved Nitrate (N)	mg/L	<0.03 (2)	0.03	4317728
Elements				
Dissolved Calcium (Ca)	mg/L	110	0.3	4323296
Dissolved Iron (Fe)	mg/L	0.07	0.06	4323296
Dissolved Magnesium (Mg)	mg/L	160	0.2	4323296
Dissolved Manganese (Mn)	mg/L	<0.004	0.004	4323296
Dissolved Potassium (K)	mg/L	45	0.3	4323296
Dissolved Sodium (Na)	mg/L	1300 (1)	5	4323296

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to matrix interference

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1)

Maxxam ID		X44159	X44206	X44207	X44208		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970	A012970	A012970		
	Units	**MALLIK_SOIL_1.1**	**MALLIK_SOIL_1.2**	**MALLIK_SOIL_1.3**	**MALLIK_SOIL_2.1**	**RDL**	**QC Batch**
Elements							
Soluble (Hot water) Boron (B)	mg/kg	0.4	0.3	0.3	0.7	0.1	4323030
Hex. Chromium (Cr 6+)	mg/kg	<0.15	<0.15	<0.15	<0.15	0.15	4317151
Total Antimony (Sb)	mg/kg	<1	<1	<1	<1	1	4327213
Total Arsenic (As)	mg/kg	5	4	6	4	1	4327213
Total Barium (Ba)	mg/kg	370	370	380	750	10	4327213
Total Beryllium (Be)	mg/kg	<0.4	<0.4	<0.4	<0.4	0.4	4327213
Total Cadmium (Cd)	mg/kg	0.3	0.2	0.4	0.3	0.1	4327213
Total Chromium (Cr)	mg/kg	10	9	13	11	1	4327213
Total Cobalt (Co)	mg/kg	6	5	8	6	1	4327213
Total Copper (Cu)	mg/kg	9	8	14	11	5	4327213
Total Lead (Pb)	mg/kg	5	5	8	13	1	4327213
Total Mercury (Hg)	mg/kg	<0.05	<0.05	<0.05	<0.05	0.05	4327213
Total Molybdenum (Mo)	mg/kg	1.0	0.9	1.4	1.1	0.4	4327213
Total Nickel (Ni)	mg/kg	17	15	23	17	1	4327213
Total Selenium (Se)	mg/kg	<0.5	<0.5	<0.5	<0.5	0.5	4327213
Total Silver (Ag)	mg/kg	<1	<1	<1	<1	1	4327213
Total Thallium (Tl)	mg/kg	<0.3	<0.3	<0.3	<0.3	0.3	4327213
Total Tin (Sn)	mg/kg	<1	<1	<1	<1	1	4327213
Total Uranium (U)	mg/kg	<1	<1	<1	<1	1	4327213
Total Vanadium (V)	mg/kg	19	18	23	18	1	4327213
Total Zinc (Zn)	mg/kg	51	47	66	100	10	4327213

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1)

Maxxam ID		X44209	X44210		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970		
	Units	**MALLIK_SOIL_2.2**	**MALLIK_SOIL_2.3**	**RDL**	**QC Batch**
Elements					
Soluble (Hot water) Boron (B)	mg/kg	0.2	0.2	0.1	4323030
Hex. Chromium (Cr 6+)	mg/kg	<0.15	<0.15	0.15	4317151
Total Antimony (Sb)	mg/kg	<1	<1	1	4327213
Total Arsenic (As)	mg/kg	5	5	1	4327213
Total Barium (Ba)	mg/kg	370	370	10	4327213
Total Beryllium (Be)	mg/kg	<0.4	<0.4	0.4	4327213
Total Cadmium (Cd)	mg/kg	0.3	0.3	0.1	4327213
Total Chromium (Cr)	mg/kg	11	11	1	4327213
Total Cobalt (Co)	mg/kg	6	6	1	4327213
Total Copper (Cu)	mg/kg	10	10	5	4327213
Total Lead (Pb)	mg/kg	7	7	1	4327213
Total Mercury (Hg)	mg/kg	<0.05	<0.05	0.05	4327213
Total Molybdenum (Mo)	mg/kg	1.1	1.1	0.4	4327213
Total Nickel (Ni)	mg/kg	18	18	1	4327213
Total Selenium (Se)	mg/kg	<0.5	<0.5	0.5	4327213
Total Silver (Ag)	mg/kg	<1	<1	1	4327213
Total Thallium (Tl)	mg/kg	<0.3	<0.3	0.3	4327213
Total Tin (Sn)	mg/kg	<1	<1	1	4327213
Total Uranium (U)	mg/kg	<1	<1	1	4327213
Total Vanadium (V)	mg/kg	20	19	1	4327213
Total Zinc (Zn)	mg/kg	56	56	10	4327213

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1) - TOTAL

Maxxam ID		X44253		X44300		X44301		
Sampling Date		2010/09/28 12:40		2010/09/28 12:40		2010/09/28 12:45		
COC Number		A012970		A012970		A012970		
	Units	**MALLIK_WATER_1**	**RDL**	**MALLIK_WATER_2**	**RDL**	**MALLIK_WATER_3**	**RDL**	**QC Batch**
Low Level Elements								
Total Cadmium (Cd)	ug/L	0.11	0.03	0.11	0.03	<0.03	0.03	4315608
Elements								
Total Aluminum (Al)	mg/L	0.019	0.001	0.090	0.001	0.069	0.001	4322615
Total Antimony (Sb)	mg/L	0.0021	0.0002	<0.0002	0.0002	<0.0002	0.0002	4322615
Total Arsenic (As)	mg/L	0.0017	0.0002	0.0020	0.0002	0.0024	0.0002	4322615
Total Barium (Ba)	mg/L	0.14	0.01	0.16	0.01	0.13	0.01	4323306
Total Beryllium (Be)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	0.001	4322615
Total Boron (B)	mg/L	0.08	0.02	0.34	0.02	0.40	0.02	4323306
Total Calcium (Ca)	mg/L	560 (1)	3	340	0.3	210	0.3	4323306
Total Chromium (Cr)	mg/L	0.001	0.001	0.002	0.001	0.001	0.001	4322615
Total Cobalt (Co)	mg/L	0.0008	0.0003	0.0010	0.0003	0.0005	0.0003	4322615
Total Copper (Cu)	mg/L	0.0033	0.0002	0.0051	0.0002	0.0039	0.0002	4322615
Total Iron (Fe)	mg/L	0.28	0.06	0.87	0.06	0.58	0.06	4323306
Total Lead (Pb)	mg/L	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	4322615
Total Lithium (Li)	mg/L	0.04	0.02	0.07	0.02	0.03	0.02	4323306
Total Magnesium (Mg)	mg/L	98	0.2	240	0.2	200	0.2	4323306
Total Manganese (Mn)	mg/L	0.098	0.004	0.15	0.004	0.025	0.004	4323306
Total Molybdenum (Mo)	mg/L	0.0025	0.0002	0.0018	0.0002	0.0013	0.0002	4322615
Total Nickel (Ni)	mg/L	0.0079	0.0005	0.010	0.0005	0.0068	0.0005	4322615
Total Phosphorus (P)	mg/L	<0.1	0.1	<0.1	0.1	<0.1	0.1	4323306
Total Potassium (K)	mg/L	960 (1)	3	670 (1)	3	88	0.3	4323306
Total Selenium (Se)	mg/L	0.0004	0.0002	0.0010	0.0002	0.0008	0.0002	4322615
Total Silicon (Si)	mg/L	2.6	0.1	0.3	0.1	0.2	0.1	4323306
Total Silver (Ag)	mg/L	<0.0001	0.0001	<0.0001	0.0001	<0.0001	0.0001	4322615
Total Sodium (Na)	mg/L	320	0.5	1900 (1)	5	1700 (1)	5	4323306
Total Strontium (Sr)	mg/L	2.5	0.02	2.5	0.02	1.7	0.02	4323306
Total Sulphur (S)	mg/L	280	0.2	200	0.2	130	0.2	4323306
Total Thallium (Tl)	mg/L	<0.0002	0.0002	<0.0002	0.0002	<0.0002	0.0002	4322615
Total Tin (Sn)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	0.001	4322615
Total Titanium (Ti)	mg/L	0.001	0.001	0.003	0.001	0.002	0.001	4322615
Total Uranium (U)	mg/L	0.0069	0.0001	0.0052	0.0001	0.0021	0.0001	4322615

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1) - TOTAL

Maxxam ID		X44253		X44300		X44301		
Sampling Date		2010/09/28 12:40		2010/09/28 12:40		2010/09/28 12:45		
COC Number		A012970		A012970		A012970		
	Units	**MALLIK_WATER_1**	**RDL**	**MALLIK_WATER_2**	**RDL**	**MALLIK_WATER_3**	**RDL**	**QC Batch**
Total Vanadium (V)	mg/L	<0.001	0.001	<0.001	0.001	<0.001	0.001	4322615
Total Zinc (Zn)	mg/L	0.009	0.003	0.009	0.003	0.003	0.003	4322615

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1) - TOTAL

Maxxam ID		X44302		
Sampling Date		2010/09/28 12:40		
COC Number		A012970		
	Units	**MALLIK_WATER_4**	**RDL**	**QC Batch**
Low Level Elements				
Total Cadmium (Cd)	ug/L	0.09	0.03	4315608
Elements				
Total Aluminum (Al)	mg/L	0.33	0.001	4322615
Total Antimony (Sb)	mg/L	<0.0002	0.0002	4322615
Total Arsenic (As)	mg/L	0.0023	0.0002	4322615
Total Barium (Ba)	mg/L	0.40	0.01	4323306
Total Beryllium (Be)	mg/L	<0.001	0.001	4322615
Total Boron (B)	mg/L	0.50	0.02	4323306
Total Calcium (Ca)	mg/L	120	0.3	4323306
Total Chromium (Cr)	mg/L	0.002	0.001	4322615
Total Cobalt (Co)	mg/L	0.0007	0.0003	4322615
Total Copper (Cu)	mg/L	0.0067	0.0002	4322615
Total Iron (Fe)	mg/L	1.3	0.06	4323306
Total Lead (Pb)	mg/L	0.0010	0.0002	4322615
Total Lithium (Li)	mg/L	0.02	0.02	4323306
Total Magnesium (Mg)	mg/L	170	0.2	4323306
Total Manganese (Mn)	mg/L	0.053	0.004	4323306
Total Molybdenum (Mo)	mg/L	0.0030	0.0002	4322615
Total Nickel (Ni)	mg/L	0.0053	0.0005	4322615
Total Phosphorus (P)	mg/L	0.2	0.1	4323306
Total Potassium (K)	mg/L	50	0.3	4323306
Total Selenium (Se)	mg/L	0.0006	0.0002	4322615
Total Silicon (Si)	mg/L	0.5	0.1	4323306
Total Silver (Ag)	mg/L	<0.0001	0.0001	4322615
Total Sodium (Na)	mg/L	1300 (1)	5	4323306
Total Strontium (Sr)	mg/L	1.2	0.02	4323306
Total Sulphur (S)	mg/L	79	0.2	4323306
Total Thallium (Tl)	mg/L	<0.0002	0.0002	4322615
Total Tin (Sn)	mg/L	0.001	0.001	4322615
Total Titanium (Ti)	mg/L	0.007	0.001	4322615

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

REGULATED METALS (CCME/AT1) - TOTAL

Maxxam ID		X44302		
Sampling Date		2010/09/28 12:40		
COC Number		A012970		
	Units	**MALLIK_WATER_4**	**RDL**	**QC Batch**
Total Uranium (U)	mg/L	0.0010	0.0001	4322615
Total Vanadium (V)	mg/L	0.001	0.001	4322615
Total Zinc (Zn)	mg/L	0.008	0.003	4322615

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		X44159	X44206	X44207		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970	A012970		
	Units	**MALLIK_SOIL_1.1**	**MALLIK_SOIL_1.2**	**MALLIK_SOIL_1.3**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	45	51	45	N/A	4313417
Cation Sum	meq/L	47	53	47	N/A	4313417
Cation/EC Ratio	N/A	9.3	9.7	9.5	0.1	4313411
Ion Balance	N/A	1.1	1.0	1.1	0.01	4313416
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	1400 (1)	1600 (1)	1400 (1)	10	4320611
Soluble Conductivity	dS/m	5.1	5.5	5.0	0.02	4317205
Soluble (CaCl2) pH	N/A	7.80	7.82	7.89	N/A	4317308
Sodium Adsorption Ratio	N/A	13	13	10	0.1	4313418
Soluble Calcium (Ca)	mg/L	170	210	220	1.5	4320837
Soluble Magnesium (Mg)	mg/L	60	73	70	1.0	4320837
Soluble Sodium (Na)	mg/L	770	840	690	2.5	4320837
Soluble Potassium (K)	mg/L	18	15	12	1.3	4320837
Saturation %	%	52.2	48.9	51.5	N/A	4316813
Soluble Sulphate (SO4)	mg/L	300	350	210	5.0	4320837
Theoretical Gypsum Requirement	tons/ac	<0.1	<0.1	<0.1	0.1	4313420

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		X44208		X44209	X44210		
Sampling Date		2010/09/28 12:00		2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970		A012970	A012970		
	Units	**MALLIK_SOIL_2.1**	**RDL**	**MALLIK_SOIL_2.2**	**MALLIK_SOIL_2.3**	**RDL**	**QC Batch**
Calculated Parameters							
Anion Sum	meq/L	310	N/A	94	110	N/A	4313417
Cation Sum	meq/L	320	N/A	96	110	N/A	4313417
Cation/EC Ratio	N/A	11	0.1	9.9	9.8	0.1	4313411
Ion Balance	N/A	1.0	0.01	1.0	0.99	0.01	4313416
Soluble Parameters							
Soluble Chloride (Cl)	mg/L	9900 (1)	50	2800 (1)	3100 (1)	30	4320611
Soluble Conductivity	dS/m	30	0.02	9.7	11	0.02	4317205
Soluble (CaCl2) pH	N/A	7.80	N/A	7.85	7.89	N/A	4317308
Sodium Adsorption Ratio	N/A	9.9	0.1	4.3	4.9	0.1	4313418
Soluble Calcium (Ca)	mg/L	2000	1.5	830	840	1.5	4320837
Soluble Magnesium (Mg)	mg/L	900	1.0	170	190	1.0	4320837
Soluble Sodium (Na)	mg/L	2100	2.5	520	610	2.5	4320837
Soluble Potassium (K)	mg/L	2300	1.3	700	940	1.3	4320837
Saturation %	%	52.4	N/A	44.5	45.0	N/A	4316813
Soluble Sulphate (SO4)	mg/L	1700	5.0	780	1000	5.0	4320837
Theoretical Gypsum Requirement	tons/ac	<0.1	0.1	<0.1	<0.1	0.1	4313420

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		X44159	X44206	X44207	X44208		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970	A012970	A012970		
	Units	**MALLIK_SOIL_1.1**	**MALLIK_SOIL_1.2**	**MALLIK_SOIL_1.3**	**MALLIK_SOIL_2.1**	**RDL**	**QC Batch**
Misc. Inorganics							
Organic Matter	%	1.5	1.9	2.9	1.7	0.2	4320604
Total Organic Carbon (C)	%	0.9	1.1	1.7	1.0	0.2	4320604
Physical Properties							
% sand by hydrometer	%	14	16	7	18	2	4317409
% silt by hydrometer	%	78	77	75	75	2	4317409
Clay Content	%	9	7	17	6	2	4317409
Texture	N/A	SILT LOAM	SILT LOAM	SILT LOAM	SILT LOAM	N/A	4315615
Moisture	%	27	32	23	28	0.3	4316805
Sieve - Pan	%	99	98	99	96	0.2	4323876
Sieve - #200 (>0.075mm)	%	0.8	2.0	1.3	3.5	0.2	4323876
Grain Size	%	FINE	FINE	FINE	FINE	0.2	4323876

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		X44209	X44210		
Sampling Date		2010/09/28 12:00	2010/09/28 12:00		
COC Number		A012970	A012970		
	Units	**MALLIK_SOIL_2.2**	**MALLIK_SOIL_2.3**	**RDL**	**QC Batch**
Misc. Inorganics					
Organic Matter	%	1.1	1.3	0.2	4320604
Total Organic Carbon (C)	%	0.6	0.7	0.2	4320604
Physical Properties					
% sand by hydrometer	%	18	21	2	4317409
% silt by hydrometer	%	73	69	2	4317409
Clay Content	%	10	10	2	4317409
Texture	N/A	SILT LOAM	SILT LOAM	N/A	4315615
Moisture	%	20	20	0.3	4316805
Sieve - Pan	%	96	93	0.2	4323876
Sieve - #200 (>0.075mm)	%	4.4	6.5	0.2	4323876
Grain Size	%	FINE	FINE	0.2	4323876

RDL = Reportable Detection Limit

Maxxam Job #: B095141
Report Date: 2010/10/12

STANTEC CONSULTING LTD
Client Project #: 110218287 MALLIK SUMP ASSESSME
Site Reference: MALLIK, NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

General Comments

Sample X44253-01: Detection limit raised for Cd due to sample matrix.

Sample X44300-01: Detection limit raised for Cd due to sample matrix.

Sample X44301-01: Detection limit raised for Cd due to sample matrix.

Sample X44302-01: Cation anion balance investigated, data quality confirmed.

Detection limit raised for Cd due to sample matrix.

Results relate only to the items tested.

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4314288	SB8	Spiked Blank	Alkalinity (Total as CaCO3)	2010/10/05		97	%	80 - 120
		Method Blank	Alkalinity (PP as CaCO3)	2010/10/05	<0.5		mg/L	
			Alkalinity (Total as CaCO3)	2010/10/05	<0.5		mg/L	
			Bicarbonate (HCO3)	2010/10/05	<0.5		mg/L	
			Carbonate (CO3)	2010/10/05	<0.5		mg/L	
			Hydroxide (OH)	2010/10/05	<0.5		mg/L	
		RPD	Alkalinity (PP as CaCO3)	2010/10/05	NC		%	20
			Alkalinity (Total as CaCO3)	2010/10/05	2.6		%	20
			Bicarbonate (HCO3)	2010/10/05	2.6		%	20
			Carbonate (CO3)	2010/10/05	NC		%	20
			Hydroxide (OH)	2010/10/05	NC		%	20
4314302	SB8	Spiked Blank	pH	2010/10/05		100	%	97 - 103
		RPD	pH	2010/10/05	0.03		%	5
4314303	SB8	Spiked Blank	Conductivity	2010/10/05		101	%	90 - 110
		Method Blank	Conductivity	2010/10/05	<1		uS/cm	
		RPD	Conductivity	2010/10/05	1		%	20
4316805	JL8	Method Blank	Moisture	2010/10/06	<0.3		%	
		RPD	Moisture	2010/10/06	4.1		%	20
4316813	UH	QC Standard	Saturation %	2010/10/06		100	%	88 - 112
		RPD	Saturation %	2010/10/06	1.7		%	12
4317151	SY1	Matrix Spike	Hex. Chromium (Cr 6+)	2010/10/06		102	%	75 - 125
		Spiked Blank	Hex. Chromium (Cr 6+)	2010/10/06		104	%	80 - 120
		Method Blank	Hex. Chromium (Cr 6+)	2010/10/06	<0.15		mg/kg	
		RPD	Hex. Chromium (Cr 6+)	2010/10/06	NC		%	35
4317205	SA4	QC Standard	Soluble Conductivity	2010/10/06		92	%	75 - 125
		Spiked Blank	Soluble Conductivity	2010/10/06		102	%	95 - 105
		Method Blank	Soluble Conductivity	2010/10/06	<0.02		dS/m	
		RPD	Soluble Conductivity	2010/10/06	0.4		%	35
4317308	KW7	QC Standard	Soluble (CaCl2) pH	2010/10/07		98	%	97 - 103
		Spiked Blank	Soluble (CaCl2) pH	2010/10/07		100	%	97 - 103
		RPD	Soluble (CaCl2) pH	2010/10/07	0.04		%	5
4317409	JB9	QC Standard	% sand by hydrometer	2010/10/07		93	%	75 - 125
			% silt by hydrometer	2010/10/07		106	%	75 - 125
			Clay Content	2010/10/07		103	%	75 - 125
		Method Blank	% sand by hydrometer	2010/10/07	<2		%	
			% silt by hydrometer	2010/10/07	<2		%	
			Clay Content	2010/10/07	<2		%	
		RPD	% sand by hydrometer	2010/10/07	0		%	35
			% silt by hydrometer	2010/10/07	2.6		%	35
			Clay Content	2010/10/07	NC		%	35
4317728	DC9	Matrix Spike	Dissolved Nitrite (N)	2010/10/07		100	%	80 - 120
			Dissolved Nitrate (N)	2010/10/07		99	%	80 - 120
		Spiked Blank	Dissolved Nitrite (N)	2010/10/07		102	%	80 - 120
			Dissolved Nitrate (N)	2010/10/07		101	%	90 - 110
		Method Blank	Dissolved Nitrite (N)	2010/10/07	<0.003		mg/L	
			Dissolved Nitrate (N)	2010/10/07	<0.003		mg/L	
		RPD	Dissolved Nitrite (N)	2010/10/07	NC		%	20
			Dissolved Nitrate (N)	2010/10/07	18.7		%	20
4320480	SY1	Matrix Spike	Dissolved Chloride (Cl)	2010/10/07		NC	%	80 - 120
		Spiked Blank	Dissolved Chloride (Cl)	2010/10/07		105	%	80 - 120
		Method Blank	Dissolved Chloride (Cl)	2010/10/07	<1		mg/L	
		RPD	Dissolved Chloride (Cl)	2010/10/07	0.4		%	20
4320487	SY1	Matrix Spike	Dissolved Sulphate (SO4)	2010/10/07		NC	%	80 - 120
		Spiked Blank	Dissolved Sulphate (SO4)	2010/10/07		108	%	80 - 120
		Method Blank	Dissolved Sulphate (SO4)	2010/10/07	<1		mg/L	

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4320487	SY1	RPD	Dissolved Sulphate (SO4)	2010/10/07	3.3 (1)		%	20
4320604	SMB	QC Standard	Organic Matter	2010/10/07		102	%	83 - 118
			Total Organic Carbon (C)	2010/10/07		102	%	83 - 118
		RPD	Organic Matter	2010/10/07	0.8		%	35
			Total Organic Carbon (C)	2010/10/07	1.3		%	35
4320611	KU	Matrix Spike	Soluble Chloride (Cl)	2010/10/07		106	%	75 - 125
		QC Standard	Soluble Chloride (Cl)	2010/10/07		100	%	75 - 125
		Spiked Blank	Soluble Chloride (Cl)	2010/10/07		100	%	80 - 120
		Method Blank	Soluble Chloride (Cl)	2010/10/07	<5		mg/L	
		RPD	Soluble Chloride (Cl)	2010/10/07	3.1		%	35
4320837	AD3	QC Standard	Soluble Calcium (Ca)	2010/10/07		95	%	75 - 125
			Soluble Magnesium (Mg)	2010/10/07		101	%	75 - 125
			Soluble Sodium (Na)	2010/10/07		106	%	75 - 125
			Soluble Potassium (K)	2010/10/07		111	%	75 - 125
			Soluble Sulphate (SO4)	2010/10/07		91	%	75 - 125
		Spiked Blank	Soluble Calcium (Ca)	2010/10/07		103	%	88 - 115
			Soluble Magnesium (Mg)	2010/10/07		111	%	80 - 120
			Soluble Sodium (Na)	2010/10/07		102	%	84 - 118
			Soluble Potassium (K)	2010/10/07		104	%	85 - 117
		Method Blank	Soluble Calcium (Ca)	2010/10/07	<1.5		mg/L	
			Soluble Magnesium (Mg)	2010/10/07	<1.0		mg/L	
			Soluble Sodium (Na)	2010/10/07	<2.5		mg/L	
			Soluble Potassium (K)	2010/10/07	<1.3		mg/L	
			Soluble Sulphate (SO4)	2010/10/07	<5.0		mg/L	
		RPD	Soluble Calcium (Ca)	2010/10/07	2.2		%	35
			Soluble Magnesium (Mg)	2010/10/07	3.0		%	35
			Soluble Sodium (Na)	2010/10/07	2.8		%	35
			Soluble Potassium (K)	2010/10/07	0.05		%	35
			Soluble Sulphate (SO4)	2010/10/07	7.3		%	35
4322615	EO1	Matrix Spike	Total Aluminum (Al)	2010/10/12		NC	%	80 - 120
			Total Antimony (Sb)	2010/10/12		116	%	80 - 120
			Total Arsenic (As)	2010/10/12		102	%	80 - 120
			Total Beryllium (Be)	2010/10/12		100	%	80 - 120
			Total Chromium (Cr)	2010/10/12		115	%	80 - 120
			Total Cobalt (Co)	2010/10/12		114	%	80 - 120
			Total Copper (Cu)	2010/10/12		106	%	80 - 120
			Total Lead (Pb)	2010/10/12		104	%	80 - 120
			Total Molybdenum (Mo)	2010/10/12		120	%	80 - 120
			Total Nickel (Ni)	2010/10/12		106	%	80 - 120
			Total Selenium (Se)	2010/10/12		96	%	80 - 120
			Total Silver (Ag)	2010/10/12		105	%	80 - 120
			Total Thallium (Tl)	2010/10/12		108	%	80 - 120
			Total Tin (Sn)	2010/10/12		109	%	80 - 120
			Total Titanium (Ti)	2010/10/12		107	%	80 - 120
			Total Uranium (U)	2010/10/12		114	%	80 - 120
			Total Vanadium (V)	2010/10/12		111	%	80 - 120
			Total Zinc (Zn)	2010/10/12		100	%	80 - 120
		Spiked Blank	Total Aluminum (Al)	2010/10/08		111	%	80 - 120
			Total Antimony (Sb)	2010/10/08		87	%	80 - 120
			Total Arsenic (As)	2010/10/08		88	%	80 - 120
			Total Beryllium (Be)	2010/10/08		88	%	80 - 120
			Total Chromium (Cr)	2010/10/08		106	%	80 - 120
			Total Cobalt (Co)	2010/10/08		106	%	80 - 120
			Total Copper (Cu)	2010/10/08		102	%	80 - 120
			Total Lead (Pb)	2010/10/08		102	%	80 - 120

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4322615	EO1	Spiked Blank	Total Molybdenum (Mo)	2010/10/08		114	%	80 - 120
			Total Nickel (Ni)	2010/10/08		103	%	80 - 120
			Total Selenium (Se)	2010/10/08		85	%	80 - 120
			Total Silver (Ag)	2010/10/08		97	%	80 - 120
			Total Thallium (Tl)	2010/10/08		105	%	80 - 120
			Total Tin (Sn)	2010/10/08		106	%	80 - 120
			Total Titanium (Ti)	2010/10/08		109	%	80 - 120
			Total Uranium (U)	2010/10/08		103	%	80 - 120
			Total Vanadium (V)	2010/10/08		106	%	80 - 120
			Total Zinc (Zn)	2010/10/08		91	%	80 - 120
		Method Blank	Total Aluminum (Al)	2010/10/12	<0.001		mg/L	
			Total Antimony (Sb)	2010/10/12	<0.0002		mg/L	
			Total Arsenic (As)	2010/10/12	<0.0002		mg/L	
			Total Beryllium (Be)	2010/10/12	<0.001		mg/L	
			Total Chromium (Cr)	2010/10/12	0.002, RDL=0.001		mg/L	
			Total Cobalt (Co)	2010/10/12	<0.0003		mg/L	
			Total Copper (Cu)	2010/10/12	<0.0002		mg/L	
			Total Lead (Pb)	2010/10/12	<0.0002		mg/L	
			Total Molybdenum (Mo)	2010/10/12	0.0002, RDL=0.0002		mg/L	
			Total Nickel (Ni)	2010/10/12	0.0009, RDL=0.0005		mg/L	
			Total Selenium (Se)	2010/10/12	<0.0002		mg/L	
			Total Silver (Ag)	2010/10/12	<0.0001		mg/L	
			Total Thallium (Tl)	2010/10/12	<0.0002		mg/L	
			Total Tin (Sn)	2010/10/12	<0.001		mg/L	
			Total Titanium (Ti)	2010/10/12	<0.001		mg/L	
			Total Uranium (U)	2010/10/12	<0.0001		mg/L	
			Total Vanadium (V)	2010/10/12	<0.001		mg/L	
			Total Zinc (Zn)	2010/10/12	<0.003		mg/L	
		RPD	Total Aluminum (Al)	2010/10/12	0.6		%	20
			Total Antimony (Sb)	2010/10/12	7.3		%	20
			Total Arsenic (As)	2010/10/12	0.8		%	20
			Total Beryllium (Be)	2010/10/12	NC		%	20
			Total Chromium (Cr)	2010/10/12	NC		%	20
			Total Cobalt (Co)	2010/10/12	NC		%	20
			Total Copper (Cu)	2010/10/12	NC		%	20
			Total Lead (Pb)	2010/10/12	NC		%	20
			Total Molybdenum (Mo)	2010/10/12	2.8		%	20
			Total Nickel (Ni)	2010/10/12	NC		%	20
			Total Selenium (Se)	2010/10/12	NC		%	20
			Total Silver (Ag)	2010/10/12	NC		%	20
			Total Thallium (Tl)	2010/10/12	NC		%	20
			Total Tin (Sn)	2010/10/12	NC		%	20
			Total Titanium (Ti)	2010/10/12	NC		%	20
			Total Uranium (U)	2010/10/12	2.0		%	20
			Total Vanadium (V)	2010/10/12	NC		%	20
			Total Zinc (Zn)	2010/10/12	NC		%	20
4323030	AD3	Matrix Spike	Soluble (Hot water) Boron (B)	2010/10/07		105	%	75 - 125
		Spiked Blank	Soluble (Hot water) Boron (B)	2010/10/07		99	%	80 - 120
		Method Blank	Soluble (Hot water) Boron (B)	2010/10/07	<0.1		mg/kg	
		RPD	Soluble (Hot water) Boron (B)	2010/10/07	NC		%	35
4323296	KL4	Matrix Spike	Dissolved Calcium (Ca)	2010/10/08		NC	%	80 - 120
			Dissolved Iron (Fe)	2010/10/08		NC	%	80 - 120
			Dissolved Magnesium (Mg)	2010/10/08		98	%	80 - 120
			Dissolved Manganese (Mn)	2010/10/08		93	%	80 - 120
			Dissolved Potassium (K)	2010/10/08		104	%	80 - 120

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4323296	KL4	Matrix Spike	Dissolved Sodium (Na)	2010/10/08		92	%	80 - 120
		Spiked Blank	Dissolved Calcium (Ca)	2010/10/08		98	%	88 - 115
			Dissolved Iron (Fe)	2010/10/08		97	%	81 - 111
			Dissolved Magnesium (Mg)	2010/10/08		102	%	80 - 120
			Dissolved Manganese (Mn)	2010/10/08		99	%	85 - 110
			Dissolved Potassium (K)	2010/10/08		106	%	85 - 117
			Dissolved Sodium (Na)	2010/10/08		95	%	84 - 118
		Method Blank	Dissolved Calcium (Ca)	2010/10/08	<0.3		mg/L	
			Dissolved Iron (Fe)	2010/10/08	<0.06		mg/L	
			Dissolved Magnesium (Mg)	2010/10/08	<0.2		mg/L	
			Dissolved Manganese (Mn)	2010/10/08	<0.004		mg/L	
			Dissolved Potassium (K)	2010/10/08	<0.3		mg/L	
			Dissolved Sodium (Na)	2010/10/08	<0.5		mg/L	
		RPD	Dissolved Calcium (Ca)	2010/10/08	0.3		%	20
			Dissolved Iron (Fe)	2010/10/08	0.03		%	20
			Dissolved Magnesium (Mg)	2010/10/08	1.1		%	20
			Dissolved Manganese (Mn)	2010/10/08	0.09		%	20
			Dissolved Potassium (K)	2010/10/08	0.2		%	20
			Dissolved Sodium (Na)	2010/10/08	1.3		%	20
4323306	KL4	Matrix Spike	Total Barium (Ba)	2010/10/08		99	%	80 - 120
			Total Boron (B)	2010/10/08		106	%	80 - 120
			Total Calcium (Ca)	2010/10/08		NC	%	80 - 120
			Total Iron (Fe)	2010/10/08		105	%	80 - 120
			Total Lithium (Li)	2010/10/08		107	%	80 - 120
			Total Magnesium (Mg)	2010/10/08		105	%	80 - 120
			Total Manganese (Mn)	2010/10/08		105	%	80 - 120
			Total Phosphorus (P)	2010/10/08		115	%	80 - 120
			Total Potassium (K)	2010/10/08		110	%	80 - 120
			Total Silicon (Si)	2010/10/08		103	%	80 - 120
			Total Sodium (Na)	2010/10/08		NC	%	80 - 120
			Total Strontium (Sr)	2010/10/08		102	%	80 - 120
		Spiked Blank	Total Barium (Ba)	2010/10/08		98	%	80 - 120
			Total Boron (B)	2010/10/08		105	%	80 - 120
			Total Calcium (Ca)	2010/10/08		101	%	80 - 120
			Total Iron (Fe)	2010/10/08		102	%	80 - 120
			Total Lithium (Li)	2010/10/08		105	%	80 - 120
			Total Magnesium (Mg)	2010/10/08		105	%	80 - 120
			Total Manganese (Mn)	2010/10/08		102	%	80 - 120
			Total Phosphorus (P)	2010/10/08		110	%	80 - 120
			Total Potassium (K)	2010/10/08		108	%	80 - 120
			Total Silicon (Si)	2010/10/08		101	%	80 - 120
			Total Sodium (Na)	2010/10/08		98	%	80 - 120
			Total Strontium (Sr)	2010/10/08		101	%	80 - 120
		Method Blank	Total Barium (Ba)	2010/10/08	<0.01		mg/L	
			Total Boron (B)	2010/10/08	<0.02		mg/L	
			Total Calcium (Ca)	2010/10/08	<0.3		mg/L	
			Total Iron (Fe)	2010/10/08	<0.06		mg/L	
			Total Lithium (Li)	2010/10/08	<0.02		mg/L	
			Total Magnesium (Mg)	2010/10/08	<0.2		mg/L	
			Total Manganese (Mn)	2010/10/08	<0.004		mg/L	
			Total Phosphorus (P)	2010/10/08	<0.1		mg/L	
			Total Potassium (K)	2010/10/08	<0.3		mg/L	
			Total Silicon (Si)	2010/10/08	<0.1		mg/L	
			Total Sodium (Na)	2010/10/08	<0.5		mg/L	
			Total Strontium (Sr)	2010/10/08	<0.02		mg/L	

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4323306	KL4	Method Blank	Total Sulphur (S)	2010/10/08	<0.2		mg/L	
		RPD	Total Barium (Ba)	2010/10/08	1.9		%	20
			Total Boron (B)	2010/10/08	1.1		%	20
			Total Calcium (Ca)	2010/10/08	0.4		%	20
			Total Iron (Fe)	2010/10/08	NC		%	20
			Total Lithium (Li)	2010/10/08	NC		%	20
			Total Magnesium (Mg)	2010/10/08	1.6		%	20
			Total Manganese (Mn)	2010/10/08	2.4		%	20
			Total Phosphorus (P)	2010/10/08	NC		%	20
			Total Potassium (K)	2010/10/08	1.8		%	20
			Total Silicon (Si)	2010/10/08	0.9		%	20
			Total Sodium (Na)	2010/10/08	1.9		%	20
			Total Strontium (Sr)	2010/10/08	0.7		%	20
			Total Sulphur (S)	2010/10/08	0.7		%	20
4323876	JB9	Method Blank	Sieve - Pan	2010/10/08	<0.2		%	
			Sieve - #200 (>0.075mm)	2010/10/08	<0.2		%	
		RPD	Sieve - Pan	2010/10/08	2.4		%	35
			Sieve - #200 (>0.075mm)	2010/10/08	6.3		%	35
4327213	SG8	Matrix Spike	Total Antimony (Sb)	2010/10/12		103	%	75 - 125
			Total Arsenic (As)	2010/10/12		89	%	75 - 125
			Total Barium (Ba)	2010/10/12		NC	%	75 - 125
			Total Beryllium (Be)	2010/10/12		91	%	75 - 125
			Total Cadmium (Cd)	2010/10/12		94	%	75 - 125
			Total Chromium (Cr)	2010/10/12		NC	%	75 - 125
			Total Cobalt (Co)	2010/10/12		95	%	75 - 125
			Total Copper (Cu)	2010/10/12		NC	%	75 - 125
			Total Lead (Pb)	2010/10/12		92	%	75 - 125
			Total Mercury (Hg)	2010/10/12		125	%	75 - 125
			Total Molybdenum (Mo)	2010/10/12		112	%	75 - 125
			Total Nickel (Ni)	2010/10/12		NC	%	75 - 125
			Total Selenium (Se)	2010/10/12		81	%	75 - 125
			Total Silver (Ag)	2010/10/12		97	%	75 - 125
			Total Thallium (Tl)	2010/10/12		93	%	75 - 125
			Total Tin (Sn)	2010/10/12		106	%	75 - 125
			Total Uranium (U)	2010/10/12		92	%	75 - 125
			Total Vanadium (V)	2010/10/12		NC	%	75 - 125
			Total Zinc (Zn)	2010/10/12		NC	%	75 - 125
		QC Standard	Total Arsenic (As)	2010/10/12		97	%	50 - 150
			Total Barium (Ba)	2010/10/12		99	%	69 - 131
			Total Chromium (Cr)	2010/10/12		96	%	41 - 159
			Total Cobalt (Co)	2010/10/12		95	%	75 - 125
			Total Copper (Cu)	2010/10/12		90	%	72 - 127
			Total Lead (Pb)	2010/10/12		90	%	54 - 146
			Total Mercury (Hg)	2010/10/12		113	%	75 - 125
			Total Nickel (Ni)	2010/10/12		101	%	61 - 139
			Total Vanadium (V)	2010/10/12		111	%	50 - 150
			Total Zinc (Zn)	2010/10/12		85	%	72 - 128
		Spiked Blank	Total Antimony (Sb)	2010/10/12		100	%	75 - 125
			Total Arsenic (As)	2010/10/12		89	%	75 - 125
			Total Barium (Ba)	2010/10/12		98	%	75 - 125
			Total Beryllium (Be)	2010/10/12		95	%	75 - 125
			Total Cadmium (Cd)	2010/10/12		96	%	75 - 125
			Total Chromium (Cr)	2010/10/12		99	%	75 - 125
			Total Cobalt (Co)	2010/10/12		97	%	75 - 125
			Total Copper (Cu)	2010/10/12		97	%	75 - 125

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4327213	SG8	Spiked Blank	Total Lead (Pb)	2010/10/12		101	%	75 - 125
			Total Mercury (Hg)	2010/10/12		121	%	75 - 125
			Total Molybdenum (Mo)	2010/10/12		106	%	75 - 125
			Total Nickel (Ni)	2010/10/12		99	%	75 - 125
			Total Selenium (Se)	2010/10/12		84	%	75 - 125
			Total Silver (Ag)	2010/10/12		101	%	75 - 125
			Total Thallium (Tl)	2010/10/12		100	%	75 - 125
			Total Tin (Sn)	2010/10/12		103	%	75 - 125
			Total Uranium (U)	2010/10/12		93	%	75 - 125
			Total Vanadium (V)	2010/10/12		101	%	75 - 125
			Total Zinc (Zn)	2010/10/12		91	%	75 - 125
		Method Blank	Total Antimony (Sb)	2010/10/08	<1		mg/kg	
			Total Arsenic (As)	2010/10/08	<1		mg/kg	
			Total Barium (Ba)	2010/10/08	<10		mg/kg	
			Total Beryllium (Be)	2010/10/08	<0.4		mg/kg	
			Total Cadmium (Cd)	2010/10/08	<0.1		mg/kg	
			Total Chromium (Cr)	2010/10/08	<1		mg/kg	
			Total Cobalt (Co)	2010/10/08	<1		mg/kg	
			Total Copper (Cu)	2010/10/08	<5		mg/kg	
			Total Lead (Pb)	2010/10/08	<1		mg/kg	
			Total Mercury (Hg)	2010/10/08	<0.05		mg/kg	
			Total Molybdenum (Mo)	2010/10/08	<0.4		mg/kg	
			Total Nickel (Ni)	2010/10/08	<1		mg/kg	
			Total Selenium (Se)	2010/10/08	<0.5		mg/kg	
			Total Silver (Ag)	2010/10/08	<1		mg/kg	
			Total Thallium (Tl)	2010/10/08	<0.3		mg/kg	
			Total Tin (Sn)	2010/10/08	<1		mg/kg	
			Total Uranium (U)	2010/10/08	<1		mg/kg	
			Total Vanadium (V)	2010/10/08	<1		mg/kg	
			Total Zinc (Zn)	2010/10/08	<10		mg/kg	
		RPD	Total Antimony (Sb)	2010/10/12	NC		%	35
			Total Arsenic (As)	2010/10/12	23.0		%	35
			Total Barium (Ba)	2010/10/12	13.3		%	35
			Total Beryllium (Be)	2010/10/12	NC		%	35
			Total Cadmium (Cd)	2010/10/12	NC		%	35
			Total Chromium (Cr)	2010/10/12	20.1		%	35
			Total Cobalt (Co)	2010/10/12	3.5		%	35
			Total Copper (Cu)	2010/10/12	3.2		%	35
			Total Lead (Pb)	2010/10/12	1.2		%	35
			Total Mercury (Hg)	2010/10/12	NC		%	35
			Total Molybdenum (Mo)	2010/10/12	NC		%	35
			Total Nickel (Ni)	2010/10/12	2.4		%	35
			Total Selenium (Se)	2010/10/12	NC		%	35
			Total Silver (Ag)	2010/10/12	NC		%	35
			Total Thallium (Tl)	2010/10/12	NC		%	35
			Total Tin (Sn)	2010/10/12	NC		%	35
			Total Uranium (U)	2010/10/12	NC		%	35
			Total Vanadium (V)	2010/10/12	1.3		%	35
			Total Zinc (Zn)	2010/10/12	3.5		%	35

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the

STANTEC CONSULTING LTD
Attention: ELAINE LITTLE
Client Project #: 110218287 MALLIK SUMP ASSESSME
P.O. #: 16300R-40
Site Reference: MALLIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB095141

spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Sample Integrity Form

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ELAINE LITTLE

Maxxam Job #:	B095141
Date Received:	2010/10/04
Your C.O.C. #:	A012970
Your Project #:	110218287 MALLIK SUMP ASSE
Your P.O. #:	16300R-40
Maxxam Project Manager:	ALAINA HUNTER
Quote #:	A90695

No discrepancies noted.

Report Comments

Received Date: 2010/10/04 **Time:** 18:34 **By:** _____

Inspected Date: _____ **Time:** _____ **By:** _____

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Validation Signature Page

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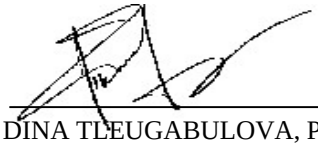

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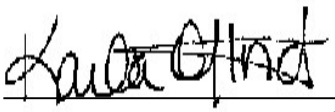

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Page: 1 of 1

	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☒	Report Distribution (E-Mail):
Company:	STANTEC		elaine.little@stantec.com
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REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 1102182287
Project # / Name: Mallik sump assessment
Site Location: Mallik, NWT
Quote #: Stantec rates
Sampled By: Olivier Piraux

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☑ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4 (detailed)	Assessment ICP Metals	Basic Class II Landfill	* Routine Analysis	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☒ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik_soil_1.1	10cm	Soil	10/09/28 12h		X		X			X										3
2	Mallik_soil_1.2	50cm	Soil	10/09/28 12h		X		X			X										3
3	Mallik_soil_1.3	100cm	Soil	10/09/28 12h		X		X			X										3
4	Mallik_soil_2.1	10cm	Soil	10/09/30 12h		X		X			X										3
5	Mallik_soil_2.2	50cm	Soil	10/09/30 12h		X		X			X										3
6	Mallik_soil_2.3	100cm	Soil	10/09/30 12h		X		X			X										3
7	Mallik_water_1	—	GW	~~10/09/28~~ 10/09/30										X		X					2
8	Mallik_water_2	—	GW	@ 10/09/28 12h40										X		X					2
9	Mallik_water_3	—	GW	10/09/28 12h45										X		X					2
10	Mallik_water_4	—	GW	10/09/28 12h40										X		X					2
11																					
12																					

Please indicate Filtered, Preserved or Both (F, P, F/P) → P DW2/RL F/P

Relinquished By (Signature/Print): OLIVIER PIRAUX — Date (YY/MM/DD): 10/10/04 — Time (24:00): 13:00

Relinquished By (Signature/Print): — Date (YY/MM/DD): — Time (24:00):

Special Instructions: * Routine analysis for soil: volumetric water content, soil texture, organic matter content, conductivity, PH.

# of Jars Used & Not Submitted: —

LAB USE ONLY

Received By: Jessica Coffey Jessica Coffey — Date: 2010/10/04 — Time: 18:34

Maxxam Job #: B095141

Lab Comments:

Custody Seal	Temperature	Ice
NO	14, 14, 14	YES

2011 Mallik Annual Sump Monitoring Report

FOR SUBMISSION TO THE NORTHWEST TERRITORIES WATER BOARD UNDER WATER LICENSE N7L1-1817

Prepared for:

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

Prepared by:

KAVIK-STANTEC

November 2011

Table of Contents

1 Introduction 1
2 Site Location 2
3 Methods 5
3.1 Visual Assessment 5
3.2 Active-Layer Depth Measurements 5
3.3 Ground Temperature Monitoring 6
3.4 Electromagnetic Surveys 6
3.5 Soil Sampling 6
3.6 Water Sampling 7
4 Results 8
4.1 Visual Assessment 8
4.2 Active Layer Depth Measurements 10
4.3 Air and Ground Temperature Monitoring 12
4.3.1 Air and Ground Surface Temperatures 12
4.3.2 Temperatures recorded along thermistor strings 13
4.4 Electromagnetic Surveys 18
4.5 Soil and Water Sampling 18
4.5.1 Soil Sampling 20
4.5.2 Water Sampling 24
5 Conclusion 27
6 References 29

Appendix A Site Photographs 31
Appendix B Thermistor Data 43
Appendix C Electromagnetic Surveys 51
Appendix D Laboratory Analysis 53

List of Tables

Table 3-1 Current Depths of Thermistor Sensors....6
Table 4-1 Summary of Active-Layer Measurements....10
Table 4-2 Air and Ground Surface Temperatures....12
Table 4-3 Ground Temperatures at thermistor 07GSC-01....14
Table 4-4 Ground Temperatures at thermistor 07GSC-02....15
Table 4-5 Ground Temperatures at thermistor 07GSC-03....16
Table 4-6 Ground Temperatures at thermistor 07GSC-04....17
Table 4-7 Soil sampling Locations....20
Table 4-8 Soil Sampling Results – Salinity....22
Table 4-9 Soil Sampling Results – Salinity....23
Table 4-10 Water Sampling Locations....24
Table 4-11 Water Sampling Results....25
Table 4-12 Water Sampling Results....26

List of Figures

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories....2
Figure 2-2 Oblique aerial view of Mallik site (photo taken on August 20th, 2011)....3
Figure 2-3 Thermistor Locations....4
Figure 4-1 Aerial view of the area from the South (August 20th, 2011). The yellow arrows indicate areas of potential thaw subsidence....9
Figure 4-2 Location of Active-Layer Transects. The black dashed lines represent the transects....11
Figure 4-3 Ground surface conditions at the thermistor locations....13
Figure 4-4 Mean ground temperature at Mallik 07GSC-1 (21/08/2010 to 20/08/2010)....14
Figure 4-5 Mean ground temperature at Mallik 07GSC-2 (21/08/2010 to 20/08/2010)....15
Figure 4-6 Mean ground temperature at Mallik 07GSC-3 (21/08/2010 to 20/08/2010)....16
Figure 4-7 Mean ground temperature at Mallik 07GSC-1 (21/08/2010 to 20/08/2010)....17
Figure 4-8 Location of soils and water samples....19
Figure A-1 Aerial View of Mallik site from the North (looking South)....33
Figure A-2 Aerial View of Mallik site from the South (looking North)....34
Figure A-3 Bird and mammal prints in the sump area....35
Figure A-4 Air and ground temperature sensors next to Mallik 2L-38 wellhead....36
Figure A-5 View of the subsidence area at the eastern edge of the 1998 Sump....37
Figure A-6 View of the subsidence area at the western edge of the 1998 Sump....37
Figure A-7 Sharp contrast between the undisturbed vegetated terrain and the bare soils along the edges of the 1998 Camp Sump....38
Figure A-8 View of the depression and ponded water at the southern corner of the 1998 Camp sump....38
Figure A-9 Small subsidence area at the southern corner of the 2002 Sump....39
Figure A-10 View of the south-western edge of the 2002 Sump....39
Figure A-11 View of the bare 2002 Sump surface looking west....40
Figure A-12 Small depression and tension cracks along the north-eastern edge of the 2002 Sump....40

Figure A-13 Ground conditions and vegetation cover along the control transect 41
Figure B-1 Daily Air Temperatures (October 2010 to August 2011) 45
Figure B-2 Daily Ground Temperatures (October 2010 to August 2011) 46
Figure B-3 Thermistor 07GSC-01 – Daily Ground Temperatures (October 2010 to August 2011) 47
Figure B-4 Thermistor 07GSC-02 – Daily Ground Temperatures (October 2010 to August 2011) 48
Figure B-5 Thermistor 07GSC-03 – Daily Ground Temperatures (October 2010 to August 2011) 49
Figure B-6 Thermistor 07GSC-04 – Daily Ground Temperatures (October 2010 to August 2011) 50

Abbreviations

ARI..... Aurora Research Institute, Aurora College
CCME..... Canadian Council of Ministers of the Environment
GSC .....Geological Survey of Canada
EM..... Electromagnetic
ESSIS..... Environmental SubSurface Imaging Solutions Ltd.
IORL..... Imperial Oil Resources Ltd.
ISR.....Inuvialuit Settlement Region
JAPEX..... JAPEX Canada Ltd.
JNOC..... Japan National Oil Corporation
mbg.....meters below ground
ml……millilitre
NWT..... Northwest Territories
SDL..... Significant Discovery Licence

1 Introduction

The Mallik L-38 lease area has been the site of three historical drilling programs (1972, 1998, and 2002), during which a total of three conventional drilling sumps were constructed to dispose of drill cuttings and fluids. Imperial Oil Ltd. (IOL) drilled the original IOL Mallik L-38 discovery well during the winter of 1971-1972, and constructed a large drilling waste disposal sump (approximately 80 m x 95 m). In 1998, the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore et al. 1999). With JAPEX Canada Ltd. (JAPEX) as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a drilling waste disposal sump (approximately 45 m x 50 m). In 2002, a seven-party participant group, again led again by JNOC and GSC with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste associated with the three wells. In the 2007-2008 Mallik program the 2L- and 3L-38 wells were re-entered and the drilling waste was removed from site (sumpless program).

The 2011 Annual Sump Monitoring Report by KAVIK-Stantec Inc. (KAVIK-Stantec) details the fourth year of a seven year monitoring program to monitor the stability of the Mallik 2L-38 and 3L/4L/5L/-38 drilling waste sumps. The monitoring program started in 2008 and is scheduled to conclude in 2014. The information in this report is required under Part H: Conditions Applying to Abandonment and Restoration of the Northwest Territories Board Licence No. N7L1-1817.

The 2011 site visit was conducted on August 20th and 22nd and included the following:

- a visual assessment of the site with an emphasis on sump cap conditions
- measurements of the active layer thickness within the sump areas, around their perimeters, as well as in an undisturbed area adjacent to the sumps
- maintenance of the monitoring equipment on site
- downloading of temperature data at five thermistor locations
- electromagnetic (EM) surveys (EM 31 and 38) conducted by two representatives from Environmental SubSurface Imaging Solutions Ltd. (ESSIS) on both sumps and surrounding areas
- soil sampling in areas showing high electromagnetic conductivities
- surface water sampling of ponded water located on the sumps and in an undisturbed area (control) adjacent to the sumps

This report herein documents the results of this site visit and presents the data gathered from the monitoring activities.

2 Site Location

The Mallik L-38 site is located on the west coast of Richards Island, in the outer region of the Mackenzie Delta and bordering the Beaufort Sea, within the Inuvialuit Settlement Region (ISR), Northwest Territories (Figure 2-1). The area consists of nearshore floodplains on the west coast of Mallik Bay. The site coordinates are approximately 69°27'38"N, 134°39'42"W. The Mallik lease area is located on Crown land within the IORL Significant Discovery License (SDL) 060. The locations of the sumps are shown on Figures 2-2 and 2-3.

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories

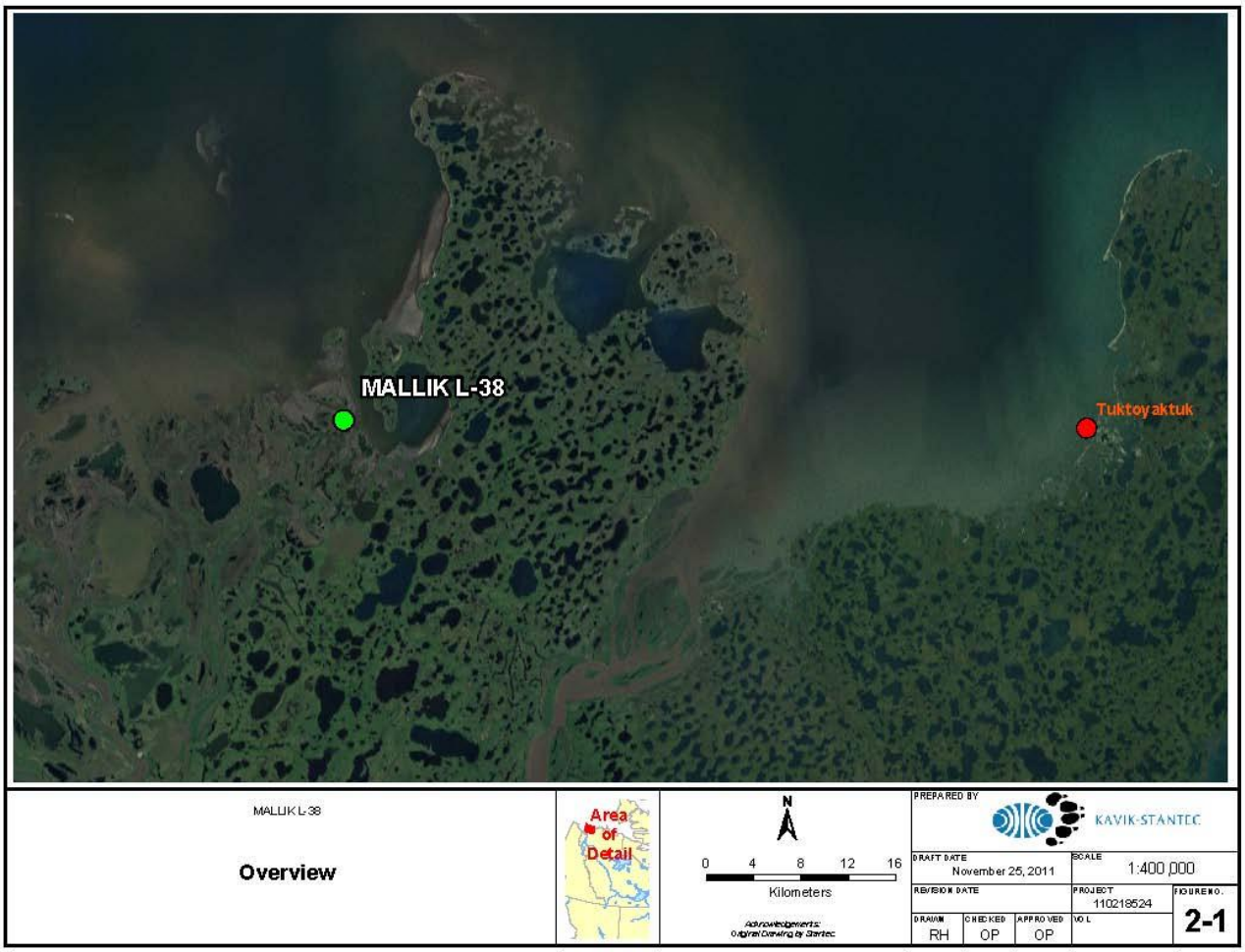


Figure 2-2 Oblique aerial view of Mallik site (photo taken on August 20th, 2011)

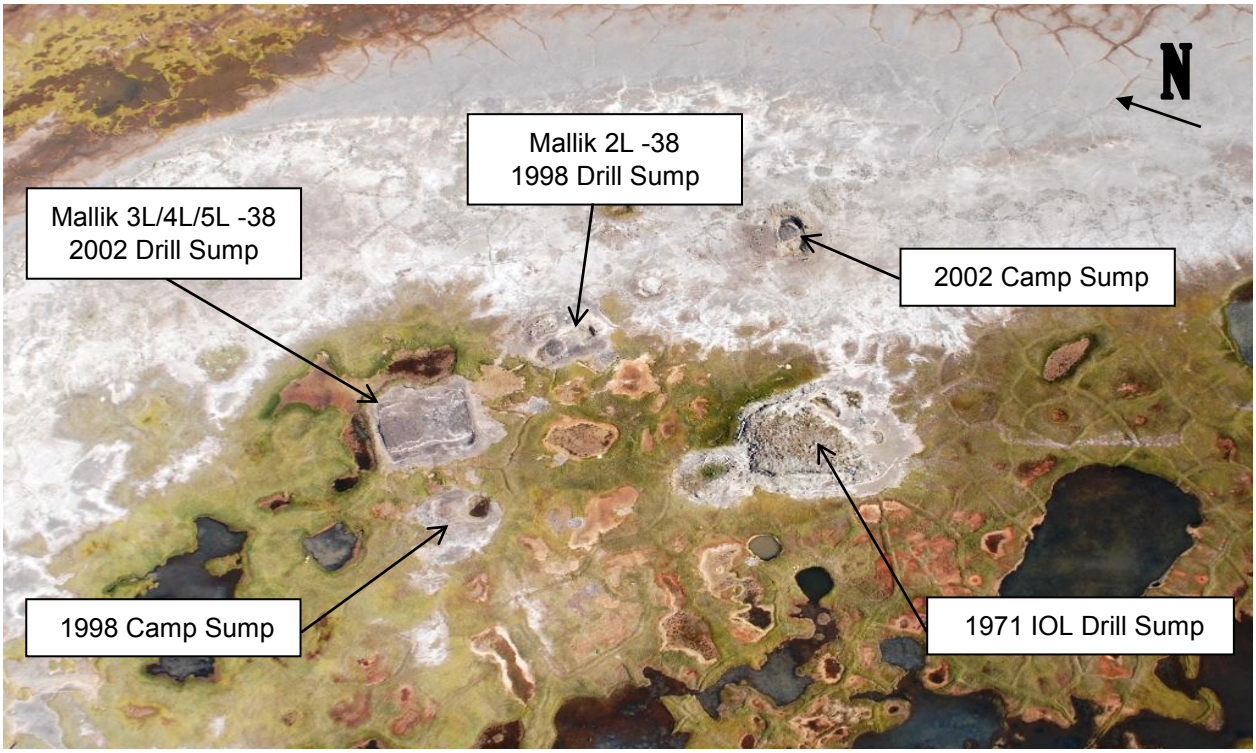
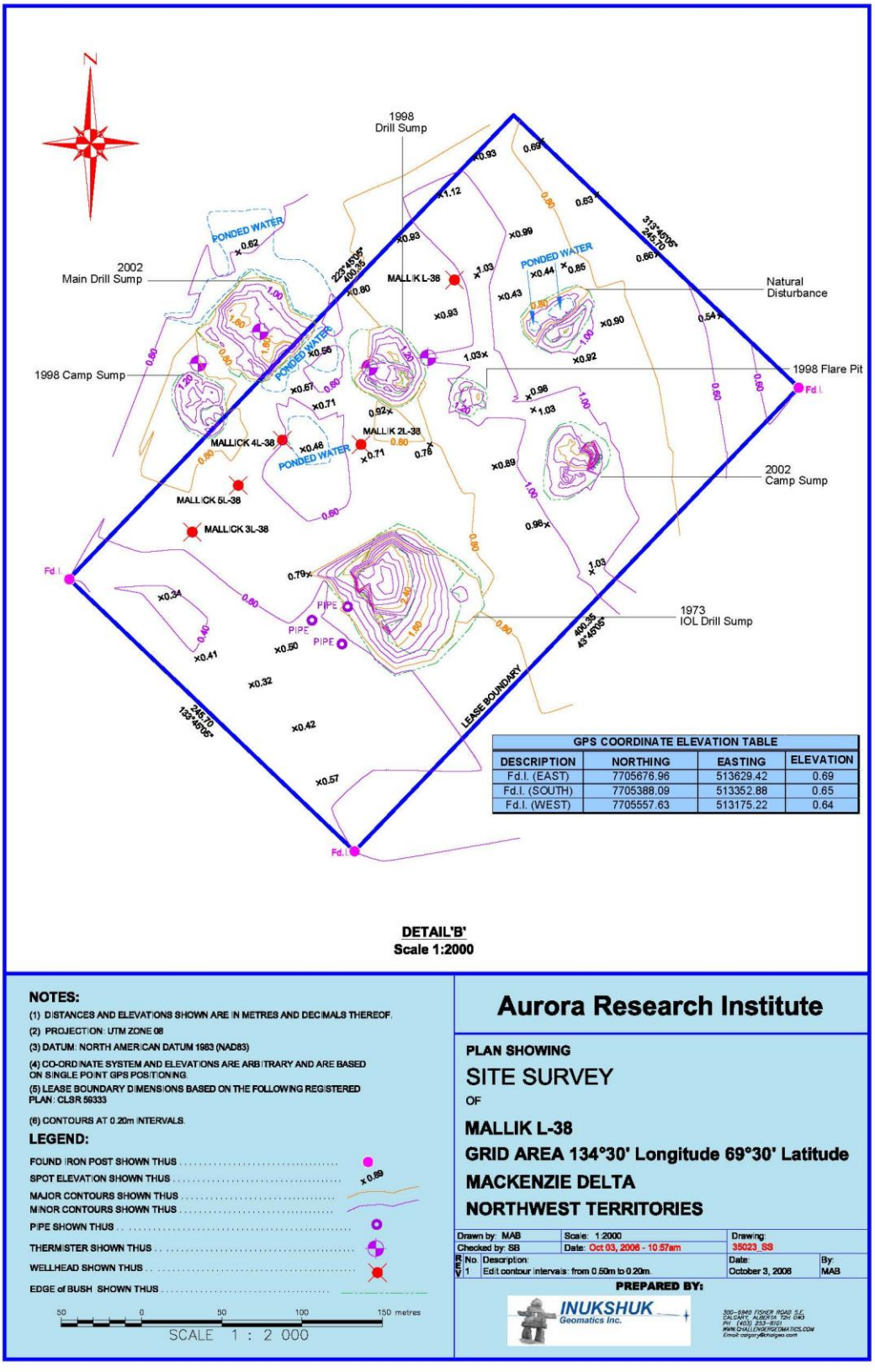


Figure 2-3 Thermistor Locations



3 Methods

The methods for monitoring the Mallik sumps were developed using the following documents:

- Water License No. N7L1-1817 (NWT Water Board, 2004)
- Previous requests and requirements from the NWT Water Board (NWT Water Board, 2006)
- *Protocol for the Management of Drilling Waste Disposal Sumps* – Inuvialuit Settlement Region NWT (NWT Water Board, 2006a)

The following sections outline the methodology followed throughout each component of the monitoring program, including: visual assessment, active layer depth measurements, ground temperature monitoring,electromagnetic surveys, and soil and water sampling.

3.1 Visual Assessment

Visual assessment was completed by a KAVIK-Stantec representative during the August 2011 visit. The purpose of the visual assessment was to document the physical conditions of the sumps and their immediate surrounding areas. Some of the key elements that were observed included:

- settlement and/or subsidence
- presence and/or absence of ponding
- damage to existing monitoring facilities (thermistors and/or dataloggers)
- erosion, stress and/or tension cracks
- vegetation health and establishment on the sump caps or surrounding areas

The visual assessments were performed from both the air and ground. Site photographs can be reviewed in Appendix A.

3.2 Active-Layer Depth Measurements

Using a specially designed probe, active-layer depths were measured during the August 2011 site assessment. The methodology and location of the measurement points were as per the *Protocol for the Monitoring of Drilling-Waste Disposal, Inuvialuit Settlement Region Northwest Territories* (NWT Water Board 2006). Active-layer depths were monitored at a control area, on the sump caps and at the perimeter of the sump caps. The number of active layer measurements was increased from the surveys in previous years based on feedback from multiple sources (including the NWT Water Board).

3.3 Ground Temperature Monitoring

In 2007, four thermistors were installed in and surrounding the Mallik sumps, as specified in *Part H: Conditions Applying to Abandonment and Restoration under NWT Water Licence No. N7L1-1817.* The thermistors cables were installed to a maximum depth of 10.5 m, with thermistors located at various levels below ground surface as required under the Licence. Figure 2-2 shows the thermistors locations and Table 3-1 the logging depth.

Table 3-1 Current Depths of Thermistor Sensors

Thermistor Sensor	Logging Depths (mbg)			
	07GSC-01[1]	07GSC-02[1]	07GSC-03[1]	07GSC-04
1	-	1.0	1.0	1.0
2	0.35	1.5	1.5	1.5
3	0.85	2.0	2.0	2.0
4	1.35	2.5	2.5	2.5
5	2.35	4.5	4.5	3.5
6	4.35	6.5	6.5	5.5
7	6.85	10.5	10.5	8.0
8	4.28	5.65	5.65	10.5

[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e. the depth of the sensor #8 is above the sensor #6).

Two new thermistors and data loggers were installed during the September 2010 field visit to replace damaged equipment. The new thermistors have been set up on the 2L-38 well head location marker and on the adjacent ground to record hourly air and ground surface temperatures (see Figure A-4). Air and ground surface data are presented in Section 4.3.1.

3.4 Electromagnetic Surveys

ESSIS conducted EM surveys (EM31 and EM38) on August 22nd, 2011 using Geonics EM31 and EM38 ground conductivity meters. These instruments are used to identify the lateral extents of ion-rich regions, which might reflect ion migration from the sump to the surrounding areas, and help identify the requirement for additional sampling. The survey measures apparent conductivity of the soil around the sump site to determine if salts in the drilling waste are migrating through the soil from the sump. The EM38 meter measures apparent conductivity at soil depths of 0.0 to 1.5 m (shallow), while the EM31 unit measures apparent conductivity at soil depths of 0.0 to 5.0 m (deep).

3.5 Soil Sampling

The purpose of the soil sampling was to investigate areas of apparent higher conductivity. Soil samples from an undisturbed control area were collected (Mallik_soil_01) for comparison. See Figure 4-3 for the location of the soil samples.

The soil samples were obtained using a clean shovel and a soil knife. The soil surface was removed and samples were collected at a target depth of 5 cm below ground surface. Approximately 1kg of soil was collected for each sample. The samples were retained for analysis in laboratory-issued zip-lock containers and submitted to Maxxam Analytics Inc. (Maxxam). See Appendix C for the certified laboratory results from Maxxam.

3.6 Water Sampling

Surface water was sampled from both natural ponding (i.e. a control area away from the sumps) and in areas related to previous ground disturbance (i.e. within the sump areas). Sampling was completed following standard water sampling protocols. Samples were collected at arm's length (about 1 m) from the edge of the ponding areas, and then stored in laboratory-issued 500 ml plastic jars and two 250 ml amber glass jars. Samples were submitted to Maxxam in Edmonton, AB for salinity analysis. The certified laboratory results are provided in Appendix C. See Figure 4-3 for the location of the water samples. The guidelines used to compare the results from the water sampling program are the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for Freshwater and Aquatic Life*.

4 Results

4.1 Visual Assessment

The 2011 visual assessment was conducted in late August, a snow free period that corresponds to near-maximum thaw depth. Refer to Appendix A for a complete set of site photographs.

The 2010 visual site assessment was conducted in late September and was limited due to extensive snow cover (15-20 cm of fresh snow on site). Although a vegetation assessment of the sump caps could not be evaluated in 2010, the general overview of the site topography and main features was noted.

Site drainage

The site appears to be generally drier than during previous years. This is based on general observations from the ground surface, from the air, and from a review and comparison of previous year's field photos. Observations in the field and from the available air photos and satellite imagery, show that the Mallik site is characterized by several small lakes, ponds and puddle areas. These ponding areas are generally shallow (i.e. <1m deep) and their extent ranges from a few square meters (m^2) to over 250 m^2. Several ponds and puddles sampled last year were dry in August 2011.

A thin layer of white crust was observed on the soil surface at several locations. It is though that the deposits consist of saline staining. This is based on the incursion of seawater on the site during the annual storm surges. Soil salinization is more evident in topographic lows, where surface water pools and then evaporates. Other evidence of storm surges is the presence of several large wood logs scattered throughout the area.

Vegetation

It is estimated that less than 10% of the total sump caps are currently covered by vegetation. The vegetation is predominantly composed of a variety of graminoid species, such as sedges and grasses, with a few sporadic low shrubs and mosses.

Surface Subsidence

The visual assessment suggests several evidences of surface subsidence in the sump areas (see Figure 4.1). The yellow arrows on Figure 4.1 indicate areas of potential thaw subsidence.

Localized depressions are present on both the eastern and western portions of the 1998 Sump. The subsidence is more prominent at the eastern extent, where the bottom of the depression is approximately 120 cm below the surrounding undisturbed soil surface. The subsidence area on the western portion is up to 70 cm deep. The total subsiding area corresponds to approximately 20% of the total sump area. No surface water was observed in the depression at the time of the site assessment in August 2011.

Signs of minor surface subsidence were also noted along the inner perimeter of the 2002 Sump, but at a much lower level than observed at the 1998 Sump. The subsidence area is located in the southwest corner and is approximately 5 m^2 in size. The bottom of the depression is approximately 60 cm lower than the surrounding undisturbed soil surface. No pooling water was observed in August 2011, but the presence of water-saturated soils and water marks along the edges of the depression suggest that water does accumulate in this depression.

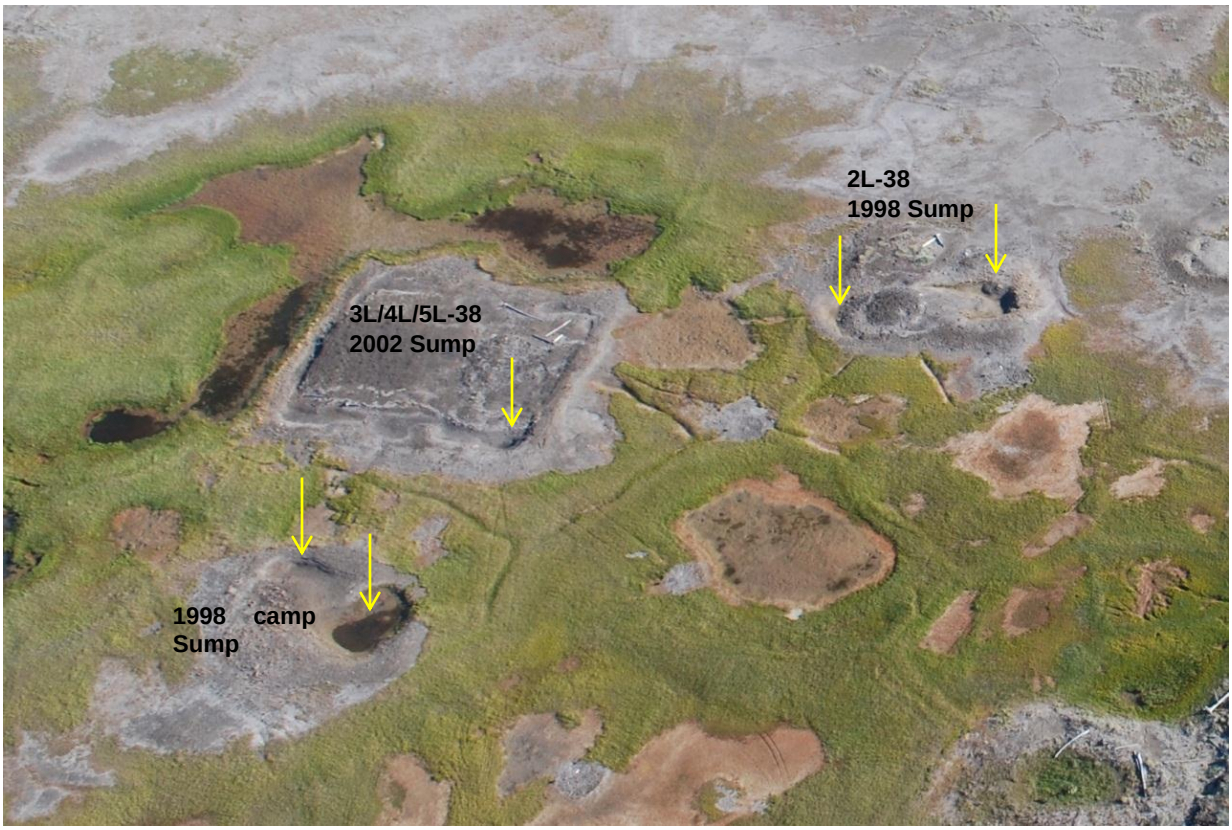
The northeast corner of the 1998 Camp Sump is also characterized by a depression and ponding water. The depression is approximately 4 meters by 6 meters in size and is about 1 meter deep. At the time of the site visit there was 22 cm of water in the base of the depression. Aquatic plant species were also noted in the water.

Several signs of wildlife were also noted at the site (see photos in Appendix 1). The most common signs consist of bird droppings, as well as birds and caribou/reindeer tracks.

Tension cracks

High-centre ice wedge polygons were also observed in some terrestrial areas in the vicinity of the Mallik site. The polygons are variable in size, and range from a few square meters to over 40 m^2. Numerous tension cracks were observed at the soil surface. Some correspond to polygon limits i.e. annual ice-wedge cracks) while other tension cracks correspond to minor thermal contractions. Most tension cracks are naturally occurring while a few, located along the edges and perimeters of the sumps, may be induced by surface subsidence.

Figure 4-1 Aerial view of the area from the South (August 20th, 2011). The yellow arrows indicate areas of potential thaw subsidence.



4.2 Active Layer Depth Measurements

Active layer depth measurements were taken on August 20th, 2011. Figure 4-2 shows the locations of the different transects. The black dashed lines represent approximate locations of the transects used for active-layer measurements. Note that the control transect covers both vegetated and unvegetated soils. Table 4-1 provides a summary and comparison of the thawing depths. Complete active layer data and relevant site photographs are presented in Appendix B.

Table 4-1 Summary of Active-Layer Measurements

	Mallik 2L-38 1998 Drilling Sump		Mallik 3L/4L/5L-38 2002 Drilling Sump		1998 Camp Sump		Control Transect
	Sump cap	perimeter	Sump cap	perimeter	Sump cap	Perimeter	
Total Number of probing	30	44	22	36	9	10	35
Minimum Thawing Depth (cm)	90	94	111	108	103	103	84
Maximum Thawing Depth (cm)	151	150	196	153	125	121	142
Average Thawing Depth (cm)	121	114	133	117	112	113	113

Mallik 2L-38 (1998 Drilling Sump)

Active layer depths on the 1998 Sump ranged between 90 cm and 151 cm and averaged 121 cm. Active-layer depths around the perimeter of the sump cap ranged from 94 cm to 150 cm and averaged 114 cm. The 2010 average active-layer depth was 119 cm for the sump cap and 113 cm for the sump perimeter.

Mallik 3L/4L/5L-38 (2002 Drilling Sump)

Active layer depths on the 2002 Sump cap ranged between 111 cm and 196 cm and averaged 133 cm. This represents an increase of 15 cm when compared to last year's data. Active-layer depths around the perimeter of sump cap the ranged from 108 cm to 153 cm and averaged 117 cm; a decrease of 3 cm from the 2010 average.

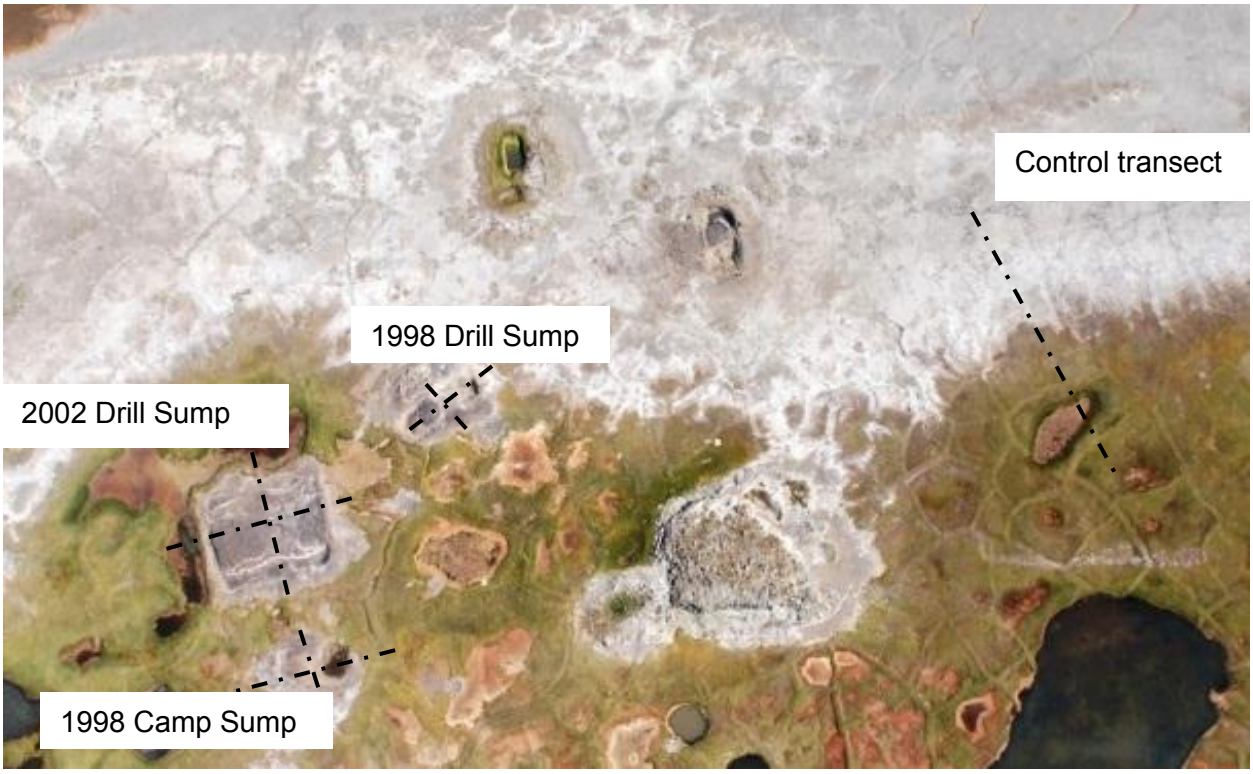
1998 Camp Sump

Active layer measurements on the 1998 camp sump ranged from 103 cm to 125 cm, with an average of 112 cm. Active layer depths around the perimeter of the sump cap are quite similar, ranging from 103 cm to 125 cm, with an average of 112 cm.

Control transect

The location of the control transect was moved slightly from last year's control transect in order to record active layer depth along various ground surface conditions (i.e. vegetated surface to bare soil). The transect is located in an undisturbed area located about 150 m east from the Mallik 3L/4L/5L-38 sump. The transect location was recorded by GPS. Active layer depths on the control transect range from 84 cm to 142 cm, with an average of 113 cm (based on an average of 35 measurements in total). The average active layer depth measured on September 28th, 2010 was also 113 cm (based on 8 measurements in total).

Figure 4-2 Location of Active-Layer Transects. The black dashed lines represent the transects.



4.3 Air and Ground Temperature Monitoring

In addition to the four thermistor cables (GSC-01 to GSC-04) already present on site, two extra thermistors were installed on September 30th 2010, to record air and ground surface temperature (i.e. 2 cm below ground surface).

The following section presents a summary of the air and ground temperature conditions recorded from October 1st, 2010 to August 20th, 2011. The locations of the thermistors are shown on Figure 2-3, and Tables 4-2 to 4-6 show the mean, maximum and minimum ground temperature for each sensor depth. The diagrams showing the annual variation of the ground temperature at each sensor depth are provided in Appendix B, and the digital raw data are attached to this report.

4.3.1 Air and Ground Surface Temperatures

Air and ground surface temperatures were recorded at the Mallik site during 2010-2011. The air temperature thermistor is installed at approximately 1.5 meters above ground level. The sensor is mounted within a radiation shield to minimize the heating effects of solar radiation and direct exposure to rain and snow. The ground temperature thermistor is buried approximately 2 cm below ground level. The soil texture consists of over 90% silt, with very minor fine sand. The ground was disturbed during drilling operations in 2002 and there is no vegetation in the area.

Table 4-2 Air and Ground Surface Temperatures

Datalogger	Maximum (°C)	Minimum (°C)	Average (°C)
Ground surface	29.1	-13.4	-2.1
Air	26.9	-39.4	-10.6

The mean air temperature recorded at Mallik from September 30th, 2010 to August 20th, 2011 is -10.6°C. It should be noted that this does not represent the annual average as the late August and September data of 2010 are missing. The warmest air temperature recorded over this period was 26.9°C (recorded on August 5th, 2011). The coldest air temperature recorded over the 2010-2011 winter was -39.4°C (recorded on January 23rd, 2011).

The mean ground temperature recorded for the period extending from September 30th, 2010 to August 20th, 2011 was −2.1°C. The insulation effect of the snow cover is clearly visible on the annual diagram (See Appendix B: Thermistor data). In contrast to the air temperature, the winter ground temperatures are more stable and are not subject to daily oscillations.

4.3.2 Temperatures recorded along thermistor strings

Automated ground temperature monitoring has been conducted at Mallik since April 2007. The thermistor depths range from just below ground surface to a maximum depth of 10.5 m. Figure 4-3 shows the ground surface conditions at each thermistor. Thermistors are set up to record the hourly temperature. Note that the data loggers connected to the thermistor strings did not record any ground temperature data between August 30th and September 30th of 2010. Unfortunately this data gap does not allow a mean annual average to be calculated. As a result, it is not possible to present an annual average comparison with last year's dataset.

Figure 4-3 Ground surface conditions at the thermistor locations

4.3.2.1 Ground temperatures at thermistor 07GSC-01

Thermistor 07GSC-01 is located in an undisturbed area approximately 200 m southwest of the Mallik sumps. The thermistor is located at the edge of a large pond which contained approximately 30 cm of water at the time of visit in August 2011. The maximum surface thawing (i.e. maximum active layer depth) ranged between 1.35 m and 2.35 m.

Figure 4-4 Mean ground temperature at Mallik 07GSC-1 (21/08/2010 to 20/08/2010)

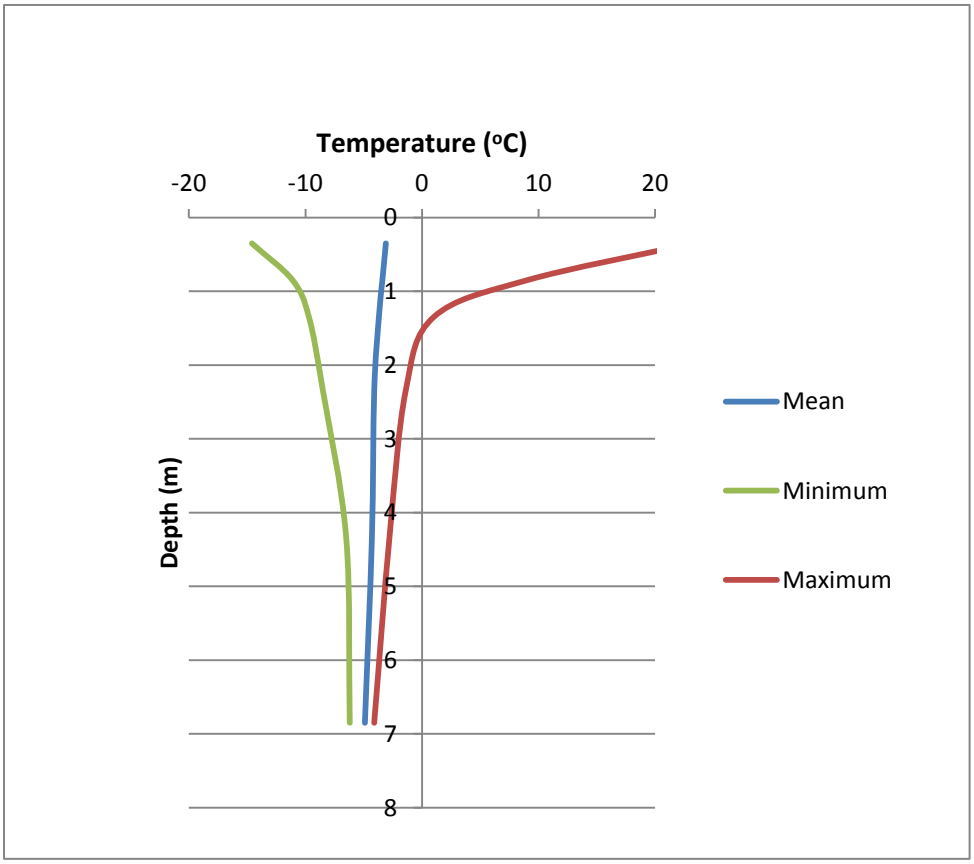


Table 4-3 Ground Temperatures at thermistor 07GSC-01

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.35	-3.4	23.2	-14.6
0.85	-3.7	9.0	-11.1
1.35	-3.8	1.0	-9.7
2.35	-4.1	-1.4	-8.5
4.35	-4.3	-2.8	-6.5
6.85	-4.9	-4.1	-5.6

4.3.2.2 Ground temperatures at thermistor 07GSC-02

Thermistor 07GSC-02 is located in an undisturbed site with low sedge and grass cover. The maximum surface thawing depth ranged between 1 m and 1.5 m.

Figure 4-5 Mean ground temperature at Mallik 07GSC-2 (21/08/2010 to 20/08/2010)

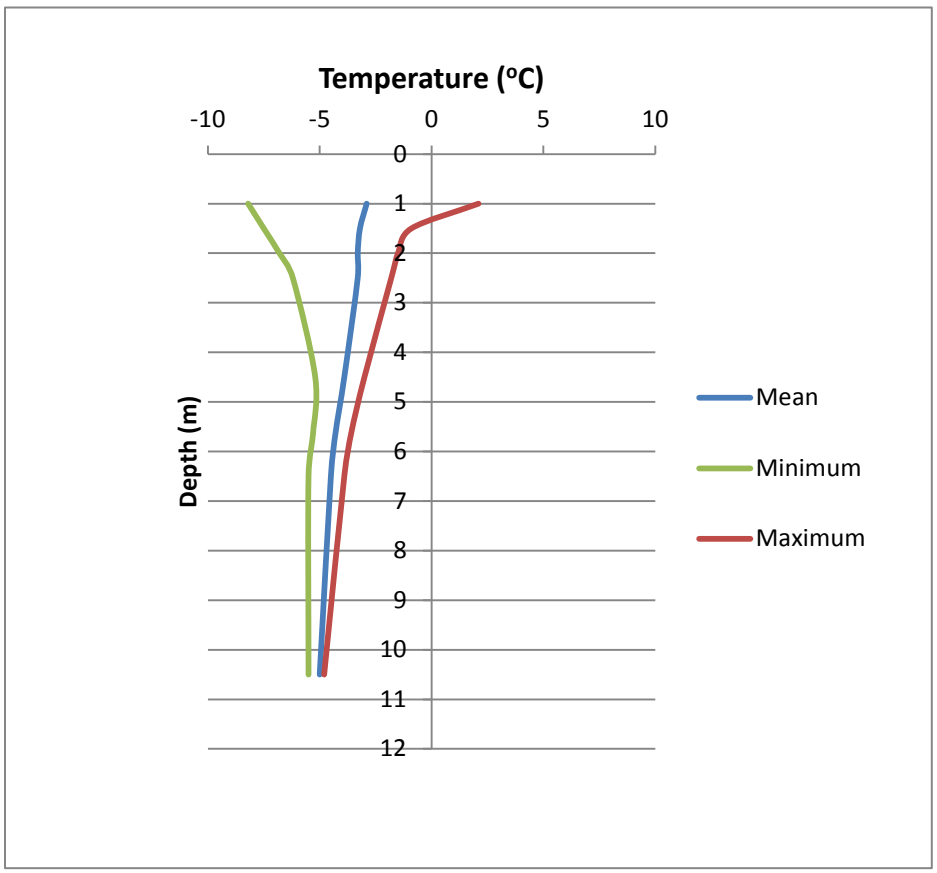


Table 4-4 Ground Temperatures at thermistor 07GSC-02

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1	-2.9	2.1	-8.2
1.5	-3.2	-0.9	-7.5
2	-3.3	-1.5	-6.8
2.5	-3.3	-1.8	-6.2
4.5	-3.9	-3.0	-5.2
5.65	-4.3	-3.6	-5.3
6.5	-4.5	-3.9	-5.5
10.5	-5.0	-4.8	-5.5

4.3.2.3 Ground temperatures at thermistor 07GSC-03

Thermistor 07GSC-03 is the only one located within disturbed material and is installed at the center of the Mallik 3L/4L5L-38 Sump (2002 Drilling Sump). The maximum active layer thickness ranged between 1 m and 1.5 m.

Figure 4-6 Mean ground temperature at Mallik 07GSC-3 (21/08/2010 to 20/08/2010)

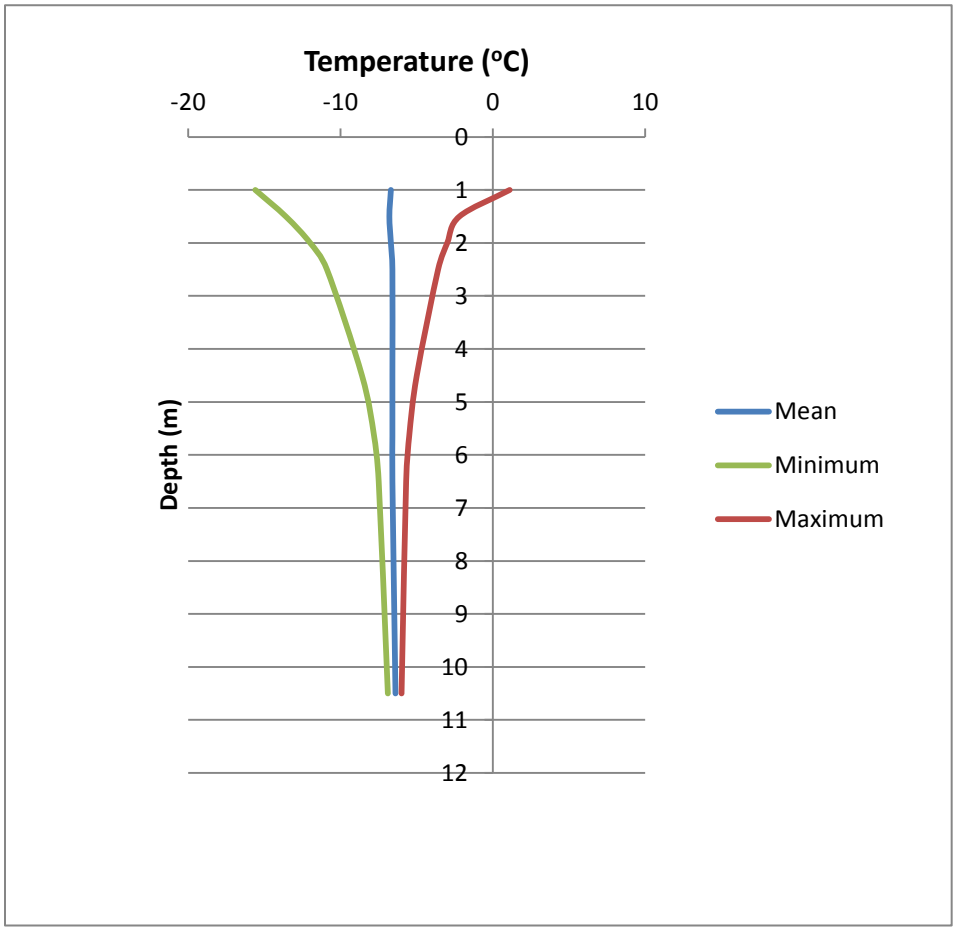


Table 4-5 Ground Temperatures at thermistor 07GSC-03

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1	-6.7	1.1	-15.6
1.5	-6.8	-2.2	-13.6
2	-6.7	-3.0	-12
2.5	-6.6	-3.6	-10.9
4.5	-6.6	-5.0	-8.6
5.65	-6.6	-5.5	-7.8
6.5	-6.6	-5.7	-7.5
10.5	-6.4	-6.0	-6.9

4.3.2.4 Ground temperatures at thermistor 07GSC-04

Thermistor 07GSC-04 is located in an undisturbed site approximately 150 m west of Mallik 2L-38 (1998 Drilling Sump). Maximum depth of the active layer ranged between 1 m and 1.5 m.

Figure 4-7 Mean ground temperature at Mallik 07GSC-1 (21/08/2010 to 20/08/2010)

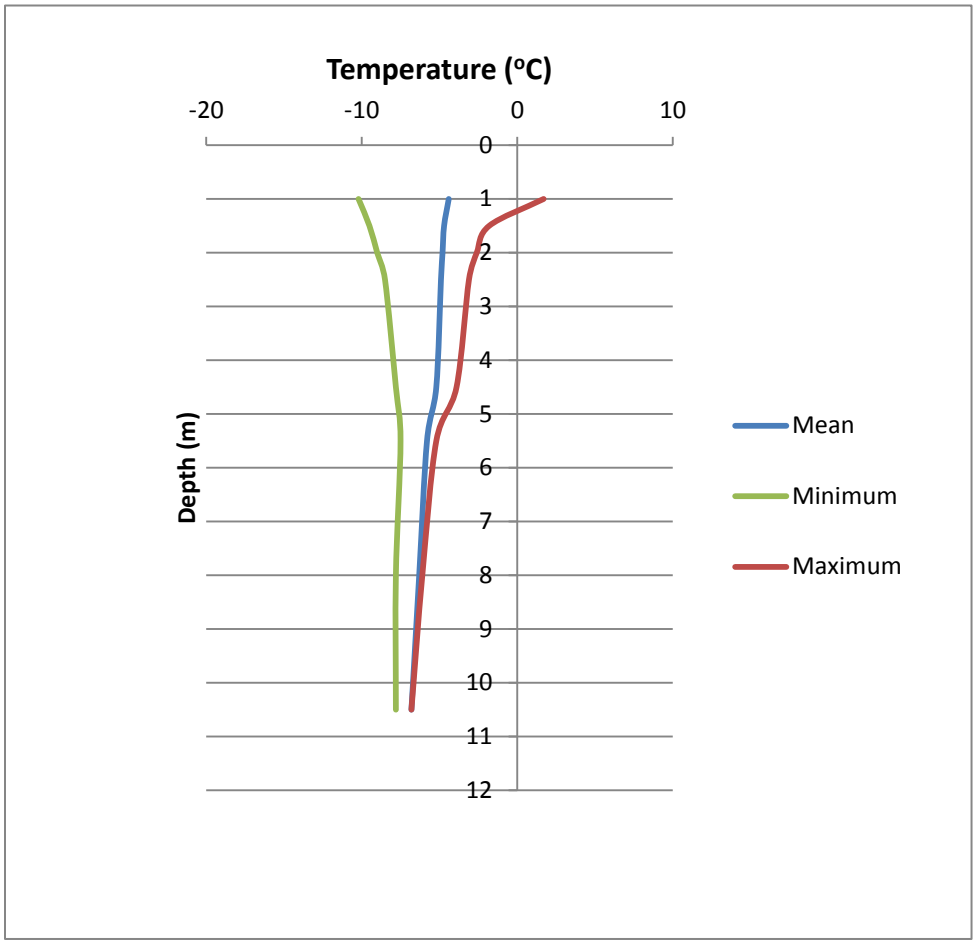


Table 4-6 Ground Temperatures at thermistor 07GSC-04

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.0	-4.4	1.7	-10.2
1.5	-4.7	-1.8	-9.5
2.0	-4.8	-2.6	-9.0
2.5	-4.9	-3.1	-8.5
4.5	-5.2	-3.9	-7.8
5.5	-5.8	-5.2	-7.5
8	-6.3	-6.1	-7.8
10.5	-6.8	-6.8	-7.8

4.4 Electromagnetic Surveys

Detailed electromagnetic survey results are presented in Appendix C.

As expected, both the EM38 Survey (0 to 1.5 m) and the EM31 Survey (0 to 5 m) have identified areas of high apparent conductivity values on both the Mallik 2L-38 sump (1998 Sump) and on the 3L/4L/5L-38 sump (2002 Sump) when compared to the surrounding areas. These elevated responses confirm the presence of saline drill cuttings within the sumps, after they have been corrected for salinity due to sea water infiltration.

Both the EM31 and EM38 surveys indicate that there is elevated apparent conductivity in an area adjacent to the northeast corner of the Mallik 2L-38 sump (1998 Sump). The conductivity is similar to that observed at the surface of the sump. It is unclear as to why the high conductivity distribution extends beyond the sump boundaries. The area is characterized as flat and seems undisturbed; however, the exact boundary or perimeter of the sump is unknown. Field observations identified a very subdued depression where surface water could possibly have pooled. There is very little or no vegetation in this area and a thin crusty salt deposit was observed at the ground surface.

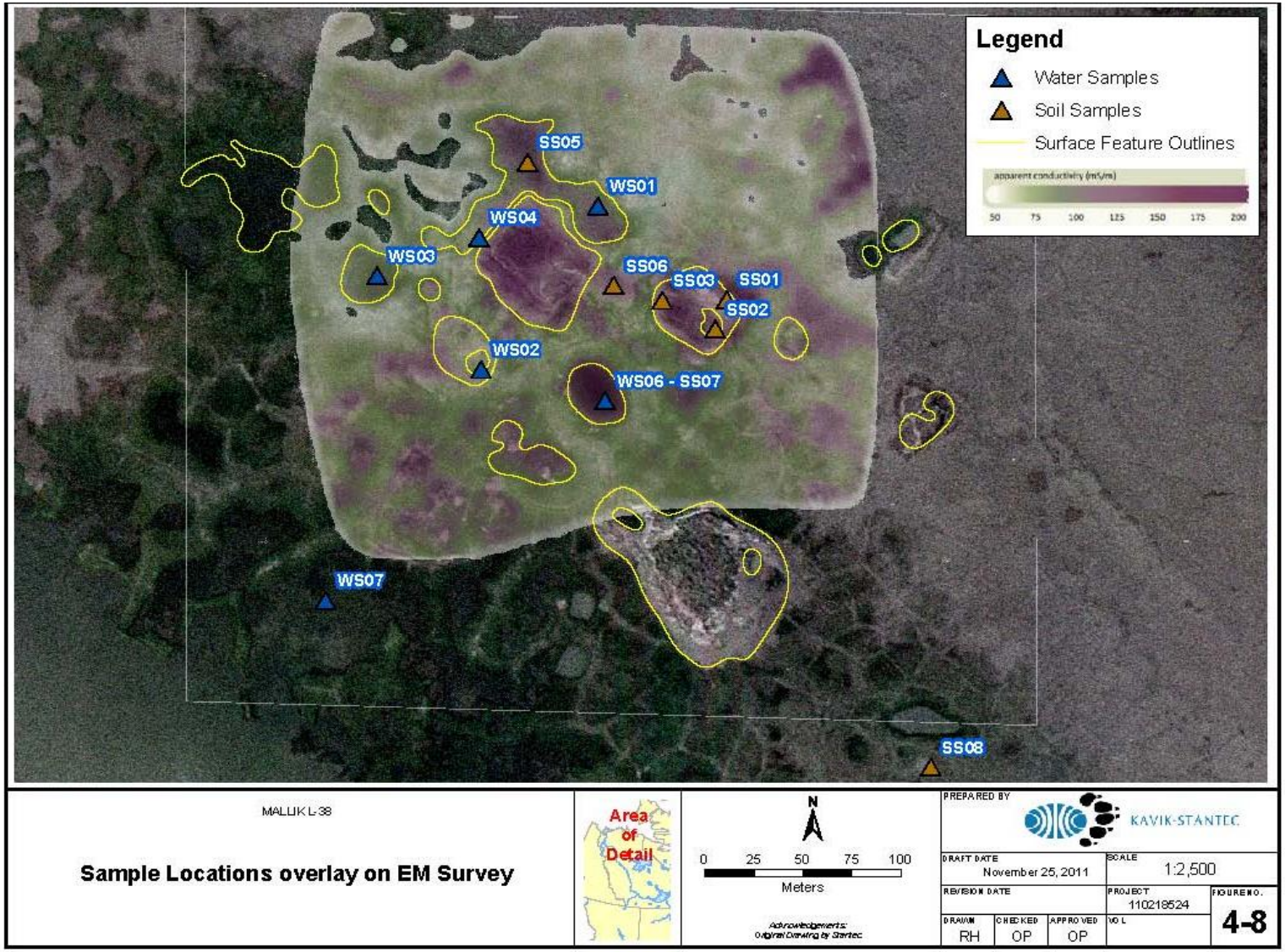
High apparent conductivity was also confirmed at an area located approximately 60 m from the southern edge of the 3L/4L/5L-38 Sump (2002 Sump). The area consists of a small topographic depression approximately 30 m x 35 m and about 60 cm deep. The depression is most probably filled with water annually but no surface water was present at the time of the visit. A soil sample was collected even though it is believed that the higher than normal conductivity is due to salt deposition from the evaporation of sea water. Section 4.5.1 provides the results of the soil analysis.

The EM surveys also indicated a moderate to high conductivity at the large pond located just north of the 2002 sump. The water level was much lower in August 2011 compared to the previous visit in late September of 2010. The high measurements are likely related to the evaporation of sea water from the annual storm surges and are not indicative of sump seepage. Soil and water samples were collected in order to investigate the apparent high conductivity.

4.5 Soil and Water Sampling

A series of soil and water samples were taken to investigate areas of high apparent conductivity and potential areas of contamination. Figure 4-8 shows the location of each sample in relation to the EM38 survey results.

Figure 4-8 Location of soils and water samples



4.5.1 Soil Sampling

Soils from seven different locations were collected during the 2011 field visit (Figure 4-8, Table 4-7). A summary of the soil analysis results is presented in Tables 4-8 and 4-9. The complete laboratory results from Maxxam are presented in Appendix D.

Table 4-7 Soil sampling Locations

Sample Number	GPS Location	Comments on sample location
Mallik/SS/2011/01	513278 / 7705857	Area of high apparent conductivity outside the perimeter of the 1998 Sump
Mallik/SS/2011/02	513272 / 7705842	Subsidence area at the western end of the 1998 Sump
Mallik/SS/2011/03	513245 / 7705857	Subsidence area at the eastern end of the 1998 Sump
Mallik/SS/2011/04	513176 / 7705929	Dried up portion of a large pond located north of the 2002 Sump. High apparent conductivity in the area
Mallik/SS/2011/05	513220 / 7705865	Small depression between the 1998 and 2002 Sumps. High apparent conductivity in the area
Mallik/SS/2011/07	513215 / 7705804	Small pond characterized by high apparent conductivity
Mallik/SS/2011/08	513382 / 7705612	Control sample

All samples consist of silt (>70%) with very minor fine sand and clay. The pH of all samples is consistent and ranges between 6.65 and 7.47. The samples with the highest amount of sodium all correspond to small ponds or areas where surface water has accumulated and then evaporated. This strongly suggests that the high sodium levels are due to the evaporation of sea water.

Soil sample 01 (SS01) was collected at the northeast corner of the 1998 sump, approximately 10 m away from the sump itself. The soil surface was relatively dry when sampled and a thin layer of salt was observed at the surface. Both the EM31 and EM38 results indicate high apparent conductivity at this specific location (see EM results in Appendix C). The soluble conductivity of the sample is high at 33dS/m, by comparison to the other samples (3.1 to 13 dS/m). The conductivity measured at the control soil sample 08 (SS08) is 10 dS/m. The presence of a salt deposit at the soil surface is confirmed by the high Sodium (Na) value (2,700 mg/L). Elevated potassium (K) value was measure for sample 01, located in an area of high apparent conductivity along the perimeter of the 1998 Sump (3,330 mg/L). The control soil sample only showed potassium (K) content of 110 mg/L. Similarly high potassium values were measured in a soils sample taken at the surface of the 2002 sump in 2010 (sample 2.1, with a potassium value of 2,100 mg/L).

High levels of chloride (Cl) were measured in soil sample 01 (SS01) and in soil sample 07 (SS07) (9,800 and 13,000 mg/L respectively). By comparison, the control soil sample has a Cl level of 2,600 mg/L. Chloride can be deposited either from sea water as NaCl, or from drilling fluid, as KCl. The ratio of sodium (Na) versus potassium (K) can help to interpret the source or origin of the chloride. In the case of SS07, the sodium (Na = 4800 mg/L), and the potassium (K= 60 mg/L) values are quite different, suggesting the input of sea water. This is different for sample 01, where both the sodium and potassium values are high (Na 2700mg/L and K = 3300mg/L), suggesting that the sodium and potassium could originate from the potassium and calcium rich drilling material. The presence of potassium rich material near the perimeter of the sump could be related to a sampling error (i.e. sampling sump material rather than clean undisturbed soil) or to a very small and localized spill of KCl salt.

In addition to the areas showing high apparent conductivities, a soil sample was taken at the bottom of each subsidence area within the 1998 Drill Sump. The sample taken at the eastern end of the sump cap (sample 03) indicates low levels of soluble sodium (Na), chloride (Cl) and potassium (K). The sample collected from the western subsidence area (sample 02) is very similar to the control sample in terms of salinity and chloride (Cl) but shows higher potassium (K) value (580 mg/L compared to 110 mg/L for the control sample). This high potassium content in the first 20 cm of the sump cap is likely a sign that some of the sump material is melting and mixing with the subsiding portion of the sump cap.

Table 4-8 Soil Sampling Results – Salinity

Maxxam ID		BJ3684	BJ3688	BJ3690	BJ3691
Sampling Date		8/22/2011 12:00	8/22/2011 12:00	8/22/2011 12:00	8/22/2011 13:00
COC Number		A049824	A049824	A049824	A049824
Sample ID		**SS01**	**SS02**	**SS03**	**SS05**
Calculated Parameters	**Units**				
Anion Sum	meq/L	290	26	70	80
Cation Sum	meq/L	280	29	72	82
Ion Balance	N/A	0.98	1.1	1.0	1.0
Soluble Parameters					
Soluble Chloride (Cl)	mg/L	9800 (1)	460	2300 (1)	2600 (1)
Soluble Conductivity	dS/m	33	3.1	7.6	8.6
Soluble (CaCl2) pH	N/A	7.47	7.15	7.00	6.73
Sodium Adsorption Ratio	N/A	18	1.9	14	13
Soluble Calcium (Ca)	mg/L	920	160	200	330
Soluble Magnesium (Mg)	mg/L	450	18	84	170
Soluble Sodium (Na)	mg/L	2700	93	930	1100
Soluble Potassium (K)	mg/L	3300	600	580	73
Saturation %	%	55	48	54	53
Soluble Sulphate (SO4)	mg/L	560	630	250	300
Theoretical Gypsum Requirement	tonnes/ha	16	<0.1	<0.1	<0.1

Table 4-9 Soil Sampling Results – Salinity

Maxxam ID		BJ3692	BJ3693	BJ3694
Sampling Date		8/22/2011 13:00	8/22/2011 13:00	8/22/2011 13:00
COC Number		A049824	A049825	A049825
Sample ID		**SS06**	**SS07**	**SS08**
Calculated Parameters	**Units**			
Anion Sum	meq/L	130	390	86
Cation Sum	meq/L	120	310	100
Ion Balance	N/A	0.99	0.81	1.2
Soluble Parameters				
Soluble Chloride (Cl)	mg/L	4200 (1)	13000 (1)	2600 (1)
Soluble Conductivity	dS/m	13	32	10
Soluble (CaCl2) pH	N/A	6.84	7.40	6.65
Sodium Adsorption Ratio	N/A	24	29	15
Soluble Calcium (Ca)	mg/L	250	910	310
Soluble Magnesium (Mg)	mg/L	210	720	250
Soluble Sodium (Na)	mg/L	2100	4800	1400
Soluble Potassium (K)	mg/L	120	60	110
Saturation %	%	56	56	73
Soluble Sulphate (SO4)	mg/L	430	490	590
Theoretical Gypsum Requirement	tons/ha	50	330	<0.1

4.5.2 Water Sampling

Surface water samples were collected at six locations (Figure 4-8 and Table 4-10). A summary of the water analysis results is presented in Tables 4-11 and 4-12. The complete laboratory results from Maxxam are presented in Appendix D.

Table 4-10 Water Sampling Locations

Sample Number	GPS Location	Comments on sample location
Mallik/WS/2011/01	513212 / 7705906	Water pooling along the north-eastern edge of the 2002 Sump. Sample from the similar water body than sample 04.
Mallik/WS/2011/02	513153 / 7705820	Water pooling within the 1998 Camp Sump depression
Mallik/WS/2011/03	513099 / 7705870	Water pooling in a pond approximately 60m west of the 2002 Sump
Mallik/WS/2011/04	513152 / 7705890	Water pooling along the north-western edge of the 2002 Sump. Sample from the similar water body than sample 01.
Mallik/WS/2011/06	513216 / 7705804	Water pooling in a depression approximately 60 m south of the 2002 Sump. Area characterized by high apparent conductivity
Mallik/WS/2011/07	513073 / 7705700	Control water sample taken in a large pond next to GSC-1

Surface water was sampled from 5 different ponds (2 samples were taken from the same pond). Water samples (WS) 01 and 04 are from a large but shallow natural pond directly in contact with the perimeter of the main 2002 Sump. Water samples 03 and 07 are from natural depressions that are far enough from the various sumps that no contaminants are expected. Water sample 02 was collected from a depression located at the northeast corner of the 1998 camp sump, and water sample 06 is from a shallow pond located 60 m south of the 2002 sump.

The electromagnetic surveys have indicated a moderate to elevate apparent conductivity at most of these locations (EM surveys were not conducted as far as the location of sample 03 and 07).

Of all the water samples collected at Mallik, sample 06 has the highest conductivity level. This water sample comes from the same location as soil sample 07 and has a conductivity reading of 27,000 uS/cm. This is approximately 3 times the conductivity value of the control water sample. The level of dissolved sodium (Na) supports the high conductivity value with 4000 mg/L of Na. For comparison, the level of dissolve sodium (Na) in the control water sample is only 1,500 mg/L. One possible reason for the high conductivity and sodium (Na) content could be that the puddle from which the water sample was taken, was quite small and receding. The pond was almost dry and only a very small area of stagnant water was present. As a result, the elevated sodium concentration could be over-evaluated due to evaporation of the sodium-rich surface waters.

Water samples 02 (taken at the edge of the 1998 Camp Sump), 01 and 04 (from a natural pond north of the 2002 Sump), show chemical properties very similar to the control sample and therefore show no signs of contamination.

Table 4-11 Water Sampling Results

Sample ID		WS01	WS02	WS03
Sampling Date		8/20/2011 16:40	8/20/2011 16:40	8/20/2011 16:50
Calculated Parameters	**Units**			
Anion Sum	meq/L	94	75	100
Cation Sum	meq/L	90	73	98
Hardness (CaCO3)	mg/L	770	1000	930
Ion Balance	N/A	0.96	0.98	0.96
Dissolved Nitrate (NO3)	mg/L	<0.01	0.01	<0.01
Nitrate plus Nitrite (N)	mg/L	<0.003	0.003	<0.003
Dissolved Nitrite (NO2)	mg/L	<0.01	<0.01	<0.01
Total Dissolved Solids	mg/L	5300	4200	5800
Misc. Inorganics				
Conductivity	uS/cm	9900	7700	11000
pH	N/A	9.75	8.24	9.06
Anions				
Alkalinity (PP as CaCO3)	mg/L	47	<0.5	22
Alkalinity (Total as CaCO3)	mg/L	130	270	130
Bicarbonate (HCO3)	mg/L	45	330	100
Carbonate (CO3)	mg/L	57	<0.5	26
Hydroxide (OH)	mg/L	<0.5	<0.5	<0.5
Dissolved Sulphate (SO4)	mg/L	34	280 (1)	110
Dissolved Chloride (Cl)	mg/L	3200 (1)	2200 (1)	3500 (1)
Nutrients				
Dissolved Nitrite (N)	mg/L	<0.003	<0.003	<0.003
Dissolved Nitrate (N)	mg/L	<0.003	0.003	<0.003
Elements				
Dissolved Calcium (Ca)	mg/L	77	150	110
Dissolved Iron (Fe)	mg/L	0.07	0.15	0.09
Dissolved Magnesium (Mg)	mg/L	140	150	160
Dissolved Manganese (Mn)	mg/L	<0.004	0.18	0.008
Dissolved Potassium (K)	mg/L	45	40	52
Dissolved Sodium (Na)	mg/L	1700 (1)	1200 (1)	1800 (1)

Table 4-12 Water Sampling Results

Sample ID	Units	WS04	WS06	WS07
Sampling Date		8/20/2011 17:00	8/20/2011 17:00	8/20/2011 17:15
Calculated Parameters				
Anion Sum	meq/L	85	260	88
Cation Sum	meq/L	83	220	83
Hardness (CaCO3)	mg/L	700	2200	880
Ion Balance	N/A	0.98	0.85	0.95
Dissolved Nitrate (NO3)	mg/L	0.02	0.21	<0.01
Nitrate plus Nitrite (N)	mg/L	0.004	0.047	<0.003
Dissolved Nitrite (NO2)	mg/L	<0.01	<0.01	<0.01
Total Dissolved Solids	mg/L	4800	14000	4900
Misc. Inorganics				
Conductivity	uS/cm	9200	27000	9300
pH	N/A	9.84	8.69	8.86
Anions				
Alkalinity (PP as CaCO3)	mg/L	45	19	20
Alkalinity (Total as CaCO3)	mg/L	120	190	170
Bicarbonate (HCO3)	mg/L	34	180	160
Carbonate (CO3)	mg/L	54	23	24
Hydroxide (OH)	mg/L	<0.5	<0.5	<0.5
Dissolved Sulphate (SO4)	mg/L	37	25	190 (1)
Dissolved Chloride (Cl)	mg/L	2900 (1)	9100 (1)	2800 (1)
Nutrients				
Dissolved Nitrite (N)	mg/L	<0.003	<0.003	<0.003
Dissolved Nitrate (N)	mg/L	0.004	0.047	<0.003
Elements				
Dissolved Calcium (Ca)	mg/L	77	170	79
Dissolved Iron (Fe)	mg/L	0.07	0.16	0.08
Dissolved Magnesium (Mg)	mg/L	120	430	170
Dissolved Manganese (Mn)	mg/L	<0.004	0.083	<0.004
Dissolved Potassium (K)	mg/L	39	160	46
Dissolved Sodium (Na)	mg/L	1600 (1)	4000 (1)	1500 (1)

5 Conclusion

The 2011 field survey was conducted between August 20th and 22nd. The visual assessment was conducted from both the air and the ground and shows that revegetation of the sump caps is limited to 10% of the total disturbed area. Localized salt deposits and the presence of drift wood scattered throughout the site indicate that the site is characterized by storm surges.

Subsidence areas were noted at all three sumps. The subsidence is more active at the 2L-38 Sump (1998 sump) where depressions at each end (70 cm and 120 cm deep) are present. Small tension cracks were noted along the edges of the depression but these do not suggest a rapid thawing process. In contrast to the 2010 visits, the depressions were free of surface waters; however, several water level marks are visible and suggest annual ponding of water.

It is unclear at this time if the thawing and subsiding processes are likely to increase with time. Some of the depressions observed on site could be linked to progressive compaction of the sump cap material rather than thaw subsidence.

Active layer measurements are quite consistent throughout the site. The average thawing depth measured on August 20th 2011 is 121 cm for the 1998 sump cap and 133 cm for the 2002 sump cap. The average thawing depths along the sump perimeters are shallower (114 cm for the 1998 sump and 117 cm for the 2002 Sump) and very close to the average depth measured along the control transect (113 cm). In comparison, the 2010 thawing depth averages were 119 cm for the sumps and 113 cm for the perimeters. It should be noted that the 2010 measurements were taken later in the season (September 28th). The active layer depths measured are consistent with other data gathered from monitoring sites located within the Mackenzie Delta region (Tarnocai et al. 2004).

The difference in active layer depth between sump caps and their perimeters can be linked to several factors such as the nature and thickness of the capping material, the level of compaction of the material, and the absence of vegetation cover.

The ground temperatures recorded on site reveal some variation between the different thermistors. For example, the temperatures measured at 10.5 m depth range from -4.8°C to -5.5°C at thermistor 07GSC-02, from -6.0°C to -6.9°C at thermistor 07GSC-03 and from -6.8°C to -7.8°C at thermistor 07GSC-04. The main cause of these differences is the variations in local site conditions (i.e. the presence or absence of surface water and vegetation, material texture and compaction, local ice content, etc.). Ground temperature data for the thermistor located at the center of the 2002 sump indicates that the maximum thaw depth is less than 1.5 m, therefore attesting that the sump material is frozen.

The findings of the electromagnetic survey are very similar to last year's results. Both the EM31 and EM38 indicate the presence of a high response area located about 60 m from the southern edge of the 3L/4L/5L-38 Sump (2002 Sump). The area is characterised by a depression (believed to be natural) and water can pool in this depression up to 30 cm deep. The high conductivity is explained by the annual input of sea water rather than by any form of seepage from one of the sumps. An increase in thaw depth caused by the presence of free standing water could also explain this high response. Most soil and water samples have revealed moderate to high salinity parameters, and for the most part they are consistent with samples collected outside of the influence of the sumps.

Soil sample SS01, collected in an area of high apparent conductivity just outside the perimeter of the 1998 sump, indicates higher than normal potassium, chloride and sodium values. These values are considered too high for a natural source and suggest the presence of sump contaminants. However, this does not automatically imply a migration of contaminants outside of the sump area, as the sample was

taken approximately 10 m from what is believed to be the sump boundary (i.e. the exact limits of the sump were not surveyed before the sump closure and therefore the sample may have been collected within the sump boundary).

In 2010, water samples taken from the area of ponding water at the western end of the 1998 sump, revealed evidence of sump contents migration. Two soil samples (SS02 and SS03) taken this year in similar dried-up depressions of the 1998 sump indicate high potassium values. The samples were taken 5 cm below ground level in what should be clean sum cap material. It is believed that the high potassium value comes from mixing of sump material into the sump cap.

The following conclusions and recommendations are based on the latest field data compiled at the Mallik site:

- Approximately 10% of the sump is revegetated,
- The influence of storm surges on the site is confirmed by the visual assessment (e.g. surface salt deposits following evaporation of sea water), soil and water sampling as well as the EM surveys,
- Compaction and subsidence were noted at all three sumps; the 1998 Sump has the largest and deepest depressions,
- EM surveys are consistent with previous years; areas of high apparent conductivity outside the sumps are related to the on-site evaporation of sea water,
- Water ponding take place annually at both ends of the 1998 Sump (as indicated by the water marks along the edges of the subsidence depressions),
- Active layer thicknesses are consistent with previous year measurements.

6 References

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Dallimore, S.R and Collett T.S. 2005. Scientific Results from Mallik 2002 Gas Hydrate Production Research Well Program, Mackenzie Delta, Northwest Territories, Canada. Geological Survey of Canada, Ottawa. Geological Survey of Canada Bulletin 585.

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NWT Water Board. 2006a. *Protocol for the Monitoring of Drilling-Waste Disposal Sumps.* Yellowknife, Northwest Territories.

Tarnocai, C. Nixon, F.M and Les Kutny. 2004. Circumpolar-Active-layer-Monitoring (CALM) Sites in the Mackenzie Valley, Northwestern Canada. Permafrost and Periglacial Processes, 15: 141-153.

Appendix A Site Photographs

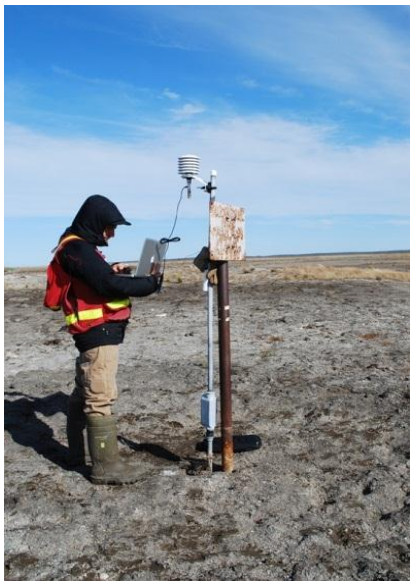
Figure A-1 Aerial View of Mallik site from the North (looking South)

Figure A-2 Aerial View of Mallik site from the South (looking North)

Figure A-3 Bird and mammal prints in the sump area

Several signs of wildlife were observed. Fresh caribou/reindeer prints and bird prints were observed throughout the site.

Figure A-4 Air and ground temperature sensors next to Mallik 2L-38 wellhead



The air sensor is located 1.5 m above ground the protected by a radiation shield. The ground thermistor is buried just below ground level (~2 cm depth) approximately one meter north from the base of the well head.

Figure A-5 View of the subsidence area at the eastern edge of the 1998 Sump

Figure A-6 View of the subsidence area at the western edge of the 1998 Sump

Figure A-7 Sharp contrast between the undisturbed vegetated terrain and the bare soils along the edges of the 1998 Camp Sump

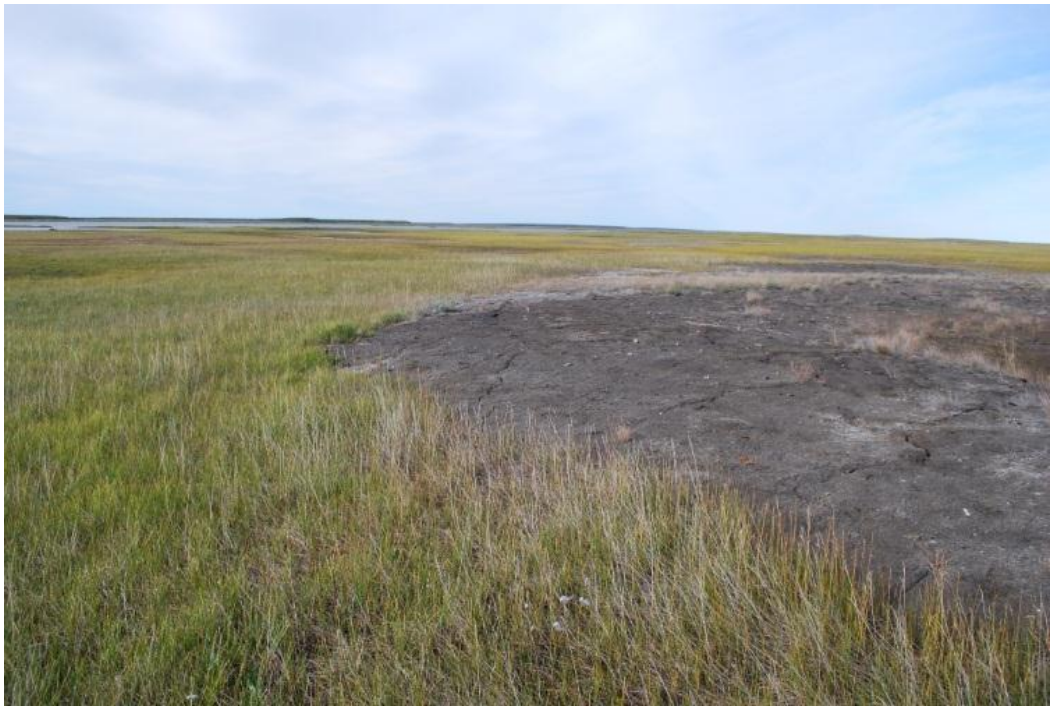


Figure A-8 View of the depression and ponded water at the southern corner of the 1998 Camp sump

Figure A-9 Small subsidence area at the southern corner of the 2002 Sump

Figure A-10 View of the south-western edge of the 2002 Sump

Figure A-11 View of the bare 2002 Sump surface looking west

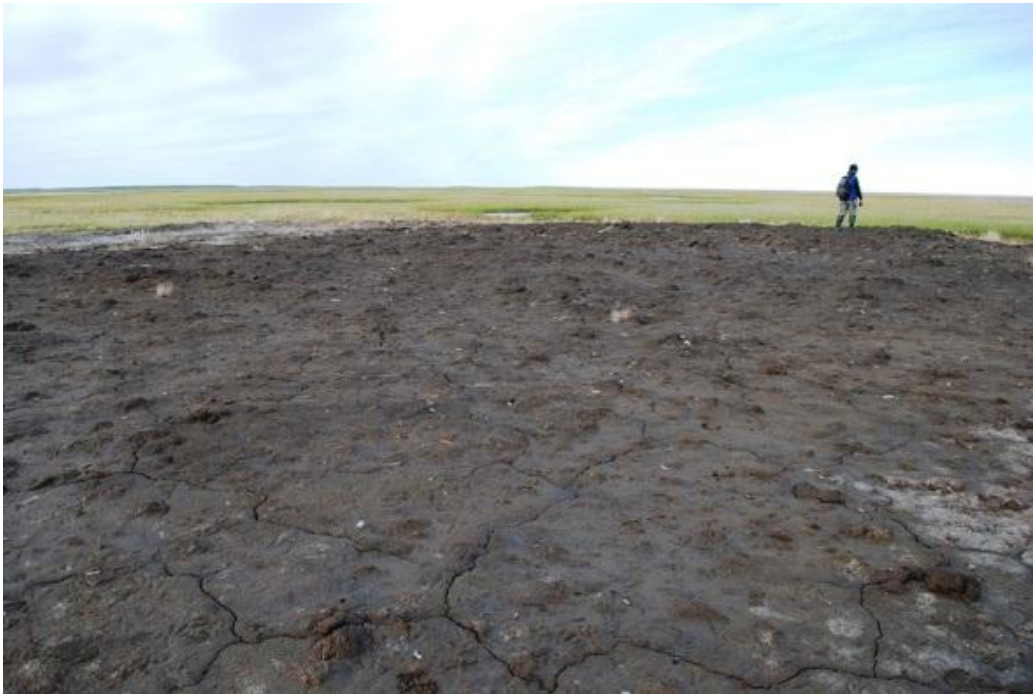
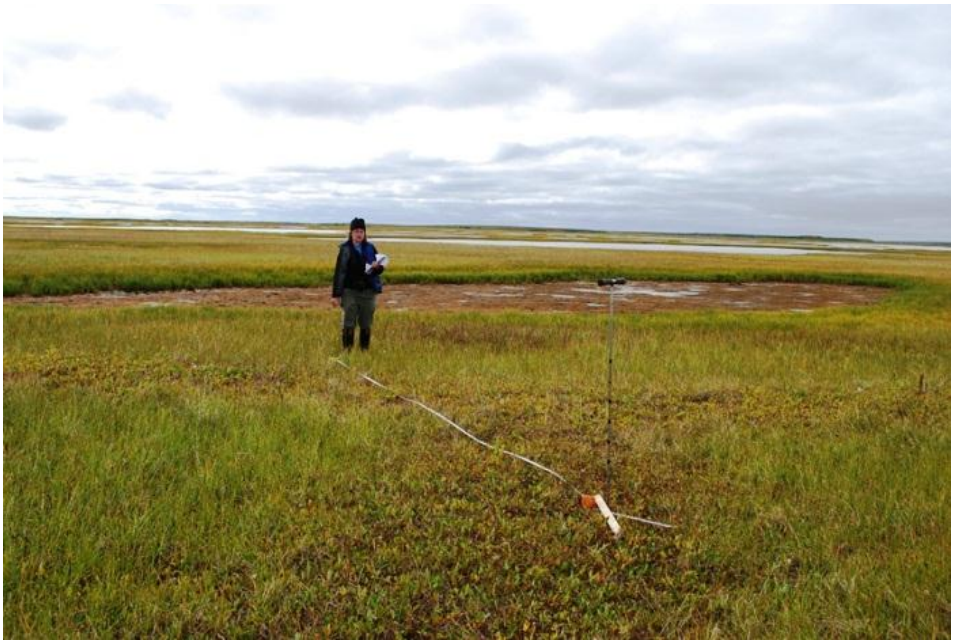
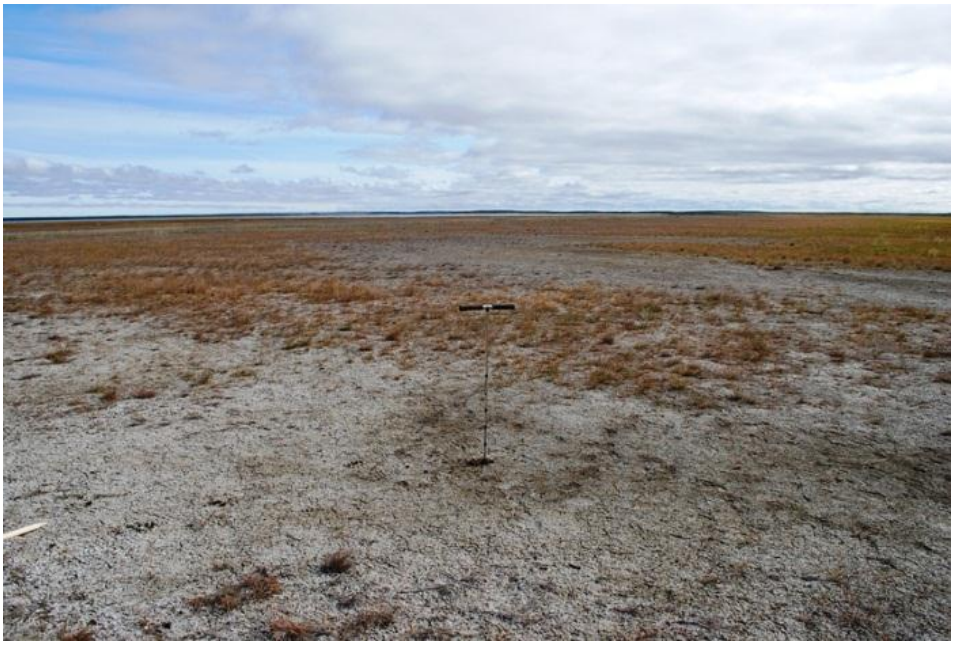


Figure A-12 Small depression and tension cracks along the north-eastern edge of the 2002 Sump

Figure A-13 Ground conditions and vegetation cover along the control transect





The surface cover along the transect ranges from densely vegetated with a mix of willows, grasses, sedges and mosses to bare soil without vegetation.

Appendix B Thermistor Data

Figure B-1 Daily Air Temperatures (October 2010 to August 2011)

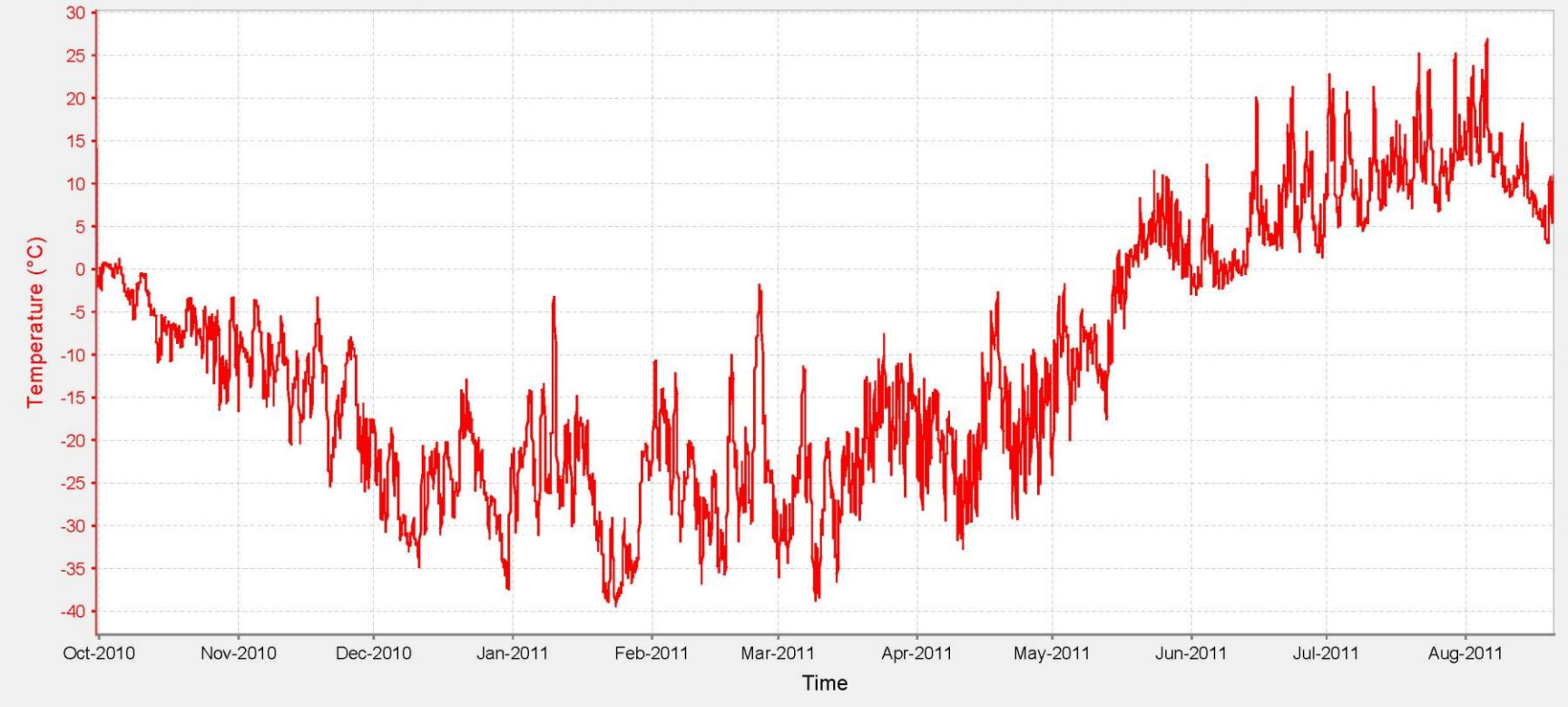
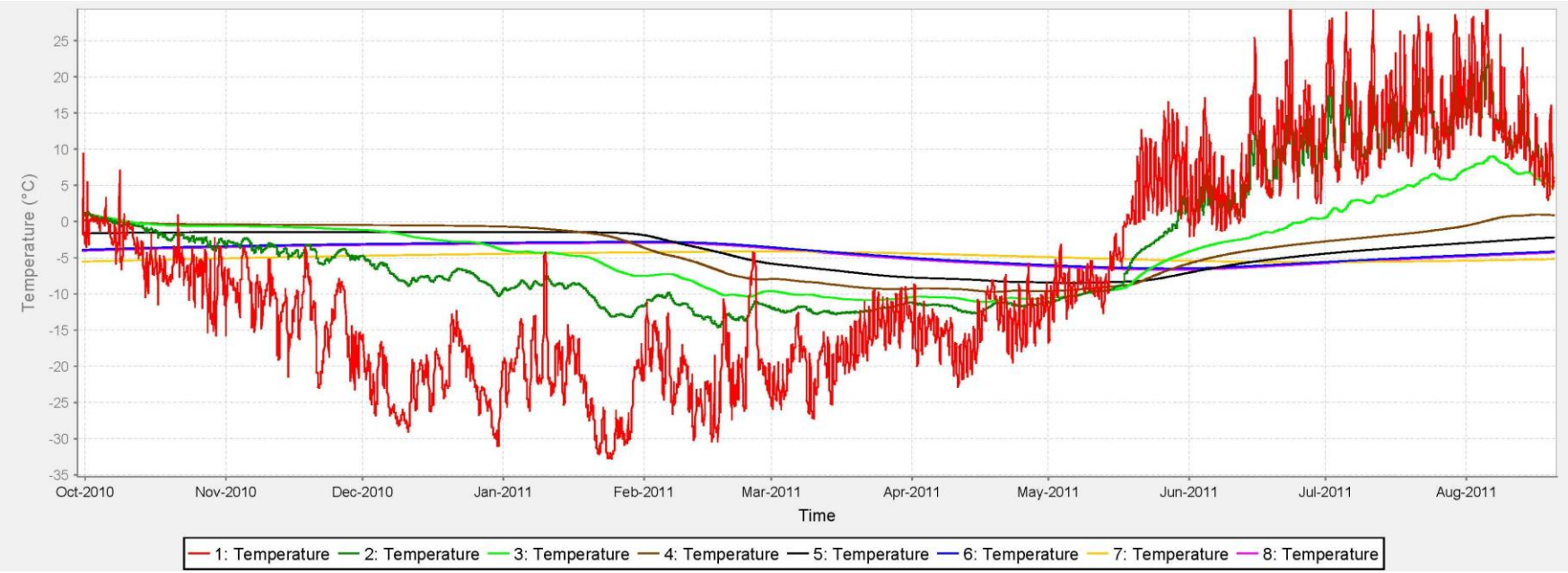


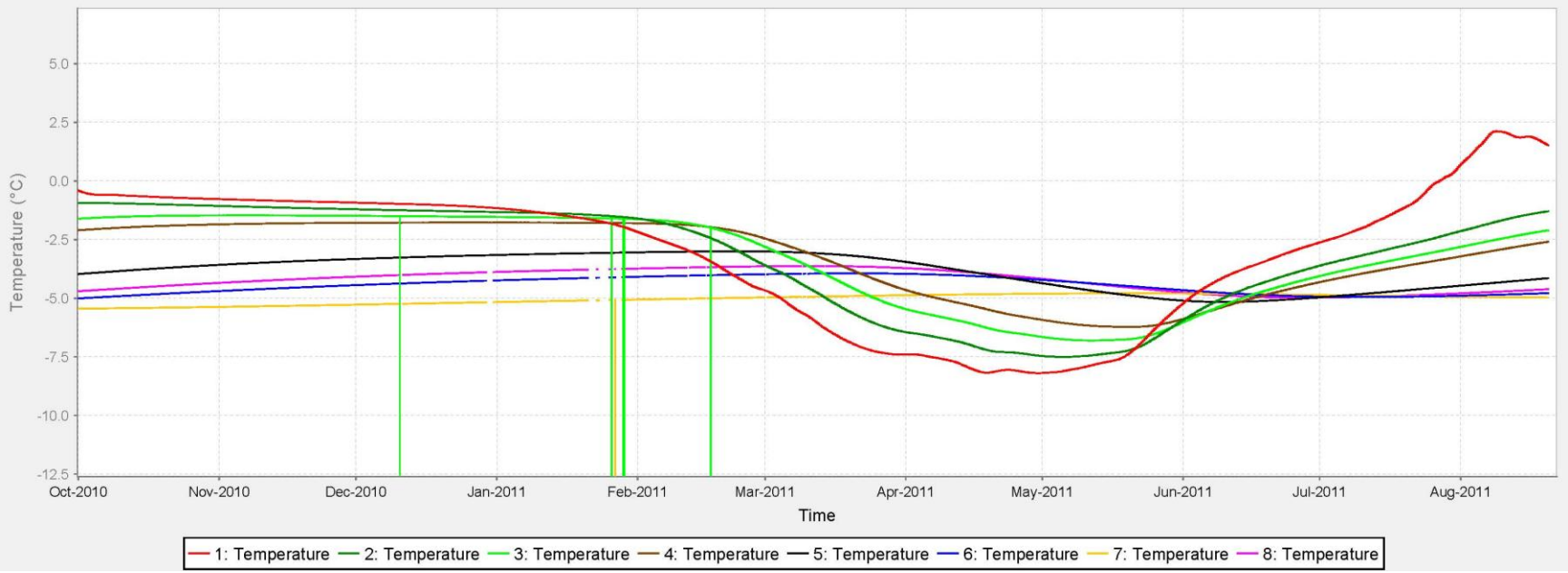
Figure B-2 Daily Ground Temperatures (October 2010 to August 2011)

Figure B-3 Thermistor 07GSC-01 – Daily Ground Temperatures (October 2010 to August 2011)



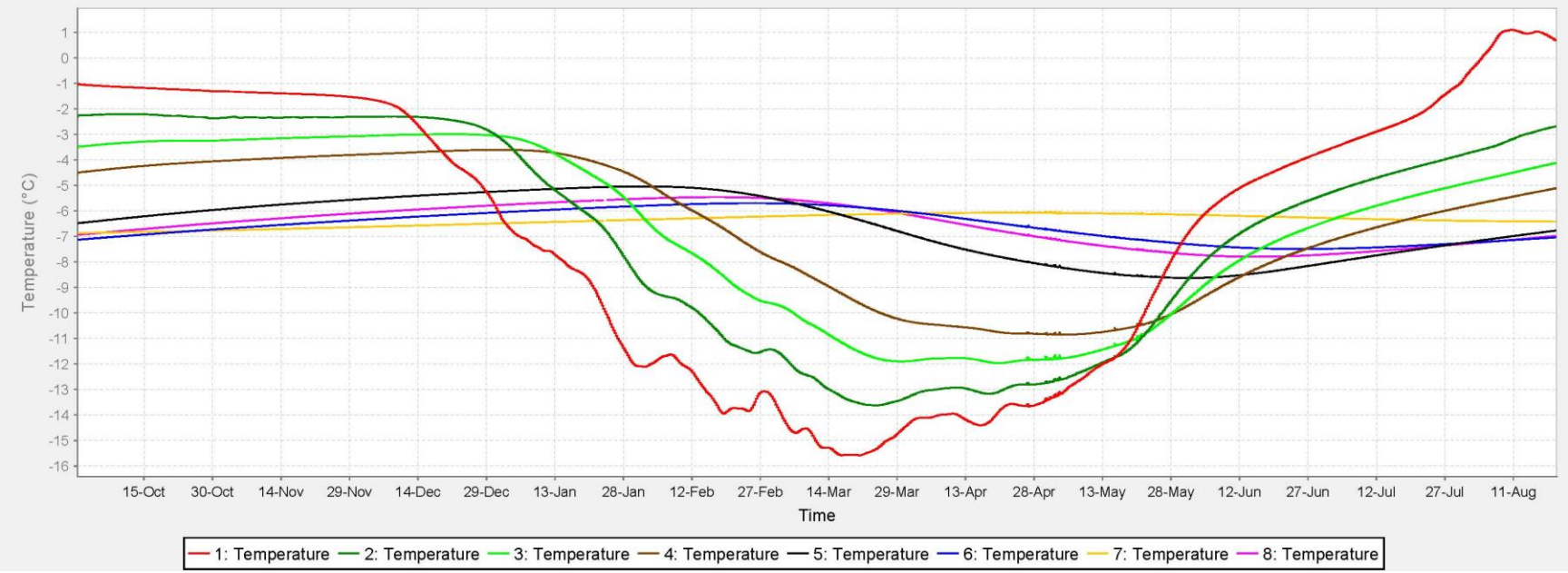
Note: The temperature sensor 1 is located above ground and is recording air temperature. Refer to Table 3-1 for current depth of the thermistor sensors.

Figure B-4 Thermistor 07GSC-02 – Daily Ground Temperatures (October 2010 to August 2011)



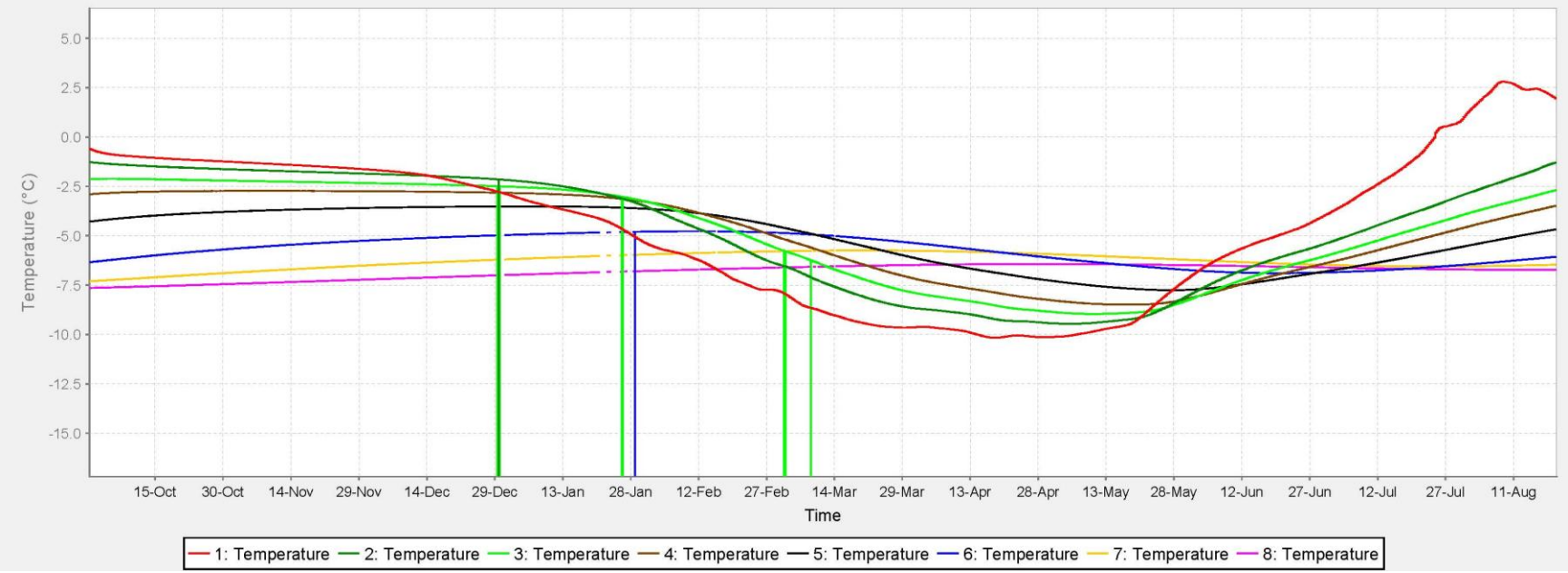
Notes: Refer to Table 3-1 for current depth of the thermistor sensors. The vertical spikes correspond to data errors.

Figure B-5 Thermistor 07GSC-03 – Daily Ground Temperatures (October 2010 to August 2011)



Notes: Refer to Table 3-1 for current depth of the thermistor sensors.

Figure B-6 Thermistor 07GSC-04 – Daily Ground Temperatures (October 2010 to August 2011)



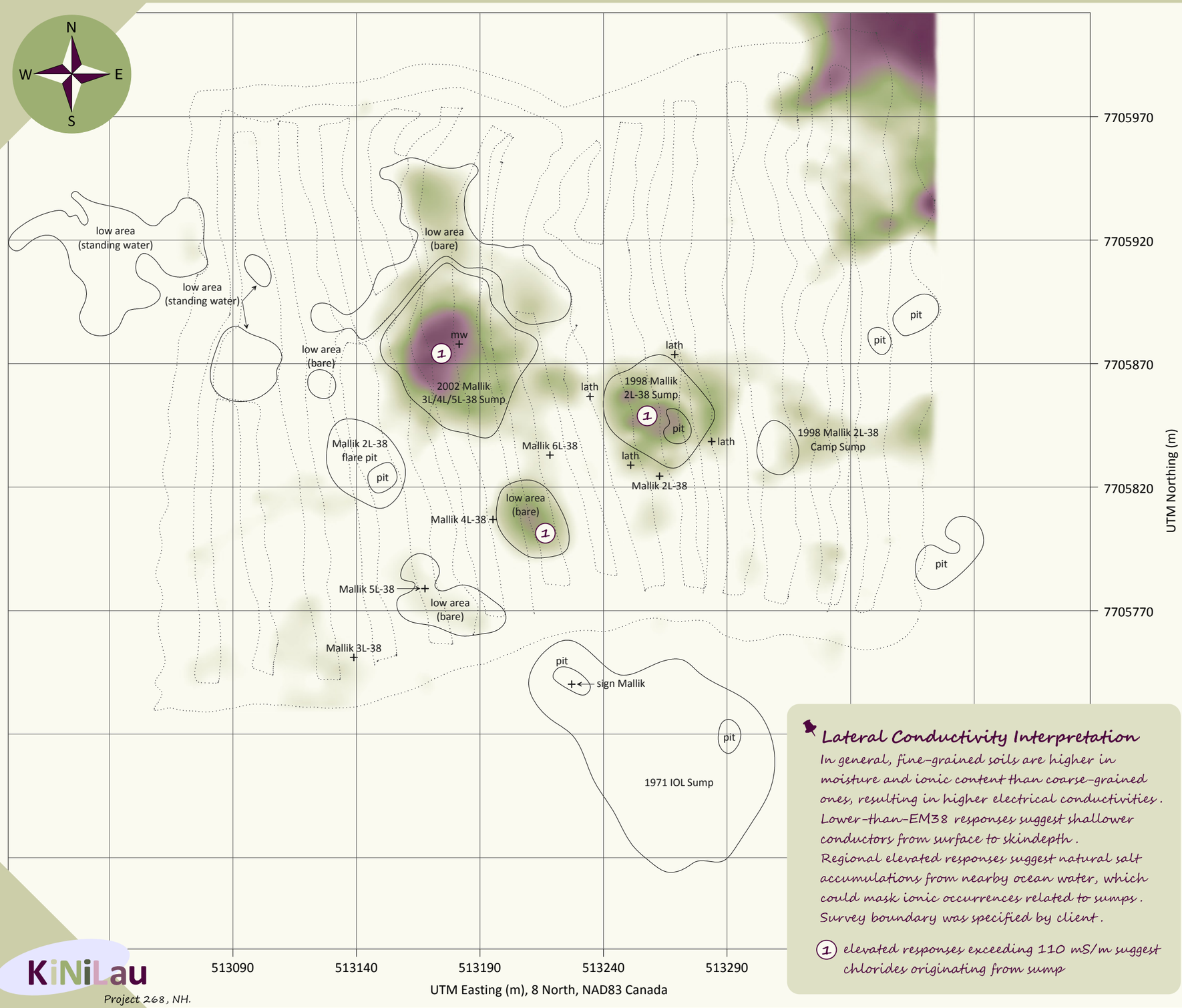
Notes: Refer to Table 3-1 for current depth of the thermistor sensors. The vertical spikes correspond to data errors.

Appendix C Electromagnetic Surveys

Lateral Conductivity Detail (EM31)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
August 22, 2011



Lateral Conductivity Interpretation

In general, fine-grained soils are higher in moisture and ionic content than coarse-grained ones, resulting in higher electrical conductivities. Lower-than-EM38 responses suggest shallower conductors from surface to skindepth. Regional elevated responses suggest natural salt accumulations from nearby ocean water, which could mask ionic occurrences related to sumps. Survey boundary was specified by client.

(1) *elevated responses exceeding 110 mS/m suggest chlorides originating from sump*

legend

- Curved Feature (road, bush)
- Straight Feature (fence, house)
- Buried pipe / Utility line
- (1) Interpretation Event
- \+ Point Feature (sign, pole, tree)
- Geophysical Measurement Station
- Outline (swamp, trees, scrap)

apparent conductivity (mS/m)

50 75 100 125 150 175 200 225

This single-page Lateral Conductivity Detail serves as all-in-one, comprehensive, graphical reporting tool. Please visit **www.kinilau.ca** to download a traditional report.

Greenish colors indicate target onset and with increased significance transition to deep maroon.

The color image is derived using EM induction and DGPS positioning. It reveals the conductivity distribution from surface to skindepth of the inducing EM signal and is not a representation of data from any particular depth. Use Vertical Conductivity data for reliable depth information.

While presented data are of high intrinsic accuracy, their interpretation has multiple solutions (equivalence). Such data should be correlated to some form of analytics.

Respectfully submitted,
KiNiLau Physics Inc.

Per:

Sean T. Clarke, P.Geoph.
Sr. Geophysicist

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Date August 22, 2011
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

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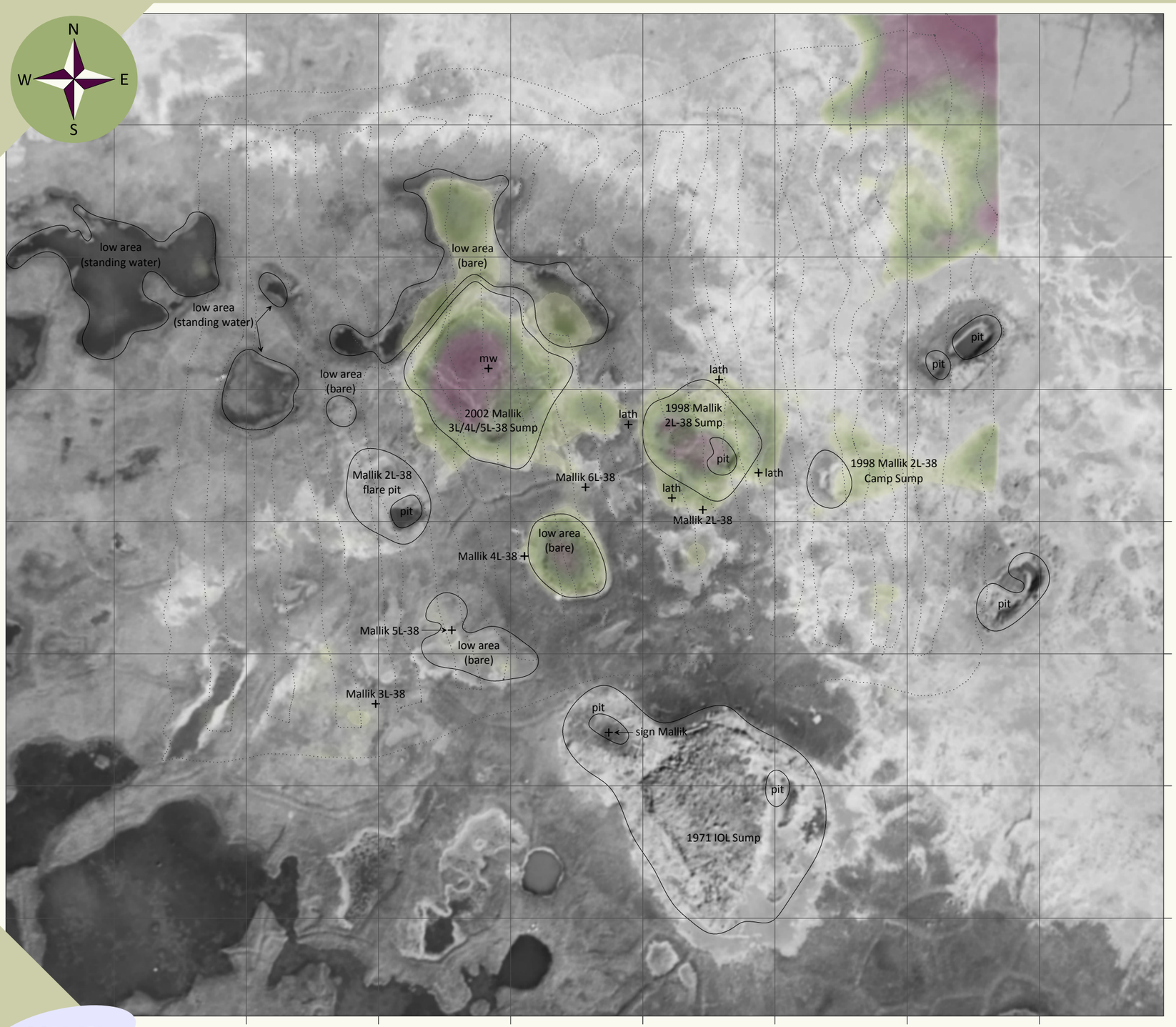
Project 268, NH.

Lateral Conductivity Detail (EM31 & Aerial Underlay)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
August 22, 2011



legend

- Curved Feature (road, bush)
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apparent conductivity (mS/m)

225

50 75 100 125 150 175 200

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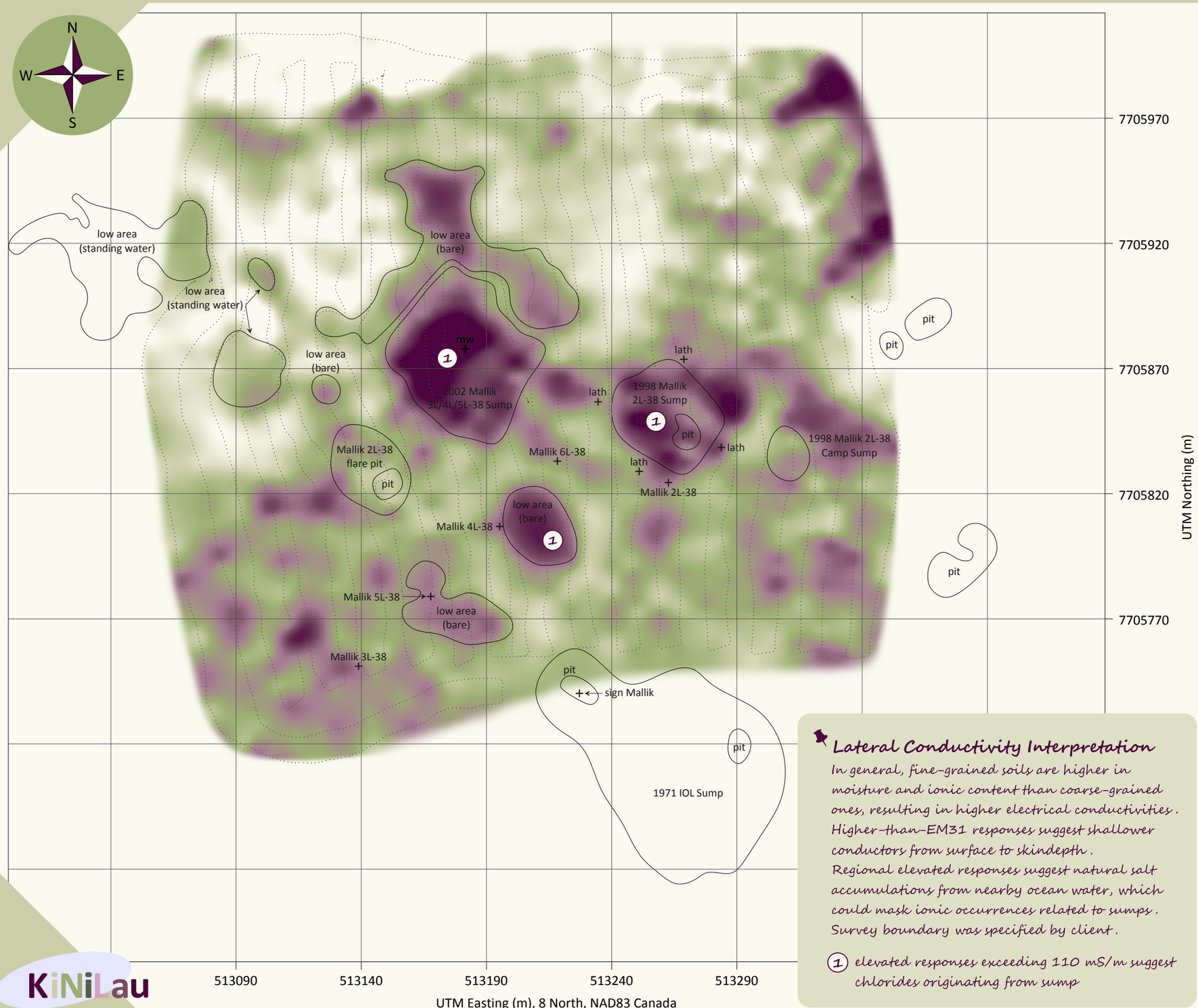
Lateral Conductivity Detail (EM38)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
August 22, 2011



legend

- Curved Feature (road, bush)
- Straight Feature (fence, house)
- Buried pipe / Utility line
- (1) Interpretation Event
- \+ Point Feature (sign, pole, tree)
- Geophysical Measurement Station
- Outline (swamp, trees, scrap)

apparent conductivity (mS/m)

50 75 100 125 150 175 200 225

This single-page Lateral Conductivity Detail serves as all-in-one, comprehensive, graphical reporting tool. Please visit **www.kinilau.ca** to download a traditional report.

Greenish colors indicate target onset and with increased significance transition to deep maroon.

The color image is derived using EM induction and DGPS positioning. It reveals the conductivity distribution from surface to skindepth of the inducing EM signal and is not a representation of data from any particular depth. Use Vertical Conductivity data for reliable depth information.

While presented data are of high intrinsic accuracy, their interpretation has multiple solutions (equivalence). Such data should be correlated to some form of analytics.

Lateral Conductivity Interpretation

In general, fine-grained soils are higher in moisture and ionic content than coarse-grained ones, resulting in higher electrical conductivities. Higher-than-EM31 responses suggest shallower conductors from surface to skindepth. Regional elevated responses suggest natural salt accumulations from nearby ocean water, which could mask ionic occurrences related to sumps. Survey boundary was specified by client.

(1) *elevated responses exceeding 110 mS/m suggest chlorides originating from sump*

Respectfully submitted,
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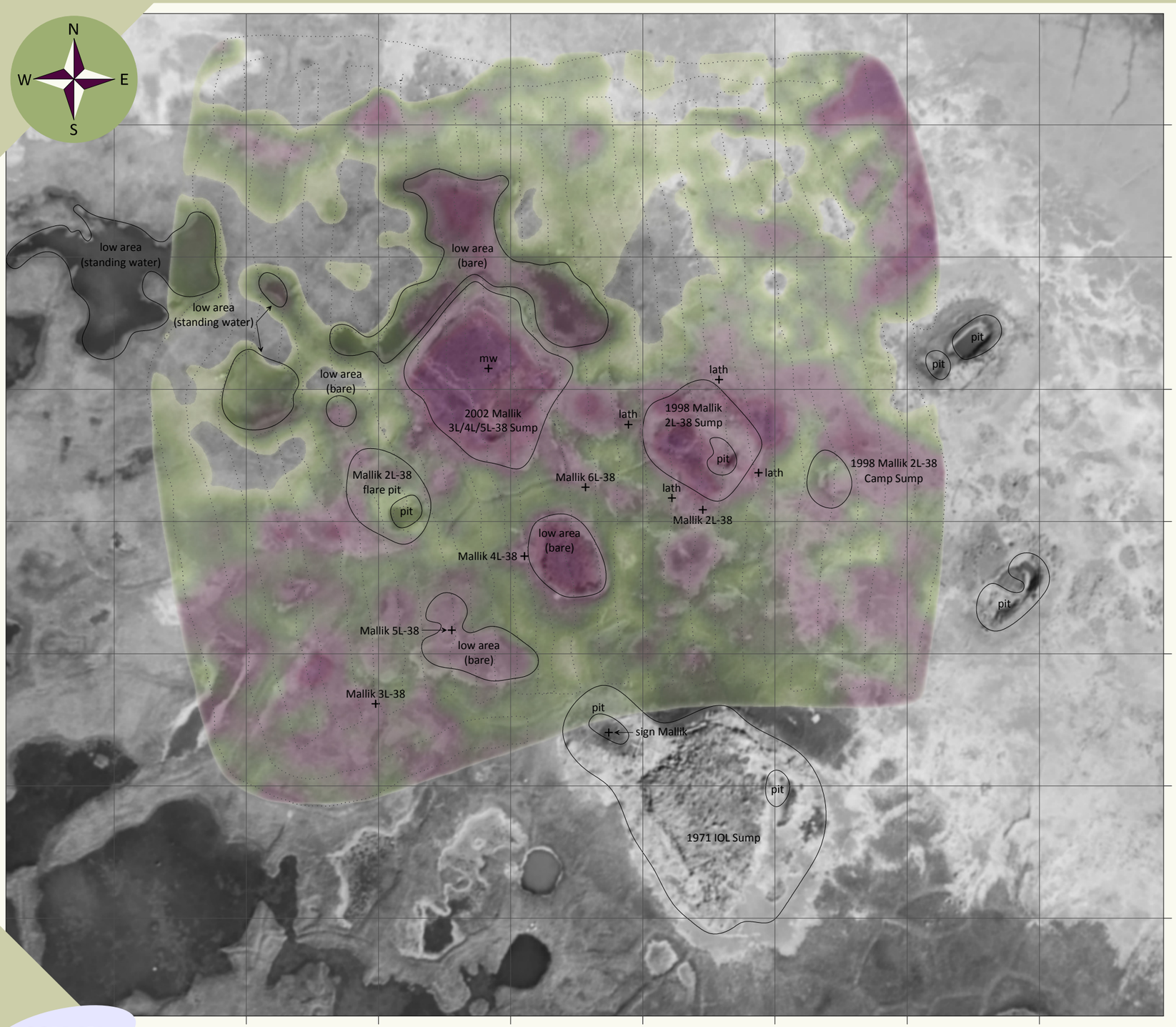
Lateral Conductivity Detail (EM38 & Aerial Underlay)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
August 22, 2011



legend

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- Buried pipe / Utility line
- Point Feature (sign, pole, tree)
- Geophysical Measurement Station
- Outline (swamp, trees, scrap)

apparent conductivity (mS/m)

225

50 75 100 125 150 175 200

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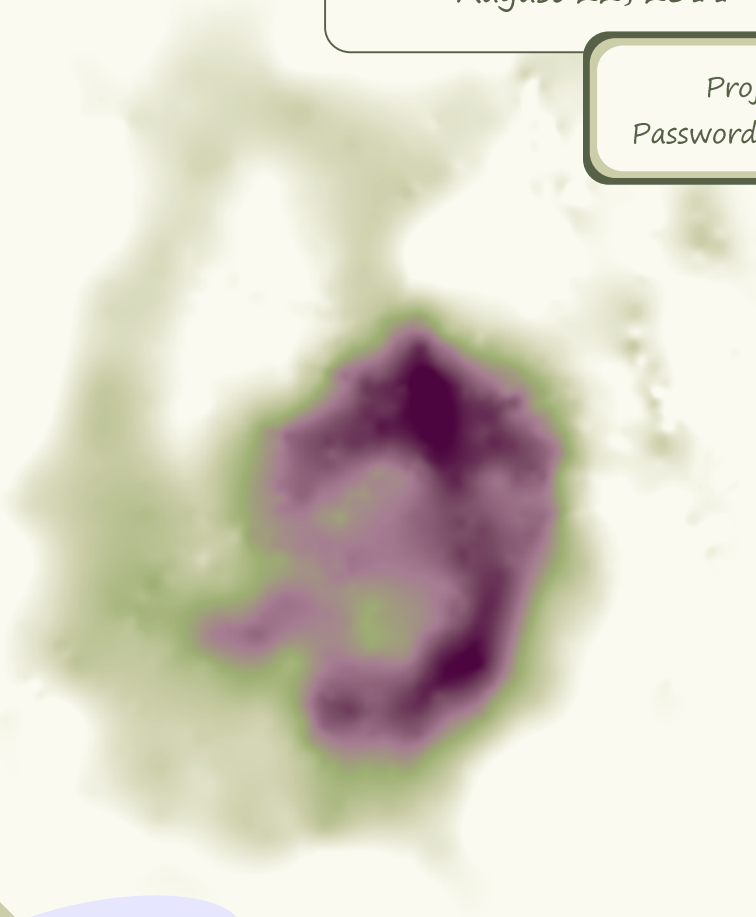
Lateral Conductivity Report

(EM31 & EM38)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
August 22, 2011

Project #: 268
Password: 268c#ri$rev@k



Respectfully submitted,
KiNiLau Physics Inc.

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Sean T. Clarke, P.Geoph.
Sr. Geophysicist

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KiNiLau Physics.

Thank you for choosing KiNiLau Physics! We hope to have delivered a technically superb, easy-to-understand and perhaps simply a great product.

Our primary product is the Lateral Conductivity Detail - EM31/38, designed to be a user-friendly but comprehensive reporting tool. It combines geophysical images, survey features and an interpretation into one package, replacing the traditional paper report.

This report provides clients a traditional reporting option. It has been obtained from a secured and privately assigned Project Page using the Project # and Password provided on the cover page of this report:

Obtaining this Report

1. Go to www.kinilau.ca
2. Enter login details at 'Project Login'
3. Print 'Traditional Report'
4. Print & append 'Lateral Conductivity Detail - EM31/38' → ***Appendix A***

While the conductivity detail satisfies all requirements for a complete geophysical analysis, KiNiLau provides additional data products to clients. These can be downloaded from the client Project Page at www.kinilau.ca using the Project # and Password provided on the cover page of this report:

- **Lateral Conductivity Detail - EM31/38 - lateral conductivity (EM induction) analysis**
- Survey Features - all surveyed features in standard AutoCAD format (dxf)
- Traditional Report - paper report (this one) to augment geophysical details
- Raw Data - lateral conductivity XYZ data files (ASCII)
- Binary Files - raw binary field data (ssf) and field map (pdf)
- Referenced Images - lateral conductivity images (jpg) with superimposed reference points (dat)
- Other - anything else
- Invoice

In addition to detailing relevant aspects of the geophysical survey, this report is designed to tutor beginners and seasoned geophysicists the advanced technical aspects of a KiNiLau survey. It serves as training tool and readers are encouraged to engage this report and enjoy the intricacies of their project.

Graphics and moss green insets are provided throughout in support of key points and terms. Geophysical jargon is printed in *italic* suggesting that explanatory relief is nearby, usually within the next inset.

Survey samples are provided in Section 6. These samples typify soil conductivity surveys encountered over the years in western Canada and give good insight to the interpretation methodology of KiNiLau conductivity surveys. Feel free to print out and distribute these hand-out style samples for educational purposes.

Table of Contents

1. Introduction 1

2. Data Acquisition 1

2.1 Lateral Conductivity (EM31/38) 1

2.2 DGPS Positioning (Trimble Pathfinder ProXT) 5

3. Data Processing 6

3.1 Lateral Conductivity (Geonics EM31/38) 7

3.2 DGPS Positioning (Trimble Pathfinder ProXT) 8

4. Conductivity Details 9

4.1 Distance Scales 9

4.2 Legend & Color Apparent Conductivity Scale 10

4.3 Maroon Interpretation Circles and Arrows 10

4.4 Conductivity Interpretation Insets 11

5. Interpretation 12

5.1 Interpretation Basics 12

5.2 Interpreting Conductivity Magnitudes 14

6. Samples 15

Appendix A - Conductivity Details

Appendix B - Instrument Specifications

1. Introduction

The survey objective was to delineate the 2D (lateral only) extent of subsurface soil conductivities. The Geonics EM31 and/or EM38 were used to map lateral extents of subsurface soil conductivities using electromagnetic (EM) inductive forces. Positioning data were acquired using the Trimble Pathfinder ProXT and differentially-corrected (DGPS) using nearby base station data and the Trimble Pathfinder Office Suite.

2. Data Acquisition

This section describes the tools used to delineate the 2D extent of subsurface soil conductivities on site. Appendix B contains Geonics EM31/38 and Trimble Pathfinder ProXT instrument specifications. Also included are specification sheets for the Trimble Pathfinder Office Suite.

2.1 Lateral Conductivity (EM31/38)

Lateral site conductivities were delineated using the Geonics EM31 and/or EM38. Both tools were operated in vertical dipole mode (horizontal coil mode), with approximate EM31 and EM38 depths-of-penetration near 5 m and 1.5 m, respectively.

As the deeper imaging tool, the EM31 is often preferred over the EM38. Having said that, it is not always the best suited for the task. Particularly, the deeper imaging EM31 carries a larger *footprint*. It images a larger surface area and is more prone to interference from nearby metal conductors such as pipes, fences or buildings. So, while the EM31 provides comfort in being able to image deeply, on metallically busy sites like gas plants it may actually yield more questionable results.

Footprint

Footprint is the aerial extent which an EM tool images. Think of the EM31 as having a sphere of investigation. The depth of investigation is the vertical radius and the *footprint* the cross-sectional area of that sphere.

The EM31/38 uses electromagnetic (EM) inductive forces to delineate subsurface conductivities. The instrument records the *quadrature* and *in-phase* components of the induced secondary EM field. The Geonics tools are designed such that the quadrature relates to lower conductivity ranges (soils) and the in-phase to higher conductivity ranges (metals or very high ionic concentrations).

In-Phase vs. Quadrature

EM conductivity tools send off signals that coax the ground into sending its own unique counteracting signal, a process called induction. It is that counteractive response by the ground that is measured and related to soil conditions, with conductive soils responding more aggressively than resistive ones.

Basically, the response itself can be split into two components, one that is aligned or *in-phase* with the coaxing signal and one that is not, the 'out-of-phase'. In search of more user-friendly terminology, geophysicists have adopted the term *quadrature* to describe the 'out-of-phase'.

Geonics has related the *quadrature* component to soil conductivity, enabling them to name their tools soil conductivity meters. The EM31/38 *in-phase* component is not used as much, but relates to higher conductivities such as those of metals or extreme ionic concentrations. Other instrument manufacturers have related the 'in-phase to quadrature ratio' to ground properties and used those relationships to, for example, find mineral deposits.

The EM31/38 yield bulk soil conductivities averaged from surface to their depths of penetration. They cannot be used to identify individual conductivity layers beneath surface, a shortcoming described by the principle of *equivalence.*

Equivalence

The principle of *equivalence* describes when buried conductors of differing size, conductivity and depth yield the same (or equivalent) secondary EM response. Heuristically, conductivity being equal, a large conductor that is deeply buried, gives the same response as a small conductor that is shallow. Size being equal, a strong conductor at depth, gives the same response as a weak conductor that is shallow. Depth being equal, a small but strong conductor yields the same response as a large but weak conductor.

In other words, the EM31 yields a combined response of an object's size, conductivity and depth. The EM31 cannot distinguish between size, conductivity or depth and should not be seen as pure depth investigation tool (nor as a pure size or conductivity investigation tool).

EM31/38 readings were taken in 'horizontal coils or vertical axes' modes, approximating measurements of the initial 5 m/1.5 m of soil, respectively. Please note that actual EM penetration depths vary as a function of soil conductivity. To emphasize this point, they are referred to as *skindepths*.

Skindepth

Skindepth refers to the depth an EM signal travels at which point it has been reduced to one third its original amplitude. Physicists use this term since theoretically a wave never completely runs out of energy. It simply gets to a point at which it has become practically insignificant; and they have agreed that point shall be 1/*e (Euler's Number)*, about one third.

Skindepth is, in part, a function of soil conductivity. EM waves penetrate resistive soils deeper than conductive ones. An EM31 wave might travel to a depth of 8 m in resistive sand but to a lesser depth of 3 m in conductive clay (and only 50 cm in highly conductive salt contamination!).

The theory suggests that the true depth of penetration of the EM31 is unknown, since it is a function of soil conductivity; and soil conductivity is what we are trying to find in the first place.

The practical implication is that EM induction tools of varying depth capability (EM38/31/34) should only be used to identify depth-onsets of conductors, rather than their depth-extents.

The EM31/38 are only capable of detecting layers exhibiting relatively high *thickness-conductivity products*.

Thickness-Conductivity Product

Vertical resolution refers to the smallest identifiable stratigraphic thickness and is a function of the *thickness-conductivity product* of individual stratigraphic layers. In other words, a thin stratigraphic layer is detectable only if it possesses large conductivity. A thick stratigraphic unit is detectable with less conductivity contrast. For our applications, the Geonics EM31 and EM38 would be considered to have poor vertical resolution, requiring stratigraphic entities to exhibit large *thickness-conductivity products*.

The Geonics EM31/38 exhibit adequate *dynamic data range* for our purposes. They have the ability to detect low conductivity variations as well as higher ones. Both instruments maintain *response linearity* over the lower part of that dynamic data range, from zero to approximately 100 mS/m.

Dynamic Data Range & Response Linearity

Dynamic data range refers to the range of data values the instrument can handle. A tool of low *dynamic data range* is sensitive to a very specific range of conductivities, but clips readings above or below a certain threshold. While it is nice to have a tool sensitive to a greater *dynamic data range* (so that we can map resistive and conductive targets with it), we also want this tool to exhibit good *response linearity* over that large data range. It needs to increase steadily from low to high conductivity.

The Geonics EM31/38 maintain instrument linearity from zero to approximately 100 mS/m. Let's say soil has specific conductivity and the EM31/38 read it as 30 mS/m. Should that soil double in conductivity (perhaps due to ionic enrichment) then we expect the EM31/38 to yield 60 mS/m. But if the soil conductivity doubles once more, all bets are off, as the instrument's linearity cap has been exceeded and we might get a reading of 110 mS/m, less than 120 mS/m in any case.

From a practical stand-point non-linearity doesn't really matter since KiNiLau uses relative behavior rather than absolute magnitude of readings to identify targets. As long as the numbers keep going up, we know it's getting worse.

2.2 DGPS Positioning (Trimble Pathfinder ProXT)

The EM31 is digitally synchronized to differentially-corrected GPS (DGPS). This arrangement allows positioning and geophysical data to be stored simultaneously on handheld dataloggers. Data are acquired swiftly at high sampling density. EM data were acquired at a measurement station spacing of approximately 2 m (along line) and a line spacing near 10 m. The correct sampling density varies and is dictated by *Nyquist's Theory.*

Nyquist's Theory

Nyquist's Theory states that the digital representation of an analog signal is valid as long as that analog signal is sampled at three times its highest frequency content, two times with known phase information. Ok, what it means is that a chloride plume 10 m wide and 100 m long should be surveyed with a minimum station spacing of 3.3 m along survey lines spaced 33 m apart. Smaller plumes could get missed.

The Trimble Pathfinder ProXT uses L1 code and carrier information to provide survey-grade positioning. The moving DGPS receiver (Rover) is digitally synchronized to geophysical instruments providing positioning control of geophysical measurements. Data are post-processed using the Trimble Pathfinder Office Suite and data from the nearest available base station. While positioning accuracies vary as a function of factors like rover-to-base station distance, satellite geometry relative to the receiver or signal interference, sub-metre accuracies are readily obtained. Site features were surveyed for inclusion on KiNiLau details and serve as reference markings for follow-up work.

Common site-specific GPS settings are *PDOP*, *Minimum Satellites* and *Elevation Mask*. All relate to obtaining optimal GPS signals in varying site conditions.

PDOP (Positional Dilution of Precision)

PDOP is a statistical measure of positioning accuracy and is a function of satellite geometry relative to the receiver (constellation). In general, *PDOP* cut-off values below five yield accuracies appropriate for our purpose. As with the other GPS instrument settings, the field engineer may elect to increase the *PDOP* limit in specific environments and forego accuracy for the sake of survey completion.

Minimum Satellites

Minimum Satellites refers to the minimum number of satellites the GPS receiver will accept before shutting down. GPS surveying requires a minimum of four satellites. Three are required to geometrically pinpoint intersections of spheres in 3D space, to get a position. One more is required to resolve timing inaccuracies between the satellite and GPS clocks.

At times, survey location and condition may prevent a view of four satellites, for example when closing salt plumes underneath dense tree canopy. In that case, the field engineer may reduce the *Minimum Satellites* setting to three and forego the elevation information. Not collecting elevation information is acceptable since GPS elevations are practically inaccurate for our purposes.

Elevation Mask

Elevation Mask is measured in degrees and refers to the GPS antenna's cone-shaped viewing angle, measured upwards from earth's horizontal surface. An *Elevation Mask* of 0° implies the view of all satellites above. An *Elevation Mask* of 90° would close the viewing angle completely and cause no satellites to be in view. Generally, the *Elevation Mask* is set to 5° and may be reduced to 0° in hope for a greater satellite view. For geometric reasons, satellites far off to the side, ones that can be seen only at low *elevation masks*, decrease positioning accuracies.

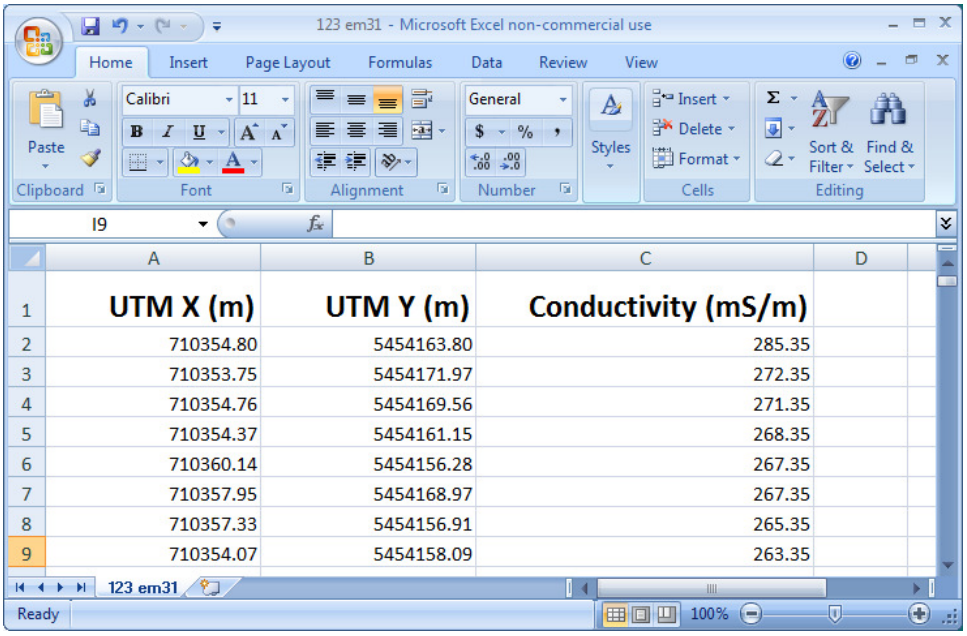
3. Data Processing

Data processing begins in the field with the KiNiLau field engineer making field maps to confirm survey completion and data integrity. These (pdf) field maps can be obtained by accessing the client's custom Project Page at www.kinilau.ca and clicking on Binary Files. The field engineer annotates field maps with pertinent observations which form the basis for the final interpretation. In essence, the field engineer writes the final interpretation immediately after survey completion, having still a keen focus on that particular project. The geophysicist then confirms that interpretation for inclusion into the Lateral Conductivity Detail - EM31/38.

3.1 Lateral Conductivity (Geonics EM31/38)

Original binary EM31/38 data files arrive from the field in Trimble proprietary format (ssf) and can be obtained from the client Project Page at www.kinilau.ca under Binary Files. Most clients will not utilize these files as they can only be accessed using specialized engineering software (KiNiLau uses the Trimble Pathfinder Office Suite, Appendix B). They contain lateral conductivity data (quadrature and in-phase) synchronized to raw GPS positions and various other data fields.

The processor converts these files into standard ASCII format, also called (txt) or (dat) format, and combines them to form the *em31/38.dat* file. The *em31/38.dat* file is a raw data file in that no algorithm has yet been applied to the lateral conductivity data. GPS positions, on the other hand, have already been differentially-corrected at that point. This file is provided to clients who would like to process their own data and is accessible at the client Project Page by clicking on Raw Data. Graphic 1 displays a typical *em31.dat* file and its column assignment.



Graphic 1: *em31.dat* and its column assignment

The *em31/38.dat* file is gridded and enhanced using in-house designed processing and imaging techniques. The resulting image is UTM-referenced. Four superimposed crosses, only faintly visible, correspond to UTM grid coordinates. The image itself is provided in (jpg) and the UTM coordinates in ASCII (dat) format, both of which are zipped together and obtainable via the client Project Page by clicking on Referenced Images.

Surveyed features are drafted using CAD software and exported as *survey features.dxf,* a drafting file in standard AutoCAD format. Clients can obtain this AutoCAD survey features file by accessing their Project Page from www.kinilau.ca and clicking on Survey Features.

The Lateral Conductivity Detail - EM31/38 is analyzed in the context of the field engineer's interpretation. Interpretation events are drafted onto the maps, which are then checked by a second data processor prior to uploading to the KiNiLau server as Lateral Conductivity Detail - EM31/38.

3.2 DGPS Positioning (Trimble Pathfinder ProXT)

KiNiLau maps are posted in *UTM* and projected in *NAD83*. GPS positions are *differentially-corrected* using the Trimble Pathfinder Office Suite (see Appendix B). This software uses differentials to correct primarily for ionospheric effects, multipath rejection and timing synchronization errors.

UTM & NAD83

Universal Transverse Mercator (UTM) is a coordinate system that allows survey data to be posted in metre units (m). The traditional coordinate system is the Latitude/Longitude system, which posts in units of degrees. Since it is easier for us to think in terms of metre units than degrees (we can walk 20 m north much better than we can walk 2° north) most maps designed for field follow-up work should probably be posted in *UTM*.

The datum represents the mathematical approximation of the earth's rounded surface for a particular region. It is used to transpose positions acquired on that rounded surface to their flat cartographic counterpart.

For example, an ant walking across a lanzones (a fruit native to the Philippines of particularly exotic and sweet flavour) from Point A to B might cover a real-life distance of 3 cm. On a flat, contoured map of that lanzones, the horizontal projection of that distance might only appear as 2 cm. The datum corrects for this error by stretching the map and making the distance from Point A to B appear as 3 cm, what it should be. We might call that Datum LANZONES83.

In western Canada, commonly used data are *NAD83* and at times NAD27. WGS84 best approximates earth as a whole and, as a result, is the one used by space roving satellites.

Differential-Corrections

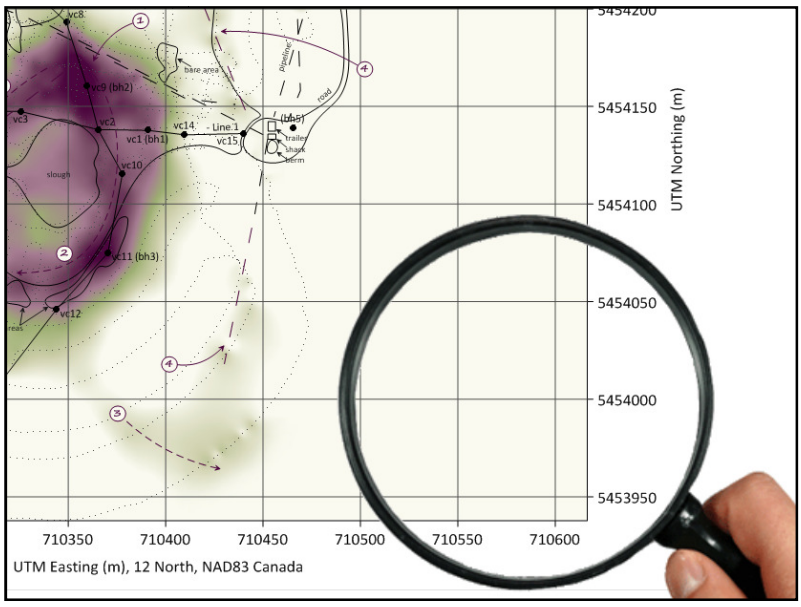
The EM31/38 are synchronized to a GPS called the rover, the mobile unit. To find out what kind of positioning errors the rover incurs, all we have to do is compare it to the positioning errors incurred by a nearby stationary point, called the base. Any recorded deviations about that stationary point are errors that would have equally affected nearby rovers. These deviations are called *differentials* and can be subtracted from time-synchronized, roving GPS data.

4. Conductivity Details

Conductivity details are included in Appendix A of this report. They are designed to serve as independent and comprehensive reporting tools replacing the traditional paper report. Details present geophysical images, superimposed survey features as well as an interpretation story line.

4.1 Distance Scales

Distance scales are omitted from digital conductivity details due to the potential for unintentional distortion. Since UTM map bases post in units of (m), they can readily be utilized to obtain scaling information instead, Graphic 2.



Graphic 2: UTM map bases provide scaling information

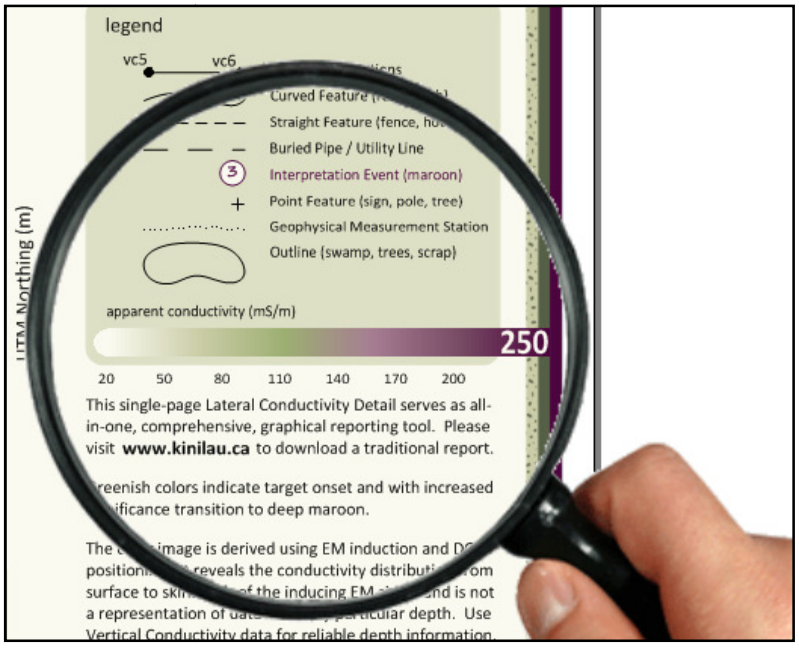
4.2 Legend & Color Apparent Conductivity Scale

The legend details surveyed features and includes a customized *apparent conductivity* color scale, displaying color gradations from beige to moss green to maroon.

Apparent Conductivity

Apparent conductivity implies that measurements do not purely represent soil conductivities, but rather a combination of properties and phenomena as described on Pages 3 and 4 of this report (see *equivalence, skindepth & thickness-conductivity product*).

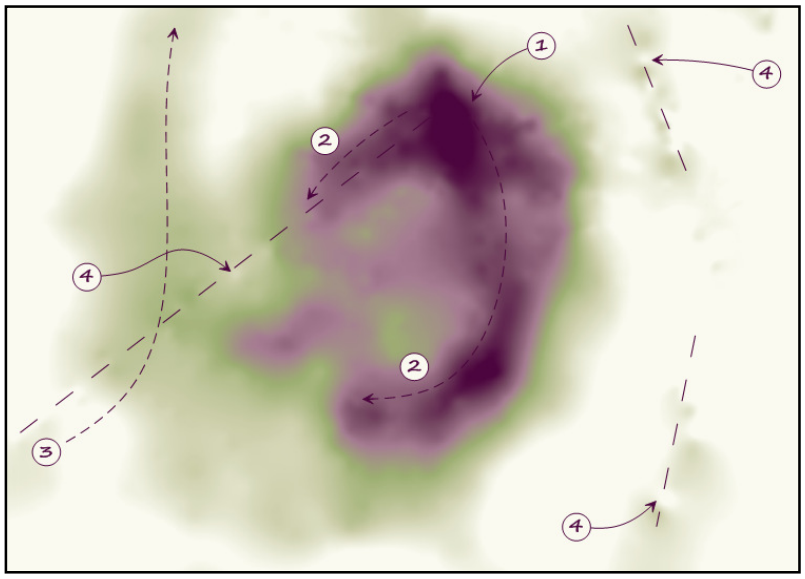
Beige regions represent background and maroon regions anomalous conductivities. The possibility of ionic contamination increases from beige to dark maroon. The peak color scale value is posted at the right side of the color scale in large bold font, Graphic 3. This value is inevitably less than the unfiltered peak survey response.



Graphic 3: The KiNiLau *apparent conductivity* color scale

4.3 Maroon Interpretation Circles and Arrows

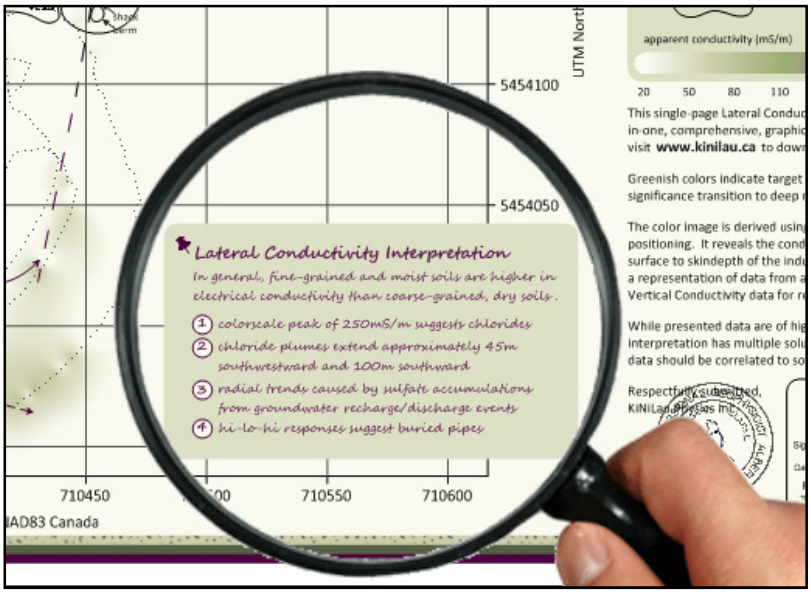
Maroon colored script is reserved for the interpretation. Maroon, numbered circles point out various geophysical interpretation events while maroon dashed arrows highlight interpreted trends, Graphic 4.



Graphic 4: Interpretation events are drafted in maroon

4.4 Conductivity Interpretation Insets

Each numbered interpretation circle on the map is further detailed in the moss colored inset titled 'Lateral Conductivity Interpretation', Graphic 5.



Graphic 5: The interpretation inset details each interpretation circle

5. Interpretation

The interpretation is included on all conductivity details. Numbered circles in maroon color each represent an interpretation event, which is elaborated on within the moss colored inset titled 'Lateral Conductivity Interpretation'. Maroon colored dashed lines and arrows highlight interpreted trends and boundaries.

Since interpretations imply a certain level of uncertainty readers at times question the validity of a particular geophysical technique. It should be noted that each geophysical technique is intrinsically very accurate and that the cause of interpretational disorientation is unfamiliarity with the theory pertaining to that technique. Readers are encouraged to familiarize themselves with the following key terms relevant to interpreting KiNiLau Conductivity Details:

Footprint ..... **Page 1**
In-Phase vs. Quadrature ..... **Page 2**
Equivalence ..... **Page 3**
Skindepth ..... **Page 3**
Thickness-Conductivity Product ..... **Page 4**
Dynamic Data Range & Response Linearity ..... **Page 4**
Nyquist's Theory ..... **Page 5**
Apparent Conductivity ..... **Page 10**

5.1 Interpretation Basics

In general, the electrical conductivity of soil increases with moisture and ionic content. Fine grained soils tend to be higher in conductivity since they usually hold more ions. Conductivity increases even further with an increase in moisture content.

Coarse-grained soils tend to attract less ions, which leads to an appropriate generalization that coarser grained soils are more resistive. Further, coarse-grained soils tend to be dryer since they don't absorb and hold moisture as well as fine-grained ones, making them even more resistive.

Fine-grained, moist soils are higher in conductivity than coarse-grained, dry ones.

Natural, usually weak, accumulations of all types of ions can be found in soils. Such ions increase electrical conductivity by freeing electrons for current flow. Clay is a good example of conductive soil that is fine grained, moist and holds weak ion accumulations. Clay often forms the impenetrable layer to contaminant plumes. It tends to contrast well to the resistivity of dry sand, which often forms the flowpath for contaminant plumes.

Ions increase soil conductivity.

Salts are ions of 'high-mobility', readily freeing up electrons into solution that cause astounding increases in soil conductivity. Consequently, salts are easy to delineate using conductivity techniques. Salts may occur naturally or man-made. In western Canada, soils are commonly enriched with naturally occurring sulfates (SO_4^{2-}). Man-made salts typically encountered are nitrates (NO_3^-) from fertilizers and chlorides (Cl^-) as by products from potash plants, oilfield facilities or tanneries. At times, acids (H^+) are encountered causing anomalous soil conductivities near sulfur storage blocks, battery storage yards or within acidic mine drainage channels.

Salts occur naturally or man-made and are easy to delineate using conductivity techniques.

Ferrous metals cause extreme conductivities that are usually easy to distinguish from salt contaminated soil. Metals respond abruptly, often swinging wildly from positive to negative peaks, whereas salt contaminated soils tend to vary gradually.

Buried metal pipelines respond aggressively creating unique, linearly-trending high-low-high (hi-lo-hi) signatures. The effect is one of 'geometric coupling' and is a function of the pipeline's relative position to the instrument's receiver and transmitter coils. Maximized when surveying perpendicularly across pipelines, the effect disappears when surveying parallel to them. As a result, EM induction tools with offset transmitter and receiver coils should not be used to detect buried metal pipelines.

Metals cause abrupt conductivity variations while ions cause smooth ones.

A buried target should be evaluated based on its relative rather than absolute response. For example, a response of 100 mS/m in a background of 90 mS/m might be less significant than a response of 50 mS/m in a background of 10 mS/m.

Interpret conductivity data based on relative response behavior, not absolute magnitudes.

5.2 Interpreting Conductivity Magnitudes

While conductivity data should be interpreted based on relative response behavior rather than absolute magnitudes, KiNiLau will provide a rough guide to interpreting absolute conductivity magnitudes of the EM31/38. Please note that while the following generalizations are derived from the acquisition and interpretation of over 1500 sites in western Canada, exceptions to this generalization will undoubtedly abound. *Conductivity magnitudes* must be understood within the theoretical context provided in this report.

Conductivity Magnitudes

In western Canadian clay till soils, average EM31 background readings hover around **50 mS/m**. 'Background' is a relative term and at times **100 mS/m** represents background in, for example, ionically enriched solonetzic soils. Background readings of **20 mS/m** may be obtained in drier silty, sandy or gravelous zones but we have also encountered backgrounds as low as **2 mS/m** corresponding to Precambrian Shield.

EM31 readings above **100 mS/m** suggest some form of ionic influence, perhaps from sulfates and/or chlorides. Only rarely do sulfates elevate EM31 conductivities past **150 mS/m**, suggesting chlorides past that range.

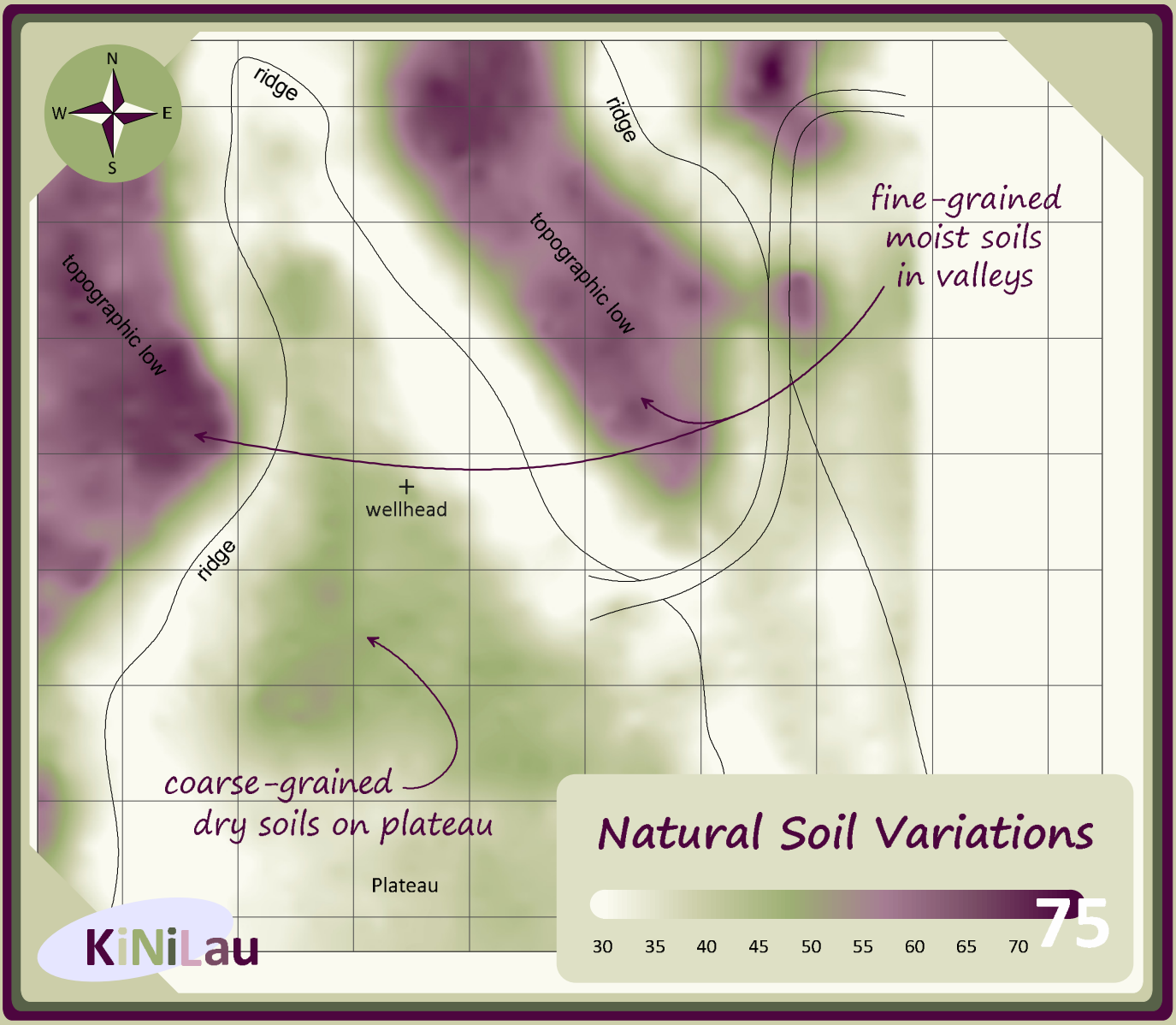
6. Samples

The following samples provide insight to interpreting conductivity details. Vertical Conductivity profiles have been included in this section of the report, enabling valuable insight to the depth response of the Geonics EM31 and EM38.

While we have learnt to interpret each site uniquely and independently, we have also been able to establish similarities between them. 'Typical responses' are presented on the following pages, providing insight to the integrity and consistency of conductivity details.

Interpretation Samples

1. Natural Soil Variations (EM31)
2. Natural Salinity & Pipes (EM31)
3. Flarepit with Chlorides (EM31 & VC)
4. Pipeline Break & Brine Spill (EM31 & VC)
5. Pipe Break, Chlorides & Sulfates (EM31 & VC)
6. Flarepit, Chlorides & Sulfates (EM31, EM38 & VC)

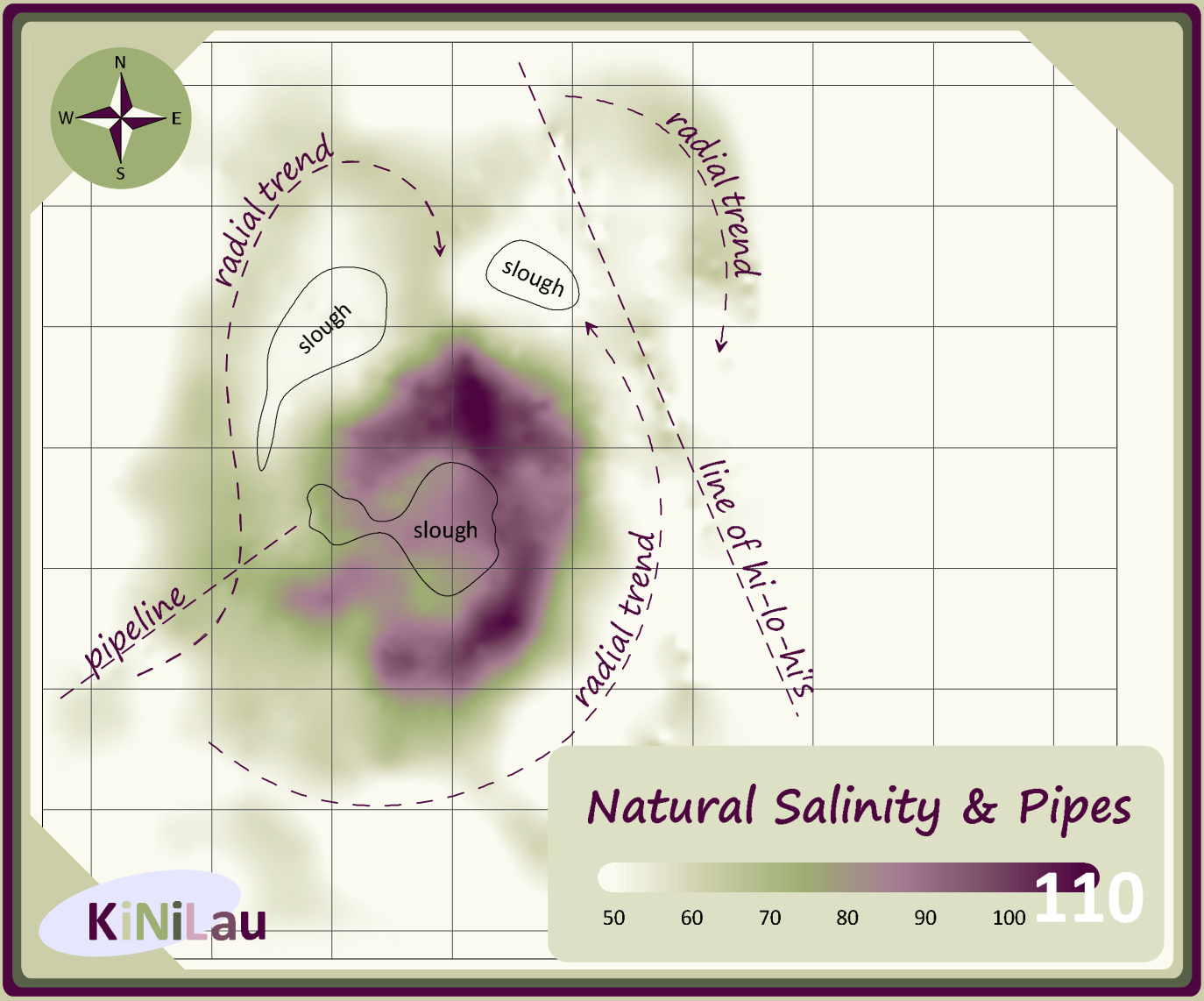


Natural Soil Variations (EM31)

The above Lateral Conductivity Detail typifies a site that 'has nothing'. Conductivity responses are low, with a dynamic range from 30 mS/m for coarser, dryer soils to 75 mS/m for finer, moist ones.

This lateral conductivity detail, in essence, details local topographic variations. Higher conductivities correlate to accumulations of fine-grained moist soils in valley like channels and lower conductivities correlate to coarse, drier material on top of the plateau.

The generalization that fine-grained, moist soils are higher in conductivity than coarse-grained, dry ones holds true since soil conductivites are predominantly affected by ionic and moisture content. Silts and clays tend to attract more ions and moisture than a permeable granite based gravel. Practically, not much else could affect soil conductivity other than minor influences such as temperature or resistive soil matrices (hydrocarbons).

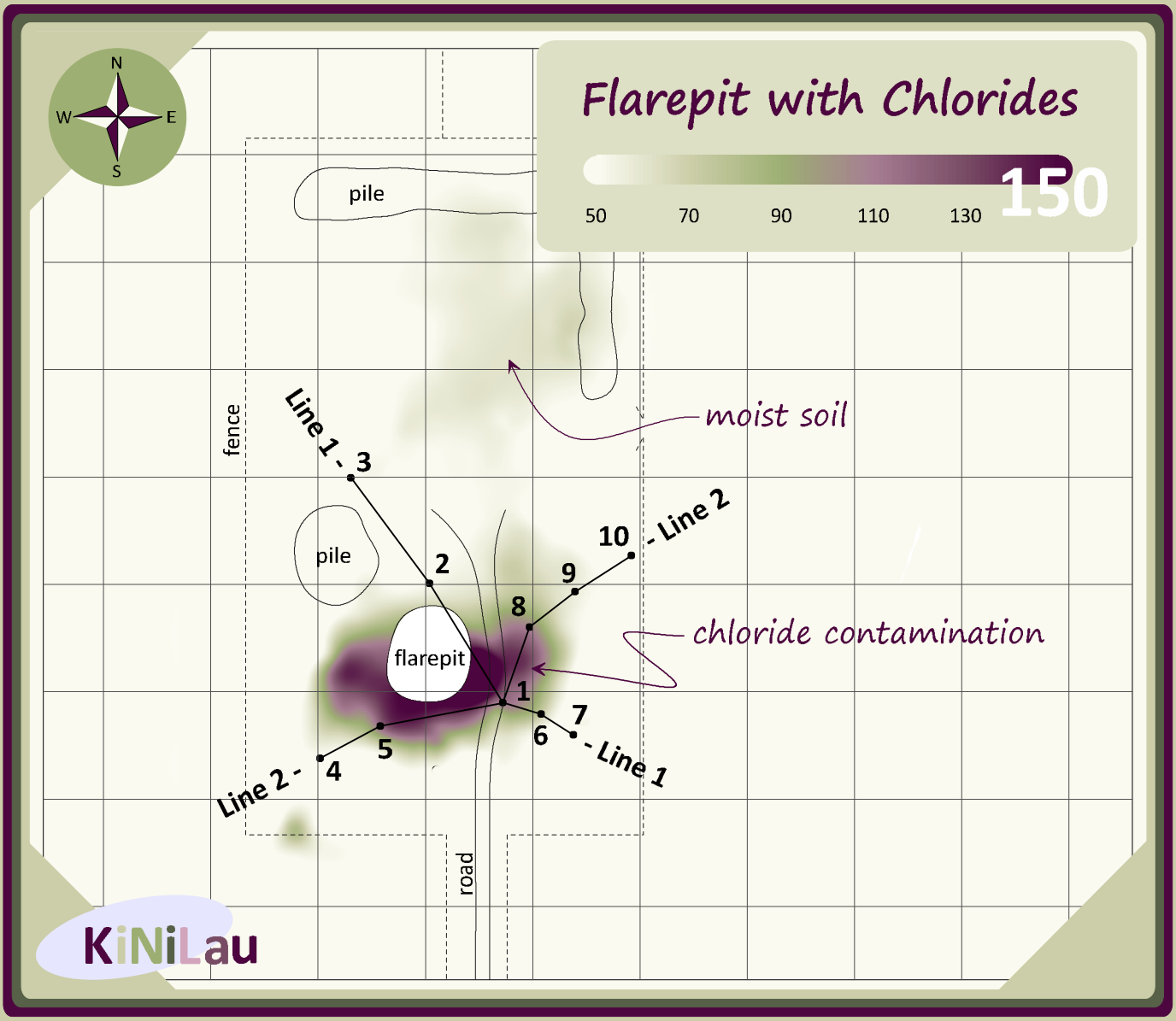


Natural Salinity & Pipes (EM31)

Naturally-saline soils contain sulfates, ions of high mobility that yield response magnitudes matching those of chlorides. To an experienced surveyor, sulfate-laden and chloride-impacted soils can usually be distinguished by their unique conductivity trends.

In western Canada radial conductivity trends often result from groundwater recharge-discharge events. Here, the slough yields elevated conductivities near 110 mS/m, surrounded by a low conductivty ring near 50 mS/m. The reverse effect may also be encountered, when a slough yields reduced conductivities in contrast to a ring of high conductivity.

Note the linearly trending 'hi-lo-hi' response signatures across the site caused by metal pipelines. The effect is one of 'geometric coupling' and is a function of the pipeline's relative position to the instrument's receiver and transmitter coils. Maximized surveying perpendicularly across pipelines, the effect disappears when surveying parallel to them. As a result, EM induction tools with offset transmitter and receiver coils should not be used to detect buried metal pipelines.



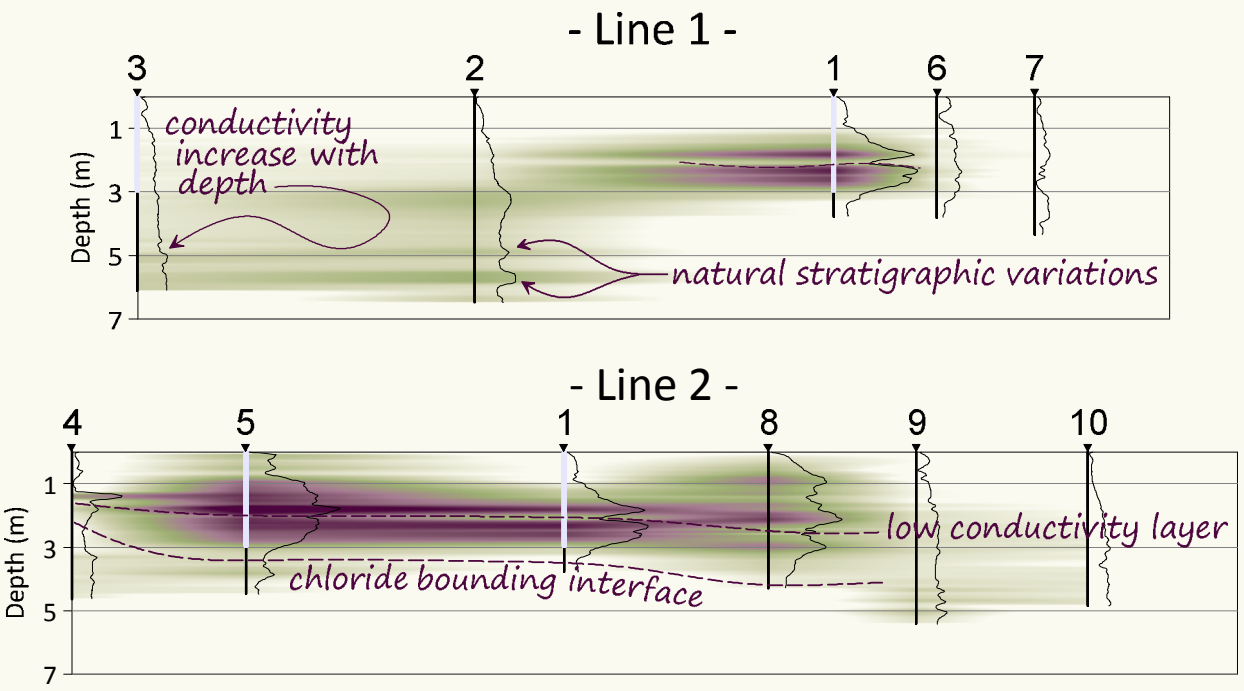
Flarepit with Chlorides (EM31)

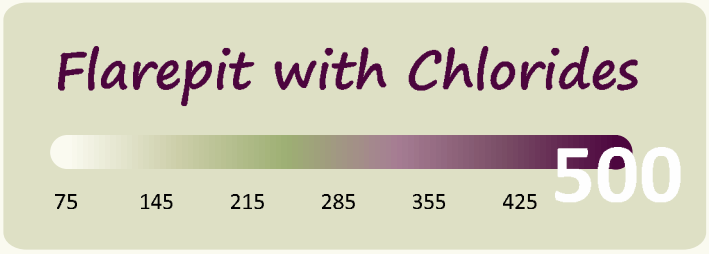
... see Vertical next page

Sites with sulfate-free backgrounds impacted by chlorides do not usually present challenges to an interpreter. Above, typical background conductivities near 50 mS/m correspond to a dry silty clay, which contrasts well to anomalous conductivites in excess of 150 mS/m caused by chlorides around the flarepit.

The trend and location of the anomalous conductivity zone provide further insight. The trend pattern appears contained and non-repetitive, suggesting minimal outward spreading of chlorides. Its location matches that of typical flarepits in the area, which allows us to conclude with reasonable certainty that chlorides are the cause of anomalous conductivites.

The slightly elevated conductivity zone northeast of the lease was caused by an increase in soil moisture. The conductivity zone peaks at 65 mS/m and appears disconnected from the flarepit.



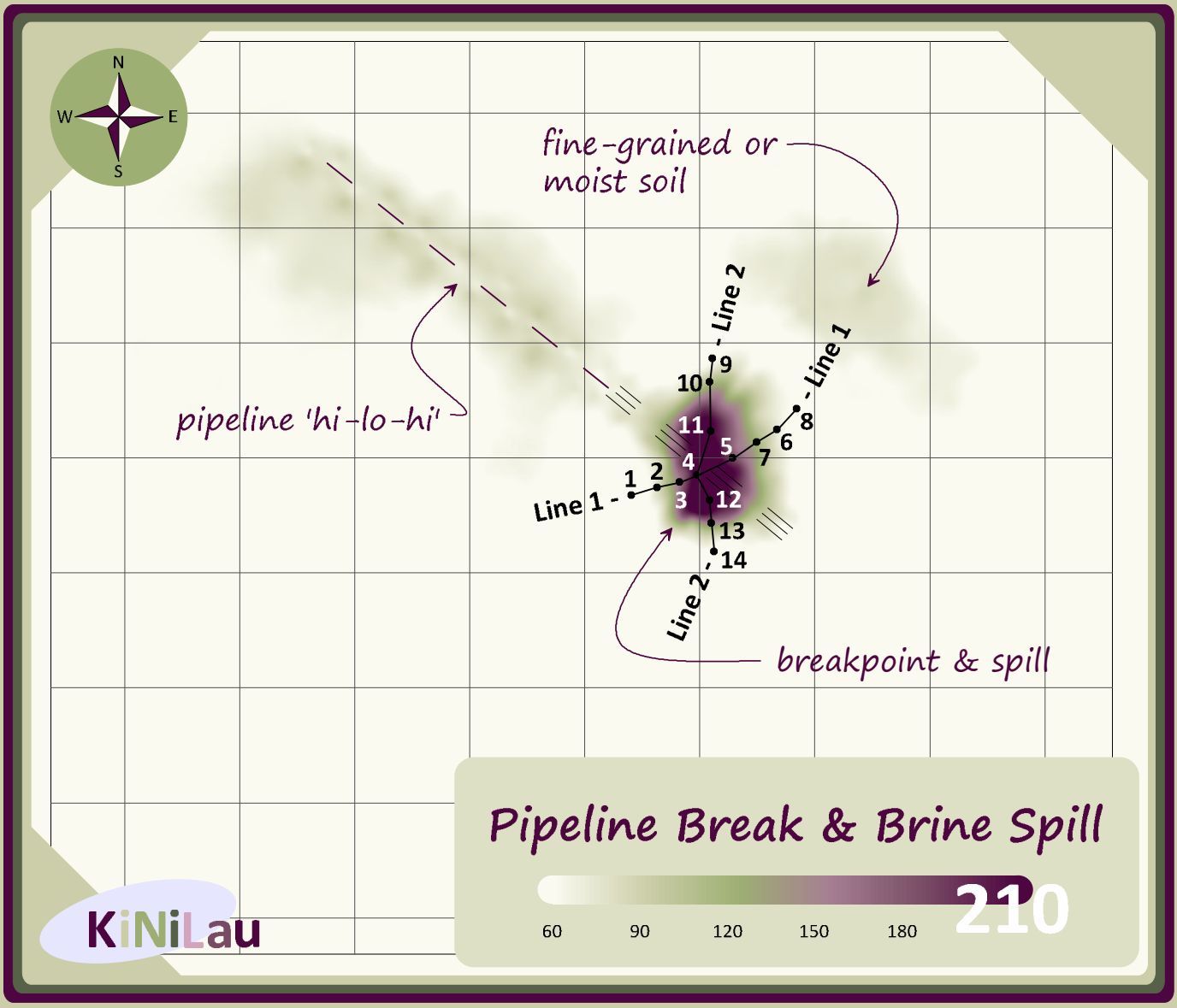


KiNiLau

Flarepit with Chlorides (VC) ... cont'd

In 3D conductivity surveys, VC profiles always target anomalous zones previously identified, usually by means of the lateral conductivity survey. Trace 3 was located to establish background conditions. Conductivities are low and increase gradually with depth, corresponding to an increase in soil moisture with depth. Trace 2, just outside the lateral anomalous conductivity zone, still reveals background conditions. The dynamic data range of Trace 2 is low (meaning, the spread between the lowest and highest readings is small) enabling recognition of subtle conductivity variations that correspond to changes in stratigraphy.

Two stratigraphic layers come into view when establishing trend continuity among VC traces on Line 2. A 'low conductivity layer' corresponds to either a permeable unit washed clean of chlorides (usually on older sites) or an impermeable clay not yet penetrated by chlorides (often on newer sites). The 'chloride bounding interface' forms the bottom of an anomalous conductivity zone and perhaps corresponds to a bottom-sealing clay.



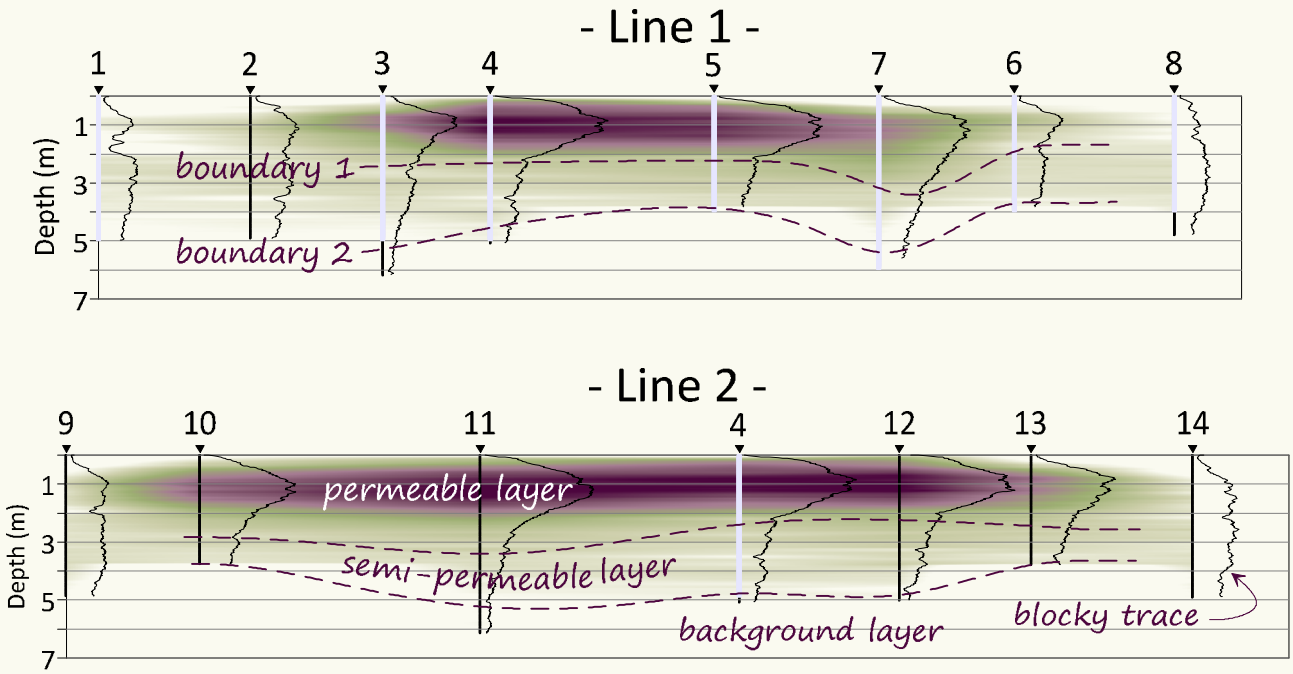
Pipeline Break & Brine Spill (EM31)

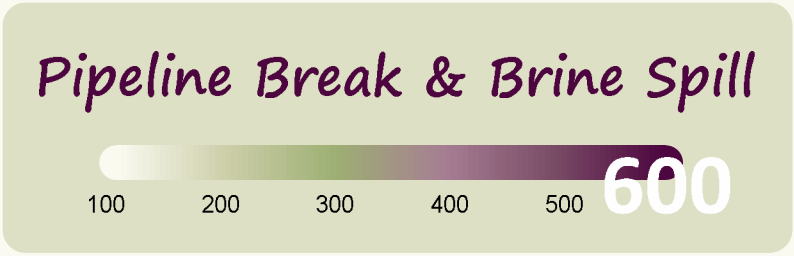
... see Vertical next page

Pipeline break points are identified by delineating their ensuing brine spill. Produced water spills may take off on adventurous paths to remote locations or remain localized, as in the above example. A plume's migratory path is simply a function of surrounding stratigraphic and soil conditions.

Peak response amplitudes near 210 mS/m leave no reasonable doubt that chlorides are involved. Sulfates are not likely to push conductivities to such high levels while it is, surely, theoretically possible.

'Hi-lo-hi' signatures are indicative of buried metal pipelines and a weakly elevated conductivity zone northeast of the main spill is probably caused by weak accumulations of moist or fine-grained soil.





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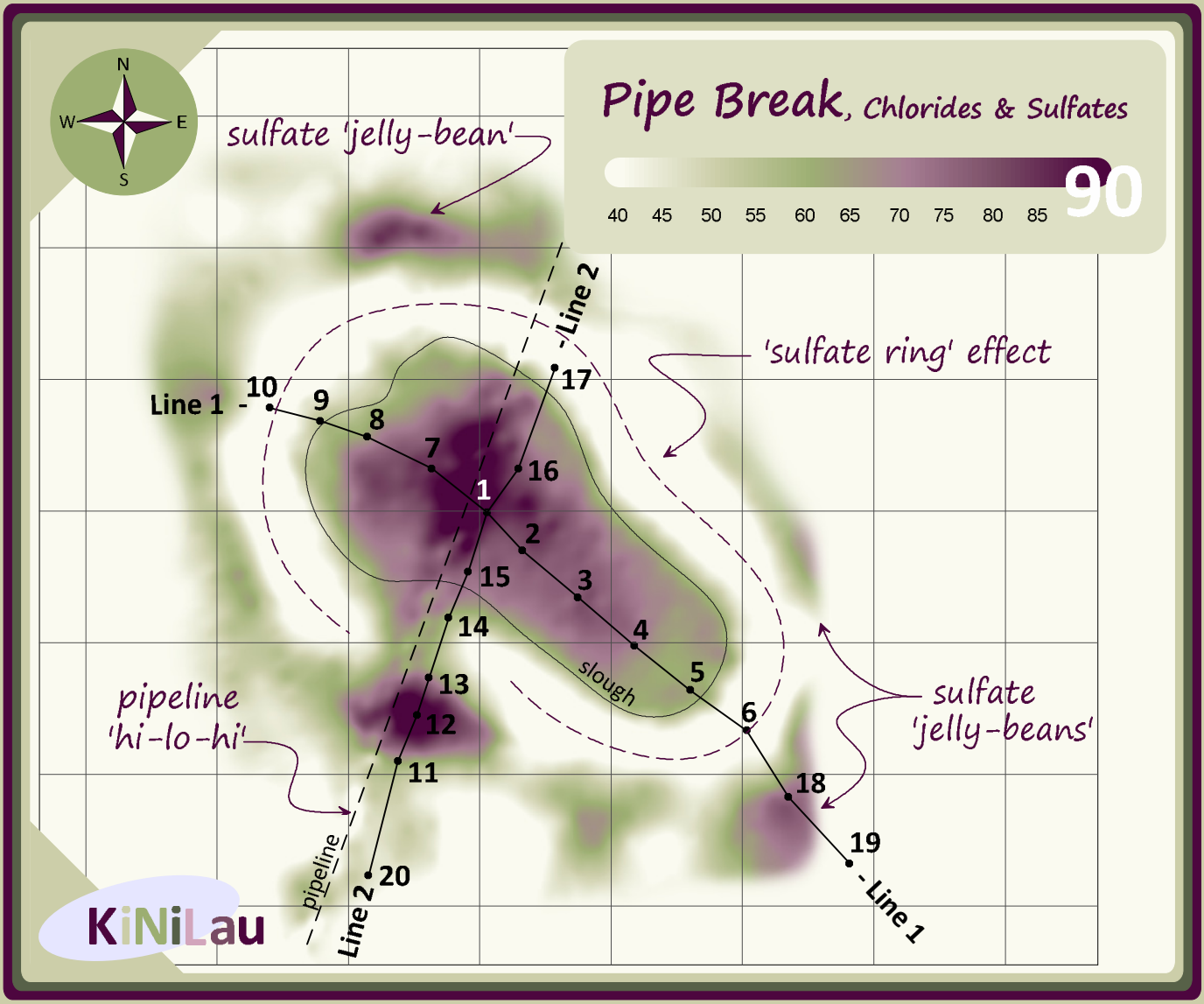
Pipeline Break & Brine Spill (VC) ... cont'd

Peak vertical conductivities near 600 mS/m further support the presence of chlorides since sulfates are not as likely to yield responses of such magnitude. Our confidence in having a proper understanding of the local soil geology grows with good trace-to-trace trend continuity revealing two stratigraphic boundaries in the vicinity of the pipeline breakpoint.

Boundary 1 represents the interface between a 2 m surficial permeable layer of high vertical conductivity and a 2 m thick semi-permeable layer of medium conductivity. Boundary 2 appears as chloride-binding interface, marking the transition from the semi-permeable layer to the background layer of low conductivity.

Note that vertical conductivity traces from within the chloride impacted region appear rounded, transitioning smoothly from peak to background. In contrast, VC background traces appear coarse and blocky, presenting an often reliable methodology for distinguishing between chloride impacted and natural soils.



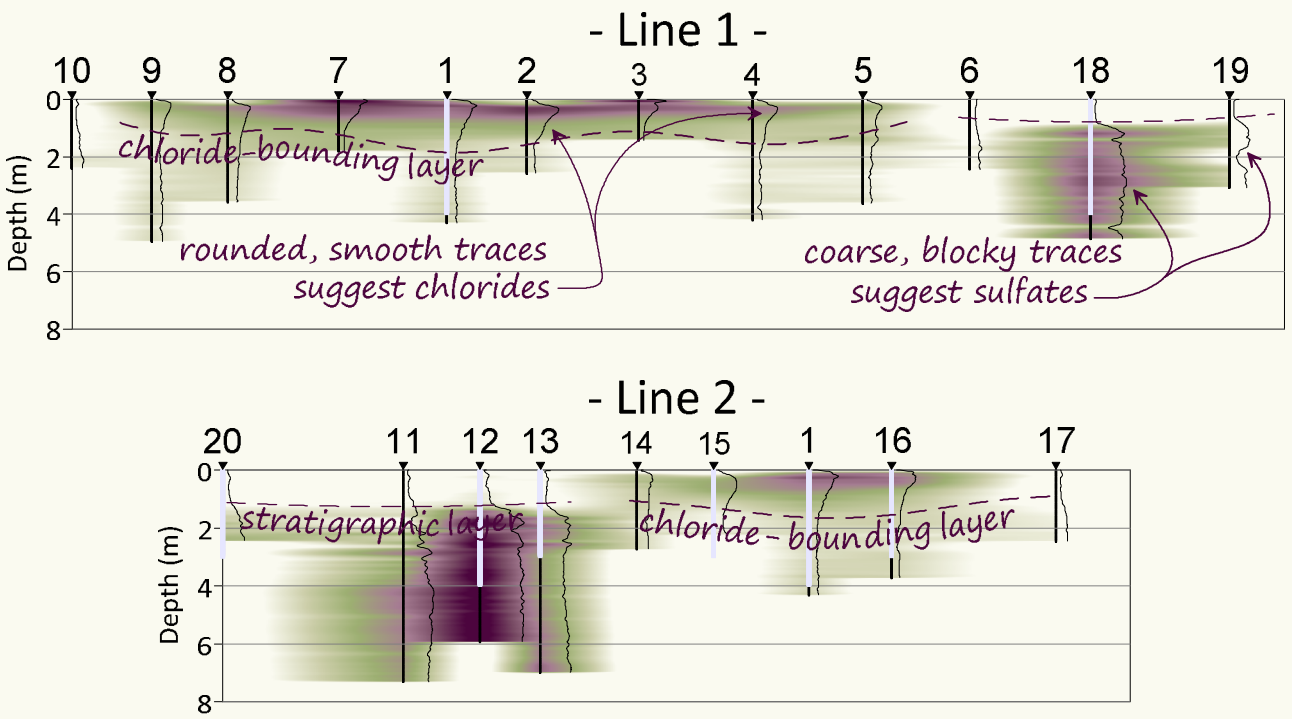
Pipe Break, Chlorides & Sulfates (EM31)

... see Vertical next page

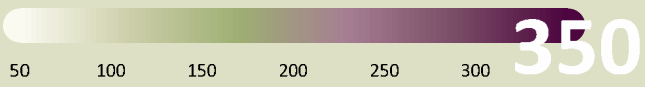
What makes this site unique is the combination of sulfates and chlorides causing anomalous soil conductivites. While response amplitudes near 90 mS/m could be caused by either sulfates or chlorides, 'jelly-bean' shaped background trends and a well defined 'sulfate-ring' strongly weigh in favour of sulfates.

Our field engineers have used other terms before to describe distinct conductivity trends of sulfate-laden soils such as 'radial', 'speckled' and 'finger-like'. Whatever shape, they tend to be repetitive unlike chloride plumes, which occur only once.

At this point nothing suggests the existence of chlorides, other than perhaps the typical 'hi-lo-hi' trend, which corresponds to a produced water carrying metal pipeline transecting the sulfate-laden slough. Let's see what the vertical conductivity tool reveals ...



Pipe Break, Chlorides & Sulfates

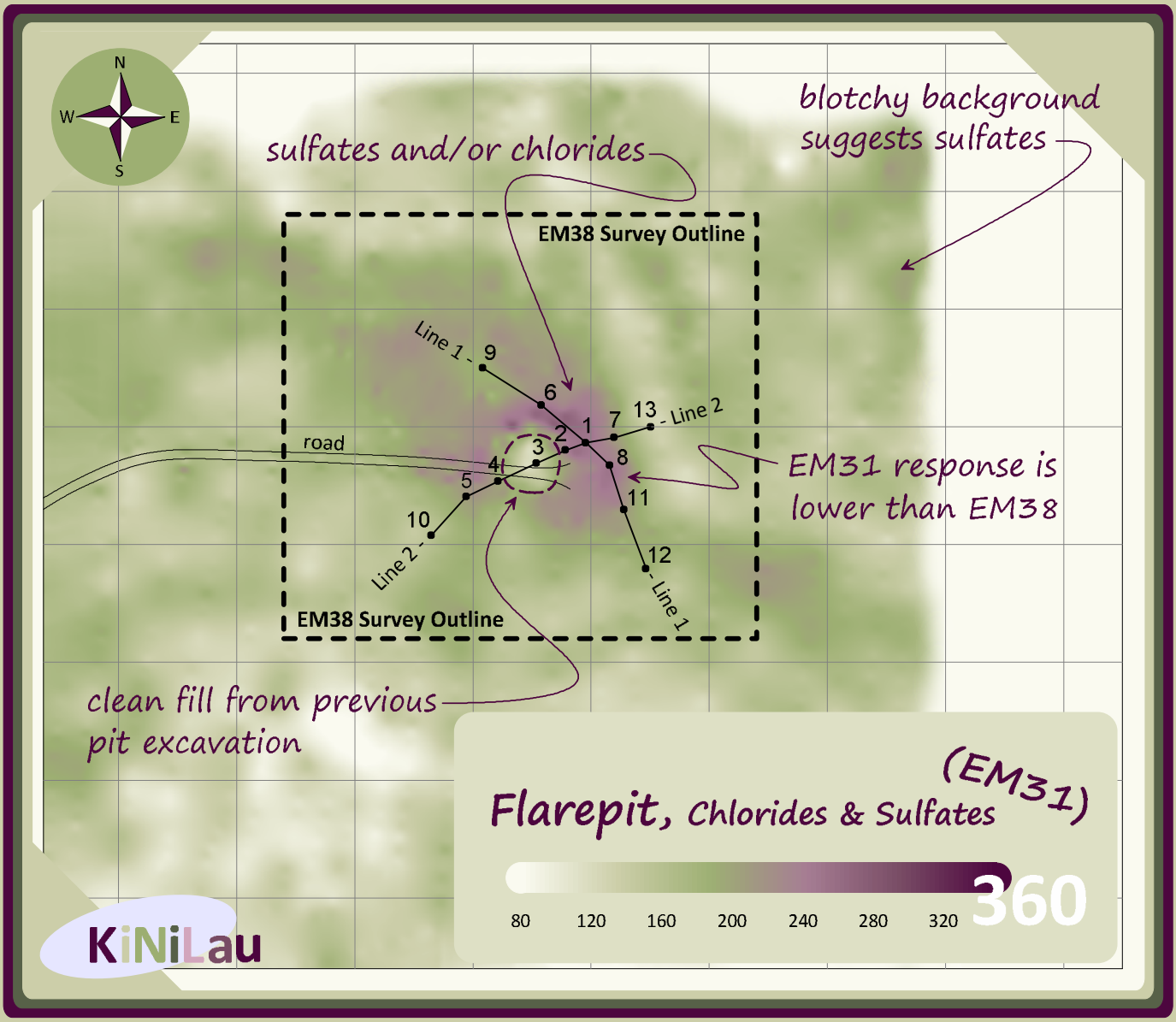


KiNiLau

Pipe Break, Chlorides & Sulfates (VC) ... cont'd

Based on magnitude alone, peak conductivities near 350 mS/m could have been caused by either sulfates or chlorides ... or both. What makes differentiation possible are the unique VC Trace shapes typically exhibited by chloride and sulfate laden soils. Rounded, smooth traces typically correspond to chloride laden soils while coarse, blocky ones suggest the influence of sulfates.

Background traces 20, 11, 12 and 13 reveal the onset of a distinct stratigraphic layer near 2 m depth. A tight clay, this layer exhibits higher conductivity than the overlying layer comprised of a dry silt. VC Traces pushed within the slough appear rounded and smooth from surface to 2 m depth. This shape suggests chlorides and, consequently, the continuation of the tight clay below the slough in the form of a chloride-bounding layer.

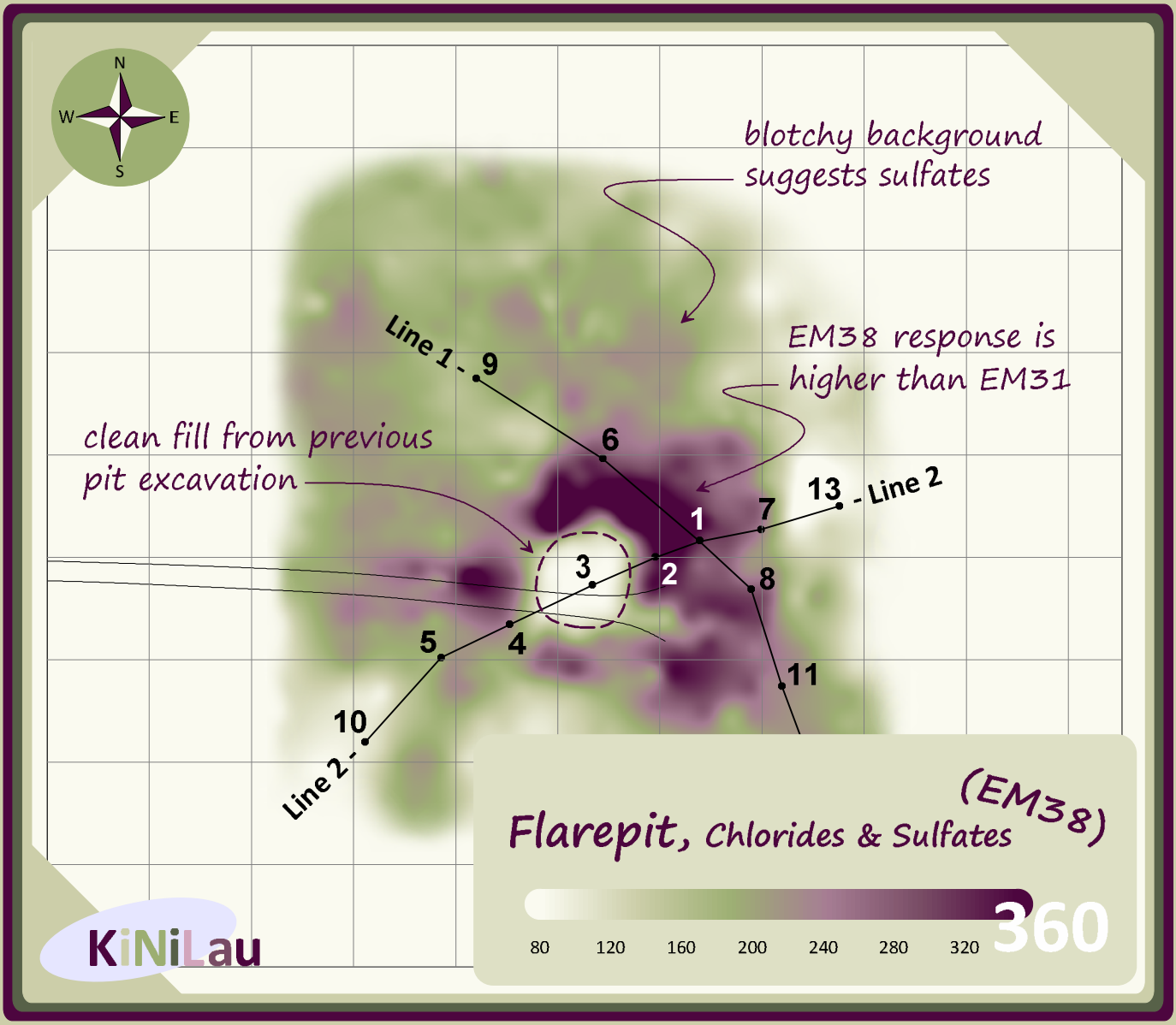


Flarepit, Chlorides & Sulfates (EM31)

... EM38 next page

The above 3D survey represents a previously reclaimed flarepit. Background conductivities exceed 200 mS/m with a typically 'blotchy' response pattern, which suggests an influence from naturally occurring sulfates. The reclaimed flarepit exhibits very low conductivity, a manifestation of a clean, low conductivity fill material used during remediation. EM31 conductivities near the flarepit exceed 240 mS/m, a response amplitude not often associated with sulfates.

Usually, no added benefit is realized by the application of both, the EM31 and EM38, during a 3D conductivity survey. The vertical conductivity technique far surpasses comparative and subjective depth information from any EM induction tool. Having an EM31, EM38 and vertical conductivity survey at hand for this site, provides a unique opportunity to compare depth interpretation methodologies for each technique. The black, dashed outline represents the survey extent of the follow-up EM38 survey.

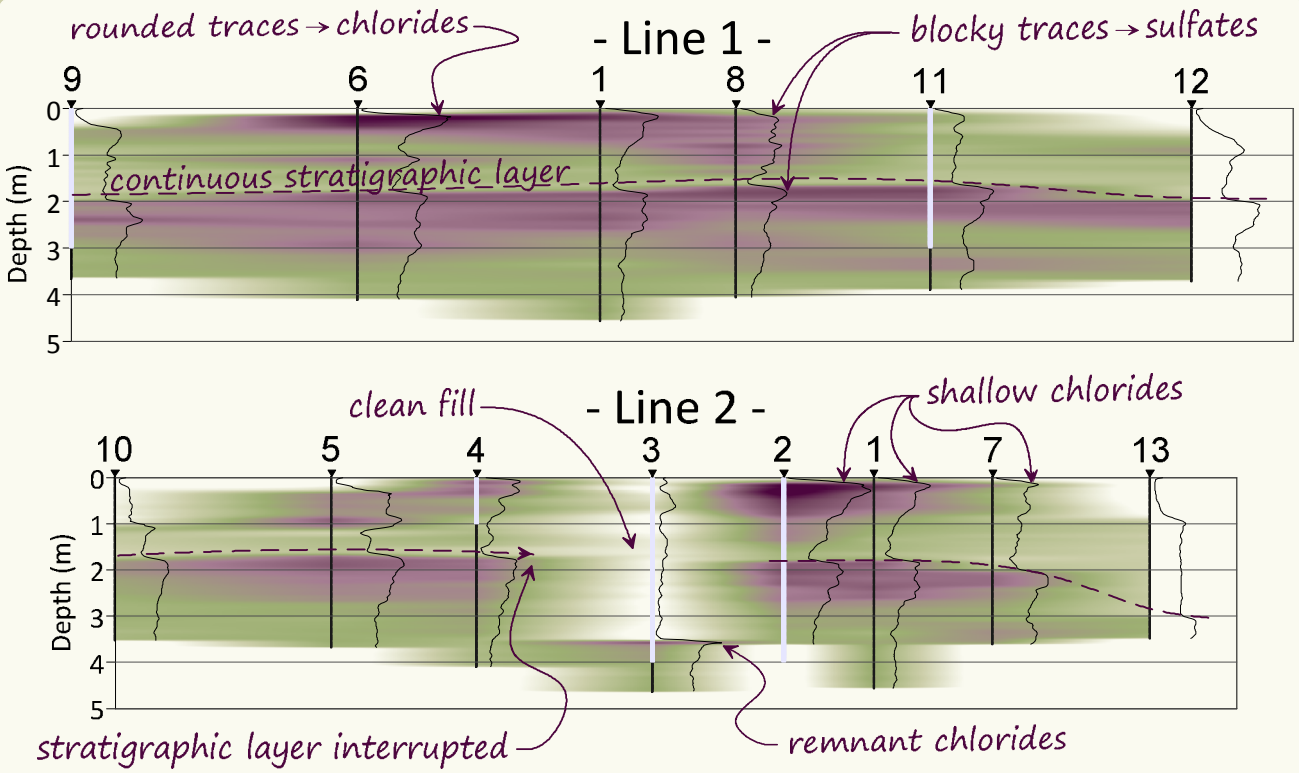


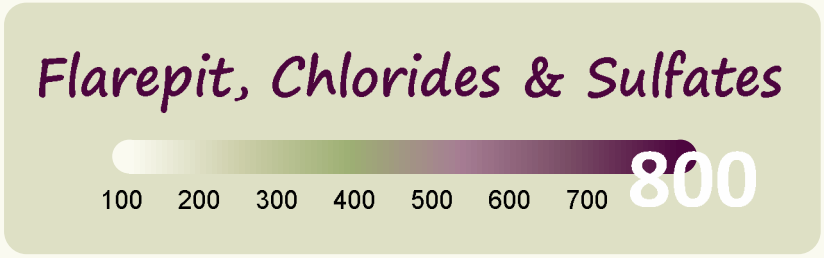
Flarepit, Chlorides & Sulfates (EM38)

... see Vertical next page

Compared to the previous EM31 detail, the EM38 reveals higher conductivities surrounding the flarepit. Since the EM38 has an intrinsically lesser skindepth than the EM31, one can interpret the main cause of anomalous response to have originated from 'shallower' depth, anywhere from surface to 2 m. Depth extent would be an unknown as would be the degree of contamination or chloride concentrations.

A more objective answer can not be provided since the induction technique inherently falls prey to theoretical factors such as skindepth, equivalence or thickness-conductivity product. Based on different technologies, the vertical conductivity technique does not suffer the same theoretical shortcomings and offers far more detailed and objective depth information.





KiNiLau

Flarepit, Chlorides & Sulfates (VC) ... cont'd

Traces 2, 1 and 7 of Line 2 confirm the initial comparative lateral conductivity interpretation that the cause of anomalous conductivities originates from 'shallower' depth; somewhere between surface and approximately 2 m. Amplitudes reach 800 mS/m, a magnitude usually associated with chlorides. From surface to 1 m depth VC Traces 6, 2, 1 and 7 are smooth and rounded, further suggesting chlorides over sulfates. While sulfate ions may cause high conductivity amplitudes, traces tend to be blocky and coarse in appearance. Generally, traces obtained from ion-free backgrounds exhibit similarly blocky signatures, albeit, at much lower conductivity.

A distinct conductivity spike on Trace 3 at 3.5 m depth suggests remnant chloride contamination. Clean fill is confirmed from surface to 3.5 m depth, exhibiting very low conductivities of less than 100 mS/m.

On Line 2, note the interruption of the stratigraphic layer by the intruding fill material. The VC image reflects that abrupt change, a testimonial to the stability of the image interpolation routine in those situations.

Appendix A
Conductivity Details

Appendix B

Instrument Specifications

EM31
GROUND CONDUCTIVITY METER with INPHASE CHANNEL

The EM31 measures the conductivity of the ground directly in mS/m. The EM31 also measures the inphase component of response, which is useful for detecting ferrous and non-ferrous buried material.

Two meters on the front panel of the EM31 simultaneously display conductivity and inphase response. Readings can be taken at successive survey stations, or continuously along the survey line.

Using the inductive method, the EM31 operates without the ground contact required by conventional resistivity. As a result, surveys can be done over highly resistive material, such as gravel or asphalt, at the pace of a walk.

Compared to resistivity surveys, EM31 surveys yield detailed, continuous data, with better resolution of small changes in conductivity. This enables the EM31 to identify subtle changes in conductivity that can be caused by contamination, and to delimit affected areas with precision.

Depth of exploration is about 6 m, which makes the EM31 suitable for many geotechnical and environmental applications.

The EM31 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements. The EM31 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM31 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. The EM31 can map conductive contamination of soil and groundwater, and simultaneously detect buried metal, which makes this instrument the ideal tool for site assessment. It is most commonly used during soil-salinity surveys.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone (905) 670-9580*

EM31 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing:	3.66 m
		Operating Frequency:	9.8 kHz
Primary Field Source (Tx):	Self-Contained Dipole Tx	Conductivity Ranges:	10-1000 mS/m
Receiver (Rx):	Self-Contained Dipole Rx		

EM38
GROUND CONDUCTIVITY METER with INPHASE CHANNEL

The EM38 measures the conductivity of the ground directly in mS/m. The EM38 also measures the inphase component of response, which enables it to be used as a metal detector or, for poorly to moderately conductive material, a magnetic-susceptibility meter.

The depth to which the EM38 measures conductivity depends solely on the orientation of the instrument. When the instrument is upright in vertical-dipole mode (as shown), depth of measurement is approximately 1.5m. With the instrument on its side, in horizontal-dipole mode, depth of measurement is approximately 0.75m. Readings are shown on digital meters which are mounted on the top and side of the EM38, for convenient reading regardless of the orientation of the instrument.

Using EM induction, the EM38 requires no contact with the ground. As a result, surveys can cover large areas rapidly. To survey at walking speed, a special handle allows the operator to carry the EM38 at ground level.

The EM38 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements.

The EM38 is most commonly used during soil-salinity surveys, in both dry-land and irrigated areas. Compared to resistivity, EM38 surveys offer better lateral-resolution, and much faster coverage. The EM38 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM38 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. These applications make good use of the excellent spatial resolution of the EM38. The EM38 can also be used to identify shallow metallic objects.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone(905) 670-9580*

EM38 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing:	1.0 m
		Operating Frequency:	14.6 kHz
Primary Field Source (Tx):	Self-Contained Dipole Tx	Conductivity Ranges:	10-1000 mS/m
Receiver (Rx):	Self-Contained Dipole Rx		

DATASHEET

GPS Pathfinder ProXT receiver

KEY FEATURES

- Real-time submeter GPS with integrated SBAS, and EVEREST multipath rejection technology
- Receiver, antenna, and battery in one compact unit
- Bluetooth wireless technology for totally cable-free operation
- Rugged and weatherproof for all conditions
- User-replaceable battery lasts a full day in the field
- Choice of field computer and software to suit your workflow

FULLY INTEGRATED BLUETOOTH GPS RECEIVER FOR SUBMETER ACCURACY

Purpose-built for GIS data collection, the GPS Pathfinder® ProXT™ receiver sets new standards for ease of use. A submeter GPS receiver, antenna, and all-day battery in one, the ProXT receiver is totally cable-free, making data collection more straightforward than ever before. Simple to set up and easy to use, we'll forgive you for taking its sophisticated technology for granted.

Accuracy you can depend on

The real test of a GPS receiver is the quality of the GPS data it produces. The ProXT receiver passes the test with flying colors, delivering consistent, reliable, submeter accuracy. The receiver's advanced design, and features like EVEREST™ multipath rejection technology let you work under canopy, in urban environments, or wherever accuracy is crucial.

If you need to be sure of your accuracy in the field, the integrated SBAS receiver or optional GeoBeacon™ receiver provides submeter accuracy in real time. For the very best results, postprocessing is easy with Trimble® GPS Pathfinder Office software or the GPS Analyst™ extension for ESRI ArcGIS software.

Cable-free convenience

Forget lost or tangled cables: with a Bluetooth® wireless connection, you are cable free between the ProXT receiver and your field computer. No more snagging as you get in and out of vehicles or move through difficult terrain. Snap it onto the convenient belt clip and you're ready to go anywhere. You can mount it on your vehicle for data collection on the move, clip it to a range pole when accuracy is critical, or even use it on a backpack. It's quick and easy to mount the ProXT receiver to suit the job at hand.

All day, every day

The receiver has an integrated battery, good for a full day's work; simply charge the battery overnight and you're ready to go again. The ProXT receiver will last the distance, and its rugged design can take a lot of punishment. Rain, hail, or shine, it's built to keep working, whatever the environment throws at you.

Options to suit your workflow

You can choose a field computer and software to suit your workflow. The ProXT receiver is ready to use with a variety of field computers, including laptops, Tablet PCs, and PDAs, and of course with Trimble's own rugged field computers: the Trimble Recon® handheld and the Trimble Ranger™ handheld.

Choosing software? Trimble's TerraSync™ software or the GPScorrect™ extension for ESRI ArcPad software provides a complete solution from field to office and back. Choose any off-the-shelf GPS field software, or use the GPS Pathfinder Tools Software Development Kit (SDK) to build an application that's customized to your needs.

Designed for the GIS professional

The high performance GPS Pathfinder ProXT receiver is purpose built for serious GIS data collection. No cables. No hassles. Just reliable submeter GPS accuracy from a system designed to work where you work.

Trimble

GPS Pathfinder ProXT receiver

STANDARD FEATURES

GPS

- Integrated GPS/SBAS[1] receiver and antenna
- Submeter accuracy in real-time
- EVEREST multipath rejection technology
- RTCM input
- NMEA and TSIP protocol support

System

- Integrated GPS receiver, antenna and battery
- Integrated Bluetooth wireless technology
- User replaceable all-day battery
- Wearable GPS receiver with ergonomic belt clip
- Rugged weatherproof housing

Software

- GPS Controller software for mission planning and GPS configuration
- Bluetooth deactivation utility

Accessories

- Power supply with international adapter kit
- Ergonomic belt clip
- Screwthread adaptor for range pole, backpack, or vehicle mounting
- Null modem cable
- User Guide

OPTIONAL FEATURES

Software

- TerraSync software
- Trimble GPScorrect extension for ESRI ArcPad software
- Custom applications built with the GPS Pathfinder Tools Software Development Kit (SDK)
- GPS Pathfinder Office software
- Trimble GPS Analyst extension for ESRI ArcGIS software

Field computers

- Field computer running Microsoft® Windows Mobile® version 5.0 software or Windows Mobile 2003 software for Pocket PCs, such as:
  - Trimble Ranger handheld
  - Trimble Recon handheld
- Field computer running Microsoft Windows® desktop operating system

Accessories

- GeoBeacon receiver
- 1 foot pole (for backpack mounting)
- Range pole bracket
- External patch antenna
- Hard carry case
- Magnetic vehicle mount
- Backpack
- 2 meter range pole
- Hurricane antenna kit
- Baseball cap with patch antenna pocket
- Serial port splitter cable

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TECHNICAL SPECIFICATIONS

Physical

Integrated GPS receiver, antenna, and battery

Size	10.6 cm × 4.0 cm × 14.6 cm (4.2 in × 1.6 in × 5.75 in)
Weight	0.53 kg (1.16 lb)
Power	
Low (GPS only)	0.8 Watts
Normal (GPS and Bluetooth)	1.0 Watt
Battery	User replaceable lithium-ion, chargeable in unit 12.6 Watt hours

Environmental

Temperature	
Operating	–20 °C to +60 °C (–4 °F to +140 °F)
Storage	–30 °C to +85 °C (–22 °F to +185 °F)
Humidity	99% non-condensing
Casing	Wind-driven rain and dust-resistant per IP 54 standard
Drop	1.22 m (4 ft), MIL-STD-810F, Method 516.5, Procedure IV
Vibration	Vibration resistant, MIL-STD-810F, Method 514.5, Procedure I
Shock	Shock resistant, MIL-STD-810F, Method 516.5, Procedure I

Input/output

Serial	Dual port in single DE9
Bluetooth[2]	2 NMEA/TSIP Serial Port (SPP) services
Interface	Power button, 3 status LEDs

GPS

Channels	12 (L1 code and carrier)
Integrated real-time	SBAS[1]
Update rate	1 Hz
Time to first fix	30 seconds (typical)
Protocols	TSIP, NMEA (GGA, VTG, GLL, GSA, ZDA, GSV, RMC)

Accuracy (HRMS)[3] after differential correction

Code postprocessed	Submeter
Carrier postprocessed[4]	
With 5 minutes tracking satellites	30 cm
With 10 minutes tracking satellites	20 cm
With 20 minutes tracking satellites	10 cm
With 45 minutes tracking satellites	1 cm
Real-time (SBAS[1] or external RTCM source)	Submeter

1 SBAS (Satellite Based Augmentation System). Includes WAAS (Wide Area Augmentation System) available in North America only. And EGNOS (European Geostationary Navigation Overlay System) available in Europe only.

2 Bluetooth type approvals are country specific. The GPS Pathfinder ProXT receiver has Bluetooth approval in the U.S. and EU. For other countries please consult your local Distributor.

3 Horizontal Root Mean Squared accuracy. Requires data to be collected with minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 39 dBHz, minimum elevation of 15 degrees, and reasonable multipath conditions. Ionospheric conditions, multipath signals or obstruction of the sky by buildings or heavy tree canopy may degrade precision by interfering with signal reception. Accuracy varies with proximity to base station by +1 ppm for postprocessing and real-time.

4 Accuracy varies with proximity to base station by +5 ppm. 45 minute carrier capability applies only to GPS Pathfinder Office software.

Specifications subject to change without notice.

Bluetooth®

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DATASHEET

GPS Pathfinder Office software

KEY FEATURES

Differentially correct to improve the quality of your GPS data

H-Star data processing for high accuracy with the GPS Pathfinder ProXRT and ProXH receivers, or the GeoXH handheld

Import and export data in a variety of GIS formats

Create sophisticated data dictionaries to match your GIS or database

Carry out quality control on your data before you transfer it to the GIS

CARRY OUT QUALITY CONTROL ON YOUR DATA BEFORE YOU TRANSFER IT TO THE GIS

The GPS Pathfinder® Office software adds value to your GIS data collection and data maintenance projects. This powerful and easy-to-use software ensures your data is consistent, reliable, and accurate—enabling you to make informed decisions.

Improve the accuracy of your GPS data

The differential correction process can improve the accuracy of your GPS positions from around 10 meters[1] to submeter and better, depending on the environment and your GPS receiver. Using Trimble's established H-Star™ technology you can now achieve decimeter accuracy with the GPS Pathfinder ProXRT receiver and GeoXH™ 2008 series handheld (using an optional Zephyr™ external antenna).

Make sure that your data is differentially corrected using the best quality base station data available with GPS Pathfinder Office software's unique Integrity Index grading system. Providing a list of monitored base data providers from around the world, the Integrity Index helps you select quality providers to use when differentially correcting your data.

Increase the efficiency of your field work

Data can be imported from a number of GIS and database formats allowing previously collected GIS data to be taken back to the field for verification and update.

The GPS Pathfinder Office software's Data Dictionary Editor creates custom lists of features and attributes for data collection. You can be confident that data collected in the field meets your specific GIS needs by creating your own data dictionary or importing one from your GIS based on its exact data schema. In the field, the data dictionary prompts the field crew to enter specific information—ensuring data integrity and compatibility with your GIS or database. You can also create waypoint files to enhance productivity in the field.

Ensure you have quality data

You can view your features for comparison against any number of background files such as aerial photographs or satellite imagery of the area you are working in. You can even display and use background data directly from a web map server.

Before transferring your data to a GIS, CAD, or database system, you can analyze it to confirm it is complete and free of errors. GIS feature and attribute data can be changed, and unnecessary or unwanted GPS positions can be deleted. This ensures that only the highest quality data is exported to your GIS.

GPS Pathfinder Office software—making it easy for you to manage, correct, and update your GIS data.

1 Typical autonomous GPS accuracy.

Trimble

GPS Pathfinder Office software

FEATURES AND OPTIONS

GPS accuracy
- Improve GPS position accuracy through differential postprocessing
- Achieve from subfoot to decimeter accuracy using postprocessed H-Star technology[1]
- Postprocess real-time differential GPS data to improve accuracy and consistency
- Review and edit GPS data before you transfer it to a GIS
- Compatible with any Trimble® GPS Pathfinder receiver, any GeoExplorer® series, Trimble Nomad™ G series, or Juno™ series handheld, or with Trimble Yuma™ rugged tablet computer

GIS compatibility
- Import data from popular GIS, CAD, and database formats
- Export data into a wide variety of GIS, CAD, and database formats
- Create data dictionaries to ensure data collected is consistent with GIS requirements

Workflow
- Use waypoints to plan GPS field sessions to ensure productive use of field time
- Set up multiple field computers with the same files and settings
- Automate data transfer, differential correction, and data export

Available languages
- Chinese (Simplified)
- English
- French
- Spanish
- German
- Italian
- Japanese
- Korean
- Portuguese
- Russian

Field software options
- TerraSync™ software
- Trimble GPScorrect™ extension for ESRI ArcPad software
- Applications developed using GPS Pathfinder Tools Software Development Kit (SDK)

RECOMMENDED PLATFORM

Operating system. . . . . .Windows® 2000,Windows XP (Home, Professional[2], or Tablet PC Edition) (32- or 64-bit versions) Windows Server 2003 or Windows Vista® (Home thru Enterprise Editions) (32- or 64-bit versions)
Processor type . . . . . Pentium
Free disk space. . . . . .270 MB
Input/output. . . . . .RS-232 serial port and USB port

GPS RECEIVERS AND ACCURACY (HRMS)[3] SPECIFICATIONS

Typical autonomous accuracy for all GPS receivers is around 10 meters. The following table shows differentially corrected accuracy specifications for supported receivers:

Receiver/Handheld	Postprocessed
GPS Pathfinder ProXRT receiver	10–20 cm[4]
GPS Pathfinder Pro XRS receiver	50 cm
GPS Pathfinder ProXH™ receiver	submeter / subfoot[4]
GPS Pathfinder ProXT™ receiver	submeter
GeoXH handheld	submeter / subfoot[4] / decimeter[5]
GeoXT™ handheld	submeter
GeoXM™ handheld	1–3 m
Juno series handheld	2–5 m
Trimble Nomad G series handheld	2–5 m
GPS Pathfinder XB receiver	2–5 m
Trimble Recon® GPS XB edition	2–5 m
GPS Pathfinder XC receiver	2–5 m
Trimble Recon GPS XC edition	2–5 m
Trimble Yuma rugged tablet computer	2–5 m

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PN 13269R (05/09)

SUPPORTED FORMATS

Import formats
- AutoCAD 2000 ASCII DXF
- dBASE
- ESRI Shapefiles
- MapInfo MIF
- Microsoft Access MDB

Export formats
- ARC/INFO (for NT and UNIX) Generate
- AutoCAD 2000 ASCII DXF (with or without blocks)
- dBASE
- ESRI Shapefiles
- GRASS
- IDRISI Vector
- MapInfo MIF
- MGAL
- Microsoft Access MDB
- Microstation version 7 DGN
- PC-ARC/INFO Generate
- PC-MOSS

Vector background formats
- AutoCAD 2000 ASCII and binary DXF (.dxf)
- ESRI Shapefiles (.shp)
- Trimble SSF format (.ssf, .cor, .imp, .phs, .wpt)

Raster (image) background formats
- JPEG (.jpg)
- JPEG 2000 (.jp2, .j2c)
- Enhanced Compression Wavelet (.ecw)
- MrSID (.sid)
- TIFF (.tif)
- Windows bitmap (.bmp)

Web map servers
- ArcIMS
- OpenGIS

SUPPORTED BASE FILE AND COMPRESSION FORMATS

Base file formats
- Hatanaka (Compressed RINEX)
- RINEX
- Trimble DAT format
- Trimble SSF format

Compression types
- GZip (.gz)
- Self-extracting executable (.exe)
- Zip (.zip)

1 Dependent on H-Star-capable receiver and antenna combination, and correction source used.
2 Windows XP Professional x64 Edition is not supported.
3 Horizontal Root Mean Squared accuracy. Requires data to be collected with minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 39 dBHz, minimum elevation of 15 degrees, and reasonable multipath conditions. For the Juno series, Trimble Nomad G series, Trimble Yuma tablet, or GPS Pathfinder XB or XC receivers, data must be collected using maximum PDOP of 99, minimum SNR of 12 dBHz, and minimum elevation of 5 degrees, under reasonable multipath conditions. The Trimble Nomad G series and GPS Pathfinder XB or XC receivers must be horizontally mounted; the Juno SB and SC handhelds must be vertically mounted. Ionospheric conditions, multipath signals or obstruction of the sky by buildings or heavy tree canopy may degrade precision by interfering with signal reception. Accuracy varies with proximity to reference station by +1 ppm for postprocessing and real-time.
4 H-Star specified accuracy is typically achieved within 2 minutes. Requires a minimum of three good quality dual frequency reference stations within 200 km, or one good quality dual frequency reference station within 80 km. With one reference station accuracy degrades at +1 ppm beyond 80 km. The ProXH receiver achieves 20 cm postprocessed accuracy with the optional Zephyr external antenna.
5 GeoXH 2008 series with optional Zephyr external antenna.

Specifications subject to change without notice.

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Appendix D Laboratory Analysis

Maxxam

Your P.O. #: 110218542
Your Project #: MALLIK
Site Location: INUVIK, NWT
NSD # 16300R
PO # 16300R
Your C.O.C. #: A049824, A049825

Attention: OLIVIER PIRAUX
STANTEC CONSULTING LTD
#200, 325- 25TH ST. SE
CALGARY, AB
CANADA

Report Date: 2011/09/06

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B179987
Received: 2011/08/27, 11:15

Sample Matrix: Soil
Samples Received: 8

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble)	3	2011/08/30	2011/09/01	AB SOP-00026	SM 4110-B
Chloride (Soluble)	5	2011/08/30	2011/09/02	AB SOP-00026	SM 4110-B
Conductivity @25C (Soluble)	8	2011/08/31	2011/08/31	AB SOP-00004	SSMA 15.3
Ion Balance	8	N/A	2011/09/02	AB WI-00065	SM 1030E
Sum of Cations, Anions	8	N/A	2011/09/02	AB WI-00065	SM 1030E
Moisture	8	N/A	2011/08/29	EENVSOP-00139	Carter SSMA 51.2
pH @25C (1:2 Calcium Chloride Extract)	8	2011/09/01	2011/09/01	AB SOP-00006	SSMA 16.3
Particle Size by Sieve (75 micron)	8	N/A	2011/09/01	AB SOP-00022	SSMA 55.4
Sodium Adsorption Ratio	8	N/A	2011/09/02	AB WI-00065	SSMA 15.4.4
Ca,Mg,Na,K,SO4 (Soluble)	8	2011/09/01	2011/09/01	AB SOP-00042	EPA 200.7
Soluble Paste	8	2011/08/30	2011/08/30	AB SOP-00033	SSMA 15.2
Theoretical Gypsum Requirement	8	N/A	2011/09/02	CAL WI-00087	CJSS 79:449-455

Sample Matrix: Water
Samples Received: 6

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity @25C (pp, total), CO3,HCO3,OH	6	N/A	2011/08/27	AB SOP-00005	SM 2320-B
Chloride by Automated Colourimetry	6	N/A	2011/08/29	AB SOP-00020	EPA 325.2
Conductivity @25C	6	N/A	2011/08/27	AB SOP-00005	SM 2510-B
Hardness	6	N/A	2011/09/02	AB WI-00065	SM 2340B
Elements by ICP - Dissolved	4	N/A	2011/09/01	AB SOP-00042	EPA 200.7
Elements by ICP - Dissolved	2	N/A	2011/09/02	AB SOP-00042	EPA 200.7
Ion Balance	6	N/A	2011/09/02	AB WI-00065	SM 1030E
Sum of cations, anions	6	N/A	2011/09/02	AB WI-00065	SM 1030E
Nitrate and Nitrite	6	N/A	2011/08/31	Calc	
Nitrate + Nitrite-N (calculated)	6	N/A	2011/08/31	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC	6	N/A	2011/08/30	AB SOP-00023	SM 4110-B
pH @25°C (Alkalinity titrator)	6	N/A	2011/08/27	AB SOP-00005	SM 4500-H+B
Sulphate by Automated Colourimetry	6	N/A	2011/08/29	AB SOP-00018	EPA 375.4
Total Dissolved Solids (Calculated)	6	N/A	2011/09/02	AB WI-00065	SM 1030E

(1) Units for TGR have changed from tons/acre to tonnes/ha

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Jeremy Wakaruk, B.Sc., Senior Project Manager
Email: JWakaruk@maxxam.ca
Phone# (780) 577-7105 Ext:7105

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		BJ3587		BJ3590		BJ3591		
Sampling Date		2011/08/20 16:40		2011/08/20 16:40		2011/08/20 16:50		
COC Number		A049824		A049824		A049824		
	Units	**MALLIK/WS/2011/01**	**RDL**	**MALLIK/WS/2011/02**	**RDL**	**MALLIK/WS/2011/03**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	94	N/A	75	N/A	100	N/A	5129809
Cation Sum	meq/L	90	N/A	73	N/A	98	N/A	5129809
Hardness (CaCO3)	mg/L	770	0.5	1000	0.5	930	0.5	5129806
Ion Balance	N/A	0.96	0.01	0.98	0.01	0.96	0.01	5129807
Dissolved Nitrate (NO3)	mg/L	<0.01	0.01	0.01	0.01	<0.01	0.01	5129811
Nitrate plus Nitrite (N)	mg/L	<0.003	0.003	0.003	0.003	<0.003	0.003	5129812
Dissolved Nitrite (NO2)	mg/L	<0.01	0.01	<0.01	0.01	<0.01	0.01	5129811
Total Dissolved Solids	mg/L	5300	10	4200	10	5800	10	5129814
Misc. Inorganics								
Conductivity	uS/cm	9900	1	7700	1	11000	1	5129948
pH	N/A	9.75	N/A	8.24	N/A	9.06	N/A	5129947
Anions								
Alkalinity (PP as CaCO3)	mg/L	47	0.5	<0.5	0.5	22	0.5	5129943
Alkalinity (Total as CaCO3)	mg/L	130	0.5	270	0.5	130	0.5	5129943
Bicarbonate (HCO3)	mg/L	45	0.5	330	0.5	100	0.5	5129943
Carbonate (CO3)	mg/L	57	0.5	<0.5	0.5	26	0.5	5129943
Hydroxide (OH)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	5129943
Dissolved Sulphate (SO4)	mg/L	34	1	280 (1)	2	110	1	5130656
Dissolved Chloride (Cl)	mg/L	3200 (1)	30	2200 (1)	30	3500 (1)	30	5130651
Nutrients								
Dissolved Nitrite (N)	mg/L	<0.003	0.003	<0.003	0.003	<0.003	0.003	5135697
Dissolved Nitrate (N)	mg/L	<0.003	0.003	0.003	0.003	<0.003	0.003	5135697
Elements								
Dissolved Calcium (Ca)	mg/L	77	0.3	150	0.3	110	0.3	5143695
Dissolved Iron (Fe)	mg/L	0.07	0.06	0.15	0.06	0.09	0.06	5143695
Dissolved Magnesium (Mg)	mg/L	140	0.2	150	0.2	160	0.2	5143695
Dissolved Manganese (Mn)	mg/L	<0.004	0.004	0.18	0.004	0.008	0.004	5143695
Dissolved Potassium (K)	mg/L	45	0.3	40	0.3	52	0.3	5143695
Dissolved Sodium (Na)	mg/L	1700 (1)	5	1200 (1)	5	1800 (1)	5	5143695

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		BJ3592		BJ3593		BJ3594		
Sampling Date		2011/08/20 17:00		2011/08/20 17:00		2011/08/20 17:15		
COC Number		A049824		A049824		A049824		
	Units	**MALLIK/WS/2011/04**	**RDL**	**MALLIK/WS/2011/06**	**RDL**	**MALLIK/WS/2011/07**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	85	N/A	260	N/A	88	N/A	5129809
Cation Sum	meq/L	83	N/A	220	N/A	83	N/A	5129809
Hardness (CaCO3)	mg/L	700	0.5	2200	0.5	880	0.5	5129806
Ion Balance	N/A	0.98	0.01	0.85	0.01	0.95	0.01	5129807
Dissolved Nitrate (NO3)	mg/L	0.02	0.01	0.21	0.01	<0.01	0.01	5129811
Nitrate plus Nitrite (N)	mg/L	0.004	0.003	0.047	0.003	<0.003	0.003	5129812
Dissolved Nitrite (NO2)	mg/L	<0.01	0.01	<0.01	0.01	<0.01	0.01	5129811
Total Dissolved Solids	mg/L	4800	10	14000	10	4900	10	5129814
Misc. Inorganics								
Conductivity	uS/cm	9200	1	27000	1	9300	1	5129948
pH	N/A	9.84	N/A	8.69	N/A	8.86	N/A	5129947
Anions								
Alkalinity (PP as CaCO3)	mg/L	45	0.5	19	0.5	20	0.5	5129943
Alkalinity (Total as CaCO3)	mg/L	120	0.5	190	0.5	170	0.5	5129943
Bicarbonate (HCO3)	mg/L	34	0.5	180	0.5	160	0.5	5129943
Carbonate (CO3)	mg/L	54	0.5	23	0.5	24	0.5	5129943
Hydroxide (OH)	mg/L	<0.5	0.5	<0.5	0.5	<0.5	0.5	5129943
Dissolved Sulphate (SO4)	mg/L	37	1	25	1	190 (1)	2	5130656
Dissolved Chloride (Cl)	mg/L	2900 (1)	30	9100 (1)	50	2800 (1)	30	5130651
Nutrients								
Dissolved Nitrite (N)	mg/L	<0.003	0.003	<0.003	0.003	<0.003	0.003	5135697
Dissolved Nitrate (N)	mg/L	0.004	0.003	0.047	0.003	<0.003	0.003	5135697
Elements								
Dissolved Calcium (Ca)	mg/L	77	0.3	170	0.3	79	0.3	5143695
Dissolved Iron (Fe)	mg/L	0.07	0.06	0.16	0.06	0.08	0.06	5143695
Dissolved Magnesium (Mg)	mg/L	120	0.2	430	0.2	170	0.2	5143695
Dissolved Manganese (Mn)	mg/L	<0.004	0.004	0.083	0.004	<0.004	0.004	5143695
Dissolved Potassium (K)	mg/L	39	0.3	160	0.3	46	0.3	5143695
Dissolved Sodium (Na)	mg/L	1600 (1)	5	4000 (1)	5	1500 (1)	5	5143695

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		BJ3684		BJ3688		BJ3689		
Sampling Date		2011/08/22 12:00		2011/08/22 12:00		2011/08/22 12:00		
COC Number		A049824		A049824		A049824		
	Units	**MALLIK/SS/2011/01**	**RDL**	**MALLIK/SS/2011/02**	**RDL**	**MALLIK/SS/2011/04**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	290	N/A	26	N/A	61	N/A	5129810
Cation Sum	meq/L	280	N/A	29	N/A	62	N/A	5129810
Ion Balance	N/A	0.98	0.01	1.1	0.01	1.0	0.01	5129808
Soluble Parameters								
Soluble Chloride (Cl)	mg/L	9800 (1)	100	460	5	2000 (1)	10	5140464
Soluble Conductivity	dS/m	33	0.02	3.1	0.02	6.5	0.02	5136295
Soluble (CaCl2) pH	N/A	7.47	N/A	7.15	N/A	6.78	N/A	5142421
Sodium Adsorption Ratio	N/A	18	0.1	1.9	0.1	16	0.1	5129813
Soluble Calcium (Ca)	mg/L	920	1.5	160	1.5	150	1.5	5143269
Soluble Magnesium (Mg)	mg/L	450	1.0	18	1.0	93	1.0	5143269
Soluble Sodium (Na)	mg/L	2700	2.5	93	2.5	1000	2.5	5143269
Soluble Potassium (K)	mg/L	3300	1.3	600	1.3	52	1.3	5143269
Saturation %	%	55	N/A	48	N/A	52	N/A	5136207
Soluble Sulphate (SO4)	mg/L	560	5.0	630	5.0	260	5.0	5143269
Theoretical Gypsum Requirement	tonnes/ha	16	0.1	<0.1	0.1	<0.1	0.1	5129815

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		BJ3690	BJ3691		BJ3692		
Sampling Date		2011/08/22 12:00	2011/08/22 13:00		2011/08/22 13:00		
COC Number		A049824	A049824		A049824		
	Units	**MALLIK/SS/2011/03**	**MALLIK/SS/2011/05**	**RDL**	**MALLIK/SS/2011/06**	**RDL**	**QC Batch**
Calculated Parameters							
Anion Sum	meq/L	70	80	N/A	130	N/A	5129810
Cation Sum	meq/L	72	82	N/A	120	N/A	5129810
Ion Balance	N/A	1.0	1.0	0.01	0.99	0.01	5129808
Soluble Parameters							
Soluble Chloride (Cl)	mg/L	2300 (1)	2600 (1)	20	4200 (1)	30	5140464
Soluble Conductivity	dS/m	7.6	8.6	0.02	13	0.02	5136295
Soluble (CaCl2) pH	N/A	7.00	6.73	N/A	6.84	N/A	5142421
Sodium Adsorption Ratio	N/A	14	13	0.1	24	0.1	5129813
Soluble Calcium (Ca)	mg/L	200	330	1.5	250	1.5	5143269
Soluble Magnesium (Mg)	mg/L	84	170	1.0	210	1.0	5143269
Soluble Sodium (Na)	mg/L	930	1100	2.5	2100	2.5	5143269
Soluble Potassium (K)	mg/L	580	73	1.3	120	1.3	5143269
Saturation %	%	54	53	N/A	56	N/A	5136207
Soluble Sulphate (SO4)	mg/L	250	300	5.0	430	5.0	5143269
Theoretical Gypsum Requirement	tonnes/ha	<0.1	<0.1	0.1	50	0.1	5129815

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		BJ3693		BJ3694		
Sampling Date		2011/08/22 13:00		2011/08/22 13:00		
COC Number		A049825		A049825		
	Units	**MALLIK/SS/2011/07**	**RDL**	**MALLIK/SS/2011/08**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	390	N/A	86	N/A	5129810
Cation Sum	meq/L	310	N/A	100	N/A	5129810
Ion Balance	N/A	0.81	0.01	1.2	0.01	5129808
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	13000 (1)	100	2600 (1)	20	5140464
Soluble Conductivity	dS/m	32	0.02	10	0.02	5136295
Soluble (CaCl2) pH	N/A	7.40	N/A	6.65	N/A	5142421
Sodium Adsorption Ratio	N/A	29	0.1	15	0.1	5129813
Soluble Calcium (Ca)	mg/L	910	1.5	310	1.5	5143269
Soluble Magnesium (Mg)	mg/L	720	1.0	250	1.0	5143269
Soluble Sodium (Na)	mg/L	4800	2.5	1400	2.5	5143269
Soluble Potassium (K)	mg/L	60	1.3	110	1.3	5143269
Saturation %	%	56	N/A	73	N/A	5136207
Soluble Sulphate (SO4)	mg/L	490	5.0	590	5.0	5143269
Theoretical Gypsum Requirement	tonnes/ha	330	0.1	<0.1	0.1	5129815

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B179987
Report Date: 2011/09/06

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 110218542
Sampler Initials: OP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		BJ3684	BJ3688	BJ3689	BJ3690		
Sampling Date		2011/08/22 12:00	2011/08/22 12:00	2011/08/22 12:00	2011/08/22 12:00		
COC Number		A049824	A049824	A049824	A049824		
	Units	**MALLIK/SS/2011/01**	**MALLIK/SS/2011/02**	**MALLIK/SS/2011/04**	**MALLIK/SS/2011/03**	**RDL**	**QC Batch**
Physical Properties							
Moisture	%	22	20	22	21	0.3	5132538
Sieve - Pan	%	99	88	99	98	0.2	5137038
Sieve - #200 (>0.075mm)	%	1.3	12	1.0	2.5	0.2	5137038
Grain Size	%	FINE	FINE	FINE	FINE	0.2	5137038

RDL = Reportable Detection Limit

Maxxam ID		BJ3691	BJ3692	BJ3693	BJ3694		
Sampling Date		2011/08/22 13:00	2011/08/22 13:00	2011/08/22 13:00	2011/08/22 13:00		
COC Number		A049824	A049824	A049825	A049825		
	Units	**MALLIK/SS/2011/05**	**MALLIK/SS/2011/06**	**MALLIK/SS/2011/07**	**MALLIK/SS/2011/08**	**RDL**	**QC Batch**
Physical Properties							
Moisture	%	22	24	21	39	0.3	5132538
Sieve - Pan	%	99	99	99	92	0.2	5137038
Sieve - #200 (>0.075mm)	%	0.7	0.8	1.5	8.2	0.2	5137038
Grain Size	%	FINE	FINE	FINE	FINE	0.2	5137038

RDL = Reportable Detection Limit

Package 1	9.3°C
Package 2	8.3°C
Package 3	7.7°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Sample BJ3593-01: Cation anion balance investigated, data quality confirmed.

Results relate only to the items tested.

Maxxam

STANTEC CONSULTING LTD
Attention: OLIVIER PIRAUX
Client Project #: MALLIK
P.O. #: 110218542
Site Location: INUVIK, NWT

Quality Assurance Report

Maxxam Job Number: EB179987

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
5129943	KG6	Spiked Blank	Alkalinity (Total as CaCO3)	2011/08/27		96	%	80 - 120
		Method Blank	Alkalinity (PP as CaCO3)	2011/08/27	<0.5		mg/L	
			Alkalinity (Total as CaCO3)	2011/08/27	<0.5		mg/L	
			Bicarbonate (HCO3)	2011/08/27	<0.5		mg/L	
			Carbonate (CO3)	2011/08/27	<0.5		mg/L	
			Hydroxide (OH)	2011/08/27	<0.5		mg/L	
		RPD	Alkalinity (PP as CaCO3)	2011/08/27	NC		%	20
			Alkalinity (Total as CaCO3)	2011/08/27	1.5		%	20
			Bicarbonate (HCO3)	2011/08/27	1.6		%	20
			Carbonate (CO3)	2011/08/27	NC		%	20
			Hydroxide (OH)	2011/08/27	NC		%	20
5129947	KG6	Spiked Blank	pH	2011/08/27		100	%	97 - 103
		RPD	pH	2011/08/27	0.05		%	5
5129948	KG6	Spiked Blank	Conductivity	2011/08/27		100	%	90 - 110
		Method Blank	Conductivity	2011/08/27	<1		uS/cm	
		RPD	Conductivity	2011/08/27	0.6		%	20
5130651	BA3	Matrix Spike	Dissolved Chloride (Cl)	2011/08/29		NC	%	80 - 120
		Spiked Blank	Dissolved Chloride (Cl)	2011/08/29		106	%	80 - 120
		Method Blank	Dissolved Chloride (Cl)	2011/08/29	<1		mg/L	
		RPD	Dissolved Chloride (Cl)	2011/08/29	0.4		%	20
5130656	BA3	Matrix Spike	Dissolved Sulphate (SO4)	2011/08/29		NC	%	80 - 120
		Spiked Blank	Dissolved Sulphate (SO4)	2011/08/29		110	%	80 - 120
		Method Blank	Dissolved Sulphate (SO4)	2011/08/29	<1		mg/L	
		RPD	Dissolved Sulphate (SO4)	2011/08/29	0.4		%	20
5132538	APA	Method Blank	Moisture	2011/08/29	<0.3		%	
		RPD	Moisture	2011/08/29	4.1		%	20
5135697	KU	Matrix Spike	Dissolved Nitrite (N)	2011/08/30		101	%	80 - 120
			Dissolved Nitrate (N)	2011/08/30		104	%	80 - 120
		Spiked Blank	Dissolved Nitrite (N)	2011/08/30		98	%	80 - 120
			Dissolved Nitrate (N)	2011/08/30		101	%	90 - 110
		Method Blank	Dissolved Nitrite (N)	2011/08/30	<0.003		mg/L	
			Dissolved Nitrate (N)	2011/08/30	<0.003		mg/L	
		RPD	Dissolved Nitrite (N)	2011/08/30	NC		%	20
			Dissolved Nitrate (N)	2011/08/30	NC		%	20
5136207	JHC	QC Standard	Saturation %	2011/08/30		102	%	88 - 112
		RPD [BJ3684-01]	Saturation %	2011/08/30	0.1		%	12
5136295	CBE	QC Standard	Soluble Conductivity	2011/08/31		105	%	75 - 125
		Spiked Blank	Soluble Conductivity	2011/08/31		100	%	90 - 110
		Method Blank	Soluble Conductivity	2011/08/31	<0.02		dS/m	
		RPD [BJ3684-01]	Soluble Conductivity	2011/08/31	9.5		%	35
5137038	JB9	Method Blank	Sieve - Pan	2011/09/01	<0.2		%	
			Sieve - #200 (>0.075mm)	2011/09/01	<0.2		%	
		RPD	Sieve - Pan	2011/09/01	3.2		%	35
			Sieve - #200 (>0.075mm)	2011/09/01	5.4		%	35
5140464	DMA	Matrix Spike	Soluble Chloride (Cl)	2011/09/02		103	%	75 - 125
		QC Standard	Soluble Chloride (Cl)	2011/09/02		99	%	75 - 125
		Spiked Blank	Soluble Chloride (Cl)	2011/09/01		100	%	80 - 120
		Method Blank	Soluble Chloride (Cl)	2011/09/01	<5		mg/L	
		RPD	Soluble Chloride (Cl)	2011/09/02	NC		%	35
5142421	LCA	QC Standard	Soluble (CaCl2) pH	2011/09/01		98	%	97 - 103
		Spiked Blank	Soluble (CaCl2) pH	2011/09/01		99	%	97 - 103
		RPD	Soluble (CaCl2) pH	2011/09/01	1.4		%	5
5143269	AD3	Matrix Spike	Soluble Calcium (Ca)	2011/09/01		97	%	80 - 120
			Soluble Magnesium (Mg)	2011/09/01		105	%	80 - 120
			Soluble Sodium (Na)	2011/09/01		97	%	80 - 120

STANTEC CONSULTING LTD
Attention: OLIVIER PIRAUX
Client Project #: MALLIK
P.O. #: 110218542
Site Location: INUVIK, NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB179987

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
5143269	AD3	Matrix Spike	Soluble Potassium (K)	2011/09/01		101	%	80 - 120
		QC Standard	Soluble Calcium (Ca)	2011/09/01		121	%	75 - 125
			Soluble Magnesium (Mg)	2011/09/01		119	%	75 - 125
			Soluble Sodium (Na)	2011/09/01		106	%	75 - 125
			Soluble Potassium (K)	2011/09/01		86	%	75 - 125
			Soluble Sulphate (SO4)	2011/09/01		114	%	75 - 125
		Spiked Blank	Soluble Calcium (Ca)	2011/09/01		94	%	80 - 120
			Soluble Magnesium (Mg)	2011/09/01		103	%	80 - 120
			Soluble Sodium (Na)	2011/09/01		95	%	80 - 120
			Soluble Potassium (K)	2011/09/01		99	%	80 - 120
		Method Blank	Soluble Calcium (Ca)	2011/09/01	<1.5		mg/L	
			Soluble Magnesium (Mg)	2011/09/01	<1.0		mg/L	
			Soluble Sodium (Na)	2011/09/01	<2.5		mg/L	
			Soluble Potassium (K)	2011/09/01	<1.3		mg/L	
			Soluble Sulphate (SO4)	2011/09/01	<5.0		mg/L	
		RPD [BJ3684-01]	Soluble Calcium (Ca)	2011/09/01	1.5		%	35
			Soluble Magnesium (Mg)	2011/09/01	1.8		%	35
			Soluble Sodium (Na)	2011/09/01	2.6		%	35
			Soluble Potassium (K)	2011/09/01	2.9		%	35
			Soluble Sulphate (SO4)	2011/09/01	3.2		%	35
5143695	SV1	Matrix Spike	Dissolved Calcium (Ca)	2011/09/01		NC	%	80 - 120
			Dissolved Iron (Fe)	2011/09/01		92	%	80 - 120
			Dissolved Magnesium (Mg)	2011/09/01		93	%	80 - 120
			Dissolved Manganese (Mn)	2011/09/01		85	%	80 - 120
			Dissolved Potassium (K)	2011/09/01		95	%	80 - 120
			Dissolved Sodium (Na)	2011/09/01		NC	%	80 - 120
		Spiked Blank	Dissolved Calcium (Ca)	2011/09/01		95	%	80 - 120
			Dissolved Iron (Fe)	2011/09/01		95	%	80 - 120
			Dissolved Magnesium (Mg)	2011/09/01		105	%	80 - 120
			Dissolved Manganese (Mn)	2011/09/01		92	%	80 - 120
			Dissolved Potassium (K)	2011/09/01		100	%	80 - 120
			Dissolved Sodium (Na)	2011/09/01		96	%	80 - 120
		Method Blank	Dissolved Calcium (Ca)	2011/09/01	<0.3		mg/L	
			Dissolved Iron (Fe)	2011/09/01	<0.06		mg/L	
			Dissolved Magnesium (Mg)	2011/09/01	<0.2		mg/L	
			Dissolved Manganese (Mn)	2011/09/01	<0.004		mg/L	
			Dissolved Potassium (K)	2011/09/01	<0.3		mg/L	
			Dissolved Sodium (Na)	2011/09/01	<0.5		mg/L	

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

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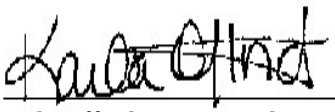
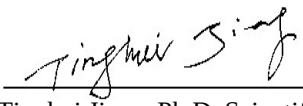


Karla Offord, Senior Analyst



Tinghui Jiang, Ph.D, Scientific Specialist

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Page: 1 of 2

	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☑
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REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	1102 18547
Project # / Name:	Mallik
Site Location:	Inuvik, NWT
Quote #:	
Sampled By:	Olivier Piraux

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☒ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4 (dissolved)	Assessment ICP Metals	Basic Class II Landfill	Routine analysis *	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☑Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik/ws/2011/01		GW	11.08.20 16h40										X							1
2	Mallik/ws/2011/02		GW	11/08/20 16h40										X							1
3	Mallik/ws/2011/03		GW	11/08/20 16h50										X							1
4	Mallik/ws/2011/04		GW	11/08/20 17h										X							1
5	Mallik/ws/2011/06		GW	11/08/20/17h										X							1
6	Mallik/ws/2011/07		GW	11/08/20 17h15										X							1
7	Mallik/ss/2011/01	10cm	soil	11/08/22 12h		X		X			X										1
8	Mallik/ss/2011/02	10 cm	soil	11/08/22 12h		X		X			X										1
9	Mallik/ss/2011/04	10cm	soil	11/08/22 12h		X		X			X										
10	Mallik/ss/2011/03	10cm	soil	11/08/22 12h		X		X			X										
11	Mallik/ss/2011/05	10cm	soil	11/08/22 13h		X		X			X										
12	Mallik/ss/2011/06	10 cm	soil	11/08/22 13h		X		X			X										

Please indicate Filtered, Preserved or Both (F, P, F/P)

ID/DL F/P

Relinquished By (Signature/Print): Olivier Piraux — Date (YY/MM/DD): 11.08.26 — Time (24:00): 11h00

Relinquished By (Signature/Print): — Date (YY/MM/DD): — Time (24:00):

Special Instructions:
* Routine for soils (conductivity / pH / gravimetric, w. content / soil texture / organic matter content

# of Jars Used & Not Submitted:

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B179987
Déjiwu DEJI WU	2011 08/27	11:15	

Lab Comments:

Custody Seal	Temperature	Ice
absent	9.9.10 8.8.9 → 8.8	absent

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☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 1102 18542
Project # / Name: Mallik
Site Location: Inuvik NWT
Quote #:
Sampled By: olivia Piraux

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☒ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	Routine analysis *	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☐ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik/SS/2011/07	15cm	Soil	11.08.22 13h		X		X			X										1
2	Mallik/SS/2011/08	10cm	Soil	11.08.22 13h		X		X			X										1
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					

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Relinquished By (Signature/Print): — Date (YY/MM/DD): — Time (24:00):

Special Instructions: * Routine for soils: conduct./ph/water content/ texture/organic matter content

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B179987
Dejan DEJI WV	2011 08/27	11:15	Custody Seal: absent / Temperature: 7.9.10 8.8.9 7.8.8 / Ice: absent

Lab Comments:

Maxxam Analytics International Corporation o/a Maxxam Analytics

2012 Mallik Annual Sump Monitoring Report

FOR SUBMISSION TO THE NORTHWEST TERRITORIES WATER BOARD UNDER WATER LICENSE N7L1-1817

Prepared for:

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

Prepared by:

KAVIK-STANTEC

November 2012

Table of Contents

1 Introduction 1
2 Site Location 2
3 Methods 5
3.1 Visual Assessment 5
3.2 Active-Layer Depth Measurements 5
3.3 Ground Temperature Monitoring 6
3.4 Electromagnetic Surveys 7
3.5 Water Sampling 7
3.6 Soil Sampling 8
4 Results 9
4.1 Visual Assessment 9
4.2 Active Layer Measurements 10
4.3 Air and Ground Temperature Monitoring 13
4.3.1 Air Temperature 13
4.3.2 Ground thermal monitoring 15
4.4 Electromagnetic Surveys 21
4.5 Soil and Water Sampling 21
4.5.1 Water Sampling 23
4.5.2 Soil Sampling 26
5 Conclusion 27
6 References 29
Appendix A Site Photographs 31
Appendix B Thermistor Data 39
Appendix C Electromagnetic Surveys 49
Appendix D Laboratory Analysis 51

List of Tables

Table 3-1 Depth below ground surface of Thermistors....7
Table 3-2 Water Sampling Locations....7
Table 4-1 Summary of Active-Layer Measurements (September 4th, 2012)....11
Table 4-2 Monthly Air Temperatures....13
Table 4-3 Ground Temperatures at thermistor 07GSC-01 (06/09/2011 to 05/09/2012)....16
Table 4-4 Ground Temperatures at thermistor 07GSC-02 (06/09/2011 to 05/09/2012)....17
Table 4-5 Ground Temperatures at thermistor 07GSC-03 (06/09/2011 to 05/09/2012)....18
Table 4-6 Ground Temperatures at thermistor 07GSC-04 (06/09/2011 to 05/09/2012)....19
Table 4-7 Water Sampling Results....24
Table 4-8 Water Sampling Results....25
Table 4-9 Soil Sampling Results – Salinity....26

List of Figures

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories....2
Figure 2-2 Oblique aerial view of the Mallik site....3
Figure 2-3 Sump Locations....4
Figure 3-1 Locations of thermistors at the Mallik site....6
Figure 4-1 Locations of subsidence areas as indicated by yellow arrows (Photo from September 5th, 2012)....10
Figure 4-2 Active-layer measurements on September 4th, 2012 (values in cm)....12
Figure 4-3 Mallik daily air temperature (October 2010 to September 2012)....14
Figure 4-4 Ground surface conditions at monitoring locations....15
Figure 4-5 Ground temperature at Mallik 07GSC-1 (06/09/2011 to 05/09/2012)....16
Figure 4-6 Ground temperature at Mallik 07GSC-2 (06/09/2011 to 05/09/2012)....17
Figure 4-7 Ground temperature at Mallik 07GSC-03 (06/09/2011 to 05/09/2012)....18
Figure 4-8 Ground temperature at Mallik 07GSC-04 (06/09/2011 to 05/09/2012)....19
Figure 4-9 2011-2012 Annual mean temperature at Mallik (11/06/2011 to 11/05/2012....20
Figure 4-10 Location of soil and water samples....22
Figure A-1 Aerial overview of Mallik site (looking southeast)....33
Figure A-2 Aerial view of the Mallik 3L/4L/5L-38 Sump (looking south)....33
Figure A-3 Subsidence and tension cracks at the eastern corner of the Mallik 3L/4L/5L-38 Sump....34
Figure A-4 Subsidence and ponding at the southern corner of the Mallik 3L/4L/5L-38 Sump....34
Figure A-5 Aerial view of the Mallik 2L-38 Sump (looking west)....35
Figure A-6 Aerial view of Mallik 2L-38 Sump (looking east)....35
Figure A-7 Subsidence area at the eastern end of the Mallik 2L-38 Sump....36
Figure A-8 Subsidence area at the western end of the Mallik 2L-38 Sump....36
Figure A-9 Subsidence and ponding around Mallik 2L-38 wellhead....37

Figure A-10 Ripple marks from a recent storm surged that flooded the Mallik site sometime between September 6th and September 20th, 2012. 37
Figure A-11 Surface subsidence at the surface of two interconnecting ice-wedges (approx. 40 m north of the Mallik 2L-38 Sump). 38
Figure A-12 Thermistor casing installed at the center of the Mallik 2L-38 Sump on September 20th, 2012. 38
Figure B-1 Thermistor 07GSC-01 – Daily Ground Temperatures (October 2010 to September 2012) 41
Figure B-2 Thermistor 07GSC-02 – Daily Ground Temperatures (October 2010 to September 2012) 43
Figure B-3 Thermistor 07GSC-03 – Daily Ground Temperatures (October 2010 to September 2012) 45
Figure B-4 Thermistor 07GSC-04 – Daily Ground Temperatures (October 2010 to September 2012) 47

Abbreviations

ARI..... Aurora Research Institute, Aurora College
CCME..... Canadian Council of Ministers of the Environment
GSC .....Geological Survey of Canada
EM..... Electromagnetic
ESSIS..... Environmental SubSurface Imaging Solutions Ltd.
IORL..... Imperial Oil Resources Ltd.
ISR.....Inuvialuit Settlement Region
JAPEX..... JAPEX Canada Ltd.
JNOC..... Japan National Oil Corporation
mbg.....meters below ground
ml……millilitre
NWT..... Northwest Territories
SDL..... Significant Discovery Licence

1 Introduction

The Mallik L-38 lease area has been the site of three historical drilling programs (1972, Mallik 2L-38, and 2002), during which a total of three conventional drilling sumps were constructed to dispose of drill cuttings and fluids. Imperial Oil Ltd. (IOL) drilled the original IOL Mallik L-38 discovery well during the winter of 1971-1972, and constructed a large drilling waste disposal sump (approximately 80 m x 95 m). In Mallik 2L-38, the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore et al. 1999). With JAPEX Canada Ltd. (JAPEX) as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a drilling waste disposal sump (approximately 45 m x 50 m). In 2002, a seven-party participant group, again led again by JNOC and GSC with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste associated with the three wells. In the 2007-2008 Mallik program the 2L- and 3L-38 wells were re-entered and the drilling waste was removed from site (sumpless program).

The 2012 Annual Sump Monitoring Report by KAVIK-Stantec Inc. (KAVIK-Stantec) details the fifth year of a seven year monitoring program to monitor the stability of the Mallik 2L-38 and 3L/4L/5L/-38 drilling waste sumps. The monitoring program started in 2008 and is scheduled to conclude in 2014. The information in this report is required under Part H: Conditions Applying to Abandonment and Restoration of the Northwest Territories Board Licence No. N7L1-1817.

The 2012 site visit was conducted on September 4th and 5th and included the following:

- a visual assessment of the site with an emphasis on sump cap conditions
- measurements of the active layer thickness within the sump areas, around their perimeters, as well as in an undisturbed area adjacent to the sumps
- maintenance of the monitoring equipment on site
- downloading of temperature data at five thermistor locations
- electromagnetic (EM) surveys (EM 31 and 38) conducted by KiNiLau on both sumps and surrounding areas
- soil sampling in areas showing high electromagnetic conductivities
- surface water sampling of ponded water located on the sumps and in an undisturbed area (control) adjacent to the sumps

In addition to the annual site visit, a new thermistor cable was installed at the center of the Mallik 2L-38 Sump. Details concerning the installation of the new thermistor are included in Section 3.3. This report herein documents the results of this site visit and presents the data gathered from the monitoring activities.

2 Site Location

The Mallik L-38 site is located on the west coast of Richards Island, in the outer region of the Mackenzie Delta and bordering the Beaufort Sea. The site is located within the Inuvialuit Settlement Region (ISR) of the Northwest Territories (Figure 2-1). The area consists of nearshore floodplains on the west coast of Mallik Bay. The site coordinates are approximately 69°27’38”N, 134°39’42”W. The Mallik lease area is located on Crown land within the IORL Significant Discovery License (SDL) 060. The locations of the sumps are shown on Figures 2-2 and 2-3. Note that the locations of the thermistors displayed on Figure 2-2 are outdated. Refer to Figure 2-3 for current thermistor locations.

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories

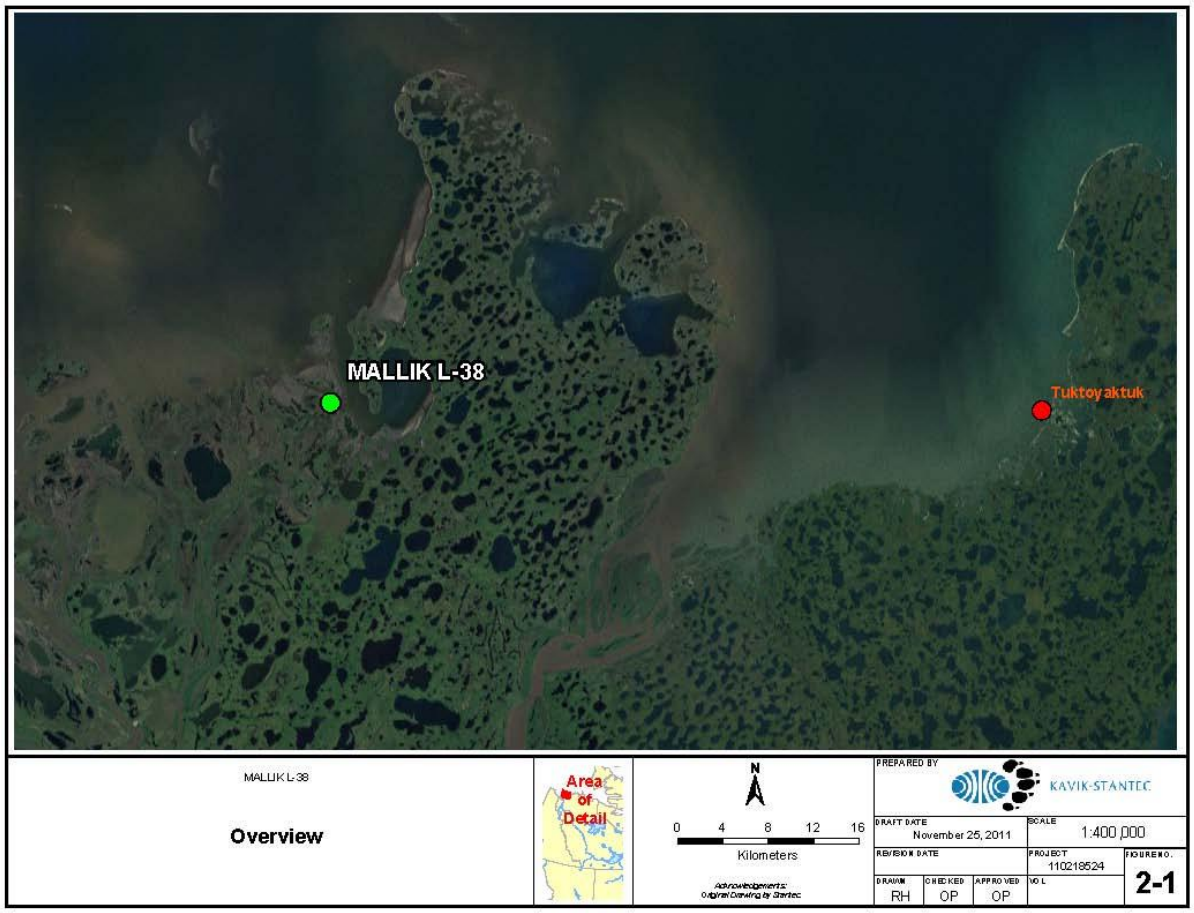


Figure 2-2 Oblique aerial view of the Mallik site

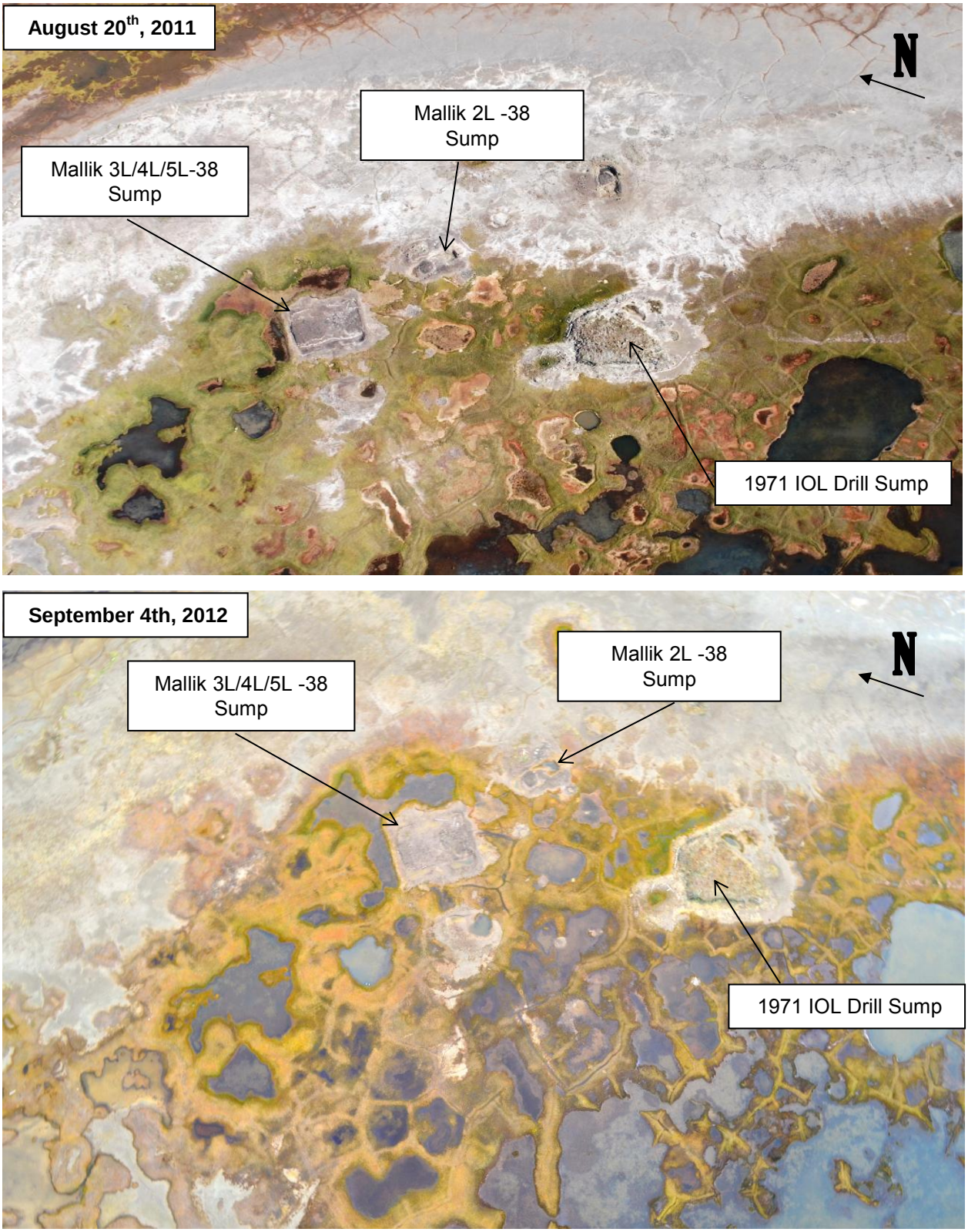
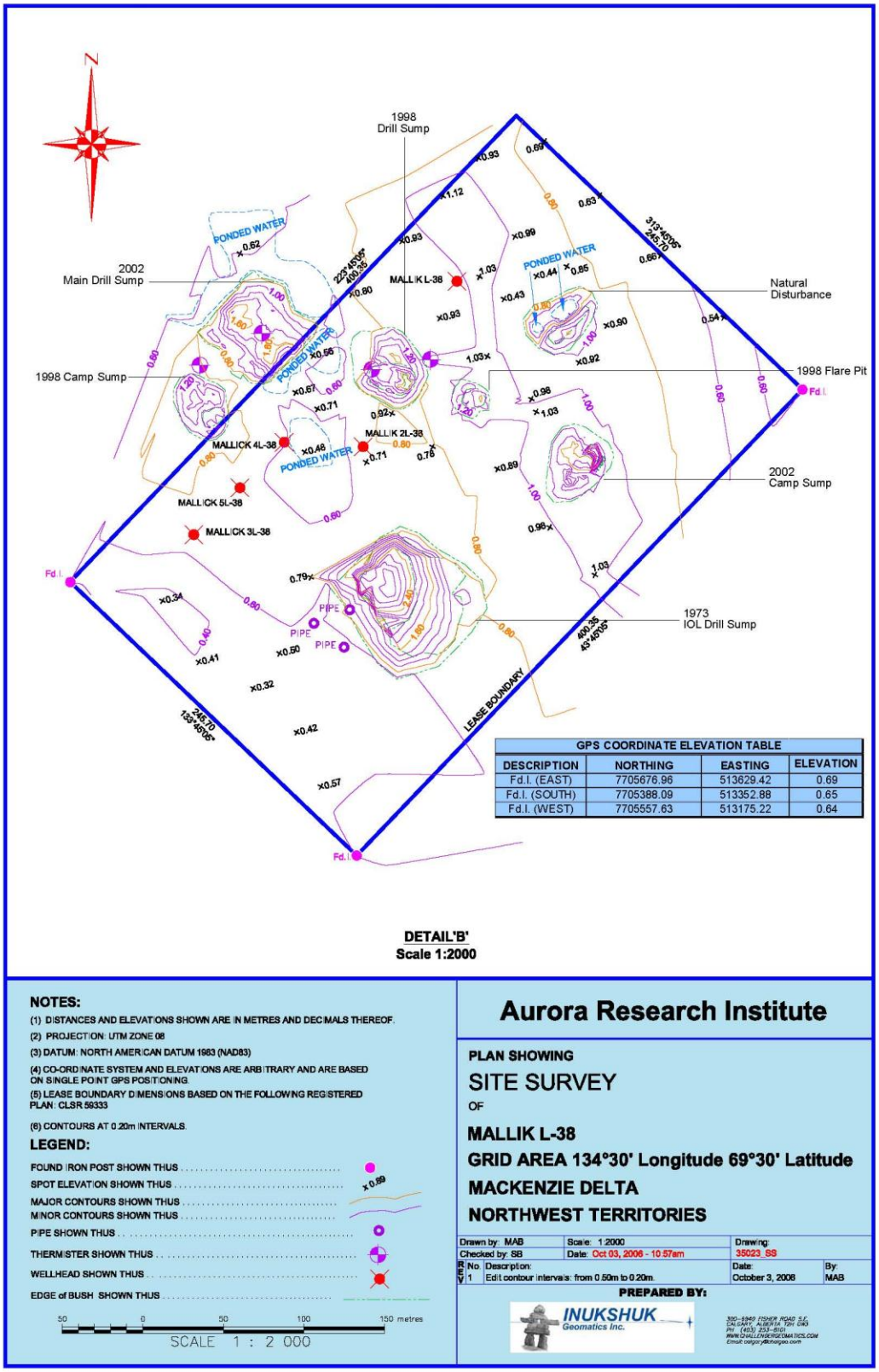


Figure 2-3 Sump Locations



3 Methods

The methods for monitoring the Mallik sumps were developed using the following documents:

- Water License No. N7L1-1817 (NWT Water Board, 2004)
- Previous requests and requirements from the NWT Water Board (NWT Water Board, 2006)
- *Protocol for the Management of Drilling Waste Disposal Sumps* – Inuvialuit Settlement Region NWT (NWT Water Board, 2006a)

The following sections outline the methodology followed throughout each component of the monitoring program, including: visual assessment, active layer depth measurements, ground temperature monitoring, electromagnetic surveys, and soil and water sampling.

3.1 Visual Assessment

Visual assessment was completed by a KAVIK-Stantec representative during the September 2012 visit. The purpose of the visual assessment is to document the physical conditions of the sumps and their immediate surrounding areas. Some of the key elements that were observed included:

- vegetation health and establishment on the sump caps or surrounding areas
- settlement and/or subsidence
- presence and/or absence of ponding water
- erosion, stress and/or tension cracks
- damage to existing monitoring facilities (thermistors and/or dataloggers)

The visual assessment was performed from both the air and ground. Site photographs can be reviewed in Appendix A.

3.2 Active-Layer Depth Measurements

Using a specially designed probe, active-layer depths were measured during the September 2012 site assessment. The methodology and location of the measurement points were recorded as specified in the *Protocol for the Monitoring of Drilling-Waste Disposal, Inuvialuit Settlement Region Northwest Territories* (NWT Water Board 2006). Active-layer depths were collected at a control area, on the sump caps and at the perimeter of the sump caps. The number of active layer measurements was increased from the surveys in previous years based on feedback from multiple sources (including the NWT Water Board).

3.3 Ground Temperature Monitoring

In 2007, four thermistors were installed in and surrounding the Mallik sumps, as specified in *Part H: Conditions Applying to Abandonment and Restoration under NWT Water Licence No. N7L1-1817.*

An additional thermistor cable (12GSC-05) was installed at the center of the Mallik 2L-38 Drilling Sump on September 20th 2012 in accordance of the Water Licence Agreement based on sump monitoring programs in the Northwest Terristories (AANDC, 2011). Auguring of the 12 m borehole was conducted by *Clean Harbour Exploration Services* using a small heliportable rig. KAVIK-Stantec installed the thermistor cable and datalogger, which was setup to record on an hourly basis. The thermistor cable and data logger were provided by the GSC and are of similar type to the other four thermistor cables previously installed in 2007 on site. This thermistor cable has a total of 8 temperature sensors spaced over the length of 12 m. Special attention was given by the installation crew to minimize any surface disturbance to the sump cap during the work.

The locations of the thermistors are presented in Figure 3-1, while Table 3-1 presents the depth of each thermistor below ground surface.

Figure 3-1 Locations of thermistors at the Mallik site.

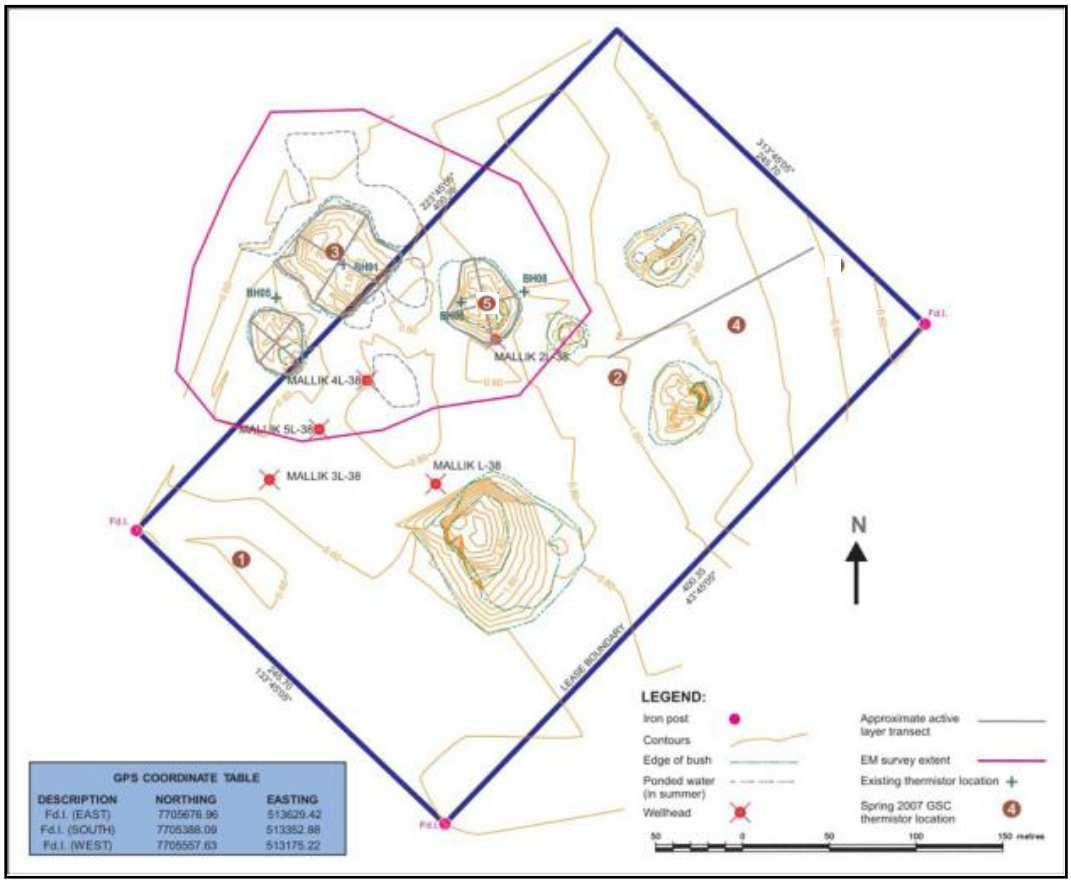


Table 3-1 Depth below ground surface of Thermistors

Thermistor	Depths (mbg)				
	07GSC-01[1]	07GSC-02[1]	07GSC-03[1]	07GSC-04	12GSC-05[2]
1	-	1.0	1.0	1.0	0.25
2	0.35	1.5	1.5	1.5	0.50
3	0.85	2.0	2.0	2.0	0.75
4	1.35	2.5	2.5	2.5	1.5
5	2.35	4.5	4.5	3.5	3
6	4.35	6.5	6.5	5.5	6
7	6.85	10.5	10.5	8.0	9
8	4.28	5.65	5.65	10.5	12

[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e. the depth of the sensor #8 is above the sensor #6).
[2] New thermistor cable installed on September 20th, 2012

3.4 Electromagnetic Surveys

KiNiLau conducted EM surveys (EM31 and EM38) on September 4th, 2012 using Geonics EM31 and EM38 ground conductivity meters. These instruments are used to identify the lateral extents of ion-rich regions, which might indicate ion migration from the sump to the surrounding areas, and to help identify the requirement for additional soil sampling. The surveys measure apparent conductivity of the soil around the sump site to determine if salts in the drilling waste are migrating through the soil from the sump. The EM38 measures apparent conductivity at soil depths of 0.0 to 1.5 m (shallow), while the EM31 unit measures apparent conductivity at soil depths of 0.0 to 5.0 m (deep).

3.5 Water Sampling

Surface water was sampled from both natural ponding (i.e. a control area away from the sumps) and in subsidence areas located within the sump perimeters. Sampling was completed following standard water sampling protocols. Samples were collected at the deepest area of the ponding water and stored in laboratory-issued 500 ml plastic jars. Samples were submitted to Maxxam Analytical (Maxxam) in Edmonton, AB for routine water analysis. The certified laboratory results are provided in Appendix C. See Figure 4-8 for the location of the water samples. The guidelines used to compare the results from the water sampling program are the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for Freshwater and Aquatic Life*.

Surface water samples were collected at eight locations during the 2012 field visit (Table 3-2 and Figure 4-10). Four samples were collected within subsidence areas located inside the sump boundaries, three within natural depressions characterized by moderate to high apparent conductivities and one control sample was collected in an undisturbed pond located approximately 150 m away from the sumps. A summary of the water analysis results is presented in Tables 4-7 and 4-8. The complete laboratory reports are presented in Appendix D.

Table 3-2 Water Sampling Locations

Sample Number	GPS Location	Comments on sample location
MALLIK2012 WS01	513242 / 7705853	Water pooling in the depression located at the western edge of the Mallik 2L-38 Sump

MALLIK2012 WS02	513269 / 7705853	Water pooling in the depression located at the eastern edge of the Mallik 2L-38 Sump.
MALLIK2012 WS03	513222 / 7705858	Water pooling in a natural depression located half way between the Mallik 2L-38 Sump and the Mallik 3L/4L/5L-38 Sump
MALLIK2012 WS04	513210 / 7705821	Water pooling in a natural depression approximately 50 m south of the Mallik 3L/4L/5L-38 Sump.
MALLIK2012 WS05	513182 / 7705848	Water pooling in the depression located at the southern edge of the Mallik 3L/4L/5L-38 Sump
MALLIK2012 WS06	513177 / 7705923	Water pooling in a natural depression in contact with the northern portion of the Mallik 3L/4L/5L-38 Sump
MALLIK2012 WS07	513153 / 7705818	Water pooling within the Mallik 2L-38 Camp Sump boundary
MALLIK2012 WS08	513043 / 7705891	Control water sample taken in a pond approx. 150 m northwest of the 2002 camp sump

3.6 Soil Sampling

The purpose of the soil sampling is to investigate areas of apparent higher conductivity. Using results from the EM Surveys, one area of high conductivity outside the sump areas was observed without justifiable cause. In this area a soil sample was collected during the 2012 field program. Other areas of high conductivity outside of the sump areas included natural ponding and depressions, which are subjected to high concentrations of seawater, therefore samples were not collected from them.

The soil sample was obtained using a clean shovel and a soil knife. The sample was collected at a depth of 20 cm below ground surface. Approximately 1 kg of soil was collected. The sample was retained for analysis in laboratory-issued zip-lock containers and submitted to Maxxam. See Appendix C for the certified laboratory results. See Figure 4-10 for the location of the soil sample.

4 Results

4.1 Visual Assessment

The annual site assessment was conducted on September 4 and 5, 2012. A second field visit was conducted on September 20 to install a new thermistor cable at the center of the Mallik 2L-38 Sump. Refer to Appendix A for site photographs.

Site drainage

An initial, striking observation was that the site appeared much wetter than during the August 2011 visit. The water level was high in most ponds, puddles were present and the soil surfaces ranged from imperfect to poorly drained. Clear evidence of a recent storm surge was noted during the September 20th field visit. The surge occurred sometime between the first and second field visit and was made evident by the pattern of ripple marks visible along areas characterized by bare ground (see Appendix A, Figure A-10). The location of large wood debris was observed to be different between the two site visit dates also supports the fact that the Mallik site was inundated by seawater during the storm surge event. The observation of high water marks as well as several erosion scars along the upper portion of the IOL Sump indicates that most of the Mallik site was submerged by water during this latest storm surge.

Vegetation and wildlife

It is estimated that less than 10% of the total sump caps are currently covered by vegetation. The vegetation present in and around the sump caps was in slightly better condition than last year. The vegetation is predominantly composed of a variety of graminoid species, such as sedges and grasses, with a few sporadic low shrubs and mosses.

Several signs of wildlife were noted on site, the most common were signs of bird droppings, as well as birds and reindeer tracks. The remains of a young reindeer calf, cause of death unknown, were found approximately 20 meters from the 07GSC-02 thermistor.

Surface Subsidence

As reported in the 2011 site assessment, several areas characterized by ground surface subsidence are present in the sump areas (see Figure 4-1).

Signs of surface subsidence were noted along the inner perimeter of the Mallik 3L/4L/5L-38 Sump. The level of subsidence is estimated to have increase since the 2011 site visit. The largest subsidence area is located in the southwest corner and is approximately 5 m^2. The bottom of the depression is approximately 60 cm lower than the surrounding undisturbed soil surface. Shallower depressions, some characterized by small tension cracks, were present at the other corners of the sump. A total of five pools of water were noted on the sump, ranging in depth from a few centimeters to a maximum of approximately 40 cm.

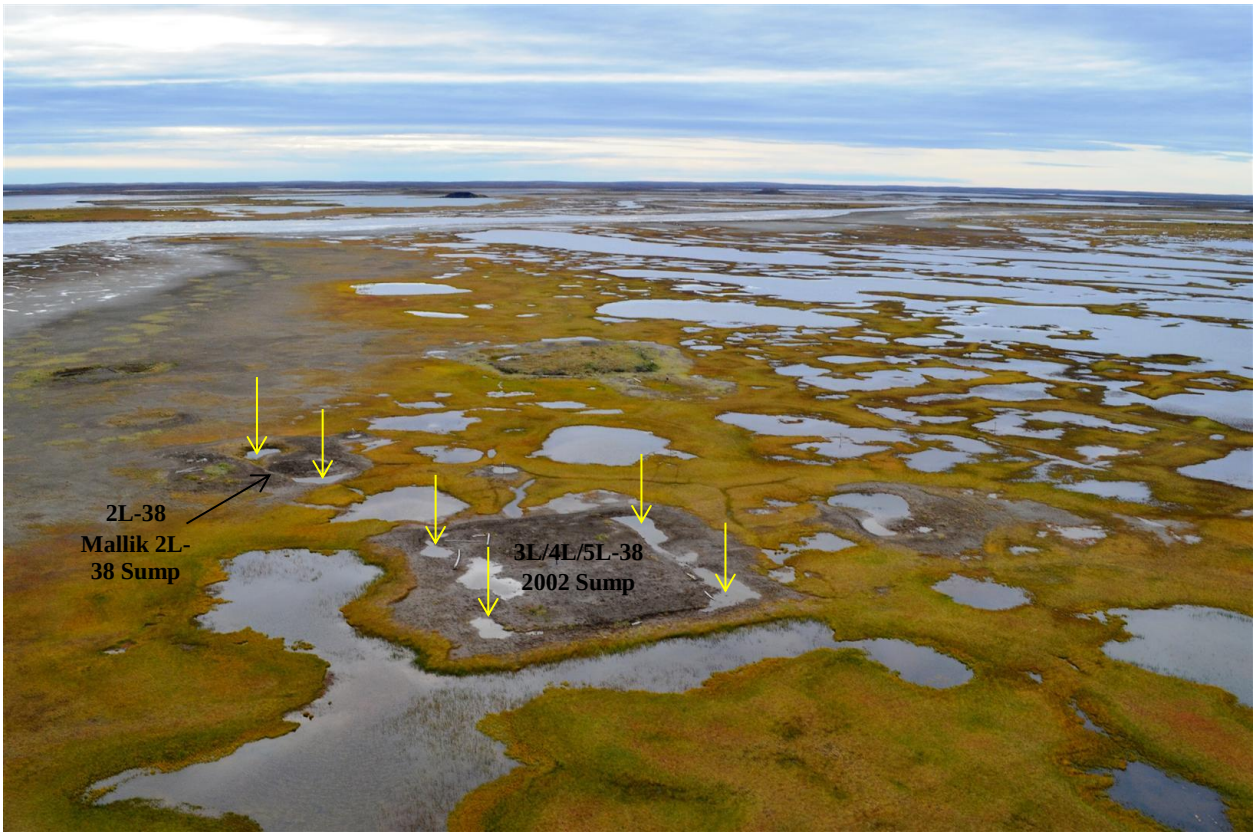
Tension cracks

Extensive pattern of ice wedge polygons are present in the vicinity of the Mallik site. The polygons are variable in size, and range from a few square meters to over 40 m^2. Numerous tension cracks can be observed at the soil surface. Some correspond to limits of ice-wedge polygon while others are associated with contraction of the surface soil. Most tension cracks are naturally occurring while a few, located along the edges and perimeters of the sumps, may be induced by surface subsidence.

Ground surface subsidence is likely taking place along a series of ice-wedge polygons just north from the Mallik 2L-38 Sump (see Appendix A: Site Photographs). Long tension cracks have formed approximately

50 cm on each side of the center of the some ice-wedges and most probably indicate the lateral extent of the wedges. The subsidence range from a few centimeters to approximately 10 cm and is deeper towards the center of the ice wedges.

Figure 4-1 Locations of subsidence areas as indicated by yellow arrows (Photo from September 5th, 2012).



4.2 Active Layer Measurements

Active layer depth measurements were taken on Sept. 4, 2012 (Figure 4-2). The control transect is not showed on the figure but is located at a similar location than last year, an undisturbed area located approximately 150 m southeast from the Mallik 2L-38 Sump. Table 4-1 provides a summary and comparison of the thawing depths. Note that there are differences in the annual survey dates.

Table 4-1 Summary of Active-Layer Measurements (September 4th, 2012)

	Mallik 2L-38 Sump		Mallik 3L/4L/5L-38 Sump		Control Transect
	Sump Cap	Perimeter	Sump Cap	Perimeter	
Total Number of probing	25	18	22	20	20
Minimum Thawing Depth (cm)	116	125	124	124	108
Maximum Thawing Depth (cm)	178	148	145	144	145
Average Thawing Depth (cm)	140	136	132	131	128
08/20/2011 Average (cm)	121	114	133	117	113
09/28/2010 Average (cm)	119	113	118	121	113

Mallik 2L-38 Sump

Active layer depths on the Mallik 2L-38 Sump ranged from 116 cm and 178 cm and averaged 140 cm. Active-layer depths around the perimeter of the sump cap ranged from 125 cm to 148 cm and averaged 132 cm. In comparison, the 2010 and 2011 average depths were of 119 and 121 cm for the sump cap and 113 and114 cm for the sump perimeter.

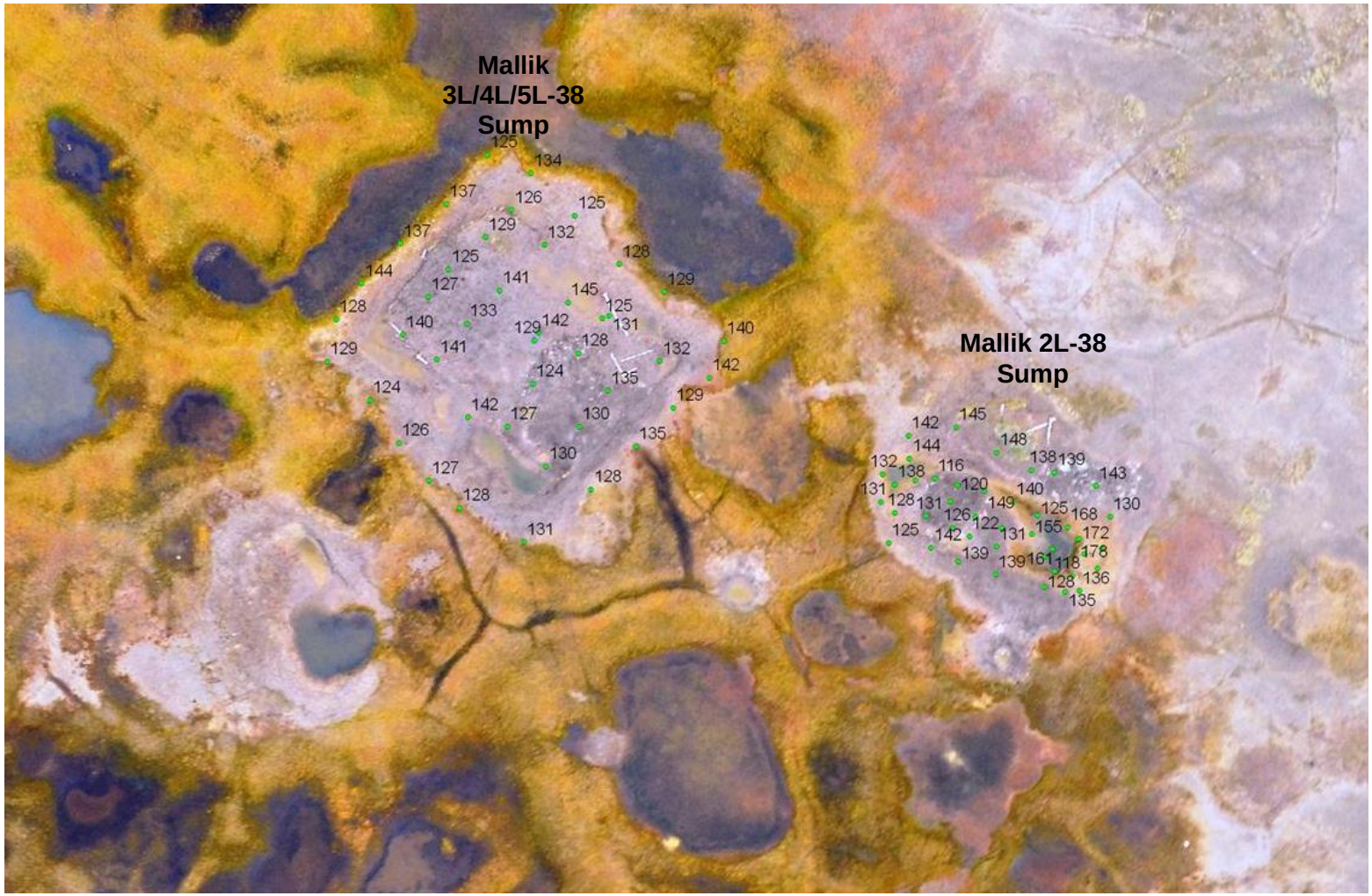
Mallik 3L/4L/5L-38 Sump

Active layer depths on the Mallik 3L/4L/5L-38 sump cap ranged from 124 cm and 145 cm, for an average of 132 cm. Active-layer depths around the perimeter of sump cap very similar and ranged from 124 cm to 144 cm, for an of averaged 131 cm. The average active layer thickness at the surface of the sump cap is very similar to last year while the average thickness measured along the perimeter has increase by 14 cm.

Control transect

The control transect was conducted at the exact same location than during the 2011 survey. The area consists of undisturbed soil located about 150 m east from the Mallik 3L/4L/5L-38 Sump. Active layer depths on the control transect range from 108 cm to 145 cm, for an average of 125 cm. This represents an increase of 15 cm when compared to the September 28th, 2010 and August 20th 2011 averages of 113 cm.

Figure 4-2 Active-layer measurements on September 4th, 2012 (values in cm)



4.3 Air and Ground Temperature Monitoring

The following section presents a summary of the air and ground temperature at the various sensors and thermistor cables present at the Mallik site. The locations of the thermistors are shown on Figure 3-1.

The mean, maximum and minimum ground temperatures of each sensor are summarized in Tables 4-2 to 4-6. Diagrams showing the annual variation of the ground temperature at each sensor depth are provided in Appendix B.

4.3.1 Air Temperature

Air temperature is recorded at an hourly frequency at the Mallik site since October 1st, 2010 (i.e. first full day of recording). The air temperature sensor is installed at approximately 1.5 meters above ground level. The sensor is mounted within a radiation shield to minimize the heating effects of solar radiation and direct exposure to rain and snow. The air temperature recorded over the last two years is presented in Table 4-2 and Figure 4-3.

Table 4-2 Monthly Air Temperatures

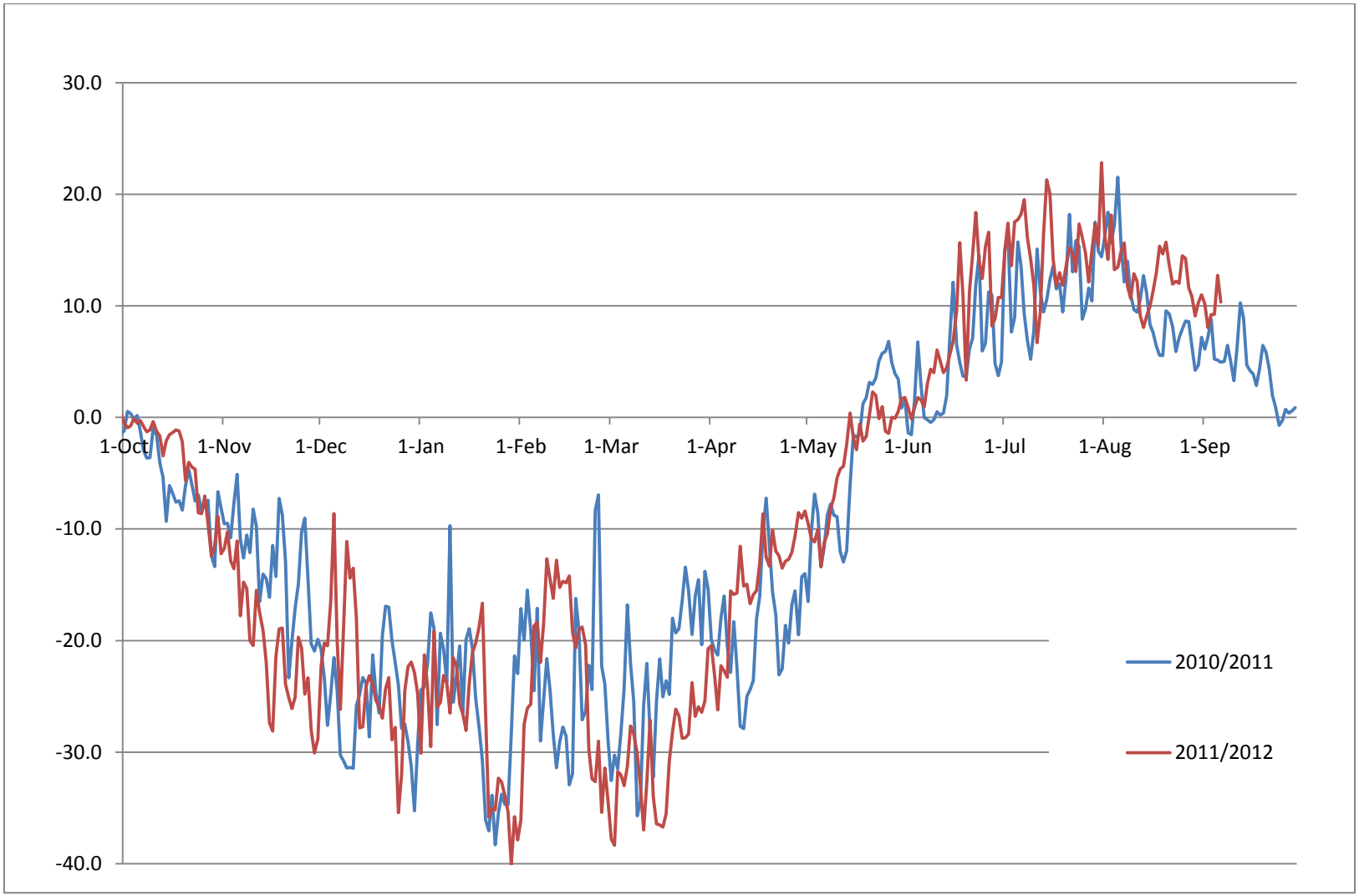
Air Temperature (°C)

	2010/2011	2011/2012
September	-	4.1
October	-5.3	-3.9
November	-13.1	-20.4
December	-25.7	-22.7
January	-25.9	-27.6
February	-23.2	-23.1
March	-23.0	-30.0
April	-19.0	-14.5
May	-3.2	-4.3
June	4.6	8.1
July	12.1	15.3
August	10.2	12.4

The annual mean air temperature for 2011 was -9.1°C. A review of the monthly temperature averages indicates that the 2012 summer was warmer than the 2011 summer. Average monthly temperatures were approximately 2 to 3.5 degrees warmer in the summer months of 2012 than in 2011 (see Table 4-2). The warmest air temperature recorded over the 2010-2011 summer was 26.9°C (August 5, 2011), while the warmest air temperature recorded over the 2010-2011 summer was 29.5°C.

The winter monthly averages are comparable, with only the March temperature average being 7 degrees colder in 2012. The coldest air temperature recorded over the 2010-2011 winter was -39.4°C (recorded on January 23rd, 2011) compared to -42.2°C for the 2011-2012 winter (recorded on January 26, 2012).

Figure 4-3 Mallik daily air temperature (October 2010 to September 2012)



4.3.2 Ground thermal monitoring

Ground thermal monitoring has been conducted at Mallik since April 2007. The thermistor depths range from just below ground surface to a maximum depth of 12 m. Figure 4-4 shows the ground surface conditions at each site. Data loggers are set up to record hourly temperature.

Ground temperature data of each thermistor cable are presented below.

Figure 4-4 Ground surface conditions at monitoring locations

4.3.2.1 Ground temperatures at thermistor 07GSC-01

Thermistor 07GSC-01 is located in an undisturbed area approximately 200 m southwest of the Mallik sumps. The thermistor is located at the edge of a large pond which contained approximately 30 cm of water at the time of visit on September 5th, 2012. The top thermistor (i.e. 0.35 m) is located at the interface between ground and water and therefore recorded highly variable temperatures.

Figure 4-5 Ground temperature at Mallik 07GSC-1 (06/09/2011 to 05/09/2012)

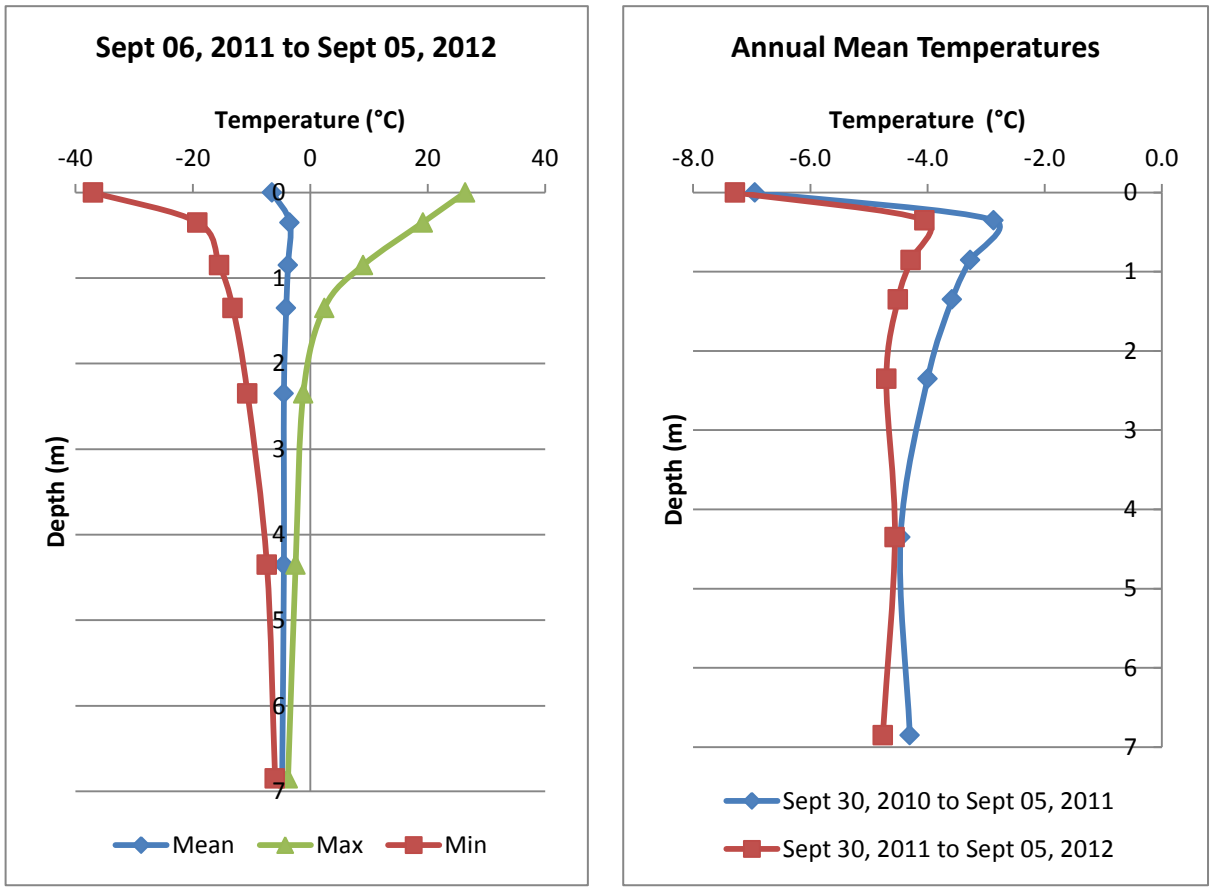


Table 4-3 Ground Temperatures at thermistor 07GSC-01 (06/09/2011 to 05/09/2012)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.35	-3.4	23.2	-14.6
0.85	-3.7	9.0	-11.1
1.35	-3.8	1.0	-9.7
2.35	-4.1	-1.4	-8.5
4.35	-4.3	-2.8	-6.5
6.85	-4.9	-4.1	-5.6

4.3.2.2 Ground temperatures at thermistor 07GSC-02

Thermistor 07GSC-02 is located in an undisturbed site with low sedge and grass cover. The surface thawing depth ranged between 1 m and 1.5 m.

Figure 4-6 Ground temperature at Mallik 07GSC-2 (06/09/2011 to 05/09/2012)

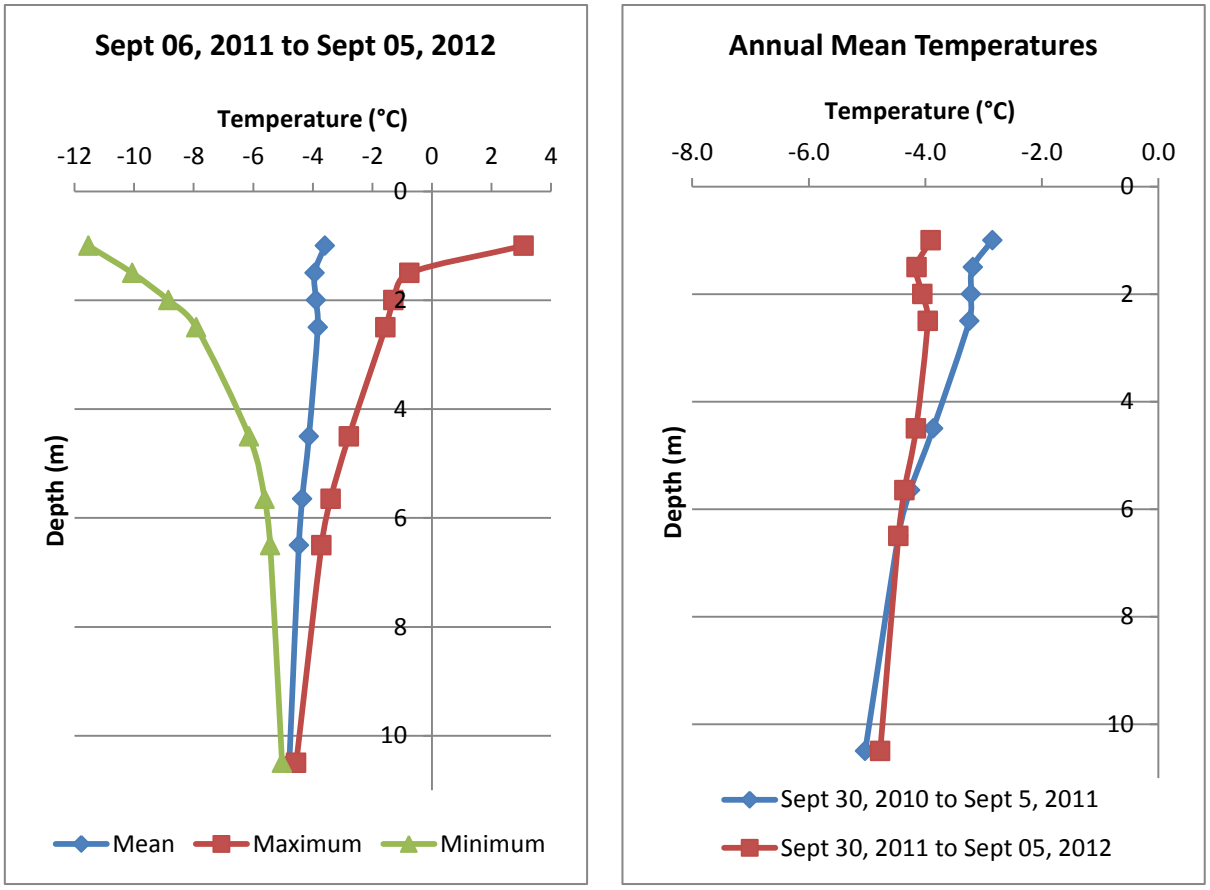


Table 4-4 Ground Temperatures at thermistor 07GSC-02 (06/09/2011 to 05/09/2012)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1	-2.9	2.1	-8.2
1.5	-3.2	-0.9	-7.5
2	-3.3	-1.5	-6.8
2.5	-3.3	-1.8	-6.2
4.5	-3.9	-3.0	-5.2
5.65	-4.3	-3.6	-5.3
6.5	-4.5	-3.9	-5.5
10.5	-5.0	-4.8	-5.5

4.3.2.3 Ground temperatures at thermistor 07GSC-03

Thermistor 07GSC-03 is located within disturbed material and is installed at the center of the Mallik 3L/4L5L-38 Sump. The active layer thickness ranged between 1 m and 1.5 m.

Figure 4-7 Ground temperature at Mallik 07GSC-03 (06/09/2011 to 05/09/2012)

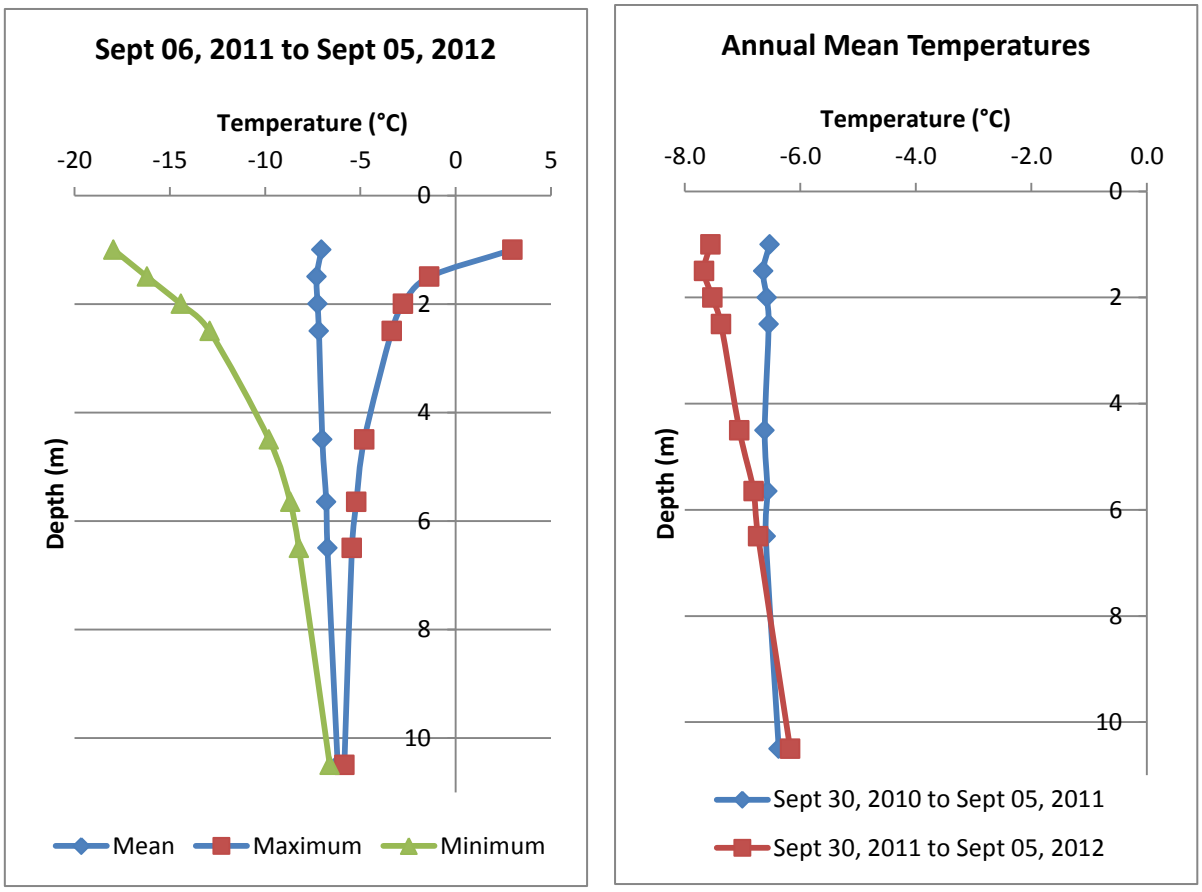


Table 4-5 Ground Temperatures at thermistor 07GSC-03 (06/09/2011 to 05/09/2012)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1	-6.7	1.1	-15.6
1.5	-6.8	-2.2	-13.6
2	-6.7	-3.0	-12
2.5	-6.6	-3.6	-10.9
4.5	-6.6	-5.0	-8.6
5.65	-6.6	-5.5	-7.8
6.5	-6.6	-5.7	-7.5
10.5	-6.4	-6.0	-6.9

4.3.2.4 Ground temperatures at thermistor 07GSC-04

Thermistor 07GSC-04 is located in an undisturbed site approximately 150 m west of Mallik 2L-38 Sump. Active layer depth ranged between 1 m and 1.5 m.

Figure 4-8 Ground temperature at Mallik 07GSC-04 (06/09/2011 to 05/09/2012)

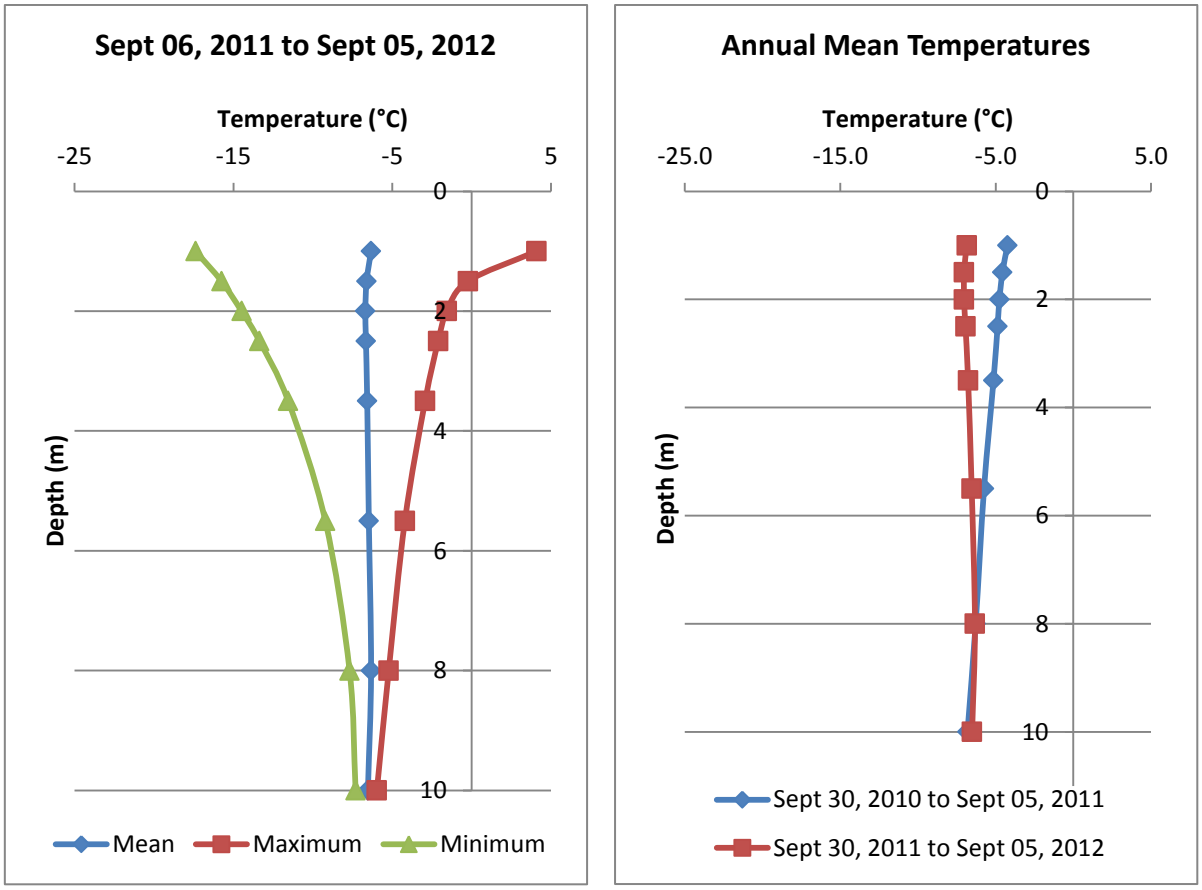


Table 4-6 Ground Temperatures at thermistor 07GSC-04 (06/09/2011 to 05/09/2012)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.0	-4.4	1.7	-10.2
1.5	-4.7	-1.8	-9.5
2.0	-4.8	-2.6	-9.0
2.5	-4.9	-3.1	-8.5
4.5	-5.2	-3.9	-7.8
5.5	-5.8	-5.2	-7.5
8	-6.3	-6.1	-7.8
10.5	-6.8	-6.8	-7.8

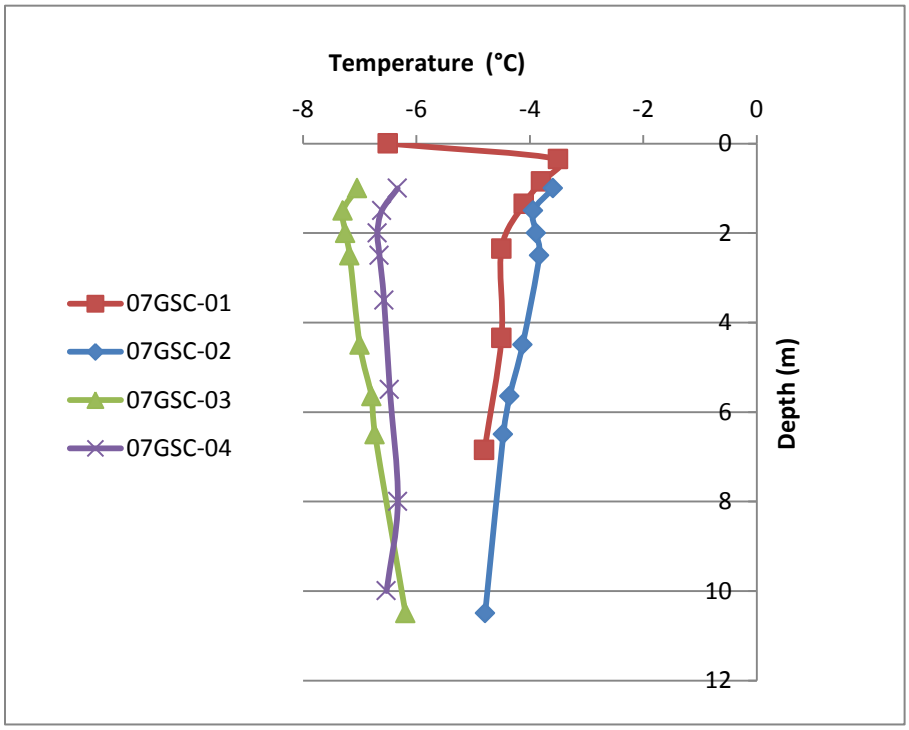
Temperatures recorded along thermistor strings

Ground thermal monitoring data demonstrate that the thermal regime recorded at the site primarily fluctuates with seasonal temperature variations, regardless of whether the thermistor is located within the sump or outside the sump. The thermistor cable that recorded the coldest temperature profile for the 2011-2012 period is thermistor 07GSC-03, located in the 3L/4L/5L-38 Sump.

Temperature differences were observed when comparing the values recorded at similar depth between the different thermistors (see Figure 4.9). For example, the average temperature recorded at a depth of 1.5 m is -3.9°C at 07GSC-02 compared to -7.3°C at 07GSC-03. These differences in temperature can be linked to several factors such as local site conditions, material texture and drainage, slope and exposure, presence or absence of vegetation, thickness of snow cover, etc. The fact that the coldest ground temperatures were recorded in the Mallik 3L/4L/5L-38 Sump is very positive as it confirms that permafrost conditions are well established in the sump and that the drilling waste are kept frozen.

The analysis of the ground temperatures data recorded at all four thermistors shows that the annual mean temperatures were colder for the 2011-2012 period than for the 2010-2011 period. The difference in average temperature between the two years is more accentuated near the ground surface then attenuates at depths of 6 to 8 m below ground level. The fact that the air temperatures were somewhat similar during the two winter periods reinforce the idea that less snow was present at the Mallik site during the 2011/2012 winter, therefore allowing an increase frost penetration. Snow is a strong insulator and limits the heat exchange between the atmosphere and the ground (Stieglitz et al. 2003). Difference in snow cover is only one off many potential explanations for the variation of ground temperature observed on site.

Figure 4-9 2011-2012 Annual mean temperature at Mallik (11/06/2011 to 11/05/2012



4.4 Electromagnetic Surveys

As expected, both the EM38 Survey (0 to 1.5 m) and the EM31 Survey (0 to 5 m) have identified areas of high apparent conductivity values on the Mallik 2L-38 Sump and on the 3L/4L/5L-38 Sump. These elevated responses confirm the presence of saline drill cuttings within the sumps, after they have been corrected for salinity due to sea water infiltration.

Similarly to the 2011 analysis, both the EM31 and EM38 surveys indicate that there is elevated apparent conductivity in an area immediately adjacent to the northeast corner of the Mallik 2L-38 Sump. The conductivity values are similar to that observed at the surface of the sump. It is unclear as to why the high conductivity distribution extends beyond the sump boundaries. Additional observation along this portion of the sump indicates that the ground surface could possibly have been disturbed and that drill muds and cuttings could be present at the ground surface. A soil sample was collected at this location and the results are presented in Section 4.5.2.

High apparent conductivity was identified at an area located approximately 50 m from the southern edge of the 3L/4L/5L-38 Sump. The area consists of a small topographic depression approximately 30 m x 35 m and about 60 cm deep. The depression was filled with water to a depth of approximately 30 cm; therefore no soil sample was taken. Knowing that the site is subject to annual storm surges reinforce the idea that the evaporation of sea water trapped in the ponds can increase the local sodium content and generate higher apparent conductivity.

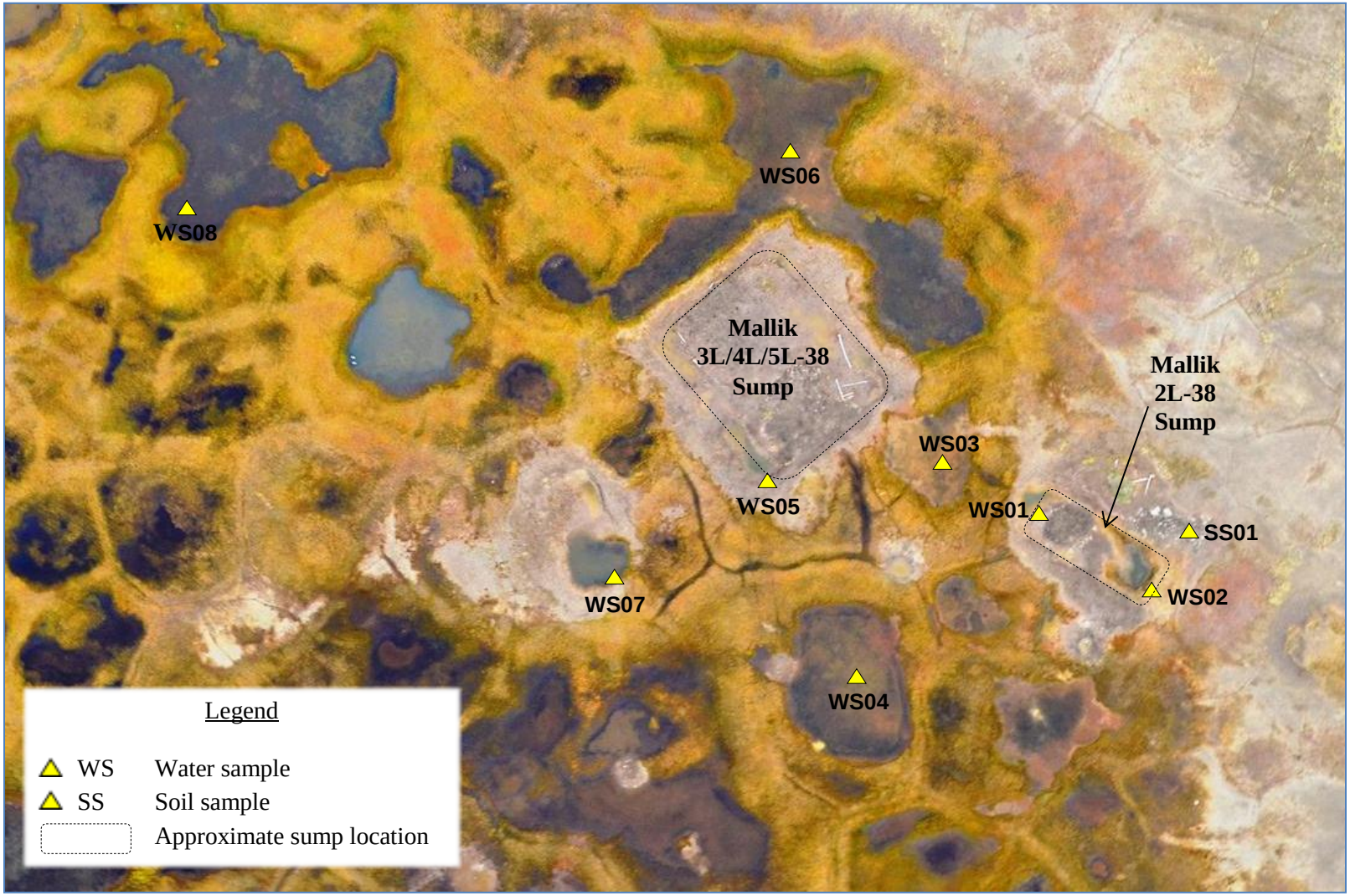
The EM surveys also indicated a moderate to high conductivity at the large pond located just north of the Mallik 3L/4L/5L-38 Sump. The high measurements are likely related to the evaporation of sea water from the annual storm surges and are not indicative of sump seepage. A water sample was collected in order to investigate the apparent high conductivity (Section 4.5.1).

Detailed electromagnetic survey results are presented in Appendix C.

4.5 Soil and Water Sampling

Water samples were collected from the subsidence areas located on the 2002 camp and drilling sumps as well as from the Mallik 2L-38 Sump. The water samples were analyzed for routine water chemistry (i.e. conductivity, pH and major cations). In addition, soil and water samples were taken from areas outside the sump to investigate high apparent conductivity and potential contamination. Figure 4-10 shows the location of each sample.

Figure 4-10 Location of soil and water samples



4.5.1 Water Sampling

The surface water samples collected at Mallik have pH values ranging from 7.55 to 8.46, which is in accordance with the CCME guidelines (CCME 1999) and within the range of values observed in several lakes and channels of the Mackenzie Delta (Anema et al. 1990).

The exact nature of the materials contained in the Mallik drilling sumps is not documented in this report but typically the constituents of brine-based drilling mud are potassium chloride, bentonite, cellulose polymers, lignosulphonates and sodium hydroxide (Piteau Engineering Ltd., 1988; Kokelj and GeoNorth, 2002).

The conductivity values measured from the water samples ranges from 5,100 uS/cm to 26,000 uS/cm. The conductivities of the sample taken in the subsidence areas of the Mallik 2L-38 and 3L/4L/5L-38 Sumps appear to be influenced by elevated sodium, potassium, calcium and chloride parameters while the samples taken in the natural depressions outside the sumps appear to be primarily influenced by elevated sodium parameters.

The sample with the highest conductivity was collected in the subsidence area marking the southern corner of the Mallik 3L/4L/5L-38 Sump (WS05). That sample also recorded the highest level of potassium (2,800 mg/L), sodium (1,800 mg/L), sulphate (1,500 mg/L) and chloride (7,700 mg/L). The second and third highest levels of potassium were recorded in the samples taken in the subsidence areas of the Sump (820 mg/L at WS01 and 600 mg/L at WS02). By comparison, the level of dissolved potassium in the control water sample (WS08) is of 24 mg/L. The potassium levels recorded in the water samples taken in the natural depressions outside the sump boundaries much lower and in range with potassium level recorded in the control sample.

The analysis suggests that there is a general correlation between elevated conductivities, sodium and potassium concentrations of the water samples taken from the subsidence areas of the two drilling sumps. These high values correlate with data of the previous years and reinforce the theory that seasonally unfrozen drill mud contaminants are mixing into the subsiding portions of the sump caps.

Table 4-7 Water Sampling Results

	UNITS	MALLIK2012 WS01	MALLIK2012 WS02	MALLIK2012 WS03	MALLIK2012 WS04
Sampling Date		9/5/2012 10:00	9/5/2012 13:15	9/5/2012 11:00	9/5/2012 13:15
Calculated Parameters					
Anion Sum	meq/L	130	46	90	110
Cation Sum	meq/L	130	44	88	100
Hardness (CaCO3)	mg/L	1900	1100	1500	1200
Ion Balance	N/A	1.0	0.97	0.98	1.0
Dissolved Nitrate (NO3)	mg/L	0.48	0.19	<0.013	<0.066
Nitrate plus Nitrite (N)	mg/L	0.11	0.049	<0.0030	<0.015
Dissolved Nitrite (NO2)	mg/L	0.014	0.018	<0.0099	<0.049
Total Dissolved Solids	mg/L	7600	2900	5200	6000
Misc. Inorganics					
Conductivity	uS/cm	14000	5600	9300	11000
pH	N/A	7.61	7.55	7.95	8.25
Anions					
Alkalinity (PP as CaCO3)	mg/L	<0.50	<0.50	<0.50	<0.50
Alkalinity (Total as CaCO3)	mg/L	240	220	150	270
Bicarbonate (HCO3)	mg/L	290	270	180	330
Dissolved Sulphate (SO4)	mg/L	600	520	600	310
Dissolved Chloride (Cl)	mg/L	3800	1100	2600	3300
Nutrients					
Dissolved Nitrite (N)	mg/L	0.0043	0.0054	<0.0030	<0.015
Dissolved Nitrate (N)	mg/L	0.11	0.043	<0.0030	<0.015
Elements					
Dissolved Calcium (Ca)	mg/L	390	330	300	150
Dissolved Iron (Fe)	mg/L	0.079	<0.060	0.074	0.064
Dissolved Magnesium (Mg)	mg/L	220	55	180	190
Dissolved Manganese (Mn)	mg/L	0.16	0.23	0.025	<0.0040
Dissolved Potassium (K)	mg/L	820	600	83	67
Dissolved Sodium (Na)	mg/L	1600	180	1300	1800

Table 4-8 Water Sampling Results

	UNITS	MALLIK2012 WS05	MALLIK2012 WS06	MALLIK2012 WS07	MALLIK2012 WS08
Sampling Date		9/5/2012 12:00	9/5/2012 12:00	9/5/2012 12:45	9/5/2012 12:30
Calculated Parameters					
Anion Sum	meq/L	250	44	72	58
Cation Sum	meq/L	250	47	76	61
Hardness (CaCO3)	mg/L	5300	580	1200	620
Ion Balance	N/A	1.0	1.1	1.1	1.0
Dissolved Nitrate (NO3)	mg/L	32	<0.013	0.52	0.29
Nitrate plus Nitrite (N)	mg/L	7.3	<0.0030	0.12	0.10
Dissolved Nitrite (NO2)	mg/L	0.076	<0.0099	<0.0099	0.11
Total Dissolved Solids	mg/L	16000	2600	4200	3300
Misc. Inorganics					
Conductivity	uS/cm	26000	5100	8200	6700
pH	N/A	7.81	8.27	8.18	8.46
Anions					
Alkalinity (PP as CaCO3)	mg/L	<0.50	<0.50	<0.50	5.8
Alkalinity (Total as CaCO3)	mg/L	170	230	290	240
Bicarbonate (HCO3)	mg/L	210	280	360	280
Dissolved Sulphate (SO4)	mg/L	1500	74	310	39
Dissolved Chloride (Cl)	mg/L	7700	1300	2100	1900
Nutrients					
Dissolved Nitrite (N)	mg/L	0.023	<0.0030	0.0030	0.033
Dissolved Nitrate (N)	mg/L	7.3	<0.0030	0.12	0.067
Elements					
Dissolved Calcium (Ca)	mg/L	1500	88	200	79
Dissolved Iron (Fe)	mg/L	0.082	<0.060	0.097	<0.060
Dissolved Magnesium (Mg)	mg/L	400	88	160	100
Dissolved Manganese (Mn)	mg/L	0.25	0.018	0.16	0.0061
Dissolved Potassium (K)	mg/L	2800	24	33	24
Dissolved Sodium (Na)	mg/L	1800	800	1200	1100

4.5.2 Soil Sampling

Only one soil sample was collected during the 2012 field visit (Figure 4-9). The sample corresponds to an area of high apparent conductivity located approximately 10 meters outside the eastern portion of the Mallik 2L-38 Sump. Note that the exact extent of the sump is unknown and that the sample could actually be located within the sump cap area. Visual assessment indicates that the ground surface was most likely disturbed in that specific area during the construction, operation or closure of the sump (i.e. irregular ground surface). Small debris of unknown origin (possibly dried-out drilling muds) was present at the ground surface in that specific area.

A summary of the laboratory results is presented in Tables 4-9. Results from a soil sample taken at the same location as well as a control sample taken in an undisturbed area away from the sumps in 2011 are also included in the table. Refer to Appendix D for the complete laboratory report.

Table 4-9 Soil Sampling Results – Salinity

	UNITS	MALLIK2012 SS01	MALLIK2011 SS01	MALLIK2011 SS08
Sampling Date		9/5/2012 13:00	8/22/2011 12:00	8/22/2011 13:00
Calculated Parameters				
Anion Sum	meq/L	200	290	86
Cation Sum	meq/L	200	280	100
Ion Balance	N/A	1.0	0.98	1.2
Soluble Parameters				
Soluble Chloride (Cl)	mg/L	6200	9800	2600
Soluble Conductivity	dS/m	22	33	10
Soluble (CaCl2) pH	N/A	7.50	7.47	6.65
Soluble Calcium (Ca)	mg/L	460	920	310
Soluble Magnesium (Mg)	mg/L	120	450	250
Soluble Sodium (Na)	mg/L	1000	2700	1400
Soluble Potassium (K)	mg/L	4700	3300	110
Saturation %	%	51	55	73
Soluble Sulphate (SO4)	mg/L	970	560	590

Although collected in the same area and at similar depth (i.e. less than 2 m apart and at 40 cm depth), the chemical properties of the two samples are slightly different. Sodium, calcium and chloride values are higher in the 2012 sample, while the potassium values are lower. Regardless, the sodium, potassium, calcium and chloride values are more than double the ones from the control soil sample.

These high values suggest rich drilling material. The presence of potassium rich material near the perimeter of the sump could be related to a sampling error (i.e. sampling sump material rather than clean undisturbed soil) or to a very small and localized spill of potassium chloride salt.

5 Conclusion

The 2012 annual field survey was conducted on September 4 and 5, 2012. A second site visit was conducted on September 20 to install a thermistor cable into the Mallik 2L-38 Sump. The visual assessment conducted from both the air and the ground shows that the site was much wetter than during the previous year. Water levels were high in most ponds and puddles and soil moisture ranged from imperfect to poor. The increase soil moisture had a positive effect on the local vegetation which appeared to be in a better condition than the previous year. The amount of vegetation at the surface of the various sumps hasn't changed and corresponds to approximately 10% of the total disturbed area.

Clear evidences of a recent storm surge were noted during the September 20 field visit. Fresh ripple marks on the ground surface were present throughout the site and the distribution of large drift wood debris had considerably changed. The successive storm surges that take place at the Mallik site clearly have an impact on the site by inundating the sump areas with saline water; water that then get trapped in the various natural depressions and subsidence areas that are present within the perimeters of the sumps.

The subsidence at all three sumps appears to have increased. This is based on visual assessment only as no precise surveying method is presently utilized to monitor subsidence. The subsidence is more active at the Mallik 2L-38 Sump where two depressions occur. In contrast to the 2011 visit, the depressions were filled with waters; potentially as a result of increase precipitations but also linked to the storm surge process.

Active layer measurements are quite consistent throughout the site. The measurements were taken on September 4 and indicate an average thawing depth of 140 cm at the Mallik 2L-38 Sump, 132 cm for the Mallik 3L/4L/5L-38 Sump and 109 cm at the 1998 Camp Sump. The differences in annual thaw penetration could be explained by an earlier snowmelt or by the warmer air temperature recorded during the 2012 summer months (2 to 3.5 degrees warmer in June/July/August of 2012 than in the similar months of 2011).

The analysis of the four thermistor strings indicates that the ground temperatures were colder for the winter 2011-2012 period than for the 2010-2011 winter period. The facts that the air temperatures were somewhat similar during the two winter periods reinforce the idea that a lesser amount of snow was present at the Mallik site during the last winter, therefore allowing an increase frost penetration and a cooling of the permafrost in the upper 6 to 8 meters.

The findings of the electromagnetic survey are consistent with last year's results and confirm that there is no evidence of contaminant migration. The EM 31 and EM38 surveys confirmed that a series of natural depression located at proximity to the sumps have high apparent conductivities. Theses depressions were all filled with water at the time of visit. The water chemistry analysis indicates that the high conductivity within those natural depression is not related to the seepage of drilling contaminants but most probably due to elevate sodium level resulting from the evaporation of sea water. Water samples taken in the subsidence areas of the Mallik 2L-38 and Mallik 3L/4L/5L-38 Sumps have high potassium values and reinforce the idea that seasonally unfrozen drill mud contaminants are mixing into the subsiding portions of the sump caps.

Both the EM31 and EM38 surveys indicate that there is elevated apparent conductivity in an area immediately adjacent to the northeast corner of the Mallik 2L-38 Sump. A review of previous years EM reports indicates that the area of elevated response has not increase in size. A new soil sample taken from this area (Mallik2012 SS01) confirm the higher than normal potassium, chloride and sodium values that were recorded from a previous sample (Mallik2011 SS01). These values are considered too high for a natural source and suggest the presence of sump contaminants. The presence of residue of unknown

nature at the ground surface in that specific area could explain the high potassium, chloride and sodium values (rather than the progressive migration of contaminants outside of the sump area).

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Appendix A Site Photographs

Figure A-1 Aerial overview of Mallik site (looking southeast)

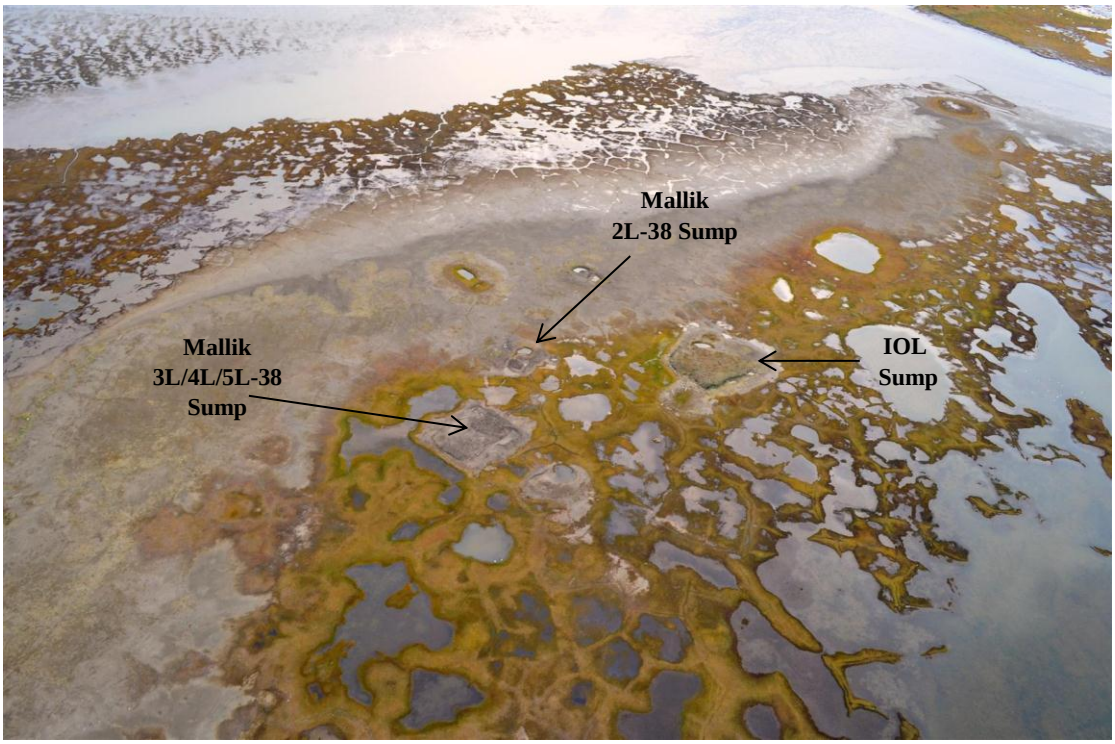


Figure A-2 Aerial view of the Mallik 3L/4L/5L-38 Sump (looking south)

Figure A-3 Subsidence and tension cracks at the eastern corner of the Mallik 3L/4L/5L-38 Sump

Figure A-4 Subsidence and ponding at the southern corner of the Mallik 3L/4L/5L-38 Sump

Figure A-5 Aerial view of the Mallik 2L-38 Sump (looking west)

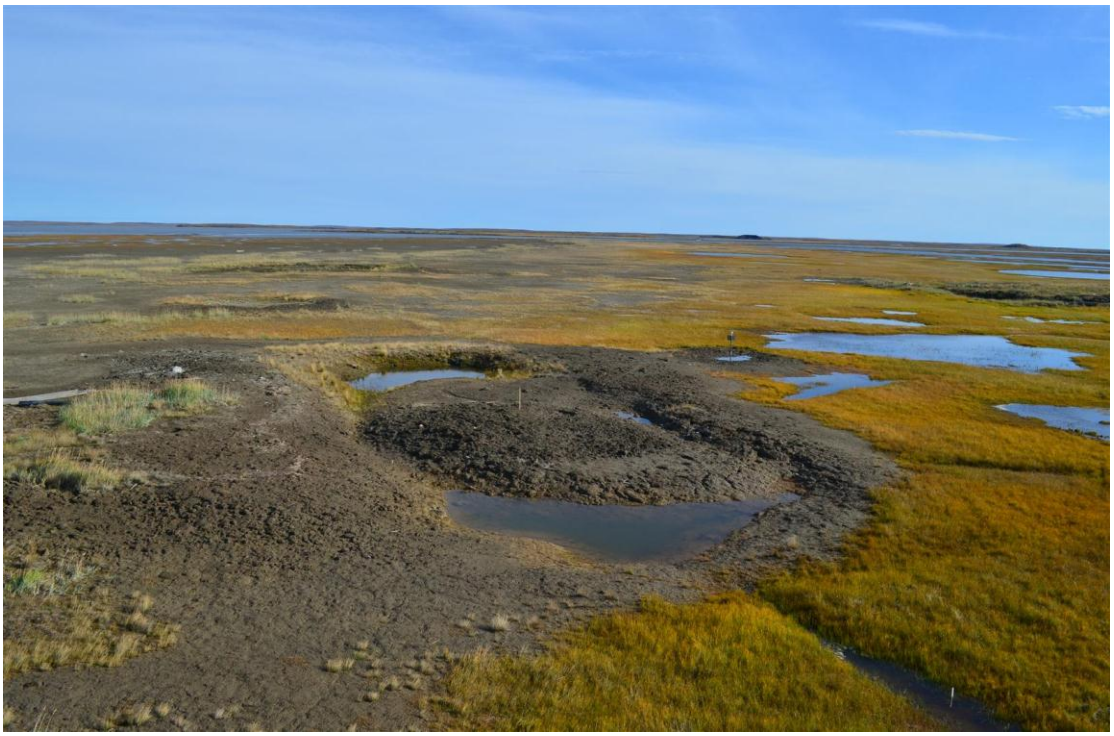


Figure A-6 Aerial view of Mallik 2L-38 Sump (looking east)

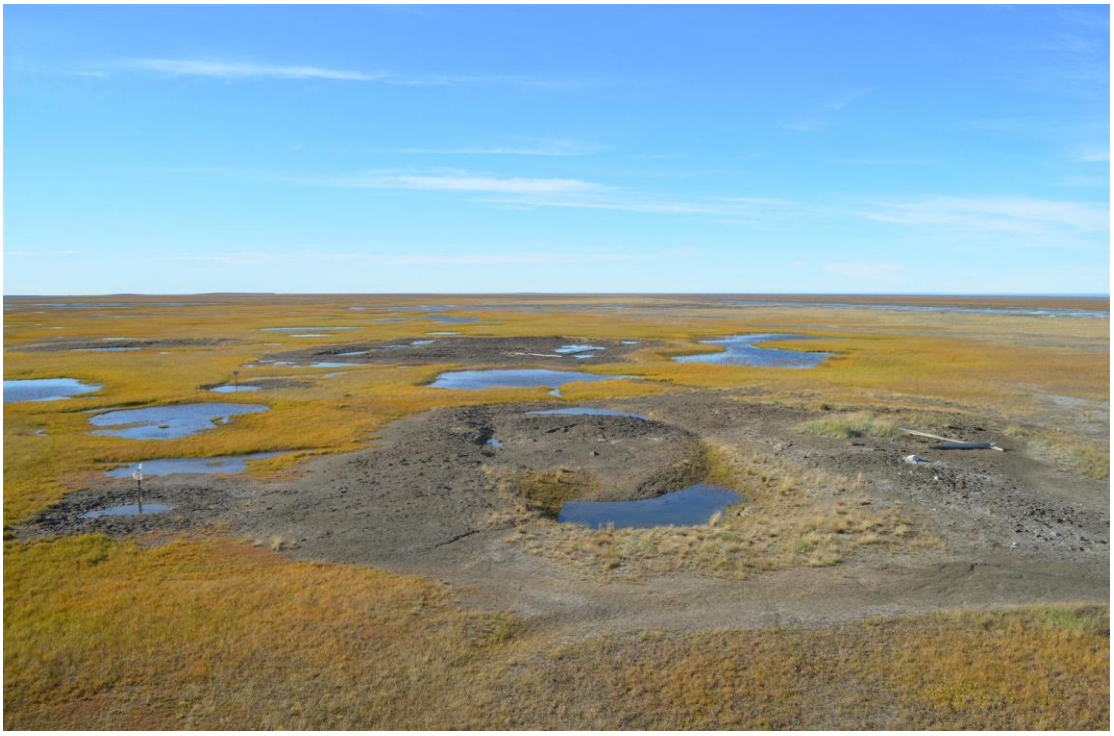


Figure A-7 Subsidence area at the eastern end of the Mallik 2L-38 Sump

Figure A-8 Subsidence area at the western end of the Mallik 2L-38 Sump

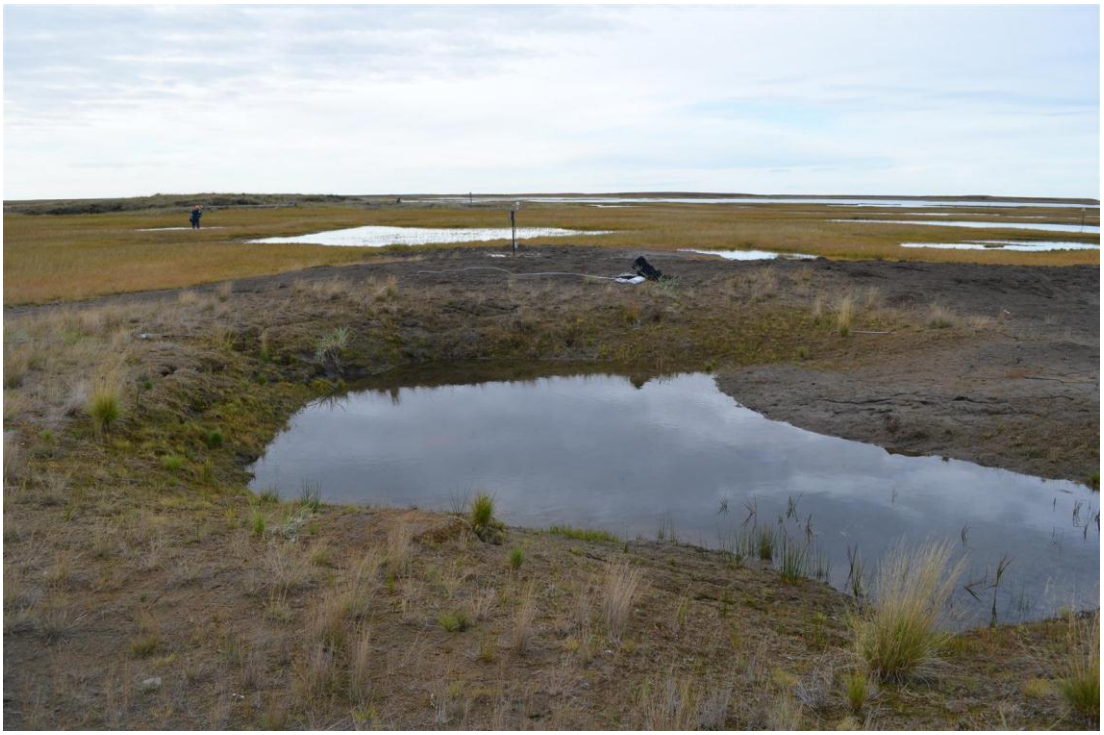
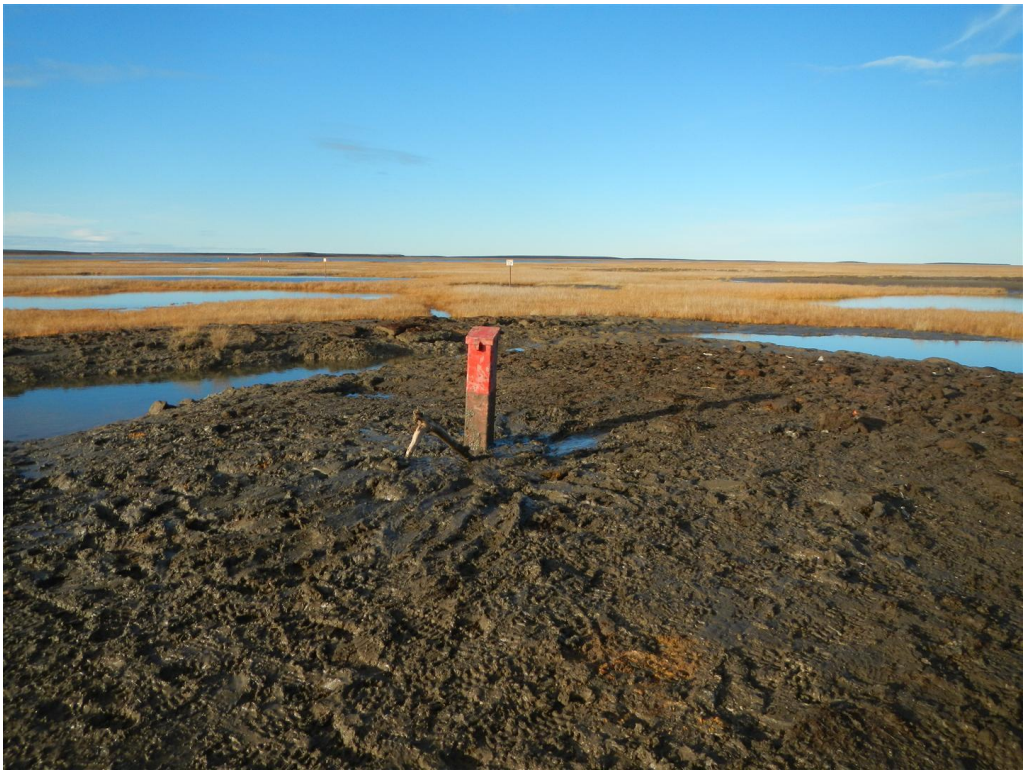


Figure A-9 Subsidence and ponding around Mallik 2L-38 wellhead

Figure A-10 Ripple marks from a recent storm surged that flooded the Mallik site sometime between September 6th and September 20th, 2012.

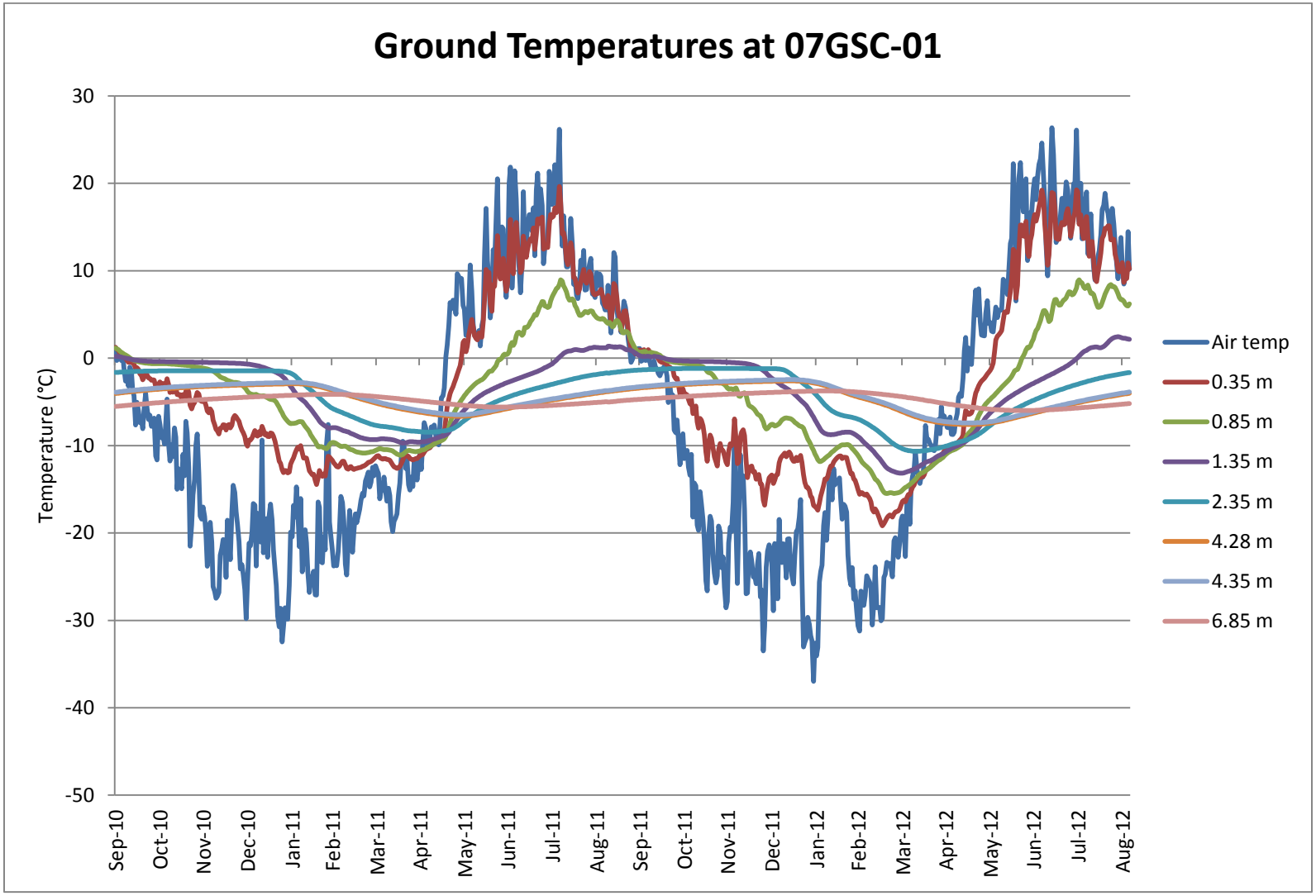
Figure A-11 Surface subsidence at the surface of two interconnecting ice-wedges (approx. 40 m north of the Mallik 2L-38 Sump).

Figure A-12 Thermistor casing installed at the center of the Mallik 2L-38 Sump on September 20th, 2012.



Appendix B Thermistor Data

Figure B-1 Thermistor 07GSC-01 – Daily Ground Temperatures (October 2010 to September 2012)



Note: The temperature sensor 1 is located above ground and is recording air temperature

Figure B-2 Thermistor 07GSC-02 – Daily Ground Temperatures (October 2010 to September 2012)

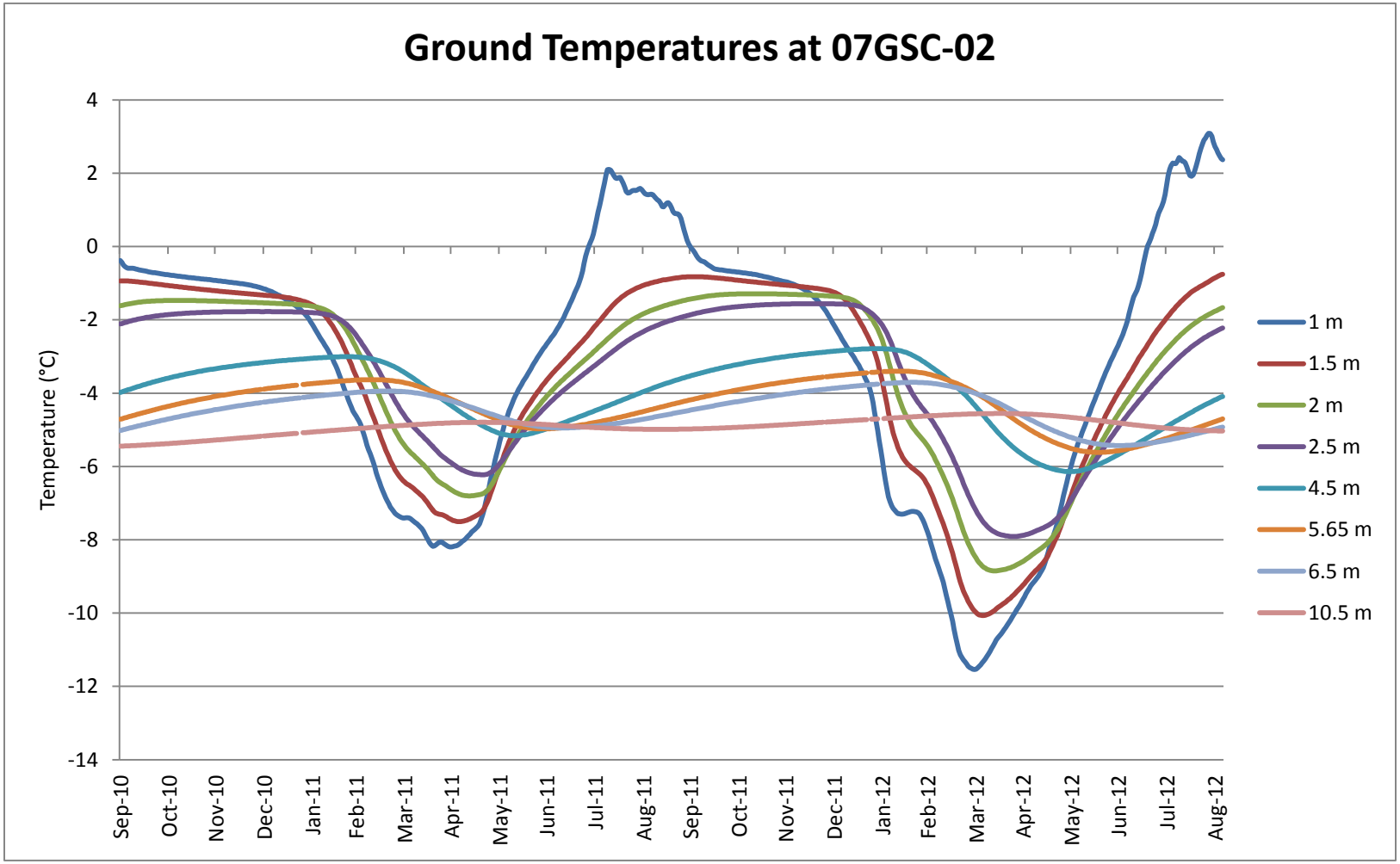


Figure B-3 Thermistor 07GSC-03 – Daily Ground Temperatures (October 2010 to September 2012)

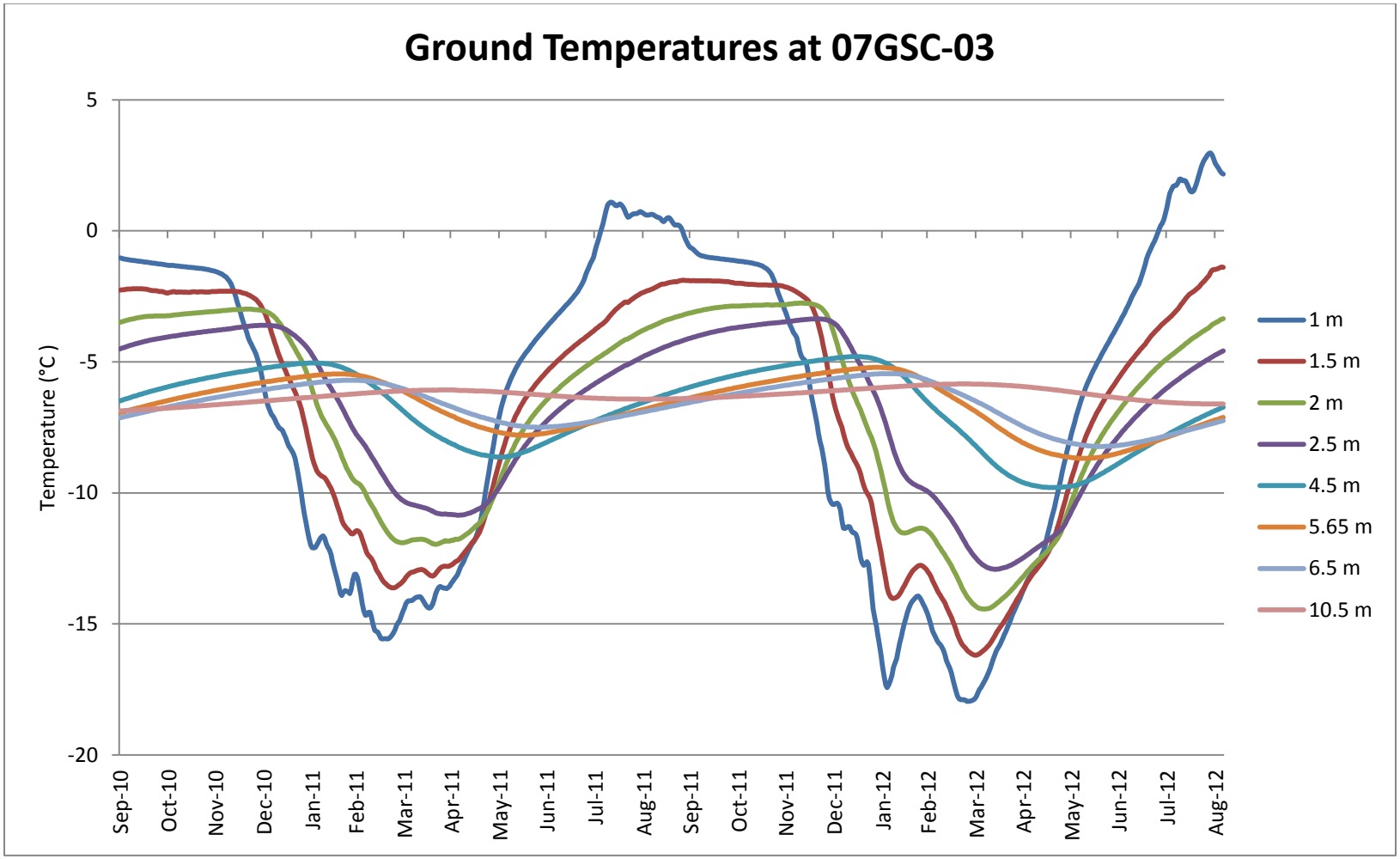
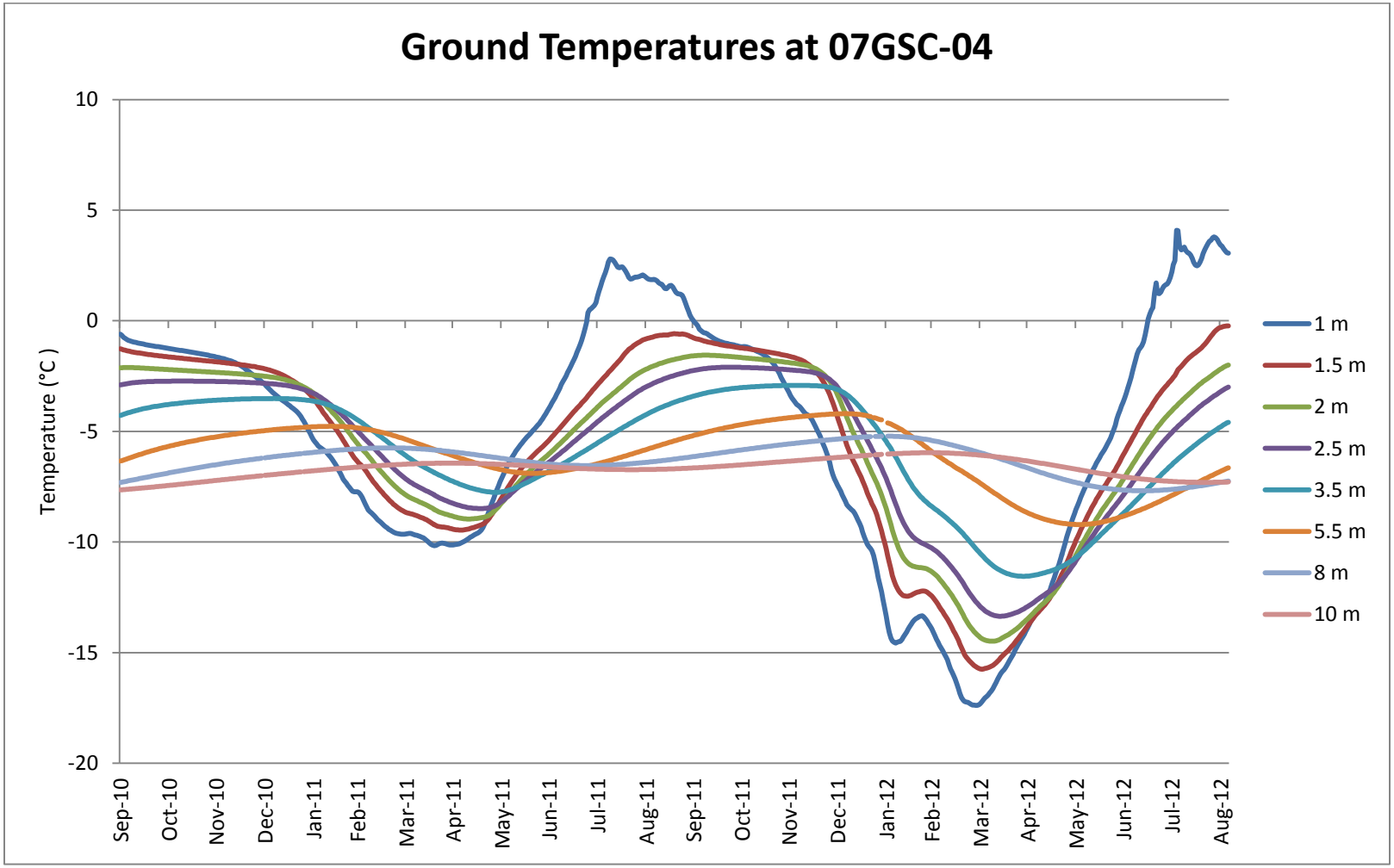


Figure B-4 Thermistor 07GSC-04 – Daily Ground Temperatures (October 2010 to September 2012)



Appendix C Electromagnetic Surveys

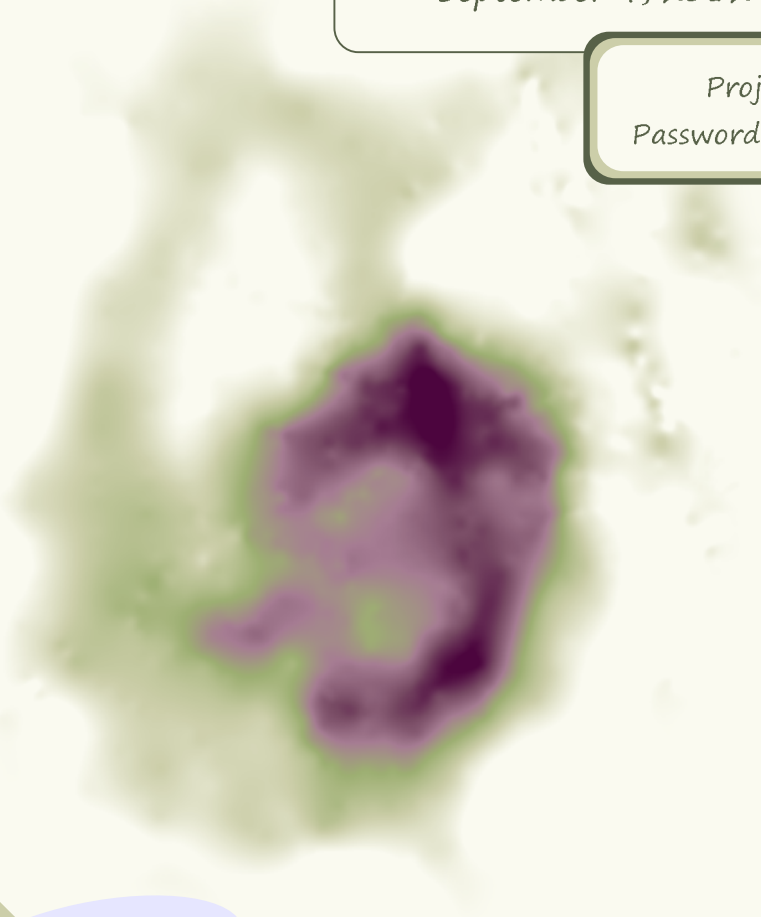
Lateral Conductivity Report

(EM31 & EM38)

Aurora Research Institute
Mallik Sump

Inuvik, Northwest Territories
September 4, 2012

Project #: 470
Password: 470c#ri$rev@k



Respectfully submitted,
KiNiLau Physics Inc.

Per:

Sean T. Clarke, P.Geoph.
Sr. Geophysicist

PERMIT TO PRACTICE
KiNiLau Physics Inc.
Signature
Date September 4, 2012
PERMIT NUMBER P10762
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

KiNiLau Physics.

Thank you for choosing KiNiLau Physics! We hope to have delivered a technically superb, easy-to-understand and perhaps simply a great product.

Our primary product is the Lateral Conductivity Detail - EM31/38, designed to be a user-friendly but comprehensive reporting tool. It combines geophysical images, survey features and an interpretation into one package, replacing the traditional paper report.

This report provides clients a traditional reporting option. It has been obtained from a secured and privately assigned Project Page using the Project # and Password provided on the cover page of this report:

Obtaining this Report

1. Go to www.kinilau.ca
2. Enter login details at 'Project Login'
3. Print 'Traditional Report'
4. Print & append 'Lateral Conductivity Detail - EM31/38' → ***Appendix A***

While the conductivity detail satisfies all requirements for a complete geophysical analysis, KiNiLau provides additional data products to clients. These can be downloaded from the client Project Page at www.kinilau.ca using the Project # and Password provided on the cover page of this report:

- **Lateral Conductivity Detail - EM31/38 - lateral conductivity (EM induction) analysis**
- Survey Features - all surveyed features in standard AutoCAD format (dxf)
- Traditional Report - paper report (this one) to augment geophysical details
- Raw Data - lateral conductivity XYZ data files (ASCII)
- Binary Files - raw binary field data (ssf) and field map (pdf)
- Referenced Images - lateral conductivity images (jpg) with superimposed reference points (dat)
- Other - anything else
- Invoice

In addition to detailing relevant aspects of the geophysical survey, this report is designed to tutor beginners and seasoned geophysicists the advanced technical aspects of a KiNiLau survey. It serves as training tool and readers are encouraged to engage this report and enjoy the intricacies of their project.

Graphics and moss green insets are provided throughout in support of key points and terms. Geophysical jargon is printed in *italic* suggesting that explanatory relief is nearby, usually within the next inset.

Survey samples are provided in Section 6. These samples typify soil conductivity surveys encountered over the years in western Canada and give good insight to the interpretation methodology of KiNiLau conductivity surveys. Feel free to print out and distribute these hand-out style samples for educational purposes.

Table of Contents

1. Introduction 1

2. Data Acquisition 1

2.1 Lateral Conductivity (EM31/38) 1

2.2 DGPS Positioning (Trimble Pathfinder ProXT) 5

3. Data Processing 6

3.1 Lateral Conductivity (Geonics EM31/38) 7

3.2 DGPS Positioning (Trimble Pathfinder ProXT) 8

4. Conductivity Details 9

4.1 Distance Scales 9

4.2 Legend & Color Apparent Conductivity Scale 10

4.3 Maroon Interpretation Circles and Arrows 10

4.4 Conductivity Interpretation Insets 11

5. Interpretation 12

5.1 Interpretation Basics 12

5.2 Interpreting Conductivity Magnitudes 14

6. Samples 15

Appendix A - Conductivity Details

Appendix B - Instrument Specifications

1. Introduction

The survey objective was to delineate the 2D (lateral only) extent of subsurface soil conductivities. The Geonics EM31 and/or EM38 were used to map lateral extents of subsurface soil conductivities using electromagnetic (EM) inductive forces. Positioning data were acquired using the Trimble Pathfinder ProXT and differentially-corrected (DGPS) using nearby base station data and the Trimble Pathfinder Office Suite.

2. Data Acquisition

This section describes the tools used to delineate the 2D extent of subsurface soil conductivities on site. Appendix B contains Geonics EM31/38 and Trimble Pathfinder ProXT instrument specifications. Also included are specification sheets for the Trimble Pathfinder Office Suite.

2.1 Lateral Conductivity (EM31/38)

Lateral site conductivities were delineated using the Geonics EM31 and/or EM38. Both tools were operated in vertical dipole mode (horizontal coil mode), with approximate EM31 and EM38 depths-of-penetration near 5 m and 1.5 m, respectively.

As the deeper imaging tool, the EM31 is often preferred over the EM38. Having said that, it is not always the best suited for the task. Particularly, the deeper imaging EM31 carries a larger *footprint*. It images a larger surface area and is more prone to interference from nearby metal conductors such as pipes, fences or buildings. So, while the EM31 provides comfort in being able to image deeply, on metallically busy sites like gas plants it may actually yield more questionable results.

Footprint

Footprint is the aerial extent which an EM tool images. Think of the EM31 as having a sphere of investigation. The depth of investigation is the vertical radius and the *footprint* the cross-sectional area of that sphere.

The EM31/38 uses electromagnetic (EM) inductive forces to delineate subsurface conductivities. The instrument records the *quadrature* and *in-phase* components of the induced secondary EM field. The Geonics tools are designed such that the quadrature relates to lower conductivity ranges (soils) and the in-phase to higher conductivity ranges (metals or very high ionic concentrations).

In-Phase vs. Quadrature

EM conductivity tools send off signals that coax the ground into sending its own unique counteracting signal, a process called induction. It is that counteractive response by the ground that is measured and related to soil conditions, with conductive soils responding more aggressively than resistive ones.

Basically, the response itself can be split into two components, one that is aligned or *in-phase* with the coaxing signal and one that is not, the 'out-of-phase'. In search of more user-friendly terminology, geophysicists have adopted the term *quadrature* to describe the 'out-of-phase'.

Geonics has related the *quadrature* component to soil conductivity, enabling them to name their tools soil conductivity meters. The EM31/38 *in-phase* component is not used as much, but relates to higher conductivities such as those of metals or extreme ionic concentrations. Other instrument manufacturers have related the 'in-phase to quadrature ratio' to ground properties and used those relationships to, for example, find mineral deposits.

The EM31/38 yield bulk soil conductivities averaged from surface to their depths of penetration. They cannot be used to identify individual conductivity layers beneath surface, a shortcoming described by the principle of *equivalence.*

Equivalence

The principle of *equivalence* describes when buried conductors of differing size, conductivity and depth yield the same (or equivalent) secondary EM response. Heuristically, conductivity being equal, a large conductor that is deeply buried, gives the same response as a small conductor that is shallow. Size being equal, a strong conductor at depth, gives the same response as a weak conductor that is shallow. Depth being equal, a small but strong conductor yields the same response as a large but weak conductor.

In other words, the EM31 yields a combined response of an object's size, conductivity and depth. The EM31 cannot distinguish between size, conductivity or depth and should not be seen as pure depth investigation tool (nor as a pure size or conductivity investigation tool).

EM31/38 readings were taken in 'horizontal coils or vertical axes' modes, approximating measurements of the initial 5 m/1.5 m of soil, respectively. Please note that actual EM penetration depths vary as a function of soil conductivity. To emphasize this point, they are referred to as *skindepths*.

Skindepth

Skindepth refers to the depth an EM signal travels at which point it has been reduced to one third its original amplitude. Physicists use this term since theoretically a wave never completely runs out of energy. It simply gets to a point at which it has become practically insignificant; and they have agreed that point shall be 1/*e (Euler's Number)*, about one third.

Skindepth is, in part, a function of soil conductivity. EM waves penetrate resistive soils deeper than conductive ones. An EM31 wave might travel to a depth of 8 m in resistive sand but to a lesser depth of 3 m in conductive clay (and only 50 cm in highly conductive salt contamination!).

The theory suggests that the true depth of penetration of the EM31 is unknown, since it is a function of soil conductivity; and soil conductivity is what we are trying to find in the first place.

The practical implication is that EM induction tools of varying depth capability (EM38/31/34) should only be used to identify depth-onsets of conductors, rather than their depth-extents.

The EM31/38 are only capable of detecting layers exhibiting relatively high *thickness-conductivity products*.

Thickness-Conductivity Product

Vertical resolution refers to the smallest identifiable stratigraphic thickness and is a function of the *thickness-conductivity product* of individual stratigraphic layers. In other words, a thin stratigraphic layer is detectable only if it possesses large conductivity. A thick stratigraphic unit is detectable with less conductivity contrast. For our applications, the Geonics EM31 and EM38 would be considered to have poor vertical resolution, requiring stratigraphic entities to exhibit large *thickness-conductivity products*.

The Geonics EM31/38 exhibit adequate *dynamic data range* for our purposes. They have the ability to detect low conductivity variations as well as higher ones. Both instruments maintain *response linearity* over the lower part of that dynamic data range, from zero to approximately 100 mS/m.

Dynamic Data Range & Response Linearity

Dynamic data range refers to the range of data values the instrument can handle. A tool of low *dynamic data range* is sensitive to a very specific range of conductivities, but clips readings above or below a certain threshold. While it is nice to have a tool sensitive to a greater *dynamic data range* (so that we can map resistive and conductive targets with it), we also want this tool to exhibit good *response linearity* over that large data range. It needs to increase steadily from low to high conductivity.

The Geonics EM31/38 maintain instrument linearity from zero to approximately 100 mS/m. Let's say soil has specific conductivity and the EM31/38 read it as 30 mS/m. Should that soil double in conductivity (perhaps due to ionic enrichment) then we expect the EM31/38 to yield 60 mS/m. But if the soil conductivity doubles once more, all bets are off, as the instrument's linearity cap has been exceeded and we might get a reading of 110 mS/m, less than 120 mS/m in any case.

From a practical stand-point non-linearity doesn't really matter since KiNiLau uses relative behavior rather than absolute magnitude of readings to identify targets. As long as the numbers keep going up, we know it's getting worse.

2.2 DGPS Positioning (Trimble Pathfinder ProXT)

The EM31 is digitally synchronized to differentially-corrected GPS (DGPS). This arrangement allows positioning and geophysical data to be stored simultaneously on handheld dataloggers. Data are acquired swiftly at high sampling density. EM data were acquired at a measurement station spacing of approximately 2 m (along line) and a line spacing near 10 m. The correct sampling density varies and is dictated by *Nyquist's Theory.*

Nyquist's Theory

Nyquist's Theory states that the digital representation of an analog signal is valid as long as that analog signal is sampled at three times its highest frequency content, two times with known phase information. Ok, what it means is that a chloride plume 10 m wide and 100 m long should be surveyed with a minimum station spacing of 3.3 m along survey lines spaced 33 m apart. Smaller plumes could get missed.

The Trimble Pathfinder ProXT uses L1 code and carrier information to provide survey-grade positioning. The moving DGPS receiver (Rover) is digitally synchronized to geophysical instruments providing positioning control of geophysical measurements. Data are post-processed using the Trimble Pathfinder Office Suite and data from the nearest available base station. While positioning accuracies vary as a function of factors like rover-to-base station distance, satellite geometry relative to the receiver or signal interference, sub-metre accuracies are readily obtained. Site features were surveyed for inclusion on KiNiLau details and serve as reference markings for follow-up work.

Common site-specific GPS settings are *PDOP*, *Minimum Satellites* and *Elevation Mask*. All relate to obtaining optimal GPS signals in varying site conditions.

PDOP (Positional Dilution of Precision)

PDOP is a statistical measure of positioning accuracy and is a function of satellite geometry relative to the receiver (constellation). In general, *PDOP* cut-off values below five yield accuracies appropriate for our purpose. As with the other GPS instrument settings, the field engineer may elect to increase the *PDOP* limit in specific environments and forego accuracy for the sake of survey completion.

Minimum Satellites

Minimum Satellites refers to the minimum number of satellites the GPS receiver will accept before shutting down. GPS surveying requires a minimum of four satellites. Three are required to geometrically pinpoint intersections of spheres in 3D space, to get a position. One more is required to resolve timing inaccuracies between the satellite and GPS clocks.

At times, survey location and condition may prevent a view of four satellites, for example when closing salt plumes underneath dense tree canopy. In that case, the field engineer may reduce the *Minimum Satellites* setting to three and forego the elevation information. Not collecting elevation information is acceptable since GPS elevations are practically inaccurate for our purposes.

Elevation Mask

Elevation Mask is measured in degrees and refers to the GPS antenna's cone-shaped viewing angle, measured upwards from earth's horizontal surface. An *Elevation Mask* of 0° implies the view of all satellites above. An *Elevation Mask* of 90° would close the viewing angle completely and cause no satellites to be in view. Generally, the *Elevation Mask* is set to 5° and may be reduced to 0° in hope for a greater satellite view. For geometric reasons, satellites far off to the side, ones that can be seen only at low *elevation masks*, decrease positioning accuracies.

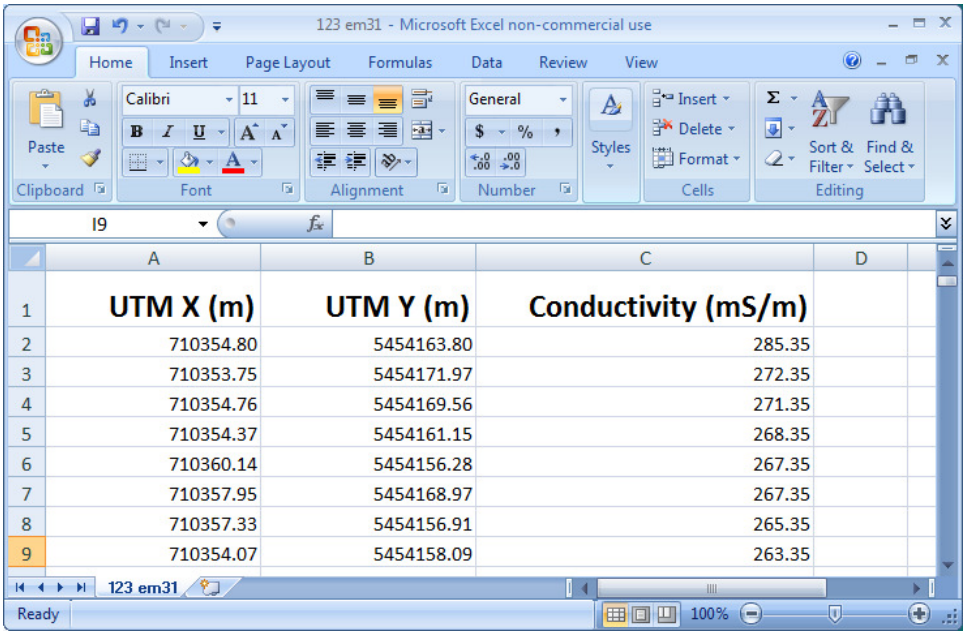
3. Data Processing

Data processing begins in the field with the KiNiLau field engineer making field maps to confirm survey completion and data integrity. These (pdf) field maps can be obtained by accessing the client's custom Project Page at www.kinilau.ca and clicking on Binary Files. The field engineer annotates field maps with pertinent observations which form the basis for the final interpretation. In essence, the field engineer writes the final interpretation immediately after survey completion, having still a keen focus on that particular project. The geophysicist then confirms that interpretation for inclusion into the Lateral Conductivity Detail - EM31/38.

3.1 Lateral Conductivity (Geonics EM31/38)

Original binary EM31/38 data files arrive from the field in Trimble proprietary format (ssf) and can be obtained from the client Project Page at www.kinilau.ca under Binary Files. Most clients will not utilize these files as they can only be accessed using specialized engineering software (KiNiLau uses the Trimble Pathfinder Office Suite, Appendix B). They contain lateral conductivity data (quadrature and in-phase) synchronized to raw GPS positions and various other data fields.

The processor converts these files into standard ASCII format, also called (txt) or (dat) format, and combines them to form the *em31/38.dat* file. The *em31/38.dat* file is a raw data file in that no algorithm has yet been applied to the lateral conductivity data. GPS positions, on the other hand, have already been differentially-corrected at that point. This file is provided to clients who would like to process their own data and is accessible at the client Project Page by clicking on Raw Data. Graphic 1 displays a typical *em31.dat* file and its column assignment.



Graphic 1: *em31.dat* and its column assignment

The *em31/38.dat* file is gridded and enhanced using in-house designed processing and imaging techniques. The resulting image is UTM-referenced. Four superimposed crosses, only faintly visible, correspond to UTM grid coordinates. The image itself is provided in (jpg) and the UTM coordinates in ASCII (dat) format, both of which are zipped together and obtainable via the client Project Page by clicking on Referenced Images.

Surveyed features are drafted using CAD software and exported as *survey features.dxf,* a drafting file in standard AutoCAD format. Clients can obtain this AutoCAD survey features file by accessing their Project Page from www.kinilau.ca and clicking on Survey Features.

The Lateral Conductivity Detail - EM31/38 is analyzed in the context of the field engineer's interpretation. Interpretation events are drafted onto the maps, which are then checked by a second data processor prior to uploading to the KiNiLau server as Lateral Conductivity Detail - EM31/38.

3.2 DGPS Positioning (Trimble Pathfinder ProXT)

KiNiLau maps are posted in *UTM* and projected in *NAD83*. GPS positions are *differentially-corrected* using the Trimble Pathfinder Office Suite (see Appendix B). This software uses differentials to correct primarily for ionospheric effects, multipath rejection and timing synchronization errors.

UTM & NAD83

Universal Transverse Mercator (UTM) is a coordinate system that allows survey data to be posted in metre units (m). The traditional coordinate system is the Latitude/Longitude system, which posts in units of degrees. Since it is easier for us to think in terms of metre units than degrees (we can walk 20 m north much better than we can walk 2° north) most maps designed for field follow-up work should probably be posted in *UTM*.

The datum represents the mathematical approximation of the earth's rounded surface for a particular region. It is used to transpose positions acquired on that rounded surface to their flat cartographic counterpart.

For example, an ant walking across a lanzones (a fruit native to the Philippines of particularly exotic and sweet flavour) from Point A to B might cover a real-life distance of 3 cm. On a flat, contoured map of that lanzones, the horizontal projection of that distance might only appear as 2 cm. The datum corrects for this error by stretching the map and making the distance from Point A to B appear as 3 cm, what it should be. We might call that Datum LANZONES83.

In western Canada, commonly used data are *NAD83* and at times NAD27. WGS84 best approximates earth as a whole and, as a result, is the one used by space roving satellites.

Differential-Corrections

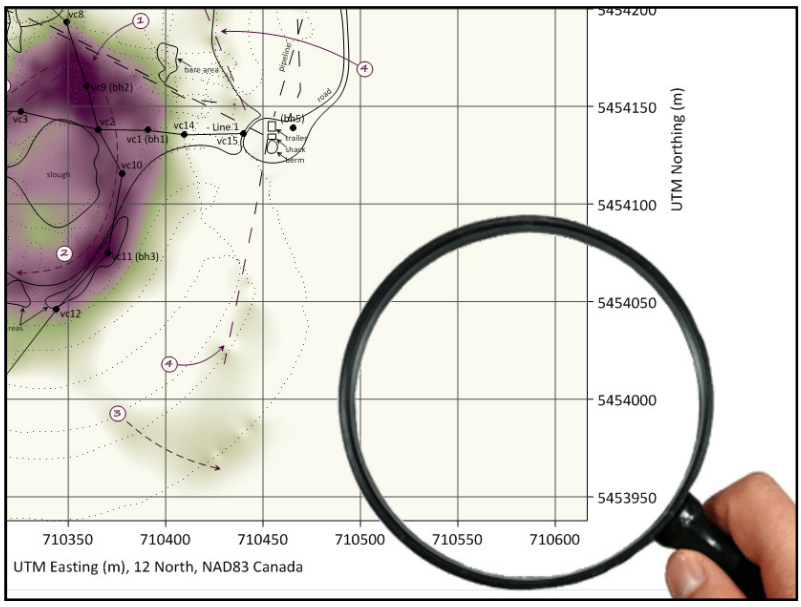
The EM31/38 are synchronized to a GPS called the rover, the mobile unit. To find out what kind of positioning errors the rover incurs, all we have to do is compare it to the positioning errors incurred by a nearby stationary point, called the base. Any recorded deviations about that stationary point are errors that would have equally affected nearby rovers. These deviations are called *differentials* and can be subtracted from time-synchronized, roving GPS data.

4. Conductivity Details

Conductivity details are included in Appendix A of this report. They are designed to serve as independent and comprehensive reporting tools replacing the traditional paper report. Details present geophysical images, superimposed survey features as well as an interpretation story line.

4.1 Distance Scales

Distance scales are omitted from digital conductivity details due to the potential for unintentional distortion. Since UTM map bases post in units of (m), they can readily be utilized to obtain scaling information instead, Graphic 2.



Graphic 2: UTM map bases provide scaling information

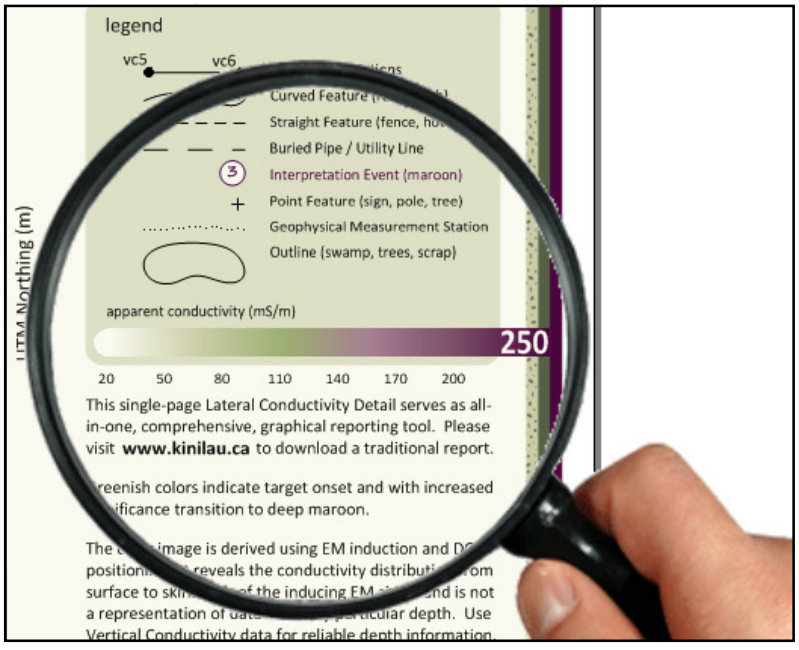
4.2 Legend & Color Apparent Conductivity Scale

The legend details surveyed features and includes a customized *apparent conductivity* color scale, displaying color gradations from beige to moss green to maroon.

Apparent Conductivity

Apparent conductivity implies that measurements do not purely represent soil conductivities, but rather a combination of properties and phenomena as described on Pages 3 and 4 of this report (see *equivalence, skindepth & thickness-conductivity product*).

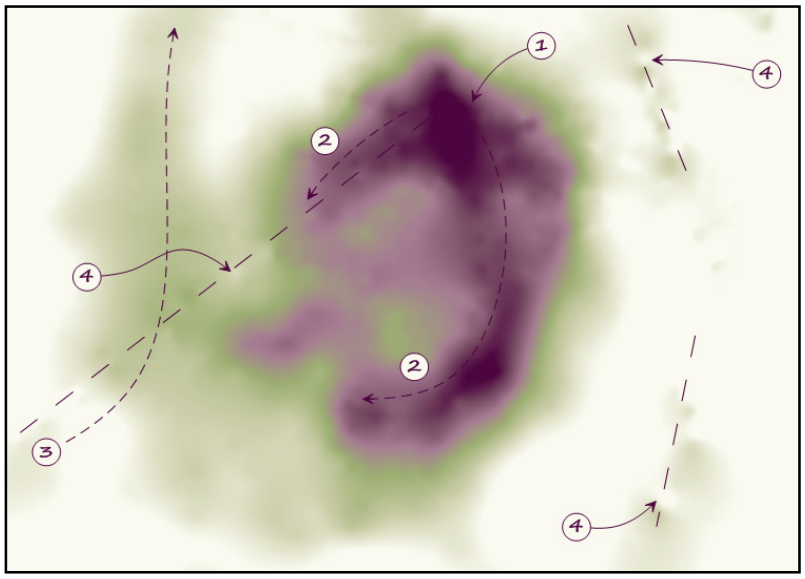
Beige regions represent background and maroon regions anomalous conductivities. The possibility of ionic contamination increases from beige to dark maroon. The peak color scale value is posted at the right side of the color scale in large bold font, Graphic 3. This value is inevitably less than the unfiltered peak survey response.



Graphic 3: The KiNiLau *apparent conductivity* color scale

4.3 Maroon Interpretation Circles and Arrows

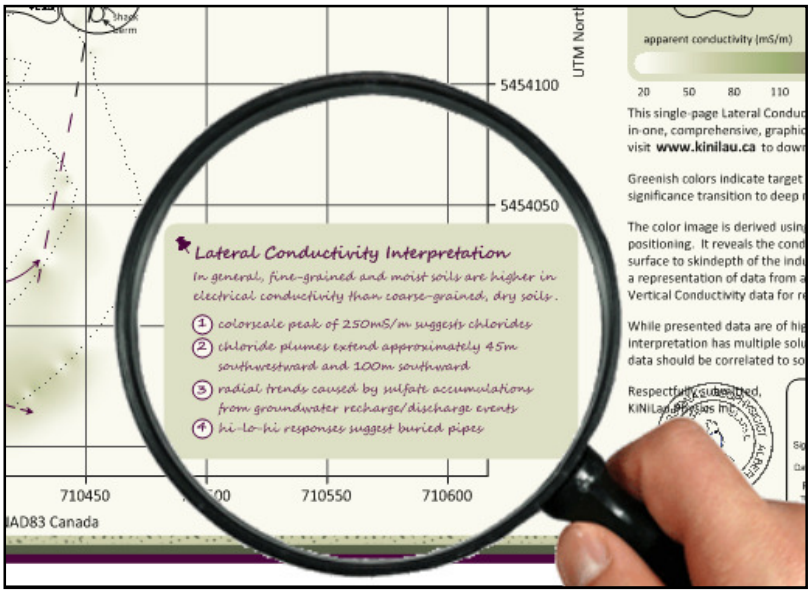
Maroon colored script is reserved for the interpretation. Maroon, numbered circles point out various geophysical interpretation events while maroon dashed arrows highlight interpreted trends, Graphic 4.



Graphic 4: Interpretation events are drafted in maroon

4.4 Conductivity Interpretation Insets

Each numbered interpretation circle on the map is further detailed in the moss colored inset titled 'Lateral Conductivity Interpretation', Graphic 5.



Graphic 5: The interpretation inset details each interpretation circle

5. Interpretation

The interpretation is included on all conductivity details. Numbered circles in maroon color each represent an interpretation event, which is elaborated on within the moss colored inset titled 'Lateral Conductivity Interpretation'. Maroon colored dashed lines and arrows highlight interpreted trends and boundaries.

Since interpretations imply a certain level of uncertainty readers at times question the validity of a particular geophysical technique. It should be noted that each geophysical technique is intrinsically very accurate and that the cause of interpretational disorientation is unfamiliarity with the theory pertaining to that technique. Readers are encouraged to familiarize themselves with the following key terms relevant to interpreting KiNiLau Conductivity Details:

Footprint ..... **Page 1**
In-Phase vs. Quadrature ..... **Page 2**
Equivalence ..... **Page 3**
Skindepth ..... **Page 3**
Thickness-Conductivity Product ..... **Page 4**
Dynamic Data Range & Response Linearity ..... **Page 4**
Nyquist's Theory ..... **Page 5**
Apparent Conductivity ..... **Page 10**

5.1 Interpretation Basics

In general, the electrical conductivity of soil increases with moisture and ionic content. Fine grained soils tend to be higher in conductivity since they usually hold more ions. Conductivity increases even further with an increase in moisture content.

Coarse-grained soils tend to attract less ions, which leads to an appropriate generalization that coarser grained soils are more resistive. Further, coarse-grained soils tend to be dryer since they don't absorb and hold moisture as well as fine-grained ones, making them even more resistive.

Fine-grained, moist soils are higher in conductivity than coarse-grained, dry ones.

Natural, usually weak, accumulations of all types of ions can be found in soils. Such ions increase electrical conductivity by freeing electrons for current flow. Clay is a good example of conductive soil that is fine grained, moist and holds weak ion accumulations. Clay often forms the impenetrable layer to contaminant plumes. It tends to contrast well to the resistivity of dry sand, which often forms the flowpath for contaminant plumes.

Ions increase soil conductivity.

Salts are ions of 'high-mobility', readily freeing up electrons into solution that cause astounding increases in soil conductivity. Consequently, salts are easy to delineate using conductivity techniques. Salts may occur naturally or man-made. In western Canada, soils are commonly enriched with naturally occurring sulfates (SO_4^{2-}). Man-made salts typically encountered are nitrates (NO_3^-) from fertilizers and chlorides (Cl^-) as by products from potash plants, oilfield facilities or tanneries. At times, acids (H^+) are encountered causing anomalous soil conductivities near sulfur storage blocks, battery storage yards or within acidic mine drainage channels.

Salts occur naturally or man-made and are easy to delineate using conductivity techniques.

Ferrous metals cause extreme conductivities that are usually easy to distinguish from salt contaminated soil. Metals respond abruptly, often swinging wildly from positive to negative peaks, whereas salt contaminated soils tend to vary gradually.

Buried metal pipelines respond aggressively creating unique, linearly-trending high-low-high (hi-lo-hi) signatures. The effect is one of 'geometric coupling' and is a function of the pipeline's relative position to the instrument's receiver and transmitter coils. Maximized when surveying perpendicularly across pipelines, the effect disappears when surveying parallel to them. As a result, EM induction tools with offset transmitter and receiver coils should not be used to detect buried metal pipelines.

Metals cause abrupt conductivity variations while ions cause smooth ones.

A buried target should be evaluated based on its relative rather than absolute response. For example, a response of 100 mS/m in a background of 90 mS/m might be less significant than a response of 50 mS/m in a background of 10 mS/m.

Interpret conductivity data based on relative response behavior, not absolute magnitudes.

5.2 Interpreting Conductivity Magnitudes

While conductivity data should be interpreted based on relative response behavior rather than absolute magnitudes, KiNiLau will provide a rough guide to interpreting absolute conductivity magnitudes of the EM31/38. Please note that while the following generalizations are derived from the acquisition and interpretation of over 1500 sites in western Canada, exceptions to this generalization will undoubtedly abound. *Conductivity magnitudes* must be understood within the theoretical context provided in this report.

Conductivity Magnitudes

In western Canadian clay till soils, average EM31 background readings hover around **50 mS/m**. 'Background' is a relative term and at times **100 mS/m** represents background in, for example, ionically enriched solonetzic soils. Background readings of **20 mS/m** may be obtained in drier silty, sandy or gravelous zones but we have also encountered backgrounds as low as **2 mS/m** corresponding to Precambrian Shield.

EM31 readings above **100 mS/m** suggest some form of ionic influence, perhaps from sulfates and/or chlorides. Only rarely do sulfates elevate EM31 conductivities past **150 mS/m**, suggesting chlorides past that range.

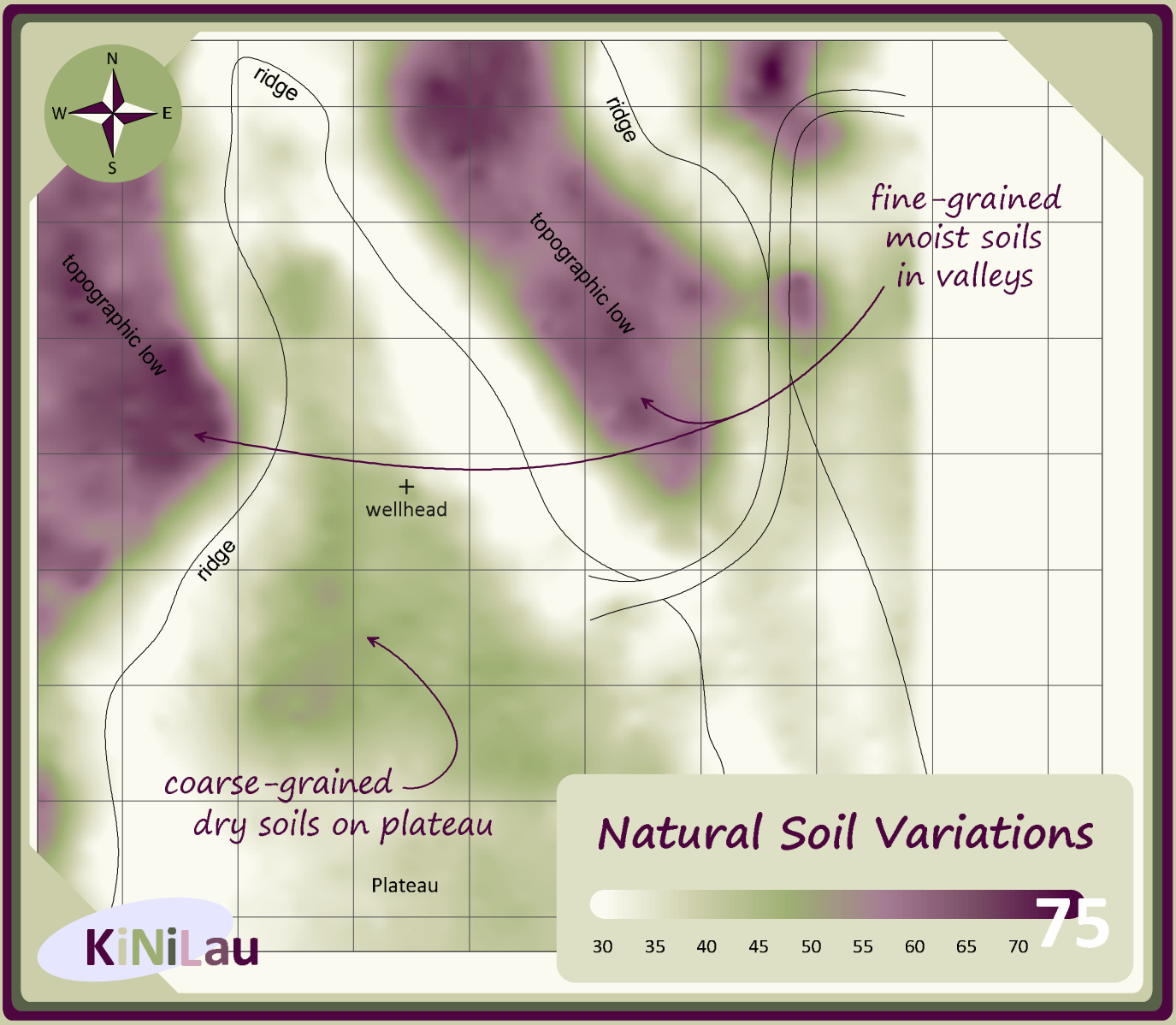
6. Samples

The following samples provide insight to interpreting conductivity details. Vertical Conductivity profiles have been included in this section of the report, enabling valuable insight to the depth response of the Geonics EM31 and EM38.

While we have learnt to interpret each site uniquely and independently, we have also been able to establish similarities between them. 'Typical responses' are presented on the following pages, providing insight to the integrity and consistency of conductivity details.

Interpretation Samples

1. Natural Soil Variations (EM31)
2. Natural Salinity & Pipes (EM31)
3. Flarepit with Chlorides (EM31 & VC)
4. Pipeline Break & Brine Spill (EM31 & VC)
5. Pipe Break, Chlorides & Sulfates (EM31 & VC)
6. Flarepit, Chlorides & Sulfates (EM31, EM38 & VC)

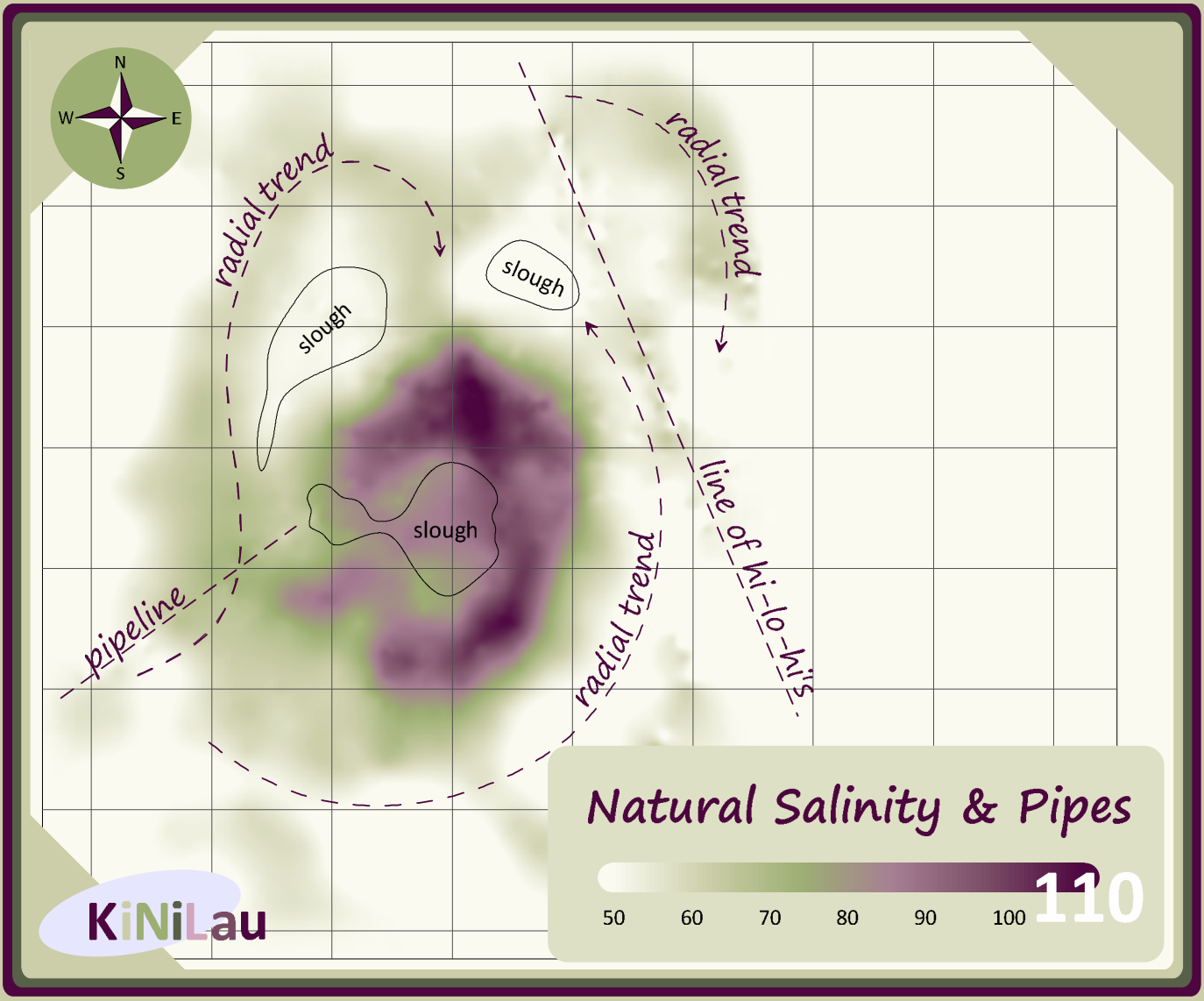


Natural Soil Variations (EM31)

The above Lateral Conductivity Detail typifies a site that 'has nothing'. Conductivity responses are low, with a dynamic range from 30 mS/m for coarser, dryer soils to 75 mS/m for finer, moist ones.

This lateral conductivity detail, in essence, details local topographic variations. Higher conductivities correlate to accumulations of fine-grained moist soils in valley like channels and lower conductivities correlate to coarse, drier material on top of the plateau.

The generalization that fine-grained, moist soils are higher in conductivity than coarse-grained, dry ones holds true since soil conductivites are predominantly affected by ionic and moisture content. Silts and clays tend to attract more ions and moisture than a permeable granite based gravel. Practically, not much else could affect soil conductivity other than minor influences such as temperature or resistive soil matrices (hydrocarbons).

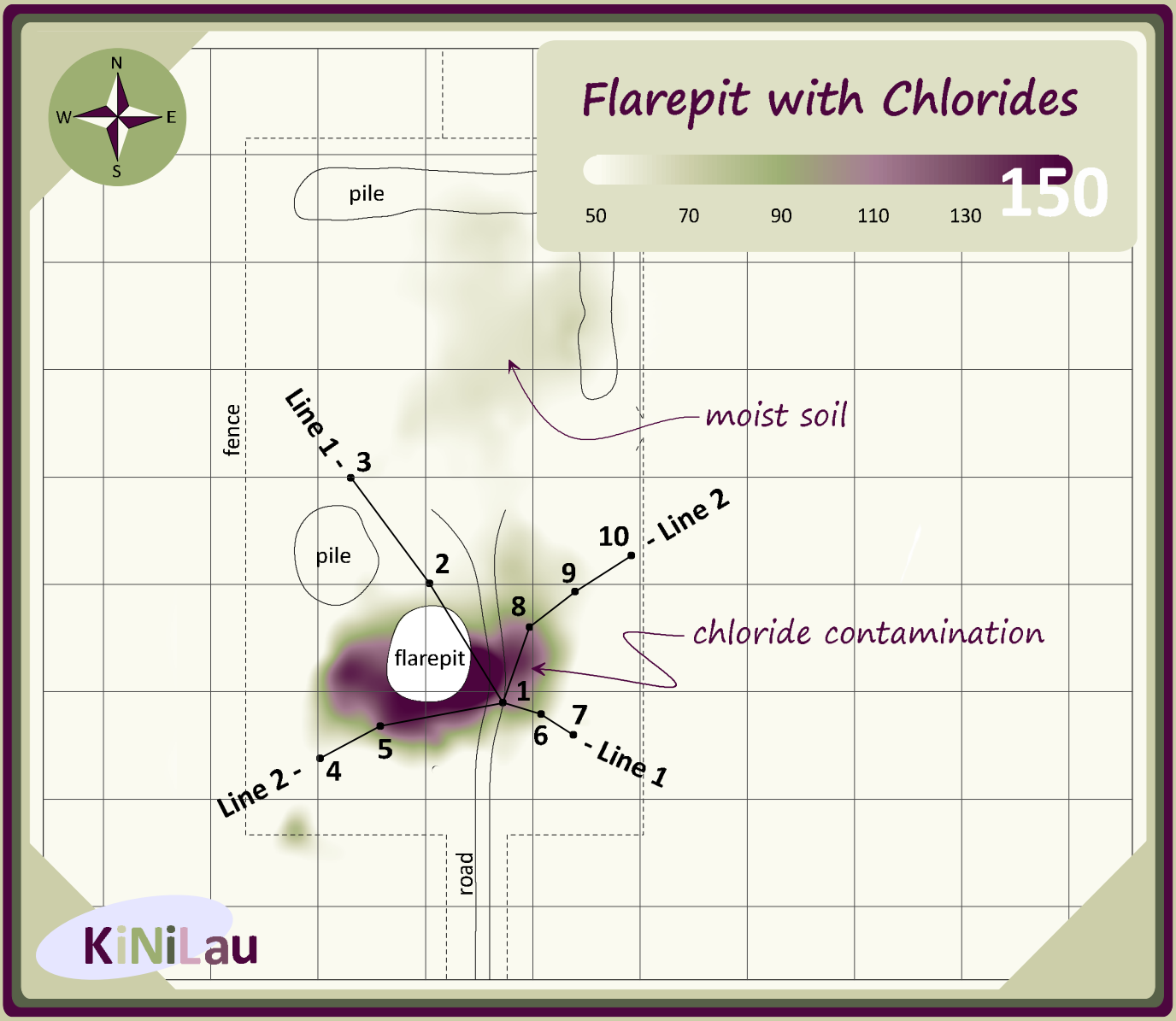


Natural Salinity & Pipes (EM31)

Naturally-saline soils contain sulfates, ions of high mobility that yield response magnitudes matching those of chlorides. To an experienced surveyor, sulfate-laden and chloride-impacted soils can usually be distinguished by their unique conductivity trends.

In western Canada radial conductivity trends often result from groundwater recharge-discharge events. Here, the slough yields elevated conductivities near 110 mS/m, surrounded by a low conductivty ring near 50 mS/m. The reverse effect may also be encountered, when a slough yields reduced conductivities in contrast to a ring of high conductivity.

Note the linearly trending 'hi-lo-hi' response signatures across the site caused by metal pipelines. The effect is one of 'geometric coupling' and is a function of the pipeline's relative position to the instrument's receiver and transmitter coils. Maximized surveying perpendicularly across pipelines, the effect disappears when surveying parallel to them. As a result, EM induction tools with offset transmitter and receiver coils should not be used to detect buried metal pipelines.



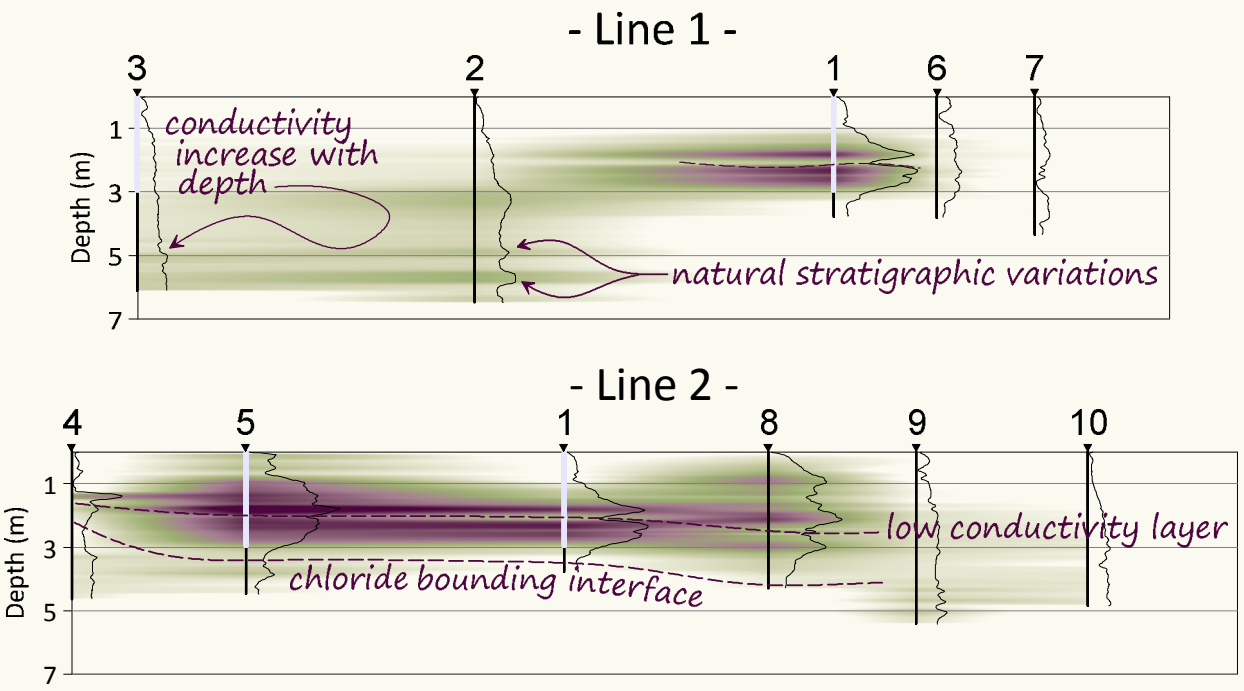
Flarepit with Chlorides (EM31)

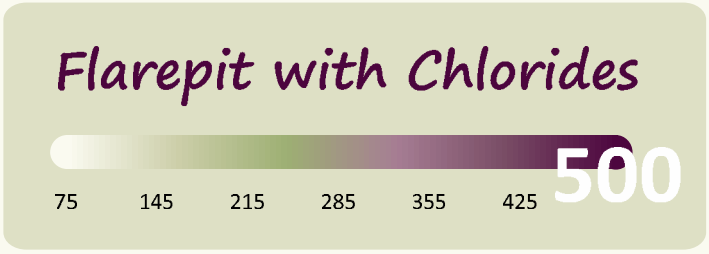
... see Vertical next page

Sites with sulfate-free backgrounds impacted by chlorides do not usually present challenges to an interpreter. Above, typical background conductivities near 50 mS/m correspond to a dry silty clay, which contrasts well to anomalous conductivites in excess of 150 mS/m caused by chlorides around the flarepit.

The trend and location of the anomalous conductivity zone provide further insight. The trend pattern appears contained and non-repetitive, suggesting minimal outward spreading of chlorides. Its location matches that of typical flarepits in the area, which allows us to conclude with reasonable certainty that chlorides are the cause of anomalous conductivites.

The slightly elevated conductivity zone northeast of the lease was caused by an increase in soil moisture. The conductivity zone peaks at 65 mS/m and appears disconnected from the flarepit.



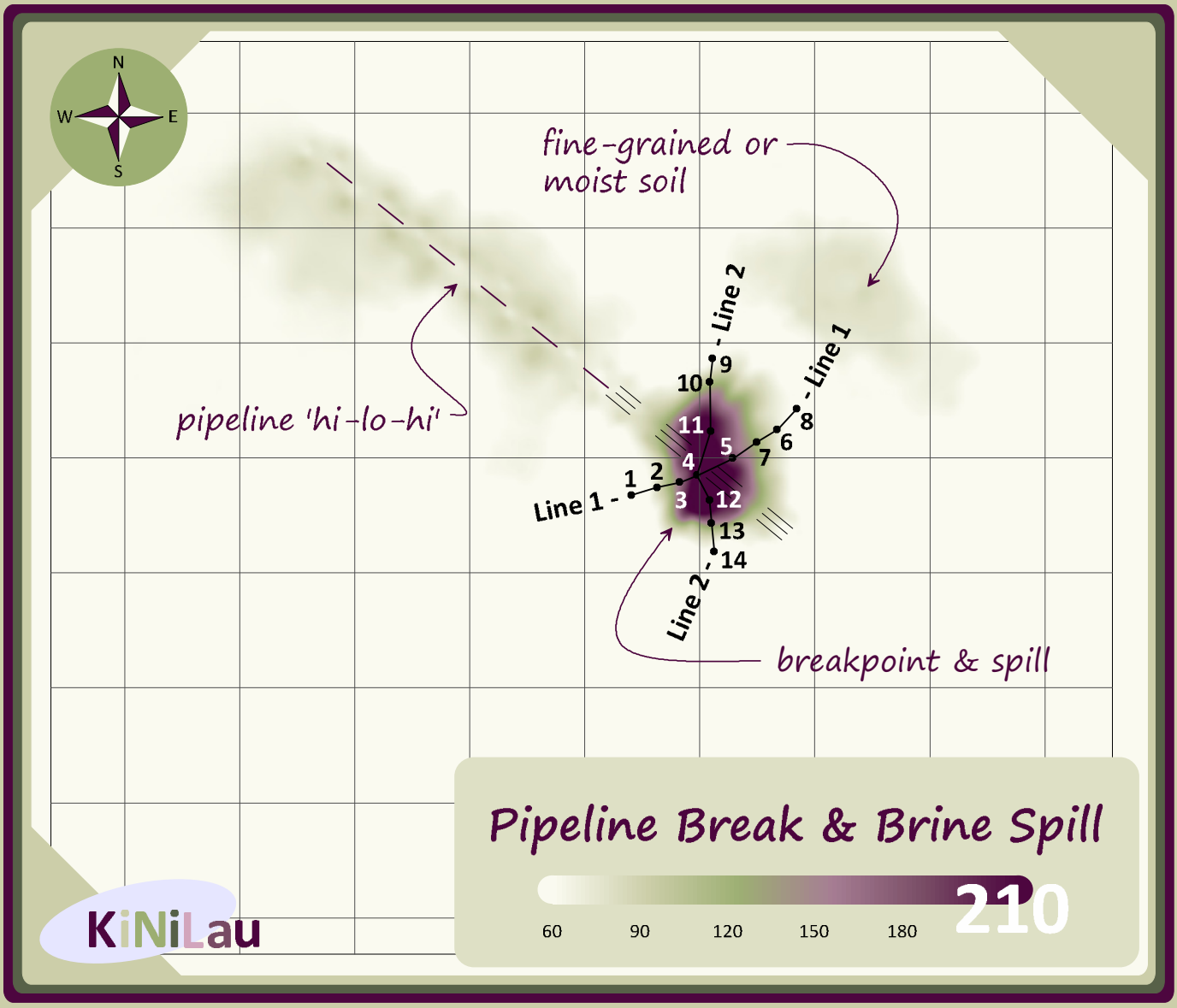


KiNiLau

Flarepit with Chlorides (VC) ... cont'd

In 3D conductivity surveys, VC profiles always target anomalous zones previously identified, usually by means of the lateral conductivity survey. Trace 3 was located to establish background conditions. Conductivities are low and increase gradually with depth, corresponding to an increase in soil moisture with depth. Trace 2, just outside the lateral anomalous conductivity zone, still reveals background conditions. The dynamic data range of Trace 2 is low (meaning, the spread between the lowest and highest readings is small) enabling recognition of subtle conductivity variations that correspond to changes in stratigraphy.

Two stratigraphic layers come into view when establishing trend continuity among VC traces on Line 2. A 'low conductivity layer' corresponds to either a permeable unit washed clean of chlorides (usually on older sites) or an impermeable clay not yet penetrated by chlorides (often on newer sites). The 'chloride bounding interface' forms the bottom of an anomalous conductivity zone and perhaps corresponds to a bottom-sealing clay.



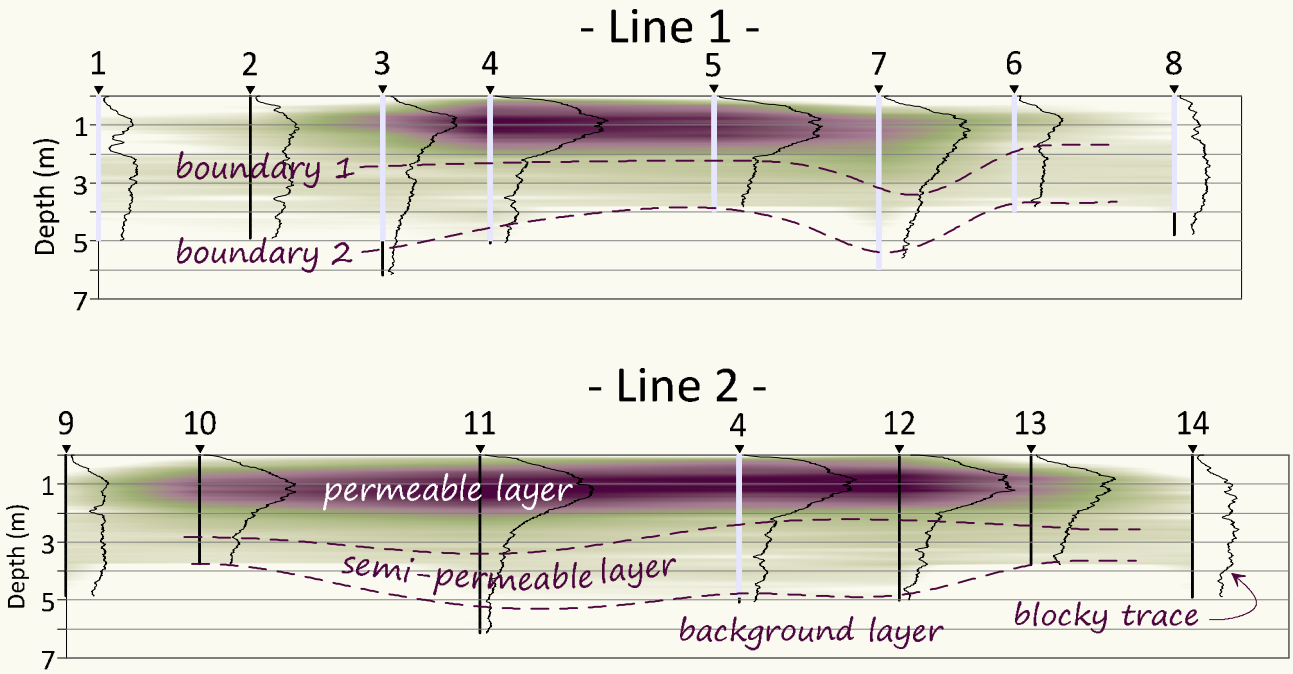
Pipeline Break & Brine Spill (EM31)

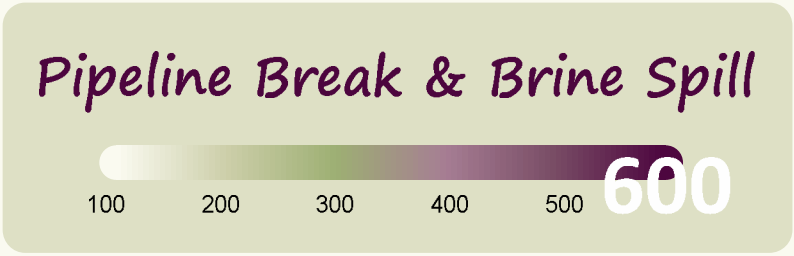
... see Vertical next page

Pipeline break points are identified by delineating their ensuing brine spill. Produced water spills may take off on adventurous paths to remote locations or remain localized, as in the above example. A plume's migratory path is simply a function of surrounding stratigraphic and soil conditions.

Peak response amplitudes near 210 mS/m leave no reasonable doubt that chlorides are involved. Sulfates are not likely to push conductivities to such high levels while it is, surely, theoretically possible.

'Hi-lo-hi' signatures are indicative of buried metal pipelines and a weakly elevated conductivity zone northeast of the main spill is probably caused by weak accumulations of moist or fine-grained soil.





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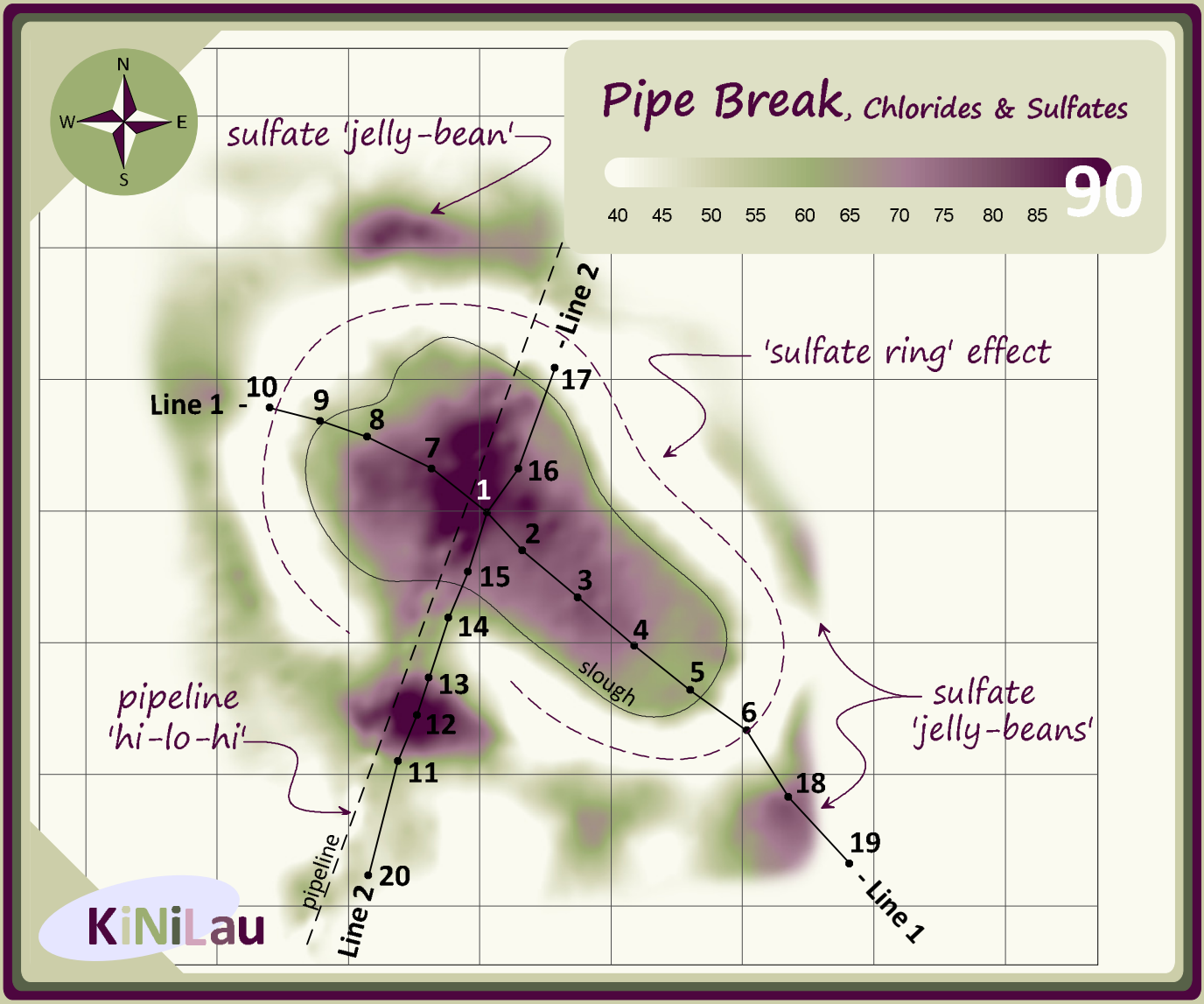
Pipeline Break & Brine Spill (VC) ... cont'd

Peak vertical conductivities near 600 mS/m further support the presence of chlorides since sulfates are not as likely to yield responses of such magnitude. Our confidence in having a proper understanding of the local soil geology grows with good trace-to-trace trend continuity revealing two stratigraphic boundaries in the vicinity of the pipeline breakpoint.

Boundary 1 represents the interface between a 2 m surficial permeable layer of high vertical conductivity and a 2 m thick semi-permeable layer of medium conductivity. Boundary 2 appears as chloride-binding interface, marking the transition from the semi-permeable layer to the background layer of low conductivity.

Note that vertical conductivity traces from within the chloride impacted region appear rounded, transitioning smoothly from peak to background. In contrast, VC background traces appear coarse and blocky, presenting an often reliable methodology for distinguishing between chloride impacted and natural soils.



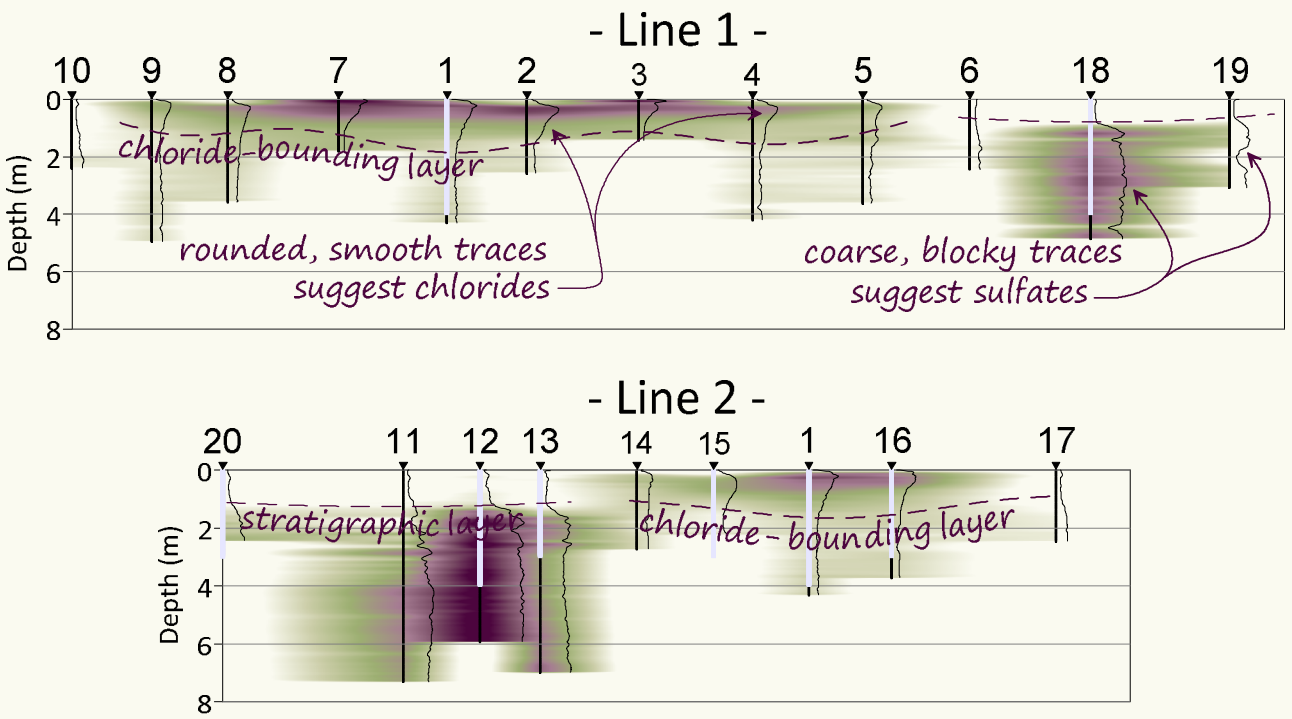
Pipe Break, Chlorides & Sulfates (EM31)

... see Vertical next page

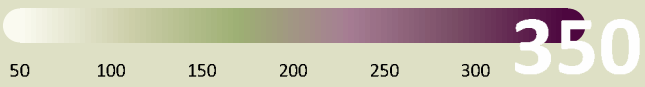
What makes this site unique is the combination of sulfates and chlorides causing anomalous soil conductivites. While response amplitudes near 90 mS/m could be caused by either sulfates or chlorides, 'jelly-bean' shaped background trends and a well defined 'sulfate-ring' strongly weigh in favour of sulfates.

Our field engineers have used other terms before to describe distinct conductivity trends of sulfate-laden soils such as 'radial', 'speckled' and 'finger-like'. Whatever shape, they tend to be repetitive unlike chloride plumes, which occur only once.

At this point nothing suggests the existence of chlorides, other than perhaps the typical 'hi-lo-hi' trend, which corresponds to a produced water carrying metal pipeline transecting the sulfate-laden slough. Let's see what the vertical conductivity tool reveals ...



Pipe Break, Chlorides & Sulfates



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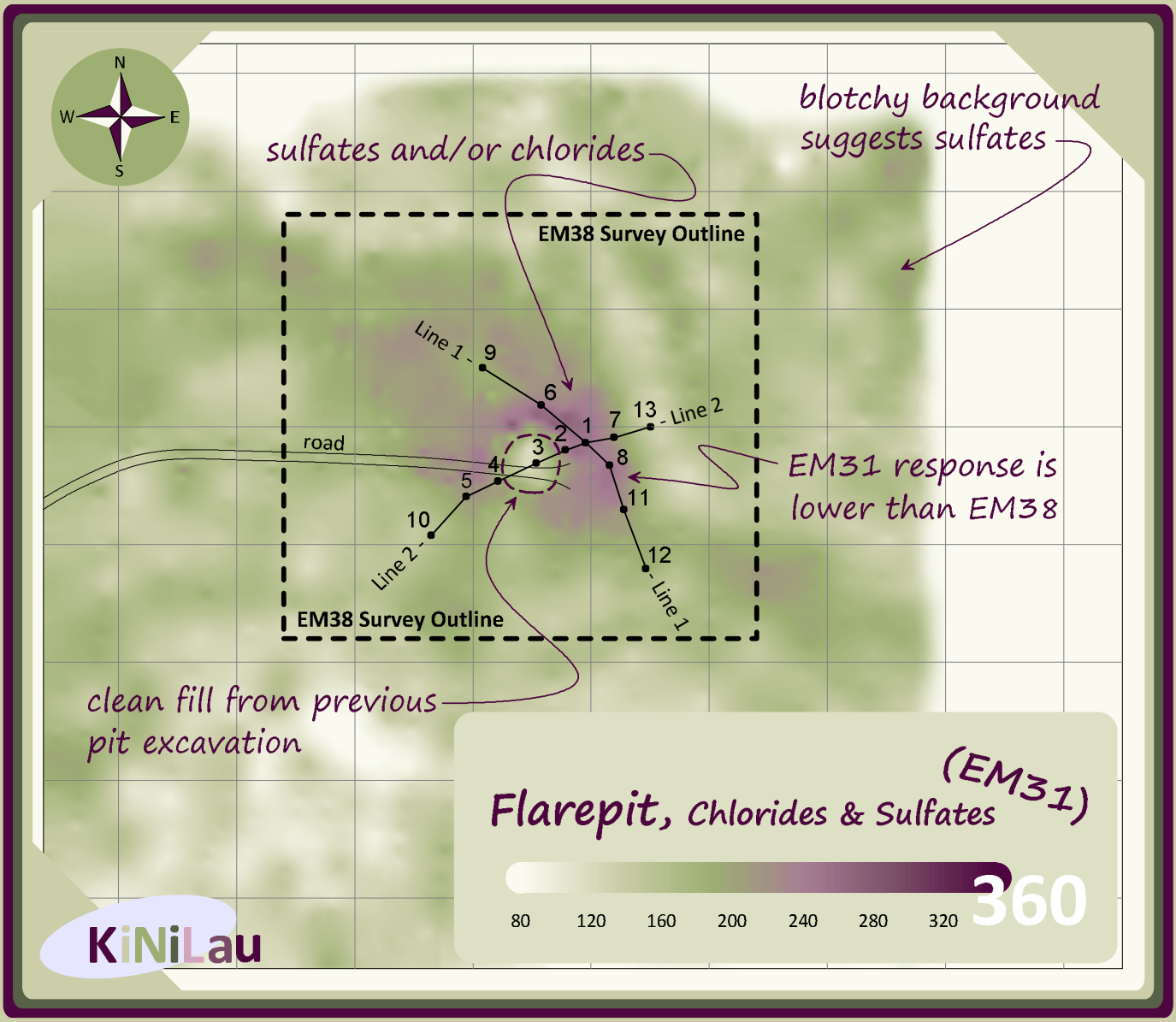
Pipe Break, Chlorides & Sulfates (VC) ... cont'd

Based on magnitude alone, peak conductivities near 350 mS/m could have been caused by either sulfates or chlorides ... or both. What makes differentiation possible are the unique VC Trace shapes typically exhibited by chloride and sulfate laden soils. Rounded, smooth traces typically correspond to chloride laden soils while coarse, blocky ones suggest the influence of sulfates.

Background traces 20, 11, 12 and 13 reveal the onset of a distinct stratigraphic layer near 2 m depth. A tight clay, this layer exhibits higher conductivity than the overlying layer comprised of a dry silt. VC Traces pushed within the slough appear rounded and smooth from surface to 2 m depth. This shape suggests chlorides and, consequently, the continuation of the tight clay below the slough in the form of a chloride-bounding layer.

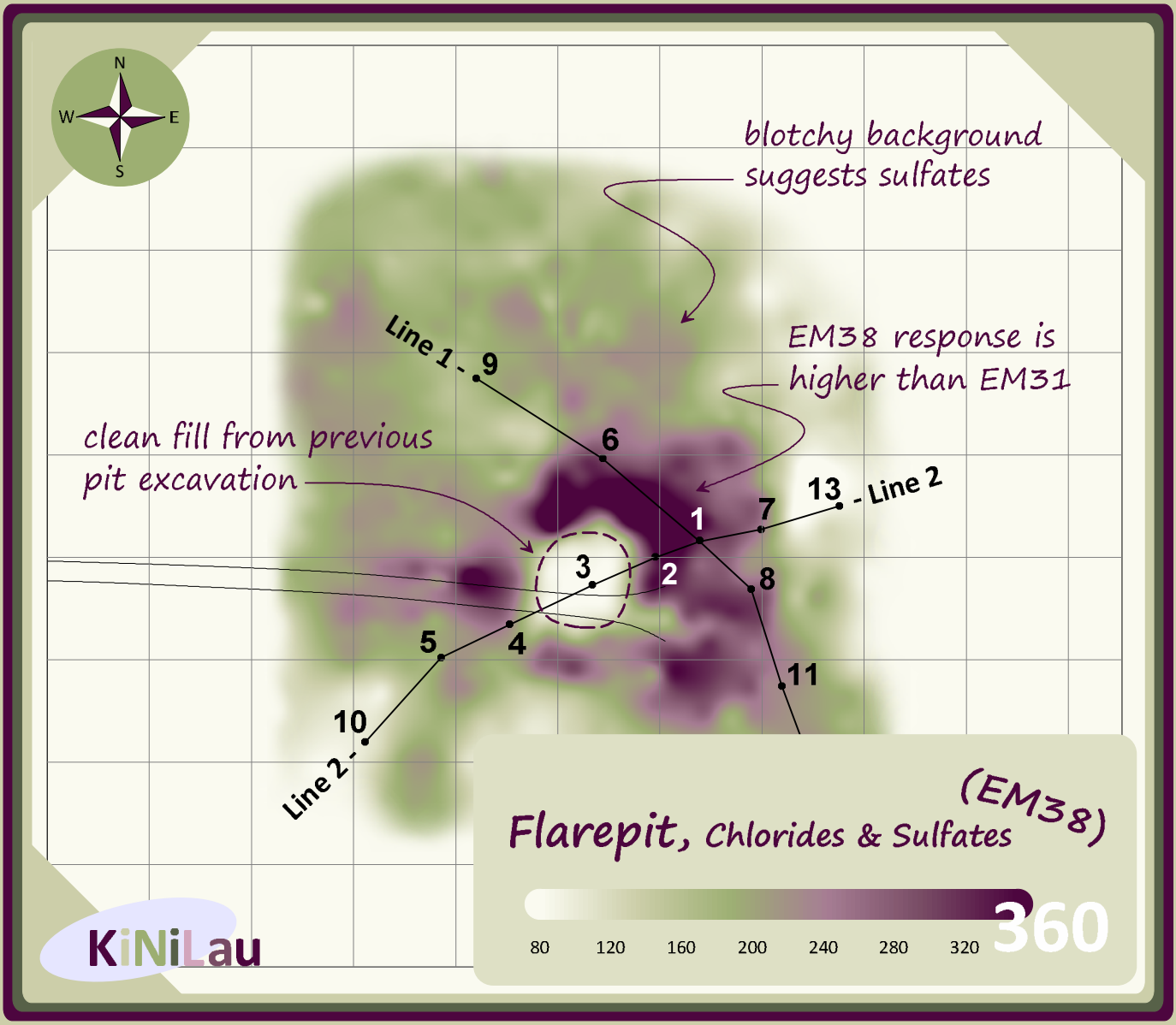


Flarepit, Chlorides & Sulfates (EM31)

... EM38 next page

The above 3D survey represents a previously reclaimed flarepit. Background conductivities exceed 200 mS/m with a typically 'blotchy' response pattern, which suggests an influence from naturally occurring sulfates. The reclaimed flarepit exhibits very low conductivity, a manifestation of a clean, low conductivity fill material used during remediation. EM31 conductivities near the flarepit exceed 240 mS/m, a response amplitude not often associated with sulfates.

Usually, no added benefit is realized by the application of both, the EM31 and EM38, during a 3D conductivity survey. The vertical conductivity technique far surpasses comparative and subjective depth information from any EM induction tool. Having an EM31, EM38 and vertical conductivity survey at hand for this site, provides a unique opportunity to compare depth interpretation methodologies for each technique. The black, dashed outline represents the survey extent of the follow-up EM38 survey.

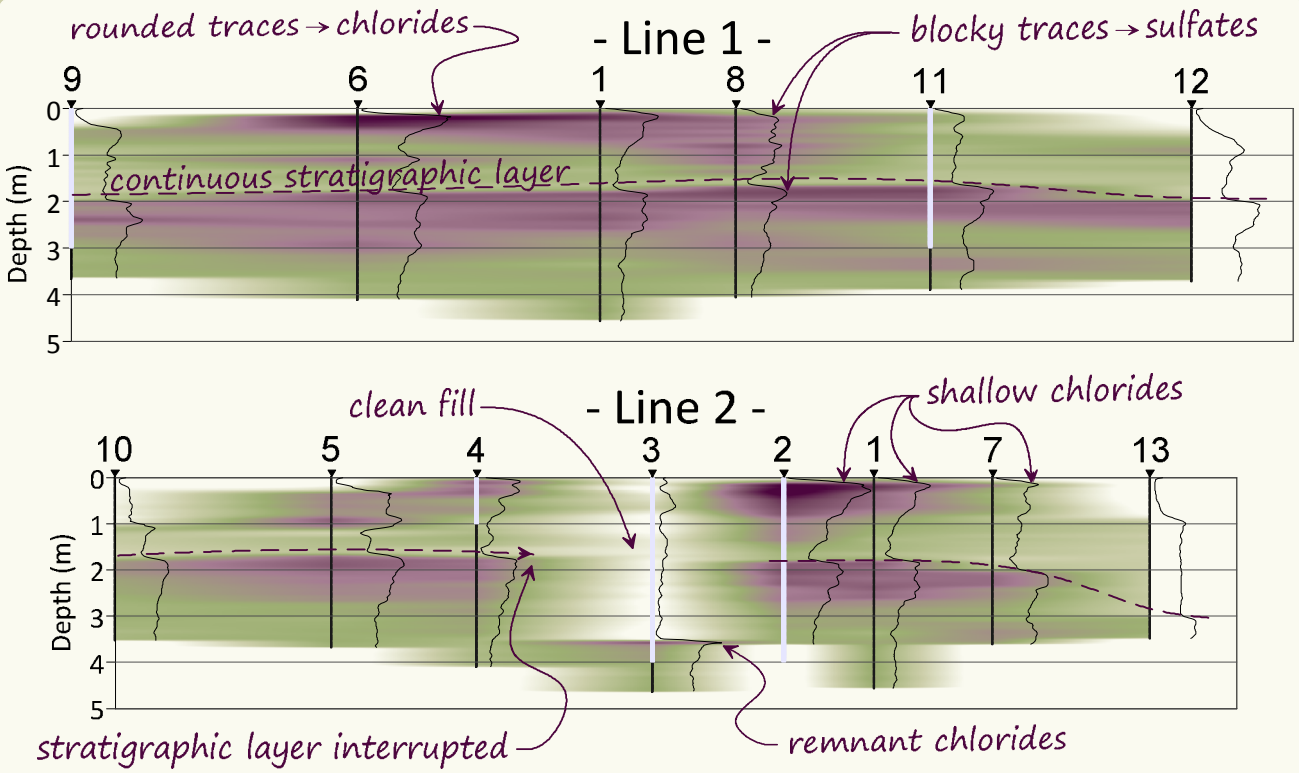


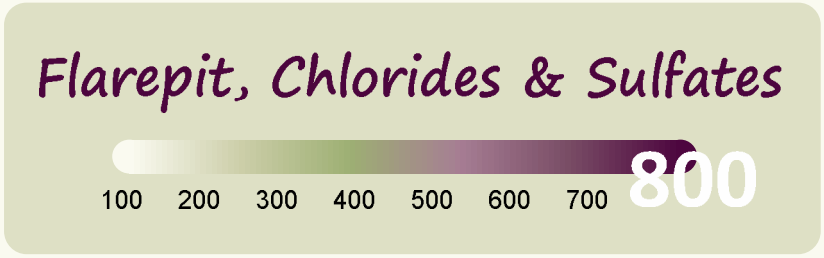
Flarepit, Chlorides & Sulfates (EM38)

... see Vertical next page

Compared to the previous EM31 detail, the EM38 reveals higher conductivities surrounding the flarepit. Since the EM38 has an intrinsically lesser skindepth than the EM31, one can interpret the main cause of anomalous response to have originated from 'shallower' depth, anywhere from surface to 2 m. Depth extent would be an unknown as would be the degree of contamination or chloride concentrations.

A more objective answer can not be provided since the induction technique inherently falls prey to theoretical factors such as skindepth, equivalence or thickness-conductivity product. Based on different technologies, the vertical conductivity technique does not suffer the same theoretical shortcomings and offers far more detailed and objective depth information.





KiNiLau

Flarepit, Chlorides & Sulfates (VC) ... cont'd

Traces 2, 1 and 7 of Line 2 confirm the initial comparative lateral conductivity interpretation that the cause of anomalous conductivities originates from 'shallower' depth; somewhere between surface and approximately 2 m. Amplitudes reach 800 mS/m, a magnitude usually associated with chlorides. From surface to 1 m depth VC Traces 6, 2, 1 and 7 are smooth and rounded, further suggesting chlorides over sulfates. While sulfate ions may cause high conductivity amplitudes, traces tend to be blocky and coarse in appearance. Generally, traces obtained from ion-free backgrounds exhibit similarly blocky signatures, albeit, at much lower conductivity.

A distinct conductivity spike on Trace 3 at 3.5 m depth suggests remnant chloride contamination. Clean fill is confirmed from surface to 3.5 m depth, exhibiting very low conductivities of less than 100 mS/m.

On Line 2, note the interruption of the stratigraphic layer by the intruding fill material. The VC image reflects that abrupt change, a testimonial to the stability of the image interpolation routine in those situations.

Appendix A
Conductivity Details

Appendix B

Instrument Specifications

EM31
GROUND CONDUCTIVITY METER with INPHASE CHANNEL

The EM31 measures the conductivity of the ground directly in mS/m. The EM31 also measures the inphase component of response, which is useful for detecting ferrous and non-ferrous buried material.

Two meters on the front panel of the EM31 simultaneously display conductivity and inphase response. Readings can be taken at successive survey stations, or continuously along the survey line.

Using the inductive method, the EM31 operates without the ground contact required by conventional resistivity. As a result, surveys can be done over highly resistive material, such as gravel or asphalt, at the pace of a walk.

Compared to resistivity surveys, EM31 surveys yield detailed, continuous data, with better resolution of small changes in conductivity. This enables the EM31 to identify subtle changes in conductivity that can be caused by contamination, and to delimit affected areas with precision.

Depth of exploration is about 6 m, which makes the EM31 suitable for many geotechnical and environmental applications.

The EM31 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements. The EM31 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM31 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. The EM31 can map conductive contamination of soil and groundwater, and simultaneously detect buried metal, which makes this instrument the ideal tool for site assessment. It is most commonly used during soil-salinity surveys.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone (905) 670-9580*

EM31 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing:	3.66 m
		Operating Frequency:	9.8 kHz
Primary Field Source (Tx):	Self-Contained Dipole Tx	Conductivity Ranges:	10-1000 mS/m
Receiver (Rx):	Self-Contained Dipole Rx		

EM38
GROUND CONDUCTIVITY METER with INPHASE CHANNEL

The EM38 measures the conductivity of the ground directly in mS/m. The EM38 also measures the inphase component of response, which enables it to be used as a metal detector or, for poorly to moderately conductive material, a magnetic-susceptibility meter.

The depth to which the EM38 measures conductivity depends solely on the orientation of the instrument. When the instrument is upright in vertical-dipole mode (as shown), depth of measurement is approximately 1.5m. With the instrument on its side, in horizontal-dipole mode, depth of measurement is approximately 0.75m. Readings are shown on digital meters which are mounted on the top and side of the EM38, for convenient reading regardless of the orientation of the instrument.

Using EM induction, the EM38 requires no contact with the ground. As a result, surveys can cover large areas rapidly. To survey at walking speed, a special handle allows the operator to carry the EM38 at ground level.

The EM38 is synchronized with DGPS instrumentation to simultaneously record positioning and geophysical measurements.

The EM38 is most commonly used during soil-salinity surveys, in both dry-land and irrigated areas. Compared to resistivity, EM38 surveys offer better lateral-resolution, and much faster coverage. The EM38 can be towed behind a skidoo or other vehicle to efficiently cover large terrain.

The EM38 can be applied to mapping ionic-contamination at a variety of site types including oil and gas, salt storage and waste-disposal. These applications make good use of the excellent spatial resolution of the EM38. The EM38 can also be used to identify shallow metallic objects.

**Technical information provided by Geonics Ltd., Mississauga, Canada. Phone(905) 670-9580*

EM38 SPECIFICATIONS

Measured Quantities:	Quadrature in mS/m Inphase in ppt, Hs/Hp	Intercoil Spacing:	1.0 m
		Operating Frequency:	14.6 kHz
Primary Field Source (Tx):	Self-Contained Dipole Tx	Conductivity Ranges:	10-1000 mS/m
Receiver (Rx):	Self-Contained Dipole Rx		

DATASHEET

GPS Pathfinder ProXT receiver

KEY FEATURES

- Real-time submeter GPS with integrated SBAS, and EVEREST multipath rejection technology
- Receiver, antenna, and battery in one compact unit
- Bluetooth wireless technology for totally cable-free operation
- Rugged and weatherproof for all conditions
- User-replaceable battery lasts a full day in the field
- Choice of field computer and software to suit your workflow

FULLY INTEGRATED BLUETOOTH GPS RECEIVER FOR SUBMETER ACCURACY

Purpose-built for GIS data collection, the GPS Pathfinder® ProXT™ receiver sets new standards for ease of use. A submeter GPS receiver, antenna, and all-day battery in one, the ProXT receiver is totally cable-free, making data collection more straightforward than ever before. Simple to set up and easy to use, we'll forgive you for taking its sophisticated technology for granted.

Accuracy you can depend on

The real test of a GPS receiver is the quality of the GPS data it produces. The ProXT receiver passes the test with flying colors, delivering consistent, reliable, submeter accuracy. The receiver's advanced design, and features like EVEREST™ multipath rejection technology let you work under canopy, in urban environments, or wherever accuracy is crucial.

If you need to be sure of your accuracy in the field, the integrated SBAS receiver or optional GeoBeacon™ receiver provides submeter accuracy in real time. For the very best results, postprocessing is easy with Trimble® GPS Pathfinder Office software or the GPS Analyst™ extension for ESRI ArcGIS software.

Cable-free convenience

Forget lost or tangled cables: with a Bluetooth® wireless connection, you are cable free between the ProXT receiver and your field computer. No more snagging as you get in and out of vehicles or move through difficult terrain. Snap it onto the convenient belt clip and you're ready to go anywhere. You can mount it on your vehicle for data collection on the move, clip it to a range pole when accuracy is critical, or even use it on a backpack. It's quick and easy to mount the ProXT receiver to suit the job at hand.

All day, every day

The receiver has an integrated battery, good for a full day's work; simply charge the battery overnight and you're ready to go again. The ProXT receiver will last the distance, and its rugged design can take a lot of punishment. Rain, hail, or shine, it's built to keep working, whatever the environment throws at you.

Options to suit your workflow

You can choose a field computer and software to suit your workflow. The ProXT receiver is ready to use with a variety of field computers, including laptops, Tablet PCs, and PDAs, and of course with Trimble's own rugged field computers: the Trimble Recon® handheld and the Trimble Ranger™ handheld.

Choosing software? Trimble's TerraSync™ software or the GPScorrect™ extension for ESRI ArcPad software provides a complete solution from field to office and back. Choose any off-the-shelf GPS field software, or use the GPS Pathfinder Tools Software Development Kit (SDK) to build an application that's customized to your needs.

Designed for the GIS professional

The high performance GPS Pathfinder ProXT receiver is purpose built for serious GIS data collection. No cables. No hassles. Just reliable submeter GPS accuracy from a system designed to work where you work.

Trimble

GPS Pathfinder ProXT receiver

STANDARD FEATURES

GPS

- Integrated GPS/SBAS[1] receiver and antenna
- Submeter accuracy in real-time
- EVEREST multipath rejection technology
- RTCM input
- NMEA and TSIP protocol support

System

- Integrated GPS receiver, antenna and battery
- Integrated Bluetooth wireless technology
- User replaceable all-day battery
- Wearable GPS receiver with ergonomic belt clip
- Rugged weatherproof housing

Software

- GPS Controller software for mission planning and GPS configuration
- Bluetooth deactivation utility

Accessories

- Power supply with international adapter kit
- Ergonomic belt clip
- Screwthread adaptor for range pole, backpack, or vehicle mounting
- Null modem cable
- User Guide

OPTIONAL FEATURES

Software

- TerraSync software
- Trimble GPScorrect extension for ESRI ArcPad software
- Custom applications built with the GPS Pathfinder Tools Software Development Kit (SDK)
- GPS Pathfinder Office software
- Trimble GPS Analyst extension for ESRI ArcGIS software

Field computers

- Field computer running Microsoft® Windows Mobile® version 5.0 software or Windows Mobile 2003 software for Pocket PCs, such as:
  - Trimble Ranger handheld
  - Trimble Recon handheld
- Field computer running Microsoft Windows® desktop operating system

Accessories

- GeoBeacon receiver
- 1 foot pole (for backpack mounting)
- Range pole bracket
- External patch antenna
- Hard carry case
- Magnetic vehicle mount
- Backpack
- 2 meter range pole
- Hurricane antenna kit
- Baseball cap with patch antenna pocket
- Serial port splitter cable

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TECHNICAL SPECIFICATIONS

Physical

Integrated GPS receiver, antenna, and battery

Size	10.6 cm × 4.0 cm × 14.6 cm (4.2 in × 1.6 in × 5.75 in)
Weight	0.53 kg (1.16 lb)
Power	
Low (GPS only)	0.8 Watts
Normal (GPS and Bluetooth)	1.0 Watt
Battery	User replaceable lithium-ion, chargeable in unit 12.6 Watt hours

Environmental

Temperature	
Operating	–20 °C to +60 °C (–4 °F to +140 °F)
Storage	–30 °C to +85 °C (–22 °F to +185 °F)
Humidity	99% non-condensing
Casing	Wind-driven rain and dust-resistant per IP 54 standard
Drop	1.22 m (4 ft), MIL-STD-810F, Method 516.5, Procedure IV
Vibration	Vibration resistant, MIL-STD-810F, Method 514.5, Procedure I
Shock	Shock resistant, MIL-STD-810F, Method 516.5, Procedure I

Input/output

Serial	Dual port in single DE9
Bluetooth[2]	2 NMEA/TSIP Serial Port (SPP) services
Interface	Power button, 3 status LEDs

GPS

Channels	12 (L1 code and carrier)
Integrated real-time	SBAS[1]
Update rate	1 Hz
Time to first fix	30 seconds (typical)
Protocols	TSIP, NMEA (GGA, VTG, GLL, GSA, ZDA, GSV, RMC)

Accuracy (HRMS)[3] after differential correction

Code postprocessed	Submeter
Carrier postprocessed[4]	
With 5 minutes tracking satellites	30 cm
With 10 minutes tracking satellites	20 cm
With 20 minutes tracking satellites	10 cm
With 45 minutes tracking satellites	1 cm
Real-time (SBAS[1] or external RTCM source)	Submeter

1 SBAS (Satellite Based Augmentation System). Includes WAAS (Wide Area Augmentation System) available in North America only. And EGNOS (European Geostationary Navigation Overlay System) available in Europe only.

2 Bluetooth type approvals are country specific. The GPS Pathfinder ProXT receiver has Bluetooth approval in the U.S. and EU. For other countries please consult your local Distributor.

3 Horizontal Root Mean Squared accuracy. Requires data to be collected with minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 39 dBHz, minimum elevation of 15 degrees, and reasonable multipath conditions. Ionospheric conditions, multipath signals or obstruction of the sky by buildings or heavy tree canopy may degrade precision by interfering with signal reception. Accuracy varies with proximity to base station by +1 ppm for postprocessing and real-time.

4 Accuracy varies with proximity to base station by +5 ppm. 45 minute carrier capability applies only to GPS Pathfinder Office software.

Specifications subject to change without notice.

Bluetooth®

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DATASHEET

GPS Pathfinder Office software

KEY FEATURES

Differentially correct to improve the quality of your GPS data

H-Star data processing for high accuracy with the GPS Pathfinder ProXRT and ProXH receivers, or the GeoXH handheld

Import and export data in a variety of GIS formats

Create sophisticated data dictionaries to match your GIS or database

Carry out quality control on your data before you transfer it to the GIS

CARRY OUT QUALITY CONTROL ON YOUR DATA BEFORE YOU TRANSFER IT TO THE GIS

The GPS Pathfinder® Office software adds value to your GIS data collection and data maintenance projects. This powerful and easy-to-use software ensures your data is consistent, reliable, and accurate—enabling you to make informed decisions.

Improve the accuracy of your GPS data

The differential correction process can improve the accuracy of your GPS positions from around 10 meters[1] to submeter and better, depending on the environment and your GPS receiver. Using Trimble's established H-Star™ technology you can now achieve decimeter accuracy with the GPS Pathfinder ProXRT receiver and GeoXH™ 2008 series handheld (using an optional Zephyr™ external antenna).

Make sure that your data is differentially corrected using the best quality base station data available with GPS Pathfinder Office software's unique Integrity Index grading system. Providing a list of monitored base data providers from around the world, the Integrity Index helps you select quality providers to use when differentially correcting your data.

Increase the efficiency of your field work

Data can be imported from a number of GIS and database formats allowing previously collected GIS data to be taken back to the field for verification and update.

The GPS Pathfinder Office software's Data Dictionary Editor creates custom lists of features and attributes for data collection. You can be confident that data collected in the field meets your specific GIS needs by creating your own data dictionary or importing one from your GIS based on its exact data schema. In the field, the data dictionary prompts the field crew to enter specific information—ensuring data integrity and compatibility with your GIS or database. You can also create waypoint files to enhance productivity in the field.

Ensure you have quality data

You can view your features for comparison against any number of background files such as aerial photographs or satellite imagery of the area you are working in. You can even display and use background data directly from a web map server.

Before transferring your data to a GIS, CAD, or database system, you can analyze it to confirm it is complete and free of errors. GIS feature and attribute data can be changed, and unnecessary or unwanted GPS positions can be deleted. This ensures that only the highest quality data is exported to your GIS.

GPS Pathfinder Office software—making it easy for you to manage, correct, and update your GIS data.

1 Typical autonomous GPS accuracy.

Trimble

GPS Pathfinder Office software

FEATURES AND OPTIONS

GPS accuracy
- Improve GPS position accuracy through differential postprocessing
- Achieve from subfoot to decimeter accuracy using postprocessed H-Star technology[1]
- Postprocess real-time differential GPS data to improve accuracy and consistency
- Review and edit GPS data before you transfer it to a GIS
- Compatible with any Trimble® GPS Pathfinder receiver, any GeoExplorer® series, Trimble Nomad™ G series, or Juno™ series handheld, or with Trimble Yuma™ rugged tablet computer

GIS compatibility
- Import data from popular GIS, CAD, and database formats
- Export data into a wide variety of GIS, CAD, and database formats
- Create data dictionaries to ensure data collected is consistent with GIS requirements

Workflow
- Use waypoints to plan GPS field sessions to ensure productive use of field time
- Set up multiple field computers with the same files and settings
- Automate data transfer, differential correction, and data export

Available languages
- Chinese (Simplified)
- English
- French
- Spanish
- German
- Italian
- Japanese
- Korean
- Portuguese
- Russian

Field software options
- TerraSync™ software
- Trimble GPScorrect™ extension for ESRI ArcPad software
- Applications developed using GPS Pathfinder Tools Software Development Kit (SDK)

RECOMMENDED PLATFORM

Operating system. . . . . .Windows® 2000,Windows XP (Home, Professional[2], or Tablet PC Edition) (32- or 64-bit versions) Windows Server 2003 or Windows Vista® (Home thru Enterprise Editions) (32- or 64-bit versions)
Processor type . . . . . Pentium
Free disk space. . . . . .270 MB
Input/output. . . . . .RS-232 serial port and USB port

GPS RECEIVERS AND ACCURACY (HRMS)[3] SPECIFICATIONS

Typical autonomous accuracy for all GPS receivers is around 10 meters. The following table shows differentially corrected accuracy specifications for supported receivers:

Receiver/Handheld	Postprocessed
GPS Pathfinder ProXRT receiver	10–20 cm[4]
GPS Pathfinder Pro XRS receiver	50 cm
GPS Pathfinder ProXH™ receiver	submeter / subfoot[4]
GPS Pathfinder ProXT™ receiver	submeter
GeoXH handheld	submeter / subfoot[4] / decimeter[5]
GeoXT™ handheld	submeter
GeoXM™ handheld	1–3 m
Juno series handheld	2–5 m
Trimble Nomad G series handheld	2–5 m
GPS Pathfinder XB receiver	2–5 m
Trimble Recon® GPS XB edition	2–5 m
GPS Pathfinder XC receiver	2–5 m
Trimble Recon GPS XC edition	2–5 m
Trimble Yuma rugged tablet computer	2–5 m

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PN 13269R (05/09)

SUPPORTED FORMATS

Import formats
- AutoCAD 2000 ASCII DXF
- dBASE
- ESRI Shapefiles
- MapInfo MIF
- Microsoft Access MDB

Export formats
- ARC/INFO (for NT and UNIX) Generate
- AutoCAD 2000 ASCII DXF (with or without blocks)
- dBASE
- ESRI Shapefiles
- GRASS
- IDRISI Vector
- MapInfo MIF
- MGAL
- Microsoft Access MDB
- Microstation version 7 DGN
- PC-ARC/INFO Generate
- PC-MOSS

Vector background formats
- AutoCAD 2000 ASCII and binary DXF (.dxf)
- ESRI Shapefiles (.shp)
- Trimble SSF format (.ssf, .cor, .imp, .phs, .wpt)

Raster (image) background formats
- JPEG (.jpg)
- JPEG 2000 (.jp2, .j2c)
- Enhanced Compression Wavelet (.ecw)
- MrSID (.sid)
- TIFF (.tif)
- Windows bitmap (.bmp)

Web map servers
- ArcIMS
- OpenGIS

SUPPORTED BASE FILE AND COMPRESSION FORMATS

Base file formats
- Hatanaka (Compressed RINEX)
- RINEX
- Trimble DAT format
- Trimble SSF format

Compression types
- GZip (.gz)
- Self-extracting executable (.exe)
- Zip (.zip)

1 Dependent on H-Star-capable receiver and antenna combination, and correction source used.
2 Windows XP Professional x64 Edition is not supported.
3 Horizontal Root Mean Squared accuracy. Requires data to be collected with minimum of 4 satellites, maximum PDOP of 6, minimum SNR of 39 dBHz, minimum elevation of 15 degrees, and reasonable multipath conditions. For the Juno series, Trimble Nomad G series, Trimble Yuma tablet, or GPS Pathfinder XB or XC receivers, data must be collected using maximum PDOP of 99, minimum SNR of 12 dBHz, and minimum elevation of 5 degrees, under reasonable multipath conditions. The Trimble Nomad G series and GPS Pathfinder XB or XC receivers must be horizontally mounted; the Juno SB and SC handhelds must be vertically mounted. Ionospheric conditions, multipath signals or obstruction of the sky by buildings or heavy tree canopy may degrade precision by interfering with signal reception. Accuracy varies with proximity to reference station by +1 ppm for postprocessing and real-time.
4 H-Star specified accuracy is typically achieved within 2 minutes. Requires a minimum of three good quality dual frequency reference stations within 200 km, or one good quality dual frequency reference station within 80 km. With one reference station accuracy degrades at +1 ppm beyond 80 km. The ProXH receiver achieves 20 cm postprocessed accuracy with the optional Zephyr external antenna.
5 GeoXH 2008 series with optional Zephyr external antenna.

Specifications subject to change without notice.

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Appendix D Laboratory Analysis

Maxxam

Your P.O. #: 16300R-40
Your Project #: 110218745
Site Location: MALLIK/INUVIK NWT
NSD # 16300NR
Your C.O.C. #: A043727

Attention: OLIVIER PIRAUX
STANTEC CONSULTING LTD
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2012/09/17

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B280550
Received: 2012/09/10, 10:52

Sample Matrix: Soil
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Cation/EC Ratio	1	N/A	2012/09/14		CALCULATION
Chloride (Soluble)	1	2012/09/14	2012/09/14	AB SOP-00020	EPA 325.2
Conductivity @25C (Soluble)	1	2012/09/14	2012/09/14	AB SOP-00004	SSMA 15.3
Ion Balance	1	N/A	2012/09/14	AB WI-00065	SM 1030E
Sum of Cations, Anions	1	N/A	2012/09/14	AB WI-00065	SM 1030E
Moisture	1	N/A	2012/09/11	AB SOP-00002	CCME PHC-CWS
pH @25C (1:2 Calcium Chloride Extract)	1	2012/09/11	2012/09/11	AB SOP-00006	SSMA 16.3
Particle Size by Sieve (75 micron)	1	N/A	2012/09/11	EENVSOP-00077	SSMA 55.4
Sodium Adsorption Ratio	1	N/A	2012/09/14	AB WI-00065	SSMA 15.4.4
Ca,Mg,Na,K,SO4 (Soluble)	1	2012/09/14	2012/09/14	AB SOP-00042	EPA 200.7
Soluble Paste	1	2012/09/14	2012/09/14	AB SOP-00033	SSMA 15.2
Soluble Ions Calculation	1	N/A	2012/09/11		CALCULATION
Theoretical Gypsum Requirement (1)	1	N/A	2012/09/14	CAL WI-00087	CJSS 79:449-455

Sample Matrix: Water
Samples Received: 8

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity @25C (pp, total), CO3,HCO3,OH	8	N/A	2012/09/11	AB SOP-00005	SM 2320-B
Chloride by Automated Colourimetry	8	N/A	2012/09/12	AB SOP-00020	EPA 325.2
Conductivity @25C	8	N/A	2012/09/11	AB SOP-00005	SM 2510-B
Hardness	8	N/A	2012/09/17	AB WI-00065	SM 2340B
Elements by ICP - Dissolved	5	N/A	2012/09/14	AB SOP-00042	EPA 200.7
Elements by ICP - Dissolved	3	N/A	2012/09/15	AB SOP-00042	EPA 200.7
Ion Balance	8	N/A	2012/09/17	AB WI-00065	SM 1030E
Sum of cations, anions	8	N/A	2012/09/17	AB WI-00065	SM 1030E
Nitrate and Nitrite	8	N/A	2012/09/14	AB SOP-00023	SM4110B
Nitrate + Nitrite-N (calculated)	8	N/A	2012/09/14	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC	8	N/A	2012/09/11	AB SOP-00023	SM 4110-B
pH @25°C (Alkalinity titrator)	8	N/A	2012/09/11	AB SOP-00005	SM 4500-H+B
Sulphate by Automated Colourimetry	8	N/A	2012/09/12	AB SOP-00018	EPA 375.4
Total Dissolved Solids (Calculated)	8	N/A	2012/09/17	AB WI-00065	SM 1030E

../2

Maxxam

Your P.O. #: 16300R-40
Your Project #: 110218745
Site Location: MALLIK/INUVIK NWT
NSD # 16300NR
Your C.O.C. #: A043727

Attention: OLIVIER PIRAUX
STANTEC CONSULTING LTD
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2012/09/17

CERTIFICATE OF ANALYSIS

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) Units for TGR have changed from tons/acre to tonnes/ha

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Jeremy Wakaruk, B.Sc., Senior Project Manager
Email: JWakaruk@maxxam.ca
Phone# (780) 577-7105 Ext:7105

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone(780)577-7100 Fax(780)450-4187

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		EK5471		EK5475		EK5476		
Sampling Date		2012/09/05 10:00		2012/09/05 13:15		2012/09/05 11:00		
COC Number		A043727		A043727		A043727		
	UNITS	**MALLIK2012 WS01**	**RDL**	**MALLIK2012 WS02**	**RDL**	**MALLIK2012 WS03**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	130	N/A	46	N/A	90	N/A	6152850
Cation Sum	meq/L	130	N/A	44	N/A	88	N/A	6152850
Hardness (CaCO3)	mg/L	1900	0.50	1100	0.50	1500	0.50	6152848
Ion Balance	N/A	1.0	0.010	0.97	0.010	0.98	0.010	6152849
Dissolved Nitrate (NO3)	mg/L	0.48	0.013	0.19	0.013	<0.013	0.013	6152851
Nitrate plus Nitrite (N)	mg/L	0.11	0.0030	0.049	0.0030	<0.0030	0.0030	6152852
Dissolved Nitrite (NO2)	mg/L	0.014	0.0099	0.018	0.0099	<0.0099	0.0099	6152851
Total Dissolved Solids	mg/L	7600	10	2900	10	5200	10	6152853
Misc. Inorganics								
Conductivity	uS/cm	14000	1.0	5600	1.0	9300	1.0	6156382
pH	N/A	7.61	N/A	7.55	N/A	7.95	N/A	6156381
Anions								
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Alkalinity (Total as CaCO3)	mg/L	240	0.50	220	0.50	150	0.50	6156380
Bicarbonate (HCO3)	mg/L	290	0.50	270	0.50	180	0.50	6156380
Carbonate (CO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Dissolved Sulphate (SO4)	mg/L	600 (1)	5.0	520 (1)	5.0	600 (1)	5.0	6159749
Dissolved Chloride (Cl)	mg/L	3800 (1)	20	1100 (1)	10	2600 (1)	20	6159746
Nutrients								
Dissolved Nitrite (N)	mg/L	0.0043	0.0030	0.0054	0.0030	<0.0030	0.0030	6156894
Dissolved Nitrate (N)	mg/L	0.11	0.0030	0.043	0.0030	<0.0030	0.0030	6156894
Elements								
Dissolved Calcium (Ca)	mg/L	390	0.30	330	0.30	300	0.30	6168361
Dissolved Iron (Fe)	mg/L	0.079	0.060	<0.060	0.060	0.074	0.060	6168361
Dissolved Magnesium (Mg)	mg/L	220	0.20	55	0.20	180	0.20	6168361
Dissolved Manganese (Mn)	mg/L	0.16	0.0040	0.23	0.0040	0.025	0.0040	6168361
Dissolved Potassium (K)	mg/L	820 (1)	3.0	600 (1)	3.0	83	0.30	6168361
Dissolved Sodium (Na)	mg/L	1600 (1)	5.0	180	0.50	1300 (1)	5.0	6168361

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		EK5477		EK5478		EK5479		
Sampling Date		2012/09/05 13:15		2012/09/05 12:00		2012/09/05 12:00		
COC Number		A043727		A043727		A043727		
	UNITS	**MALLIK2012 WS04**	**RDL**	**MALLIK2012 WS05**	**RDL**	**MALLIK2012 WS06**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	110	N/A	250	N/A	44	N/A	6152850
Cation Sum	meq/L	100	N/A	250	N/A	47	N/A	6152850
Hardness (CaCO3)	mg/L	1200	0.50	5300	0.50	580	0.50	6152848
Ion Balance	N/A	1.0	0.010	1.0	0.010	1.1	0.010	6152849
Dissolved Nitrate (NO3)	mg/L	<0.066	0.066	32	0.013	<0.013	0.013	6152851
Nitrate plus Nitrite (N)	mg/L	<0.015	0.015	7.3	0.0030	<0.0030	0.0030	6152852
Dissolved Nitrite (NO2)	mg/L	<0.049	0.049	0.076	0.0099	<0.0099	0.0099	6152851
Total Dissolved Solids	mg/L	6000	10	16000	10	2600	10	6152853
Misc. Inorganics								
Conductivity	uS/cm	11000	1.0	26000	1.0	5100	1.0	6156382
pH	N/A	8.25	N/A	7.81	N/A	8.27	N/A	6156381
Anions								
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Alkalinity (Total as CaCO3)	mg/L	270	0.50	170	0.50	230	0.50	6156380
Bicarbonate (HCO3)	mg/L	330	0.50	210	0.50	280	0.50	6156380
Carbonate (CO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	6156380
Dissolved Sulphate (SO4)	mg/L	310 (1)	5.0	1500 (1)	20	74	1.0	6159893
Dissolved Chloride (Cl)	mg/L	3300 (1)	20	7700 (1)	50	1300 (1)	20	6159884
Nutrients								
Dissolved Nitrite (N)	mg/L	<0.015 (2)	0.015	0.023	0.0030	<0.0030	0.0030	6156894
Dissolved Nitrate (N)	mg/L	<0.015 (2)	0.015	7.3	0.0030	<0.0030	0.0030	6156894
Elements								
Dissolved Calcium (Ca)	mg/L	150	0.30	1500 (1)	3.0	88	0.30	6168361
Dissolved Iron (Fe)	mg/L	0.064	0.060	0.082	0.060	<0.060	0.060	6168361
Dissolved Magnesium (Mg)	mg/L	190	0.20	400	0.20	88	0.20	6168361
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	0.25	0.0040	0.018	0.0040	6168361
Dissolved Potassium (K)	mg/L	67	0.30	2800 (1)	3.0	24	0.30	6168361
Dissolved Sodium (Na)	mg/L	1800 (1)	5.0	1800 (1)	5.0	800 (1)	5.0	6168361

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to matrix interference.

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

ROUTINE WATER (WATER)

Maxxam ID		EK5480		EK5481		
Sampling Date		2012/09/05 12:45		2012/09/05 12:30		
COC Number		A043727		A043727		
	UNITS	**MALLIK2012 WS07**	**RDL**	**MALLIK2012 WS08**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	72	N/A	58	N/A	6152850
Cation Sum	meq/L	76	N/A	61	N/A	6152850
Hardness (CaCO3)	mg/L	1200	0.50	620	0.50	6152848
Ion Balance	N/A	1.1	0.010	1.0	0.010	6152849
Dissolved Nitrate (NO3)	mg/L	0.52	0.013	0.29	0.066	6152851
Nitrate plus Nitrite (N)	mg/L	0.12	0.0030	0.10	0.015	6152852
Dissolved Nitrite (NO2)	mg/L	<0.0099	0.0099	0.11	0.049	6152851
Total Dissolved Solids	mg/L	4200	10	3300	10	6152853
Misc. Inorganics						
Conductivity	uS/cm	8200	1.0	6700	1.0	6156382
pH	N/A	8.18	N/A	8.46	N/A	6156381
Anions						
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	5.8	0.50	6156380
Alkalinity (Total as CaCO3)	mg/L	290	0.50	240	0.50	6156380
Bicarbonate (HCO3)	mg/L	360	0.50	280	0.50	6156380
Carbonate (CO3)	mg/L	<0.50	0.50	6.9	0.50	6156380
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	6156380
Dissolved Sulphate (SO4)	mg/L	310 (1)	5.0	39	1.0	6159893
Dissolved Chloride (Cl)	mg/L	2100 (1)	50	1900 (1)	25	6159884
Nutrients						
Dissolved Nitrite (N)	mg/L	0.0030	0.0030	0.033 (2)	0.015	6156894
Dissolved Nitrate (N)	mg/L	0.12	0.0030	0.067 (2)	0.015	6156894
Elements						
Dissolved Calcium (Ca)	mg/L	200	0.30	79	0.30	6168361
Dissolved Iron (Fe)	mg/L	0.097	0.060	<0.060	0.060	6168361
Dissolved Magnesium (Mg)	mg/L	160	0.20	100	0.20	6168361
Dissolved Manganese (Mn)	mg/L	0.16	0.0040	0.0061	0.0040	6168361
Dissolved Potassium (K)	mg/L	33	0.30	24	0.30	6168361
Dissolved Sodium (Na)	mg/L	1200 (1)	5.0	1100 (1)	5.0	6168361

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.
(2) Detection limits raised due to matrix interference.

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		EK5530		
Sampling Date		2012/09/05 13:00		
COC Number		A043727		
	UNITS	**MALLIK2012 SS01**	**RDL**	**QC Batch**
Calculated Parameters				
Anion Sum	meq/L	200	N/A	6154407
Cation Sum	meq/L	200	N/A	6154407
Cation/EC Ratio	N/A	9.2	0.10	6154405
Ion Balance	N/A	1.0	0.010	6154406
Calculated Calcium (Ca)	mg/kg	230	0.76	6152978
Calculated Magnesium (Mg)	mg/kg	62	0.51	6152978
Calculated Sodium (Na)	mg/kg	530	1.3	6152978
Calculated Potassium (K)	mg/kg	2400	0.66	6152978
Calculated Chloride (Cl)	mg/kg	3100	63	6152978
Calculated Sulphate (SO4)	mg/kg	490	2.5	6152978
Soluble Parameters				
Soluble Chloride (Cl)	mg/L	6200 (1)	130	6168404
Soluble Conductivity	dS/m	22	0.020	6167666
Soluble (CaCl2) pH	N/A	7.50	N/A	6156495
Sodium Adsorption Ratio	N/A	11	0.10	6154408
Soluble Calcium (Ca)	mg/L	460	1.5	6168718
Soluble Magnesium (Mg)	mg/L	120	1.0	6168718
Soluble Sodium (Na)	mg/L	1000	2.5	6168718
Soluble Potassium (K)	mg/L	4700	1.3	6168718
Saturation %	%	51	N/A	6167271
Soluble Sulphate (SO4)	mg/L	970	5.0	6168718
Theoretical Gypsum Requirement	tonnes/ha	<0.10	0.10	6154409

RDL = Reportable Detection Limit
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

RESULTS OF CHEMICAL ANALYSES OF SOIL

Maxxam ID		EK5530		
Sampling Date		2012/09/05 13:00		
COC Number		A043727		
	UNITS	**MALLIK2012 SS01**	**RDL**	**QC Batch**
Physical Properties				
Moisture	%	24	0.30	6156948
Sieve - Pan	%	98	0.20	6155529
Sieve - #200 (>0.075mm)	%	1.6	0.20	6155529
Grain Size	%	FINE	0.20	6155529

RDL = Reportable Detection Limit

Maxxam Job #: B280550
Report Date: 2012/09/17

STANTEC CONSULTING LTD
Client Project #: 110218745
Site Location: MALLIK/INUVIK NWT
Your P.O. #: 16300R-40
Sampler Initials: OP

General Comments

Results relate only to the items tested.

Maxxam

STANTEC CONSULTING LTD
Attention: OLIVIER PIRAUX
Client Project #: 110218745
P.O. #: 16300R-40
Site Location: MALLIK/INUVIK NWT

Quality Assurance Report

Maxxam Job Number: EB280550

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6155529	JF8	Method Blank	Sieve - Pan	2012/09/11	<0.20		%	
			Sieve - #200 (>0.075mm)	2012/09/11	<0.20		%	
		RPD	Sieve - Pan	2012/09/11	20.8		%	35
			Sieve - #200 (>0.075mm)	2012/09/11	6.1		%	35
6156380	CBE	Spiked Blank	Alkalinity (Total as CaCO3)	2012/09/11		97	%	80 - 120
		Method Blank	Alkalinity (PP as CaCO3)	2012/09/11	<0.50		mg/L	
			Alkalinity (Total as CaCO3)	2012/09/11	<0.50		mg/L	
			Bicarbonate (HCO3)	2012/09/11	<0.50		mg/L	
			Carbonate (CO3)	2012/09/11	<0.50		mg/L	
			Hydroxide (OH)	2012/09/11	<0.50		mg/L	
		RPD [EK5471-01]	Alkalinity (PP as CaCO3)	2012/09/11	NC		%	20
			Alkalinity (Total as CaCO3)	2012/09/11	0.2		%	20
			Bicarbonate (HCO3)	2012/09/11	0.2		%	20
			Carbonate (CO3)	2012/09/11	NC		%	20
			Hydroxide (OH)	2012/09/11	NC		%	20
6156381	CBE	Spiked Blank	pH	2012/09/11		100	%	97 - 103
		RPD [EK5471-01]	pH	2012/09/11	0.4		%	5
6156382	CBE	Spiked Blank	Conductivity	2012/09/11		100	%	90 - 110
		Method Blank	Conductivity	2012/09/11	<1.0		uS/cm	
		RPD [EK5471-01]	Conductivity	2012/09/11	0.07		%	20
6156495	LCA	QC Standard	Soluble (CaCl2) pH	2012/09/11		99	%	97 - 103
		Spiked Blank	Soluble (CaCl2) pH	2012/09/11		99	%	97 - 103
		RPD	Soluble (CaCl2) pH	2012/09/11	0.7		%	5
6156894	DPB	Matrix Spike	Dissolved Nitrite (N)	2012/09/11		98	%	80 - 120
			Dissolved Nitrate (N)	2012/09/11		96	%	80 - 120
		Spiked Blank	Dissolved Nitrite (N)	2012/09/11		101	%	80 - 120
			Dissolved Nitrate (N)	2012/09/11		100	%	90 - 110
		Method Blank	Dissolved Nitrite (N)	2012/09/11	<0.0030		mg/L	
			Dissolved Nitrate (N)	2012/09/11	<0.0030		mg/L	
		RPD	Dissolved Nitrite (N)	2012/09/11	NC		%	20
			Dissolved Nitrate (N)	2012/09/11	1.1		%	20
6156948	KH7	Method Blank	Moisture	2012/09/11	<0.30		%	
		RPD	Moisture	2012/09/11	13.9		%	20
6159746	BA3	Matrix Spike	Dissolved Chloride (Cl)	2012/09/12		NC	%	80 - 120
		Spiked Blank	Dissolved Chloride (Cl)	2012/09/12		100	%	80 - 120
		Method Blank	Dissolved Chloride (Cl)	2012/09/12	<1.0		mg/L	
		RPD	Dissolved Chloride (Cl)	2012/09/12	0.6		%	20
6159749	BA3	Matrix Spike	Dissolved Sulphate (SO4)	2012/09/12		NC	%	80 - 120
		Spiked Blank	Dissolved Sulphate (SO4)	2012/09/12		107	%	80 - 120
		Method Blank	Dissolved Sulphate (SO4)	2012/09/12	<1.0		mg/L	
		RPD	Dissolved Sulphate (SO4)	2012/09/12	3.8		%	20
6159884	BA3	Matrix Spike [EK5477-01]	Dissolved Chloride (Cl)	2012/09/12		NC	%	80 - 120
		Spiked Blank	Dissolved Chloride (Cl)	2012/09/12		92	%	80 - 120
		Method Blank	Dissolved Chloride (Cl)	2012/09/12	<1.0		mg/L	
		RPD [EK5477-01]	Dissolved Chloride (Cl)	2012/09/12	0.8 (1)		%	20
6159893	BA3	Matrix Spike [EK5477-01]	Dissolved Sulphate (SO4)	2012/09/12		NC	%	80 - 120
		Spiked Blank	Dissolved Sulphate (SO4)	2012/09/12		98	%	80 - 120
		Method Blank	Dissolved Sulphate (SO4)	2012/09/12	<1.0		mg/L	
		RPD [EK5477-01]	Dissolved Sulphate (SO4)	2012/09/12	0.3 (1)		%	20
6167271	LX	QC Standard	Saturation %	2012/09/14		101	%	93 - 107
		RPD	Saturation %	2012/09/14	0.8		%	12
6167666	LZ2	QC Standard	Soluble Conductivity	2012/09/14		106	%	85 - 115
		Spiked Blank	Soluble Conductivity	2012/09/14		100	%	90 - 110

STANTEC CONSULTING LTD
Attention: OLIVIER PIRAUX
Client Project #: 110218745
P.O. #: 16300R-40
Site Location: MALLIK/INUVIK NWT

Quality Assurance Report (Continued)

Maxxam Job Number: EB280550

QA/QC Batch Num	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	UNITS	QC Limits
6167666	LZ2	Method Blank	Soluble Conductivity	2012/09/14	<0.020		dS/m	
		RPD	Soluble Conductivity	2012/09/14	7.3		%	35
6168361	JK9	Matrix Spike	Dissolved Calcium (Ca)	2012/09/14		NC	%	80 - 120
			Dissolved Iron (Fe)	2012/09/14		99	%	80 - 120
			Dissolved Magnesium (Mg)	2012/09/14		NC	%	80 - 120
			Dissolved Manganese (Mn)	2012/09/14		95	%	80 - 120
			Dissolved Potassium (K)	2012/09/14		100	%	80 - 120
			Dissolved Sodium (Na)	2012/09/14		NC	%	80 - 120
		Spiked Blank	Dissolved Calcium (Ca)	2012/09/14		97	%	80 - 120
			Dissolved Iron (Fe)	2012/09/14		96	%	80 - 120
			Dissolved Magnesium (Mg)	2012/09/14		96	%	80 - 120
			Dissolved Manganese (Mn)	2012/09/14		98	%	80 - 120
			Dissolved Potassium (K)	2012/09/14		96	%	80 - 120
			Dissolved Sodium (Na)	2012/09/14		98	%	80 - 120
		Method Blank	Dissolved Calcium (Ca)	2012/09/15	<0.30		mg/L	
			Dissolved Iron (Fe)	2012/09/15	<0.060		mg/L	
			Dissolved Magnesium (Mg)	2012/09/15	<0.20		mg/L	
			Dissolved Manganese (Mn)	2012/09/15	0.0041, RDL=0.0040		mg/L	
			Dissolved Potassium (K)	2012/09/15	<0.30		mg/L	
			Dissolved Sodium (Na)	2012/09/15	0.75, RDL=0.50		mg/L	
		RPD	Dissolved Calcium (Ca)	2012/09/15	0.2		%	20
			Dissolved Magnesium (Mg)	2012/09/15	0.3		%	20
			Dissolved Potassium (K)	2012/09/15	1.2		%	20
			Dissolved Sodium (Na)	2012/09/15	0.1		%	20
6168404	KD5	Matrix Spike	Soluble Chloride (Cl)	2012/09/14		101	%	75 - 125
		QC Standard	Soluble Chloride (Cl)	2012/09/14		96	%	75 - 125
		Spiked Blank	Soluble Chloride (Cl)	2012/09/14		99	%	75 - 125
		Method Blank	Soluble Chloride (Cl)	2012/09/14	<5.0		mg/L	
		RPD	Soluble Chloride (Cl)	2012/09/14	NC		%	35
6168718	JHC	Matrix Spike	Soluble Calcium (Ca)	2012/09/14		104	%	75 - 125
			Soluble Magnesium (Mg)	2012/09/14		102	%	75 - 125
			Soluble Sodium (Na)	2012/09/14		105	%	75 - 125
			Soluble Potassium (K)	2012/09/14		102	%	75 - 125
		QC Standard	Soluble Calcium (Ca)	2012/09/14		124	%	75 - 125
			Soluble Magnesium (Mg)	2012/09/14		120	%	75 - 125
			Soluble Sodium (Na)	2012/09/14		100	%	75 - 125
			Soluble Potassium (K)	2012/09/14		101	%	75 - 125
			Soluble Sulphate (SO4)	2012/09/14		122	%	78 - 122
		Spiked Blank	Soluble Calcium (Ca)	2012/09/14		105	%	75 - 125
			Soluble Magnesium (Mg)	2012/09/14		104	%	75 - 125
			Soluble Sodium (Na)	2012/09/14		98	%	75 - 125
			Soluble Potassium (K)	2012/09/14		103	%	75 - 125
		Method Blank	Soluble Calcium (Ca)	2012/09/14	<1.5		mg/L	
			Soluble Magnesium (Mg)	2012/09/14	<1.0		mg/L	
			Soluble Sodium (Na)	2012/09/14	<2.5		mg/L	
			Soluble Potassium (K)	2012/09/14	<1.3		mg/L	
			Soluble Sulphate (SO4)	2012/09/14	<5.0		mg/L	
		RPD	Soluble Calcium (Ca)	2012/09/14	6.4		%	35
			Soluble Magnesium (Mg)	2012/09/14	NC		%	35
			Soluble Sodium (Na)	2012/09/14	7.3		%	35
			Soluble Potassium (K)	2012/09/14	5.9		%	35
			Soluble Sulphate (SO4)	2012/09/14	18.7		%	35

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

STANTEC CONSULTING LTD
Attention: OLIVIER PIRAUX
Client Project #: 110218745
P.O. #: 16300R-40
Site Location: MALLIK/INUVIK NWT

Quality Assurance Report (Continued)

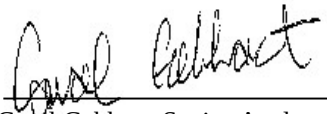
Maxxam Job Number: EB280550

Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

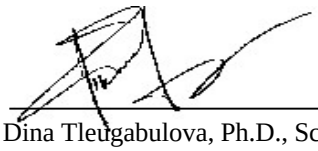
Validation Signature Page

Maxxam Job #: B280550

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Carol Gebhart, Senior Analyst



Dina Tleugabulova, Ph.D., Scientific Specialist, Inorganics Department

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
Edmonton: 9331 - 48 Street, T6B 2R4. Ph: (780) 577-7100, Fax: (780) 450-4187, Toll free: (877) 465-8889
www.maxxamanalytics.com

09/250

Chain of Custody

A043727

Page: 1 of 1

Company:	Invoice To: Stantec	C/O Report Address ☐
Contact:	Olivier Piraux	
Address:	10106 112 AV Edmonton	
	Prov: Alb PC:	
Contact #s:	Ph: 514 738-0708 Cell: 514-245-1045	

Report To:	Same as Invoice ☒
Prov:	PC:
Ph:	Cell:

Report Distribution (E-Mail):
olivier.piraux@stantec.com
elaine.little@stantec.com

REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 1102187445
Project # / Name: Mallik
Site Location: Mallik / Inuvik NWT
Quote #:
Sampled By: OLIVIER PIRAUX

SERVICE REQUESTED:
☐ RUSH (Contact lab to reserve) Date Required:
☒ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4 (dissolved)	Assessment ICP Metals	Basic Class II Landfill	Routine analysis*	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☐ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik2012 WS01		GW	2012/09/05 10PM										X							1
2	Mallik2012 WS02		GW	" 1315										X							1
3	Mallik2012 WS03		GW	" 11h AM										X							1
4	Mallik2012 WS04		GW	" 1415PM										X							1
5	Mallik2012 WS05		GW	" 12PM										X							1
6	Mallik2012 WS06		GW	" 12PM										X							1
7	Mallik2012 WS07		GW	" 1245										X							1
8	Mallik2012 WS08		GW	" 1230										X							1
9	Mallik2012 SS01	25cm	~~Sed~~ Soil	" 1300		X		X			X										1
10																					
11																					
12																					

DF-7/APM F/P

Please indicate Filtered, Preserved or Both (F, P, F/P)

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
Olivier Piraux	2012-09-08	10 AM
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):

Special Instructions: Routine for soil: conductivity, Ph

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B120550
ALYSSA HUEBC Alyssa Hueb	2012/09/10	10:52	

Custody Seal	Temperature	Ice
absent	3, 3, 5	present

Lab Comments:

2013 Mallik Annual Sump Monitoring Report

FOR SUBMISSION TO THE NORTHWEST TERRITORIES WATER BOARD UNDER WATER LICENSE N7L1-1817

Prepared for:

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

Prepared by:

KAVIK-STANTEC

November 2013

Table of Contents

1 Introduction 1
2 Site Location 2
3 Methods 4
3.1 Visual Assessment 4
3.2 Active-Layer Depth Measurements 4
3.3 Ground Temperature Monitoring 5
3.4 Electromagnetic Surveys 5
3.5 Water Sampling 5
3.6 Soil Sampling 5
4 Results 7
4.1 Visual Assessment 7
4.2 Active Layer Measurements 8
4.3 Air and Ground Temperature Monitoring 9
4.3.1 Air Temperature 9
4.3.2 Ground thermal monitoring 10
4.4 Electromagnetic Surveys 17
4.5 Soil and Water Sampling 18
4.5.1 Water Sampling 20
4.5.2 Soil Sampling 22
5 Conclusion 24
6 References 26

List of Tables

Table 3-1 Depth below ground surface of Thermistors....5
Table 4-1 Summary of Active-Layer Measurements....8
Table 4-2 Monthly Air Temperatures....9
Table 4-3 Ground Temperatures at thermistor 07GSC-01 (06/09/2012 to 05/09/2013)....11
Table 4-4 Ground Temperatures at thermistor 07GSC-02 (06/09/2011 to 05/09/2012)....12
Table 4-5 Ground Temperatures at thermistor 07GSC-03 (06/09/2012 to 05/09/2013)....13
Table 4-6 Ground Temperatures at thermistor 07GSC-04 (06/09/2012 to 05/09/2013)....14
Table 4-6 Ground Temperatures at thermistor 12GSC-05 (06/09/2012 to 05/09/2013)....15
Table 4-7 Soil and Water Sampling Locations....18
Table 4-8 Water Sampling Results....21
Table 4-9 Soil Sampling Results....23

List of Figures

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories....2
Figure 2-2 Aerial view of the Mallik site (photo taken September 11, 2013)....3
Figure 4-1 Ground surface conditions at monitoring locations....10
Figure 4-2 Ground temperature at thermistor 07GSC-1 (06/09/2012 to 05/09/2013)....11
Figure 4-3 Ground temperature at thermistor 07GSC-2 (06/09/2012 to 05/09/2013)....12
Figure 4-4 Ground temperature at thermistor 07GSC-03 (06/09/2012 to 05/09/2013)....13
Figure 4-5 Ground temperature at thermistor 07GSC-04 (06/09/2012 to 05/09/2013)....14
Figure 4-6 Ground temperature at thermistor 12GSC-05 (20/09/2012 to 05/09/2013)....15
Figure 4-7 2012-2013 Annual mean temperatures at the various thermistors....16
Figure 4-8 Location of soil and water samples....19

Abbreviations

ARI ..... Aurora Research Institute, Aurora College
CCME ..... Canadian Council of Ministers of the Environment
GSC ..... Geological Survey of Canada
EM ..... Electromagnetic
ESSIS ..... Environmental SubSurface Imaging Solutions Ltd.
IORL ..... Imperial Oil Resources Ltd.
ISR ..... Inuvialuit Settlement Region
JAPEX ..... JAPEX Canada Ltd.
JNOC ..... Japan National Oil Corporation
Mbg ..... meters below ground
ml ..... millilitre
NWT ..... Northwest Territories
SDL ..... Significant Discovery Licence

1 Introduction

The Mallik L-38 lease area has been the site of three historical drilling programs, Mallik L-38 in 1972, Mallik 2L-38 in 1998, and Mallik 3L/4L/5L-38 in 2002. Each program constructed and used a conventional drilling sump to dispose of drill cuttings and fluids. Imperial Oil Ltd. (IOL) drilled the original IOL Mallik L-38 discovery well during the winter of 1971-1972 and constructed a large drilling waste disposal sump (approximately 80 m x 95 m). Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore et al. 1999). With JAPEX Canada Ltd. (JAPEX) acting as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a second drilling waste disposal sump (approximately 45 m x 50 m) on the property. In 2002, a seven-party participant group also led by JNOC and GSC, with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste generated during drilling of the three wells.

A fourth drilling program in 2007-2008 (JOGMEC/NRCan/Aurora Mallik 2007-2008 Gas Hydrate Production Research Well Program) where the 2L- and 3L-38 wells were re-entered did not utilize a sump with all drilling waste removed from site and disposed of at an approved facility (Dallimore et al, 2013).

As part of the Water Board License No. N7L1-1817, JAPEX/JNOC/GSC et al. was required to monitoring the Mallik 2L-38 and 3L/4L/5L-38 sumps. The original Mallik L-38 sump was not required to be monitored as part of scope for the monitoring program.

This 2013 Annual Sump Monitoring Report by KAVIK-Stantec Inc. (KAVIK-Stantec) details the sixth year of a required seven year monitoring program to monitor the stability of the Mallik 2L-38 and 3L/4L/5L-38 drilling waste sumps. The monitoring program started in 2008 and is scheduled to conclude in 2014. The information in this report is required under Part H: Conditions Applying to Abandonment and Restoration of the Northwest Territories Board Licence No. N7L1-1817. The 2013 site visit was conducted on September 10 and 11 and included the following:

- a visual assessment of the site with an emphasis on sump cap conditions
- measurements of the active layer thickness on the sump caps, around their perimeter of the sump caps, as well as in an undisturbed area adjacent to the sumps
- maintenance of the monitoring equipment on site
- downloading of temperature data at five thermistor locations
- electromagnetic (EM) surveys (EM 31 and 38) conducted on both sumps and surrounding areas
- soil sampling in areas showing elevated electromagnetic conductivities
- surface water sampling of ponded water located on the sump cap and in an undisturbed area adjacent to the sumps

This report herein documents the results of this site visit and presents the data gathered from the monitoring activities.

2 Site Location

The Mallik L-38 site is located on the west coast of Richards Island, in the outer region of the Mackenzie Delta, bordering the Beaufort Sea. The site is located within the Inuvialuit Settlement Region (ISR) of the Northwest Territories (Figure 2-1). The area consists of nearshore floodplains on the west coast of Mallik Bay. The site coordinates are approximately 69°27'38"N, 134°39'42"W. The Mallik lease area is located on Crown land within the IORL Significant Discovery License (SDL) 060. The locations of the sumps are shown on Figures 2-2 and 3-1. Refer to Figure 3-1 for current thermistor locations.

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories

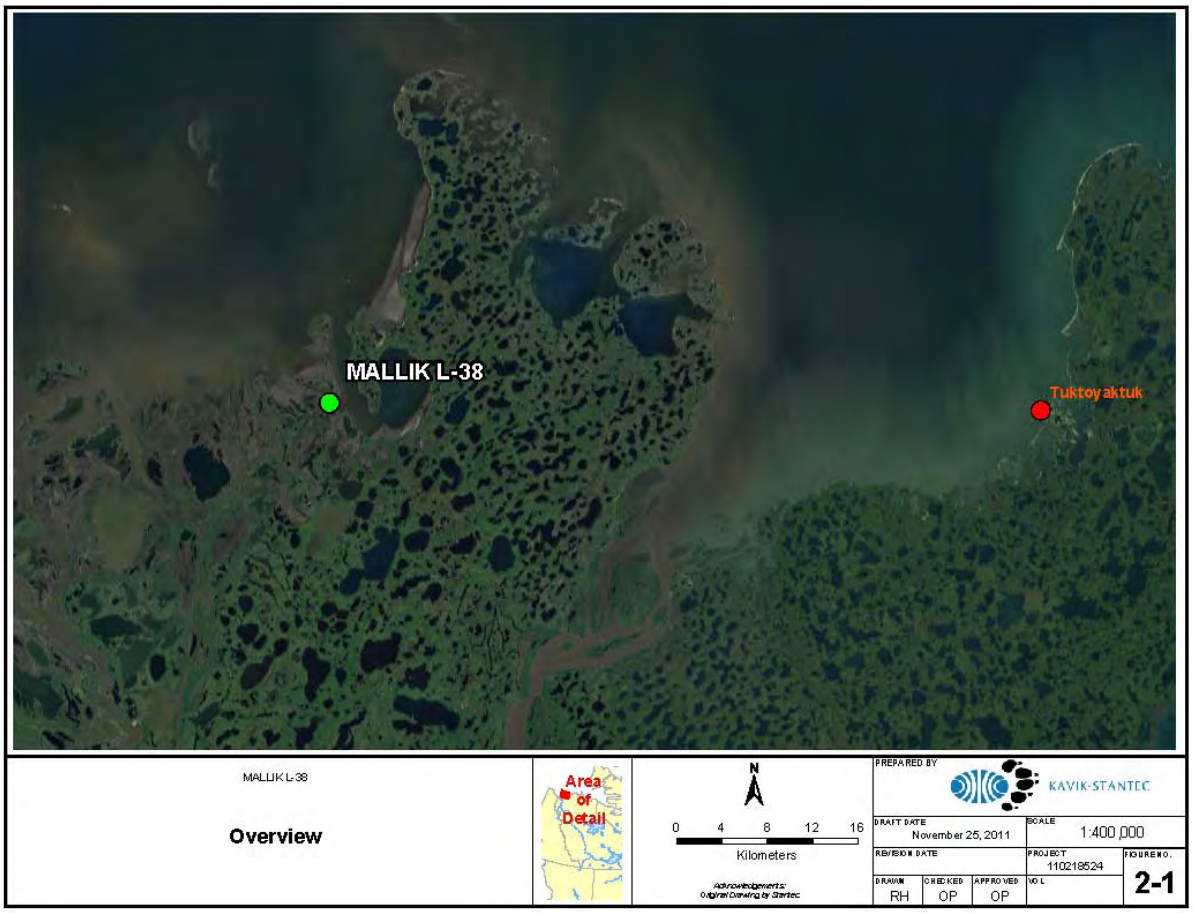
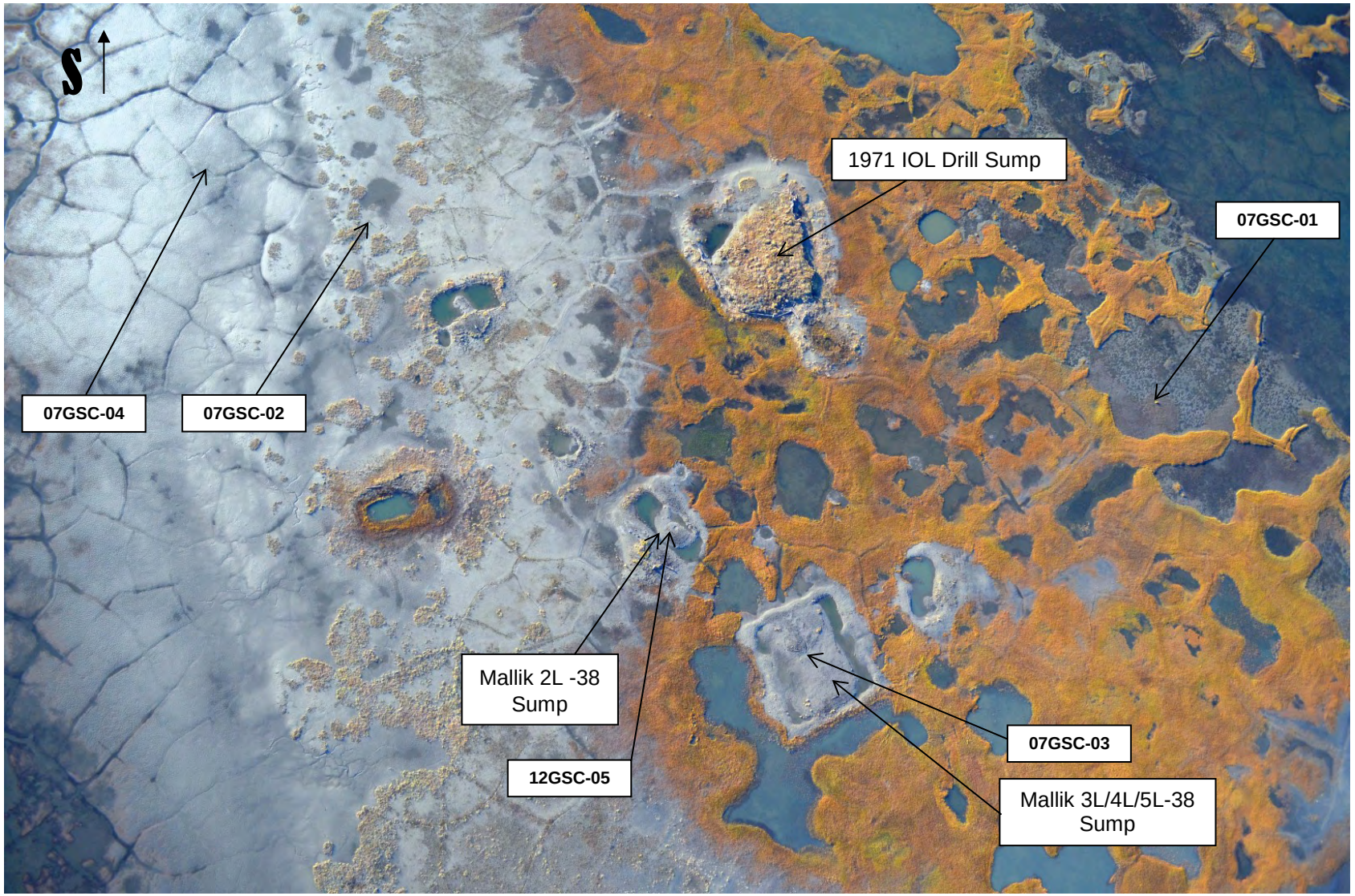


Figure 2-2 Aerial view of the Mallik site (photo taken September 11, 2013)



3 Methods

The methods for monitoring the Mallik sumps were developed using the following documents:

- Water License No. N7L1-1817 (NWT Water Board, 2004)
- *Protocol for the Management of Drilling Waste Disposal Sumps* – Inuvialuit Settlement Region NWT (NWT Water Board, 2006a)

The following sections outline the methodology followed throughout each component of the monitoring program, including: visual assessment, active layer depth measurements, ground temperature monitoring, electromagnetic surveys, and soil and water sampling.

3.1 Visual Assessment

Visual assessment was completed by a KAVIK-Stantec representative during the September 2013 visits. The purpose of the visual assessment is to document the physical conditions of the sumps and their immediate surrounding areas. Some of the key elements that were observed included:

- vegetation health and establishment on the sump caps or surrounding areas
- settlement and/or subsidence
- presence and/or absence of ponding water
- erosion, stress and/or tension cracks
- damage to existing monitoring facilities (thermistors and/or dataloggers)

The visual assessment was performed from both the air and ground. Site photographs can be reviewed in Appendix A.

3.2 Active-Layer Depth Measurements

Using a specially designed probe, active-layer depths were measured during the September 2013 site assessment. The methodology and location of the measurement points were recorded as specified in the *Protocol for the Monitoring of Drilling-Waste Disposal, Inuvialuit Settlement Region Northwest Territories* (NWT Water Board 2006). Active-layer depths were collected at a control area, on the sump caps and at the perimeter of the sump caps within 2 m of the interface between the sump cap and the surrounding undisturbed area.

3.3 Ground Temperature Monitoring

In 2007, four thermistors were installed in and surrounding the Mallik sumps, as specified in *Part H: Conditions Applying to Abandonment and Restoration under NWT Water Licence No. N7L1-1817.* An additional thermistor cable (12GSC-05) was installed at the center of the Mallik 2L-38 Drilling Sump on September 20 2012 in accordance of the Water Licence Agreement based on sump monitoring programs in the Northwest Territories (AANDC, 2011). The locations of the thermistors are presented in Figure 2-2, while Table 3-1 presents the depth of each thermistor in meters below grade (mbg).

Table 3-1 Depth below ground surface of Thermistors

Thermistor Sensors	Thermistor Recording Depths (mbg)				
	07GSC-01[1]	07GSC-02[1]	07GSC-03[1]	07GSC-04	12GSC-05[2]
1	-	1.0	1.0	1.0	0.25
2	0.35	1.5	1.5	1.5	0.50
3	0.85	2.0	2.0	2.0	0.75
4	1.35	2.5	2.5	2.5	1.5
5	2.35	4.5	4.5	3.5	3
6	4.35	6.5	6.5	5.5	6
7	6.85	10.5	10.5	8.0	9
8	4.28	5.65	5.65	10.5	12

[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e., the depth of the sensor #8 is above the sensor #6).
[2] New thermistor cable installed on September 20, 2012

3.4 Electromagnetic Surveys

Stantec's geophysicist conducted the EM surveys (EM31 and EM38) on September 11, 2013 using Geonics EM31 and EM38 ground conductivity meters. These instruments are used to identify the lateral extents of ion-rich regions, which might indicate ion migration from the sump to the surrounding areas, and to help identify the requirement for additional soil sampling. The surveys measure apparent conductivity of the soil around the sump site to determine if salts in the drilling waste are migrating through the soil from the sump. The EM38 measures apparent conductivity at soil depths of 0.0 to 1.5 m (shallow), while the EM31 unit measures apparent conductivity at soil depths of 0.0 to 5.0 m (deep).

3.5 Water Sampling

Surface water was sampled from subsidence areas located either within the sump cap or adjacent to the sump's perimeters. Samples were collected at arm's reach within the deepest area of the ponded water and stored in laboratory-issued 500 ml plastic jars. Samples were submitted to Maxxam Analytical (Maxxam) in Yellowknife, NWT for routine water analysis. The certified laboratory results are provided in Appendix C. The locations of the 10 water samples collected are presented in Figure 4-8. The guidelines used to compare the results from the water sampling program are the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for Freshwater and Aquatic Life (CCME 1999)*.

3.6 Soil Sampling

The purpose of the soil sampling program was to investigate anomalous areas of with elevated measurements of apparent conductivity. Using results from the EM surveys, one area with an elevated

apparent conductivity anomaly was observed outside of the sump areas and a soil sample was collected. Other areas of elevated conductivity outside of the sump areas included natural ponding and depressions, which are subjected to high concentrations of seawater, therefore samples were not collected at these locations.

Each soil sample was collected using a clean shovel and a soil knife at depths between 10 cm to 50 cm. Approximately 1 kg of soil was collected in laboratory-issued zip-lock containers and submitted to Maxxam Laboratory in Yellowknife, NWT for analysis. See Appendix C for the certified laboratory results. The locations of the five soil samples collected are presented in Figure 4-10.

4 Results

4.1 Visual Assessment

Site drainage

The overall drainage conditions of the site (i.e. the sumps and immediate surrounding area) can be characterized as imperfect to poor with water present in all ponds and topographic depressions. A visual comparison against 2012 indicates that the water level of most ponds was higher in 2013 than in 2012. The water level of a large pond corresponding to the location of thermistor 07GSC-01 was significantly lower (i.e. approximately 30cm lower) this year than during the last two years.

Indications of a storm surge were visible at the site and include ripples mark at the surface of the bare mineral soil as well as high water marks along the edge of the sump IOL sump (this sump is the highest topographic point at the Mallik site).

Vegetation and wildlife

It is estimated that less than 10% of the total sump caps are currently covered by vegetation. The vegetation is predominantly composed of a variety of graminoid species, such as sedges and grasses, with a few sporadic low shrubs and mosses. The conditions of the vegetation are comparable to last year.

Several signs of wildlife were noted on site. The most common were bird droppings, as well as bird and caribou (*Rangifer tarandus*) tracks.

Surface subsidence

As reported in the 2011 and 2012 site assessment reports, there are several areas with ground surface subsidence on both sumps (see site photographs in Appendix A). The subsidence appears more extensive at the 2L-38 sump than at the Mallik 3L/4L/5L-38 sump.

Surface subsidence was observed along the edges of the Mallik 3L/4L/5L-38 sump cap, most notably along the southwest and northeast sides of the sump. The depression along the southwest portion of this sump covers the full width of the sump (i.e. approximately 50 m) while three interconnected depressions are present on northeast portion.

The subsidence areas on the eastern and western sides of the 2L-38 sump cap appear to be extending and connecting with each other along the northern portion of the sump cap. The water levels in the subsidence areas were higher in 2013 but it is unclear if the overall depressions have increased in size or depth.

Ice-wedge polygons and tension cracks

Extensive patterns of ice-wedge polygons are present in the vicinity of the Mallik site. The polygons are variable in size, and range from about a few square meters to over 40 m^2. Some ice-wedge polygons located appear to be forming within the sump locations with aerial view of the sump area showing the ice-wedges connecting at the perimeter of the sumps. Several tension cracks can be observed at the soil surface at the Mallik site. Some correspond to limits of ice-wedge polygon while others are associated with contraction of somewhat dry soils surface soil. Most tension cracks are naturally occurring while a few, located along the edges and perimeters of the sumps, may be induced by surface subsidence.

Some minor subsidence appears to be occurring along a series of ice-wedge polygons about 30m north of the Mallik 2L-38 Sump (see figure A-10 in Appendix A). Long tension cracks have formed approximately 50 cm from the center of these ice-wedges and may indicate the lateral extent of the

wedges. The subsidence is estimated to range from a few centimeters to approximately 10 cm and is deepest towards the center of the ice-wedges.

4.2 Active Layer Measurements

Active layer measurements were collected on Sept. 11, 2013. The control transect is located at the same location than last year at an undisturbed area located approximately 150 m southeast from the Mallik 2L-38 Sump. Table 4-1 provides a summary and comparison of the active layer depths. A figure showing the location of each individual measurement is located in appendix A.

Table 4-1 Summary of Active-Layer Measurements

	Mallik 2L-38 Sump		Mallik 3L/4L/5L-38 Sump		Control Transect
	Sump Cap	Perimeter	Sump Cap	Perimeter	
Measurements collected	17	16	25	21	22
Minimum thawing depth (cm)	110	113	109	108	100
Maximum thawing depth (cm)	140	140	152	145	125
Average thawing depth (cm)	123	125	121	123	113
2012 average (cm)	140	136	132	131	128
2011 average (cm)	121	114	133	117	113
2010 average (cm)	119	113	118	121	113

Mallik 2L-38 Sump

Active layer depths in 2013 on the Mallik 2L-38 sump cap ranged from 110 cm to 140 cm and averaged 123 cm. Active-layer depths around the perimeter of the sump cap ranged from 113 cm to 140 cm and averaged 125 cm. In comparison, the 2011 and 2012 average depths were 116 and 178 cm respectively for the sump cap and 125 and 148 cm for the sump perimeter.

Mallik 3L/4L/5L-38 Sump

Active layer depths on the Mallik 3L/4L/5L-38 sump cap ranged from 109 cm to 152 cm, for an average of 121 cm. Active-layer depths around the perimeter of sump cap had a similar range from 108 cm to 145 cm, for an average of 123 cm. In comparison, the 2011 and 2012 depths were 124 cm and 145 cm respectively for the sump cap and 124 cm and 144 cm for the sump perimeter which also had very similar ranges.

Control transect

The control transect was conducted at the same location as during the 2011 and 2012 surveys. Active layer depths on the control transect range from 100 cm to 125 cm, for an average of 113 cm. This represents a decrease of 15 cm when compared to the 2012 average of 128 cm.

4.3 Air and Ground Temperature Monitoring

The following section presents a summary of the air and ground temperature data collected at the various sensors and thermistor cables present at the Mallik site. The locations of the thermistors are shown on Figure 3-1.

The mean, maximum and minimum ground temperatures of each sensor are summarized in Tables 4-2 to 4-6. Diagrams showing the annual variation of mean ground temperature at each sensor depth are provided in Appendix B.

4.3.1 Air Temperature

Air temperature is recorded at an hourly frequency at the Mallik site since October 1, 2010 The air temperature sensor is installed at approximately 1.5 meters above ground level. The sensor is mounted within a radiation shield to minimize the heating effects of solar radiation and direct exposure to rain and snow. The average monthly air temperature recorded over the last three years is presented in Table 4-2.

Table 4-2 Monthly Air Temperatures

	Air Temperature (°C)		
	2010/2011	**2011/2012**	**2012/2013**
September	-	4.1	5.8
October	-5.3	-3.9	-2.8
November	-13.1	-20.4	-15.4
December	-25.7	-22.7	-26.7
January	-25.9	-27.6	-28.4
February	-23.2	-23.1	-29.2
March	-23.0	-30.0	-26.0
April	-19.0	-14.5	-18.9
May	-3.2	-4.3	-5.6
June	4.6	8.1	5.5
July	12.1	15.3	9.9
August	10.2	12.4	10.5
Annual Mean	**-**	**-8.9**	**-10.1**

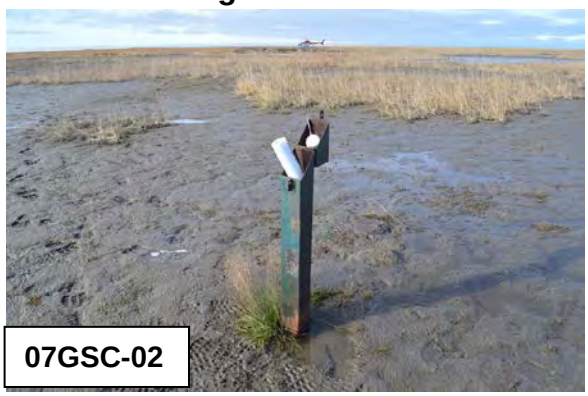
The annual mean air temperature for 2012-2013 was -10.1°C, compared to -8.9°C in 2011-2012. A review of the monthly temperature averages indicates that the 2013 summer months were approximately 2 to 5 °C colder than the equivalent months in 2012 (see Table 4-2). The warmest air temperature recorded over the 2013 summer was 27.7°C (August 13, 2013).

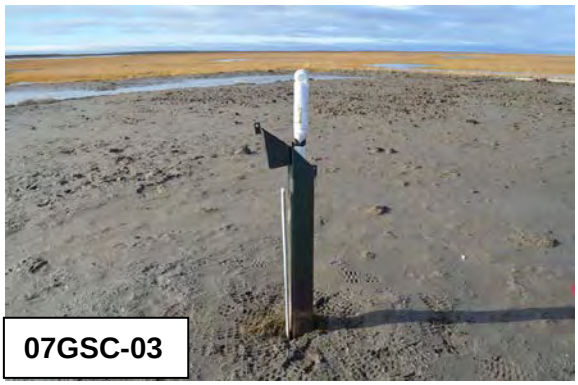
The winter monthly averages are colder in 2012-2013 than 2011-2012, with only the March temperature average being 4°C warmer than in 2012 (with the exception of November that was warmer in 2013). The coldest air temperature recorded over the 2012-2013 winter was -38.8°C (recorded on January 23, 2013) compared to -42.2°C for the 2011-2012 winter (recorded on January 26, 2012).

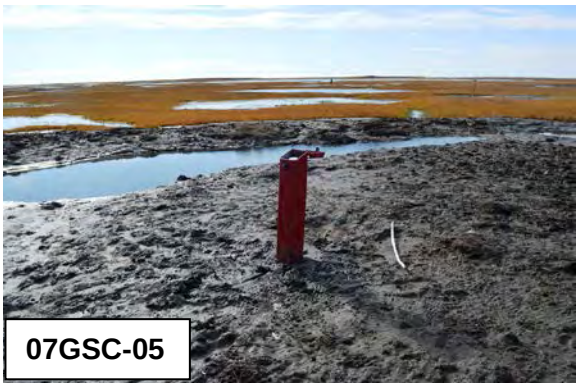
4.3.2 Ground thermal monitoring

Ground thermal monitoring has been conducted at the Mallik site since April 2007. The thermistor sensor depths range from just below ground surface to a maximum depth of 12 m with data loggers set up to record hourly temperatures. Figure 4-1 shows the ground surface conditions at each site. Ground temperature data of each thermistor cable are presented below.

Figure 4-1 Ground surface conditions at monitoring locations







Themister	2013 Active layer depth
07GSC-01	108 cm
07GSC-02	126 cm
07GSC-03	129 cm
07GSC-04	132 cm
07GSC-05	128 cm

4.3.2.1 Ground temperatures at thermistor 07GSC-01

Thermistor 07GSC-01 is located in an undisturbed area approximately 200 m southwest of the Mallik sumps at the edge of a large but shallow pond. The water level in the pond is considerably lower than last year, decreasing from a depth of approximately 30 cm in 2012, to only a few centimeters in 2013. The top thermistor (i.e. 0.35 mbg) is located at the interface between ground and water which may have resulted in highly variable temperatures.

Figure 4-2 Ground temperature at thermistor 07GSC-1 (06/09/2012 to 05/09/2013)

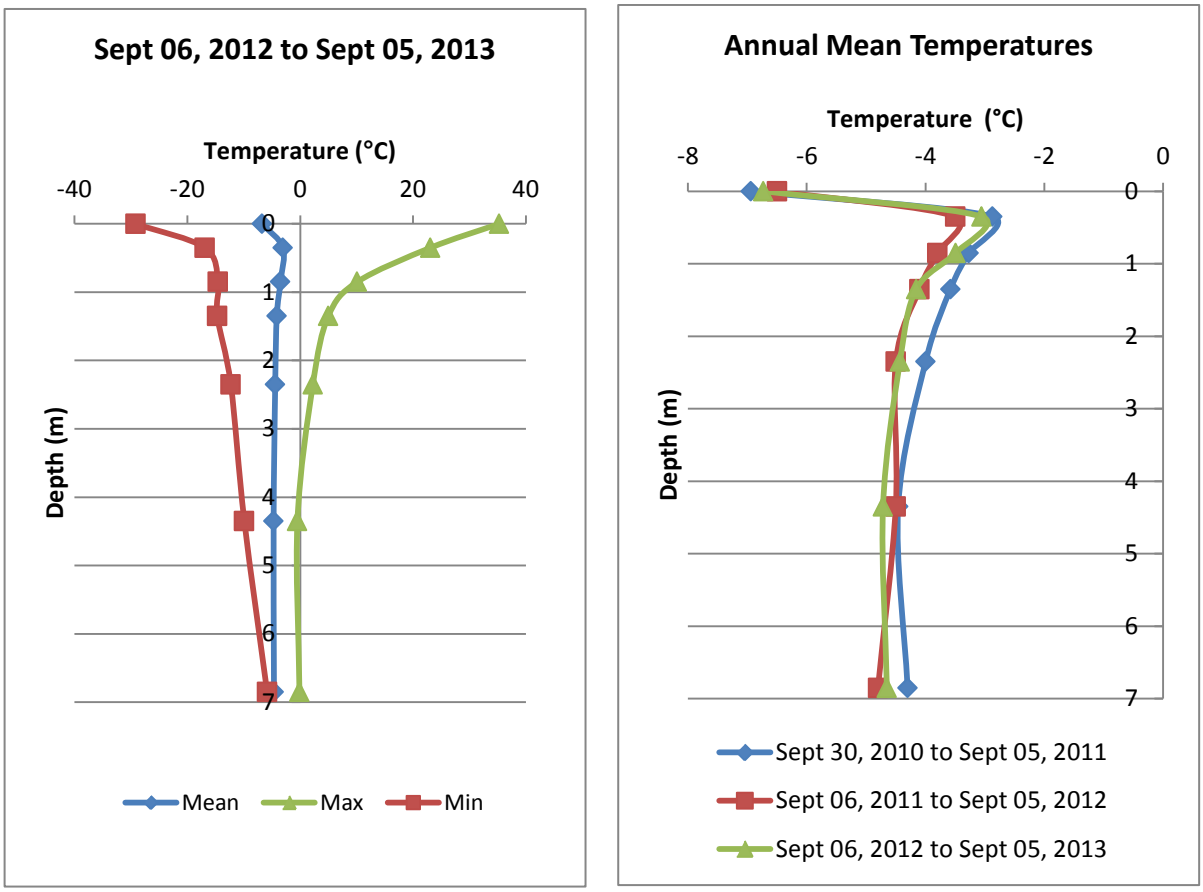


Table 4-3 Ground Temperatures at thermistor 07GSC-01 (06/09/2012 to 05/09/2013)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.35	-3.1	23.1	-16.9
0.85	-3.5	10.1	-14.6
1.35	-4.2	5.0	-14.7
2.35	-1.2	-0.2	-1.6
4.35	-4.7	-0.5	-9.9
6.85	-4.7	-0.1	-5.9

4.3.2.2 Ground temperatures at thermistor 07GSC-02

Thermistor 07GSC-02 is located approximately 200 m southeast from the 2L-38 sump in an undisturbed site with low sedge and grass cover.

Figure 4-3 Ground temperature at thermistor 07GSC-2 (06/09/2012 to 05/09/2013)

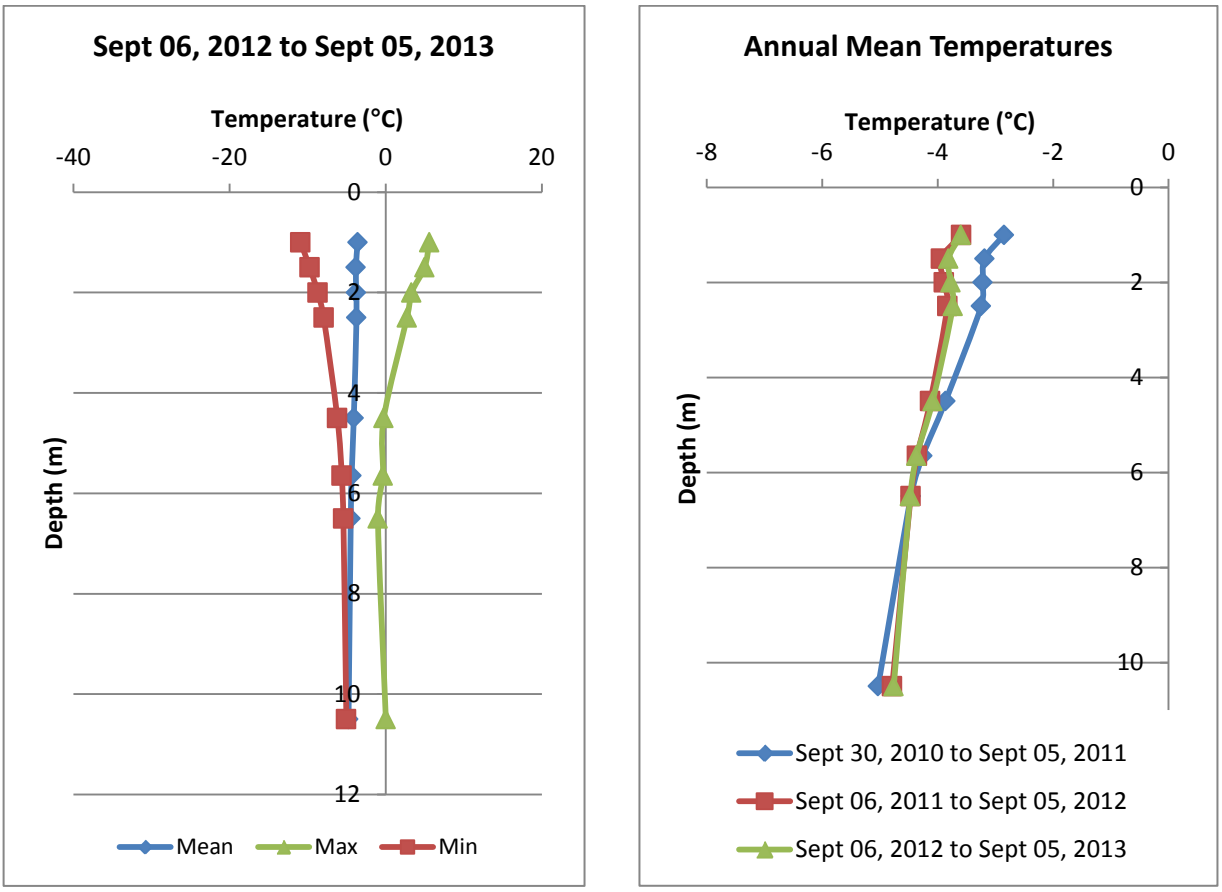


Table 4-4 Ground Temperatures at thermistor 07GSC-02 (06/09/2011 to 05/09/2012)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.00	-3.6	5.6	-10.9
1.50	-3.8	5.0	-9.7
2.00	-3.8	3.3	-8.7
2.50	-3.7	2.7	-8.0
4.50	-4.1	-0.3	-6.2
5.65	-4.4	-0.4	-5.6
6.50	-4.5	-1.0	-5.4
10.50	-4.8	0.0	-5.0

4.3.2.3 Ground temperatures at thermistor 07GSC-03

Thermistor 07GSC-03 is located within disturbed material at the center of the Mallik 3L/4L/5L-38 Sump.

Figure 4-4 Ground temperature at thermistor 07GSC-03 (06/09/2012 to 05/09/2013)

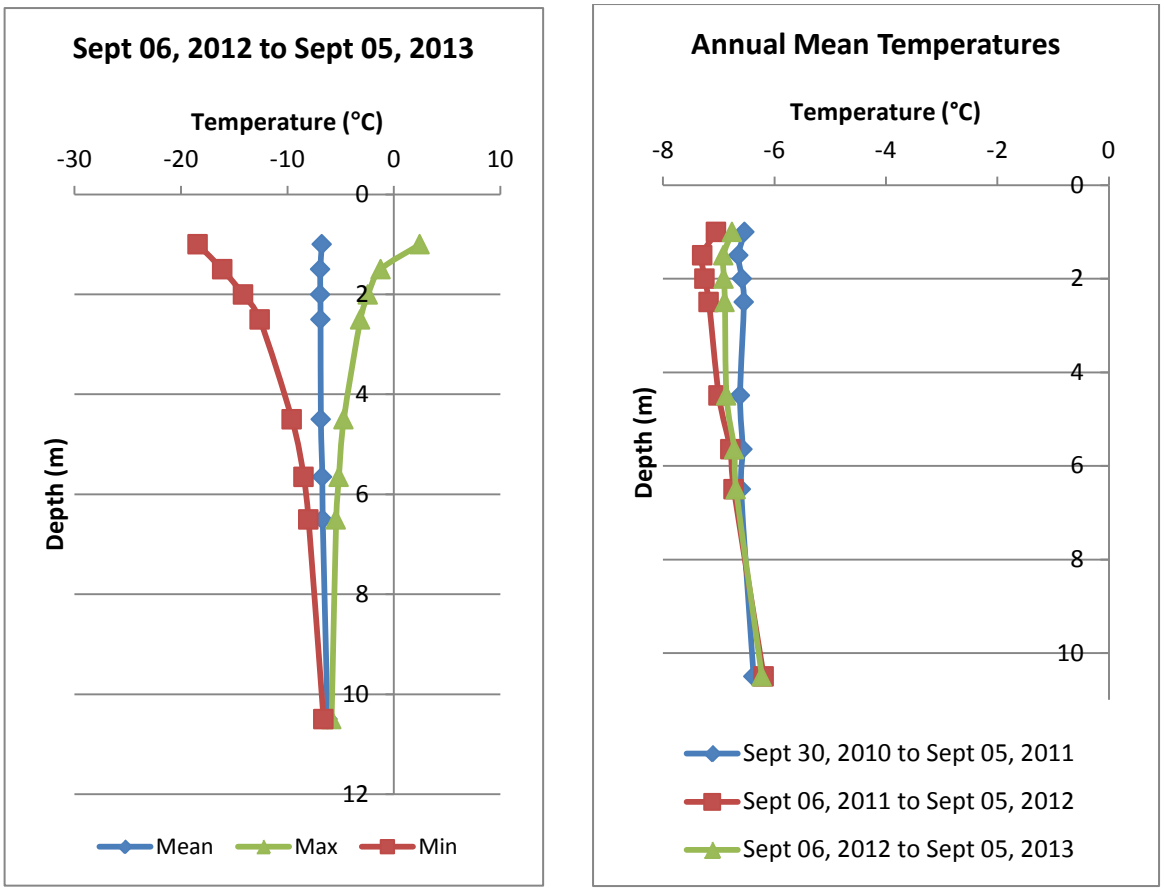


Table 4-5 Ground Temperatures at thermistor 07GSC-03 (06/09/2012 to 05/09/2013)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.00	-6.8	2.5	-18.4
1.50	-6.9	-1.2	-16.1
2.00	-6.9	-2.4	-14.2
2.50	-6.9	-3.1	-12.6
4.50	-6.9	-4.7	-9.6
5.65	-6.7	-5.2	-8.5
6.50	-6.7	-5.4	-8.0
10.50	-6.2	-5.9	-6.6

4.3.2.4 Ground temperatures at thermistor 07GSC-04

Thermistor 07GSC-04 is located in an undisturbed area approximately 150 m west of Mallik 2L-38 Sump.

Figure 4-5 Ground temperature at thermistor 07GSC-04 (06/09/2012 to 05/09/2013)

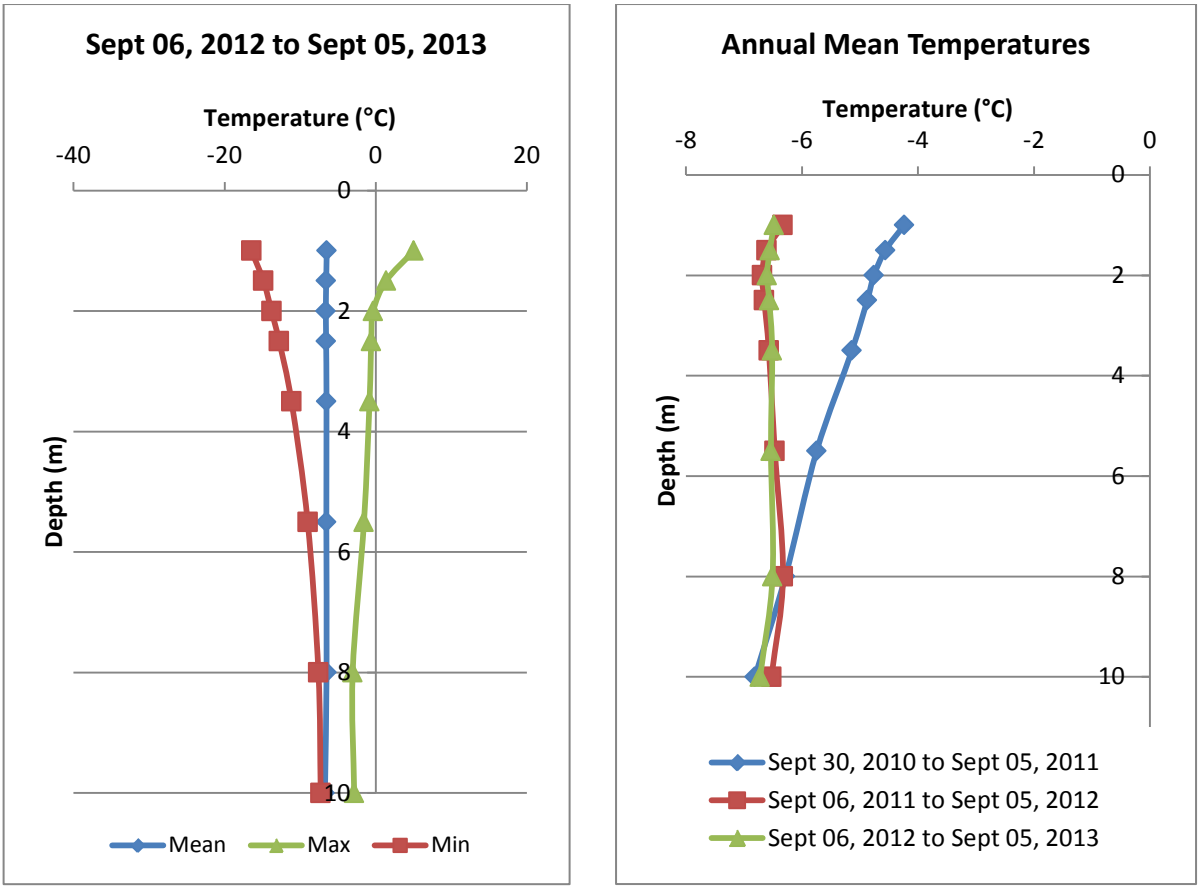


Table 4-6 Ground Temperatures at thermistor 07GSC-04 (06/09/2012 to 05/09/2013)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.0	-6.5	5.1	-16.5
1.5	-6.6	1.4	-14.9
2.0	-6.6	-0.3	-13.8
2.5	-6.6	-0.6	-12.8
3.5	-6.5	-0.8	-11.2
5.5	-6.5	-1.6	-9.0
8.0	-6.5	-3.1	-7.6
10.5	-6.7	-2.9	-7.3

4.3.2.5 Ground temperatures at thermistor 12GSC-05

Thermistor 12GSC-05 is located at the centre of the Mallik 2L-38 Sump and was installed on September 20, 2012.

Figure 4-6 Ground temperature at thermistor 12GSC-05 (20/09/2012 to 05/09/2013)

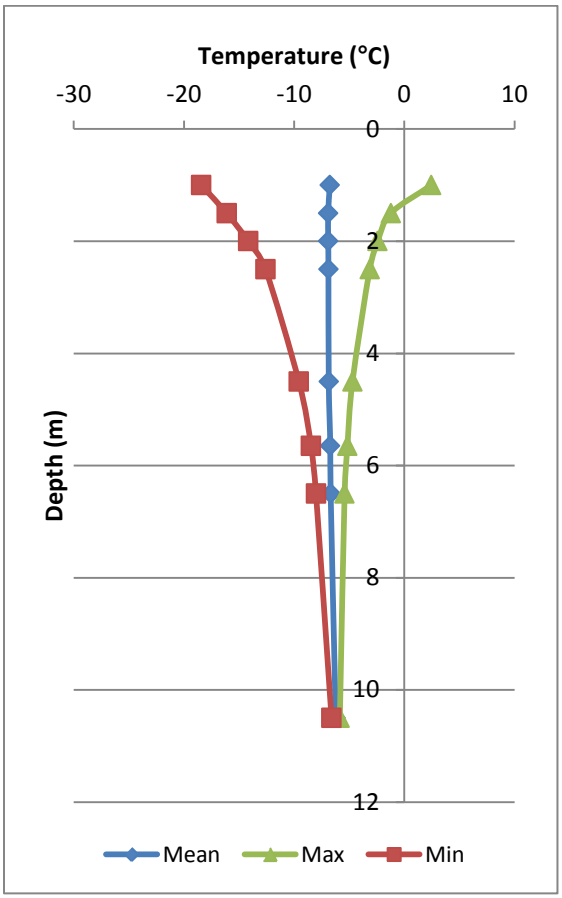


Table 4-6 Ground Temperatures at thermistor 12GSC-05 (06/09/2012 to 05/09/2013)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.25	-7.1	8.8	-19.7
0.50	-7.0	4.6	-18.1
0.75	-6.9	0.8	-16.7
1.50	-6.5	-0.7	-13.1
3.00	-5.9	-2.4	-8.4
6.00	-5.3	-2.8	-6.1
9.00	-5.2	-2.7	-5.5
12.00	-5.2	-2.1	-5.4

Temperatures recorded along thermistor strings

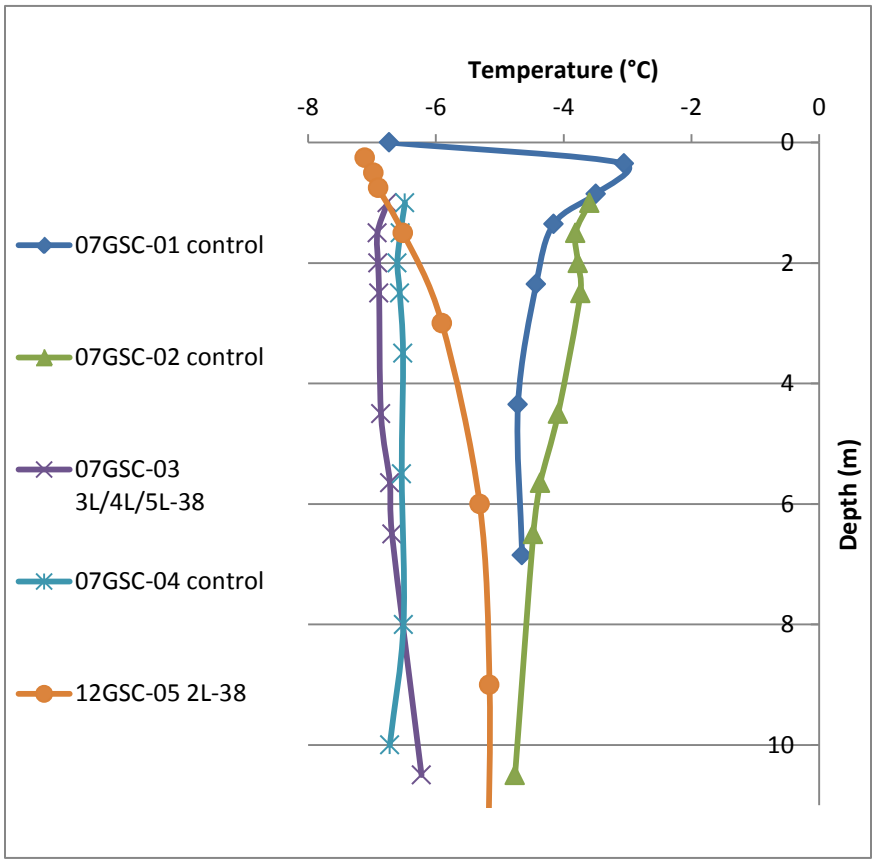
Ground temperature monitoring data demonstrates that the thermal regime recorded at the site appears to primarily fluctuate with seasonal temperature variations, regardless of whether the thermistor is located within the sump or outside the sump. Variances in temperature are also assumed to be secondly a function of several factors such as local site conditions, material texture and drainage, slope and exposure, presence or absence of vegetation, annual thickness of snow cover, etc.

The annual mean temperatures measured for the 2012-2013 period are very close to the ones of 2011-2012. The comparison of the mean annual temperatures recorded at the various thermistors (Figure 4-7) indicates that the ground temperature within the two sumps are colder than 2 of the 3 control locations.

Similarly to 2011-2012, the thermistor cable that recorded the coldest temperatures for the 2012-2013 period is thermistor 07GSC-03, located in the 3L/4L/5L-38 Sump (annual average temperatures ranging from -6.2°C to-6.8°C). In 2012, the material at 1 mbg was above 0°C from July 26 to October 7; however, in 2013, the temperature at 1 mbg went above 0°C approximately 1 week later, on August 4. An active layer of 129 cm was measured next to thermistor 07GSC-03 on September 11, 2013.

Thermistor cable 12GSC-05 is located at the center of 2L-38 Sump and records temperature at depth ranging from 0.25 mbg to 12 mbg. The annual average temperatures range from -5.2°C (just below the surface) to -7.1°C (at 12 mbg). The material at 1.5 mbg remained frozen for the last 12 months period (-6.5°C average for the 2L-38 Sump and -6.9°C for the 3L/4L/5L-38 Sump).

Figure 4-7 2012-2013 Annual mean temperatures at the various thermistors



4.4 Electromagnetic Surveys

As expected, the EM38 Survey (0 to 1.5 m) and the EM31 Survey (0 to 5 m) both identified areas of elevated apparent conductivity on the Mallik 2L-38 Sump and on the Mallik 3L/4L/5L-38 Sump which correspond primarily to the presence of saline drill cuttings within the sumps (See EM figures in Appendix C).

Similar to the 2011 and 2012 analysis, both the EM31 and EM38 surveys indicate that there is also elevated apparent conductivity at several areas outside the sumps perimeters. Interpreting inductive electromagnetic (EM) geophysical data in this dynamic permafrost setting is quite challenging (see additional information on the principles of inductive geophysical methods located in Appendix C). When interpreting inductive electromagnetic (EM) geophysical data in areas of permafrost the critical factor to consider is the depth of the active layer. The close proximity of the Site to the ocean and the associated storm surges should also be considered; identifying potential anthropogenic impacts is complicated by naturally occurring sediment salts and/or naturally occurring changes in the active layer depth related to these salts. Differentiating anthropogenic from naturally occurring terrain apparent EC anomalies therefore is complex and interpretations should be considered as such. To assist in the interpretation of the EM data, intrusive sampling techniques of both water and soil were used.

The east portion of the EM31 and EM38 surveys is characterized by highly elevated terrain apparent EC that is especially pronounced in the EM38 data. This implies that the source of elevated terrain apparent EC is primarily within the upper 1.5 m of the soil profile. Due to the close correspondence of this elevated terrain apparent with bare areas, it is assumed to be naturally occurring from inundation and subsequent evaporation of sea water. The two depressions in the eastern portion of the Mallik, correspond with lower terrain apparent EC in both data sets. The origin of these depressions is unknown, and the cause of this lower apparent EC is not clear.

Elevated terrain apparent EC measurements have been observed to correspond with several natural ponds each year the EM surveys have been conducted. These are most evident as areas of moderately elevated terrain apparent EC in the EM38 data. Past water sample analyses indicate that the high conductivity is most likely related to the evaporation of trapped sea water from the annual storm surges and are not indicative of sump seepage. Water from a pond with a particular distinctive higher elevated terrain apparent EC, in both data sets was sampled (W09). The cation values are similar to those of background water samples; therefore the elevated instrument response may primarily result from instrument response to a relatively deep active layer rather than high salinity concentrations. Probing of the active layer beneath these probes to confirm this hypothesis could be carried out next year.

Elevated terrain apparent EC readings extend northeast from the assumed boundary of the Mallik 2L-38 Sump. However, additional observation along this portion of the sump indicates that the ground surface could possibly have been disturbed and that drill muds and cuttings could be present at the ground surface. It is also important to note that the actual boundary of the sump cap is very difficult to accurately determine in this environment. A soil sample was collected at this location (S03) and the results are presented in Section 4.5.2.

4.5 Soil and Water Sampling

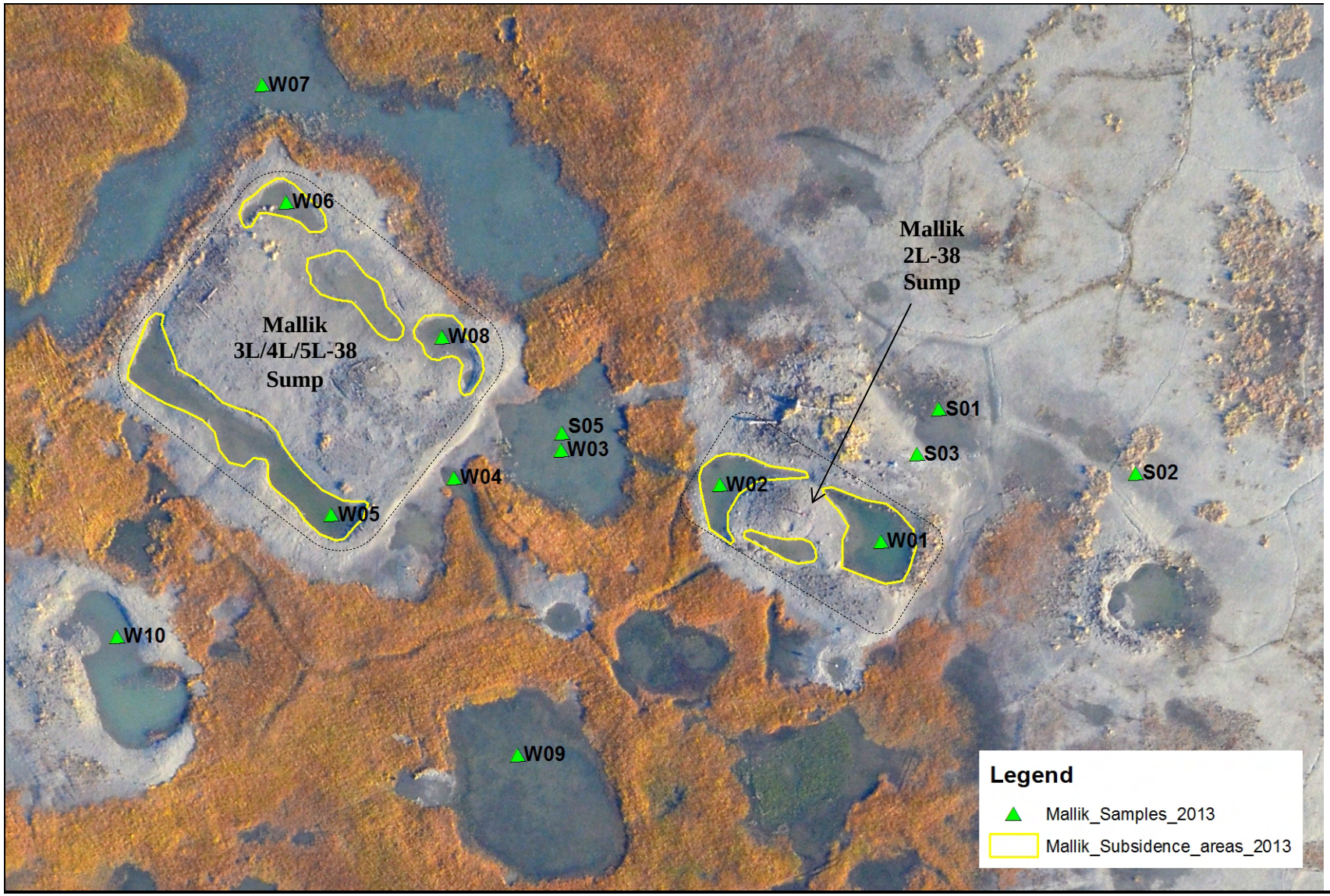
Water samples were collected from the areas of ponding water located within the sumps. The water samples were analyzed for routine water chemistry (i.e., conductivity, pH and major cations). In addition, soil and water samples were taken from areas outside the sump to investigate the elevated apparent conductivity.

Surface water samples were collected at ten locations during the 2013 field visit (see Table 4-7 and Figure 4-8). Five samples were collected within subsidence areas located inside the sump boundaries and five more were samples from depressions characterized by elevated apparent conductivities located outside the sumps boundaries. A summary of the water analysis results is presented in Tables 4-8. The complete laboratory reports are presented in Appendix D.

Table 4-7 Soil and Water Sampling Locations

Sample Number	Comments on sample location
MALLIK-2013-W01	Water pooling in the depression located at the eastern edge of the Mallik 2L-38 Sump
MALLIK-2013-W02	Water pooling in the depression located at the western edge of the Mallik 2L-38 Sump
MALLIK-2013-W03	Water pooling in a depression located half way between the Mallik 2L-38 Sump and the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W04	Water pooling in a depression associated to an ice-wedge connecting to the southeast edge of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W05	Water pooling in the depression located at the southern edge of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W06	Water pooling in the depression located at the northern edge of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W07	Water pooling in a natural depression in contact with the northern portion of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W08	Water pooling in the depression located at the eastern edge of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W09	Water pooling in a natural depression showing elevated apparent conductivity approximately 50 m south of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-W10	Water pooling within the Mallik 2L-38 Camp Sump boundary
MALLIK-2013-S01	Soil sample from elevated apparent conductivity area next to the Mallik 2L-38 Sump
MALLIK-2013-S02	Soil sample from elevated apparent conductivity area next to the Mallik 2L-38 Sump
MALLIK-2013-S03	White textured material found in the elevated apparent conductivity area next to the Mallik 2L-38 Sump
MALLIK-2013-S04	Control sample taken approx. 150 m northeast of the Mallik 3L/4L/5L-38 Sump
MALLIK-2013-S05	Soil sample taken at the bottom of the pond located between the two sumps

Figure 4-8 Location of soil and water samples



4.5.1 Water Sampling

The surface water samples collected at Mallik have pH values ranging from 7.82 to 8.22, which is in accordance with the CCME guidelines (CCME 1999) and within the range of values observed in several lakes and channels of the Mackenzie Delta (Anema et al. 1990).

The conductivity values measured from the water samples range from 1,200 uS/cm to 11,000 uS/cm. The samples with the highest conductivities (W02, W05, W06 and W08) are located at the surface of the sumps and correlate with the elevated apparent conductivities measured during both the EM31 and EM38 surveys.

The exact nature of the materials contained in the Mallik drilling sumps is not documented in this report but typically the constituents of brine-based drilling mud are potassium chloride, bentonite, cellulose polymers, lignosulphonates and sodium hydroxide (Piteau Engineering Ltd., 1988; Kokelj and GeoNorth, 2002).

Water samples showing elevated potassium levels were taken from the pools located within the sumps perimeters (W02-330 mg/L, W05-210 mg/L, W06-230 mg/L and W08-650 mg/L). In comparison, the potassium levels measured in samples located outside the sumps perimeters varied from 6 to 28 mg/L. The highest concentrations of chloride were also measured from samples taken within the sumps perimeters (W02, W05 and W06). The water samples taken in the ponds surrounding the Mallik 3L/4L/5L-38 Sump showed low potassium, calcium and chloride levels.

The conductivities of the sample taken in the subsidence areas of the Mallik 2L-38 and Mallik 3L/4L/5L-38 Sumps appear to be influenced by elevated sodium, potassium, calcium and chloride parameters while the samples taken in the natural depressions outside the sumps appear to be primarily influenced by elevated sodium parameters.

The analysis suggests that there is some correlation between the apparent elevated conductivities observed in the EM31 and EM38 surveys and the sodium, potassium, calcium and chloride concentrations of the water samples taken from the subsidence areas of the two drilling sumps. These elevated values correlate with data from the previous years and suggest that some seasonally unfrozen drill mud contaminants are present in the water pooling within the subsiding portions of the sump caps.

Table 4-8 Water Sampling Results

	UNITS	MALLIK-2013-W01	MALLIK-2013-W02	MALLIK-2013-W03	MALLIK-2013-W04	MALLIK-2013-W05	MALLIK-2013-W06	MALLIK-2013-W07	MALLIK-2013-W08	MALLIK-2013-W09	MALLIK-2013-W10
Sampling Date		9/10/2013 16:20	9/10/2013 16:25	9/10/2013 16:30	9/10/2013 16:30	9/10/2013 16:35	9/10/2013 16:35	9/10/2013 16:40	9/10/2013 16:45	9/10/2013 16:45	9/10/2013 16:50
Calculated Parameters											
Anion Sum	meq/L	14	39	15	17	36	56	12	110	20	11
Cation Sum	meq/L	16	38	17	19	37	56	13	110	22	12
Hardness (CaCO3)	mg/L	310	690	360	400	740	1200	300	2700	410	250
Ion Balance	N/A	1.1	0.99	1.1	1.1	1.0	1.0	1.1	0.98	1.1	1.1
Dissolved Nitrate (NO3)	mg/L	0.027	16	0.027	0.035	7.6	8.6	0.032	120	0.016	0.014
Nitrate plus Nitrite (N)	mg/L	0.0060	3.7	0.0060	0.0080	1.7	2.0	0.0070	28	0.0040	0.0030
Dissolved Nitrite (NO2)	mg/L	<0.0099	0.046	<0.0099	<0.0099	0.027	0.025	<0.0099	0.19	<0.0099	<0.0099
Total Dissolved Solids	mg/L	850	2300	870	1000	2200	3200	710	6700	1200	630
Misc. Inorganics											
Conductivity	uS/cm	1600	4100	1700	1900	3900	6000	1400	11000	2200	1200
pH	N/A	7.99	8.07	8.07	8.01	7.99	7.97	8.02	7.82	8.22	8.10
Anions											
Alkalinity (PP as CaCO3)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Alkalinity (Total as CaCO3)	mg/L	120	150	160	160	120	93	140	83	200	120
Bicarbonate (HCO3)	mg/L	150	190	190	200	140	110	180	100	240	140
Carbonate (CO3)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Hydroxide (OH)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Dissolved Sulphate (SO4)	mg/L	94	180	80	86	200	200	74	490	82	75
Dissolved Chloride (Cl)	mg/L	360	1100	350	440	1000	1700	280	3500	520	250
Nutrients											
Dissolved Nitrite (N)	mg/L	<0.0030	0.014	<0.0030	<0.0030	0.0083	0.0077	<0.0030	0.059	<0.0030	<0.0030
Dissolved Nitrate (N)	mg/L	0.0060	3.7	0.0060	0.0080	1.7	1.9	0.0072	28	0.0037	0.0031
Elements											
Dissolved Calcium (Ca)	mg/L	67	160	83	90	180	290	71	690	89	55
Dissolved Iron (Fe)	mg/L	0.075	0.13	0.10	0.11	0.13	0.20	0.089	0.36	0.16	0.071
Dissolved Magnesium (Mg)	mg/L	33	69	36	41	69	120	30	250	45	28
Dissolved Manganese (Mn)	mg/L	<0.0040	0.013	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	0.0095	<0.0040	<0.0040
Dissolved Potassium (K)	mg/L	28	330	21	23	210	230	8.3	650	20	6.4
Dissolved Sodium (Na)	mg/L	200	370	200	240	380	590	160	910	300	150

4.5.2 Soil Sampling

Five soil samples were collected during the 2013 field visit (Figure 4-8). Three of the samples (S01, S02 and S03) were taken from the area of elevated apparent conductivity located immediately east from the Mallik 2L-38 Sump. Sample S04 is a control sample taken approximately 150 m north of the two sumps. Sample S05 was taken at the bottom of the small pond located in between the two sumps. A summary of the laboratory results is presented in Tables 4-9 with full laboratory report present in Appendix D.

The conductivity level of the samples collected appears similar to the results from the EM surveys. Samples S01, S02 and S03 have the highest conductivity, while the control sample has the lowest.

Sample S03 was collected at an area where light brown debris was present at the ground surface in a 5 to 10 m^2 area directly east from the Mallik 2L-38 Sump (see Figure A-11 in Appendix A). The exact nature of the material is still unknown but may be a drilling-related product (e.g., drilling mud or cement). The sample indicates elevated potassium (3,100 mg/kg), chloride (5,400 mg/kg) and sulphate (1,300 mg/kg) levels compared to other samples, especially from the control sample (10 mg/kg, 480 mg/kg and 110 mg/kg respectively). The lab result of sample S03 did suggest that some drilling material is present outside the assumed sump perimeter. It is unknown exactly how much material is present but a visual assessment in addition to several other soil samples taken in that specific area suggest that the volume of material is minimal (< $2m^2$).

Table 4-9 Soil Sampling Results

		MALLIK-2013-S01	MALLIK-2013-S02	MALLIK-2013-S03	MALLIK-2013-S04	MALLIK-2013-S05
Sampling Depth	**UNITS**	**30-50 cm**	**30-50 cm**	**10-25 cm**	**20-40 cm**	**0-10 cm**
Calculated Parameters						
Anion Sum	meq/L	190	200	250	37	90
Cation Sum	meq/L	190	190	250	36	95
Cation/EC Ratio	N/A	9.9	9.6	9.3	8.7	10
Ion Balance	N/A	1.0	0.97	1.0	0.96	1.1
Calculated Calcium (Ca)	mg/kg	600	220	1000	58	250
Calculated Magnesium (Mg)	mg/kg	180	130	55	16	110
Calculated Sodium (Na)	mg/kg	730	1300	970	250	470
Calculated Potassium (K)	mg/kg	49	19	3100	10	30
Calculated Chloride (Cl)	mg/kg	2500	2700	5400	480	1200
Calculated Sulphate (SO4)	mg/kg	280	230	1300	110	360
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	6100	6600	7700	1100	2600
Soluble Conductivity	dS/m	19	20	27	4.1	9.5
Soluble (CaCl2) pH	N/A	7.38	7.55	8.39	7.34	6.81
Sodium Adsorption Ratio	N/A	11	26	9.6	11	9.4
Soluble Calcium (Ca)	mg/L	1500	540	1500	140	560
Soluble Magnesium (Mg)	mg/L	440	330	78	38	240
Soluble Sodium (Na)	mg/L	1800	3200	1400	590	1100
Soluble Potassium (K)	mg/L	120	47	4500	24	67
Soluble Sulphate (SO4)	mg/L	700	580	1900	250	800

5 Conclusion

Ground surface drainage conditions ranged from imperfect to poor on the entire Mallik L-38 Site. The water level of most ponds, both on and off the sump caps, was higher in 2013 than during the September 2012 field visit. Local surface drainage conditions are known to vary quite significantly at the Mallik site and are due to several factors including: geographic location, recent precipitations, and storm surges.

The surface conditions of the two sumps are similar to the previous visit in September 2012. There is no vegetation growing at the surface of the sumps with signs of subsidence evident on both sumps. Depressions filled with water are present at either sides of the Mallik 2L-38 Sump. The depressions are deeper than any natural ponds in the area and have a maximum depth of approximately 1.2 m. A long linear depression is present on the southwest side of the 3L/4L/5L-38 Sump. The depression is 50m long by approximately 6m wide and filled with 20 to 40cm of water. The depressions on the opposite side of the sump (northeast) are only slightly smaller. It is unknown if these subsidence areas have increase in size since the 2012 field visit.

The successive storm surges that take place clearly have an impact on the site by inundating the sump areas with saline water; water that then get trapped in the various natural depressions and subsidence areas that are present within the perimeters of the sumps.

Active layer measurements indicate a decrease in active layer depth compare to last year. Measurements taken on September 11 indicate an average thaw depth of 123 cm at the surface of the 2L-38 and 121 cm at the surface of the 3L/4L/5L-38 Sump, compare to 140 cm and 132 cm on September 4 of 2012. The active layer measured at the surface of the sumps is approximately 10 cm deeper than along the control transect.

The air temperature sensor indicates that 2013 summer months were approximately 2 to 5°C colder than the equivalent months of 2012. Colder summer temperatures could explain the decrease in active layer depth. Other factors such as the amount of snow that was on site during the winter, as well as the date at which the snow melted could explain the difference in annual thaw penetration.

The temperature profiles recorded during the September 2012 to September 2013 period are very similar to those of the 2011-2012. The coldest temperature profile of the last 12 months was recorded at the Mallik 3L/4L/5L-38 Sump (-6 °C to -7°C average between 1 and 10 m depth). The temperature sensor at 1.5 m depth recorded negative temperatures over the last 12 months period.

The thermistor installed in the Mallik 2L-38 Sump last September (12GSC-05) indicates average ground temperatures ranging between -5°C and -7°C, although it is likely still returning to equilibrium condition. The warmest temperature profile was recorded at 07GSC-02, which is located in an undisturbed area approximately 200m east from the two sumps.

The findings of the electromagnetic survey are consistent with previous year's results. The EM38 and the EM31 Survey have identified areas of elevated apparent conductivity values at both sumps locations. The EM31 and especially the EM38 surveys indicate areas of elevated apparent conductivity outside the sump areas. These areas correspond to areas of bare soils as well as a series of natural depression located at proximity to the sumps. Water and soil samples taken from those high apparent conductivity areas indicates high sodium content believed to result from the evaporation of sea water. Water samples taken in the subsidence areas of both sumps have high potassium values and suggesting that seasonally unfrozen drill mud contaminants are mixing into the subsiding portions of the sump caps.

Soil samples taken from an area of elevated apparent conductivity located immediately east from the Mallik 2L-38 Sump indicates that some material used during the drilling process is present at the ground

surface in that specific area. A distinct white colored and fine textured material was observed on the ground surface. A sample of this material indicates high levels of potassium, chloride and sodium that could correspond to drilling fluid material. A comparison of the EM31 and EM38 data suggest that the contaminant is mostly present at the near surface and therefore not related to the seepage of drilling contaminants from the sump.

6 References

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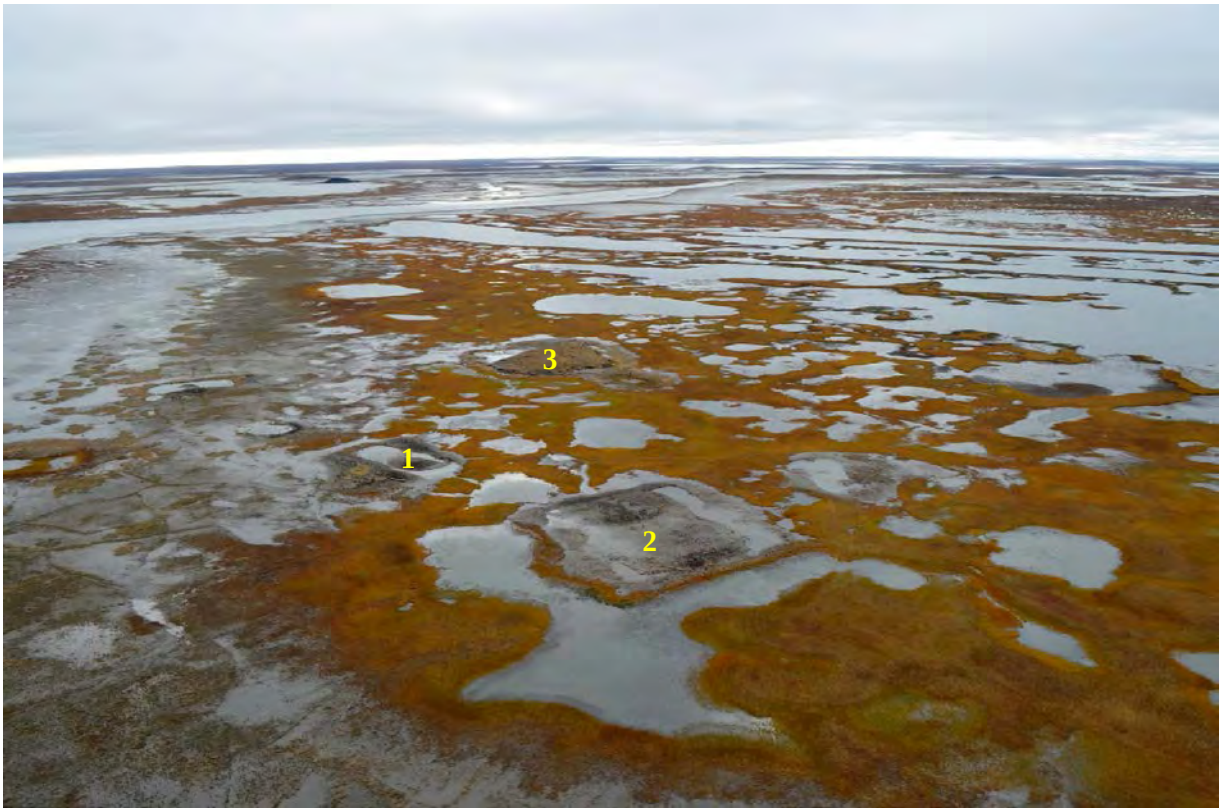
Appendix A Site Photographs

Figure A-1 Aerial overview of Mallik site (looking south)



1- Mallik 2L-38 Sump
2- Mallik 3L/4L/5L-38 Sump
3- IOL Sump

Figure A-2 Aerial view of Mallik 3L/4L/5L-38 Sump

The yellow arrows are pointing to the areas of ground subsidence.

Figure A-3 Subsidence and water ponding along the southwestern side of Mallik 3L/4L/5L-38 Sump

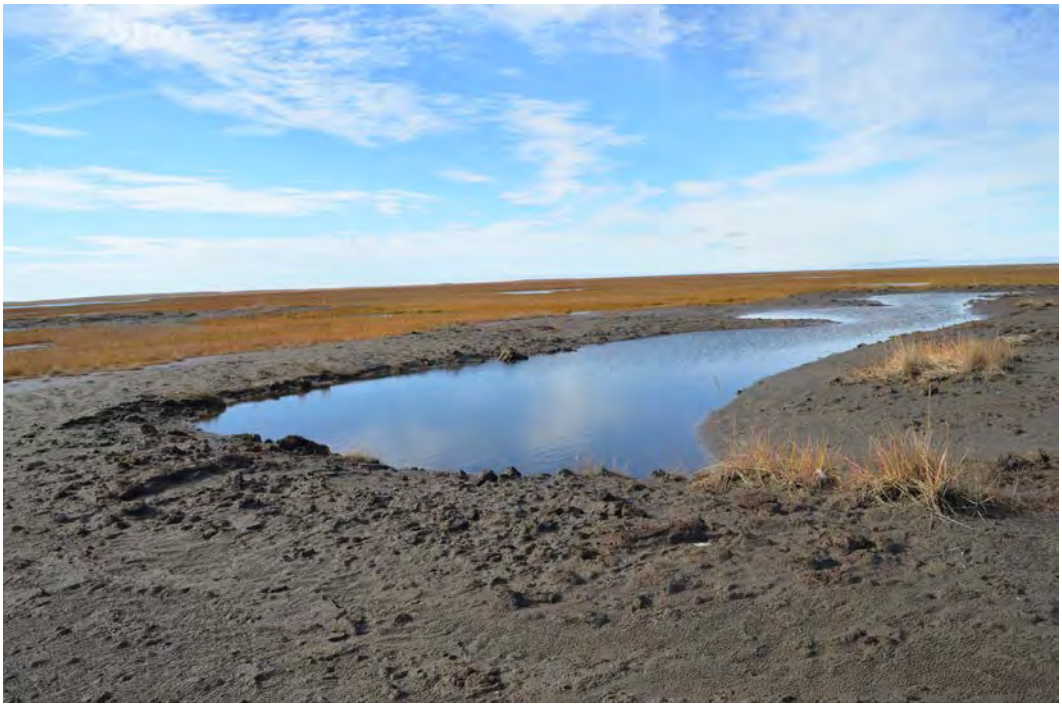
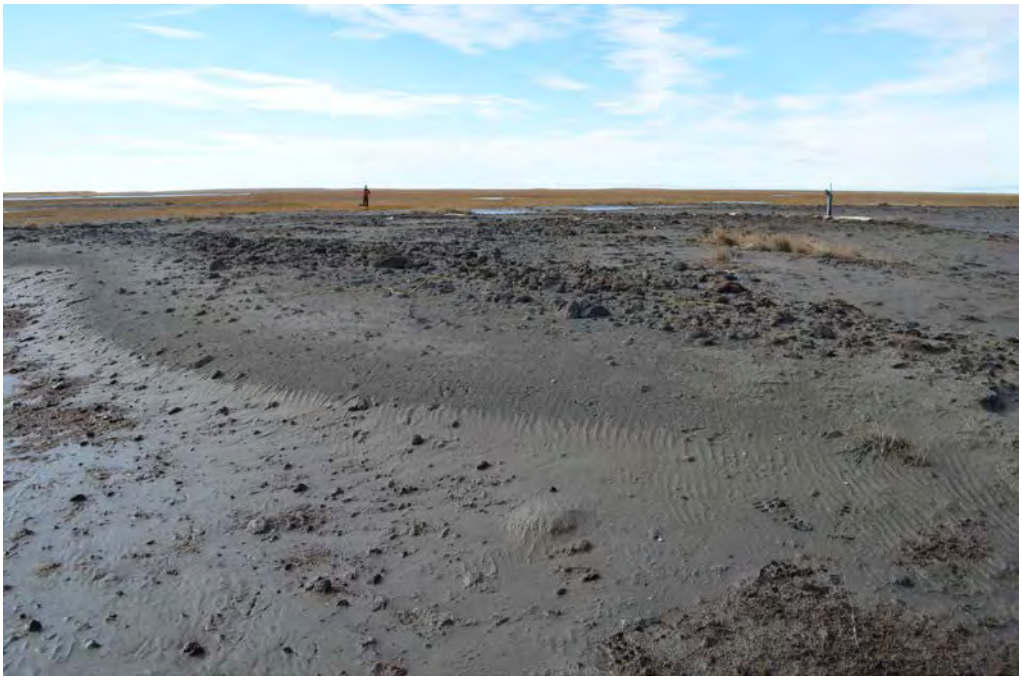


Figure A-4 View of Mallik 3L/4L/5L-38 Sump cap (looking northwest)



Note the presence of ripple marks left by a recent storm surge that flooded the area.

Figure A-5 Subsidence and signs of surface erosion along the southern corner of Mallik 3L/4L/5L-38 Sump

A series of small and shallow gullies are present along the very edge of the sump, probably due to the drainage of excess water brought in by the storm surge

Figure A-6 Aerial view of the Mallik 2L-38 Sump (looking north)

Figure A-7 Oblique view of Mallik 2L-38 Sump (looking west)

Note the casing of the new thermistor (GSC05) at the center of the sump

Figure A-8 Subsidence area at the eastern end of the Mallik 2L-38 Sump

Figure A-9 Subsidence area at the western end of the Mallik 2L-38 Sump

Figure A-10 Minor surface subsidence at the surface of two interconnecting ice-wedges (approx. 40 m north of the Mallik 2L-38 Sump).

Figure A-11 White residue found at the ground surface just east from Mallik 2L-38 Sump (soil sample S03).

Figure A-12 2011 and 2012 aerial views of the Mallik site

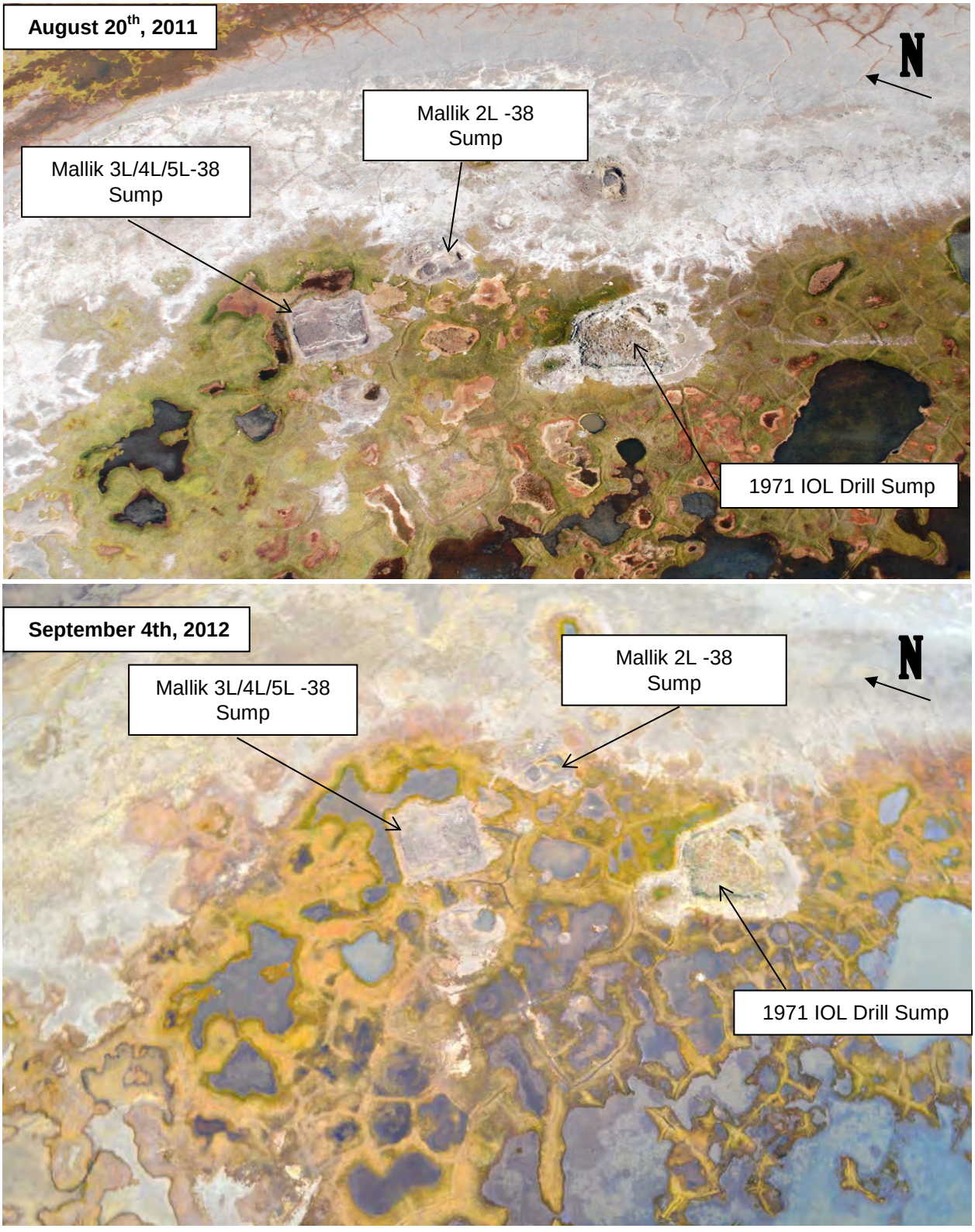
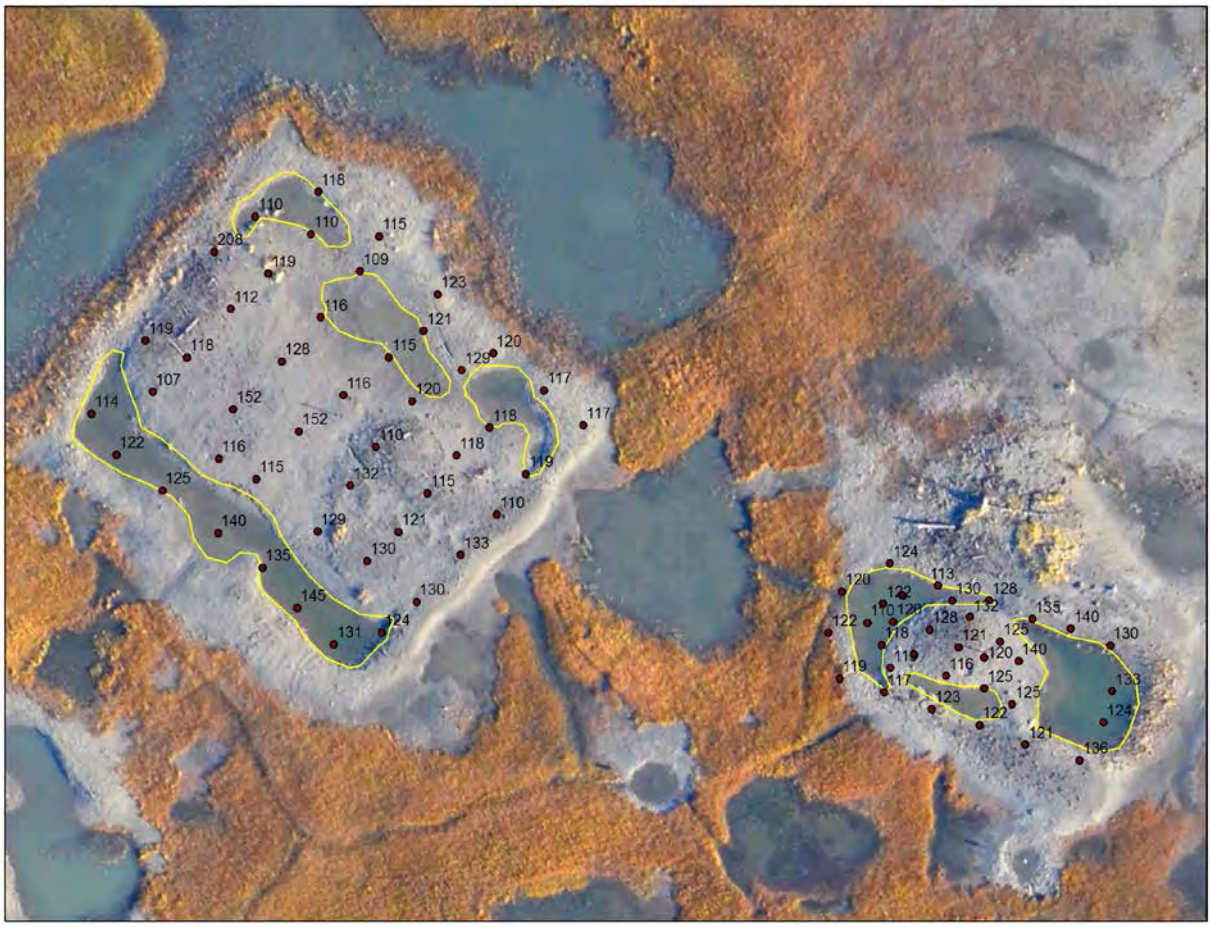


Figure A-13 Active layer measurement on both sumps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Appendix B Thermistor Data

Figure B-1 **Daily mean air temperature at the Mallik site (05/09/2012 to 11/09/2013)**

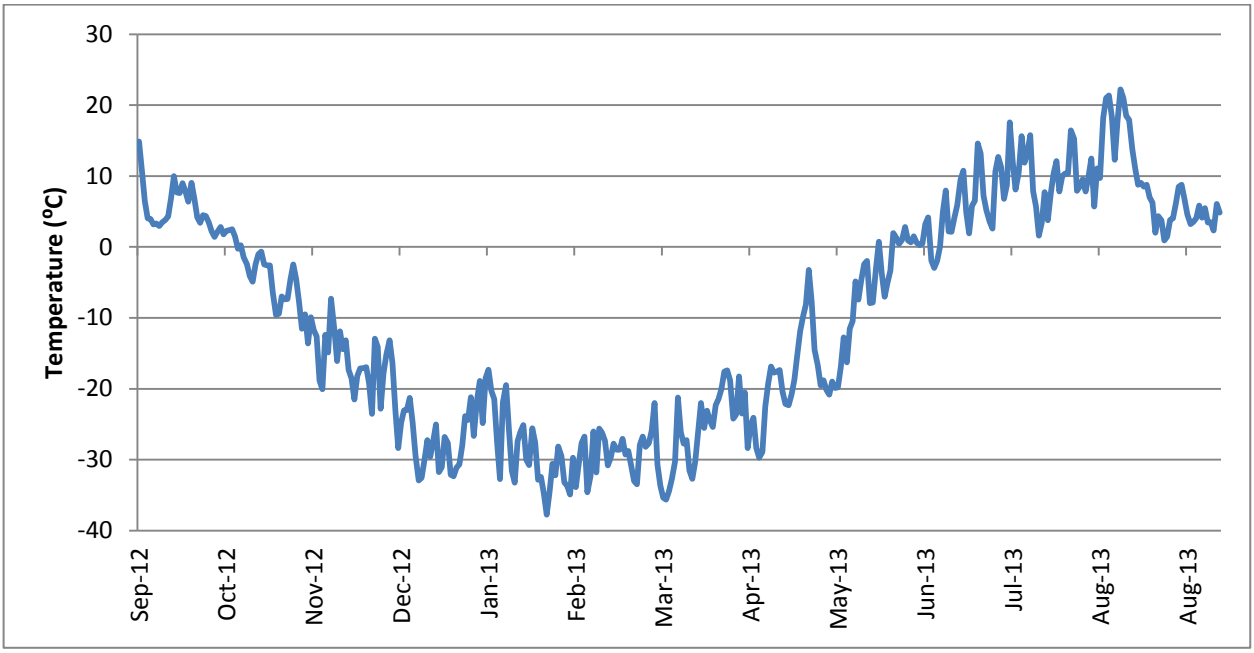


Figure B-2 **Daily mean ground temperature at the Mallik site (05/09/2012 to 11/09/2013)**

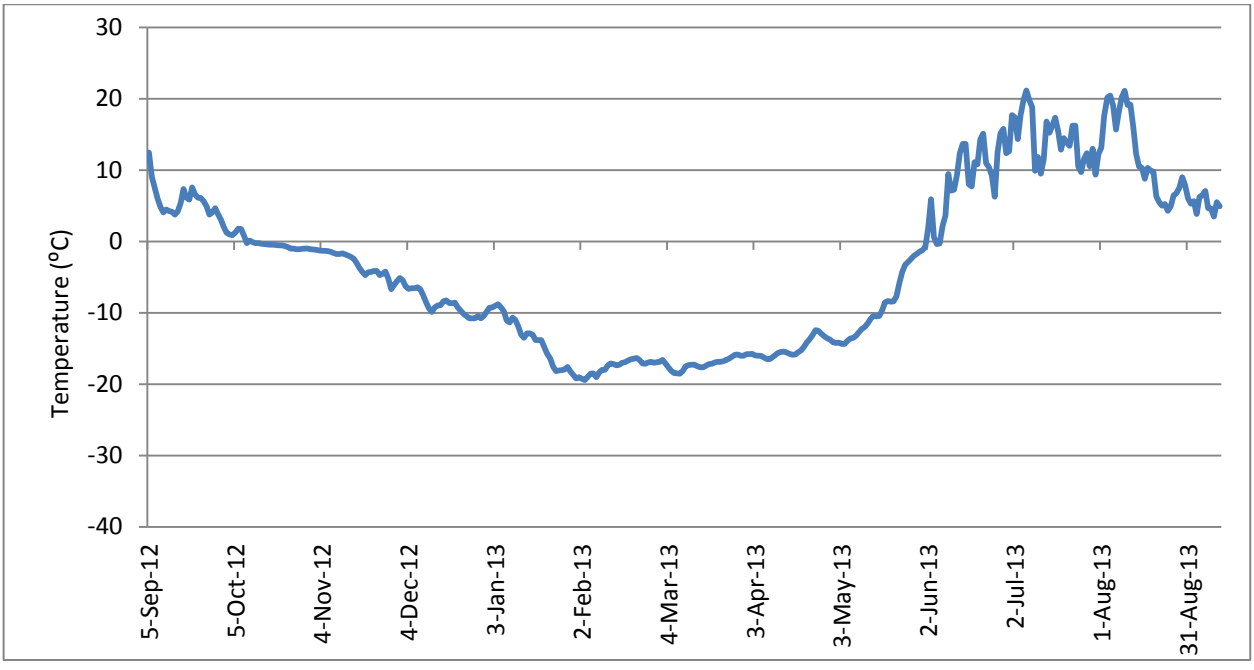


Figure B-3 Monthly mean air temperature (October 2010 to August 2013)

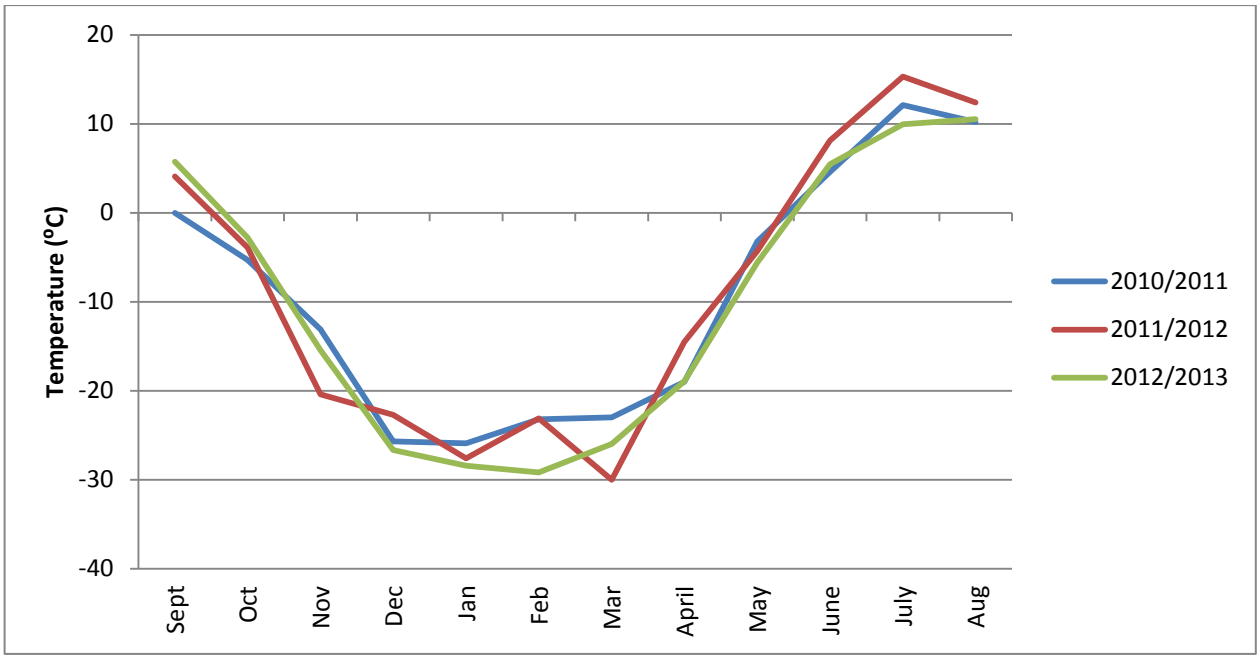


Figure B-4 Thermistor 07GSC-01 – Daily Ground Temperatures (9/6/2012 to 9/5/2013)

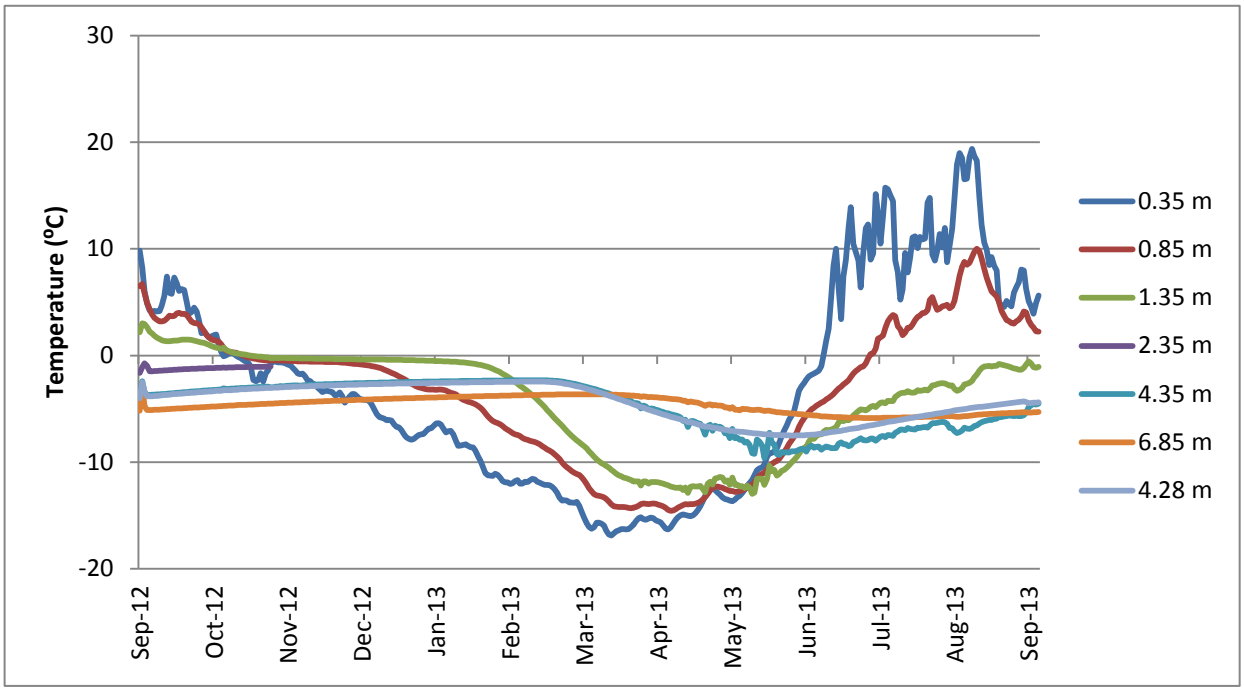


Figure B-5 Thermistor 07GSC-02 – Daily Ground Temperatures (9/6/2012 to 9/5/2013)

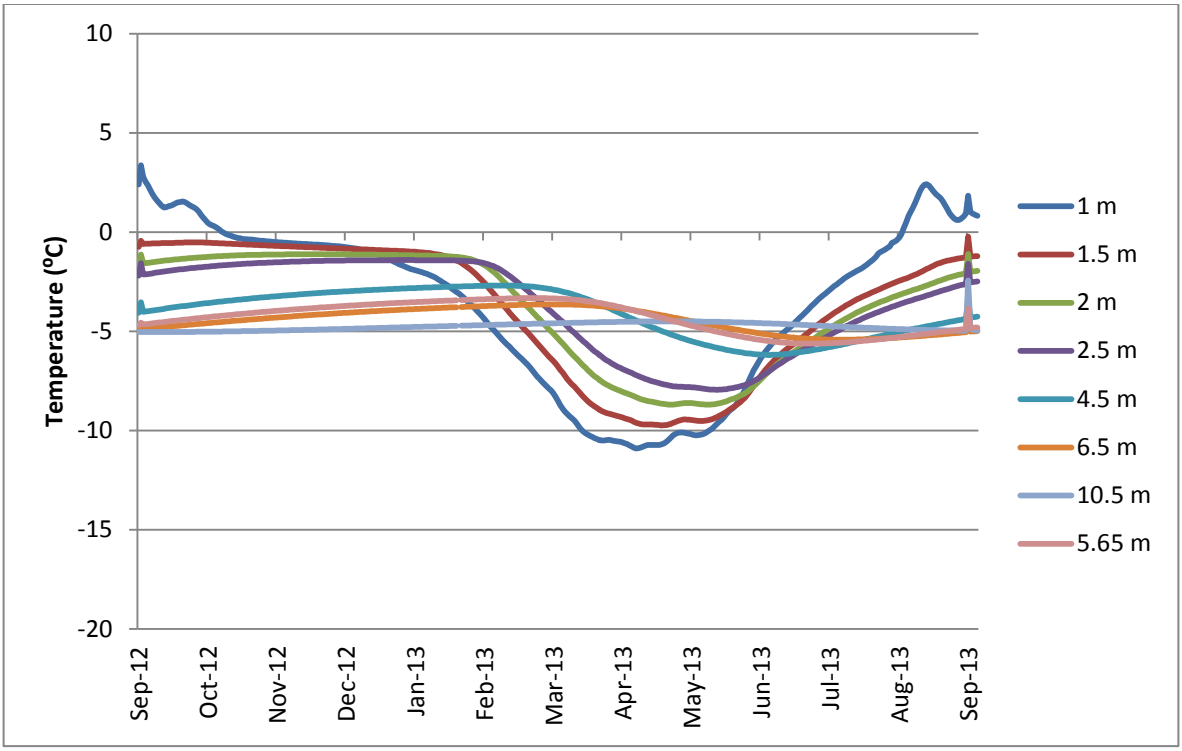


Figure B-6 Thermistor 07GSC-03 – Daily Ground Temperatures (9/6/2012 to 9/5/2013)

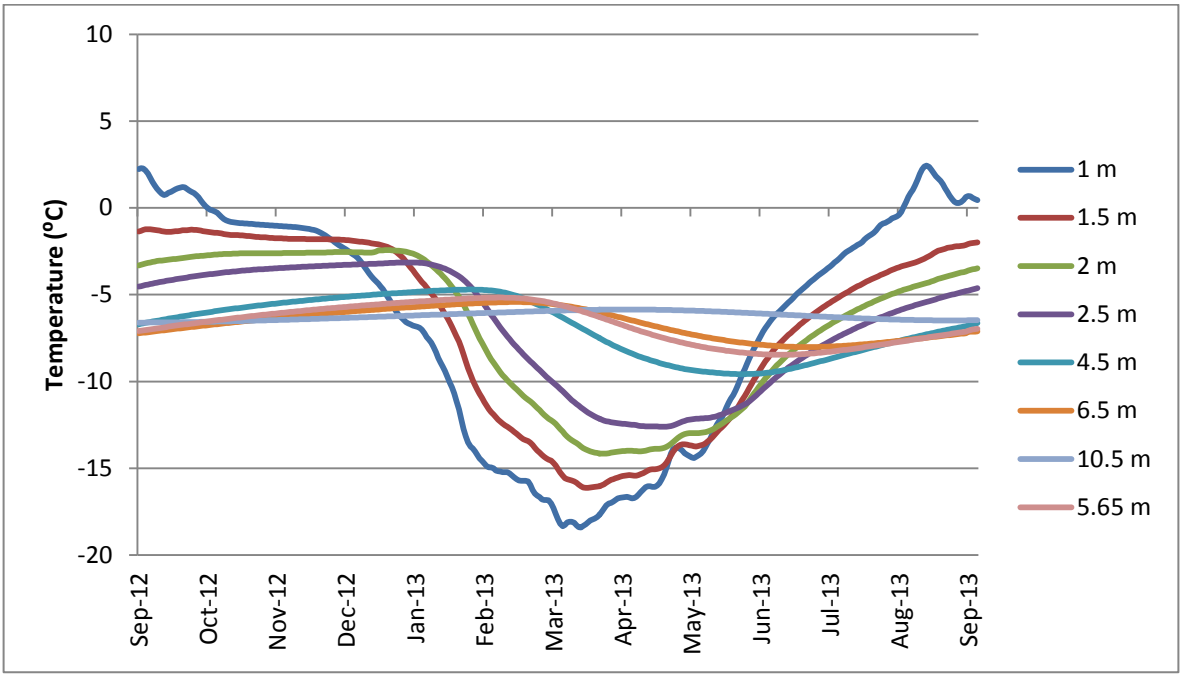


Figure B-7 Thermistor 07GSC-04 – Daily Ground Temperatures (9/6/2012 to 9/5/2013)

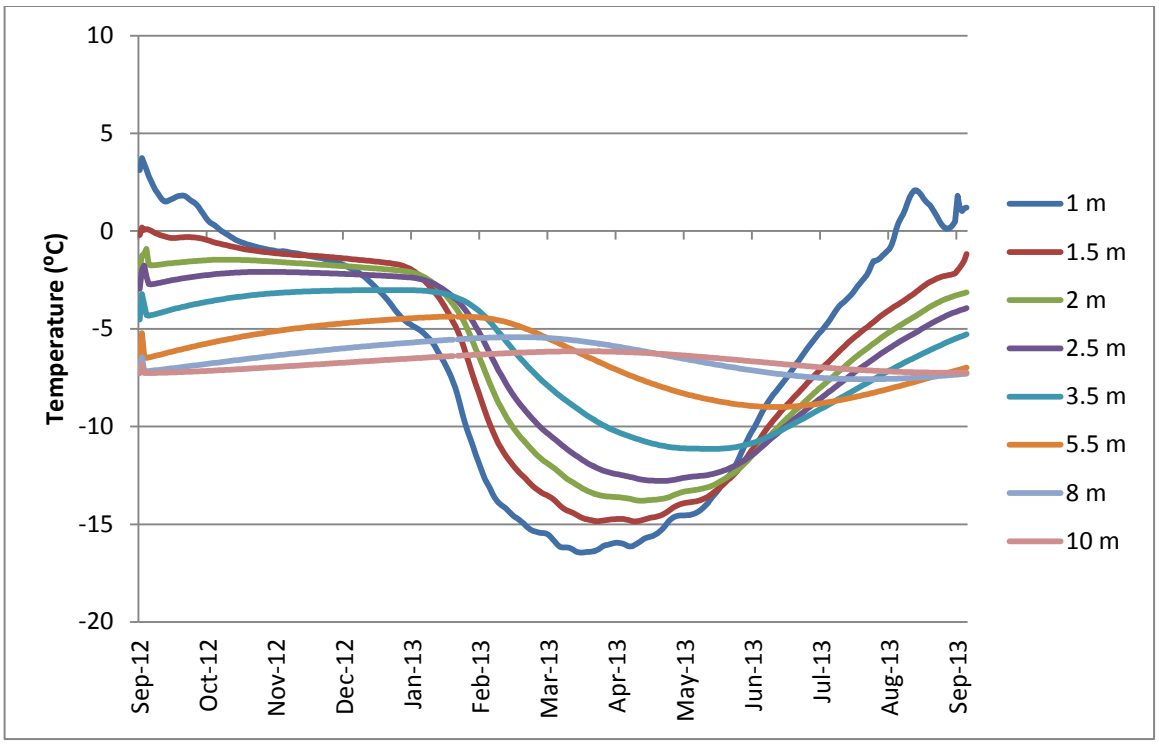
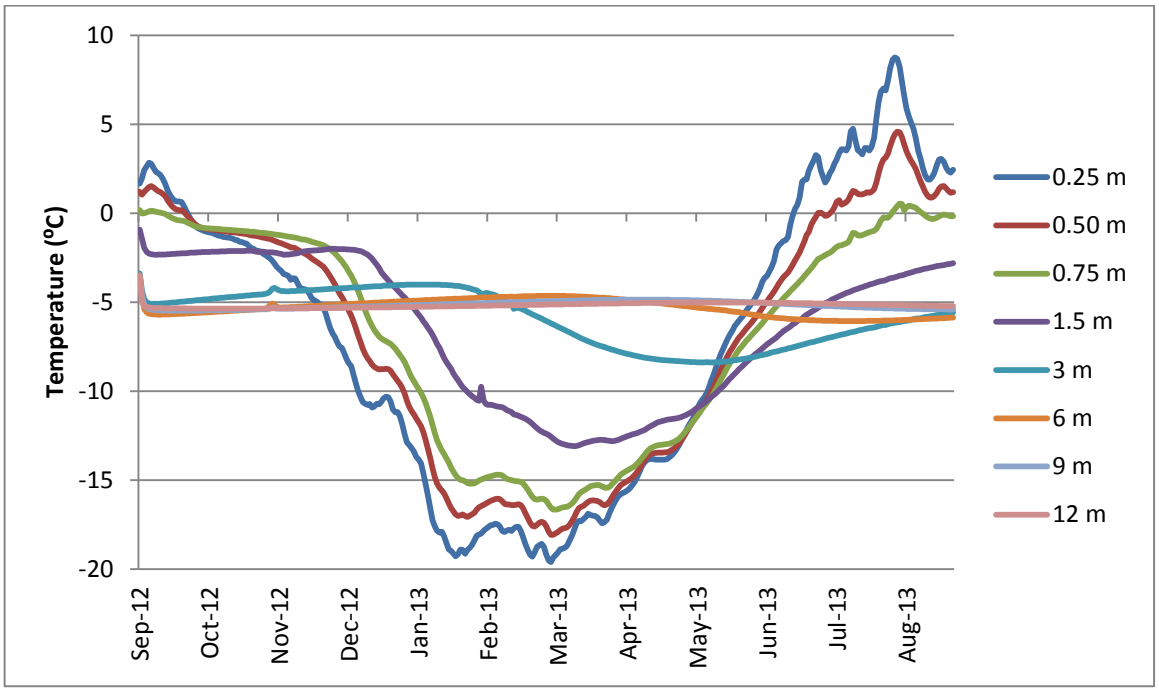


Figure B-8 **Thermistor 12GSC-05 – Daily Ground Temperatures (9/6/2012 to 9/5/2013)**



Appendix C Electromagnetic Surveys

Stantec

Memo

To:	Olivier Piraux Edmonton, AB	From:	James Hulsebosch Saskatoon, SK
File:	Mallik Em Surveys	Date:	November 27, 2013

Reference: Mallik EM Survey Data Results

When interpreting inductive electromagnetic (EM) geophysical data in areas of permafrost the critical factor to consider is the depth of the active layer. Frozen subsurface does not conduct electricity to any significant degree (see *Principles of Inductive Geophysical Methods* below for further details) and therefore, any measureable variations in terrain apparent EC resulting from elevated salinity will only be evident if within the active layer.

This is most pronounced in the EM31 data set due to its effective maximum 5.5 m depth of penetration and response curve; an EM terrain conductivity meter reading, referred to as the terrain apparent EC, is an average of the subsurface conductivity within the response curve at that location and time of that instrument. Subsequently, the EM31 response to elevated soil salinity in an area with a shallow active layer will be relatively subdued even if the elevated soil salinity extends deeper than the active layer. Overall, the EM31 data in areas with a relatively shallow (>1 m) active layer will be characterized by correspondingly low terrain apparent EC readings, except in areas of deeper active layer and/or exceptionally high shallow subsurface salinity.

The EM38, due to its shallower maximum 1.5 m depth of effective penetration, is considerably more sensitive to minor variations in the active layer depth and the salinity concentrations within that layer. Overall, the EM38 data set will be characterized by relatively higher terrain apparent EC readings compared to the EM31 data and better resolution of near-surface salinity anomalies.

The close proximity of the Site to the ocean and the associated storm surges should also be considered; identifying potential anthropogenic impacts is complicated by naturally occurring sediment salts and/or naturally occurring changes in the active layer depth related to these salts. Differentiating anthropogenic from naturally occurring terrain apparent EC anomalies therefore is complex and interpretations should be considered as such; intrusive sampling techniques should always be used to confirm any interpretations of geophysical data.

The EM31 survey and the EM38 survey have identified areas of highly elevated terrain apparent EC on the Mallik 2L-38 Sump and on the 3L/4L/5L-38 Sump. These elevated responses likely are related in part to the presence of saline drill cuttings and drilling fluids within the sumps, although an increased depth of active layer associated with these features is possible. Further assessment of the active layer depth would be required to confirm this.

Similarly to the 2011 and 2012 analysis, the EM31 and EM38 surveys also reveal elevated terrain apparent EC in areas outside the sump perimeters. These areas of elevated terrain apparent EC appear to be associated with both naturally occurring and anthropogenic sources.

The east portion of the EM31 and EM38 surveys is characterized by highly elevated terrain apparent EC that is especially pronounced in the EM38 data. This implies that the source of elevated terrain apparent EC is primarily within the upper 1.5 m of the soil profile. Due to the close correspondence

of this elevated terrain apparent with bare areas, assumed to be naturally occurring, it is also assumed that the source of this elevated terrain apparent EC is also primarily naturally occurring. Two pits, assumed to be anthropogenic, in this region correspond with lower terrain apparent EC in both data sets. The influence of these pits on terrain apparent EC is not clear, although it could be a result of removal of naturally saline soil during their excavation, a shallower active layer, or both.

Elevated terrain apparent EC measurements have been observed to correspond with several natural ponds each year the EM surveys have been conducted. These are most evident as areas of moderately elevated terrain apparent EC in the EM38 data. Past water sample analyses indicate that the high conductivity is most likely related to the evaporation of trapped sea water from the annual storm surges and are not indicative of sump seepage. Water analyses are presented in Section 4.5.1.

Elevated terrain apparent EC, evident in both data sets, corresponds with the footprint of a small pond located approximately 50 m from the southern edge of the 3L/4L/5L-38 Sump. The pond is approximately 30 m x 35 m and was filled by approximately 40 cm of water at the time of visit. The similarity of this feature in size and terrain apparent EC between the EM 38 and EM31 data sets indicates that the elevated instrument response could result from instrument response to a relatively deep active layer rather than high salinity concentrations. Further assessment would be required to confirm this.

Elevated terrain apparent EC readings extend northeast from the Mallik 2L-38 Sump and cannot be differentiated from assumed naturally occurring elevated terrain apparent EC. However, additional observation along this portion of the sump indicates that the ground surface could possibly have been disturbed and that drill muds and cuttings could be present at the ground surface. A soil sample was collected at this location and the results are presented in Section 4.5.2.

Finally, an area of moderately elevated terrain apparent EC, primarily evident in the EM38 data, can be seen extending approximately 80 m west of the Mallik 2l-38 Flare Pit. This anomalous feature is associated with bare surface areas but no depressions or standing water. It seems unlikely therefore that this features is a result of greater active layer depth or influence from storm surges. Rather, it seems to indicate a plume of overland and/or near-surface flow of saline fluids. The source of these suspected fluids is unclear since the flare pit does not exhibit anomalously elevated terrain apparent EC despite its seeming origin of the plume. This suspected plume could represent a historical spill(s) originating at the flare pit.

Principles of Inductive Geophysical Methods

Inductive geophysical or electromagnetic (EM) terrain conductivity instruments operate under these principles:

- An alternating electrical current is passed through a transmitter coil, thus generating an alternating magnetic field called the primary magnetic field;
- The alternating primary magnetic field induces an electrical current in the shallow subsurface; and,

Reference: Mallik EM Survey Data Results

- This subsurface electrical current generates a secondary magnetic field that is detected by the receiver coil. The ratio of the primary to secondary fields is equivalent to the terrain electrical conductivity (EC) in units of millisiemens per meter (mS/m) (McNeill, 1980a).

The EC of soils and rocks is "primarily electrolytic and [takes] place through the moisture filled pores and openings within the matrix of insulating materials" (McNeill, 1980b). Although the subsurface (soil and water) may be complex, the following factors primarily influence EC:

1. ***Texture and Particle Distribution***. Finer-grained media, such as clay and organic matter (humus), tend to have a higher EC than coarser grained media. The greater surface area and electrically charged surfaces of these media result in a corresponding increase in ionic exchange sites, a subsequent increase in available ions, and a significant increase in soil conductivity. Humus-rich, clay sediments therefore, generally have higher electrical conductivities than gravel, sand or silt with low organic matter content. In areas of minimally saline porewater, changes in electrical conductivity are highly dependent on the amount of clay. This is particularly pronounced in predominantly clean (low clay content), saturated material where the presence of even small amounts of clay may have marked effects on EC. The presence of quartz (high resistivity or low conductivity) in sand and/or sandstone results in especially low electrical conductivity values.

2. ***Porosity***. Finer textured sediments and organic colloids typically have a greater porosity and subsequently, an increased water-holding capacity. The result is a corresponding increase in electrical conductivity under saturated conditions. Also, the size and tortuosity of soil passages will affect water/solute movement and hence, electrical conductivity.

3. ***Degree of water saturation***. The same medium will have a higher EC if it is saturated. In an unsaturated medium air/gas bubbles limit the flow of water/ions.

4. ***Temperature*** *and phase state of the pore water.* Most ions exhibit a 2.2% change of conductivity per degree centigrade change in water temperature. A 20°C increase in soil water temperature would therefore result in a 50% increase in conductivity. Clearly, considerable changes in conductivity may be observed in soil water near enough to the surface to be affected by typical seasonal changes in ambient air temperature. Also, when pore water changes phase to pore ice there is a rapid drop in conductivity as the mobility of ions is reduced to near-zero. The speed with which this phase change occurs is regulated by impurities and colloids which impede the formation of ice. For example, saline water in a clay-sand mixture will retain a degree of liquid phase, and subsequent conductivity, to a lower temperature than would pure water in a sand medium.

5. ***Ionic strength of the pore water***. The EC of a medium will increase as the ionic strength of the pore water within that medium increases. Therefore, brackish or saline groundwater has a higher EC than fresh groundwater (McNeill, 1980b).

The presence of subsurface metal debris should also be considered in the interpretation of inductive geophysical data. Since the Geonics EM instruments have been calibrated for media with relatively

low EC they present anomalously high or low responses near metallic objects. Finally, electromagnetic interference from nearby electrical infrastructure (e.g. overhead power lines) or solar activity can impact the quality of collected data.

It is important to note that the response from an EM instrument is the average electrical conductivity of a hemispherical volume of the subsurface. Transmitter-receiver intercoil spacing and orientation define the hemispherical volume. Electrical conductivity may vary considerably within the depth interval encompassed by that hemisphere (approximately 6 m and 1.5 m for the EM31 and EM38 vertical dipole, respectively) depending on the heterogeneity of the subsurface (McNeill 1980b). The EC measured is unique to the instrument and the environmental conditions at the time of measurement. This measurement is referred to as terrain apparent EC.

EM surveys are well suited for mapping lateral changes in shallow subsurface EC, while vertical variations are best delineated using intrusive techniques.

Global Positioning System

A 2008 Series Trimble Geo XH linked via Bluetooth with an external backpack mounted Trimble Pro XRT receiver and Tornado antenna was used to collect EM data and positional data for geophysical measurements. GPS data are provided in the Universal Transverse Mercator (UTM) coordinate system referenced to the World Geodetic System 1984 Datum. Discrete positions are given in meters Easting and Northing. Real-time correction was provided by the OmniSTAR G2 system and was further enhanced to sub 0.15 m accuracy by post-processing differential correction.

Under ideal conditions, this system provides horizontal accuracy of within 0.15 m; positional accuracy may decrease under the following conditions:

- Under tree canopy or in areas of congested above-ground infrastructure, errors may result if the signal received by the GPS has been reflected off of a surface (post-processing minimizes such errors);
- Interfering obstacles can also cause signal strength degradation due to reflection or partial blockage of the signal; and,
- Solar storms emit electromagnetic radiation that causes variability in the geomagnetic field. This may result in interference with GPS signals and in turn a reduction in data quality and hence accuracy.

Data Collection and Processing

Positional and Geophysical data are collected at 1 second intervals corresponding to a linear distance of approximately 1 to 1.5 m. Spacing between traversed lines varies with the required resolution of the particular survey. However, spatial coverage is such that variations in terrain apparent EC can be mapped with a high degree of accuracy.

Reference: Mallik EM Survey Data Results

Data is transferred from the GPS unit to a laptop computer and is exported in an ASCII format using GPS Pathfinder Office. Using the Surfer software package, a Kriging method of data interpolation is employed to grid the positional and geophysical data. The resulting grid is utilized to create a variable color image map which highlights changes in terrain apparent EC. A contour map created from this grid is also overlaid to facilitate interpretation. Finally, site features mapped with the GPS are processed as digital exchange files (.dxf) in AutoCAD and added as a Base Map layer in the Surfer plot.

REFERENCES

McNeill, J.D., 1980a. Technical Note TN-5 Electrical Conductivity of Soils and Rocks. Geonics Ltd. Canada.

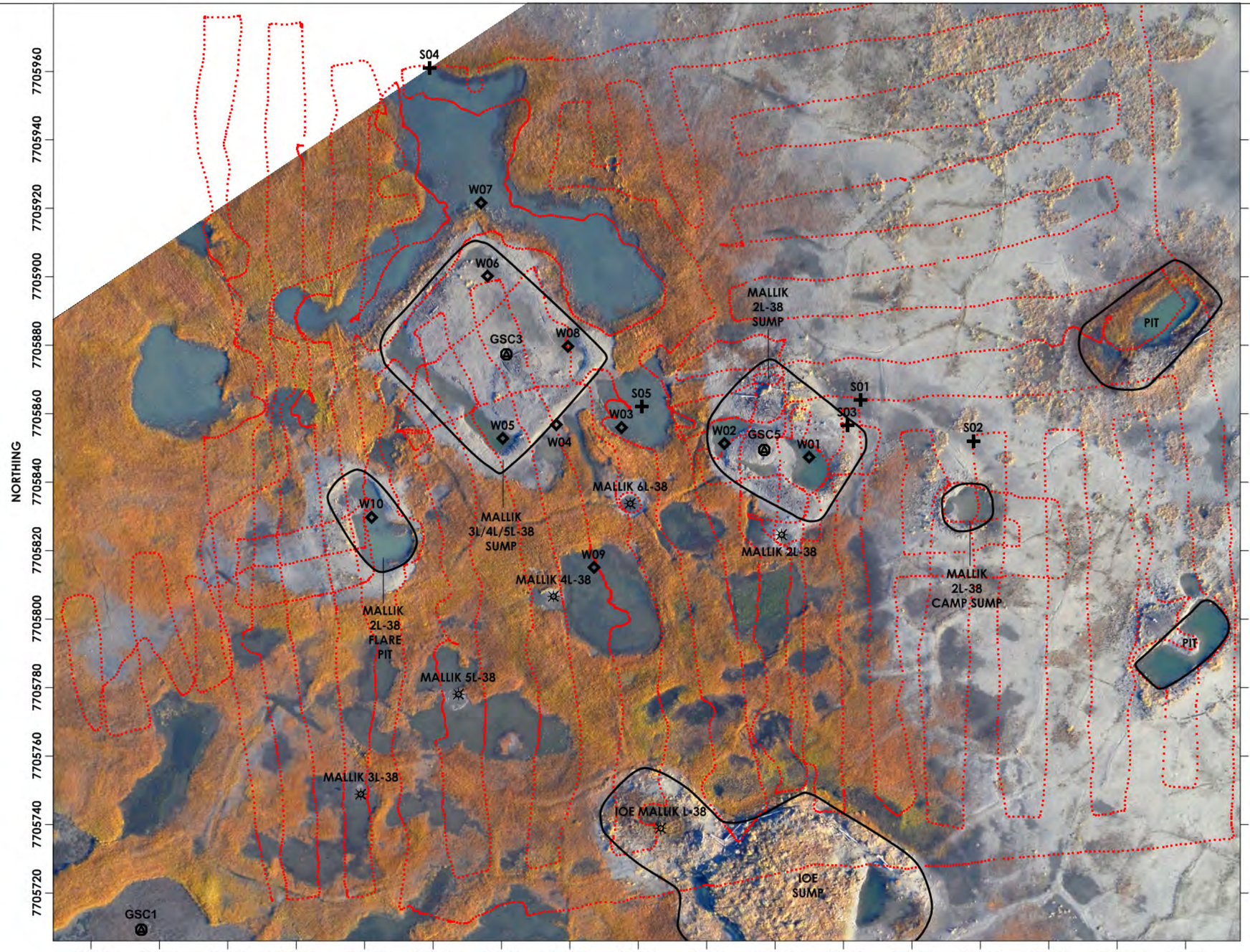
McNeill, J.D., 1980b. Technical Note TN-6 Electromagnetic Terrain Conductivity Measurement at Low Induction Numbers. Geonics Ltd. Canada.

Entity

James Hulsebosch
Environmental Scientist
Phone: 306-667-2457
Fax: Sender's Fax
James.hulsebosch@stantec.com

Attachment: Attachment

c. Cc List



Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

LEGEND

- MONITORING WELL
- SOIL SAMPLE
- SURFACE WATER SAMPLE
- WELLHEAD SIGN
- –150– CONDUCTIVITY CONTOURS

N

0 10 20 30 40 50 60 70 80 90 100 METERS

SCALE 1:1,250

Stantec

Stantec Consulting Ltd.
10160 - 112 Street
Edmonton AB Canada
T5K 2L6
Tel 780.969.3324
Fax 780.917.7011

Client/Project/Location

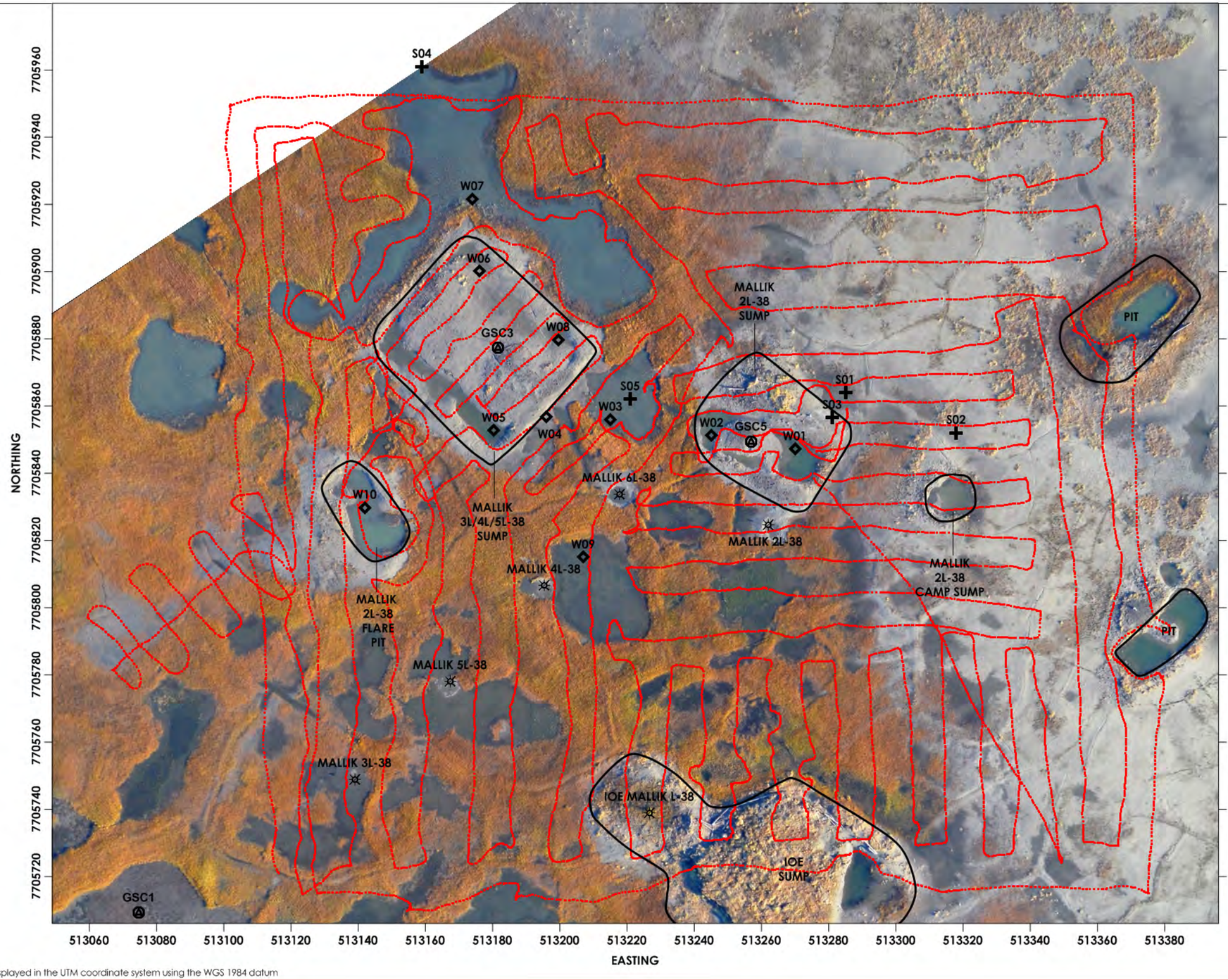
AURORA RESEARCH INSTITUTE
MALLIK SUMP MONITORING

Figure No. **1-A**

Title **EM38 SURVEY AREA**

Date **NOVEMBER 2013**

Stantec Project No. **110219049**



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LEGEND

- MONITORING WELL
- SOIL SAMPLE
- SURFACE WATER SAMPLE
- WELLHEAD SIGN
- –150– CONDUCTIVITY CONTOURS

0 10 20 30 40 50 60 70 80 90 100 METERS

SCALE 1:1,250

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

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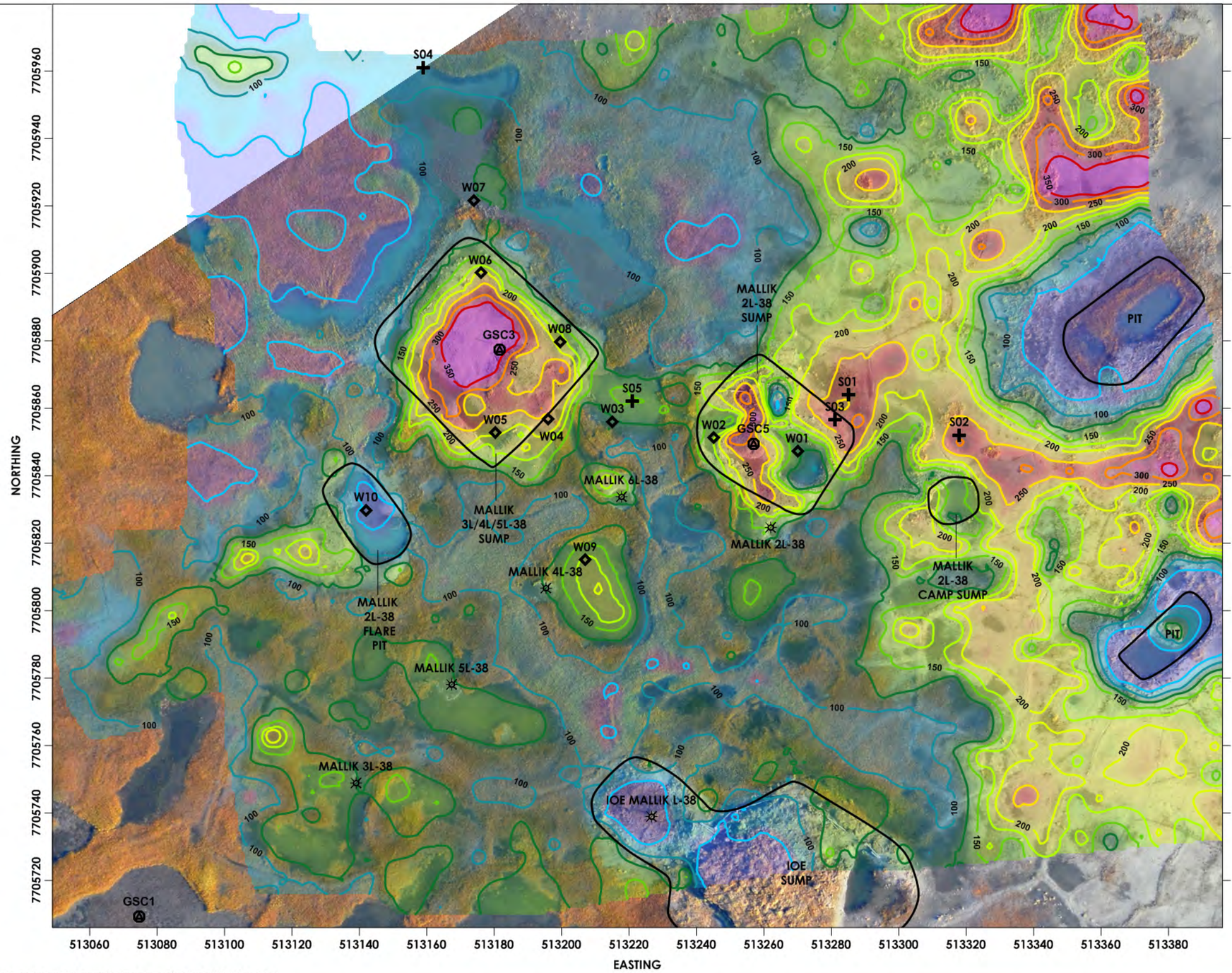
MALLIK SUMP MONITORING

Figure No. **1-B**

Title **EM31 SURVEY AREA**

Date **NOVEMBER 2013**

Stantec Project No. **110219049**



Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

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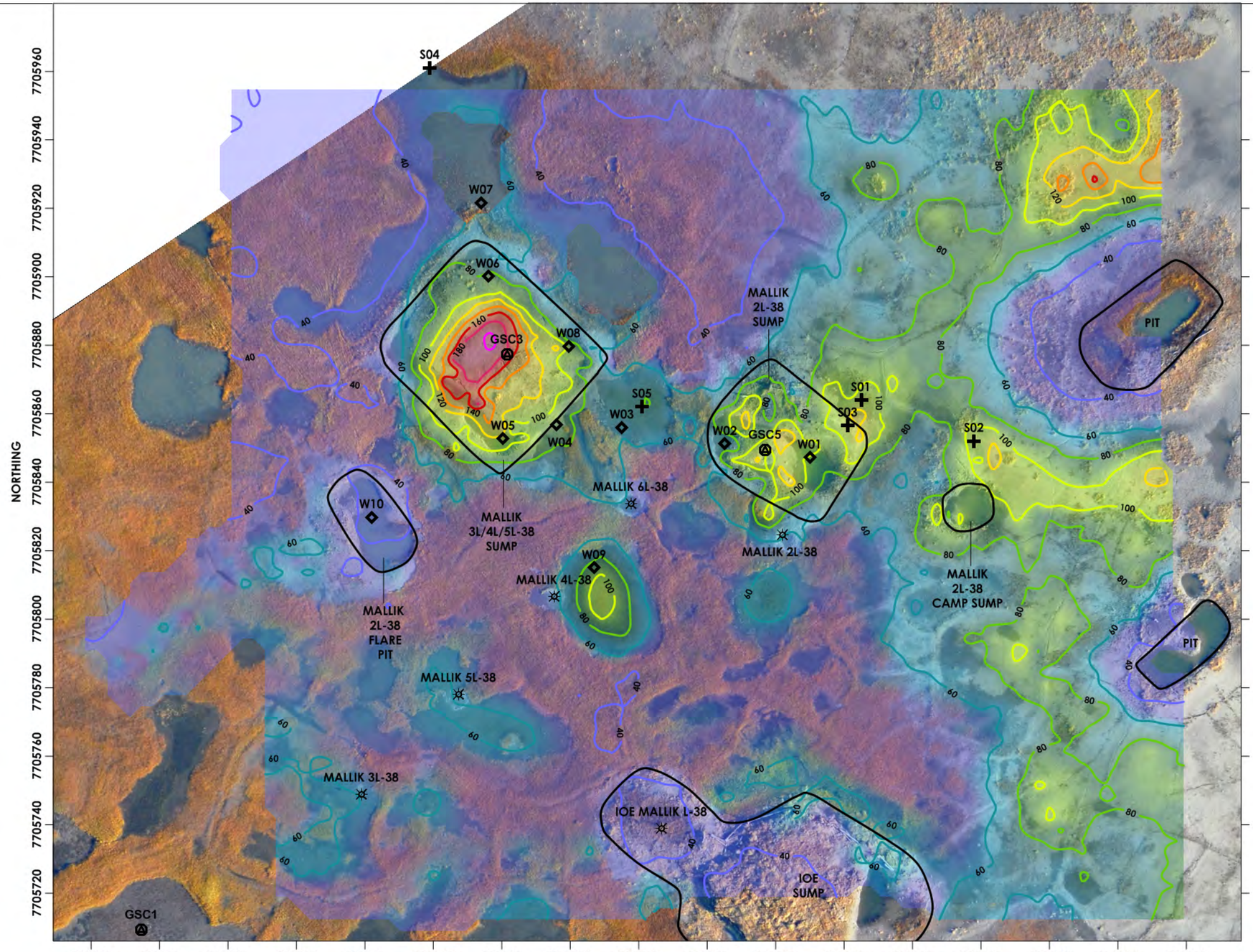
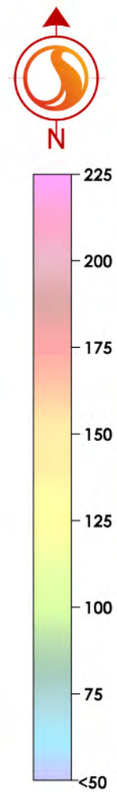
Figure No. **2-A**

Title **EM38 DATA PLOT & AERIAL PHOTO**

Date **NOVEMBER 2013**

Stantec Project No. **110219049**





LEGEND

- MONITORING WELL
- SOIL SAMPLE
- SURFACE WATER SAMPLE
- WELLHEAD SIGN
- –150– CONDUCTIVITY CONTOURS

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SCALE 1:1,250

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

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Client/Project/Location

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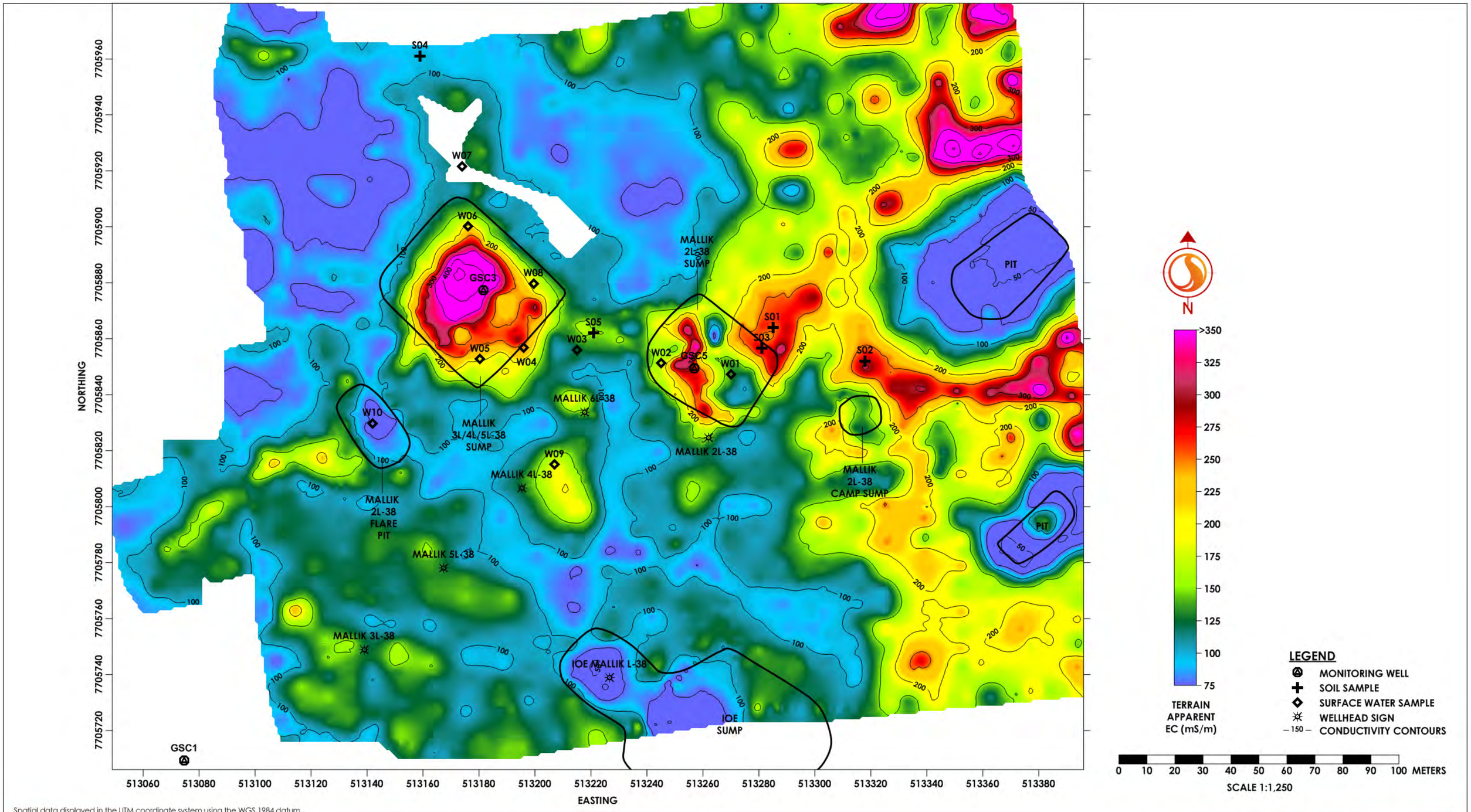
MALLIK SUMP MONITORING

Figure No. **2-B**

Date **NOVEMBER 2013**

Title **EM31 DATA PLOT & AERIAL PHOTO**

Stantec Project No. **110219049**



Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

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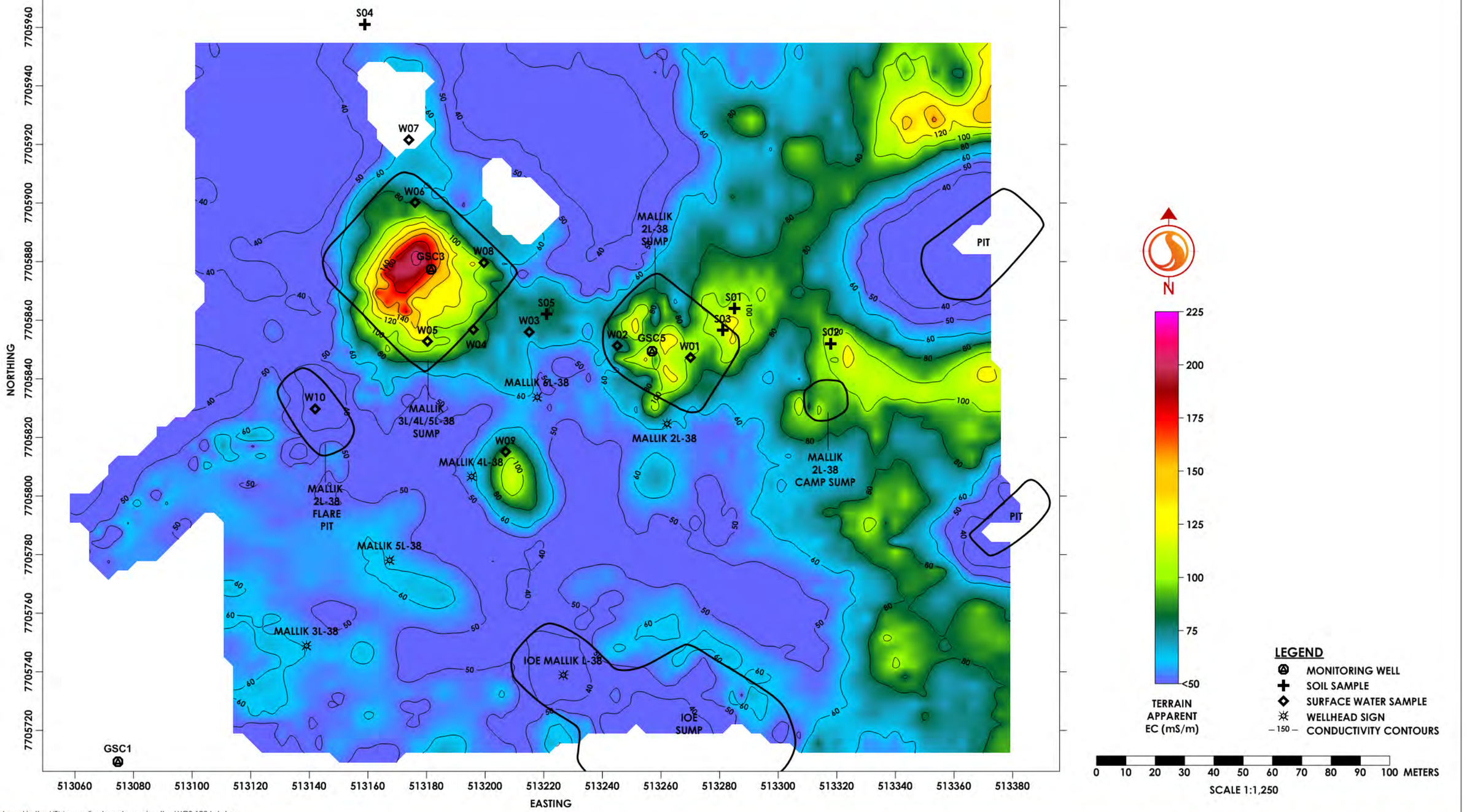
MALLIK SUMP MONITORING

Figure No. **3-A**

Date **NOVEMBER 2013**

Title **EM38 DATA PLOT**

Stantec Project No. **110219049**



Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

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MALLIK SUMP MONITORING

Figure No.
3-B

Date
NOVEMBER 2013

Title
EM31 DATA PLOT

Stantec Project No.
110219049

Appendix D Laboratory Analysis

Maxxam

Your P.O. #: 16300R-20
Your Project #: MALLIK
Site Location: INUVIK, NWT
NSD # 16300R
PO # 16300R
Your C.O.C. #: A134873, A134875

Attention: OLIVIER PIRAUX
STANTEC CONSULTING LTD
#200, 325- 25TH ST. SE
CALGARY, AB
CANADA

Report Date: 2013/09/23

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B383677
Received: 2013/09/14, 10:15

Sample Matrix: Soil
Samples Received: 5

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Cation/EC Ratio (1)	4	N/A	2013/09/20		CALCULATION
Cation/EC Ratio (1)	1	N/A	2013/09/23		CALCULATION
Chloride (Soluble) (1)	4	2013/09/19	2013/09/20	AB SOP-00020	SSMA 4500 CL-E
Chloride (Soluble) (1)	1	2013/09/21	2013/09/23	AB SOP-00020	SSMA 4500 CL-E
Conductivity @25C (Soluble) (1)	4	2013/09/19	2013/09/19	AB SOP-00004	SSMA 15.3
Conductivity @25C (Soluble) (1)	1	2013/09/21	2013/09/21	AB SOP-00004	SSMA 15.3
Elements by ICP -Soils (1)	4	2013/09/20	2013/09/20	AB SOP-00042	EPA 200.7
Elements by ICP -Soils (1)	1	2013/09/21	2013/09/23	AB SOP-00042	EPA 200.7
Elements by ICPMS - Soils (1)	4	2013/09/20	2013/09/20	AB SOP-00043	EPA 200.8
Elements by ICPMS - Soils (1)	1	2013/09/21	2013/09/23	AB SOP-00043	EPA 200.8
Ion Balance (1)	4	N/A	2013/09/19	AB WI-00065	SM 1030E
Ion Balance (1)	1	N/A	2013/09/20	AB WI-00065	SM 1030E
Sum of Cations, Anions (1)	4	N/A	2013/09/20	AB WI-00065	SM 1030E
Sum of Cations, Anions (1)	1	N/A	2013/09/23	AB WI-00065	SM 1030E
pH @25C (1:2 Calcium Chloride Extract) (1)	5	2013/09/20	2013/09/20	AB SOP-00006	SSMA 16.3
Sodium Adsorption Ratio (1)	4	N/A	2013/09/20	AB WI-00065	SSMA 15.4.4
Sodium Adsorption Ratio (1)	1	N/A	2013/09/23	AB WI-00065	SSMA 15.4.4
Ca,Mg,Na,K,SO4 (Soluble) (1)	4	2013/09/19	2013/09/20	AB SOP-00042	EPA 200.7
Ca,Mg,Na,K,SO4 (Soluble) (1)	1	2013/09/21	2013/09/22	AB SOP-00042	EPA 200.7
Soluble Paste (1)	4	2013/09/19	2013/09/19	AB SOP-00033	SSMA 15.2
Soluble Paste (1)	1	2013/09/21	2013/09/21	AB SOP-00033	SSMA 15.2
Soluble Ions Calculation (1)	4	N/A	2013/09/19		CALCULATION
Soluble Ions Calculation (1)	1	N/A	2013/09/20		CALCULATION
Theoretical Gypsum Requirement (1,2)	4	N/A	2013/09/20	CAL WI-00087	CJSS 79:449-455
Theoretical Gypsum Requirement (1,2)	1	N/A	2013/09/23	CAL WI-00087	CJSS 79:449-455

Sample Matrix: Water
Samples Received: 10

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity @25C (pp, total), CO3,HCO3,OH (1)	10	N/A	2013/09/17	AB SOP-00005	SM 2320-B
Chloride by Automated Colourimetry (1)	10	N/A	2013/09/20	AB SOP-00020	SSMA 4500 CL- E
Conductivity @25C (1)	10	N/A	2013/09/17	AB SOP-00005	SM 2510-B
Hardness (1)	10	N/A	2013/09/20	AB WI-00065	SM 2340B
Elements by ICP (Dissolved) Lab Filtered (1)	10	N/A	2013/09/20	AB SOP-00042	EPA 200.7
Ion Balance (1)	10	N/A	2013/09/18	AB WI-00065	SM 1030E
Sum of cations, anions (1)	10	N/A	2013/09/20	AB WI-00065	SM 1030E
Nitrate and Nitrite (1)	1	N/A	2013/09/19	AB SOP-00023	SM4110B

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

Sample Matrix: Water
Samples Received: 10

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Nitrate and Nitrite (1)	9	N/A	2013/09/20	AB SOP-00023	SM4110B
Nitrate + Nitrite-N (calculated) (1)	1	N/A	2013/09/19	AB SOP-00023	SM 4110-B
Nitrate + Nitrite-N (calculated) (1)	9	N/A	2013/09/20	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC (1)	4	N/A	2013/09/18	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC (1)	6	N/A	2013/09/19	AB SOP-00023	SM 4110-B
pH @25°C (Alkalinity titrator) (1)	10	N/A	2013/09/17	AB SOP-00005	SM 4500-H+B
Sulphate by Automated Colourimetry (1)	10	N/A	2013/09/20	AB SOP-00018	SM 4500 SO4-E
Total Dissolved Solids (Calculated) (1)	10	N/A	2013/09/20	AB WI-00065	SM 1030E

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
* Results relate only to the items tested.

(1) This test was performed by Maxxam Calgary Environmental
(2) Units for TGR have changed from tons/acre to tonnes/ha

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Wendy Sears, Project manager
Email: WSears@maxxam.ca
Phone# (780) 577-7100

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 2

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		HN4755		HN4756		HN4757	HN4758		
Sampling Date		2013/09/10 16:20		2013/09/10 16:25		2013/09/10 16:30	2013/09/10 16:30		
	UNITS	**MALLIK-2013-W01**	**RDL**	**MALLIK-2013-W02**	**RDL**	**MALLIK-2013-W03**	**MALLIK-2013-W04**	**RDL**	**QC Batch**
Calculated Parameters									
Anion Sum	meq/L	14	N/A	39	N/A	15	17	N/A	7170650
Cation Sum	meq/L	16	N/A	38	N/A	17	19	N/A	7170650
Hardness (CaCO3)	mg/L	310	0.50	690	0.50	360	400	0.50	7170648
Ion Balance	N/A	1.1	0.010	0.99	0.010	1.1	1.1	0.010	7170649
Dissolved Nitrate (NO3)	mg/L	0.027	0.013	16	0.013	0.027	0.035	0.013	7170651
Nitrate plus Nitrite (N)	mg/L	0.0060	0.0030	3.7	0.0030	0.0060	0.0080	0.0030	7170652
Dissolved Nitrite (NO2)	mg/L	<0.0099	0.0099	0.046	0.0099	<0.0099	<0.0099	0.0099	7170651
Total Dissolved Solids	mg/L	850	10	2300	10	870	1000	10	7170653
Misc. Inorganics									
Conductivity	uS/cm	1600	1.0	4100	1.0	1700	1900	1.0	7174527
pH	N/A	7.99	N/A	8.07	N/A	8.07	8.01	N/A	7174528
Anions									
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	<0.50	0.50	7174525
Alkalinity (Total as CaCO3)	mg/L	120	0.50	150	0.50	160	160	0.50	7174525
Bicarbonate (HCO3)	mg/L	150	0.50	190	0.50	190	200	0.50	7174525
Carbonate (CO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	<0.50	0.50	7174525
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	<0.50	0.50	7174525
Dissolved Sulphate (SO4)	mg/L	94	1.0	180	1.0	80	86	1.0	7183738
Dissolved Chloride (Cl)	mg/L	360(1)	5.0	1100(1)	10	350(1)	440(1)	5.0	7183737
Nutrients									
Dissolved Nitrite (N)	mg/L	<0.0030	0.0030	0.014	0.0030	<0.0030	<0.0030	0.0030	7176914
Dissolved Nitrate (N)	mg/L	0.0060	0.0030	3.7	0.0030	0.0060	0.0080	0.0030	7176914
Elements									
Dissolved Calcium (Ca)	mg/L	67	0.30	160	0.30	83	90	0.30	7180810
Dissolved Iron (Fe)	mg/L	0.075	0.060	0.13	0.060	0.10	0.11	0.060	7180810
Dissolved Magnesium (Mg)	mg/L	33	0.20	69	0.20	36	41	0.20	7180810
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	0.013	0.0040	<0.0040	<0.0040	0.0040	7180810
Dissolved Potassium (K)	mg/L	28	0.30	330	0.30	21	23	0.30	7180810
Dissolved Sodium (Na)	mg/L	200	0.50	370	0.50	200	240	0.50	7180810

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		HN4759		HN4760		HN4761		
Sampling Date		2013/09/10 16:35		2013/09/10 16:35		2013/09/10 16:40		
	UNITS	**MALLIK-2013-W05**	**RDL**	**MALLIK-2013-W06**	**RDL**	**MALLIK-2013-W07**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	36	N/A	56	N/A	12	N/A	7170650
Cation Sum	meq/L	37	N/A	56	N/A	13	N/A	7170650
Hardness (CaCO3)	mg/L	740	0.50	1200	0.50	300	0.50	7170648
Ion Balance	N/A	1.0	0.010	1.0	0.010	1.1	0.010	7170649
Dissolved Nitrate (NO3)	mg/L	7.6	0.013	8.6	0.013	0.032	0.013	7170651
Nitrate plus Nitrite (N)	mg/L	1.7	0.0030	2.0	0.0030	0.0070	0.0030	7170652
Dissolved Nitrite (NO2)	mg/L	0.027	0.0099	0.025	0.0099	<0.0099	0.0099	7170651
Total Dissolved Solids	mg/L	2200	10	3200	10	710	10	7170653
Misc. Inorganics								
Conductivity	uS/cm	3900	1.0	6000	1.0	1400	1.0	7174527
pH	N/A	7.99	N/A	7.97	N/A	8.02	N/A	7174528
Anions								
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Alkalinity (Total as CaCO3)	mg/L	120	0.50	93	0.50	140	0.50	7174525
Bicarbonate (HCO3)	mg/L	140	0.50	110	0.50	180	0.50	7174525
Carbonate (CO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Dissolved Sulphate (SO4)	mg/L	200(1)	2.0	200(1)	2.0	74	1.0	7183738
Dissolved Chloride (Cl)	mg/L	1000(1)	10	1700(1)	20	280(1)	2.0	7183737
Nutrients								
Dissolved Nitrite (N)	mg/L	0.0083	0.0030	0.0077	0.0030	<0.0030	0.0030	7176901
Dissolved Nitrate (N)	mg/L	1.7	0.0030	1.9	0.0030	0.0072	0.0030	7176901
Elements								
Dissolved Calcium (Ca)	mg/L	180	0.30	290	0.30	71	0.30	7180810
Dissolved Iron (Fe)	mg/L	0.13	0.060	0.20	0.060	0.089	0.060	7180810
Dissolved Magnesium (Mg)	mg/L	69	0.20	120	0.20	30	0.20	7180810
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	<0.0040	0.0040	<0.0040	0.0040	7180810
Dissolved Potassium (K)	mg/L	210	0.30	230	0.30	8.3	0.30	7180810
Dissolved Sodium (Na)	mg/L	380	0.50	590(1)	2.5	160	0.50	7180810

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		HN4762		HN4763		HN4764		
Sampling Date		2013/09/10 16:45		2013/09/10 16:45		2013/09/10 16:50		
	UNITS	**MALLIK-2013-W08**	**RDL**	**MALLIK-2013-W09**	**RDL**	**MALLIK-2013-W10**	**RDL**	**QC Batch**
Calculated Parameters								
Anion Sum	meq/L	110	N/A	20	N/A	11	N/A	7170650
Cation Sum	meq/L	110	N/A	22	N/A	12	N/A	7170650
Hardness (CaCO3)	mg/L	2700	0.50	410	0.50	250	0.50	7170648
Ion Balance	N/A	0.98	0.010	1.1	0.010	1.1	0.010	7170649
Dissolved Nitrate (NO3)	mg/L	120	0.13	0.016	0.013	0.014	0.013	7170651
Nitrate plus Nitrite (N)	mg/L	28	0.030	0.0040	0.0030	0.0030	0.0030	7170652
Dissolved Nitrite (NO2)	mg/L	0.19	0.0099	<0.0099	0.0099	<0.0099	0.0099	7170651
Total Dissolved Solids	mg/L	6700	10	1200	10	630	10	7170653
Misc. Inorganics								
Conductivity	uS/cm	11000	1.0	2200	1.0	1200	1.0	7174527
pH	N/A	7.82	N/A	8.22	N/A	8.10	N/A	7174528
Anions								
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Alkalinity (Total as CaCO3)	mg/L	83	0.50	200	0.50	120	0.50	7174525
Bicarbonate (HCO3)	mg/L	100	0.50	240	0.50	140	0.50	7174525
Carbonate (CO3)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7174525
Dissolved Sulphate (SO4)	mg/L	490(1)	5.0	82	1.0	75	1.0	7183738
Dissolved Chloride (Cl)	mg/L	3500(1)	25	520(1)	5.0	250(1)	2.0	7183737
Nutrients								
Dissolved Nitrite (N)	mg/L	0.059	0.0030	<0.0030	0.0030	<0.0030	0.0030	7176901
Dissolved Nitrate (N)	mg/L	28(1)	0.030	0.0037	0.0030	0.0031	0.0030	7176901
Elements								
Dissolved Calcium (Ca)	mg/L	690(1)	1.5	89	0.30	55	0.30	7180810
Dissolved Iron (Fe)	mg/L	0.36	0.060	0.16	0.060	0.071	0.060	7180810
Dissolved Magnesium (Mg)	mg/L	250	0.20	45	0.20	28	0.20	7180810
Dissolved Manganese (Mn)	mg/L	0.0095	0.0040	<0.0040	0.0040	<0.0040	0.0040	7180810
Dissolved Potassium (K)	mg/L	650(1)	1.5	20	0.30	6.4	0.30	7180810
Dissolved Sodium (Na)	mg/L	910(1)	2.5	300	0.50	150	0.50	7180810

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

SOIL SALINITY 4 (SOIL)

Maxxam ID		HN4792		HN4793		
Sampling Date		2013/09/11		2013/09/11		
	UNITS	**MALLIK-2013-S01 @ 30-50CM**	**RDL**	**MALLIK-2013-S02 @ 30-50CM**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	190	N/A	200	N/A	7172903
Cation Sum	meq/L	190	N/A	190	N/A	7172903
Cation/EC Ratio	N/A	9.9	0.10	9.6	0.10	7172900
Ion Balance	N/A	1.0	0.010	0.97	0.010	7172902
Calculated Calcium (Ca)	mg/kg	600	1.2	220	1.2	7171184
Calculated Magnesium (Mg)	mg/kg	180	0.81	130	0.81	7171184
Calculated Sodium (Na)	mg/kg	730	2.0	1300	2.0	7171184
Calculated Potassium (K)	mg/kg	49	1.1	19	1.0	7171184
Calculated Chloride (Cl)	mg/kg	2500	10	2700	10	7171184
Calculated Sulphate (SO4)	mg/kg	280	4.1	230	4.0	7171184
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	6100(1)	25	6600(1)	25	7181648
Soluble Conductivity	dS/m	19	0.020	20	0.020	7180947
Soluble (CaCl2) pH	N/A	7.38	N/A	7.55	N/A	7182200
Sodium Adsorption Ratio	N/A	11	0.10	26	0.10	7172904
Soluble Calcium (Ca)	mg/L	1500	3.0	540	3.0	7181698
Soluble Magnesium (Mg)	mg/L	440	2.0	330	2.0	7181698
Soluble Sodium (Na)	mg/L	1800	5.0	3200	5.0	7181698
Soluble Potassium (K)	mg/L	120	2.6	47	2.6	7181698
Saturation %	%	41	N/A	40	N/A	7179186
Soluble Sulphate (SO4)	mg/L	700	10	580	10	7181698
Theoretical Gypsum Requirement	tonnes/ha	44	0.10	160	0.10	7172909

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

SOIL SALINITY 4 (SOIL)

Maxxam ID		HN4794		HN4795		
Sampling Date		2013/09/11		2013/09/11		
	UNITS	**MALLIK-2013-S03 @ 10-25CM**	**RDL**	**MALLIK-2013-S04 @ 20-40CM**	**RDL**	**QC Batch**
Calculated Parameters						
Anion Sum	meq/L	250	N/A	37	N/A	7172903
Cation Sum	meq/L	250	N/A	36	N/A	7172903
Cation/EC Ratio	N/A	9.3	0.10	8.7	0.10	7172900
Ion Balance	N/A	1.0	0.010	0.96	0.010	7172902
Calculated Calcium (Ca)	mg/kg	1000	5.3	58	0.63	7171184
Calculated Magnesium (Mg)	mg/kg	55	3.5	16	0.42	7171184
Calculated Sodium (Na)	mg/kg	970	8.8	250	1.1	7171184
Calculated Potassium (K)	mg/kg	3100	4.6	10	0.55	7171184
Calculated Chloride (Cl)	mg/kg	5400	18	480	2.1	7171184
Calculated Sulphate (SO4)	mg/kg	1300	18	110	2.1	7171184
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	7700(1)	25	1100	5.0	7181648
Soluble Conductivity	dS/m	27	0.020	4.1	0.020	7180947
Soluble (CaCl2) pH	N/A	8.39	N/A	7.34	N/A	7182200
Sodium Adsorption Ratio	N/A	9.6	0.10	11	0.10	7172904
Soluble Calcium (Ca)	mg/L	1500	7.5	140	1.5	7181698
Soluble Magnesium (Mg)	mg/L	78	5.0	38	1.0	7181698
Soluble Sodium (Na)	mg/L	1400	13	590	2.5	7181698
Soluble Potassium (K)	mg/L	4500	6.5	24	1.3	7181698
Saturation %	%	70	N/A	42	N/A	7179186
Soluble Sulphate (SO4)	mg/L	1900	25	250	5.0	7181698
Theoretical Gypsum Requirement	tonnes/ha	44	0.10	5.0	0.10	7172909

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

SOIL SALINITY 4 (SOIL)

Maxxam ID		HN4796		
Sampling Date		2013/09/11		
	UNITS	**MALLIK-2013-04X**	**RDL**	**QC Batch**
Calculated Parameters				
Anion Sum	meq/L	90	N/A	7173258
Cation Sum	meq/L	95	N/A	7173258
Cation/EC Ratio	N/A	10	0.10	7173253
Ion Balance	N/A	1.1	0.010	7173257
Calculated Calcium (Ca)	mg/kg	250	0.67	7173261
Calculated Magnesium (Mg)	mg/kg	110	0.44	7173261
Calculated Sodium (Na)	mg/kg	470	1.1	7173261
Calculated Potassium (K)	mg/kg	30	0.58	7173261
Calculated Chloride (Cl)	mg/kg	1200	4.4	7173261
Calculated Sulphate (SO4)	mg/kg	360	2.2	7173261
Soluble Parameters				
Soluble Chloride (Cl)	mg/L	2600(1)	10	7186180
Soluble Conductivity	dS/m	9.5	0.020	7184378
Soluble (CaCl2) pH	N/A	6.81	N/A	7182200
Sodium Adsorption Ratio	N/A	9.4	0.10	7173260
Soluble Calcium (Ca)	mg/L	560	1.5	7184569
Soluble Magnesium (Mg)	mg/L	240	1.0	7184569
Soluble Sodium (Na)	mg/L	1100	2.5	7184569
Soluble Potassium (K)	mg/L	67	1.3	7184569
Saturation %	%	44	N/A	7184185
Soluble Sulphate (SO4)	mg/L	800	5.0	7184569
Theoretical Gypsum Requirement	tonnes/ha	16	0.10	7173262

N/A = Not Applicable
RDL = Reportable Detection Limit
(1) - Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

ASSESSMENT ICP METALS (SOIL)

Maxxam ID		HN4792	HN4793	HN4794	HN4795		HN4796		
Sampling Date		2013/09/11	2013/09/11	2013/09/11	2013/09/11		2013/09/11		
	UNITS	**MALLIK-2013-S01 @ 30-50CM**	**MALLIK-2013-S02 @ 30-50CM**	**MALLIK-2013-S03 @ 10-25CM**	**MALLIK-2013-S04 @ 20-40CM**	**QC Batch**	**MALLIK-2013-04X**	**RDL**	**QC Batch**
Elements									
Total Aluminum (Al)	mg/kg	5600	5200	5100	5700	7181149	5400	10	7184270
Total Boron (B)	mg/kg	<2.0	<2.0	<2.0	<2.0	7181149	<2.0	2.0	7184270
Total Calcium (Ca)	mg/kg	62000	62000	220000	63000	7181149	57000	50	7184270
Total Iron (Fe)	mg/kg	16000	15000	8200	17000	7181149	14000	10	7184270
Total Lithium (Li)	mg/kg	<10	<10	<10	<10	7181149	<10	10	7184270
Total Magnesium (Mg)	mg/kg	25000	26000	9800	26000	7181149	23000	20	7184270
Total Manganese (Mn)	mg/kg	320	280	110	280	7181149	270	10	7184270
Total Phosphorus (P)	mg/kg	770	800	180	780	7181149	690	20	7184270
Total Potassium (K)	mg/kg	880(1)	700	7600	760	7181149	660(1)	25	7184270
Total Sodium (Na)	mg/kg	1200	1900	1800	590	7181149	630	50	7184270
Total Strontium (Sr)	mg/kg	81	75	320	78	7181149	73	10	7184270
Total Sulphur (S)	mg/kg	460	380	75000	380	7181149	990	20	7184270
Total Antimony (Sb)	mg/kg	<1.0	<1.0	1.1	<1.0	7181143	<1.0	1.0	7184265
Total Arsenic (As)	mg/kg	5.3	6.2	3.5	7.0	7181143	5.6	1.0	7184265
Total Barium (Ba)	mg/kg	620	590	120	580	7181143	400	10	7184265
Total Beryllium (Be)	mg/kg	<0.40	<0.40	<0.40	<0.40	7181143	<0.40	0.40	7184265
Total Cadmium (Cd)	mg/kg	0.35	0.34	0.16	0.41	7181143	0.48	0.10	7184265
Total Chromium (Cr)	mg/kg	10	12	17	13	7181143	12	1.0	7184265
Total Cobalt (Co)	mg/kg	6.1	6.9	2.8	7.4	7181143	6.3	1.0	7184265
Total Copper (Cu)	mg/kg	11	12	15	14	7181143	12	5.0	7184265
Total Lead (Pb)	mg/kg	5.6	6.4	4.3	7.2	7181143	6.6	1.0	7184265
Total Molybdenum (Mo)	mg/kg	1.0	1.2	1.5	1.2	7181143	0.96	0.40	7184265
Total Nickel (Ni)	mg/kg	18	21	14	22	7181143	19	1.0	7184265
Total Selenium (Se)	mg/kg	<0.50	<0.50	<0.50	<0.50	7181143	0.72	0.50	7184265
Total Silver (Ag)	mg/kg	<1.0	<1.0	<1.0	<1.0	7181143	<1.0	1.0	7184265
Total Thallium (Tl)	mg/kg	<0.30	<0.30	<0.30	<0.30	7181143	<0.30	0.30	7184265
Total Tin (Sn)	mg/kg	<1.0	<1.0	<1.0	<1.0	7181143	<1.0	1.0	7184265
Total Uranium (U)	mg/kg	<1.0	<1.0	<1.0	<1.0	7181143	<1.0	1.0	7184265
Total Vanadium (V)	mg/kg	18(1)	22	20	25	7181143	24	1.0	7184265
Total Zinc (Zn)	mg/kg	60	69	28	74	7181143	68	10	7184265

RDL = Reportable Detection Limit
(1) - Matrix Spike exceeds acceptance limits due to matrix interference. Reanalysis yields similar results.

Package 1	5.3°C

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

As per client request, the client ID for sample HN4796 was changed from MALLIK-2013-04 to MALLIK-2013-04X.

SOIL SALINITY 4 (SOIL) Comments

Sample HN4792-01 Ca,Mg,Na,K,SO4 (Soluble): Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly

Sample HN4793-01 Ca,Mg,Na,K,SO4 (Soluble): Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly

Sample HN4794-01 Ca,Mg,Na,K,SO4 (Soluble): Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7174525	Alkalinity (Total as CaCO3)	2013/09/17			91	80 - 120	0.53, RDL=0.50	mg/L	2.2	20		
7174525	Alkalinity (PP as CaCO3)	2013/09/17					<0.50	mg/L	NC	20		
7174525	Bicarbonate (HCO3)	2013/09/17					0.65, RDL=0.50	mg/L	2.2	20		
7174525	Carbonate (CO3)	2013/09/17					<0.50	mg/L	NC	20		
7174525	Hydroxide (OH)	2013/09/17					<0.50	mg/L	NC	20		
7174527	Conductivity	2013/09/17			103	90 - 110	<1.0	uS/cm	1	20		
7174528	pH	2013/09/17			99	97 - 102			0.6	5		
7176901	Dissolved Nitrite (N)	2013/09/19	99	80 - 120	100	90 - 110	<0.0030	mg/L	NC	20		
7176901	Dissolved Nitrate (N)	2013/09/19	104	80 - 120	101	90 - 110	<0.0030	mg/L	0.2	20		
7176914	Dissolved Nitrite (N)	2013/09/18	100	80 - 120	104	90 - 110	<0.0030	mg/L	NC	20		
7176914	Dissolved Nitrate (N)	2013/09/18	99	80 - 120	103	90 - 110	0.0050, RDL=0.0030	mg/L	3.4	20		
7179186	Saturation %	2013/09/19							1	12	93	88 - 112
7180810	Dissolved Calcium (Ca)	2013/09/19	67(1)	80 - 120	104	80 - 120	<0.30	mg/L	4.0	20		
7180810	Dissolved Iron (Fe)	2013/09/19	103	80 - 120	104	80 - 120	<0.060	mg/L	NC	20		
7180810	Dissolved Magnesium (Mg)	2013/09/19	88	80 - 120	101	80 - 120	<0.20	mg/L	4.4	20		
7180810	Dissolved Manganese (Mn)	2013/09/19	101	80 - 120	102	80 - 120	<0.0040	mg/L	NC	20		
7180810	Dissolved Potassium (K)	2013/09/19	101	80 - 120	104	80 - 120	<0.30	mg/L	NC	20		
7180810	Dissolved Sodium (Na)	2013/09/19	73(1)	80 - 120	103	80 - 120	<0.50	mg/L	2.9	20		
7180947	Soluble Conductivity	2013/09/19			100	90 - 110	<0.020	dS/m			103	92 - 108
7181143	Total Antimony (Sb)	2013/09/20	108	75 - 125	106	75 - 125	<1.0	mg/kg	NC	35		
7181143	Total Arsenic (As)	2013/09/20	111	75 - 125	103	75 - 125	<1.0	mg/kg	5.1	35	143	50 - 150
7181143	Total Barium (Ba)	2013/09/20	NC	75 - 125	104	75 - 125	<10	mg/kg	10.9	35	106	69 - 131
7181143	Total Beryllium (Be)	2013/09/20	116	75 - 125	104	75 - 125	<0.40	mg/kg	NC	35		
7181143	Total Cadmium (Cd)	2013/09/20	105	75 - 125	103	75 - 125	<0.10	mg/kg	NC	35		
7181143	Total Chromium (Cr)	2013/09/20	111	75 - 125	95	75 - 125	<1.0	mg/kg	1.1	35	121	41 - 159
7181143	Total Cobalt (Co)	2013/09/20	103	75 - 125	97	75 - 125	<1.0	mg/kg	3.8	35	120	75 - 125
7181143	Total Copper (Cu)	2013/09/20	104	75 - 125	99	75 - 125	<5.0	mg/kg	NC	35	118	73 - 127
7181143	Total Lead (Pb)	2013/09/20	106	75 - 125	98	75 - 125	<1.0	mg/kg	3.5	35	117	54 - 146
7181143	Total Molybdenum (Mo)	2013/09/20	111	75 - 125	103	75 - 125	<0.40	mg/kg	NC	35		
7181143	Total Nickel (Ni)	2013/09/20	108	75 - 125	101	75 - 125	<1.0	mg/kg	4.6	35	126	61 - 139
7181143	Total Selenium (Se)	2013/09/20	106	75 - 125	103	75 - 125	<0.50	mg/kg	NC	35		
7181143	Total Silver (Ag)	2013/09/20	104	75 - 125	102	75 - 125	<1.0	mg/kg	NC	35		
7181143	Total Thallium (Tl)	2013/09/20	101	75 - 125	98	75 - 125	<0.30	mg/kg	NC	35		
7181143	Total Tin (Sn)	2013/09/20	108	75 - 125	102	75 - 125	<1.0	mg/kg	NC	35		
7181143	Total Uranium (U)	2013/09/20	101	75 - 125	99	75 - 125	<1.0	mg/kg	NC	35		
7181143	Total Vanadium (V)	2013/09/20	132(1)	75 - 125	98	75 - 125	<1.0	mg/kg	0.2	35	140	50 - 150
7181143	Total Zinc (Zn)	2013/09/20	NC	75 - 125	101	75 - 125	<10	mg/kg	3.4	35	126	72 - 128
7181149	Total Aluminum (Al)	2013/09/20	NC	75 - 125	107	75 - 125	<10	mg/kg	1.9	35	107	51 - 149
7181149	Total Boron (B)	2013/09/20	117	75 - 125	106	75 - 125	<2.0	mg/kg	NC	35		

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7181149	Total Calcium (Ca)	2013/09/20	NC	75 - 125	107	75 - 125	<50	mg/kg	0.2	35	115	77 - 123
7181149	Total Iron (Fe)	2013/09/20	NC	75 - 125	100	75 - 125	<10	mg/kg	0.5	35	118	61 - 139
7181149	Total Lithium (Li)	2013/09/20	103	75 - 125	99	75 - 125	<10	mg/kg	NC	35	99	75 - 125
7181149	Total Magnesium (Mg)	2013/09/20	NC	75 - 125	105	75 - 125	<20	mg/kg	0.06	35	116	69 - 131
7181149	Total Manganese (Mn)	2013/09/20	NC	75 - 125	103	75 - 125	<10	mg/kg	1	35	114	71 - 129
7181149	Total Phosphorus (P)	2013/09/20	NC	75 - 125	107	75 - 125	<20	mg/kg	2.7	35	106	89 - 117
7181149	Total Potassium (K)	2013/09/20	214(1)	75 - 125	108	75 - 125	<25	mg/kg	0.3	35	113	60 - 140
7181149	Total Sodium (Na)	2013/09/20	NC	75 - 125	105	75 - 125	<50	mg/kg	6.3	35	118	60 - 140
7181149	Total Strontium (Sr)	2013/09/20	NC	75 - 125	100	75 - 125	<10	mg/kg	1.3	35	104	75 - 125
7181149	Total Sulphur (S)	2013/09/20					<20	mg/kg	8.8	35		
7181648	Soluble Chloride (Cl)	2013/09/20	NC	75 - 125	106	75 - 125	6.5, RDL=5.0	mg/L	18.6	35	103	83 - 117
7181698	Soluble Calcium (Ca)	2013/09/20	99	75 - 125	101	80 - 120	1.6, RDL=1.5	mg/L			92	84 - 117
7181698	Soluble Magnesium (Mg)	2013/09/20	94	75 - 125	95	80 - 120	<1.0	mg/L			89	84 - 114
7181698	Soluble Sodium (Na)	2013/09/20	95	75 - 125	96	80 - 120	<2.5	mg/L			96	85 - 117
7181698	Soluble Potassium (K)	2013/09/20	96	75 - 125	97	80 - 120	<1.3	mg/L			92	78 - 122
7181698	Soluble Sulphate (SO4)	2013/09/20					<5.0	mg/L			92	85 - 113
7182200	Soluble (CaCl2) pH	2013/09/20			100	97 - 103			1.9	5	100	98 - 102
7183737	Dissolved Chloride (Cl)	2013/09/20	108	80 - 120	102	80 - 120	<1.0	mg/L	NC	20		
7183738	Dissolved Sulphate (SO4)	2013/09/20	NC	80 - 120	101	80 - 120	<1.0	mg/L	0.04	20		
7184185	Saturation %	2013/09/21							1	12	102	91 - 109
7184265	Total Antimony (Sb)	2013/09/23	105	75 - 125	114	75 - 125	<1.0	mg/kg	NC	35		
7184265	Total Arsenic (As)	2013/09/23	100	75 - 125	105	75 - 125	<1.0	mg/kg	4.5	35	114	50 - 150
7184265	Total Barium (Ba)	2013/09/23	NC	75 - 125	99	75 - 125	<10	mg/kg	5.6	35	102	69 - 131
7184265	Total Beryllium (Be)	2013/09/23	111	75 - 125	122	75 - 125	<0.40	mg/kg	NC	35		
7184265	Total Cadmium (Cd)	2013/09/23	103	75 - 125	107	75 - 125	<0.10	mg/kg	NC	35		
7184265	Total Chromium (Cr)	2013/09/23	98	75 - 125	100	75 - 125	<1.0	mg/kg	7.5	35	105	41 - 159
7184265	Total Cobalt (Co)	2013/09/23	92	75 - 125	99	75 - 125	<1.0	mg/kg	6.0	35	98	75 - 125
7184265	Total Copper (Cu)	2013/09/23	92	75 - 125	100	75 - 125	<5.0	mg/kg	NC	35	100	73 - 127
7184265	Total Lead (Pb)	2013/09/23	100	75 - 125	105	75 - 125	<1.0	mg/kg	6.4	35	103	54 - 146
7184265	Total Molybdenum (Mo)	2013/09/23	104	75 - 125	107	75 - 125	<0.40	mg/kg	NC	35		
7184265	Total Nickel (Ni)	2013/09/23	92	75 - 125	100	75 - 125	<1.0	mg/kg	7.2	35	108	61 - 139
7184265	Total Selenium (Se)	2013/09/23	101	75 - 125	106	75 - 125	<0.50	mg/kg	NC	35		
7184265	Total Silver (Ag)	2013/09/23	102	75 - 125	107	75 - 125	<1.0	mg/kg	NC	35		
7184265	Total Thallium (Tl)	2013/09/23	99	75 - 125	106	75 - 125	<0.30	mg/kg	NC	35		
7184265	Total Tin (Sn)	2013/09/23	107	75 - 125	108	75 - 125	<1.0	mg/kg	NC	35		
7184265	Total Uranium (U)	2013/09/23	91	75 - 125	106	75 - 125	<1.0	mg/kg	NC	35		
7184265	Total Vanadium (V)	2013/09/23	105	75 - 125	105	75 - 125	<1.0	mg/kg	9.4	35	125	50 - 150
7184265	Total Zinc (Zn)	2013/09/23	NC	75 - 125	104	75 - 125	<10	mg/kg	5.3	35	107	72 - 128
7184270	Total Aluminum (Al)	2013/09/23	NC	75 - 125	111	75 - 125	16, RDL=10	mg/kg	1.4	35	109	75 - 125

Maxxam Job #: B383677
Report Date: 2013/09/23

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: INUVIK, NWT
Your P.O. #: 16300R-20

QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
7184270	Total Boron (B)	2013/09/23	124	75 - 125	112	75 - 125	<2.0	mg/kg	NC	35		
7184270	Total Calcium (Ca)	2013/09/23	NC	75 - 125	100	75 - 125	<50	mg/kg	0.3	35	103	75 - 125
7184270	Total Iron (Fe)	2013/09/23	NC	75 - 125	103	75 - 125	<10	mg/kg	1.3	35	110	75 - 125
7184270	Total Lithium (Li)	2013/09/23	108	75 - 125	102	75 - 125	<10	mg/kg	NC	35	96	75 - 125
7184270	Total Magnesium (Mg)	2013/09/23	NC	75 - 125	106	75 - 125	<20	mg/kg	0.1	35	108	75 - 125
7184270	Total Manganese (Mn)	2013/09/23	NC	75 - 125	104	75 - 125	<10	mg/kg	0.5	35	109	75 - 125
7184270	Total Phosphorus (P)	2013/09/23	NC	75 - 125	101	75 - 125	<20	mg/kg	2.3	35	97	75 - 125
7184270	Total Potassium (K)	2013/09/23	187(1)	75 - 125	98	75 - 125	<25	mg/kg	3.3	35	103	75 - 125
7184270	Total Sodium (Na)	2013/09/23	110	75 - 125	103	75 - 125	<50	mg/kg	9.4	35	111	75 - 125
7184270	Total Strontium (Sr)	2013/09/23	NC	75 - 125	98	75 - 125	<10	mg/kg	1.9	35	96	75 - 125
7184270	Total Sulphur (S)	2013/09/23					20, RDL=20	mg/kg	3.5	35		
7184378	Soluble Conductivity	2013/09/21			99	90 - 110	<0.020	dS/m	14.9	35	99	89 - 111
7184569	Soluble Calcium (Ca)	2013/09/22	105	75 - 125	114	80 - 120	<1.5	mg/L	20.1	35	102	83 - 117
7184569	Soluble Magnesium (Mg)	2013/09/22	104	75 - 125	111	80 - 120	<1.0	mg/L	19.5	35	99	85 - 115
7184569	Soluble Sodium (Na)	2013/09/22	NC	75 - 125	107	80 - 120	<2.5	mg/L	17.8	35	98	83 - 117
7184569	Soluble Potassium (K)	2013/09/22	105	75 - 125	110	80 - 120	<1.3	mg/L	7.4	35	106	75 - 125
7184569	Soluble Sulphate (SO4)	2013/09/22					<5.0	mg/L	16.5	35	103	86 - 114
7186180	Soluble Chloride (Cl)	2013/09/23	NC	75 - 125	102	75 - 125	<5.0	mg/L	13.1	35	98	83 - 117

N/A = Not Applicable
RDL = Reportable Detection Limit
RPD = Relative Percent Difference
Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.
Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.
QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.
Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.
NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.
NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.
(1) - Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Validation Signature Page

Maxxam Job #: B383677

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Peng Liang, Analyst II

==========

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13-586

Chain of Custody A134873

Page: 1 of 2

	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☒
Company:	STANTEC	
Contact:	Olivier PIRAUX	
Address:		
	Prov: PC: 1102	Prov: PC:
Contact #s:	Ph: 514 739-0708 Cell: 514 245-1045	Ph: Cell:

Report Distribution (E-Mail):
olivier.piraux@stantec.com
elaine.little@stantec.com

REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 1102 19049
Project # / Name: MALLIK
Site Location: INUVIK, NWT
Quote #:
Sampled By: OLIVIER PIRAUX

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☒ REGULAR (5 to 7 Days)

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	WATER: ☐ BTEX F1 ☐ VOCs	☐ BTEX F1-F2 ☐ BTEX F1-F4	☒ Routine Water ☐ Turb ☐ F	☐ TOC ☐ DOC	Regulated Metals (CCME/AT1) Total	Dissolved	Mercury ☐ Total ☐ Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	MALLIK-2013-W01		SW	2013.09.10 16h20									X							1
2	MALLIK-2013-W02		SW	" 16h25									X							1
3	MALLIK-2013-W03		SW	" 16h30									X							1
4	MALLIK-2013-W04		SW	" 16h30									X							1
5	MALLIK-2013-W05		SW	" 16h35									X							1
6	MALLIK-2013-W06		SW	" 16h35									X							1
7	MALLIK-2013-W07		SW	" 16h40									X							1
8	~~MALLIK-2013-W07~~		~~SW~~	~~" 16h45~~									X							1
9	MALLIK-2013-W08		SW	" 16h45									X							1
10	MALLIK-2013-W09		SW	" 16h45									X							1
11	MALLIK-2013-W10		SW	" 16h50									X							1
12																				

14-Sep-13 10:15
Wendy Sears
B383677
SDG INS-0021

RECEIVED IN YELLOWKNIFE
By: 2013-09-14 10:15

Temp: 6 / 4 / 16

Please indicate Filtered, Preserved or Both (F, P, F/P) — F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
Olivier PIRAUX	2013.09.12	10 AM
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):

Special Instructions:

# of Jars Used & Not Submitted

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B383677
Posit Kingsbury		16:22	

Lab Comments:	Custody Seal	Temperature	Ice
2013/09/16	yes	1, 2, 1	yes

Maxxam

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Chain of Custody A134875

Invoice To:	C/O Report Address ☐	Report To:	Same as Invoice ☒	Report Distribution (E-Mail):
Company:	STANTEC			OLIVIER.PIRAUX@STANTEC.COM
Contact:	OLIVIER PIRAUX			
Address:	10160-112 St Edmonton			
	Prov: AB PC: T5K 2L6	Prov:	PC:	
Contact #s:	Ph: 514 739-0708 Cell: 514 245-1045	Ph:	Cell:	

REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #:	1102190 49
Project # / Name:	MALLIK
Site Location:	INUVIK, NWT
Quote #:	
Sampled By:	OLIVIER PIRAUX

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☒ REGULAR (5 to 7 Days)

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	Sieve (75 micron)	Regulated Metals (CCME / AT1)	Salinity 4	Assessment ICP Metals	Basic Class II Landfill	WATER: ☐BTEX F1 ☐VOCs	☐BTEX F1-F2 ☐BTEX F1-F4	☐Routine Water ☐Turb ☐F	☐TOC ☐DOC	Regulated Metals (CCME / AT1) Total	Dissolved	Mercury ☐Total ☐Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik-2013-S01	30-50cm	soil	2013/09/11				X	X											1
2	Mallik-2013-S02	30-50cm	soil	2013/09/11				X	X											1
3	Mallik-2013-S03	10-25cm	soil	2013/09/11				X	X											1
4	Mallik-2013-S04	20-40	soil	2013/09/11				X	X											1
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

See reverse for package specifics

RECEIVED IN YELLOWKNIFE
By: [signature]
2013-09-14 10:15

Temp: 6 / 4 / 16

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
Olivier PIRAUX	2013.09.12	10 AM
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):

Special Instructions:

# of Jars Used & Not Submitted:

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #: B383677
JOSH KNIGHT		16:22	

Custody Seal	Temperature	Ice
Y	1, 2, 1	Y-S

Lab Comments: 2013/09/16

2014 Mallik Annual Sump Monitoring Report

FOR SUBMISSION TO THE NORTHWEST TERRITORIES WATER BOARD UNDER WATER LICENSE N7L1-1817

Prepared for:

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

Prepared by:

KAVIK-STANTEC

November 2014

Table of Contents

1 Introduction 1
2 Site Location 2
3 Methods 4
3.1 Visual Assessment 4
3.2 Active-Layer Depth Measurements 4
3.3 Ground Temperature Monitoring 5
3.4 Electromagnetic Surveys 5
3.5 Water Sampling 5
3.6 Soil Sampling 6
4 Results 7
4.1 Visual Assessment 7
4.2 Active Layer Measurements 8
4.3 Air and Ground Temperature Monitoring 9
4.3.1 Air Temperature 9
4.3.2 Ground thermal monitoring 10
4.4 Electromagnetic Surveys 17
4.5 Soil and Water Sampling 18
4.5.1 Soil Sampling 20
4.5.2 Water Sampling 21
5 Conclusion 23
6 References 24
Appendix A Site Photographs 25
Appendix B Thermistor Data 33
Appendix C Electromagnetic surveys 38
Appendix D Laboratory analysis 39

List of Tables

Table 3-1 Depth below ground surface of Thermistors....5
Table 4-1 Summary of Active-Layer Measurements....8
Table 4-2 Monthly Air Temperatures....9
Table 4-3 Ground Temperatures at thermistor 07GSC-01....11
Table 4-4 Ground Temperatures at thermistor 07GSC-02....12
Table 4-5 Ground Temperatures at thermistor 07GSC-03....13
Table 4-6 Ground Temperatures at thermistor 07GSC-04....14
Table 4-7 Ground Temperatures at thermistor 12GSC-05....15
Table 4-8 Soil and Water Sampling Locations....18
Table 4-9 Soil Sampling Results....20
Table 4-10 Water Sampling Results....22

List of Figures

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories....2
Figure 2-2 Aerial oblique view of the Mallik site looking southwest. Key features and the location of temperature cables are identified (photo taken on August 12th, 2014)....3
Figure 4-1 Ground surface conditions at monitoring locations....10
Figure 4-2 Ground temperature at thermistor 07GSC-01 (10/09/2013 to 12/08/2014)....11
Figure 4-3 Ground temperature at thermistor 07GSC-2 (10/09/2013 to 12/08/2014)....12
Figure 4-4 Ground temperature at thermistor 07GSC-03 (10/09/2013 to 12/08/2014)....13
Figure 4-5 Ground temperature at thermistor 07GSC-04 (10/09/2013 to 12/08/2014)....14
Figure 4-6 Ground temperature at thermistor 12GSC-05 (10/09/2013 to 12/08/2014)....15
Figure 4-7 2013-2014 Annual mean temperature profiles at the various monitoring locations....16
Figure 4-8 Location of soil and water samples....19
Figure A-1 Aerial overview of the Mallik site....26
Figure A-2 Aerial view of Mallik 3L/4L/5L-38 Sump....27
Figure A-3 Aerial view of Mallik 3L/4L/5L-38 Sump....27
Figure A-4 Subsidence and water ponding along the western corner of the 3L/4L/5L-38 Sump....28
Figure A-5 Localized depression (dashed area) along the eastern corner of the 3L/4L/5L-38 Sump....28
Figure A-6 Aerial view of the Mallik 2L-38 Sump....29
Figure A-7 Oblique view of Mallik 2L-38 Sump (looking south)....29
Figure A-8 Subsidence area at the eastern end of the Mallik 2L-38 Sump....30
Figure A-9 Subsidence area at the western end of the Mallik 2L-38 Sump....30
Figure A-10 Various wildlife tracks observed at the site....31
Figure A-11 Active layer measurement (in cm) on both sumps....32
Figure B-1 Daily mean air temperature at the Mallik site....34
Figure B-2 Daily mean ground surface temperature at the Mallik site....34
Figure B-3 Monthly mean air temperature at the Mallik site....35
Figure B-4 Thermistor 07GSC-01 – Daily Ground Temperatures....35

Figure B-5 Thermistor 07GSC-02 – Daily Ground Temperatures 36
Figure B-6 Thermistor 07GSC-03 – Daily Ground Temperatures 36
Figure B-7 Thermistor 12GSC-04 – Daily Ground Temperatures 37
Figure B-8 Thermistor 12GSC-05 – Daily Ground Temperatures 37

Abbreviations

ARI	Aurora Research Institute, Aurora College
CCME	Canadian Council of Ministers of the Environment
GSC	Geological Survey of Canada
EM	Electromagnetic
ESSIS	Environmental SubSurface Imaging Solutions Ltd.
IORL	Imperial Oil Resources Ltd.
ISR	Inuvialuit Settlement Region
JAPEX	JAPEX Canada Ltd.
JNOC	Japan National Oil Corporation
Mbg	meters below ground
ml	millilitre
NWT	Northwest Territories
SDL	Significant Discovery Licence

1 Introduction

The Mallik L-38 lease area has been the site of three historical drilling programs, Mallik L-38 in 1972, Mallik 2L-38 in 1998, and Mallik 3L/4L/5L-38 in 2002. Each program constructed and used a conventional drilling sump to dispose of drill cuttings and fluids. Imperial Oil Ltd. (IOL) drilled the original IOL Mallik L-38 discovery well during the winter of 1971-1972 and constructed a large drilling waste disposal sump (approximately 80 m x 95 m). Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore et al. 1999). With JAPEX Canada Ltd. (JAPEX) acting as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a second drilling waste disposal sump (approximately 45 m x 50 m) on the property. In 2002, a seven-party participant group also led by JNOC and GSC, with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC et al. Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste generated during drilling of the three wells.

A fourth drilling program in 2007-2008 (JOGMEC/NRCan/Aurora Mallik 2007-2008 Gas Hydrate Production Research Well Program) where the 2L- and 3L-38 wells were re-entered did not utilize a sump with all drilling waste removed from site and disposed of at an approved facility (Dallimore et al., 2013).

As part of the Water Board License No. N7L1-1817, JAPEX/JNOC/GSC et al. was required to monitoring the Mallik 2L-38 and 3L/4L/5L-38 sumps. The original Mallik L-38 sump was not required to be monitored as part of scope for the monitoring program.

This 2014 Annual Sump Monitoring Report by KAVIK-Stantec Inc. (KAVIK-Stantec) details the last year of a required seven year monitoring program (i.e. 2008 to 2014) to monitor the stability of the Mallik 2L-38 and 3L/4L/5L-38 drilling waste sumps. The information in this report is required under Part H: Conditions Applying to Abandonment and Restoration of the Northwest Territories Board Licence No. N7L1-1817. The 2014 site visit was conducted on August 12 and 13 and included the following:

- a visual assessment of the site with an emphasis on sump cap conditions
- measurements of the active layer thickness on the sump caps, around their perimeter of the sump caps, as well as in an undisturbed area adjacent to the sumps
- maintenance and/or removal of some of the monitoring equipment on site
- downloading of temperature data at five thermistor locations
- Electromagnetic (EM) surveys (EM31 and 38) conducted on both sumps and surrounding areas
- soil sampling in areas showing elevated electromagnetic conductivities
- surface water sampling of ponded water located on the sump cap and in an undisturbed area adjacent to the sumps

This report herein documents the results of this site visit and presents the data gathered from the monitoring activities.

2 Site Location

The Mallik L-38 site is located on the west coast of Richards Island, in the outer region of the Mackenzie Delta, bordering the Beaufort Sea. The site is located within the Inuvialuit Settlement Region (ISR) of the Northwest Territories (Figure 2-1). The area consists of nearshore floodplains on the west coast of Mallik Bay. The site coordinates are approximately 69°27'38"N, 134°39'42"W. The Mallik lease area is located on Crown land within the IORL Significant Discovery License (SDL) 060. The locations of the sumps are shown on Figures 2-2 and 3-1. Refer to Figure 3-1 for current thermistor locations.

Figure 2-1 Location of the Mallik L-38 site in the Northwest Territories

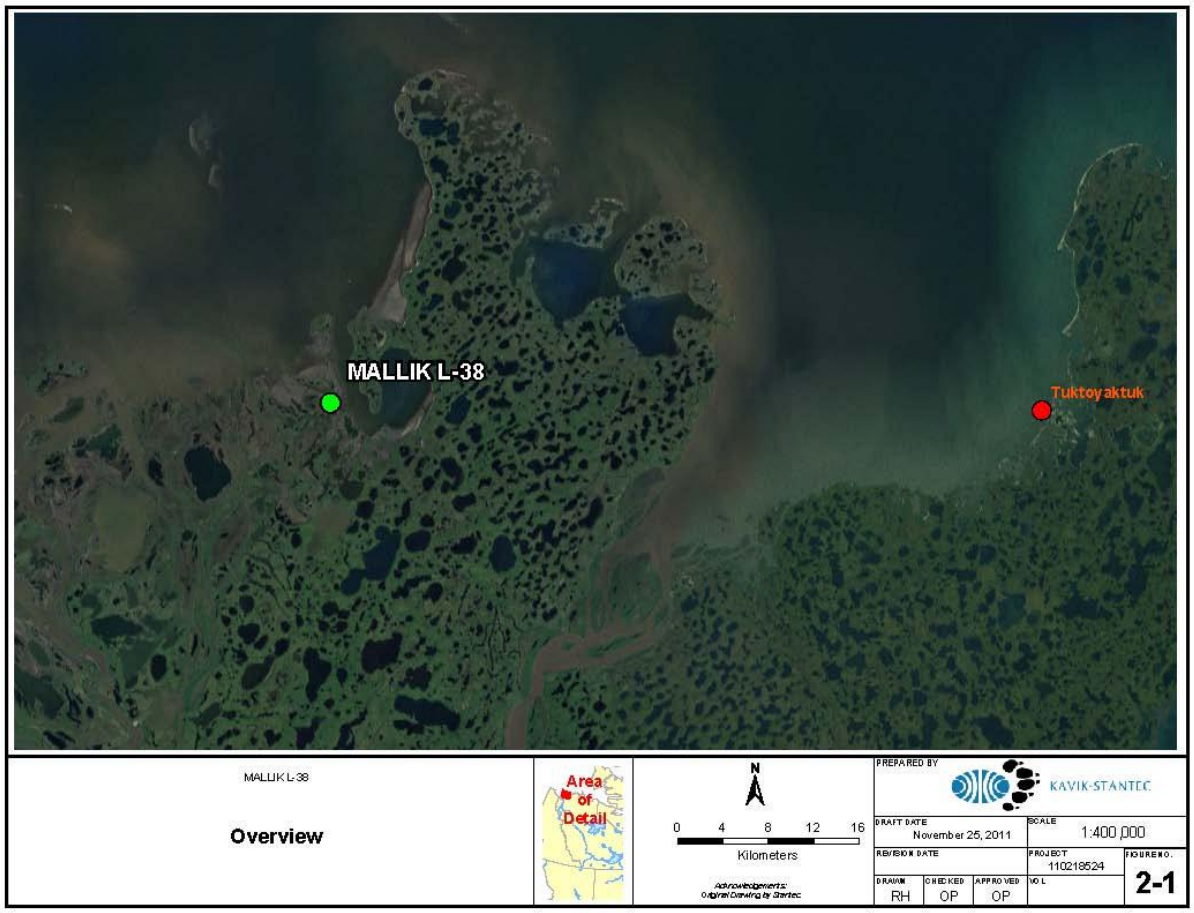
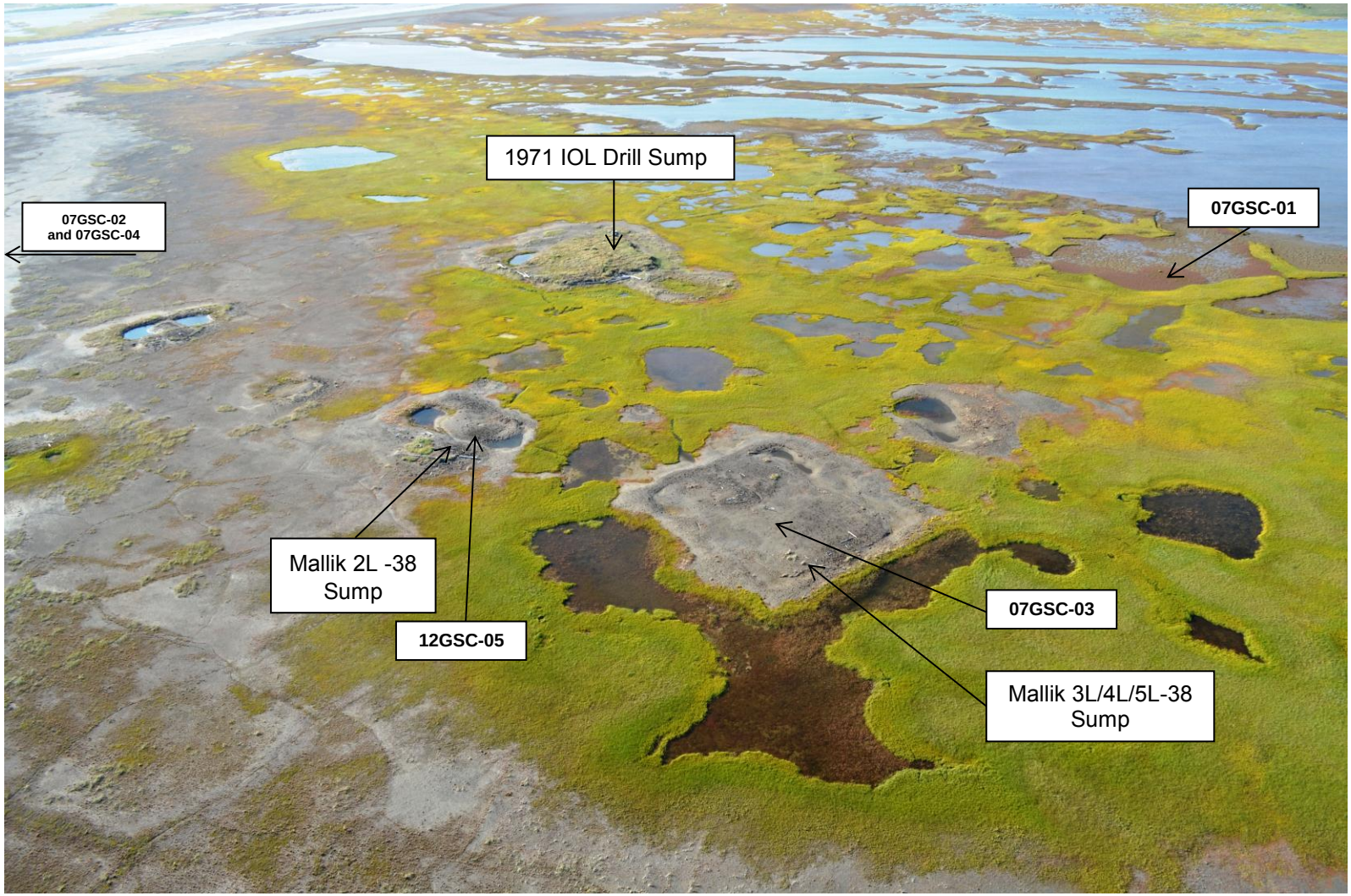


Figure 2-2 **Aerial oblique view of the Mallik site looking southwest. Key features and the location of temperature cables are identified (photo taken on August 12th, 2014)**



3 Methods

The methods for monitoring the Mallik drilling waste sumps were developed using the following documents:

- Water License No. N7L1-1817 (NWT Water Board, 2004)
- *Protocol for the Management of Drilling Waste Disposal Sumps* – Inuvialuit Settlement Region NWT (NWT Water Board, 2006)

The following sections outline the methodology followed throughout each component of the monitoring program, including: visual assessment, active layer depth measurements, ground temperature monitoring, electromagnetic surveys, and soil and water sampling.

3.1 Visual Assessment

Visual assessment was completed by a KAVIK-Stantec representative during the August 2014 visit. The purpose of the visual assessment is to document the physical conditions of the sumps and their immediate surrounding areas. Some of the key elements that were observed included:

- vegetation health and establishment on the sump caps or surrounding areas
- settlement and/or subsidence
- presence and/or absence of ponding water
- erosion, stress and/or tension cracks
- damage to existing monitoring facilities (thermistors and/or dataloggers)

The visual assessment was performed from both the air and ground. Site photographs can be reviewed in Appendix A.

3.2 Active-Layer Depth Measurements

Using a specially designed probe, active-layer depths were measured during the August 2014 site assessment. The methodology and location of the measurement points were recorded as specified in the *Protocol for the Monitoring of Drilling-Waste Disposal*, Inuvialuit Settlement Region NWT (NWT Water Board, 2006). Active-layer depths were collected at a control area, on the sump caps and at the perimeter of the sump caps within 2 m of the assumed interface between the sump cap and the surrounding undisturbed area.

3.3 Ground Temperature Monitoring

In 2007, four thermistors were installed in and surrounding the Mallik sumps, as specified in *Part H: Conditions Applying to Abandonment and Restoration* under *NWT Water Licence No. N7L1-1817.* An additional thermistor cable (12GSC-05) was installed at the center of the Mallik 2L-38 Drilling Sump on September 20, 2012 in accordance with the Water Licence Agreement based on sump monitoring programs in the Northwest Territories (AANDC, 2011). The locations of the thermistors are presented in Figure 2-2, while Table 3-1 presents the depth of each thermistor in meters below grade (mbg).

Table 3-1 Depth below ground surface of Thermistors

Thermistor Sensors	Thermistor Recording Depths (mbg)				
	07GSC-01[1]	07GSC-02[1]	07GSC-03[1]	07GSC-04	12GSC-05[2]
1	-	1.0	1.0	1.0	0.25
2	0.35	1.5	1.5	1.5	0.50
3	0.85	2.0	2.0	2.0	0.75
4	1.35	2.5	2.5	2.5	1.5
5	2.35	4.5	4.5	3.5	3
6	4.35	6.5	6.5	5.5	6
7	6.85	10.5	10.5	8.0	9
8	4.28	5.65	5.65	10.5	12

[1] Cables are longer than the depth of the holes at these sites. Therefore, the cables were looped back up the hole (i.e., the depth of the sensor #8 is above the sensor #6).
[2] New thermistor cable installed on September 20, 2012

3.4 Electromagnetic Surveys

Stantec's geophysicist conducted the EM surveys (EM31 and EM38) on August 12, 2014 using Geonics EM31 and EM38 ground conductivity meters. These instruments are used to identify the lateral extents of ion-rich regions and to help identify the locations for additional soil sampling, if deemed necessary. The surveys measure apparent conductivity of the soil around the sump site and can be used to identify potential migration of drilling waste ions from the sump into the surrounding soil. The EM38 measures apparent conductivity at soil depths of 0.0 to 1.5 m (shallow), while the EM31 unit measures apparent conductivity at soil depths of 0.0 to 5.0 m (deep).

3.5 Water Sampling

Surface water was sampled from subsidence areas located either within the sump cap or adjacent to the sump's perimeters. Surface water was also sampled from ponded water in undisturbed areas. Samples were collected at arm's reach within the deepest area of the ponded water and stored in laboratory-issued 500 ml plastic jars. Samples were submitted to Maxxam Analytical (Maxxam) in Yellowknife, NWT for routine water analysis. The certified laboratory results are provided in Appendix C. The locations of the 7 water samples collected are presented in Figure 4-8. The guidelines used to compare the results from the water sampling program are the Canadian Council of Ministers of the Environment (CCME) *Water Quality Guidelines for Freshwater and Aquatic Life (CCME 1999)*.

3.6 Soil Sampling

The purpose of the soil sampling program was to investigate anomalous areas with elevated measurements of apparent conductivity. Using results from the EM surveys, one area with an elevated apparent conductivity anomaly was observed outside of the sump areas and a soil sample was collected. This area of elevated apparent conductivity was identified in previous monitoring programs and past samples from this location showed high potassium value. Other areas of elevated conductivity outside of the sump areas included areas with natural ponding and depressions, which are subjected to high concentrations of seawater. In previous monitoring programs, soil samples from these locations were analyzed and found to be high in naturally occurring salts, therefore samples were not collected at these locations this year. Two soils samples were collected during the 2014 site assessment.

Both soil samples were collected using a clean shovel and a soil knife at an approximate depth of 30 cm. Approximately 1 kg of soil was collected in laboratory-issued zip-lock containers and submitted to Maxxam Laboratory in Yellowknife, NWT for analysis. See Appendix C for the certified laboratory results. The locations of the five soil samples collected are presented in Figure 4-8.

4 Results

4.1 Visual Assessment

The following section provides a summary of the site conditions observed at the Mallik site on August 12-13th, 2014. Selected site photographs are presented in Appendix A.

Site Drainage

The overall soil drainage conditions at the time of visit can be characterized as moderate to imperfect. Surface water was present in most natural ponds but at lower levels then what was observed during the 2013 survey. Similarly, less water was present in the depressions present within the limits of the two drilling sumps.

Unlike the last two site visits (i.e. 2012 and 2013), no clear indicators of a recent storm surge were visible at the site.

Vegetation and Wildlife

It is estimated that less than 10% of the total sump caps are currently covered by vegetation. The vegetation is predominantly composed of a variety of graminoid species, such as sedges and grasses, with a few sporadic low shrubs and mosses. The conditions of the vegetation are comparable to last year.

Several signs of wildlife were noted on site. The most common were bird droppings, as well as bird and caribou (*Rangifer tarandus*) tracks. Bear tracks, most likely from a juvenile bear, were seen at the site.

Surface Subsidence

As reported in the 2011, 2012 and 2013 site assessment reports, there are several areas with ground surface subsidence on both sumps (see site photographs in Appendix A). The subsidence appears more extensive at the 2L-38 sump than at the 3L/4L/5L-38 sump.

The subsidence areas on the eastern and western sides of the 2L-38 sump cap appear to be extending and connecting with each other along the northern portion of the sump cap. The depressions on either side of the sumps are approximately 1.2 m lower than the surrounding topography. The water levels in the two depressions were lower this year than in 2013.

Surface subsidence is present along the edges of the 3L/4L/5L-38 sump cap, most notably along the southwest and northeast sides of the sump. The depression along the southwest portion of this sump covers the full width of the sump (i.e. approximately 50 m) while three interconnected depressions are present on northeast portion. The deepest depression is located at south corner of the sump and is approximately 80 cm in depth.

Base on visual observation only, approximately 60 percent of the 2L-38 sump cap and approximately 10 percent of 3L/4L/5L-38 sump cap is located below the surrounding sump cap level. It is not possible to say if these depressions have increased in size or depth during the 2013/2014 period.

4.2 Active Layer Measurements

Active layer measurements were collected on August 13th, 2014. The control transect is located at the same location as the previous years at an undisturbed area, located approximately 150 m southeast from the Mallik 2L-38 Sump. Table 4-1 provides a summary and comparison of the active layer depths. A figure showing the location of each individual measurement is located in appendix A.

Table 4-1 Summary of Active-Layer Measurements

	Mallik 2L-38 Sump		Mallik 3L/4L/5L-38 Sump		Control Transect
	Sump Cap	Perimeter	Sump Cap	Perimeter	
Measurements collected	17	20	26	20	20
Minimum thawing depth (cm)	100	105	90	105	90
Maximum thawing depth (cm)	137	130	138	121	138
2014 Average thawing depth (cm)	114	114	115	111	110
2013 average (cm)	123	125	121	123	113
2012 average (cm)	140	136	132	131	128
2011 average (cm)	121	114	133	117	113
2010 average (cm)	119	113	118	121	113

Mallik 2L-38 Sump

Active layer depths in 2014 on the Mallik 2L-38 sump cap ranged from 100 cm to 137 cm and averaged 114 cm. Active-layer depths around the perimeter of the sump cap ranged from 105 cm to 130 cm and averaged 114 cm. The minimum, maximum and average values for both the cap and perimeter areas are a few centimeters shallower in 2014 when compared the 2013 values (note that the measurements were taken a month earlier in 2014) .

Mallik 3L/4L/5L-38 Sump

Active layer depths on the Mallik 3L/4L/5L-38 sump cap ranged from 90 cm to 138 cm, for an average of 115 cm. Active-layer depths around the perimeter of sump cap had a similar range from 105 cm to 121 cm, for an average of 111 cm. Similarly to the 2L-38 sump, the minimum, maximum and average values for both the cap and perimeter areas are a few centimeters shallower to the 2013 depths.

Control transect

The control transect was conducted at the same location as during the previous surveys. Active layer depths along the control transect range from 90 cm to 138 cm, for an average of 110 cm. The thinnest active layer measurements correspond to well vegetated area (i.e. at the south end of the transect), while the thicker measurements were taken in moist soils devoid of any vegetation (north end of the transect).

4.3 Air and Ground Temperature Monitoring

The following section presents a summary of the air and ground temperature data collected at the various sensors and thermistor cables at the Mallik site. The locations of the thermistors are shown on Figure 3-1.

The mean, maximum and minimum ground temperatures of each sensor are summarized in Tables 4-2 to 4-6. Diagrams showing the annual variation of mean ground temperature at each sensor depth are provided in Appendix B.

4.3.1 Air Temperature

Air temperature has been recorded hourly at the Mallik site since October 1, 2010. The air temperature sensor is installed at approximately 1.5 meters above the ground surface. The sensor is mounted within a radiation shield to minimize the heating effects of solar radiation and direct exposure to rain and snow. The average monthly air temperature recorded over the last three years is presented in Table 4-2.

Table 4-2 Monthly Air Temperatures

Air Temperature (°C)

	2010/2011	2011/2012	2012/2013	2013/2014
September	-	4.1	5.8	2.9
October	-5.3	-3.9	-2.8	-0.3
November	-13.1	-20.4	-15.4	-13.3
December	-25.7	-22.7	-26.7	-23.2
January	-25.9	-27.6	-28.4	-24.0
February	-23.2	-23.1	-29.2	-25.1
March	-23.0	-30.0	-26.0	-21.6
April	-19.0	-14.5	-18.9	-13.7
May	-3.2	-4.3	-5.6	-0.9
June	4.6	8.1	5.5	5.8
July	12.1	15.3	9.9	10.8
August	10.2	12.4	10.5	10.1*
Annual Mean	**-**	**-8.9°C**	**-10.1°C**	**-8.5°C**

*Based on the first 12 days of August only

Summary of air temperature

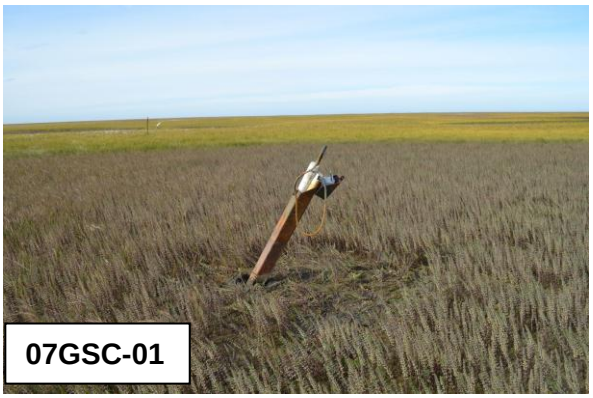
The annual mean air temperature for 2013/2014 was of -8.5°C, compared to -10.1°C in 2012/2013 and -8.9°C in 2011/2012.

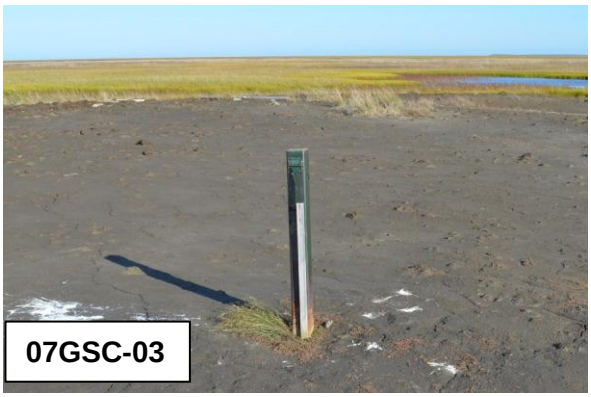
The warmest air temperature recorded over the August 2013 to August 2014 period was of 26.8°C (recorded on June 23rd, 2014) while the coldest was of -40°C recorded on (recorded on February 21st, 2014). A review of the monthly temperature averages indicates that the months of March, April and May 2014 were warmer than the similar months of 2013 by 4 to 5°C (see Table 4-2).

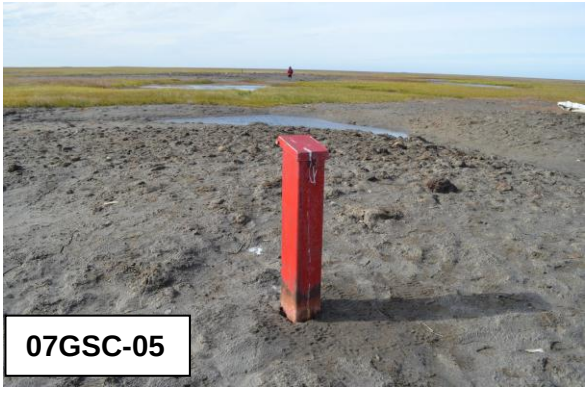
4.3.2 Ground thermal monitoring

Ground thermal monitoring has been conducted at the Mallik site since April 2007. The thermistor sensor depths range from just below ground surface to a maximum depth of 12 m with data loggers set up to record hourly temperatures. Figure 4-1 shows the ground surface conditions at each site. Ground temperature data of each thermistor cable are presented below.

Figure 4-1 Ground surface conditions at monitoring locations







Themistor	Active layer depth measured at thermistor on August 13th, 2014
07GSC-01	N.A.
07GSC-02	119 cm
07GSC-03	129 cm
07GSC-04	N.A.
07GSC-05	117 cm

4.3.2.1 Ground temperatures at thermistor 07GSC-01

Thermistor 07GSC-01 is located in an undisturbed area approximately 200 m southwest of the Mallik sumps at the edge of a large but shallow pond. The water level in the pond decreased considerably between the 2012 and 2013 summer season. No surface water was present during the 2014 survey at the area where the thermistor is located. Note that the thermistor located at 2.35 mbg stopped measuring temperature near the end of September 2013 due to instrument error.

Figure 4-2 Ground temperature at thermistor 07GSC-01 (10/09/2013 to 12/08/2014)

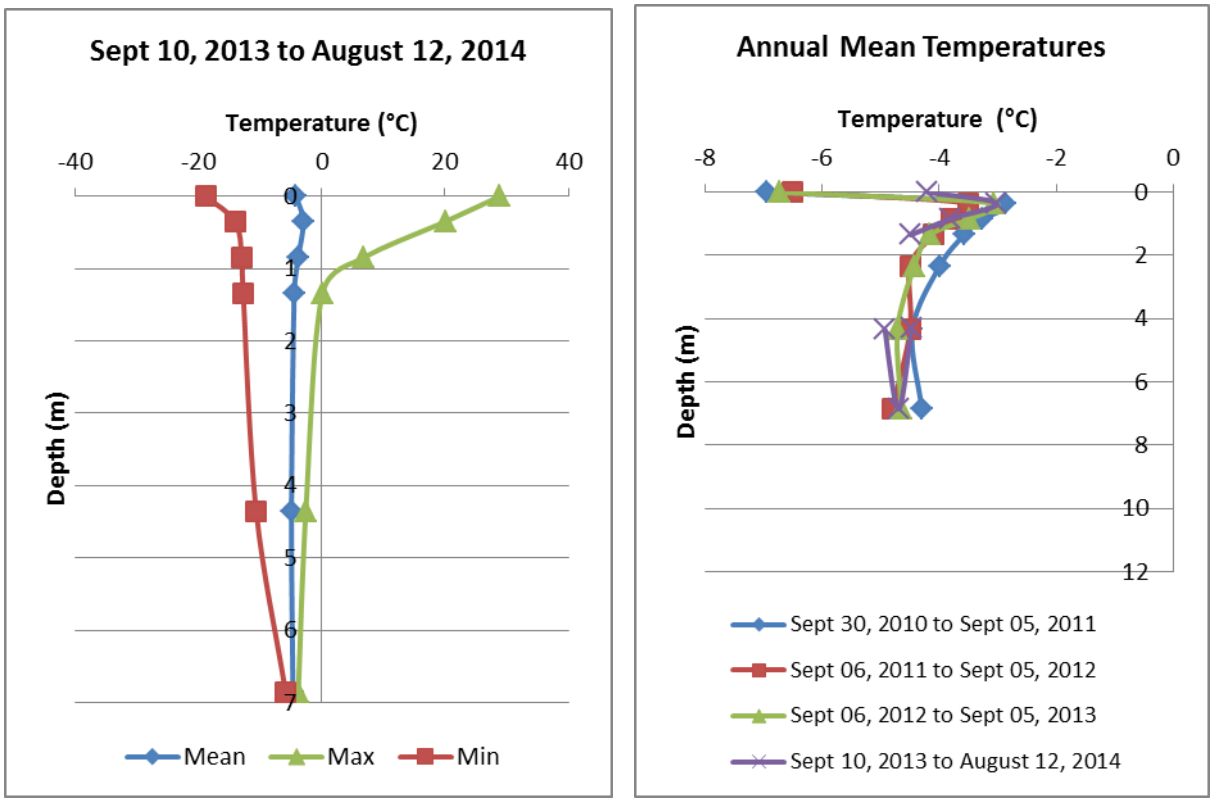


Table 4-3 Ground Temperatures at thermistor 07GSC-01 (10/09/2013 to 12/08/2014)

Sensor Depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.35	-4.2	28.9	-18.9
0.85	-3.0	20.0	-14.1
1.35	-3.8	6.8	-13.0
2.35	Invalid data		
4.35	-4.9	-2.6	-10.7
6.85	-4.7	-3.8	-5.9

4.3.2.2 Ground temperatures at thermistor 07GSC-02

Thermistor 07GSC-02 is located approximately 200 m southeast from the 2L-38 sump in an undisturbed site with low sedge and grass cover.

Figure 4-3 Ground temperature at thermistor 07GSC-2 (10/09/2013 to 12/08/2014)

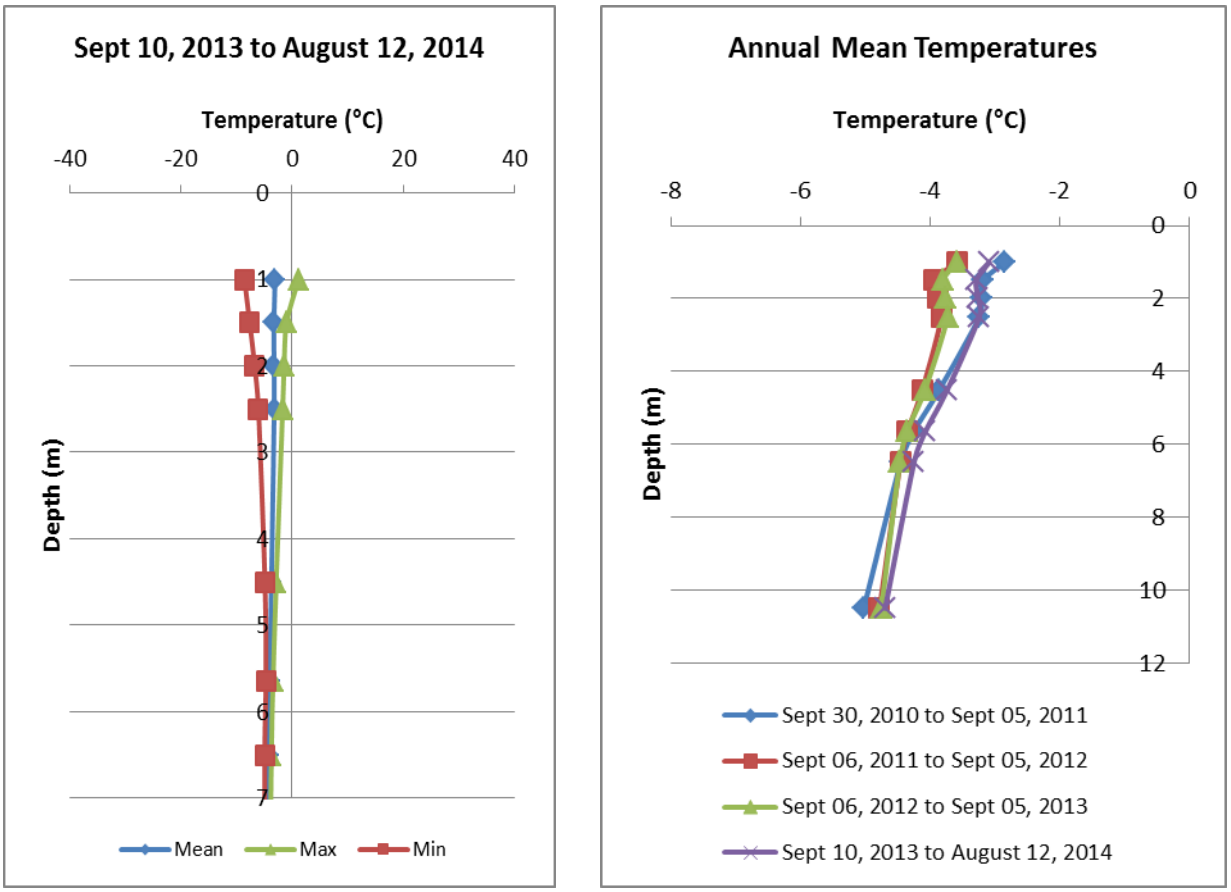


Table 4-4 Ground Temperatures at thermistor 07GSC-02 (10/09/2013 to 12/08/2014)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.00	-3.1	1.1	-8.6
1.50	-3.3	-1.0	-7.7
2.00	-3.3	-1.5	-6.8
2.50	-3.2	-1.7	-6.1
4.50	-3.7	-2.9	-4.9
5.65	-4.1	-3.5	-4.7
6.50	-4.3	-3.7	-4.9
10.50	-4.7	-4.5	-5.0

4.3.2.3 Ground temperatures at thermistor 07GSC-03

Thermistor 07GSC-03 is located within disturbed material at the center of the Mallik 3L/4L/5L-38 Sump.

Figure 4-4 Ground temperature at thermistor 07GSC-03 (10/09/2013 to 12/08/2014)

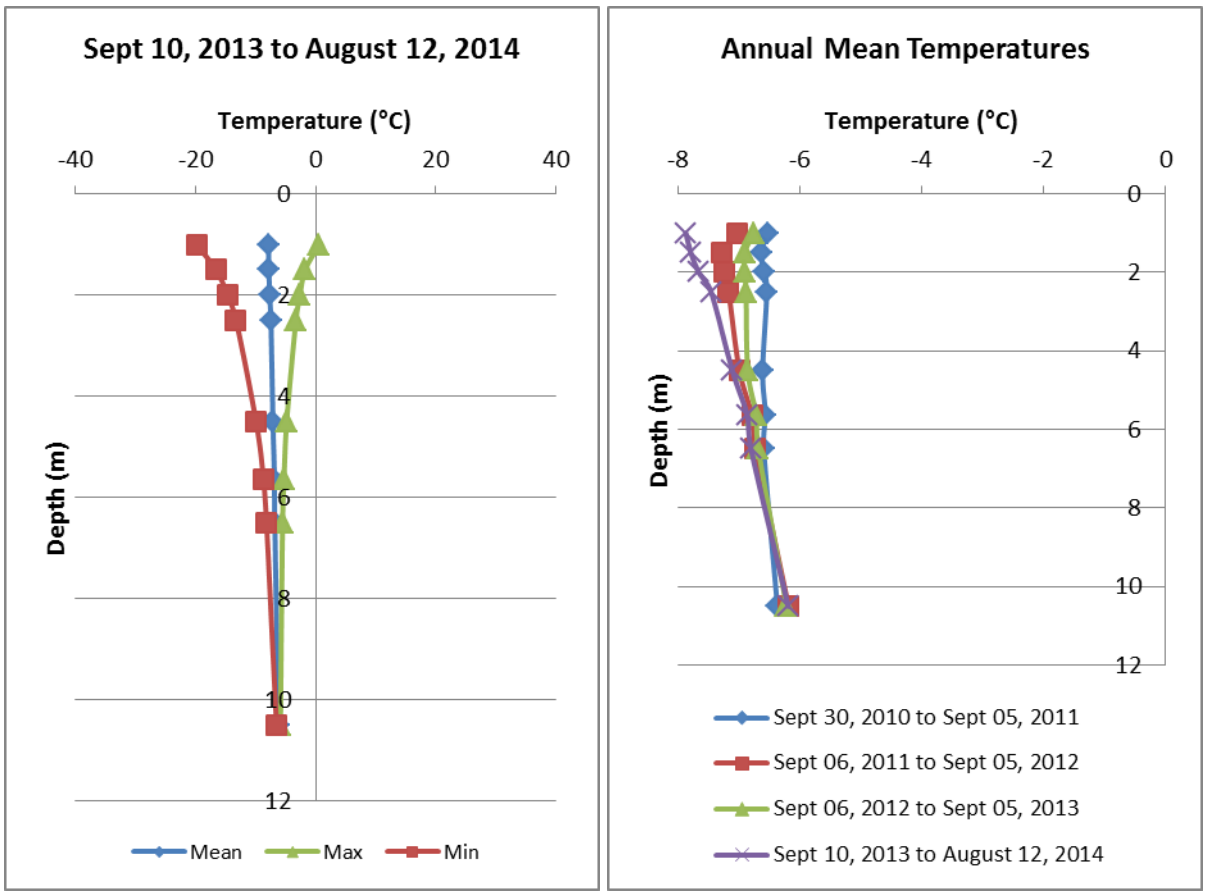


Table 4-5 Ground Temperatures at thermistor 07GSC-03 (10/09/2013 to 12/08/2014)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.00	-7.9	0.6	-19.8
1.50	-7.8	-1.8	-16.6
2.00	-7.7	-2.6	-14.6
2.50	-7.5	-3.3	-13.3
4.50	-7.1	-4.8	-9.9
5.65	-6.87	-5.3	-8.7
6.50	-6.8	-5.5	-8.2
10.50	-6.2	-5.9	-6.5

4.3.2.4 Ground temperatures at thermistor 07GSC-04

Thermistor 07GSC-04 is located in an undisturbed area approximately 150 m west of Mallik 2L-38 Sump.

Figure 4-5 Ground temperature at thermistor 07GSC-04 (10/09/2013 to 12/08/2014)

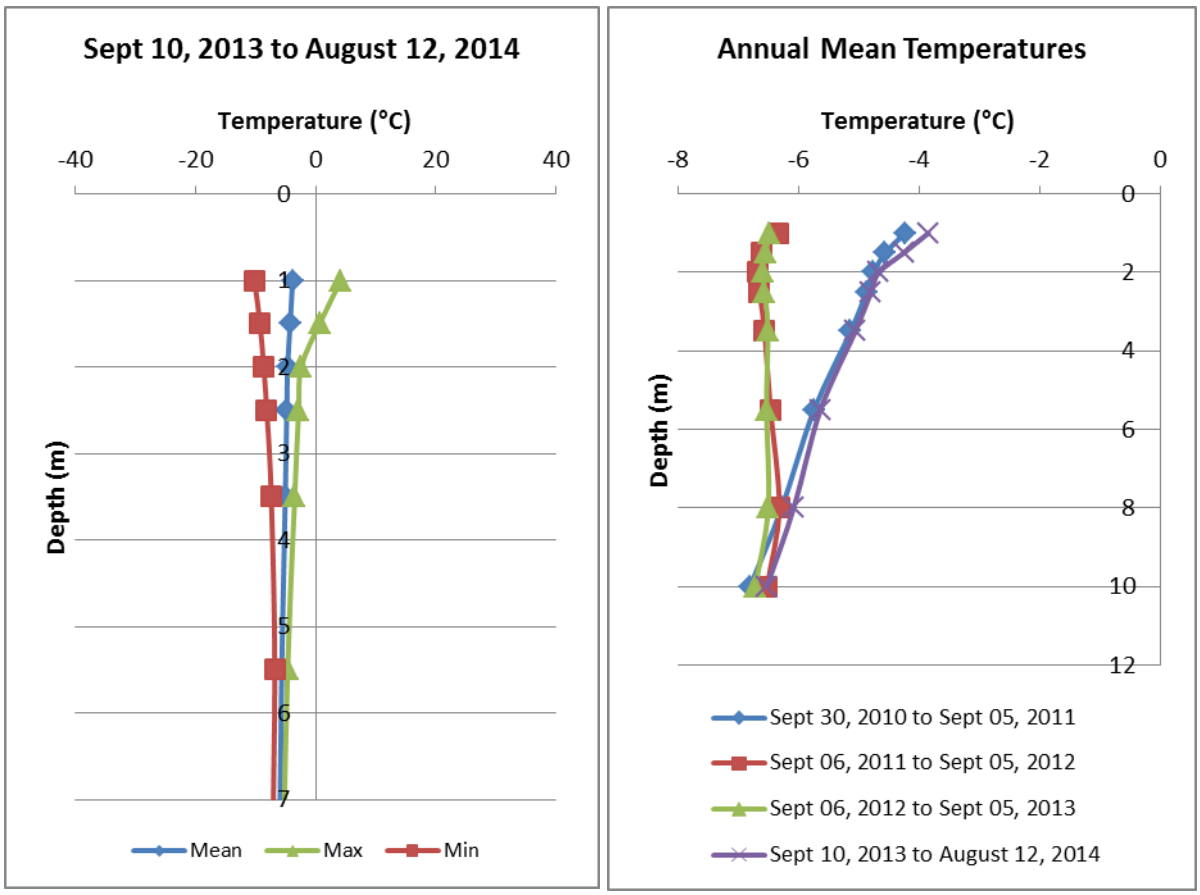


Table 4-6 Ground Temperatures at thermistor 07GSC-04 (10/09/2013 to 12/08/2014)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
1.0	-3.8	4.2	-10.2
1.5	-4.3	0.6	-9.3
2.0	-4.7	-2.4	-8.7
2.5	-4.8	-2.8	-8.2
3.5	-5.1	-3.5	-7.4
5.5	-5.6	-4.7	-6.8
8.0	-6.1	-5.5	-7.2
10.5	-6.5	-6.1	-7.2

4.3.2.5 Ground temperatures at thermistor 12GSC-05

Thermistor 12GSC-05 is located at the centre of the Mallik 2L-38 Sump and was installed on September 20, 2012.

Figure 4-6 Ground temperature at thermistor 12GSC-05 (10/09/2013 to 12/08/2014)

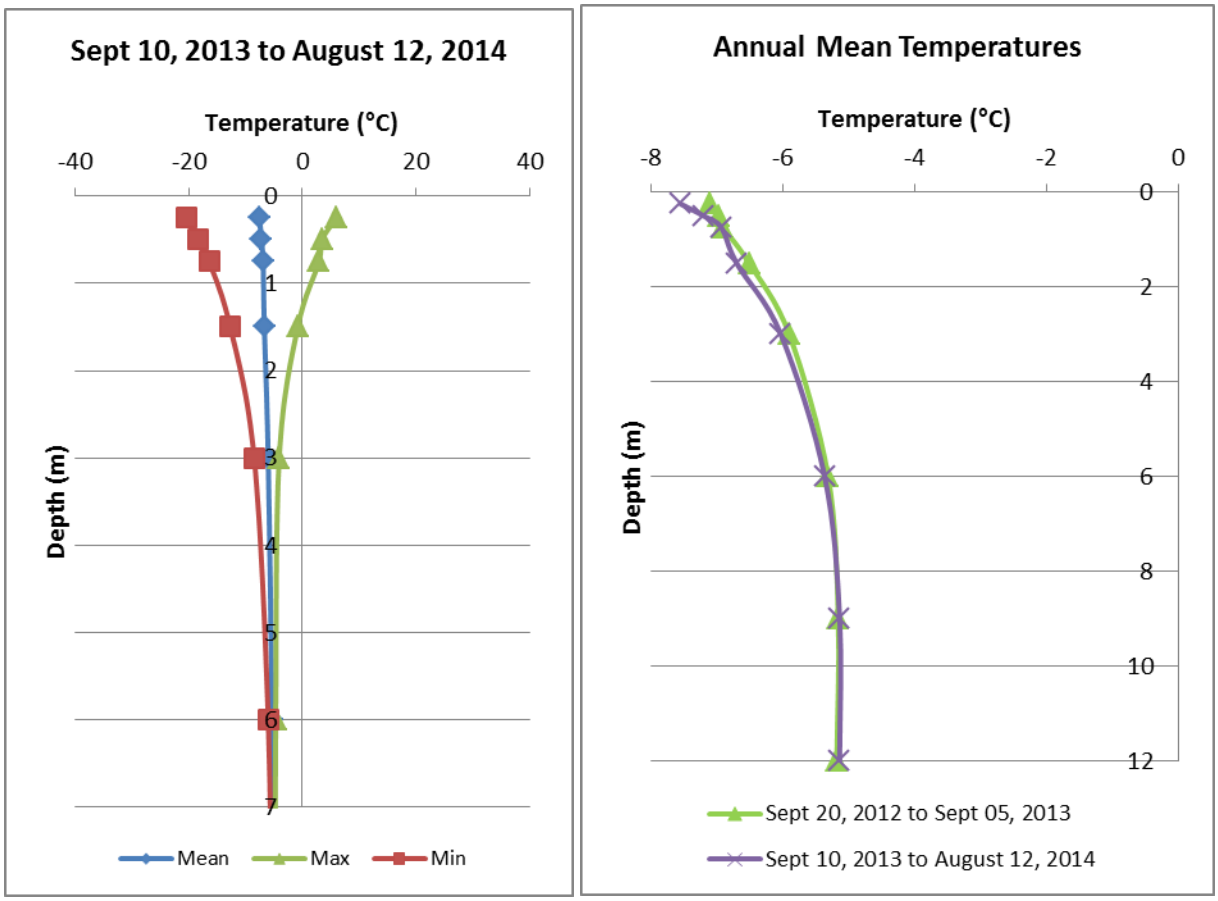


Table 4-7 Ground Temperatures at thermistor 12GSC-05 (10/09/2013 to 12/08/2014)

Sensor depth (m)	Mean (°C)	Maximum (°C)	Minimum (°C)
0.25	-7.6	6.0	-20.4
0.50	-7.2	3.5	-18.3
0.75	-6.9	2.9	-16.4
1.50	-6.7	-0.8	-12.7
3.00	-6.0	-4.1	-8.5
6.00	-5.4	-4.7	-6.0
9.00	-5.1	-4.9	-5.4
12.00	-5.1	-5.0	-5.3

Temperatures recorded along thermistor strings

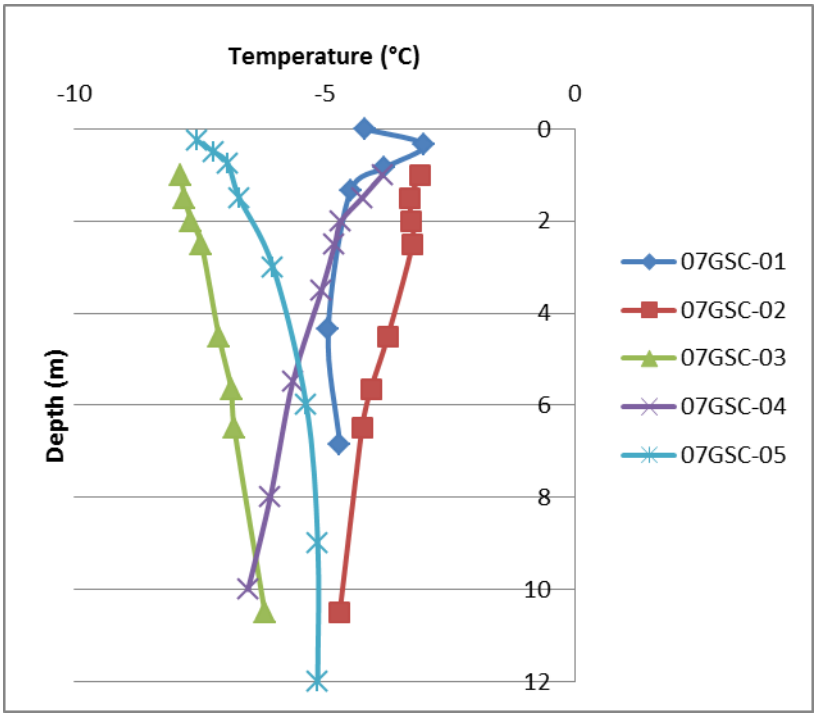
Ground temperature monitoring data demonstrates that the thermal regime recorded at the site appears to primarily fluctuate with seasonal temperature variations, regardless of whether the thermistor is located within the sump or outside the sump. Variances in temperature are also assumed to be secondly a function of several factors such as local site conditions, material texture and drainage, slope and exposure, presence or absence of vegetation, annual thickness of snow cover, etc.

The comparison of the mean annual temperatures recorded at the various thermistors (Figure 4-7) indicates that the ground temperature in the upper portion (i.e. between 0 and 5 mbg) of the two sumps are colder than 2 of the 3 control locations.

Thermistor cable 07GSC-03 is located in the 3L/4L/5L-38 Sump and records temperature at depth ranging from 1 mbg to 10.5 mbg. The thermistor at 1 m depth indicates that the material at that depth was unfrozen from July 25th, 2014 and reached a daily maximum temperature of 0.5°C on August 11th (i.e. the last few day of data recording before the site visit). The thermistor located at 1.5 mbg indicates that the material remained frozen for the last 12 months period, with an annual average temperature of -7.8°C. The data is in accordance with the active layer measured at the thermistor during the site visit (i.e. 129 cm).

Thermistor cable 12GSC-05 is located at the center of 2L-38 Sump and records temperature at depth ranging from 0.25 mbg to 12 mbg. The thermistor at 0.75 cm depth indicates that the material at that depth was unfrozen from July 13th, 2014, reached a daily maximum temperature of 2.5°C on July 24th and was being to freeze-back (0.3°C) at the survey date on August 12th, 2014. The thermistor located at 1.5 mbg indicates that the material remained frozen for the last 12 months period, with an annual average temperature of -6.7°C.

Figure 4-7 2013-2014 Annual mean temperature profiles at the various monitoring locations



4.4 Electromagnetic Surveys

As expected, the EM38 Survey (0 to 1.5 m) and the EM31 Survey (0 to 5 m) both identified areas of elevated apparent conductivity on the Mallik 2L-38 sump and on the Mallik 3L/4L/5L-38 sump which correspond primarily to the presence of saline drill cuttings within the sumps (See EM figures in Appendix C).

Similar to the analysis conducted during the previous year, both the EM31 and EM38 surveys also indicate that there is elevated apparent conductivity at several areas outside the sumps perimeters.

The eastern portion of the Mallik site (i.e. east of the 2L-38 sump) is characterized by highly elevated terrain apparent EC that is especially pronounced in the EM38 data. This implies that the source of elevated terrain apparent EC is primarily within the upper 1.5 m of the soil profile. Several factors could explain this elevated EM, including the fact that the area is slightly lower in elevation than western portion of the site and that it is more subject to annual inundation and subsequent evaporation of sea water than the rest of the site, but also the fact that the area is bare of any vegetation and that the active layer is generally thicker than the rest of the site.

Elevated terrain apparent EC measurements have been observed to correspond with several natural ponds each year the EM surveys have been conducted. These are most evident as areas of moderately elevated terrain apparent EC in the EM38 data. Past water sample analyses indicate that the high conductivity is most likely related to the evaporation of trapped sea water from the annual storm surges and are not indicative of sump seepage.

Interpreting inductive electromagnetic (EM) geophysical data in this dynamic permafrost setting is quite challenging. When interpreting inductive electromagnetic (EM) geophysical data in areas of permafrost the critical factor to consider is the depth of the active layer. The close proximity of the site to the ocean and the associated storm surges should also be considered. Therefore, identifying potential anthropogenic impacts is complicated by naturally occurring sediment salts and/or naturally occurring changes in the active layer depth related to these salts. Differentiating anthropogenic from naturally occurring terrain apparent EC anomalies thus is complex and interpretations should be considered as such. To assist in the interpretation of the EM data, intrusive sampling techniques of both water and soil were used.

4.5 Soil and Water Sampling

Soil samples were taken from two separate locations; the first sample in an area of apparent elevated EM east from the 2L-38 Sump and the second from an undisturbed location southwest from the sumps.

Surface water samples were collected at seven locations. Three samples were collected within subsidence areas located inside the sump boundaries and three more were samples from depressions characterized by elevated apparent conductivities located outside the sumps boundaries. A control sample was collected from a natural pond away from the sumps. Table 4-7 and Figure 4-8 provide some information on the locations of each sample. A summary of the water and soil analysis results is presented in Tables 4-8 and Table 4-9. The complete laboratory reports are presented in Appendix D.

Table 4-8 Soil and Water Sampling Locations

Sample Number	Comments on sample location
MALLIK-2014-S01	Soil sampled from an area showing elevated apparent conductivity located approximately 15 m east from the southeast corner of the Mallik 2L-38 Sump
MALLIK-2014-S02	Control soil sample from an undisturbed area located 150 m southwest from the various sumps
MALLIK-2014-W01	Water sampled from a depression located at the eastern edge of the Mallik 2L-38 Sump
MALLIK-2014-W02	Water sampled from a depression located at the western edge of the Mallik 2L-38 Sump
MALLIK-2014-W03	Water sampled from a natural shallow pond located half way between the Mallik 2L-38 Sump and the Mallik 3L/4L/5L-38 Sump
MALLIK-2014-W04	Water pooling in the depression located at the southern edge of the Mallik 3L/4L/5L-38 Sump
MALLIK-2014-W05	Water pooling in the depression located at the southern edge of the 1998 Camp Sump
MALLIK-2014-W06	Water sampled from a natural shallow pond showing elevated apparent conductivity located approximately 50m south from the 3L/4L/5L-38 Sump and 50 m southwest from the Mallik 2L-38 Sump
MALLIK-2014-W07	Control water sample taken from a natural shallow pond located 150 m southwest from the sumps

Figure 4-8 Location of soil and water samples

4.5.1 Soil Sampling

Only two soil samples were collected during the 2014 field visit (Figure 4-8). Sample S1 was taken from the area of elevated apparent conductivity located immediately east from the Mallik 2L-38 Sump. Sample S2 is a control sample taken in an undisturbed area located 150 m southwest from the sumps. A summary of the laboratory results is presented in Tables 4-8 with full laboratory report present in Appendix D.

Sample S1 shows much higher potassium content than the control sample (1,700 mg/kg for sample S1 versus 28 mg/kg for sample S2) while the pH, conductivity and chloride values are fairly similar between both samples. This high potassium value was also recorded in 2013 (sample S03) and is likely due to a surface spill dating from the past drilling operation. Of the two soil samples taken in 2014, the sample having the highest sodium level corresponds to the control sample (1,400 mg/kg for sample S2 versus 540 mg/kg for sample S1). Past soil sampling results indicate that sodium levels are highly variable at the site, including in areas located outside the sumps.

Table 4-9 Soil Sampling Results

Maxxam ID		KJ1760	KJ1761	
	Units	**MALLIK-2014-S1**	**MALLIK-2014-S2**	**RDL**
Calculated Parameters				
Anion Sum	meq/L	130	130	N/A
Cation Sum	meq/L	140	140	N/A
Cation/EC Ratio	N/A	9.3	9.8	0.10
Ion Balance	N/A	1.1	1.0	0.010
Calculated Calcium (Ca)	mg/kg	520	300	0.98
Calculated Magnesium (Mg)	mg/kg	87	160	0.65
Calculated Sodium (Na)	mg/kg	540	1400	1.6
Calculated Potassium (K)	mg/kg	1700	28	0.85
Calculated Chloride (Cl)	mg/kg	2700	2800	65
Calculated Sulphate (SO4)	mg/kg	700	380	3.3
Soluble Parameters				
Soluble Chloride (Cl)	mg/L	4000 (1)	4300 (1)	100
Soluble Conductivity	dS/m	15	14	0.020
Soluble (CaCl2) pH	pH	7.27	7.14	N/A
Sodium Adsorption Ratio	N/A	7.0	20	0.10
Soluble Calcium (Ca)	mg/L	750	450	1.5
Soluble Magnesium (Mg)	mg/L	130	240	1.0
Soluble Sodium (Na)	mg/L	780	2200	2.5
Soluble Potassium (K)	mg/L	2400	42	1.3
Saturation %	%	69	65	N/A
Soluble Sulphate (SO4)	mg/L	1000	580	5.0
Theoretical Gypsum Requirement	tonnes/ha	11	120	0.10

RDL = Reportable Detection Limit, N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

4.5.2 Water Sampling

The surface water samples collected at Mallik have pH values ranging from 7.92 to 9.21, which is in accordance with the CCME guidelines (CCME 1999) and within the range of values observed in several lakes and channels of the Mackenzie Delta (Anema et al., 1990).

The conductivity values measured from the water samples range from 2,300 uS/cm to 9,600 uS/cm. The two samples with the highest conductivities (W2 and W4) are located at the surface of both sumps and correlate with the elevated apparent conductivities measured during from the EM survey.

The exact nature of the materials contained in the Mallik drilling sumps is not documented in this report but typically the constituents of brine-based drilling mud are potassium chloride, bentonite, cellulose polymers, lignosulphonates and sodium hydroxide (Piteau Engineering Ltd., 1988; Kokelj and GeoNorth, 2002).

The water samples showing the most elevated potassium levels (i.e. sample W2 with 720 mg/L and W4 with 510 mg/L) were taken from the pools located within the ponding surrounding both sumps perimeters. In comparison, the potassium levels measured in samples located outside the sumps areas varied from 35 to 71 mg/L. The water samples showing the highest concentrations of chloride were also measured from samples taken within the sumps perimeters (i.e. sample W2 with 2,700 mg/L and W4 with 2,800 mg/L). Water samples W2 and W4 were also showing the highest levels of calcium of all water samples (i.e. sample W2 with 250 mg/L and W4 with 410 mg/L). A summary of the water analysis is presented in Table 4.9.

The conductivities of the sample taken in the subsidence areas of the Mallik 2L-38 and Mallik 3L/4L/5L-38 sumps appear to be influenced by elevated sodium, potassium, calcium and chloride parameters, Samples taken in the natural depressions outside the sumps appear to be primarily influenced by elevated sodium parameters.

The analysis suggests that there is some correlation between the apparent elevated conductivities observed in the EM31 and EM38 surveys and the sodium, potassium, calcium and chloride concentrations of the water samples taken from the subsidence areas of the two drilling sumps. These elevated values correlate with data from the previous years and suggest that some diluted drill mud contaminants are present in the water pooling within the subsiding portions of the sump caps.

Table 4-10 Water Sampling Results

	Units	MALLIK-2014-W1	MALLIK-2014-W2	MALLIK-2014-W3	MALLIK-2014-W4	MALLIK-2014-W5	MALLIK-2014-W6	MALLIK-2014-W7	RDL
Calculated Parameters									
Anion Sum	meq/L	33	84	60	96	21	77	62	N/A
Cation Sum	meq/L	29	78	55	84	18	70	64	N/A
Hardness (CaCO3)	mg/L	460	1200	700	1700	270	850	750	0.50
Ion Balance	N/A	0.88	0.92	0.91	0.88	0.88	0.91	1.0	0.010
Dissolved Nitrate (NO3)	mg/L	<0.044	<0.044	<0.044	<0.044	<0.044	0.060	<0.044	0.044
Nitrate plus Nitrite (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	<0.010	0.010
Dissolved Nitrite (NO2)	mg/L	<0.033	<0.033	<0.033	<0.033	<0.033	<0.033	<0.033	0.033
Total Dissolved Solids	mg/L	1800	5000	3300	5500	1100	4300	3600	10
Misc. Inorganics									
Conductivity	uS/cm	3600	9100	6400	9600	2300	7800	6500	1.0
pH	pH	8.41	8.05	9.21	7.92	9.01	8.89	8.59	N/A
Anions									
Alkalinity (PP as CaCO3)	mg/L	2.0	<0.50	16	<0.50	13	12	7.7	0.50
Alkalinity (Total as CaCO3)	mg/L	150	100	84	89	130	110	160	0.50
Bicarbonate (HCO3)	mg/L	180	130	64	110	130	99	180	0.50
Carbonate (CO3)	mg/L	2.4	<0.50	19	<0.50	16	14	9.2	0.50
Hydroxide (OH)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.50
Dissolved Sulphate (SO4)	mg/L	190	330 (1)	140	690 (1)	84	320 (1)	300 (1)	5.0
Dissolved Chloride (Cl)	mg/L	910 (1)	2700 (1)	2000 (1)	2800 (1)	590 (1)	2400 (1)	1800 (1)	20
Nutrients									
Dissolved Nitrite (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010
Dissolved Nitrate (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.014	<0.010	0.010
Lab Filtered Elements									
Dissolved Calcium (Ca)	mg/L	81	250	79	410	33	87	92	0.30
Dissolved Iron (Fe)	mg/L	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	<0.060	0.060
Dissolved Magnesium (Mg)	mg/L	62	150	120	170	44	150	130	0.20
Dissolved Manganese (Mn)	mg/L	<0.0040	0.025	0.0041	0.024	0.0053	<0.0040	<0.0040	0.0040
Dissolved Potassium (K)	mg/L	110	720 (1)	71	510 (1)	11	46	35	0.30
Dissolved Sodium (Na)	mg/L	390	800 (1)	890 (1)	850 (1)	290	1200 (1)	1100	0.50

RDL = Reportable Detection Limit
N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

5 Conclusion

The 2014 site visit was conducted on August 12th and 13th. The surface conditions of the two sumps are similar to the previous visit conducted in September 2013. The drainage conditions of the site ranged from moderate to imperfect. The water level of most ponds, both on and off the sump caps, was lower than September 2013, with only a single pond of water present at the surface of the 3L/4L/5L-38 Sump. No vegetation is growing at the surface of the 2L-38 sump cap and only very localized patches of grass are growing at the surface of the 3L/4L/5L-38 sump cap (covering less than 10% of the overall cap).

Depressions related to ground subsidence are present at the surface of both sumps. The extent and depth of the various depressions appear to be similar to the previous year. The depressions are more accentuated at the 2L-38 Sump, where approximately 60% of the sump cap is believed to be impacted (approximately 10% for the 3L/4L/5L-38 Sump). The depressions in the 2L-38 Sump are approximately 120 cm deep and are partially filled with water, while the depressions in the 3L/4L/5L-38 Sump are not as deep and only one contained ponded water at the time of visit. No field indicator of recent ground subsidence (e.g. tension cracks along the edges of the depressions) was noted on site.

Active layer measurements indicate a decrease in active layer depth compared to last year. Measurements taken on August 13th indicate an average thaw depth of 114 cm at the surface of the 2L-38 and 115 cm at the surface of the 3L/4L/5L-38 Sump, compare to 123 cm and 121 cm measured on September 11th of 2012. The active layer measured along the control transects ranged from 90 cm (in the vegetated area) to 138 cm (bare, moist area), for an average of 110 cm.

The air temperature sensor indicates that the months of March, April and May 2014 were warmer than the similar months of 2013 by 4 to 5°C. The average temperatures of the months of June, July and August are comparable to the 2013 temperatures.

The temperature profiles recorded during the September 2013 to August 2014 period are very similar to those of the 2012-2013. The coldest temperature profiles recorded at the sites correspond to thermistor 07GSC-03 (3L/4L/5L-38 Sump) and 12GSC-05 (2L-38 Sump). Both thermistors indicate that the material at 1.5 m depth recorded negative temperatures over the past 12 month period.

The findings of the electromagnetic surveys are consistent with previous year's results. As expected, the EM38 and the EM31 surveys have identified areas of elevated apparent conductivity values at both sumps locations. The EM31 and especially the EM38 surveys indicate areas of elevated apparent conductivity outside the sump. These areas correspond to areas of bare soils as well as a series of natural depression located at proximity to the sumps. Water and soil samples taken from those high apparent conductivity areas indicates high sodium content believed to result from the evaporation of sea water brought to site during storm surge events. Water samples taken in the subsidence areas of the sumps have high potassium values and suggesting that seasonally unfrozen drill mud contaminants are mixing into the subsiding portions of the sump caps.

A soil sample taken from an area of elevated apparent conductivity located immediately east from the Mallik 2L-38 Sump showed a high potassium value that is believed to correspond to the remains of drilling-related material present at the ground surface in that specific area. This material is mostly present at the near surface and therefore not related to the seepage of drilling-related materials from the sump.

6 References

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Appendix A Site Photographs

Figure A-1 Aerial overview of the Mallik site (looking south) (photo taken on August 12th, 2014)

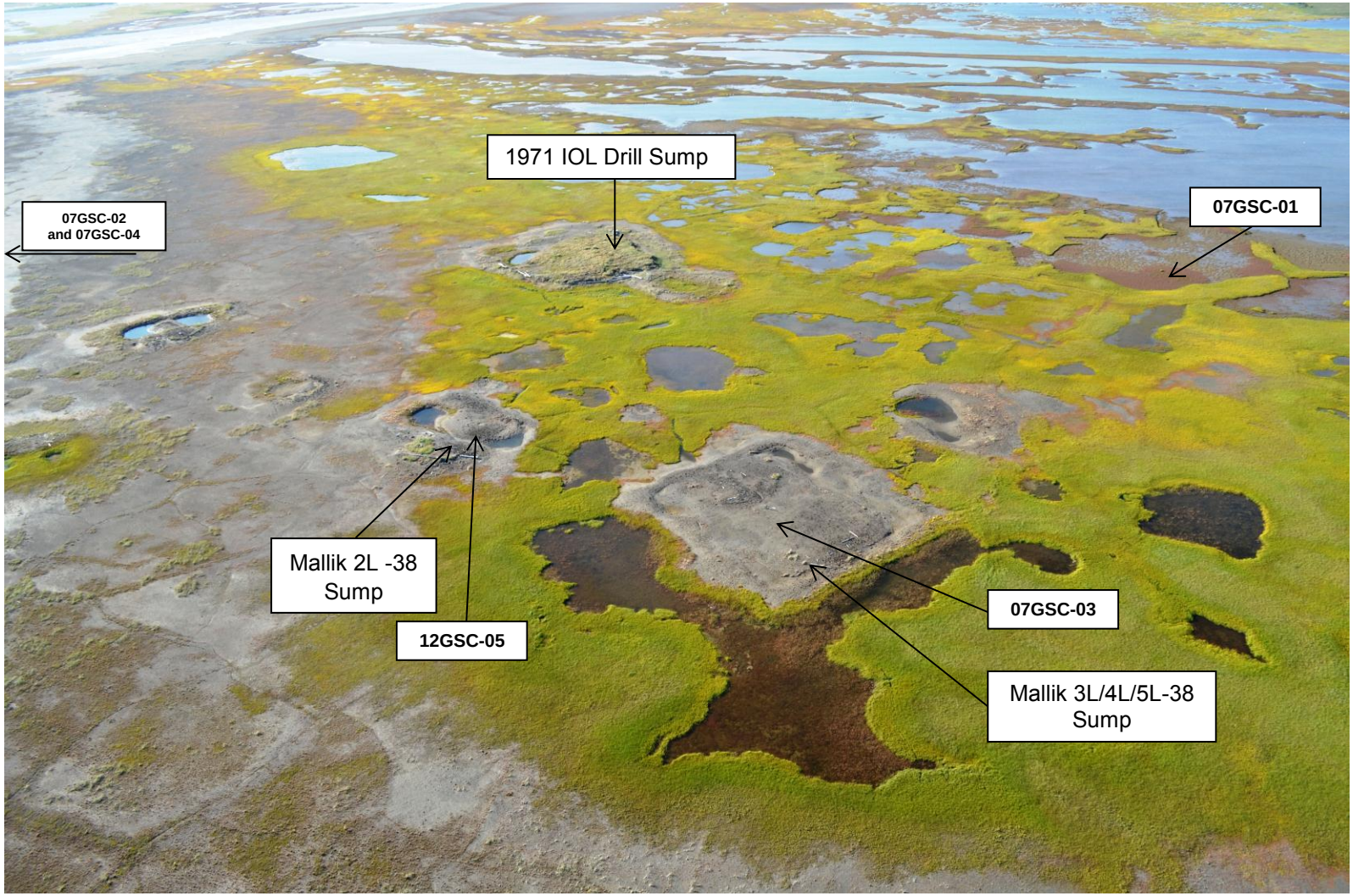


Figure A-2 Aerial view of Mallik 3L/4L/5L-38 Sump (looking north) (photo taken on August 12th, 2014)

Figure A-3 Aerial view of Mallik 3L/4L/5L-38 Sump (looking south) (photo taken on August 12th, 2014)

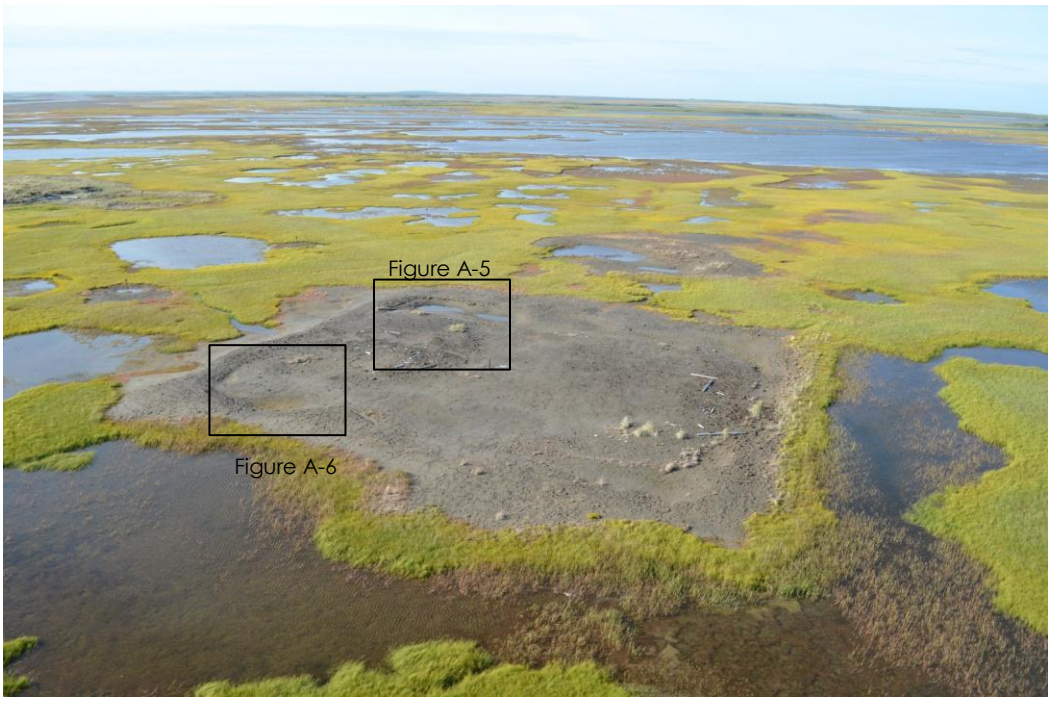


Figure A-4 Subsidence and water ponding along the western corner of the 3L/4L/5L-38 Sump (photo taken on August 12th, 2014)

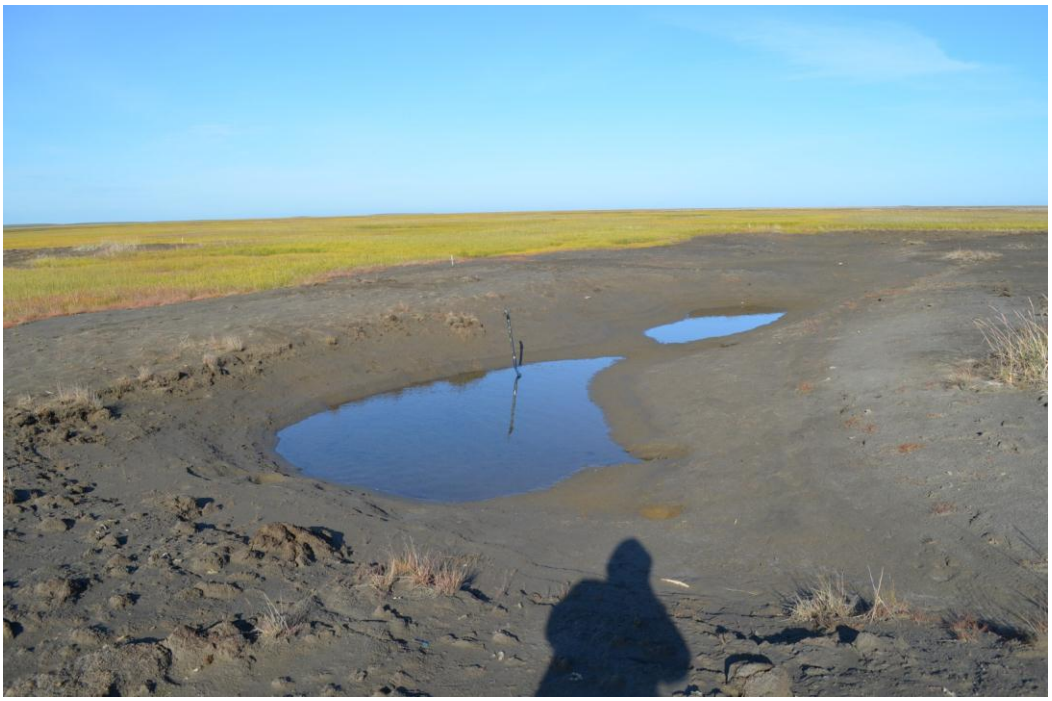


Figure A-5 Localized depression (dashed area) along the eastern corner of the 3L/4L/5L-38 Sump (photo taken on August 12th, 2014)

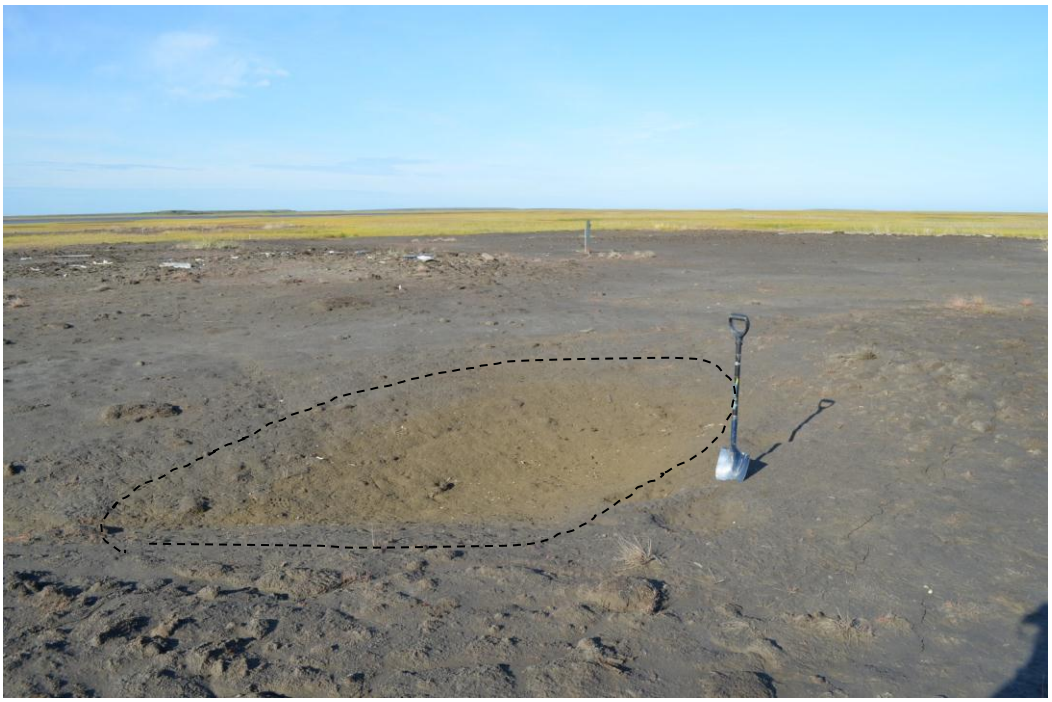


Figure A-6 Aerial view of the Mallik 2L-38 Sump (looking north) (photo taken on August 12th, 2014)

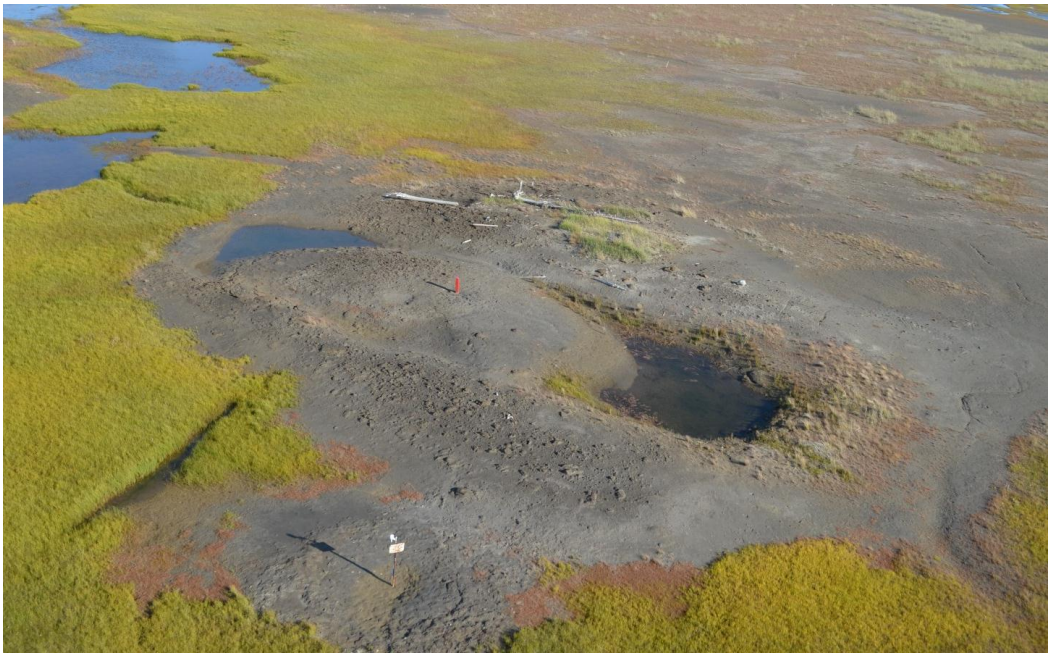


Figure A-7 Oblique view of Mallik 2L-38 Sump (looking south) (photo taken on August 12th, 2014)

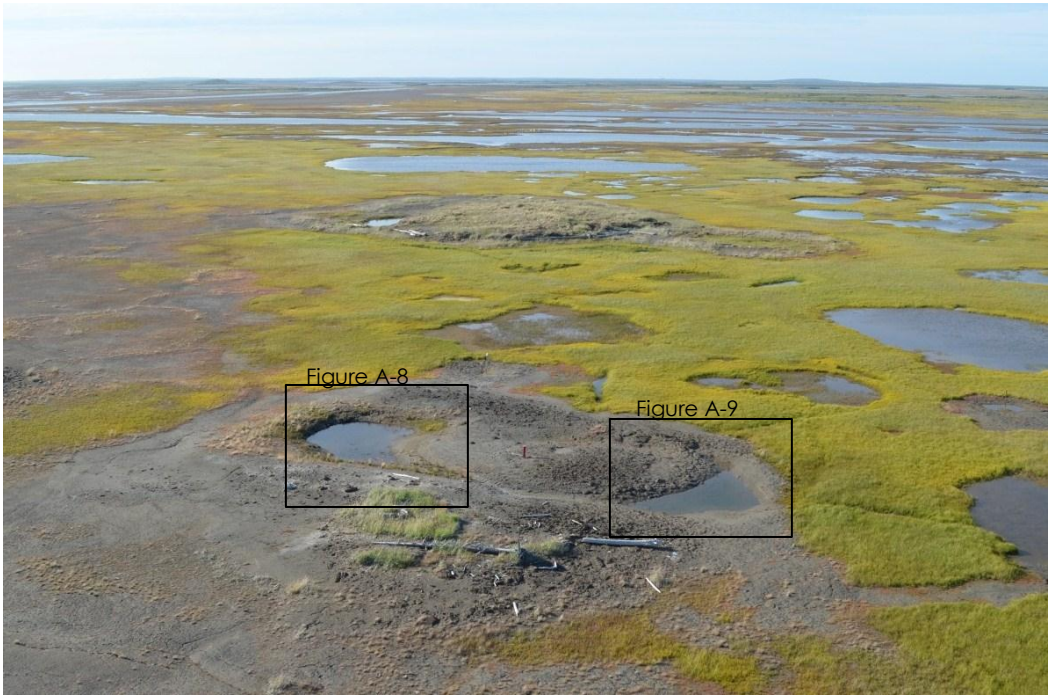


Figure A-8 Subsidence area at the eastern end of the Mallik 2L-38 Sump (photo taken on August 12th, 2014)

Figure A-9 Subsidence area at the western end of the Mallik 2L-38 Sump (photo taken on August 12th, 2014)

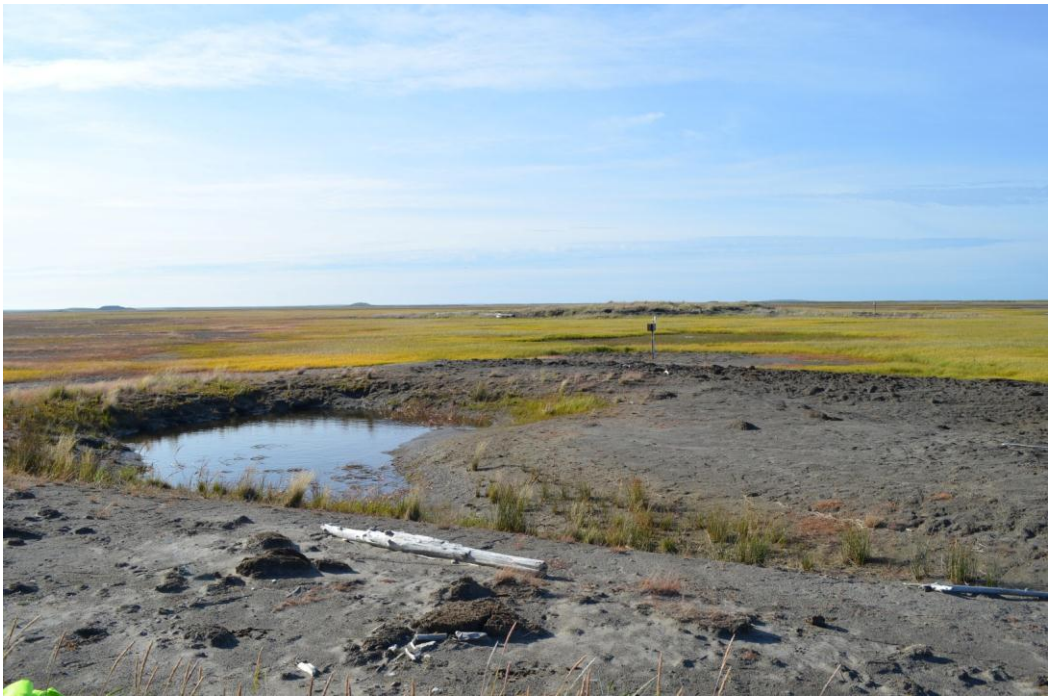
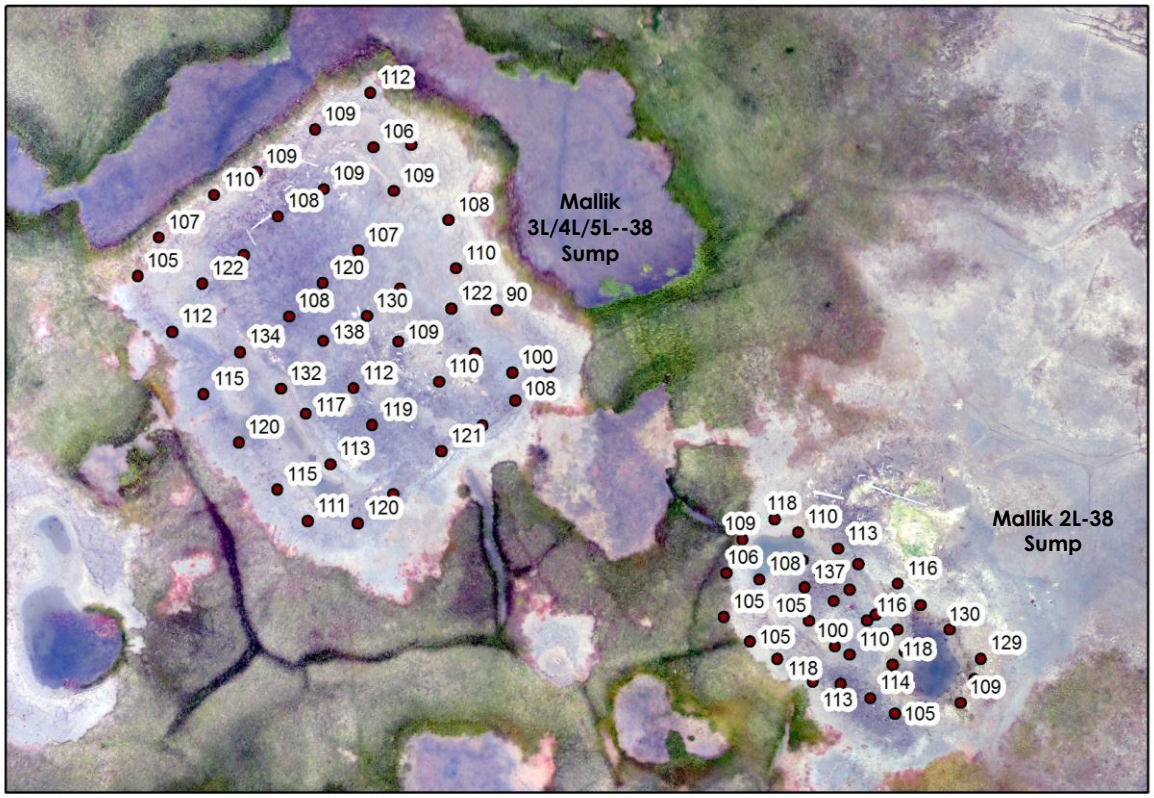


Figure A-10 Various wildlife tracks observed at the site (photo taken on August 12th, 2014)

Figure A-11 Active layer measurement (in cm) on both sumps (measurements taken on August 12th, 2014)



Appendix B Thermistor Data

Figure B-1 Daily mean air temperature at the Mallik site (12/09/2013 to 14/08/2014)

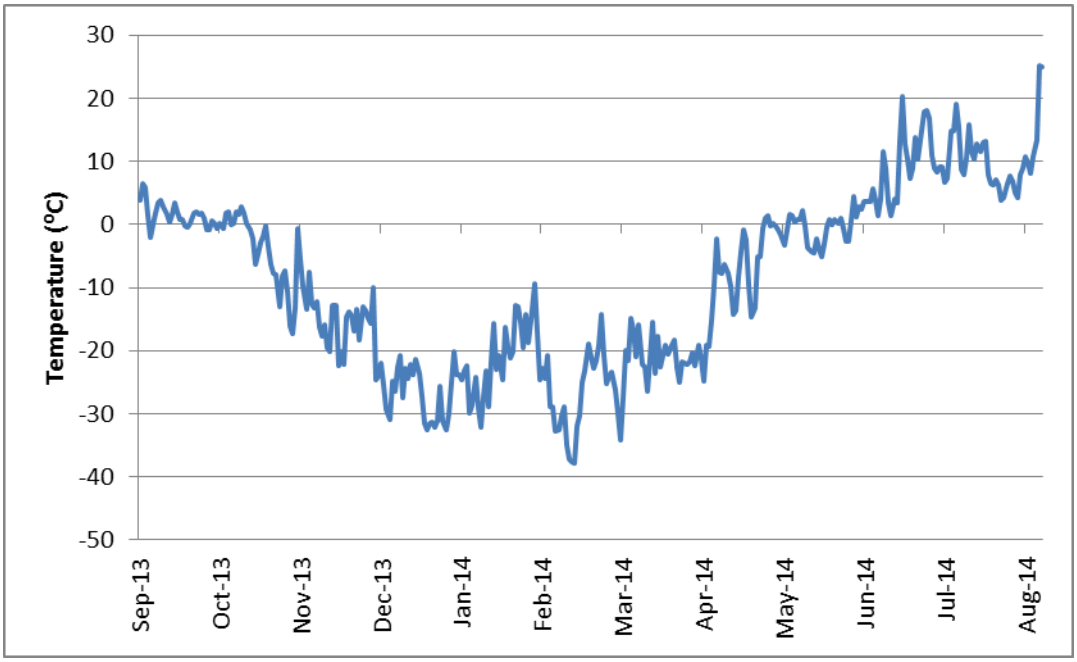
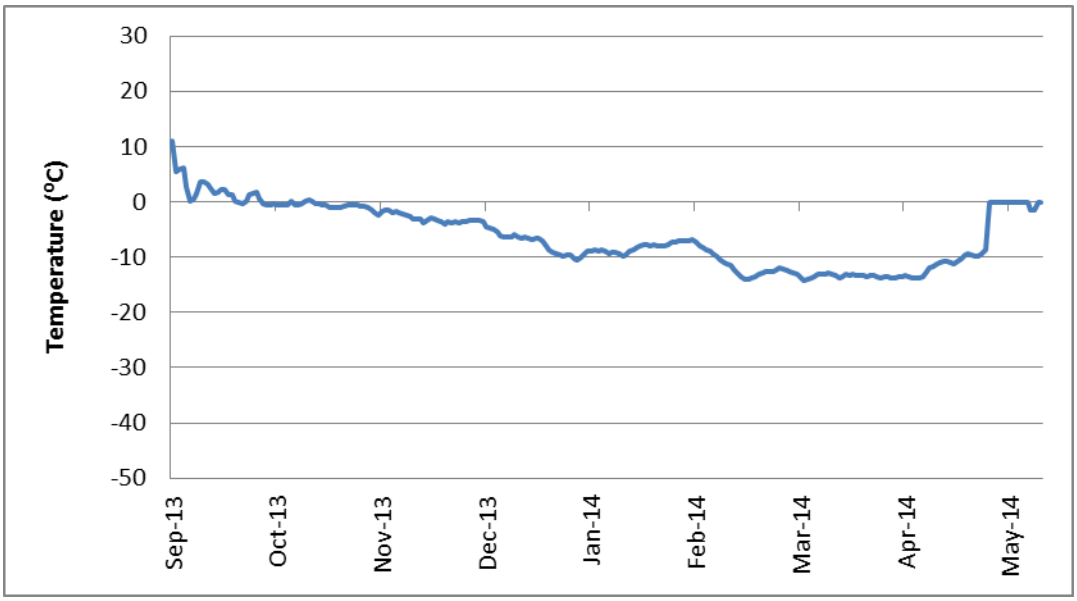


Figure B-2 Daily mean ground surface temperature at the Mallik site (11/09/2013 to 16/05/2014)



*Note that the data logger stopped recording data in May.

Figure B-3 Monthly mean air temperature at the Mallik site (October 2010 to August 2014)

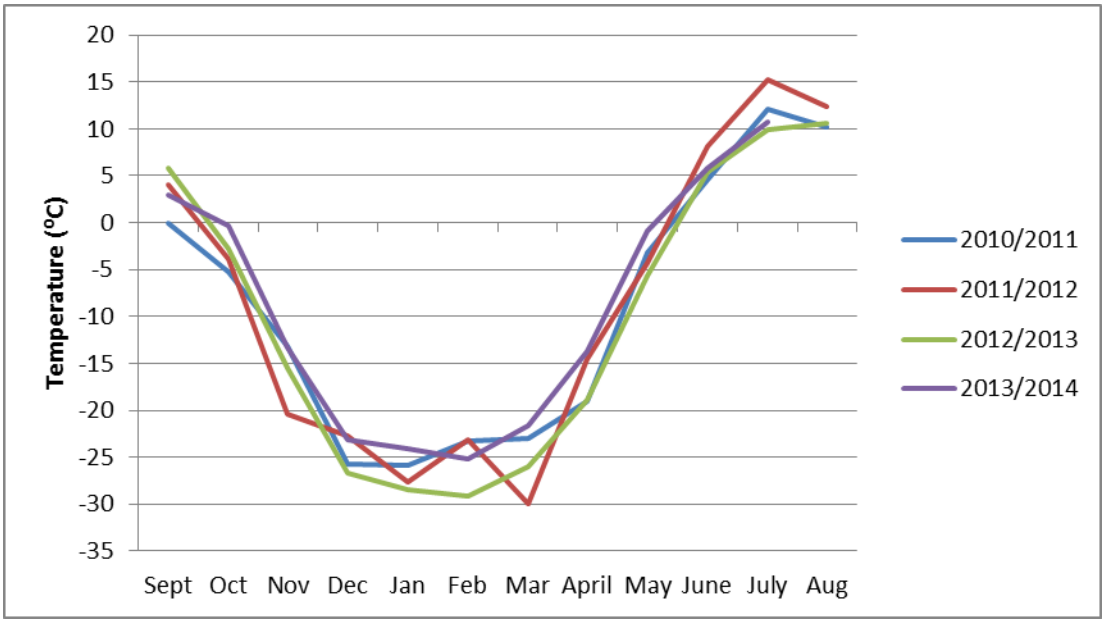


Figure B-4 Thermistor 07GSC-01 – Daily Ground Temperatures (10/09/2013 to 12/08/2014)

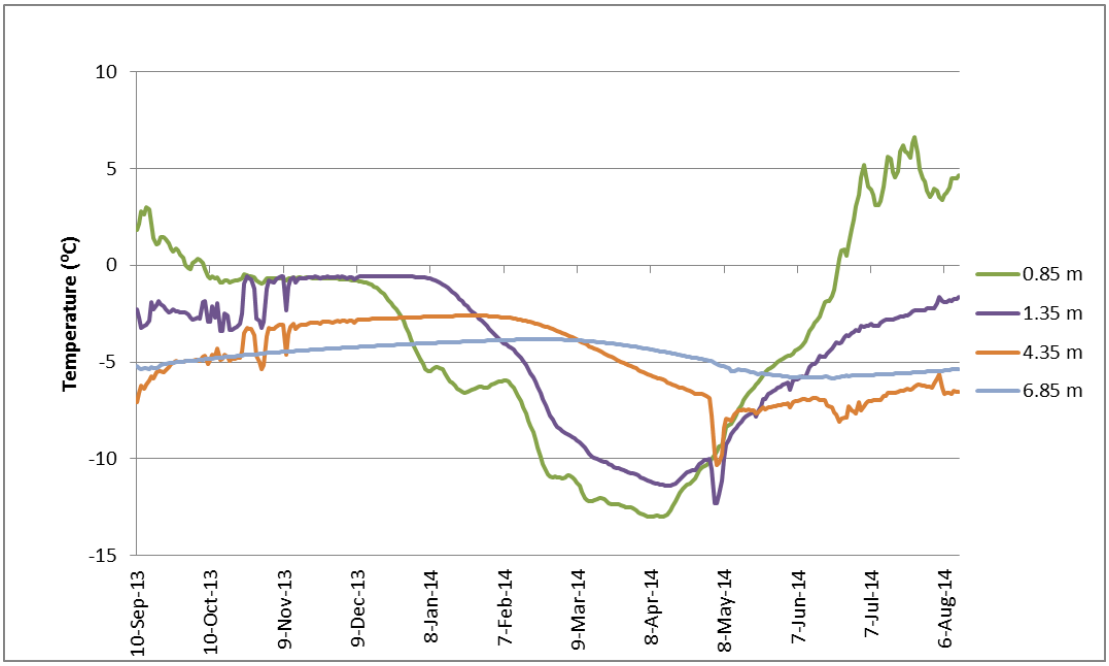


Figure B-5 Thermistor 07GSC-02 – Daily Ground Temperatures (10/09/2013 to 12/08/2014)

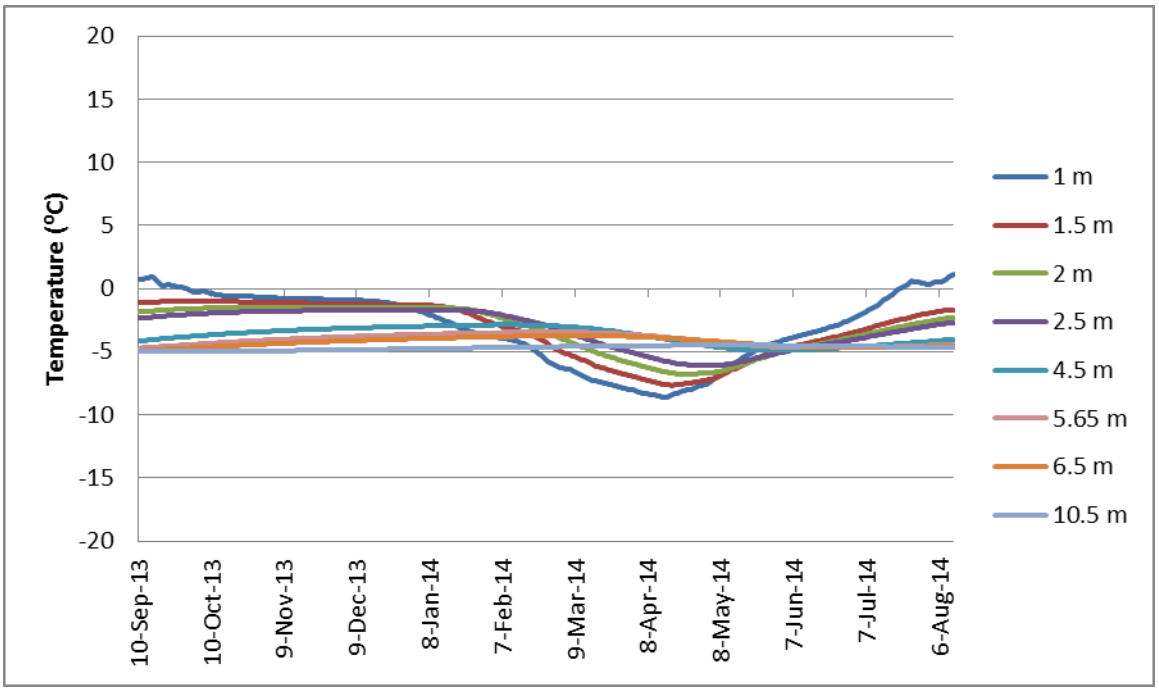


Figure B-6 Thermistor 07GSC-03 – Daily Ground Temperatures (10/09/2013 to 12/08/2014)

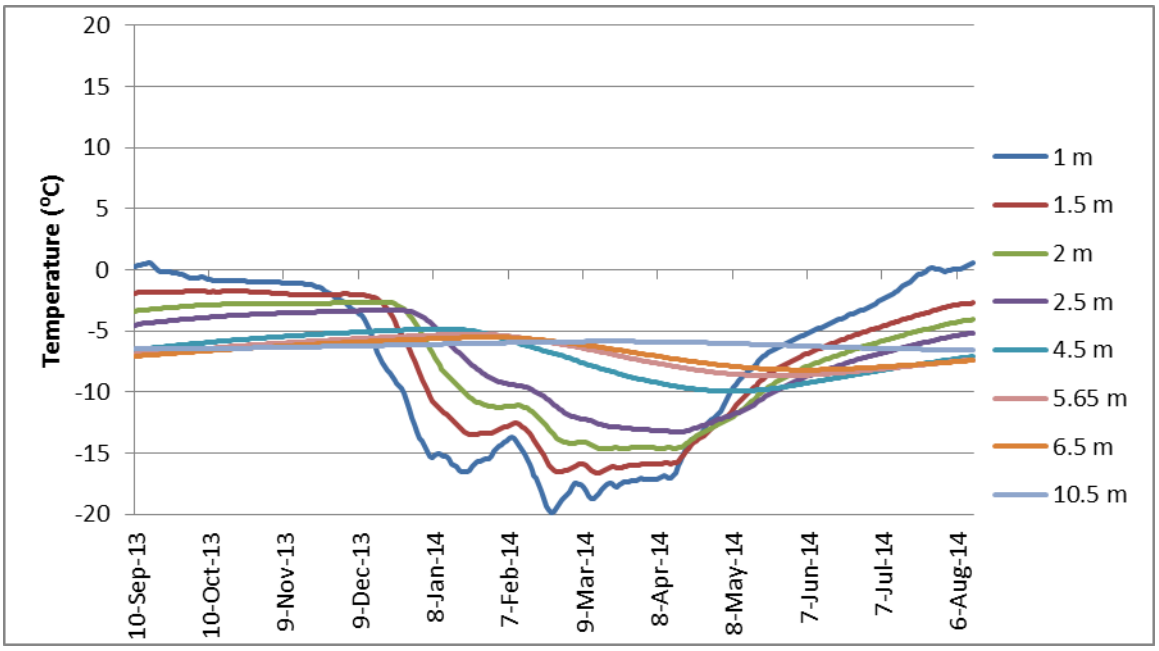


Figure B-7 Thermistor 12GSC-04 – Daily Ground Temperatures (10/09/2013 to 12/08/2014)

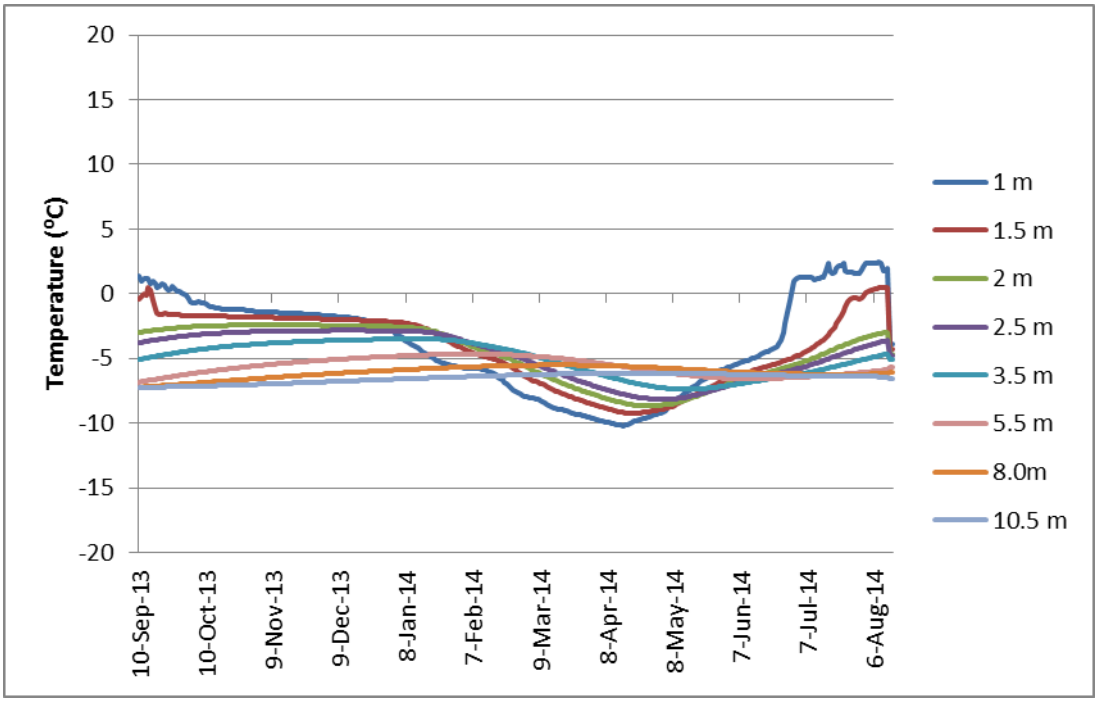
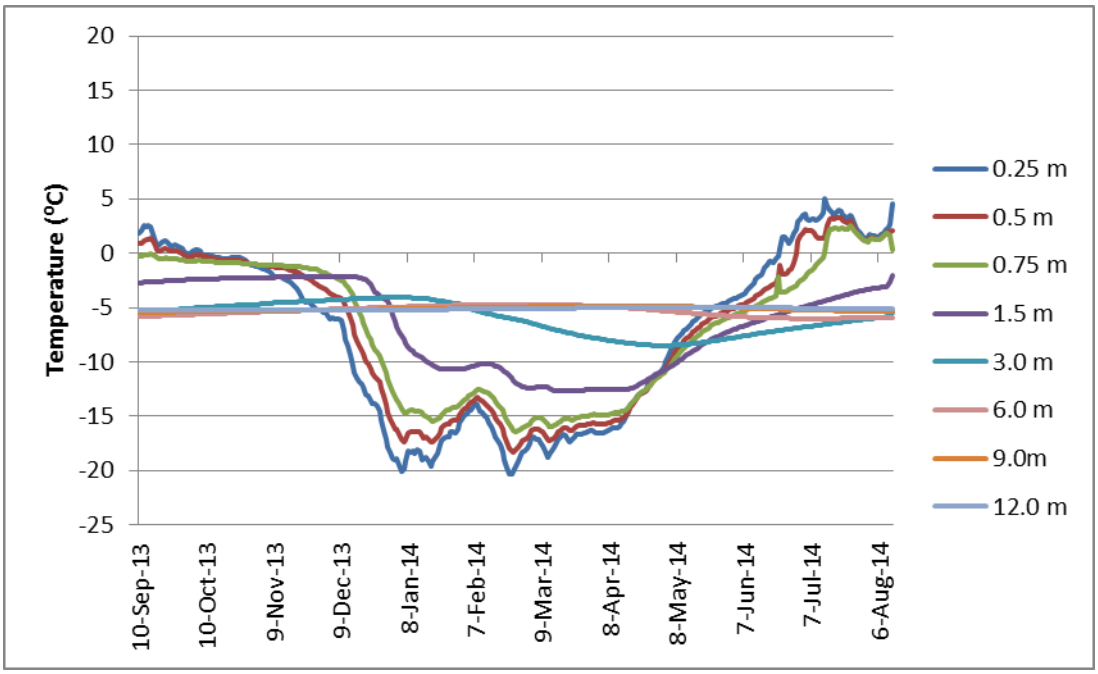


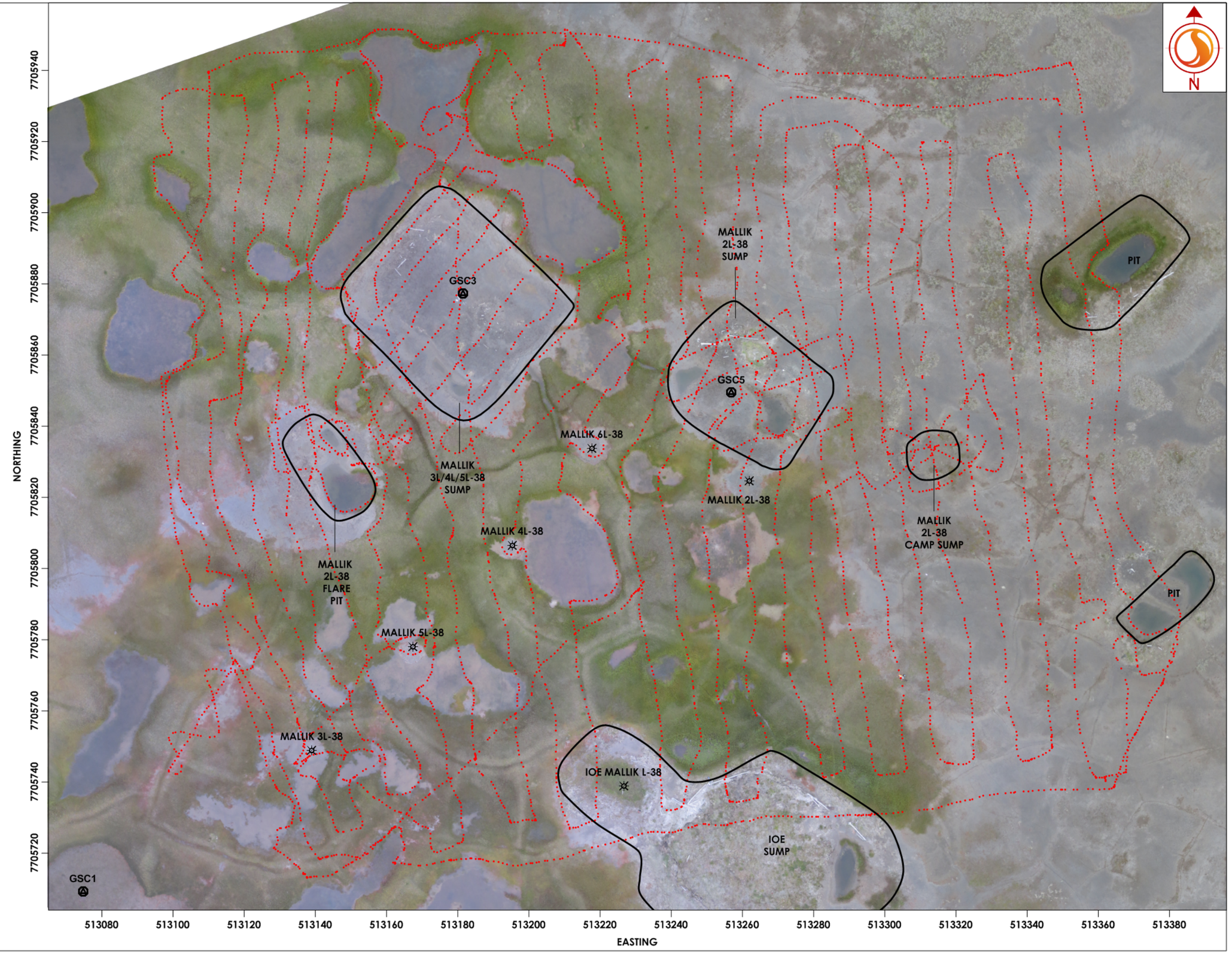
Figure B-8 Thermistor 12GSC-05 – Daily Ground Temperatures (10/09/2013 to 12/08/2014)



Appendix C Electromagnetic surveys

Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- EM SURVEY LINE

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

Title

2014 EM31 SURVEY AREA

Date

OCTOBER 2014

Stantec Project No.

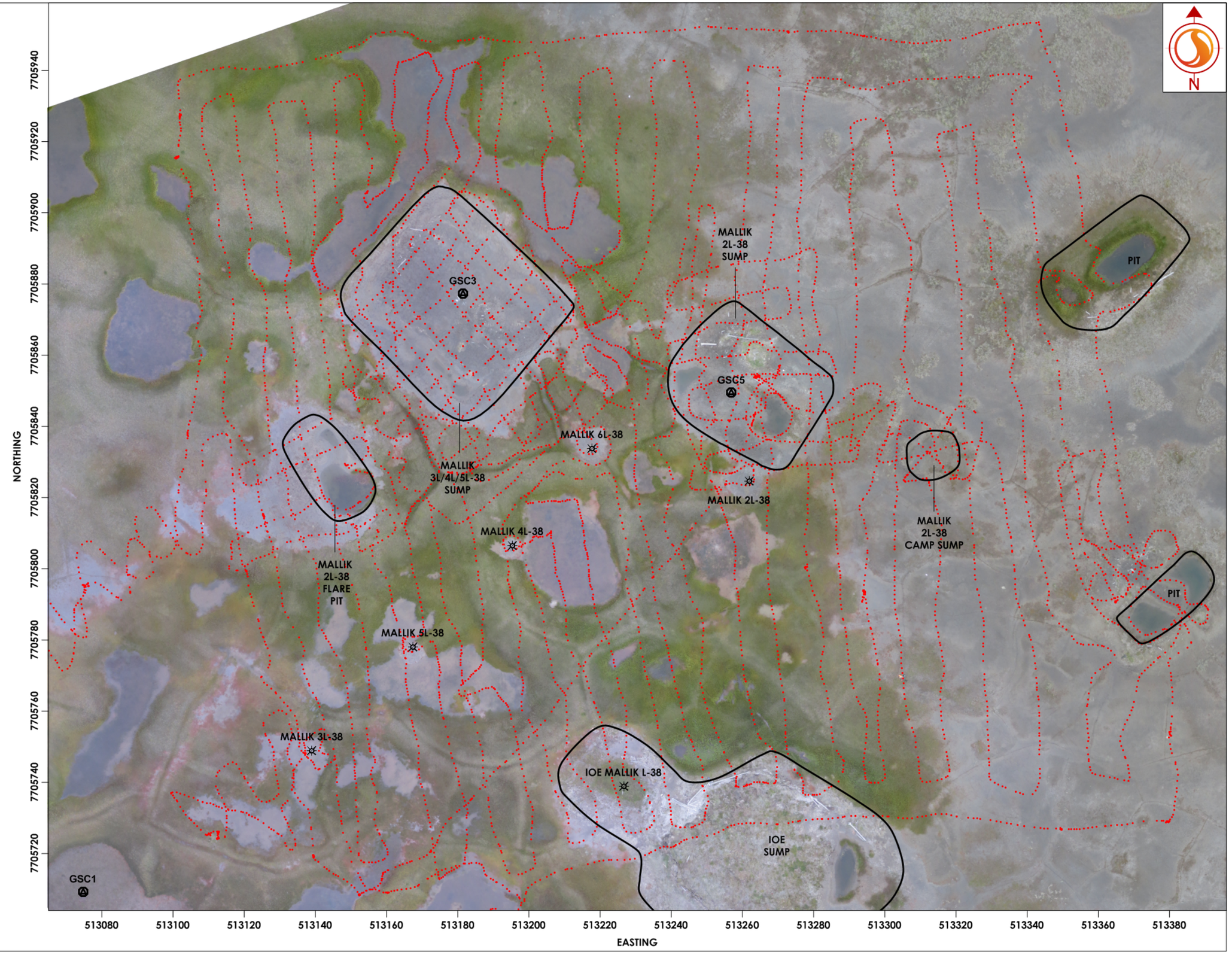
110219248

Figure No.

1-B

Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- EM SURVEY LINE

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

Title

2014 EM38 SURVEY AREA

Date

OCTOBER 2014

Stantec Project No.

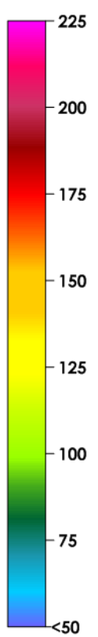
110219248

Figure No.

1-A

Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



TERRAIN
APPARENT
EC (mS/m)

LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- –150– CONDUCTIVITY CONTOURS

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

Title

2014 EM31 DATA PLOT

Date

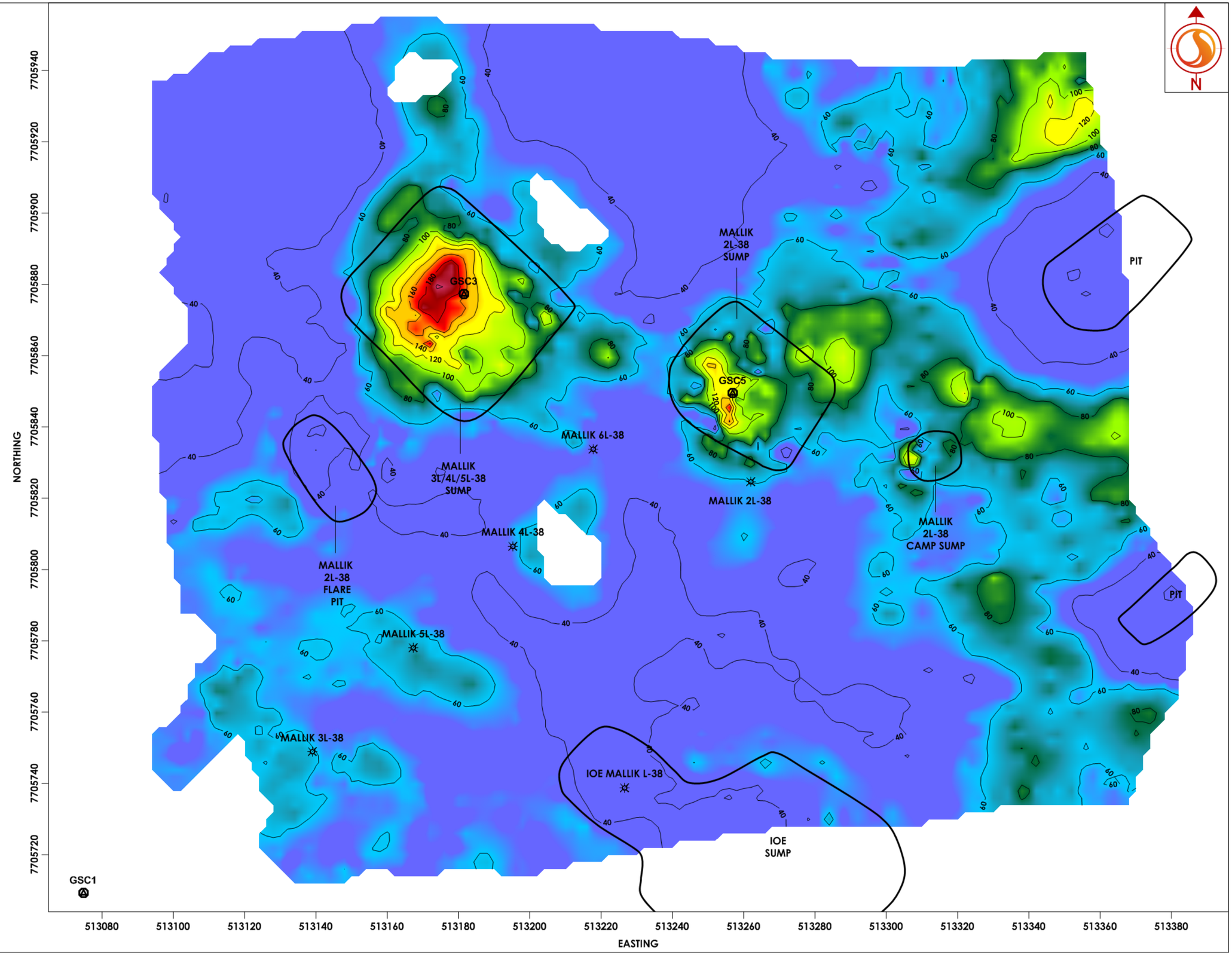
OCTOBER 2014

Stantec Project No.

110219248

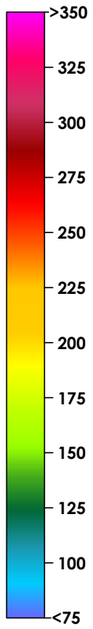
Figure No.

3-B



Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



TERRAIN
APPARENT
EC (mS/m)

LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- 150 — CONDUCTIVITY CONTOURS

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

Title

2014 EM38 DATA PLOT

Date

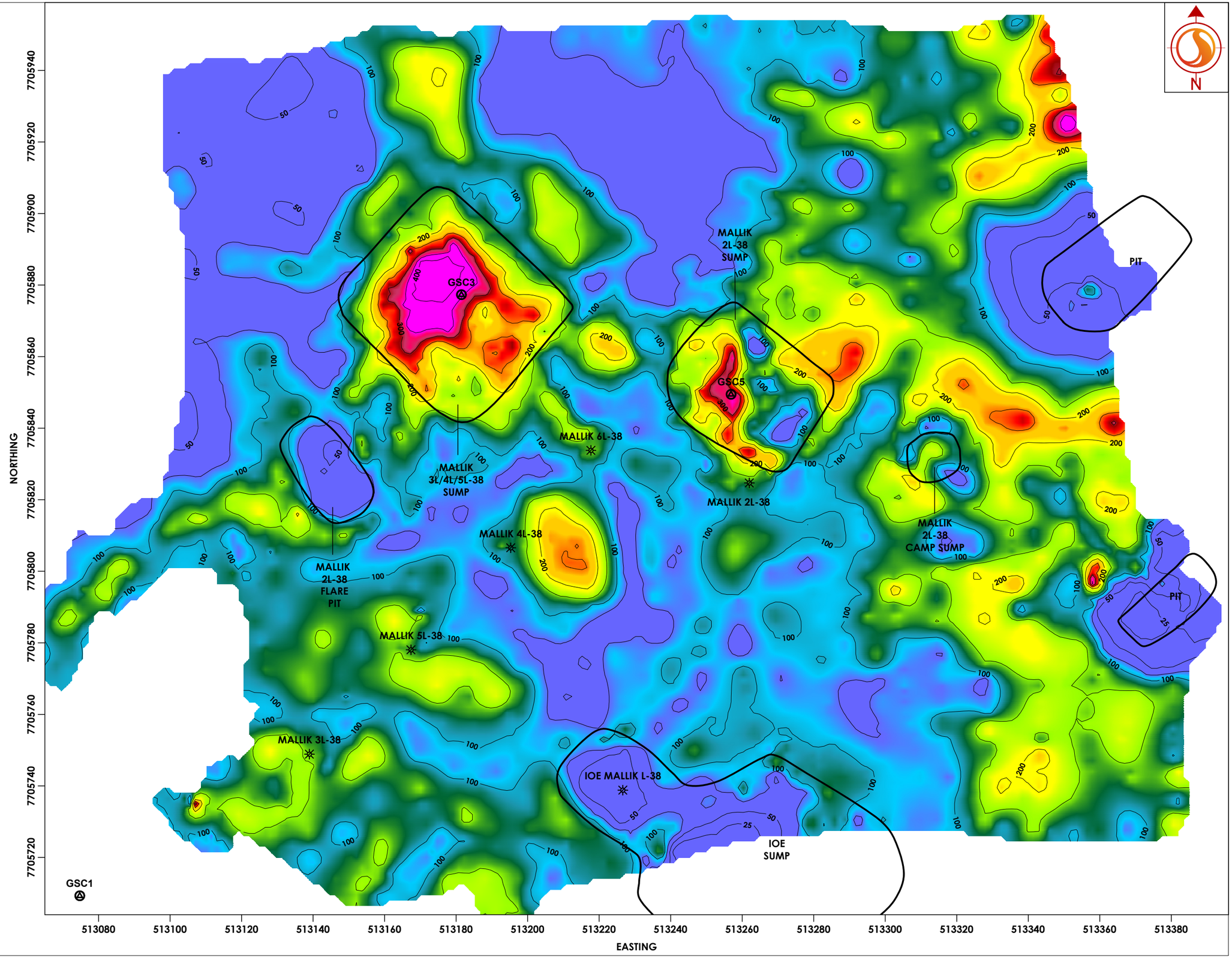
OCTOBER 2014

Stantec Project No.

110219248

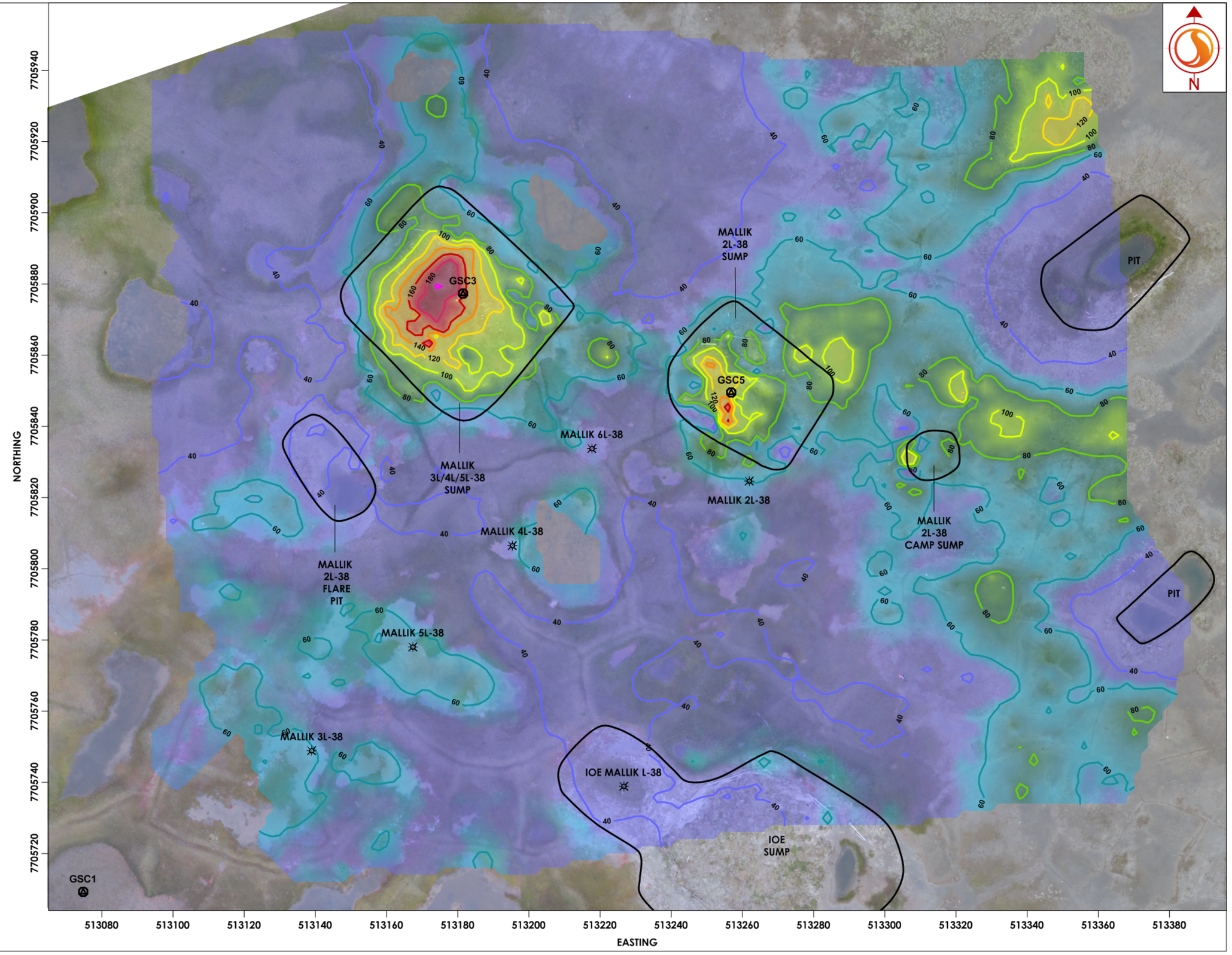
Figure No.

3-A



Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



225
200
175
150
125
100
75
<50

TERRAIN APPARENT EC (mS/m)

LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- 150 CONDUCTIVITY CONTOURS

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

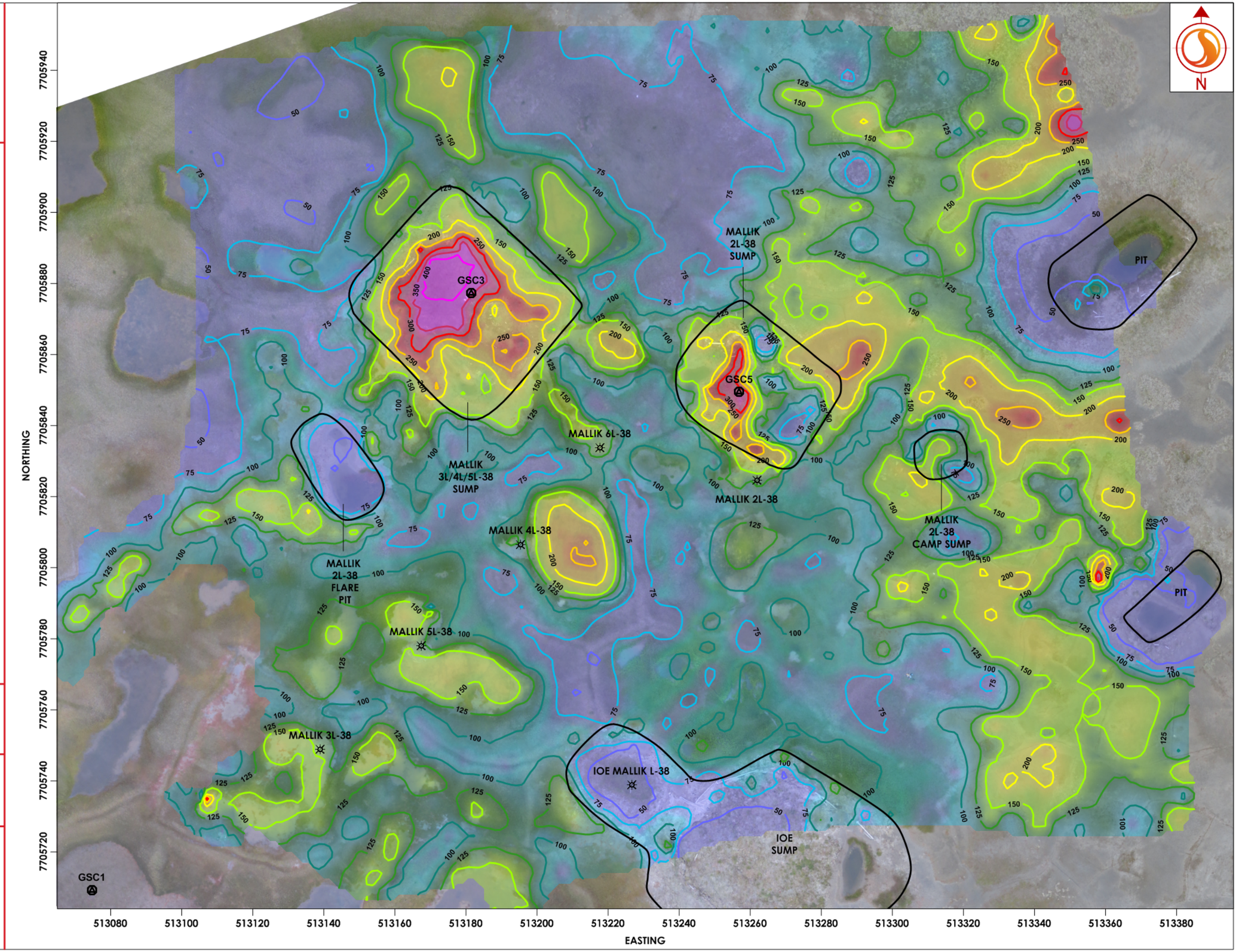
Title

2014 EM31 DATA PLOT & AERIAL PHOTO

Date
OCTOBER 2014
Stantec Project No.
110219248
Figure No.
2-B

Stantec

Stantec Consulting Ltd.
100 75-24 Street
Saskatoon SK Canada
S7K 0K3
Tel 306.667.2400
Fax 306.667.2500



>350
325
300
275
250
225
200
175
150
125
100
<75

TERRAIN APPARENT EC (mS/m)

LEGEND

- MONITORING WELL
- WELLHEAD SIGN
- 150 CONDUCTIVITY CONTOURS

0 10 20 30 40 50 METERS

SCALE 1:1,000

Spatial data displayed in the UTM coordinate system using the WGS 1984 datum

Client/Project/Location

AURORA RESEARCH INSTITUTE
2014 MALLIK SUMP MONITORING

Title

2014 EM38 DATA PLOT & AERIAL PHOTO

Date

OCTOBER 2014

Stantec Project No.

110219248

Figure No.

2-A

Appendix D Laboratory analysis

Maxxam
A Bureau Veritas Group Company

Success Through Science®

Your P.O. #: 16300R-20
Your Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
PO # 16300R-20
Your C.O.C. #: A131759

Attention:OLIVIER PIRAUX

STANTEC CONSULTING LTD
EDMONTON-NATIONAL CONTRACT
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2014/08/25
Report #: R1628443
Version: 1

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B471505
Received: 2014/08/15, 09:10

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Cation/EC Ratio	1	N/A	2014/08/22	N/A	Auto Calc
Cation/EC Ratio	1	N/A	2014/08/23	N/A	Auto Calc
Chloride (Soluble)	2	2014/08/22	2014/08/22	AB SOP-00033 / AB SOP-00020	SM 22 4500-Cl G m
Conductivity @25C (Soluble)	2	2014/08/22	2014/08/22	AB SOP-00033 / AB SOP-00004	Carter 2nd ed 55.2 m
Elements by ICP -Soils	2	2014/08/22	2014/08/22	AB SOP-00001 / AB SOP-00042	EPA 200.7 CFR 2012 m
Elements by ICPMS - Soils	2	2014/08/22	2014/08/22	AB SOP-00001 / AB SOP-00043	EPA 200.8 R5.4 m
Ion Balance	1	N/A	2014/08/22	AB WI-00065	SM 1030E
Ion Balance	1	N/A	2014/08/23	AB WI-00065	SM 1030E
Sum of Cations, Anions	1	N/A	2014/08/22	AB WI-00065	SM 1030E
Sum of Cations, Anions	1	N/A	2014/08/23	AB WI-00065	SM 1030E
pH @25C (1:2 Calcium Chloride Extract)	2	2014/08/20	2014/08/21	AB SOP-00033 / AB SOP-00006	Carter 2nd ed 16.2 m
Sodium Adsorption Ratio	1	N/A	2014/08/22	AB WI-00065	SSMA 15.4.4
Sodium Adsorption Ratio	1	N/A	2014/08/23	AB WI-00065	SSMA 15.4.4
Ca,Mg,Na,K,SO4 (Soluble)	2	2014/08/21	2014/08/22	AB SOP-00033 / AB SOP-00042	EPA 200.7 CFR 2012 m
Soluble Paste	2	2014/08/21	2014/08/22	AB SOP-00033	Carter 2nd ed 15.2m
Soluble Ions Calculation	2	N/A	2014/08/21		CALCULATION
Theoretical Gypsum Requirement (1)	1	N/A	2014/08/22	CAL WI-00087	CJSS 79:449-455
Theoretical Gypsum Requirement (1)	1	N/A	2014/08/23	CAL WI-00087	CJSS 79:449-455

Sample Matrix: Water
Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity @25C (pp, total), CO3,HCO3,OH	7	N/A	2014/08/19	AB SOP-00005	SM 22 2320 B m
Chloride by Automated Colourimetry	7	N/A	2014/08/21	AB SOP-00020	SM 22 4500-Cl G m

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Your P.O. #: 16300R-20
Your Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
PO # 16300R-20
Your C.O.C. #: A131759

Attention:OLIVIER PIRAUX

STANTEC CONSULTING LTD
EDMONTON-NATIONAL CONTRACT
10160 112 STREET
EDMONTON, AB
CANADA T5K 2L6

Report Date: 2014/08/25
Report #: R1628443
Version: 1

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B471505
Received: 2014/08/15, 09:10

Sample Matrix: Water
Samples Received: 7

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Conductivity @25C	7	N/A	2014/08/19	AB SOP-00005	SM 22 2510 B m
Hardness	7	N/A	2014/08/25	AB WI-00065	SM 2340B
Elements by ICP-Dissolved-Lab Filtered	6	N/A	2014/08/24	AB SOP-00042	EPA 200.7
Elements by ICP-Dissolved-Lab Filtered	1	N/A	2014/08/25	AB SOP-00042	EPA 200.7
Ion Balance	7	N/A	2014/08/25	AB WI-00065	SM 1030E
Sum of cations, anions	7	N/A	2014/08/25	AB WI-00065	SM 1030E
Nitrate and Nitrite	5	N/A	2014/08/21	AB SOP-00023	Auto Calc
Nitrate and Nitrite	2	N/A	2014/08/22	AB SOP-00023	Auto Calc
Nitrate + Nitrite-N (calculated)	5	N/A	2014/08/21	AB SOP-00023	SM 4110-B
Nitrate + Nitrite-N (calculated)	2	N/A	2014/08/22	AB SOP-00023	SM 4110-B
Nitrogen, (Nitrite, Nitrate) by IC	7	N/A	2014/08/20	AB SOP-00023	SM 22 4110 B m
pH @25°C (Alkalinity titrator)	7	N/A	2014/08/19	AB SOP-00005	SM 22 4500-H B m
Sulphate by Automated Colourimetry	7	N/A	2014/08/21	AB SOP-00018	SM 22 4500-SO4 E m
Total Dissolved Solids (Calculated)	7	N/A	2014/08/25	AB WI-00065	SM 1030E

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) Units for TGR have changed from tons/acre to tonnes/ha

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Jeremy Wakaruk, B.Sc., Senior Project Manager
Email: JWakaruk@maxxam.ca
Phone# (780)577-7105 Ext:7105

==========

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		KJ1753		KJ1754		KJ1755		
Sampling Date		2014/08/13		2014/08/13		2014/08/13		
COC Number		A131759		A131759		A131759		
	Units	MALLIK-2014-W1	RDL	MALLIK-2014-W2	RDL	MALLIK-2014-W3	RDL	QC Batch
Calculated Parameters								
Anion Sum	meq/L	33	N/A	84	N/A	60	N/A	7604860
Cation Sum	meq/L	29	N/A	78	N/A	55	N/A	7604860
Hardness (CaCO3)	mg/L	460	0.50	1200	0.50	700	0.50	7604857
Ion Balance	N/A	0.88	0.010	0.92	0.010	0.91	0.010	7604859
Dissolved Nitrate (NO3)	mg/L	<0.044	0.044	<0.044	0.044	<0.044	0.044	7604861
Nitrate plus Nitrite (N)	mg/L	<0.010	0.010	<0.010	0.010	<0.010	0.010	7604862
Dissolved Nitrite (NO2)	mg/L	<0.033	0.033	<0.033	0.033	<0.033	0.033	7604861
Total Dissolved Solids	mg/L	1800	10	5000	10	3300	10	7604863
Misc. Inorganics								
Conductivity	uS/cm	3600	1.0	9100	1.0	6400	1.0	7605871
pH	pH	8.41	N/A	8.05	N/A	9.21	N/A	7605618
Anions								
Alkalinity (PP as CaCO3)	mg/L	2.0	0.50	<0.50	0.50	16	0.50	7605868
Alkalinity (Total as CaCO3)	mg/L	150	0.50	100	0.50	84	0.50	7605868
Bicarbonate (HCO3)	mg/L	180	0.50	130	0.50	64	0.50	7605868
Carbonate (CO3)	mg/L	2.4	0.50	<0.50	0.50	19	0.50	7605868
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	<0.50	0.50	7605868
Dissolved Sulphate (SO4)	mg/L	190	1.0	330 (1)	5.0	140	1.0	7606089
Dissolved Chloride (Cl)	mg/L	910 (1)	5.0	2700 (1)	20	2000 (1)	20	7606085
Nutrients								
Dissolved Nitrite (N)	mg/L	<0.010	0.010	<0.010	0.010	<0.010	0.010	7607940
Dissolved Nitrate (N)	mg/L	<0.010	0.010	<0.010	0.010	<0.010	0.010	7607940
Lab Filtered Elements								
Dissolved Calcium (Ca)	mg/L	81	0.30	250	0.30	79	0.30	7612603
Dissolved Iron (Fe)	mg/L	<0.060	0.060	<0.060	0.060	<0.060	0.060	7612603
Dissolved Magnesium (Mg)	mg/L	62	0.20	150	0.20	120	0.20	7612603
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	0.025	0.0040	0.0041	0.0040	7612603
Dissolved Potassium (K)	mg/L	110	0.30	720 (1)	3.0	71	0.30	7612603
Dissolved Sodium (Na)	mg/L	390	0.50	800 (1)	5.0	890 (1)	5.0	7612603

RDL = Reportable Detection Limit
N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		KJ1756		KJ1757			KJ1758		
Sampling Date		2014/08/13		2014/08/13			2014/08/13		
COC Number		A131759		A131759			A131759		
	Units	MALLIK-2014-W4	RDL	MALLIK-2014-W5	RDL	QC Batch	MALLIK-2014-W6	RDL	QC Batch
Calculated Parameters									
Anion Sum	meq/L	96	N/A	21	N/A	7604860	77	N/A	7604860
Cation Sum	meq/L	84	N/A	18	N/A	7604860	70	N/A	7604860
Hardness (CaCO3)	mg/L	1700	0.50	270	0.50	7604857	850	0.50	7604857
Ion Balance	N/A	0.88	0.010	0.88	0.010	7604859	0.91	0.010	7604859
Dissolved Nitrate (NO3)	mg/L	<0.044	0.044	<0.044	0.044	7604861	0.060	0.044	7604861
Nitrate plus Nitrite (N)	mg/L	<0.010	0.010	<0.010	0.010	7604862	0.014	0.010	7604862
Dissolved Nitrite (NO2)	mg/L	<0.033	0.033	<0.033	0.033	7604861	<0.033	0.033	7604861
Total Dissolved Solids	mg/L	5500	10	1100	10	7604863	4300	10	7604863
Misc. Inorganics									
Conductivity	uS/cm	9600	1.0	2300	1.0	7605871	7800	1.0	7605871
pH	pH	7.92	N/A	9.01	N/A	7605618	8.89	N/A	7605618
Anions									
Alkalinity (PP as CaCO3)	mg/L	<0.50	0.50	13	0.50	7605868	12	0.50	7605868
Alkalinity (Total as CaCO3)	mg/L	89	0.50	130	0.50	7605868	110	0.50	7605868
Bicarbonate (HCO3)	mg/L	110	0.50	130	0.50	7605868	99	0.50	7605868
Carbonate (CO3)	mg/L	<0.50	0.50	16	0.50	7605868	14	0.50	7605868
Hydroxide (OH)	mg/L	<0.50	0.50	<0.50	0.50	7605868	<0.50	0.50	7605868
Dissolved Sulphate (SO4)	mg/L	690 (1)	5.0	84	1.0	7606089	320 (1)	5.0	7606089
Dissolved Chloride (Cl)	mg/L	2800 (1)	20	590 (1)	5.0	7606085	2400 (1)	20	7606085
Nutrients									
Dissolved Nitrite (N)	mg/L	<0.010	0.010	<0.010	0.010	7607940	<0.010	0.010	7607937
Dissolved Nitrate (N)	mg/L	<0.010	0.010	<0.010	0.010	7607940	0.014	0.010	7607937
Lab Filtered Elements									
Dissolved Calcium (Ca)	mg/L	410	0.30	33	0.30	7612603	87	0.30	7612603
Dissolved Iron (Fe)	mg/L	<0.060	0.060	<0.060	0.060	7612603	<0.060	0.060	7612603
Dissolved Magnesium (Mg)	mg/L	170	0.20	44	0.20	7612603	150	0.20	7612603
Dissolved Manganese (Mn)	mg/L	0.024	0.0040	0.0053	0.0040	7612603	<0.0040	0.0040	7612603
Dissolved Potassium (K)	mg/L	510 (1)	3.0	11	0.30	7612603	46	0.30	7612603
Dissolved Sodium (Na)	mg/L	850 (1)	5.0	290	0.50	7612603	1200 (1)	5.0	7612603

RDL = Reportable Detection Limit
N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

ROUTINE WATER - FILTERED (WATER)

Maxxam ID		KJ1759		
Sampling Date		2014/08/13		
COC Number		A131759		
	Units	MALLIK-2014-W7	RDL	QC Batch
Calculated Parameters				
Anion Sum	meq/L	62	N/A	7604860
Cation Sum	meq/L	64	N/A	7604860
Hardness (CaCO3)	mg/L	750	0.50	7604857
Ion Balance	N/A	1.0	0.010	7604859
Dissolved Nitrate (NO3)	mg/L	<0.044	0.044	7604861
Nitrate plus Nitrite (N)	mg/L	<0.010	0.010	7604862
Dissolved Nitrite (NO2)	mg/L	<0.033	0.033	7604861
Total Dissolved Solids	mg/L	3600	10	7604863
Misc. Inorganics				
Conductivity	uS/cm	6500	1.0	7605871
pH	pH	8.59	N/A	7605618
Anions				
Alkalinity (PP as CaCO3)	mg/L	7.7	0.50	7605868
Alkalinity (Total as CaCO3)	mg/L	160	0.50	7605868
Bicarbonate (HCO3)	mg/L	180	0.50	7605868
Carbonate (CO3)	mg/L	9.2	0.50	7605868
Hydroxide (OH)	mg/L	<0.50	0.50	7605868
Dissolved Sulphate (SO4)	mg/L	300 (1)	5.0	7606089
Dissolved Chloride (Cl)	mg/L	1800 (1)	20	7606085
Nutrients				
Dissolved Nitrite (N)	mg/L	<0.010	0.010	7607937
Dissolved Nitrate (N)	mg/L	<0.010	0.010	7607937
Lab Filtered Elements				
Dissolved Calcium (Ca)	mg/L	92	0.30	7613564
Dissolved Iron (Fe)	mg/L	<0.060	0.060	7613564
Dissolved Magnesium (Mg)	mg/L	130	0.20	7613564
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	7613564
Dissolved Potassium (K)	mg/L	35	0.30	7613564
Dissolved Sodium (Na)	mg/L	1100	0.50	7613564

RDL = Reportable Detection Limit
N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

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Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

SOIL SALINITY 4 (SOIL)

Maxxam ID		KJ1760			KJ1761		
Sampling Date		2014/08/13			2014/08/13		
COC Number		A131759			A131759		
	Units	MALLIK-2014-S1	RDL	QC Batch	MALLIK-2014-S2	RDL	QC Batch
Calculated Parameters							
Anion Sum	meq/L	130	N/A	7604994	130	N/A	7604994
Cation Sum	meq/L	140	N/A	7604994	140	N/A	7604994
Cation/EC Ratio	N/A	9.3	0.10	7604081	9.8	0.10	7604081
Ion Balance	N/A	1.1	0.010	7604993	1.0	0.010	7604993
Calculated Calcium (Ca)	mg/kg	520	1.0	7604996	300	0.98	7604996
Calculated Magnesium (Mg)	mg/kg	87	0.69	7604996	160	0.65	7604996
Calculated Sodium (Na)	mg/kg	540	1.7	7604996	1400	1.6	7604996
Calculated Potassium (K)	mg/kg	1700	0.90	7604996	28	0.85	7604996
Calculated Chloride (Cl)	mg/kg	2700	69	7604996	2800	65	7604996
Calculated Sulphate (SO4)	mg/kg	700	3.5	7604996	380	3.3	7604996
Soluble Parameters							
Soluble Chloride (Cl)	mg/L	4000 (1)	100	7610321	4300 (1)	100	7610339
Soluble Conductivity	dS/m	15	0.020	7609762	14	0.020	7609716
Soluble (CaCl2) pH	pH	7.27	N/A	7607597	7.14	N/A	7607597
Sodium Adsorption Ratio	N/A	7.0	0.10	7604995	20	0.10	7604995
Soluble Calcium (Ca)	mg/L	750	1.5	7611229	450	1.5	7611118
Soluble Magnesium (Mg)	mg/L	130	1.0	7611229	240	1.0	7611118
Soluble Sodium (Na)	mg/L	780	2.5	7611229	2200	2.5	7611118
Soluble Potassium (K)	mg/L	2400	1.3	7611229	42	1.3	7611118
Saturation %	%	69	N/A	7609644	65	N/A	7609700
Soluble Sulphate (SO4)	mg/L	1000	5.0	7611229	580	5.0	7611118
Theoretical Gypsum Requirement	tonnes/ha	11	0.10	7604997	120	0.10	7604997

RDL = Reportable Detection Limit
N/A = Not Applicable
(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

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STANTEC CONSULTING LTD
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Your P.O. #: 16300R-20
Sampler Initials: OP

ASSESSMENT ICP METALS (SOIL)

Maxxam ID		KJ1760	KJ1761		
Sampling Date		2014/08/13	2014/08/13		
COC Number		A131759	A131759		
	Units	MALLIK-2014-S1	MALLIK-2014-S2	RDL	QC Batch
Elements					
Total Aluminum (Al)	mg/kg	7300	7000	10	7610815
Total Boron (B)	mg/kg	8.9	10	2.0	7610815
Total Calcium (Ca)	mg/kg	45000	64000	50	7610815
Total Iron (Fe)	mg/kg	20000	19000	10	7610815
Total Lithium (Li)	mg/kg	12	12	10	7610815
Total Magnesium (Mg)	mg/kg	20000	26000	20	7610815
Total Manganese (Mn)	mg/kg	330	360	10	7610815
Total Phosphorus (P)	mg/kg	710	870	20	7610815
Total Potassium (K)	mg/kg	4000	810	25	7610815
Total Sodium (Na)	mg/kg	740	2100	50	7610815
Total Strontium (Sr)	mg/kg	70	94	10	7610815
Total Sulphur (S)	mg/kg	920	760	20	7610815
Total Antimony (Sb)	mg/kg	<1.0	<1.0	1.0	7610822
Total Arsenic (As)	mg/kg	6.8	5.5	1.0	7610822
Total Barium (Ba)	mg/kg	390	410	10	7610822
Total Beryllium (Be)	mg/kg	<0.40	<0.40	0.40	7610822
Total Cadmium (Cd)	mg/kg	0.47	0.30	0.10	7610822
Total Chromium (Cr)	mg/kg	13	11	1.0	7610822
Total Cobalt (Co)	mg/kg	7.1	6.3	1.0	7610822
Total Copper (Cu)	mg/kg	14	11	5.0	7610822
Total Lead (Pb)	mg/kg	7.3	6.0	1.0	7610822
Total Molybdenum (Mo)	mg/kg	1.2	1.0	0.40	7610822
Total Nickel (Ni)	mg/kg	22	19	1.0	7610822
Total Selenium (Se)	mg/kg	0.50	<0.50	0.50	7610822
Total Silver (Ag)	mg/kg	<1.0	<1.0	1.0	7610822
Total Thallium (Tl)	mg/kg	<0.30	<0.30	0.30	7610822
Total Tin (Sn)	mg/kg	<1.0	<1.0	1.0	7610822
Total Uranium (U)	mg/kg	<1.0	<1.0	1.0	7610822
Total Vanadium (V)	mg/kg	23	20	1.0	7610822
Total Zinc (Zn)	mg/kg	78	65	10	7610822
RDL = Reportable Detection Limit					

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Sampler Initials: OP

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	4.0°C

Sample KJ1753-01 : Cation anion balance investigated, data quality confirmed

Sample KJ1756-01 : Cation anion balance investigated, data quality confirmed

Sample KJ1757-01 : Cation anion balance investigated, data quality confirmed

Results relate only to the items tested.

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QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
7605618	MA4	Spiked Blank	pH	2014/08/19		100	%	97 - 103
7605868	MA4	Spiked Blank	Alkalinity (Total as CaCO3)	2014/08/19		100	%	80 - 120
7605868	MA4	Method Blank	Alkalinity (PP as CaCO3)	2014/08/19	<0.50		mg/L	
			Alkalinity (Total as CaCO3)	2014/08/19	<0.50		mg/L	
			Bicarbonate (HCO3)	2014/08/19	<0.50		mg/L	
			Carbonate (CO3)	2014/08/19	<0.50		mg/L	
			Hydroxide (OH)	2014/08/19	<0.50		mg/L	
7605871	MA4	Spiked Blank	Conductivity	2014/08/19		100	%	90 - 110
7605871	MA4	Method Blank	Conductivity	2014/08/19	<1.0		uS/cm	
7606085	ARD	Matrix Spike	Dissolved Chloride (Cl)	2014/08/21		110	%	80 - 120
7606085	ARD	Spiked Blank	Dissolved Chloride (Cl)	2014/08/21		101	%	80 - 120
7606085	ARD	Method Blank	Dissolved Chloride (Cl)	2014/08/21	<1.0		mg/L	
7606089	ARD	Matrix Spike	Dissolved Sulphate (SO4)	2014/08/21		NC	%	80 - 120
7606089	ARD	Spiked Blank	Dissolved Sulphate (SO4)	2014/08/21		100	%	80 - 120
7606089	ARD	Method Blank	Dissolved Sulphate (SO4)	2014/08/21	<1.0		mg/L	
7607597	BMC	QC Standard	Soluble (CaCl2) pH	2014/08/21		99	%	97 - 103
7607597	BMC	Spiked Blank	Soluble (CaCl2) pH	2014/08/21		100	%	97 - 103
7607937	MPH	Matrix Spike	Dissolved Nitrite (N)	2014/08/20		101	%	80 - 120
			Dissolved Nitrate (N)	2014/08/20		NC	%	80 - 120
7607937	MPH	Spiked Blank	Dissolved Nitrite (N)	2014/08/20		101	%	80 - 120
			Dissolved Nitrate (N)	2014/08/20		102	%	80 - 120
7607937	MPH	Method Blank	Dissolved Nitrite (N)	2014/08/20	<0.010		mg/L	
			Dissolved Nitrate (N)	2014/08/20	<0.010		mg/L	
7607940	MPH	Matrix Spike [KJ1753-01]	Dissolved Nitrite (N)	2014/08/20		101	%	80 - 120
			Dissolved Nitrate (N)	2014/08/20		102	%	80 - 120
7607940	MPH	Spiked Blank	Dissolved Nitrite (N)	2014/08/20		101	%	80 - 120
			Dissolved Nitrate (N)	2014/08/20		102	%	80 - 120
7607940	MPH	Method Blank	Dissolved Nitrite (N)	2014/08/20	<0.010		mg/L	
			Dissolved Nitrate (N)	2014/08/20	<0.010		mg/L	
7607940	MPH	RPD [KJ1753-01]	Dissolved Nitrite (N)	2014/08/20	NC		%	20
			Dissolved Nitrate (N)	2014/08/20	NC		%	20
7609644	LX	QC Standard	Saturation %	2014/08/22		99	%	90 - 110
7609700	UH	QC Standard	Saturation %	2014/08/22		99	%	90 - 110
7609716	LZ2	QC Standard	Soluble Conductivity	2014/08/22		103	%	91 - 109
7609716	LZ2	Spiked Blank	Soluble Conductivity	2014/08/22		100	%	90 - 110
7609716	LZ2	Method Blank	Soluble Conductivity	2014/08/22	<0.020		dS/m	
7609762	LZ2	QC Standard	Soluble Conductivity	2014/08/22		100	%	91 - 109
7609762	LZ2	Spiked Blank	Soluble Conductivity	2014/08/22		100	%	90 - 110
7609762	LZ2	Method Blank	Soluble Conductivity	2014/08/22	<0.020		dS/m	
7610321	KD5	Matrix Spike	Soluble Chloride (Cl)	2014/08/22		105	%	75 - 125
7610321	KD5	QC Standard	Soluble Chloride (Cl)	2014/08/22		117	%	75 - 125
7610321	KD5	Spiked Blank	Soluble Chloride (Cl)	2014/08/22		99	%	75 - 125
7610321	KD5	Method Blank	Soluble Chloride (Cl)	2014/08/22	<5.0		mg/L	
7610339	KD5	Matrix Spike	Soluble Chloride (Cl)	2014/08/22		105	%	75 - 125
7610339	KD5	QC Standard	Soluble Chloride (Cl)	2014/08/22		109	%	75 - 125
7610339	KD5	Spiked Blank	Soluble Chloride (Cl)	2014/08/22		103	%	75 - 125
7610339	KD5	Method Blank	Soluble Chloride (Cl)	2014/08/22	<5.0		mg/L	
7610815	JHC	Matrix Spike [KJ1760-01]	Total Aluminum (Al)	2014/08/22		NC	%	75 - 125
			Total Boron (B)	2014/08/22		98	%	75 - 125
			Total Calcium (Ca)	2014/08/22		NC	%	75 - 125
			Total Iron (Fe)	2014/08/22		NC	%	75 - 125

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Maxxam Job #: B471505
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STANTEC CONSULTING LTD
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Sampler Initials: OP

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
			Total Lithium (Li)	2014/08/22		108	%	75 - 125
			Total Magnesium (Mg)	2014/08/22		NC	%	75 - 125
			Total Manganese (Mn)	2014/08/22		NC	%	75 - 125
			Total Phosphorus (P)	2014/08/22		NC	%	75 - 125
			Total Potassium (K)	2014/08/22		NC	%	75 - 125
			Total Sodium (Na)	2014/08/22		105	%	75 - 125
			Total Strontium (Sr)	2014/08/22		NC	%	75 - 125
7610815	JHC	QC Standard	Total Aluminum (Al)	2014/08/22		103	%	75 - 125
			Total Calcium (Ca)	2014/08/22		108	%	75 - 125
			Total Iron (Fe)	2014/08/22		109	%	75 - 125
			Total Lithium (Li)	2014/08/22		118	%	75 - 125
			Total Magnesium (Mg)	2014/08/22		116	%	75 - 125
			Total Manganese (Mn)	2014/08/22		109	%	75 - 125
			Total Phosphorus (P)	2014/08/22		124	%	75 - 125
			Total Potassium (K)	2014/08/22		121	%	75 - 125
			Total Sodium (Na)	2014/08/22		102	%	75 - 125
			Total Strontium (Sr)	2014/08/22		120	%	75 - 125
7610815	JHC	Spiked Blank	Total Aluminum (Al)	2014/08/22		104	%	75 - 125
			Total Boron (B)	2014/08/22		98	%	75 - 125
			Total Calcium (Ca)	2014/08/22		92	%	75 - 125
			Total Iron (Fe)	2014/08/22		96	%	75 - 125
			Total Lithium (Li)	2014/08/22		94	%	75 - 125
			Total Magnesium (Mg)	2014/08/22		98	%	75 - 125
			Total Manganese (Mn)	2014/08/22		95	%	75 - 125
			Total Phosphorus (P)	2014/08/22		96	%	75 - 125
			Total Potassium (K)	2014/08/22		95	%	75 - 125
			Total Sodium (Na)	2014/08/22		98	%	75 - 125
			Total Strontium (Sr)	2014/08/22		94	%	75 - 125
			Total Sulphur (S)	2014/08/22		100	%	75 - 125
7610815	JHC	Method Blank	Total Aluminum (Al)	2014/08/22	<10		mg/kg	
			Total Boron (B)	2014/08/22	2.2 , RDL=2.0		mg/kg	
			Total Calcium (Ca)	2014/08/22	<50		mg/kg	
			Total Iron (Fe)	2014/08/22	<10		mg/kg	
			Total Lithium (Li)	2014/08/22	<10		mg/kg	
			Total Magnesium (Mg)	2014/08/22	<20		mg/kg	
			Total Manganese (Mn)	2014/08/22	<10		mg/kg	
			Total Phosphorus (P)	2014/08/22	<20		mg/kg	
			Total Potassium (K)	2014/08/22	<25		mg/kg	
			Total Sodium (Na)	2014/08/22	<50		mg/kg	
			Total Strontium (Sr)	2014/08/22	<10		mg/kg	
			Total Sulphur (S)	2014/08/22	<20		mg/kg	
7610815	JHC	RPD [KJ1760-01]	Total Aluminum (Al)	2014/08/22	18.0		%	35
			Total Boron (B)	2014/08/22	NC		%	35
			Total Calcium (Ca)	2014/08/22	19.8		%	35
			Total Iron (Fe)	2014/08/22	18.6		%	35
			Total Lithium (Li)	2014/08/22	NC		%	35
			Total Magnesium (Mg)	2014/08/22	18.9		%	35
			Total Manganese (Mn)	2014/08/22	17.9		%	35
			Total Phosphorus (P)	2014/08/22	24.8		%	35
			Total Potassium (K)	2014/08/22	20.4		%	35

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Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
			Total Sodium (Na)	2014/08/22	20.4		%	35
			Total Strontium (Sr)	2014/08/22	18.8		%	35
			Total Sulphur (S)	2014/08/22	17.5		%	35
7610822	JEP	Matrix Spike [KJ1760-01]	Total Antimony (Sb)	2014/08/22		87	%	75 - 125
			Total Arsenic (As)	2014/08/22		92	%	75 - 125
			Total Barium (Ba)	2014/08/22		NC	%	75 - 125
			Total Beryllium (Be)	2014/08/22		94	%	75 - 125
			Total Cadmium (Cd)	2014/08/22		91	%	75 - 125
			Total Chromium (Cr)	2014/08/22		98	%	75 - 125
			Total Cobalt (Co)	2014/08/22		91	%	75 - 125
			Total Copper (Cu)	2014/08/22		90	%	75 - 125
			Total Lead (Pb)	2014/08/22		92	%	75 - 125
			Total Molybdenum (Mo)	2014/08/22		96	%	75 - 125
			Total Nickel (Ni)	2014/08/22		93	%	75 - 125
			Total Selenium (Se)	2014/08/22		92	%	75 - 125
			Total Silver (Ag)	2014/08/22		92	%	75 - 125
			Total Thallium (Tl)	2014/08/22		91	%	75 - 125
			Total Tin (Sn)	2014/08/22		95	%	75 - 125
			Total Uranium (U)	2014/08/22		92	%	75 - 125
			Total Vanadium (V)	2014/08/22		107	%	75 - 125
			Total Zinc (Zn)	2014/08/22		NC	%	75 - 125
7610822	JEP	QC Standard	Total Arsenic (As)	2014/08/22		109	%	50 - 150
			Total Barium (Ba)	2014/08/22		100	%	69 - 131
			Total Chromium (Cr)	2014/08/22		98	%	41 - 159
			Total Cobalt (Co)	2014/08/22		95	%	75 - 125
			Total Copper (Cu)	2014/08/22		100	%	73 - 127
			Total Lead (Pb)	2014/08/22		97	%	54 - 146
			Total Nickel (Ni)	2014/08/22		104	%	61 - 139
			Total Vanadium (V)	2014/08/22		114	%	50 - 150
			Total Zinc (Zn)	2014/08/22		103	%	72 - 128
7610822	JEP	Spiked Blank	Total Antimony (Sb)	2014/08/22		87	%	75 - 125
			Total Arsenic (As)	2014/08/22		90	%	75 - 125
			Total Barium (Ba)	2014/08/22		89	%	75 - 125
			Total Beryllium (Be)	2014/08/22		89	%	75 - 125
			Total Cadmium (Cd)	2014/08/22		88	%	75 - 125
			Total Chromium (Cr)	2014/08/22		90	%	75 - 125
			Total Cobalt (Co)	2014/08/22		88	%	75 - 125
			Total Copper (Cu)	2014/08/22		91	%	75 - 125
			Total Lead (Pb)	2014/08/22		89	%	75 - 125
			Total Molybdenum (Mo)	2014/08/22		91	%	75 - 125
			Total Nickel (Ni)	2014/08/22		90	%	75 - 125
			Total Selenium (Se)	2014/08/22		90	%	75 - 125
			Total Silver (Ag)	2014/08/22		89	%	75 - 125
			Total Thallium (Tl)	2014/08/22		90	%	75 - 125
			Total Tin (Sn)	2014/08/22		90	%	75 - 125
			Total Uranium (U)	2014/08/22		92	%	75 - 125
			Total Vanadium (V)	2014/08/22		93	%	75 - 125
			Total Zinc (Zn)	2014/08/22		93	%	75 - 125
7610822	JEP	Method Blank	Total Antimony (Sb)	2014/08/22	<1.0		mg/kg	
			Total Arsenic (As)	2014/08/22	<1.0		mg/kg	
			Total Barium (Ba)	2014/08/22	<10		mg/kg	

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Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
			Total Beryllium (Be)	2014/08/22	<0.40		mg/kg	
			Total Cadmium (Cd)	2014/08/22	<0.10		mg/kg	
			Total Chromium (Cr)	2014/08/22	<1.0		mg/kg	
			Total Cobalt (Co)	2014/08/22	<1.0		mg/kg	
			Total Copper (Cu)	2014/08/22	<5.0		mg/kg	
			Total Lead (Pb)	2014/08/22	<1.0		mg/kg	
			Total Molybdenum (Mo)	2014/08/22	<0.40		mg/kg	
			Total Nickel (Ni)	2014/08/22	<1.0		mg/kg	
			Total Selenium (Se)	2014/08/22	<0.50		mg/kg	
			Total Silver (Ag)	2014/08/22	<1.0		mg/kg	
			Total Thallium (Tl)	2014/08/22	<0.30		mg/kg	
			Total Tin (Sn)	2014/08/22	<1.0		mg/kg	
			Total Uranium (U)	2014/08/22	<1.0		mg/kg	
			Total Vanadium (V)	2014/08/22	<1.0		mg/kg	
			Total Zinc (Zn)	2014/08/22	<10		mg/kg	
7610822	JEP	RPD [KJ1760-01]	Total Antimony (Sb)	2014/08/22	NC		%	35
			Total Arsenic (As)	2014/08/22	1.9		%	35
			Total Barium (Ba)	2014/08/22	0.8		%	35
			Total Beryllium (Be)	2014/08/22	NC		%	35
			Total Cadmium (Cd)	2014/08/22	NC		%	35
			Total Chromium (Cr)	2014/08/22	0.08		%	35
			Total Cobalt (Co)	2014/08/22	0.6		%	35
			Total Copper (Cu)	2014/08/22	NC		%	35
			Total Lead (Pb)	2014/08/22	0.1		%	35
			Total Molybdenum (Mo)	2014/08/22	NC		%	35
			Total Nickel (Ni)	2014/08/22	0.09		%	35
			Total Selenium (Se)	2014/08/22	NC		%	35
			Total Silver (Ag)	2014/08/22	NC		%	35
			Total Thallium (Tl)	2014/08/22	NC		%	35
			Total Tin (Sn)	2014/08/22	NC		%	35
			Total Uranium (U)	2014/08/22	NC		%	35
			Total Vanadium (V)	2014/08/22	0.3		%	35
			Total Zinc (Zn)	2014/08/22	0.2		%	35
7611118	SDH	Matrix Spike	Soluble Calcium (Ca)	2014/08/22		106	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		106	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		101	%	75 - 125
			Soluble Potassium (K)	2014/08/22		104	%	75 - 125
7611118	SDH	QC Standard	Soluble Calcium (Ca)	2014/08/22		113	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		111	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		103	%	75 - 125
			Soluble Potassium (K)	2014/08/22		99	%	75 - 125
			Soluble Sulphate (SO4)	2014/08/22		113	%	75 - 125
7611118	SDH	Spiked Blank	Soluble Calcium (Ca)	2014/08/22		96	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		96	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		93	%	75 - 125
			Soluble Potassium (K)	2014/08/22		95	%	75 - 125
7611118	SDH	Method Blank	Soluble Calcium (Ca)	2014/08/22	<1.5		mg/L	
			Soluble Magnesium (Mg)	2014/08/22	<1.0		mg/L	
			Soluble Sodium (Na)	2014/08/22	<2.5		mg/L	
			Soluble Potassium (K)	2014/08/22	<1.3		mg/L	
			Soluble Sulphate (SO4)	2014/08/22	<5.0		mg/L	

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
7611229	SDH	Matrix Spike	Soluble Calcium (Ca)	2014/08/22		96	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		103	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		108	%	75 - 125
			Soluble Potassium (K)	2014/08/22		105	%	75 - 125
7611229	SDH	QC Standard	Soluble Calcium (Ca)	2014/08/22		115	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		120	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		123	%	75 - 125
			Soluble Potassium (K)	2014/08/22		111	%	75 - 125
			Soluble Sulphate (SO4)	2014/08/22		121	%	75 - 125
7611229	SDH	Spiked Blank	Soluble Calcium (Ca)	2014/08/22		94	%	75 - 125
			Soluble Magnesium (Mg)	2014/08/22		100	%	75 - 125
			Soluble Sodium (Na)	2014/08/22		105	%	75 - 125
			Soluble Potassium (K)	2014/08/22		102	%	75 - 125
7611229	SDH	Method Blank	Soluble Calcium (Ca)	2014/08/22	<1.5		mg/L	
			Soluble Magnesium (Mg)	2014/08/22	<1.0		mg/L	
			Soluble Sodium (Na)	2014/08/22	<2.5		mg/L	
			Soluble Potassium (K)	2014/08/22	<1.3		mg/L	
			Soluble Sulphate (SO4)	2014/08/22	<5.0		mg/L	
7612603	JHC	Matrix Spike	Dissolved Calcium (Ca)	2014/08/24		NC	%	80 - 120
			Dissolved Iron (Fe)	2014/08/24		96	%	80 - 120
			Dissolved Magnesium (Mg)	2014/08/24		NC	%	80 - 120
			Dissolved Manganese (Mn)	2014/08/24		NC	%	80 - 120
			Dissolved Potassium (K)	2014/08/24		109	%	80 - 120
			Dissolved Sodium (Na)	2014/08/24		NC	%	80 - 120
7612603	JHC	Spiked Blank	Dissolved Calcium (Ca)	2014/08/24		102	%	80 - 120
			Dissolved Iron (Fe)	2014/08/24		100	%	80 - 120
			Dissolved Magnesium (Mg)	2014/08/24		110	%	80 - 120
			Dissolved Manganese (Mn)	2014/08/24		100	%	80 - 120
			Dissolved Potassium (K)	2014/08/24		108	%	80 - 120
			Dissolved Sodium (Na)	2014/08/24		103	%	80 - 120
7612603	JHC	Method Blank	Dissolved Calcium (Ca)	2014/08/24	<0.30		mg/L	
			Dissolved Iron (Fe)	2014/08/24	<0.060		mg/L	
			Dissolved Magnesium (Mg)	2014/08/24	<0.20		mg/L	
			Dissolved Manganese (Mn)	2014/08/24	<0.0040		mg/L	
			Dissolved Potassium (K)	2014/08/24	<0.30		mg/L	
			Dissolved Sodium (Na)	2014/08/24	<0.50		mg/L	
7613564	JHC	Matrix Spike	Dissolved Calcium (Ca)	2014/08/25		NC	%	80 - 120
			Dissolved Iron (Fe)	2014/08/25		86	%	80 - 120
			Dissolved Magnesium (Mg)	2014/08/25		NC	%	80 - 120
			Dissolved Manganese (Mn)	2014/08/25		NC	%	80 - 120
			Dissolved Potassium (K)	2014/08/25		85	%	80 - 120
			Dissolved Sodium (Na)	2014/08/25		NC	%	80 - 120
7613564	JHC	Spiked Blank	Dissolved Calcium (Ca)	2014/08/25		97	%	80 - 120
			Dissolved Iron (Fe)	2014/08/25		97	%	80 - 120
			Dissolved Magnesium (Mg)	2014/08/25		101	%	80 - 120
			Dissolved Manganese (Mn)	2014/08/25		98	%	80 - 120
			Dissolved Potassium (K)	2014/08/25		98	%	80 - 120
			Dissolved Sodium (Na)	2014/08/25		101	%	80 - 120
7613564	JHC	Method Blank	Dissolved Calcium (Ca)	2014/08/25	<0.30		mg/L	
			Dissolved Iron (Fe)	2014/08/25	<0.060		mg/L	
			Dissolved Magnesium (Mg)	2014/08/25	<0.20		mg/L	

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam Job #: B471505
Report Date: 2014/08/25

STANTEC CONSULTING LTD
Client Project #: MALLIK
Site Location: MALLIK, INUVIK NWT
Your P.O. #: 16300R-20
Sampler Initials: OP

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	Units	QC Limits
			Dissolved Manganese (Mn)	2014/08/25	<0.0040		mg/L	
			Dissolved Potassium (K)	2014/08/25	<0.30		mg/L	
			Dissolved Sodium (Na)	2014/08/25	<0.50		mg/L	

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone (780)577-7100 Fax (780)450-4187

Maxxam

Calgary: 4000 19st St. NE, T2E 6P8. Ph: (403) 291-3077, Fax: (403) 735-2240, Toll free: (800) 386-7247
Edmonton: 9331 - 48 Street, T6B 2R4. Ph: (780) 577-7100, Fax: (780) 450-4187, Toll free: (877) 465-8889
www.maxxamanalytics.com

08/847(1) SM

Chain of Custody A131759

Page: 1 of 1

	Invoice To: C/O Report Address ☐	Report To: Same as Invoice ☒
Company:	STANTEC	
Contact:	OLIVIER PIRAUX	
Address:	10160-112 St.	
	Prov: AB PC: T5K 2L6	Prov: PC:
Contact #s:	Ph: 514 245 1045 (Cell)	Ph: Cell:

Report Distribution (E-Mail):
olivier.piraux@stantec.com
Elaine.Little@stantec.com

REGULATORY GUIDELINES:
☐ AT1
☐ CCME
☐ Regulated Drinking Water
☐ Other:

All samples are held for 60 calendar days after sample receipt, unless specified otherwise.

PO #: 1102192844.
Project # / Name: Mallik
Site Location: Mallik, INUVIK NWT
Quote #:
Sampled By: OLIVIER PIRAUX

SERVICE REQUESTED: ☐ RUSH (Contact lab to reserve) Date Required: ☒ REGULAR (5 to 7 Days)

See reverse for package specifics

	Sample ID	Depth (unit)	Matrix GW / SW Soil	Date/Time Sampled YY/MM/DD 24:00	SOIL: BTEX F1-F4	SOIL: Sieve (75 micron)	SOIL: Regulated Metals (CCME / AT1)	SOIL: Salinity 4	SOIL: Assessment ICP Metals	SOIL: Basic Class II Landfill	WATER: ☐BTEX F1 ☐VOCs	WATER: ☐BTEX F1-F2 ☐BTEX F1-F4	WATER: ☒Routine Water ☐Turb ☐F	WATER: ☐TOC ☐DOC	WATER: Regulated Metals (CCME / AT1) Total	WATER: Regulated Metals (CCME / AT1) Dissolved	WATER: Mercury ☐Total ☐Dissolved	Other Analysis	HOLD - Do not Analyze	# of Containers Submitted
1	Mallik.2014.W1	surface	SW	2014.08.13 1PM									X							1
2	Mallik.2014.W2		SW										X							1
3	Mallik.2014.W3		SW										X							1
4	Mallik.2014.W4		SW										X							1
5	Mallik.2014.W5		SW										X							1
6	Mallik.2014.W6		SW										X							1
7	Mallik.2014.W7	surface	SW										X							1
8	Mallik.2014.S1	100	soil					X	X											1
9	Mallik.2014.S2	10	soil					X	X											1
10																				
11																				
12																				

RECEIVED IN YELLOWKNIFE
By: Laughlin Lauchlan Lauchlan Lauchlan
2014 -08- 15 09:10

Temp: 4 / 4 / 4

Please indicate Filtered, Preserved or Both (F, P, F/P) → F/P F/P F/P F/P

Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
OLIVIER PIRAUX	14.08.13	6PM
Relinquished By (Signature/Print):	Date (YY/MM/DD):	Time (24:00):
Special Instructions:	# of Jars Used & Not Submitted	

LAB USE ONLY

Received By:	Date:	Time:	Maxxam Job #:		
amanda		0940	B471505		
Lab Comments:			Custody Seal	Temperature	Ice
Hirondelle 20140816@				1,1,2 present	

AB FCD-00331 Rev3 2010/05

Maxxam Analytics International Corporation o/a Maxxam Analytics

APPENDIX C

Annual Site Inspection Report

Indian and Northern Affairs Canada
www.inac.gc.ca

North Mackenzie
P.O. Box 2100
Inuvik, NT X0E 0T0

Affaires Indiennes et du Nord Canada
www.ainc.gc.ca

Telephone: (867) 777-3361
Fax: (867) 777-2090

COPY
BOARD 5
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E. A. 1
W. RES. 1
NMDO 1
FILE 1817
JM
PdP

November 27, 2007

NORTHWEST TERRITORIES WATER BOARD
NOV 27 2007
YELLOWKNIFE, NWT

Northwest Territories Water Board
Box 1326
Yellowknife NT
Canada X1A 2N9

Attn: Vicki Losier, Executive Assistant

RE: Industrial Water Use (N7L1-1817)
Mallik

Please find the enclosed Inspection Report for your review and/or records.

An electronic copy (un-editable Adobe pdf.) has also been provided by e-mail.

A previous letter of response was received November 19, 2007 from the Aurora Research Institute that addressed the violations, spills and concerns in the above mentioned inspection and has been provided with the Inspection Report in addition to an electronic copy (Adobe pdf.) by e-mail.

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT
Inuvik Sub-District

Enclosure: Industrial Inspection Report (two pages)
Letter of Response from Aurora Research Institute (two pages)

Indian and Northern Affairs Canada | Affaires Indiennes et du Nord Canada

INDUSTRIAL WATER USE INSPECTION REPORT

DATE:	September 4, 2007	**COMPANY REP:**	None present
LICENCEE:	Aurora Research Institute	**LICENCE #:**	N7L1-1817

WATER SUPPLY

Source:	Swan Channel Mackenzie River	Quantity Used:	N/A	Meter Rdg:	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Intake Facilities	N/A	Storage Structures	N/A	Treatment Systems	N/A	Recycling	N/A
Flow Meas. Device	N/A	Conveyance Lines	N/A	Pumping Stations	N/A	Modifications	N/A

WASTE DISPOSAL

Tailings:	Tailings Pond	N/A	Natural Lake	N/A	Underground	N/A		
Sewage:	Sewage Treat. System	N/A	Tailings pond		Natural Water Body	N/A		
	Continuous Discharge	N/A	Inter. Discharge	N/A				
Solid Waste:	Open Dump	N/A	Landfill	N/A	Burn & Bury	N/A	Under ground	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Discharge Quality	N/A	Conveyance Lines	N/A	Disch. Meas. Dev.	N/A	Freeboard	N/A
Decant Structures	N/A	Pond Treatment	N/A	Dams, Dykes	N/A	Seepages	N/A
Dyke Inspections	N/A	Runoff Diversion	N/A	Erosion	N/A	Spills	U[1]

Effluent Discharge Rate:	N/A	Samples Collected:	N/A

Comments:
Concerns:
1. During the follow up inspection the deposit of drill cuttings were located at one location(N 69° 27' 32.9" W 134° 39' 44.7") and it was observed that dead vegetation was in the vicinity of the cuttings(see figure 1). During a previous site visit another pile of cuttings were located southwest of the old sump(see figure 2). The cuttings should be removed and the area with dead vegetation needs to be sampled to determine the cause of the dead vegetation. Based on lab analysis results a subsequent course of action/restoration plan will need to be determined in consultation with Indian and Northern Affairs Canada Inspectors.

Note:
- On March 2, 2007 there was an unauthorized discharge of waste. A deposit of drill cuttings had occurred when a vacuum truck was spreading treated sewage effluent on the land surface surrounding the lease site pad. The vacuum truck had been previously used to transport drill cuttings before being dedicated to transporting sewage effluent. The truck had been cleaned but there was still a particulate/residue in the bottom of the tank that got spread with the sewage effluent.

GENERAL CONDITIONS

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Ore & Waste Rock Stockpiles	N/A	Records & Reporting	N/A	Surv. Net. Prog.	N/A
Geotechnical Inspection	N/A	Posting, Signage	N/A	Contingency Plan	N/A
Restorations Activities	N/A	New Construction	N/A	Fuel Storage	N/A
Mine Water Discharge	N/A	Chemical Storage	N/A	Annual Report	N/A

Violations of Act of Licence:

1. Part D, section 14. Unauthorized discharge of drill cuttings along with sewage effluent to the land surface of the lease site. See concern 1 under Waste Disposal.

Inspector's Signature: _____

Indian and Northern Affairs Canada | Affaires Indiennes et du Nord Canada

INDUSTRIAL WATER USE INSPECTION REPORT Pg. 2

(Continued)

Date:	September 4, 2007	Licence #:	N7L1-1817

Inspection Images:

Figure 1
Cuttings from previous spill and area of dead vegetation.

Figure 2
Cuttings found southwest of the old sump.

AURORA COLLEGE
Aurora Research Institute

November 19, 2007

To: Mr. Conrad Baetz
District Manager, North Mackenzie District
Indian and Northern Affairs Canada
P.O. Box 2100
Inuvik, NT X0E 0T0

From: Alan E. Taylor, P.Eng.,
Mallik Operations Manager
Aurora Research Institute,
Aurora College,
Inuvik, NT X0E 0T0
ataylor@auroracollege.nt.ca

Re: **Aurora College's response to:**
Water License N7L1-1817 / Land Use Permit N2006A0034
inspection of September 4, 2007

Dear Mr. Baetz:

This is Aurora Research Institute (ARI) / Aurora College's response to your letter of November 13, 2007 regarding the INAC inspection of the Mallik site on September 4, 2007.

We appreciate your site Environmental Inspection Report and assessment of the "end-of-summer" conditions at the Mallik location following our winter 2007 operations.

Briefly, 3 issues were identified in the inspection, and ARI proposes the following action:

1. "...hole drilled that would have to be refilled (Fig. 1)": this is probably beside Mallik 3L-38 and may be the mouse hole. I will make note for this to be filled in next summer, during our post-2008 operating season clean-up.
2. "some drill cuttings are to be cleaned out in a couple locations" : these drill cuttings (Fig. 5, 6) probably originate from the unreportable spill of March 2, 2007 logged in the Schlumberger spill log entry #14 for March:
    a. Your inspectors coincidentally were on location at the time, and the problem was discussed and a clean-up strategy developed that included a chemical analysis (see our response dated April 13, 2007 to the INAC inspection of March 21, 2007).
    b. Subsequent to the Sept. 4 inspection report, Mr. Jan Davies has provided us (email of Nov. 14, 2007) with location information for these cuttings

Box 1450
Inuvik, NT X0E 0T0
Tel: (867) 777-3298
Fax: (867) 777-4264

piles that will assist us next summer in removing what we can rake up and disposing to a proper facility:

   i. Fig. 6: we appreciate that the main concern is this area where grass is dead: N 69° 27' 32.9" W 134° 39' 44.7"]
   ii. Fig. 5: this is southwest of old sump.

3. With regards to Fig. 2 (Debris on 2002 sump?); Fig. 3 (Edge of 2002 sump with surface thermistor cable spooled on tripod); and Fig. 4 (Pile of mud likely close to 2L – origin of mud is uncertain). In all cases the areas will be attended to in summer, 2008.

If I can provide further information, please let me know.

Respectively submitted,

Alan E. Taylor, P.Eng.,
Mallik Operations Manager,
Aurora Research Institute
191 Mackenzie Road,
Box 1450,
Inuvik, NT X0E 0T0

ataylor@auroracollege.nt.ca
867-678-0854 (cell)
867-777-5328 (Fax)

CC: Andrew Applejohn, Director, ARI
Doug Ashford, Project Manager, IPM-IOFS (Schlumberger)
Masato Yasuda, Project Director, Engineering, JOGMEC
Scott Dallimore, Canadian Lead Scientist, NRCan.

Indian and Northern Affairs Canada
www.inac.gc.ca

Affaires Indiennes et du Nord Canada
www.ainc.gc.ca

North Mackenzie District
P.O. Box 2100
Inuvik, NT

Telephone: 867-777-3662
Fax: 867-777-2090

May 29, 2008

Northwest Territories Water Board
Box 1326
Yellowknife, NT X1A 2N9

Attn: Ron Wallace, Excutive Director

RE: Industrial Water Use (N7L1-1817)
Mallik

Dear Mr. Wallace,

Please find the enclosed Inspection Report for your review and/or records.

An electronic copy (un-editable Adobe pdf.) has also been provided by e-mail.

If you have any questions/concerns regarding the enclosed, and/or if additional information is required, please do not hesitate to contact me at (867) 777-3662.

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT
Inuvik Sub-District

Enclosure: Industrial Inspection Report (one page)

Indian and Northern Affairs Canada | Affaires Indiennes et du Nord Canada

INDUSTRIAL WATER USE INSPECTION REPORT

DATE:	March 10, 2008	**COMPANY REP:**	Andrew Applejohn
LICENCEE:	Aurora Research Institute	**LICENCE #:**	N7L1-1817

WATER SUPPLY

Source:	Mackenzie River Channel	Quantity Used:	>500 m3/day *see Concern 1 under Water Supply	Meter Rdg:	N/I

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Intake Facilities	A[2,3]	Storage Structures	A	Treatment Systems	N/A	Recycling	A
Flow Meas. Device	A	Conveyance Lines	A	Pumping Stations	A	Modifications	N/A

Comments:
Concerns:
1. Water usage was under 500m3 except for 2 days in which the daily quantity of water was exceeded. Water usage was 509m3 on Feb 3, 2008 and 508m3 on Feb 4, 2008. Upon the exceedences being discovered by the Licensee, action was taken to prevent further water usage over the Water Licence limit of 500m3. On February 6, 2008 Al Taylor visited the INAC Inuvik District Office and explained the situation. Future water usage has since been within Water Licence criteria according to water withdrawal records.
2. Fish screen for pump okay but screen cover has come undone in one area and needs to be tightened to close the hole.
3. Generator is leaking oil onto pump station floor and the oil has pooled behind generator. Oil needs to be cleaned, leak repaired and/or a drip tray put in place. Upon inspection there was no evidence of oil leakage from the shack containing the generator. When the pump shack is demobilized ensure that no oil leaked on to snow or ice underneath the pump shack.

WASTE DISPOSAL

Well Waste	Off-Site Removal	A	Drilling Sump	N/A	Downhole	A	Land spread	N/A
Tailings:	Tailings Pond	N/A	Natural Lake	N/A	Under ground	N/A		
Sewage:	Sewage Treat. System	U[1]	Tailings pond		Natural Water Body	N/A		
	Continuous Discharge	N/A	Inter. Discharge	N/A				
Solid Waste:	Open Dump	N/A	Landfill	A	Burn & Bury	A	Under ground	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Discharge Quality	U[1]	Conveyance Lines	N/I	Disch. Meas. Dev.	A	Freeboard	N/A
Decant Structures	N/A	Pond Treatment	N/A	Dams, Dykes	N/A	Seepages	U[2]
Dyke Inspections	N/A	Runoff Diversion	N/A	Erosion	N/A	Spills	A

Effluent Discharge Rate:	N/A	Samples Collected:	Samples are being collected

Comments:
Concerns:

1. As of this inspection date, discharge quality of sewage effluent has not been met for 4 consecutive times at the Mallik site, consequently the treated sewage is being trucked to the Town of Inuvik Sewage Lagoon.
2. Numerous small leaks from sewage treatment plant through floor. Drip trays present and will continue to be needed to ensure containment until leaks are repaired.

GENERAL CONDITIONS

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

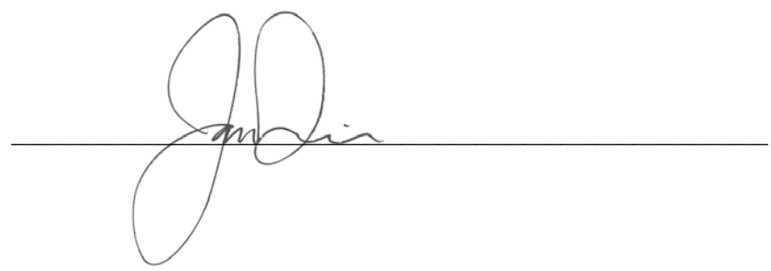
Ore & Waste Rock Stockpiles	N/A	Records & Reporting	A	Surv. Net. Prog.	A
Geotechnical Inspection	N/A	Posting, Signage	A	Contingency Plan	A
Restorations Activities	A	New Construction	N/A	Fuel Storage	A
Mine Water Discharge	N/A	Chemical Storage	A	Annual Report	N/A

Comments:

Violations of Act of Licence:

1. Part C, section 2. The daily quantity of water exceeded 500 m3 on February 3 and 4, 2007. See Concern 1 under Water Supply.

General Comments:

Inspector's Signature: 

Aboriginal Affairs and
Northern Development Canada
http://www.aandc-aadnc.gc.ca

Affaires autochtones et
Développement du Nord Canada
http://www.aadnc-aandc.gc.ca

North Mackenzie District
P.O. Box 2100
Inuvik, NT X0E 0T0

Telephone: 867-777-8900
Fax: 867-777-2090

November 9, 2011

Aurora Research Institute
Box 1450
Inuvik, NT X0E 0T0

Attn: Pippa Seccombe-Hett

RE: Industrial Water Use N7L1-1817
CLASS B - INDUSTRIAL
Swan Channel - Mackenzie River

Dear Ms. Seccombe-Hett,

An inspection/audit of the Aurora Research Institute Water Licence N7L1-1817 was conducted on August 24, 2011. The operation under the above mentioned Industrial Water Use was inspected to assess compliance and ensure that the terms and conditions were met. Enclosed is a copy of the Inspection Report (3 pages) for your review and records.

Unfortunately, there was one violation during this inspection period. Please review and address this violation and the concerns as indicated in the enclosed Inspection Report. Please address the aforementioned items as non-compliance with the Water Licence is a serious matter.

Aboriginal Affairs and Northern Development Canada (AANDC) North Mackenzie District acknowledges there is infrastructure on site to monitor the existing drilling Waste Sumps 2L-38 and 3L/4L/5L-38 after closure for a period of at least seven (7) years as per Part H: Conditions Applying to Abandonment and Restoration, Item 2 of the Water Licence. Please note that final consideration for the maintenance of security for this Water Licence is mandated by the NWT Water Board. To ensure consistency with other sump monitoring programs in the region AANDC North Mackenzie District therefore **"Recommends the Maintaining of Security" for Water Licence N7L1-1817**.

Please note that it is the Licensee's responsibility to ensure compliance with all of the terms and conditions of its Water Licence. Aboriginal Affairs and Northern Development Canada looks forward to working with you as much as possible to achieve compliance.

A copy of this report will be sent to the Northwest Territories Water Board for their review and public records.

If you have any questions regarding the enclosed and/or if additional information is required, please do not hesitate to contact me at (867) 777-8909.

INDUSTRIAL WATER USE INSPECTION REPORT

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT

Enclosure: Industrial Water Use Inspection /Audit Report (3 pages)

INDUSTRIAL WATER USE INSPECTION REPORT

LICENCE #:	N7L1-1817	**EXPIRY DATE:**	November 30, 2016
LICENCEE:	Aurora Research Institute	**PREVIOUS INSPECTION:**	August 28, 2008
COMPANY REP:	Pippa Seccombe-Hett	**INSPECTION DATE:**	August 24, 2011

WATER SUPPLY

Source:	N/A	Quantity Used:	N/A
Owner/Operator:	N/A	Meter Reading:	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Intake Facilities	N/A	Storage Structures	N/A	Treatment Systems	N/A	Recycling	N/A
Flow Meas. Device	N/A	Conveyance Lines	N/A	Pumping Stations	N/A	Chem. Storage	N/A
						Modifications	N/A

Water Supply Comments:
- N/A

WASTE DISPOSAL

Well Waste:	Off-Site Removal	N/A	Drilling Sump	N/A	Downhole	N/A	Land spread	N/A
Solid Waste:	Open Dump	N/A	Landfill	A	Burn & Bury	N/A	Under ground	N/A
	Owner / Operator	N/A	Sludge Disposal	N/A	Other	N/A		
Tailings:	Tailings Pond	N/A	Natural Lake	N/A	Under ground	N/A		
Sewage:	Sewage Treat. System	N/A	Camp Sump	N/A	Natural Water Body	N/A	Wetland Treatment	N/A
	Continuous Discharge	N/A	Inter. Discharge	N/A	Seasonal Discharge	N/A	Trench	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Discharge Quality	N/A	Construction	N/A	Disch. Meas. Dev.	N/A	Freeboard	N/A
Decant Structures	N/A	O&M Plan	N/A	Dams, Dykes	N/A	Seepages	N/A
Dyke Inspections	N/A	A&R Plan	N/A	Erosion	N/A	Spills	A
Conveyance Lines	N/A	Pond Treatment	N/A	Runoff Diversion	N/A	Sump Treatment	N/A
Sump Liners	N/A			SNP Samples Collected	N/A		
Periods of Discharge	N/A			Effluent Discharge Rate	N/A		

Waste Disposal Comments:
- Cuttings location (N 69° 27' 32.9" W 134° 39' 44.7") from the March 2, 2007 spill with cuttings is barely detectable when compared to the previous inspections dated September 4, 2007 and August 28, 2008. Site visits during June 18, 2010 and August 23, 2010 during the summer months shows the area looking acceptable and it has had no lingering effects from the spill incident. The whole surrounding area has recovered without any problems. During futher inspections of the Mallik area it is recommended to continue monitoring the spill area. (see the Inspection Images section)
- The effects from the Mallik Gas Hydrate Production Research Project have been minimal on the surrounding area and the sumps that are present. There seems to be no issues noted from its having taken place.
- Solid waste associated with the project has been removed and the site appears acceptable.

INDUSTRIAL WATER USE INSPECTION REPORT

GENERAL CONDITIONS

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Ore & Waste Rock Stockpiles	N/A	Records & Reporting	U[1]	Surv. Net. Prog.	N/A
Geotechnical Inspection	A	Posting, Signage	N/A	Contingency Plan	N/A
Restorations Activities	U[1,2]	New Construction	N/A	Fuel Storage	N/A
Mine Water Discharge	N/A	Chemical Storage	N/A	Annual Report	U[1]

General Condition Comments:
Concerns:
1. Upon review of the 2008 – 2010 Mallik Annual Sump Monitoring Reports submitted for this project including the Aurora Research Institute Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program as submitted to the Environmental Impact Screening Committee (EISC) – February 2008, it appears there was no thermistor or thermal monitoring results for the 1998 2L-38 drilling sump. This is a violation of Part H: Conditions Applying to Abandonment and Restoration, Item 2 of the Water Licence. The existing drilling Waste Sumps 2L-38 and 3L/4L/5L-38 shall be monitored in accordance with the Northwest Territories Water Board publication "Protocol for the Monitoring of Drilling-Waste Disposal Sumps, October 2005", specifically thermal monitoring will be conducted of sumps.

This lack of information is of particular concern since it is going against commitments made by the Aurora Research Institute in their supporting documentation for this program. According to the Sump Monitoring and Retrofit Program at section 8 – Alternatives, page 22, it was stated that "during the first year of the 2006-2008 Mallik Gas Hydrate Production Research Project, a portion of the Mallik 2L-38 sump was overlain with a thick (30cm) ice pad....Monitoring of the thermal stability of the Mallik 2L-38 sump, therefore, is important for the Mallik Gas Hydrate Production Research Project and is also a requirement of project regulatory approvals (NEB Information Request No. 1, Appendix A)."

Upon consultation with the Sump Monitoring and Retrofit Program document at section 5.5 – Sump Monitoring Program, page 13, it stated that "The planned borehole in the centre of the Mallik 2L-38 sump was not completed as planned because the sump was covered by drilling equipment at the time....The planned Mallik 2L-38 borehole, along with one to five strategically place additional boreholes, may be drilled in winter 2007-08 as part of the Mallik 2006-08 Gas Hydrate Production Research Project. Soil sampling will take place at each borehole and a thermistor cable and datalogger will be added. If winter installation is not possible, installation by water jet drilling as part of the later summer field work is proposed."
2. Further soil and water sampling of areas of concern as stated in the 2010 Mallik Annual Sump Monitoring Report needs to occur to further assess the presence of high response from electromagnetic surveys and revealed evidence of sump content migration.

Notes:
- No issues evident from the residual cuttings incident.
- Area looked good, same subsidence and issues noted from the sump sites as before.
- It is important to note that no sumps were used for this project but there were commitments to the monitoring of other drilling sumps in the area. The following information is from the 2010 Mallik Annual Sump Monitoring Report:

It was stated that the active layer measurements are consistent for the sumps and control location on site. There were slight variations for the ground temperatures recorded by the different thermistors which the report said could be explained by factors such as climate, vegetation covers, material type and size, compactions, etc. High salinity parameters were revealed from soil and water sampling which is for the most part consistent with samples taken from outside the influence of the sumps.

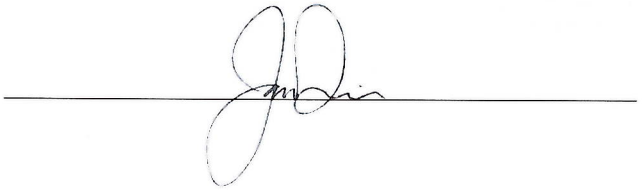
Ground temperature data for the 3L/4L/5L-38 sump (2002 sump) shows that the maximum thaw depth is 1.5m which should allow the sump material to stay frozen all year. From the electromagnetic survey an area of high response was located 60 m from the southern edge of the 3L/4L/5L-38 sump (2002 sump). There is a depression present (believed to be natural) which has about 30 cm of water and the high conductivity is thought to be from the annual input of sea water as compared to seepage from one of the sumps. The presence of free standing water could cause an increased thaw depth and this high response. Soil samples from this site were planned to be taken during the 2011 field visit.

Two small depressional areas were observed at each end of the 2L-38 sump (1998 sump). A water sample taken from the NW ponding water of the 1998 sump revealed evidence of sump contents migration. It was stated in the report that further sampling for both water and soil should be conducted in this location. No other major signs of settlement, erosion or instability in other sump areas were observed.

NON-COMPLIANCE/VIOLATIONS OF ACT OR LICENCE

Part H: Conditions Applying to Abandonment and Restoration, Item 2,

"The Licensee shall monitor the existing drilling Waste Sumps 2L-38 and 3L/4L/5L-38 after closure for a period of at least seven (7) years in accordance with the Northwest Territories Water Board publication "Protocol for the Monitoring of Drilling-Waste Disposal Sumps, October 2005"."

Inspector's Signature: 

INDUSTRIAL WATER USE INSPECTION REPORT

Inspection Images:

Figure 1
Cuttings and affected area from the March 2, 2007 spill with cuttings. Photo taken September 4, 2007.

Figure 2
Cuttings significantly reduced from previous spill. Photo taken August 28, 2008.

Figure 3
Cuttings spill area - photo taken June 17, 2010.

Figure 4
Cuttings spill area - photo taken August 23, 2010.

Figure 5
Surrounding vegetation in vicinity of cuttings spill – photo taken August 23, 2010.

Figure 6
Cuttings spill area - photo taken August 24, 2011.

Aboriginal Affairs and Northern Development Canada
http://www.aandc-aadnc.gc.ca

Affaires autochtones et Développement du Nord Canada
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North Mackenzie District
P.O. Box 2100
Inuvik, NT X0E 0T0

Telephone: 867-777-8900
Fax: 867-777-2090

December 29, 2012

Aurora Research Institute
Box 1450
Inuvik, NT X0E 0T0

Attn: Pippa Seccombe-Hett

RE: Industrial Water Use N7L1-1817
CLASS B - INDUSTRIAL
Swan Channel - Mackenzie River

Dear Ms. Seccombe-Hett,

An inspection of the Aurora Research Institute Water Licence N7L1-1817 was conducted on October 2, 2012. The operation under the above mentioned Industrial Water Use was inspected to assess compliance and ensure that the terms and conditions were met. Enclosed is a copy of the Inspection Report (3 pages) for your review and records.

The efforts by the Aurora Research Istitute to maintain compliance with their Water Licence in relation to the Mallik 2L-38 Sump thermistor cable installation is acknowledged and appreciated. **Please note that the 2012 Annual Report (not the Sump Monitoring Report) is due no later than March 31, 2013.** This report needs to be submitted each year the Water Licence is active and reporting needs to be up to date in order for a Licence to be closed and security returned.

Please note that it is the Licensee's responsibility to ensure compliance with all of the terms and conditions of its Water Licence. A copy of this report will be sent to the Northwest Territories Water Board for their review and public records.

If you have any questions regarding the enclosed and/or if additional information is required, please do not hesitate to contact me at (867) 777-8909.

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT

Enclosure: Industrial Water Use Inspection Report (3 pages)

INDUSTRIAL WATER USE INSPECTION REPORT

LICENCE #:	N7L1-1817	**EXPIRY DATE:**	November 30, 2016
LICENCEE:	Aurora Research Institute	**PREVIOUS INSPECTION:**	August 24, 2011
COMPANY REP:	Pippa Seccombe-Hett	**INSPECTION DATE:**	October 2, 2012

WATER SUPPLY

Source:	Mackenzie River - Swan Channel	Quantity Used:	N/A
Owner/Operator:	N/A	Meter Reading:	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Intake Facilities	N/A	Storage Structures	N/A	Treatment Systems	N/A	Recycling	N/A
Flow Meas. Device	N/A	Conveyance Lines	N/A	Pumping Stations	N/A	Chem. Storage	N/A
						Modifications	N/A

Water Supply Comments:
N/A

WASTE DISPOSAL

Well Waste:	Off-Site Removal	N/A	Drilling Sump	N/A	Downhole	N/A	Land spread	N/A
Solid Waste:	Open Dump	N/A	Landfill	A	Burn & Bury	N/A	Under ground	N/A
	Owner / Operator	N/A	Sludge Disposal	N/A	Other	N/A		
Tailings:	Tailings Pond	N/A	Natural Lake	N/A	Under ground	N/A		
Sewage:	Sewage Treat. System	N/A	Camp Sump	N/A	Natural Water Body	N/A	Wetland Treatment	N/A
	Continuous Discharge	N/A	Inter. Discharge	N/A	Seasonal Discharge	N/A	Trench	N/A

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Discharge Quality	N/A	Construction	N/A	Disch. Meas. Dev.	N/A	Freeboard	N/A
Decant Structures	N/A	O&M Plan	N/A	Dams, Dykes	N/A	Seepages	N/A
Dyke Inspections	N/A	A&R Plan	N/A	Erosion	N/A	Spills	A
Conveyance Lines	N/A	Pond Treatment	N/A	Runoff Diversion	N/A	Sump Treatment	N/A
Sump Liners	N/A			SNP Samples Collected	N/A		
Periods of Discharge	N/A			Effluent Discharge Rate	N/A		

Waste Disposal Comments:
- Thermistor cable installation at the center of the Mallik 2L-38 drilling sump to monitor sump stability and maintain compliance with Part H: Conditions Applying to Abandonment and Restoration, Item 2 of the Water Licence and address the violation identified in the previous Water Licence Inspection Report dated August 24, 2011. Area surrounding the thermistor was acceptable for cleanliness and debris from the installation.

INDUSTRIAL WATER USE INSPECTION REPORT

- Solid waste associated with the project has been removed and the site appears acceptable. There was only some small garbage present during the Water Licence Inspection consisting of a little plastic at the 1998 drilling sump that appeared to have arrived on site through natural means. Upon a subsequent visit to the Mallik site for sump monitoring if this plastic could be removed from the Mallik 2L-38 drilling sump that would be appreciated.
- The suspected portion of the residual cuttings location (at N 69° 27' 32.9" W 134° 39' 44.7") from the March 2, 2007 spill incident was difficult to identify as the area is barely detectable when compared to previous inspections. The area looked acceptable and there are no lingering effects from the spill incident. The spill incident area including the residual cuttings location will continue to be monitored during further inspections.
- The Mallik Gas Hydrate Production Research Project appears to have had minimal effects on the surrounding area and sumps. No issues have been noted since the project took place.

GENERAL CONDITIONS

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

Ore & Waste Rock Stockpiles	N/A	Records & Reporting	A	Surv. Net. Prog.	N/A
Geotechnical Inspection	A	Posting, Signage	N/A	Contingency Plan	N/A
Restorations Activities	A	New Construction	A	Fuel Storage	N/A
Mine Water Discharge	N/A	Chemical Storage	N/A	Annual Report	A

General Condition Comments:
- **Please note that the 2012 Annual Report (not the Sump Monitoring Report) is due no later than March 31, 2013** as per Part B: General Conditions, Item 1 of the Water Licence and needs to be submitted to the Northwest Territories Water Board and an Inspector. It is important to note that this Annual Report needs to be submitted every year and reporting must be up to date in order for a Water Licence to be closed and security returned. The following items must be addressed in the Annual Report:
  a) the total quantity in cubic metres of fresh Water obtained from each Water source(s);
  b) the total quantities in cubic metres of each and all Waste discharged;
  c) the location and direction of flow of all Waste discharged to the land or Water;
  d) an itemized list indicating the names and quantities of all drilling mud additives used;
  e) details of work completed;
  f) a list of spills and unauthorized discharges;
  g) details on the restoration of any sumps;
  h) results from all monitoring programs; and,
  i) any other details on Water use or Waste disposal requested by the Board within forty-five (45) days before the annual report is due.
- Subsidence and issues noted at the sump sites from previous inspections appear to be similar, there was more water present on site.
- March 2, 2007 spill incident does not appear to have left any lingering effects.
- No sumps were used for the Mallik 2006-08 Gas Hydrate Production Research Project, however there were commitments to monitor the other drilling sumps Mallik 2L-38 and Mallik 3L/4L/5L-38 in the area.
- The 2012 Mallik Annual Sump Monitoring Report stated: That the subsidence at all three sumps appears to have increased base on visual assessment. Active layer measurements were consistent throughout the site. The EM (electromagnetic) surveys are consistent with last year's results and confirm that there is no evidence of contaminant migration. Natural depressions with high conductivity located at proximity to the sumps is not related to seepage of drilling contaminants but most probably due to sea water. Water samples taken from subsidence areas of the Mallik 2L-38 and Mallik 3L/4L/5L-38 sumps have high potassium values and the idea is that seasonally unfrozen drill mud contaminants are mixing into the subsiding portions of the sump caps.

An area adjacent to the northeast corner of the Mallik 2L-38 Sump with elevated apparent conductivity indicated by EM survey has not increased in size when compared to previous reports. A soil sample revealed parameters with higher than normal values, considered too high for a natural source and suggests the presence of sump contaminants. Residue of unknown nature present at the ground surface in that specific area could explain the high parameter values rather than the progressive migration of contaminants outside of the sump area.

NON-COMPLIANCE/VIOLATIONS OF ACT OR LICENCE

N/A

Inspector's Signature: _____

INDUSTRIAL WATER USE INSPECTION REPORT

Inspection Images:

Figure 1
Suspected location for residual cuttings and part of the spill incident from March 2, 2007. The area continues to show no impacts.

Figure 2
2002 Drilling Sump from the southeast corner.

Figure 3
2002 Camp Sump from the northeast corner.

Figure 4
1998 Camp Sump from the southeast corner.

Figure 5
1998 Drilling Sump from the south side of the sump, new thermistor has been installed.

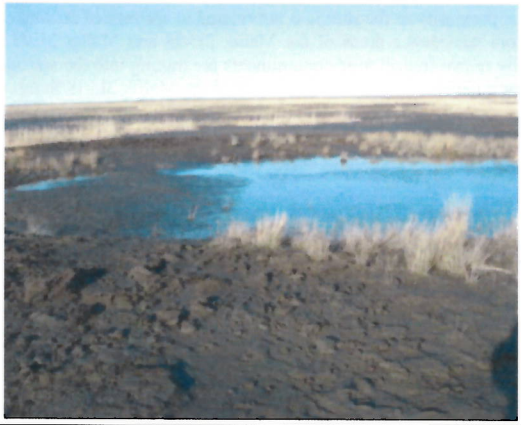


Figure 6
1998 Flare Sump from the southeast corner.

Aboriginal Affairs and Northern Development Canada
http://www.aandc-aadnc.gc.ca

Affaires autochtones et Développement du Nord Canada
http://www.aadnc-aandc.gc.ca

North Mackenzie District
P.O. Box 2100
Inuvik, NT X0E 0T0

Telephone: 867-777-8900
Fax: 867-777-2090

March 29, 2014

Northwest Territories Water Board
P.O. Box 2531
Inuvik, NT X0E 0T0

Attn: Freda Wilson, Office and Finance Administrator

RE: INDUSTRIAL Water Use N7L1-1817
CLASS B – INDUSTRIAL
Mallik
Swan Channel - Mackenzie River

Dear Ms. Wilson,

Please find the enclosed Inspection Report for your review and records.

An electronic copy (un-editable Adobe pdf.) has also been provided by e-mail.

If you have any questions or concerns regarding the enclosed, and/or if additional information is required please contact me at (867) 777-8909.

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT

Enclosure: Industrial Water Use Inspection Report and Cover Letter (4 pages)

Aboriginal Affairs and Northern Development Canada
http://www.aandc-aadnc.gc.ca

Affaires autochtones et Développement du Nord Canada
http://www.aadnc-aandc.gc.ca

North Mackenzie District
P.O. Box 2100
Inuvik, NT X0E 0T0

Telephone: 867-777-8900
Fax: 867-777-2090

March 29, 2014

Aurora Research Institute
Box 1450
Inuvik, NT X0E 0T0

Attn: Pippa Seccombe-Hett

RE: INDUSTRIAL Water Use N7L1-1817
CLASS B – INDUSTRIAL
Mallik
Swan Channel - Mackenzie River

Dear Ms. Seccombe-Hett,

An inspection of the Aurora Research Institute Water Licence N7L1-1817 (expiry on November 30, 2016) was conducted on August 26, 2013. The operation under the above mentioned Industrial Water Use was inspected to assess compliance and ensure that the terms and conditions were met. Enclosed is a copy of the Inspection Report (3 pages) for your review and records.

There were no violations identified during the course of this Inspection. Please review and address the concerns and other items throughout the Inspection Report.

Please note that it is the Licensee's responsibility to ensure compliance with all of the terms and conditions of its Water Licence. A copy of this report will be sent to the Northwest Territories Water Board for their review and public records.

If you have any questions regarding the enclosed and/or if additional information is required, please do not hesitate to contact me at (867) 777-8900.

Sincerely,

Jan Davies
Water Resource Officer

Cc: Conrad Baetz, District Manager, North Mackenzie District, Inuvik, NT

Enclosure: Industrial Water Use Inspection Report (3 pages)

INDUSTRIAL WATER USE INSPECTION REPORT

LICENCE #:	**N7L1-1817, Mallik**	**EXPIRY DATE:**	**November 30, 2016**
LICENCEE:	**Aurora Research Institute**	**PREVIOUS INSPECTION:**	**October 02, 2012**
COMPANY REP:	**Pippa Seccombe-Hett**	**INSPECTION DATE:**	**August 26, 2013**

WATER SUPPLY

Source:	Swan Channel - Mackenzie River	Quantity Used:	N/A
Owner/Operator:	Aurora Research Institute	Meter Reading:	N/A

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Intake Facilities	N/A	Storage Structures	N/A	Treatment Systems	N/A	Recycling	N/A
Flow Meas. Device	N/A	Conveyance Lines	N/A	Pumping Stations	N/A	Chem. Storage	N/A
						Modifications	N/A

Water Supply Comments:
N/A

WASTE DISPOSAL – WELL WASTE

Disposal Method		Off - Site Removal							
Off-Site Removal	Y	Drilling Sump	N	Downhole Injection	N	Treat and Landspread	N	Other	N/A

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Sump Liners	N/A	Sump Treatment	N/A	Freeboard	N/A
Erosion	N/A	Construction	N/A		
SNP Samples Collected	N/A				

Well Waste Comments:
- Subsidence similar to before.
- Ponding occurring in subsided areas.
- Large cracks present on 2002 camp sump.

WASTE DISPOSAL – SOLID WASTE

Disposal Method		Landfill					
Open Dump	N	Landfill	Y	Burn & Landfill	N	Underground	N
Offsite Removal	N	Other	N/A				
Owner / Operator	Aurora Research Institute						

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Runoff Diversion	N/A	SNP Samples Collected	N/A

INDUSTRIAL WATER USE INSPECTION REPORT

Solid Waste Comments:
- Site clean of debris.
- It looks like there is some garbage that washed up onto the site. If on site it would be prudent to remove.

GENERAL CONDITIONS/REPORTS/PLANS

Indicate: A - Acceptable U - Unacceptable N/A - Not Applicable N/I - Not Inspected

C &R Plan	N/A	Records & Reporting	N/I	Final Report	N/A
Geotechnical Inspection	N/A	Posting, Signage	N/A	Contingency Plan	N/A
Restorations Activities	A	Spills	A	O&M Plan	N/A
Maintenance	N/A	Modifications	N/A	Annual Report	N/I

General Condition Comments:
- Subsidence on camp sump had some restoration and borehole sampling work done back in August 2009.
- Sumps look similar, compared to before.
- 10-20% vegetation cover on most sumps, slow vegetation growth.
- Very little bare soil due to disturbance.
- Area appears to have little influence from the Mallik Gas Hydrate Research project.
- No sumps were used for the Mallik 2006-08 Gas Hydrate Production Research Project, however there were commitments to monitor the other drilling sumps Mallik 2L-38 and Mallik 3L/4L/5L-38 in the area.

NON-COMPLIANCE/VIOLATIONS OF ACT OR LICENCE

N/A

Inspector's Signature:

INDUSTRIAL WATER USE INSPECTION REPORT

Inspection Images:

Figure 1
1998 Flare Pit at northend, subsidence present.

Figure 2
1998 Camp Sump subsidenceat and ponding at east end.

Figure 3
1998 Drill Sump subsidence and ponding at east end and throughout.

Figure 4
March 2, 2007 cuttings spill area. No cuttings seen and no sign of impacts.

Figure 5
2002 Camp Sump subsidence at southend.

Figure 6
2002 Drill Sump subsidence at southend.

Beaufort Delta Region
Bag Service #1
Inuvik, NT X0E 0T0

Telephone: 867 777-8900
Fax: 867-777-2090

August 8, 2014

Inuvialuit Water Board
P.O. Box 2531
Inuvik, NT X0E 0T0

Attn: Freda Wilson, Office and Finance Administrator

RE: INDUSTRIAL Water Use N7L1-1817
CLASS B – INDUSTRIAL
Mallik Project

To: Ms. Wilson,

Please find the enclosed Inspection Report for your review and records.

An electronic copy (un-editable Adobe pdf.) has also been provided by e-mail.

If you have any questions or concerns regarding the enclosed, and/or if additional information is required please contact me at (867) 777-8900.

Regards,

ORIGINAL Signed

Donald Arey
Manager Resource Management
Department of Lands
Beaufort Delta Region-Inuvik

Cc:
Conrad Baetz, Superintendent, Dept. of Lands, Beaufort Delta Region
Stephen Charlie, Superintendent, Dept. of Environment and Natural Resources

Beaufort Delta Region
Bag Service #1
Inuvik, NT X0E 0T0

Telephone: 867 777-8900
Fax: 867-777-2090

August 8, 2014

Aurora Research Institute
Box 1450
Inuvik, NT X0E 0T0

Attn: Pippa Seccombe-Hett

RE: INDUSTRIAL Water Use N7L1-1817
CLASS B - INDUSTRIAL
Swan Channel

Dear Pippa Seccombe-Hett,

An inspection of the above noted operation was conducted on July 31, 2014 by Manager Resource Management Donald Arey.

Enclosed is a copy of the Industrial Water Use Inspection Report.

If you have any questions, please contact me at 867 777-8900.

Sincerely,

ORIGINAL SIGNED

Donald Arey
Manager Resource Management
Department of Lands
Beaufort Delta Region-Inuvik

Cc:
Conrad Baetz, Superintendent, Dept. of Lands, Beaufort Delta Region
Stephen Charlie, Superintendent, Dept. of Environment and Natural Resources

INDUSTRIAL WATER USE INSPECTION REPORT

LICENCE #:	**N7L1-1817**	**EXPIRY DATE:**	**November 30, 2016**
LICENCEE:	**Aurora Research Institute**	**PREVIOUS INSPECTION:**	**August 26, 2013**
COMPANY REP:	**Pippa Seccombe-Hett**	**INSPECTION DATE:**	**July 31, 2014**

WATER SUPPLY

Source:	Swan Channel	Quantity Used:	N/A
Owner/Operator:	Aurora Research Institute	Meter Reading:	N/A

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Intake Facilities	N/A	Storage Structures	N/A	Treatment Systems	N/A	Recycling	N/A
Flow Meas. Device	N/A	Conveyance Lines	N/A	Pumping Stations	N/A	Chem. Storage	N/A
						Modifications	N/A

Water Supply Comments:
N/A

WASTE DISPOSAL – WELL WASTE

Disposal Method		Off-Site Removal							
Off-Site Removal	Y	Drilling Sump	N	Downhole Injection	N	Treat and Landspread	N	Other	

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Sump Liners	N/A	Sump Treatment	N/A	Freeboard	N/A
Erosion	N/A	Construction	N/A		
SNP Samples Collected	N/A				

Well Waste Comments:
Due to the amount of rain this year it was difficult to determine if any further subsidence has occured.

WASTE DISPOSAL – SOLID WASTE

Disposal Method		LandFill					
Open Dump	N	Landfill	N	Burn & Landfill	N	Underground	N
Offsite Removal	N	Other	N/A				
Owner / Operator	Aurora Research Institute						

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

Runoff Diversion	N/A	SNP Samples Collected	N/A

INDUSTRIAL WATER USE INSPECTION REPORT

Solid Waste Comments:
No solid waste observed at site.

GENERAL CONDITIONS/REPORTS/PLANS

Indicate: **A - Acceptable** **U - Unacceptable** **N/A - Not Applicable** **N/I - Not Inspected**

C &R Plan	N/A	Records & Reporting	N/I	Final Report	N/A
Geotechnical Inspection	N/A	Posting, Signage		Contingency Plan	N/A
Restorations Activities	A	Spills	A	O&M Plan	N/A
Maintenance	N/A	Modifications	N/A	Annual Report	N/I

General Condition Comments:
Due to the amount of rain over the summer, inspector was unable to determine if any further subsidence has occurred. No sumps were used for this program however committments to monitor the sumps were required. The 2,3,4,5 and 6L-38 posts were still intact.

Inspector's Signature: _____ ORIGINAL SIGNED_____

Inspection Images:

Figure 1

Aerial of posts

Figure 2

1998 camp sump

Figure 3

1998 drill sump

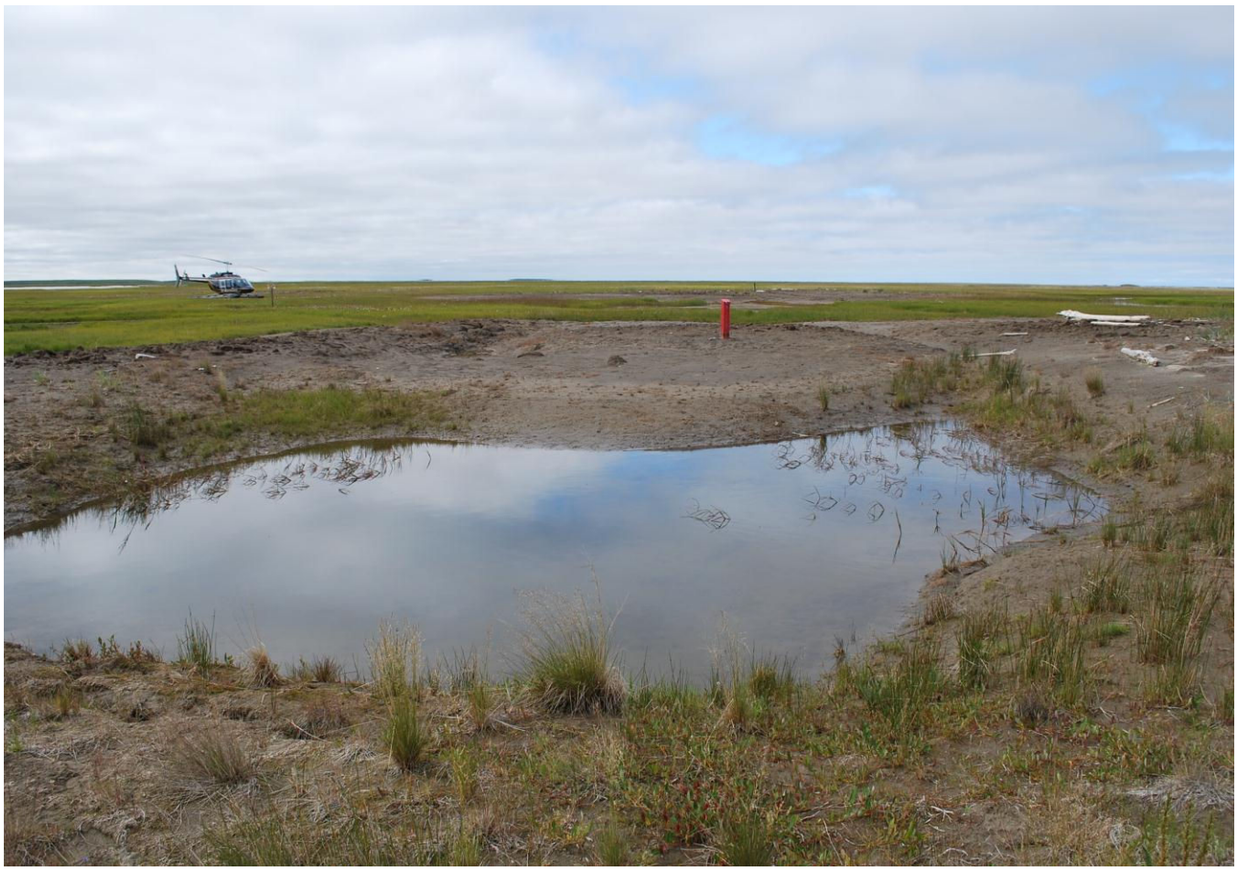


Figure 4

2002 camp sump

Figure 5
2002 drill sump

Figure 6
2L-38 post

Figure 7
1998 flare pit

APPENDIX D Site Photographs

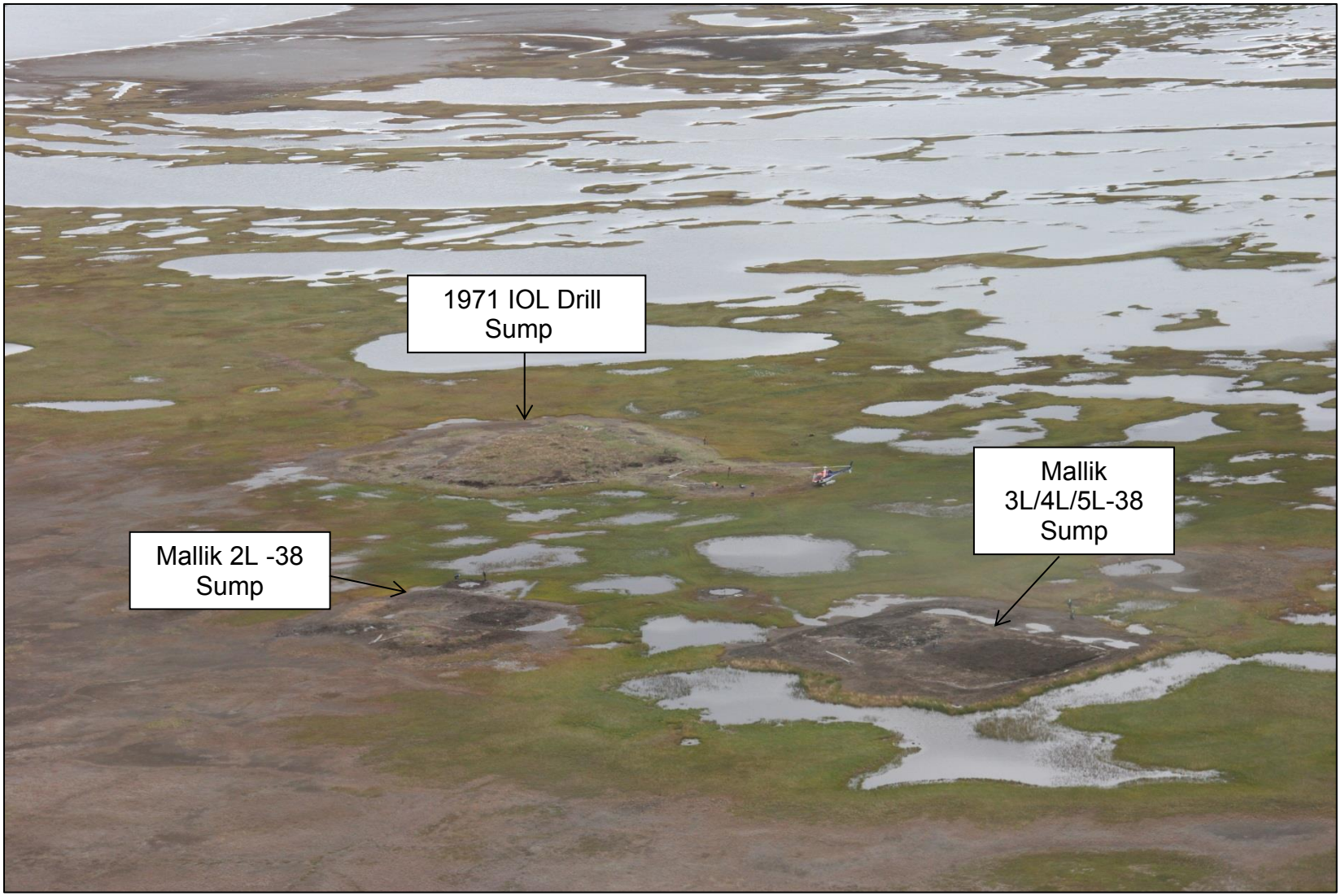


Photo D-1 Aerial overview of the Mallik site looking north (photo taken on August 5, 2008)

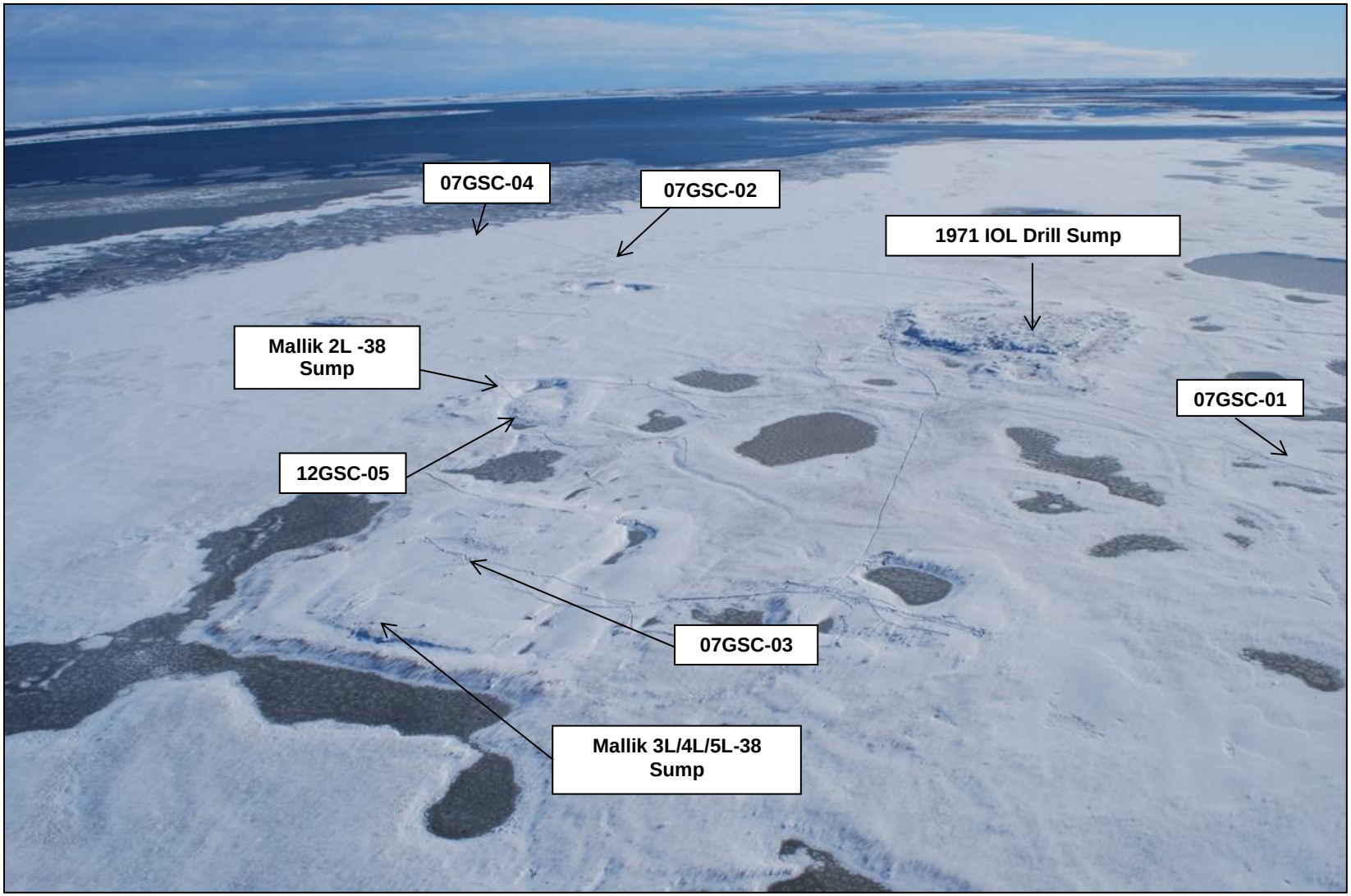


Photo D-2 Aerial overview of the Mallik site looking west (photo taken on September 28, 2010)

Photo D-3 Aerial overview of the Mallik site (looking south) (photo taken on August 20, 2011)

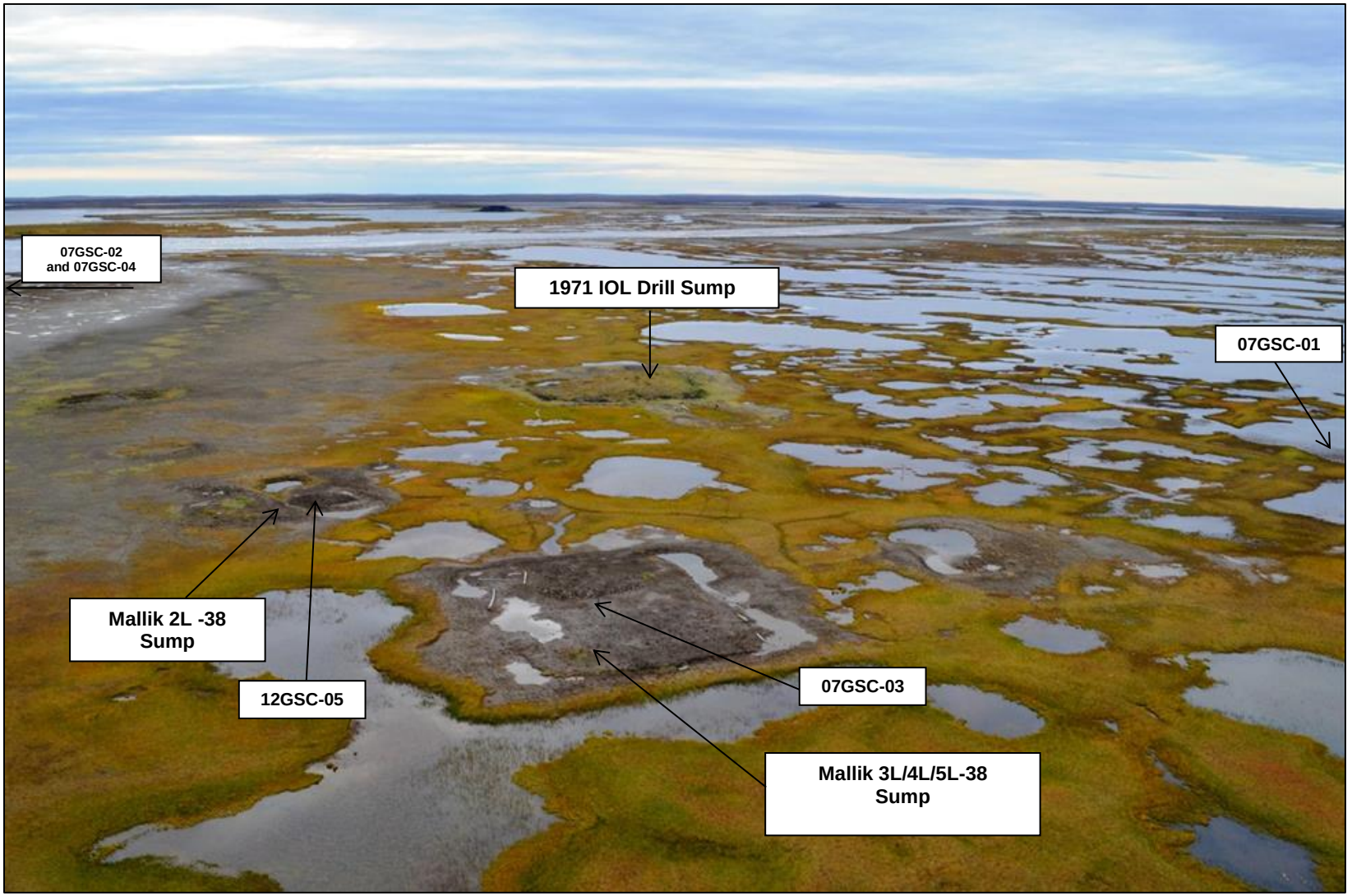


Photo D-4 Aerial overview of the Mallik site (looking south) (photo taken on September 5, 2012)

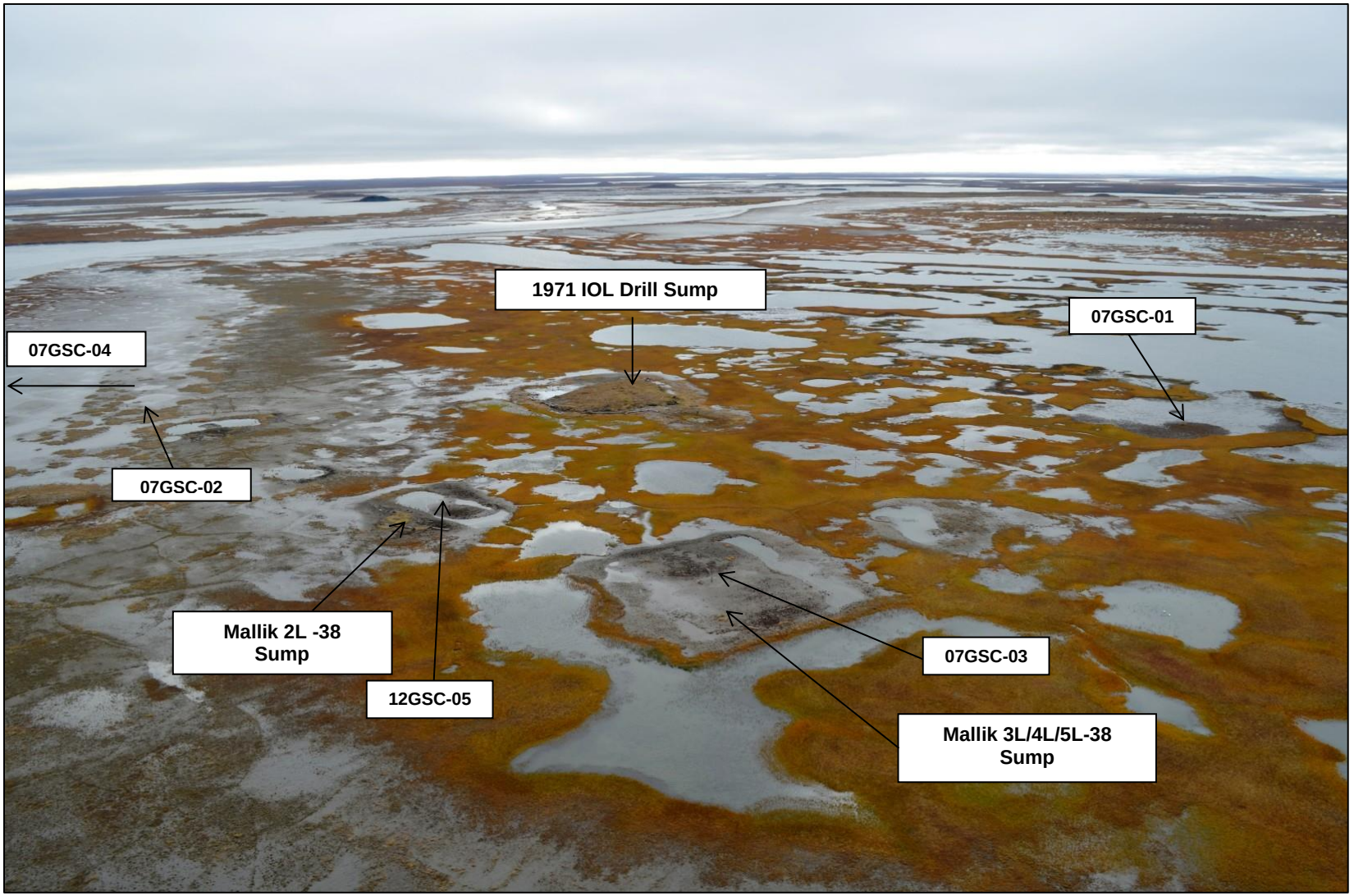


Photo D-5 Aerial overview of the Mallik site (looking south) (photo taken on September 10, 2013)

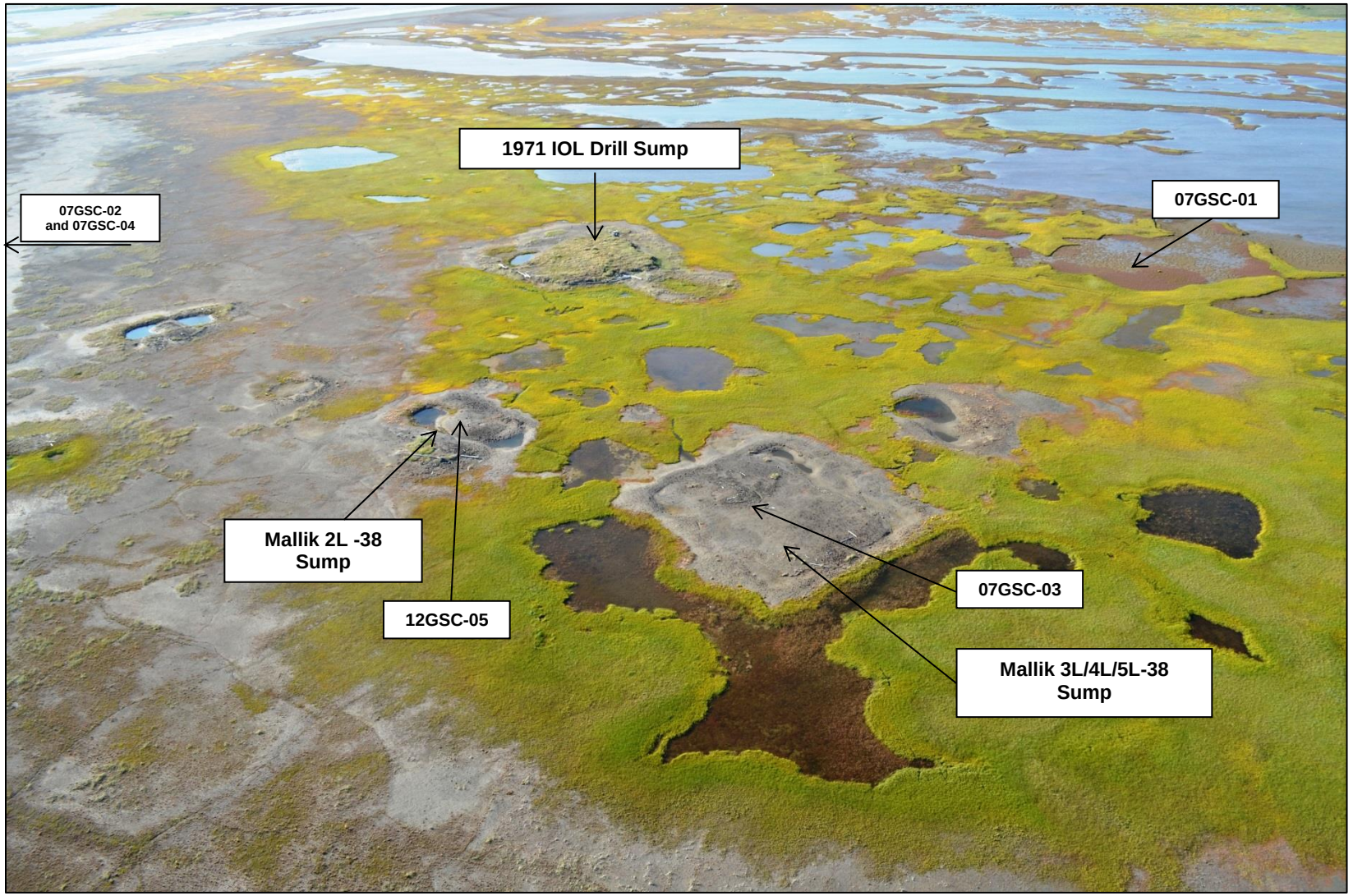


Photo D-6 Aerial overview of the Mallik site (looking south) (photo taken on August 12, 2014)

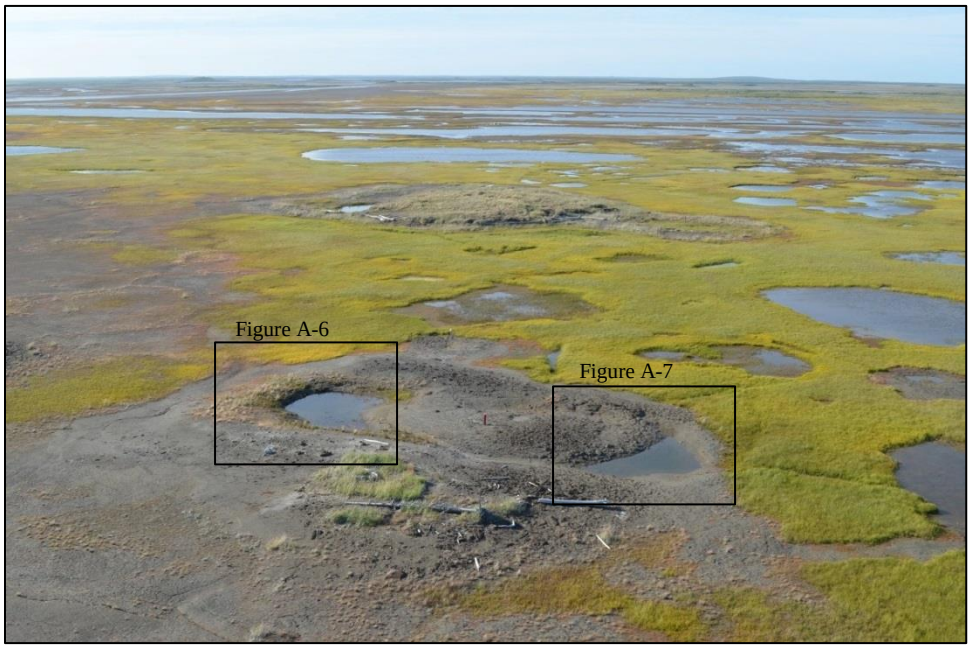


Photo D-7 **Oblique view of Mallik 2L-38 Sump (looking south) (photo taken on August 12, 2014)**

Photo D-8 **Subsidence area at the eastern end of the Mallik 2L-38 Sump (photo taken on August 12, 2014)**

Photo D-9 **Subsidence area at the western end of the Mallik 2L-38 Sump (photo taken on August 12, 2014)**

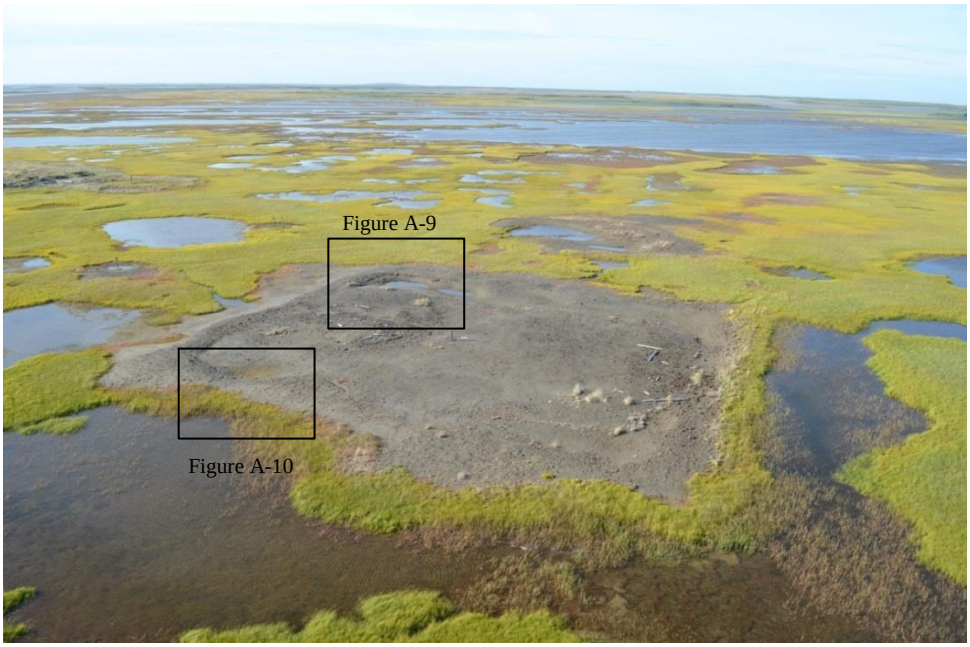


Photo D-10 **Aerial view of Mallik 3L/4L/5L-38 Sump (looking south) (photo taken on August 12, 2014)**

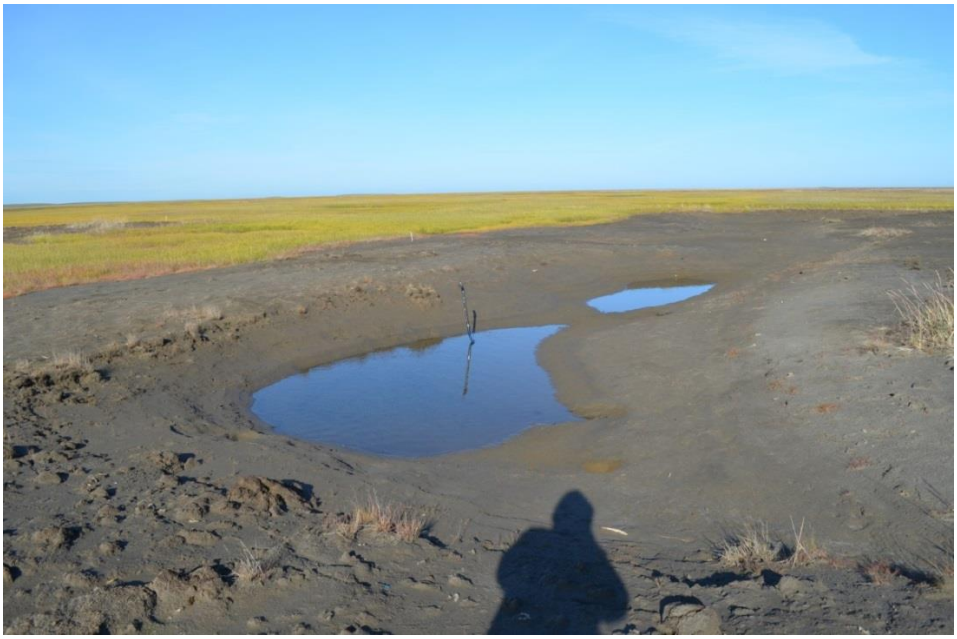


Photo D-11 Subsidence and water ponding along the western corner of the 3L/4L/5L-38 Sump (photo taken on August 12, 2014)

Photo D-12 Localized depression (dashed area) along the eastern corner of the 3L/4L/5L-38 Sump (photo taken on August 12, 2014)

Photo D-13 Various wildlife tracks observed at the site (photo taken on August 12, 2014)

Photo D-14 Ripple marks from a recent storm surged that flooded the Mallik site sometime between September 6th and September 20th, 2012

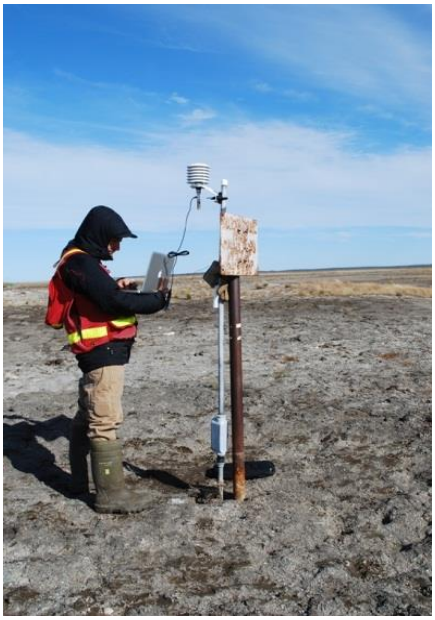


Photo D-15 Air and ground temperature sensors adjacent to Mallik 2L-38 wellhead

APPENDIX E Thermistor Data

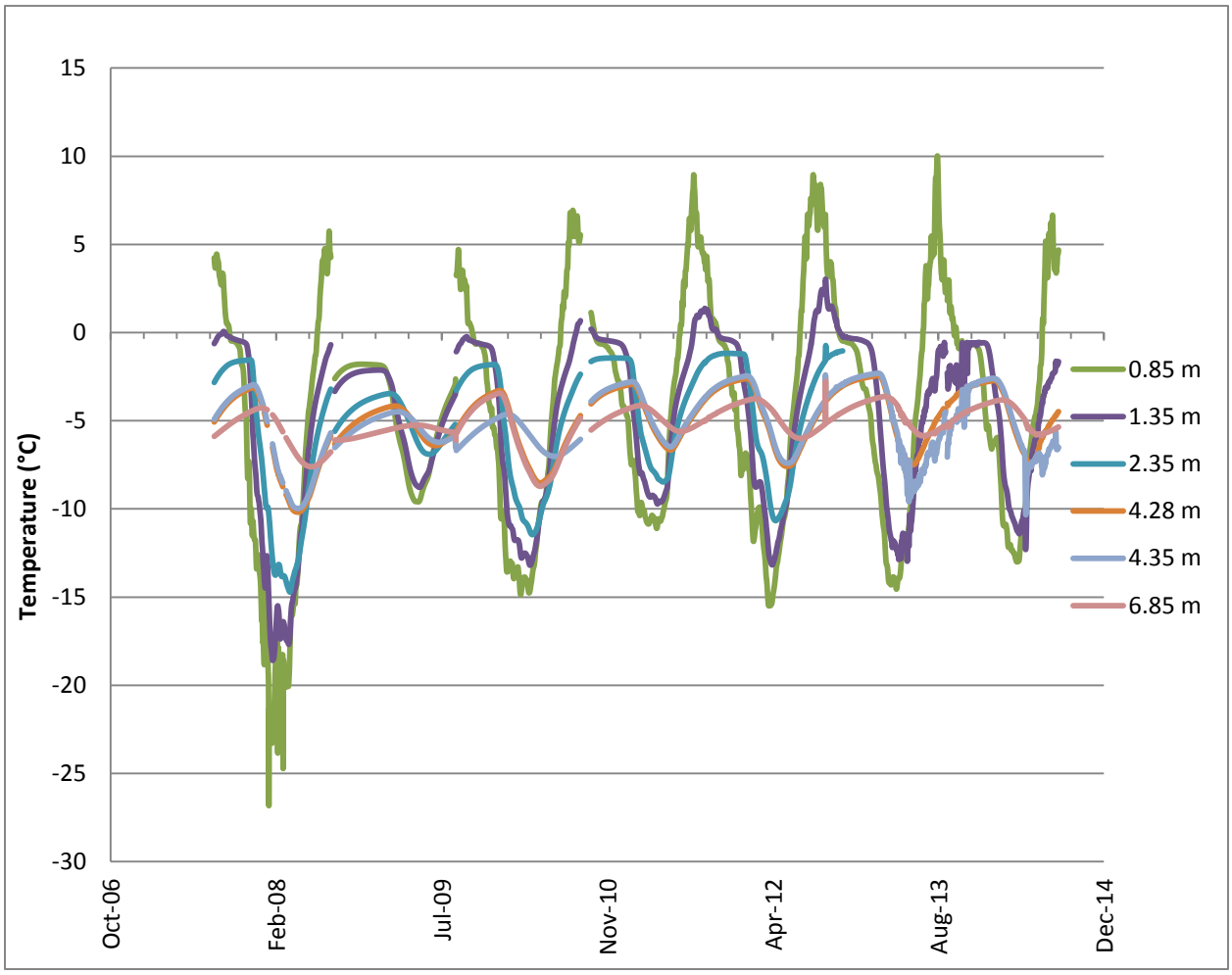


Figure E-1 Daily average ground temperatures for cable 07GSC-01 from August 19, 2007 to August 12, 2014

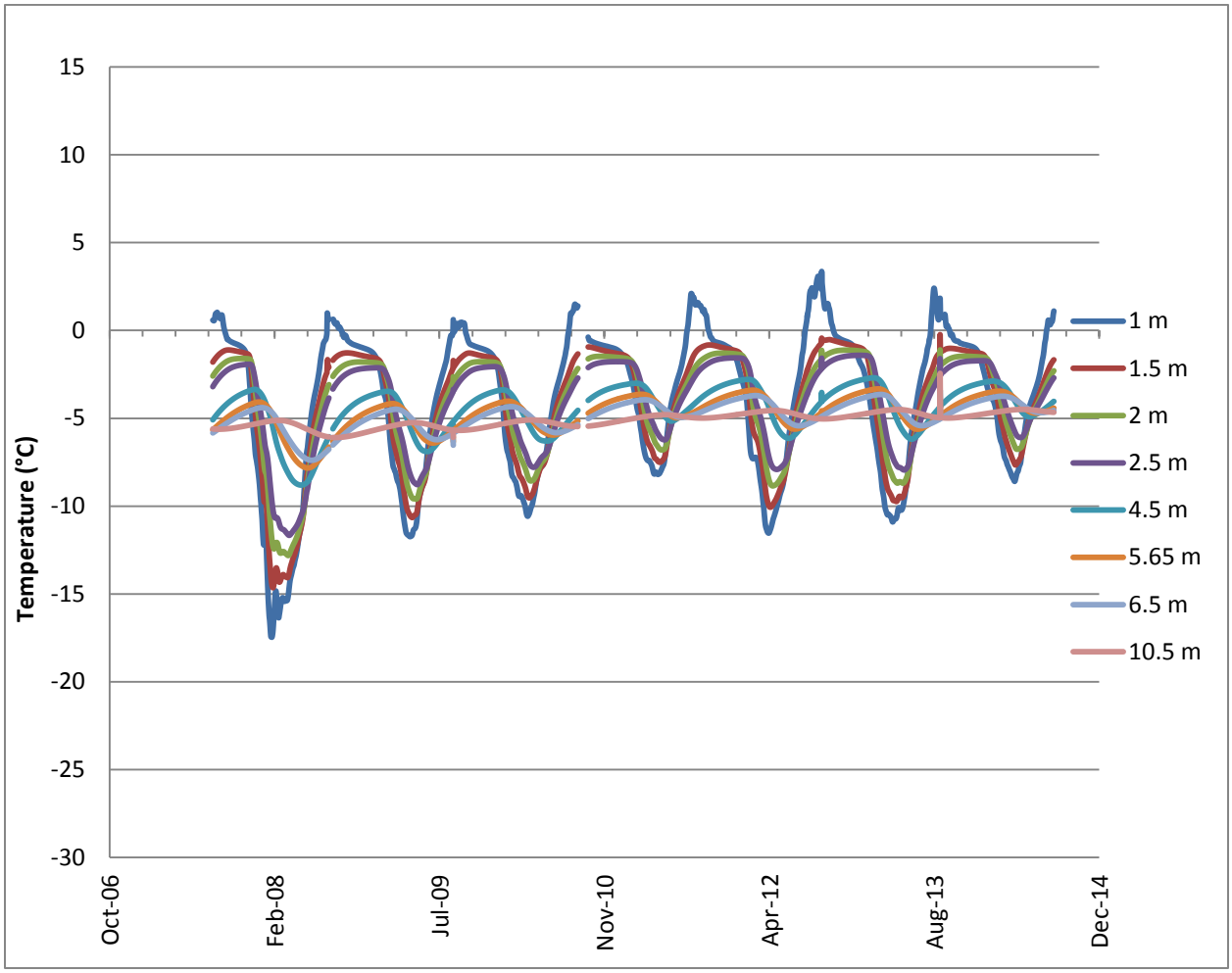


Figure E-2 Daily average ground temperatures for cable 07GSC-02 from August 19, 2007 to August 12, 2014

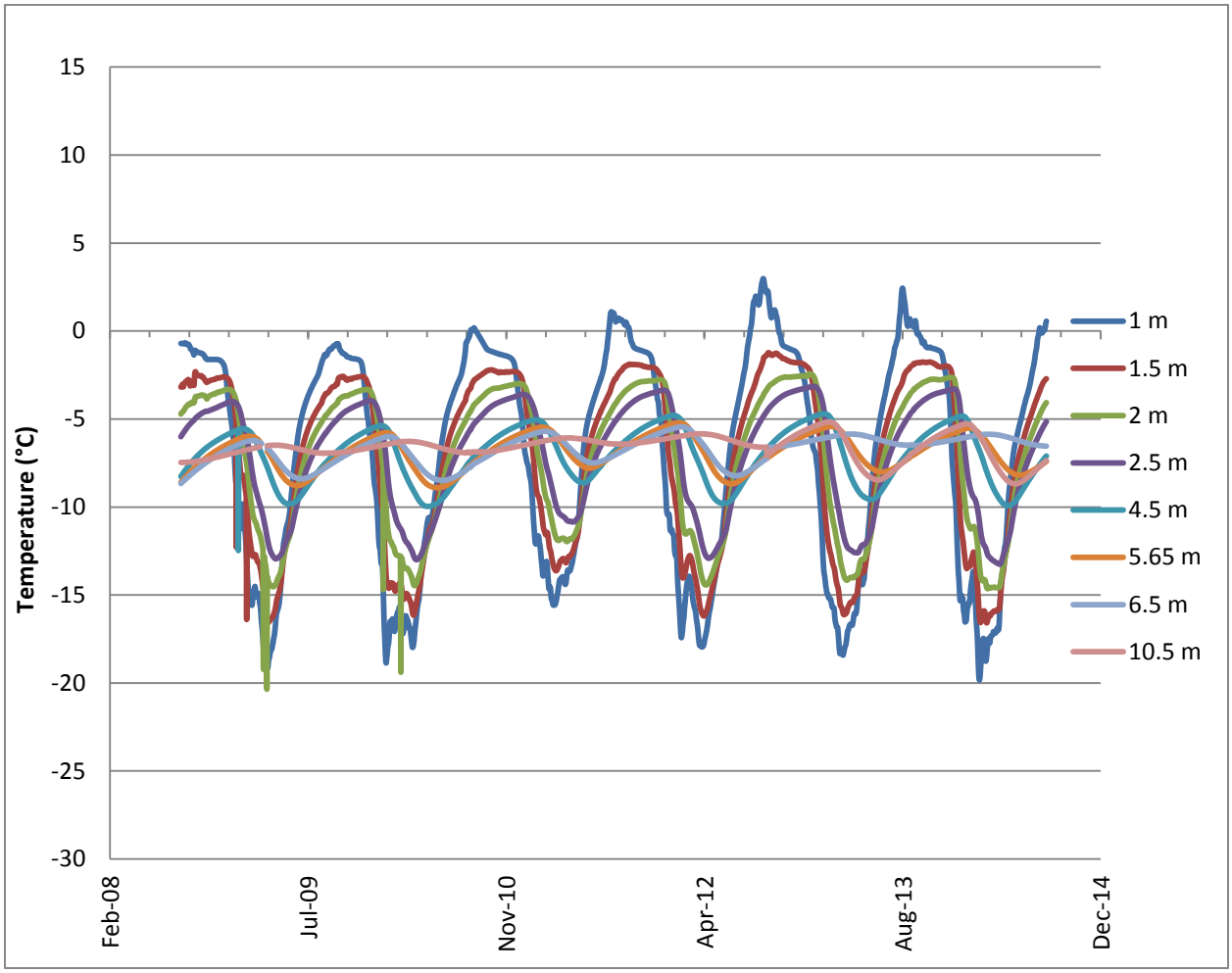


Figure E-3 Daily Average Ground temperatures for Cable 07 GSC-03 from August 17, 2008 to August 12, 2014

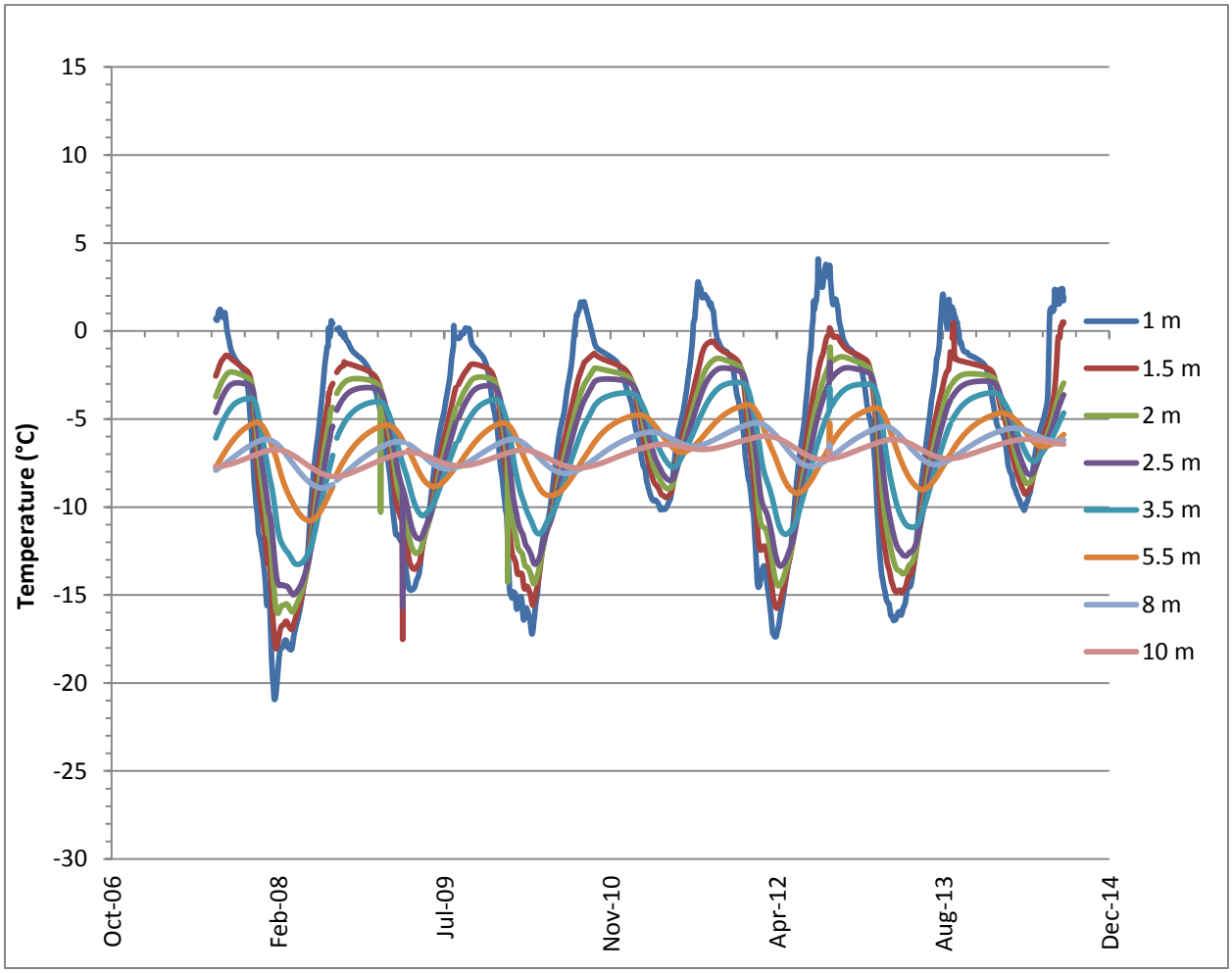


Figure E-4 Daily Average Ground Temperature for Cable 07GSC-04 from August 19, 2007 to August 12, 2014

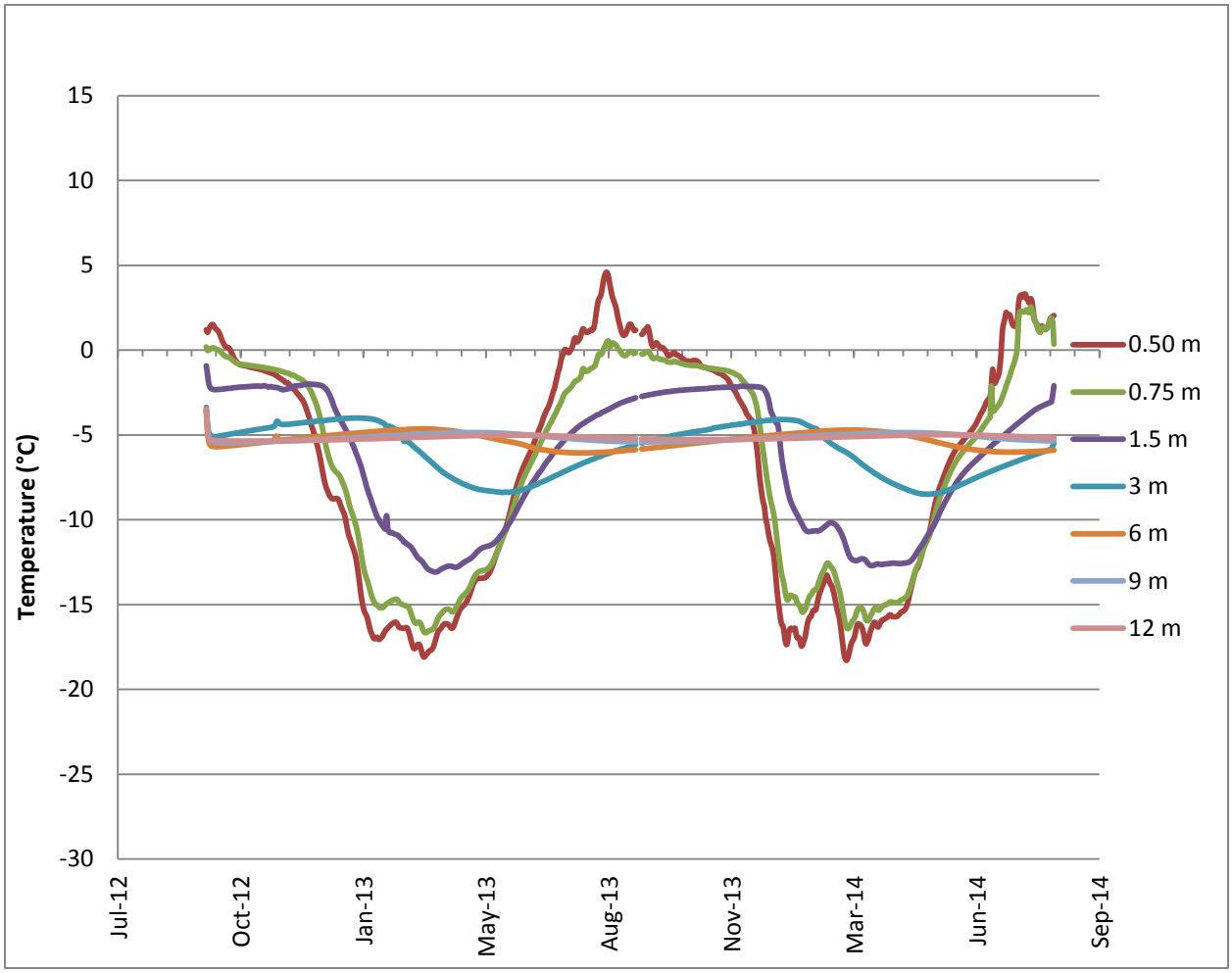


Figure E-5 Daily Average Ground temperature for Cable12GSC-05 from September 20, 2012 to August 12, 2014

APPENDIX F

Drilling Waste Sump Monitoring and Retrofit Program, Project Description

Aurora Research Institute Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program

PROJECT DESCRIPTION

SUBMISSION TO THE ENVIRONMENTAL IMPACT SCREENING COMMITTEE

SUBMISSION

Operator:
Aurora Research Institute, Aurora College
Inuvik, Northwest Territories

Prepared by:
KAVIK-AXYS Inc.
Calgary, Alberta
and
Inuvik, Northwest Territories

February 2008

KA90930

Executive Summary

What is the Proposed Program?

Components

The Aurora Research Institute, Aurora College (ARI), operator of the 2006-2008 Mallik Gas Hydrate Production Research Project on behalf of the Japan Oil, Gas and Metals National Corporation (JOGMEC) and Natural Resources Canada (NRCan), is proposing to conduct a seven-year program at the Mallik L-38 site to monitor the stability of the Mallik 2L-38 and 3L/4L/5L-38 drilling waste sumps (the Program). Field work will be conducted periodically throughout the year; it will commence in 2008 and conclude in 2014. The Program will involve the following activities:

- Active layer and ground temperature monitoring of the sumps, around the perimeter of the sumps and in adjacent undisturbed terrain;
- Geophysical surveys of both sumps and surrounding areas;
- Soil sampling and analysis of undisturbed areas adjacent to the sumps;
- Surface water sampling and analysis of any ponded water located on or near the sumps and in adjacent undisturbed terrain;
- Sump recontouring;
- Sump revegetation trials;
- Measurement of the storm surge flooding frequency and duration; and
- Snow cover profiling of the sump caps, around the perimeter of the sumps and in adjacent undisturbed terrain.

The Program will further existing knowledge of sump integrity and monitoring techniques, will provide training for ARI students interested in northern science and engineering, and will meet the commitments of the 2006-2008 Mallik Gas Hydrate Production Research Project. The Program has been designed to meet and exceed the criteria outlined in the *Protocol for the Monitoring of Drilling Waste Disposal Sumps* (NWT Water Board 2005). Reports of the findings of the monitoring activities will be submitted to the NWT Water Board annually, and peer-reviewed scientific paper(s) in the scientific/engineering literature will be produced if the results warrant.

Location

All Program work will be conducted at the existing Mallik L-38 site (SDL 060) on Richards Island. The Mallik L-38 site is located in the nearshore floodplain on the western side of Mallik Bay. The site coordinates are approximately 69°27’38”N, 134°39’42”W. The Project is located on Crown land in the Inuvialuit Settlement Region (ISR).

Proponent

The operator of the Program is ARI, on behalf of JOGMEC and NRCan.

Why was an Assessment Done?

Environmental Impact Screening Committee

The Environmental Impact Screening Committee (EISC) screens all proposed developments inside the ISR for impacts that may negatively affect the environment and/or Inuvialuit wildlife harvesting.

Other approvals

A Northwest Territories Scientific Permit under the *Scientists Act* from ARI is required to conduct research in the ISR.

How was the Public Involved?

Purpose of consultation

The purpose of the consultation meetings was to inform the Aklavik, Inuvik and Tuktoyaktuk Hunters and Trappers Committees about the proposed Program and to listen to and address any concerns raised.

Meetings and correspondence

Community consultation meetings for the Program were conducted April 2 to 3, 2007 in Inuvik, Aklavik and Tuktoyaktuk. Additional consultation on the sump program was conducted as part of information and consultation sessions for the 2006-2008 Mallik Gas Hydrate Production Research Project on June 22 and July 3, 2007. Section 10 summarizes issues and responses; Appendix C presents the complete consultation record.

What was Assessed?

Focus of assessment

The assessment was conducted to ascertain whether the Program is likely to have adverse affects on the environment or Inuvialuit harvesting. The assessment focused on potential effects on migratory birds, grizzly bear and Inuvialuit harvesting. The assessment incorporated elements of both traditional and current knowledge of the Program area, and concerns raised during consultations.

Program effects

The Program is not expected to cause negative environmental effects or impact Inuvialuit harvesting, provided the mitigation measures outlined in Section 12 are applied. The assessment results are summarised below.

Cumulative effects

Activity levels in the western Mackenzie Delta are relatively low, but are likely to increase if the Mackenzie Gas Project proceeds. There is potential for the effects of individual projects to act cumulatively. However, given the short-term schedule of isolated activities, relatively small terrestrial footprint, and proposed mitigation measures, no measurable Program-specific effects are predicted. Thus, the Program is not expected to contribute significantly to cumulative effects.

Did the Assessment Find Anything of Concern?

Activity	Potential Impacts and Mitigation Measures
Helicopter use	• Noise generated by helicopters has the potential to cause a temporary sensory disturbance to wildlife. Helicopter noise may also disturb traditional Inuvialuit harvesting activities. Mitigations will involve conformance with the Inuvialuit Game Council (IGC) Overflight Guidelines and recommendations (Appendix B) wherever possible. The number of flights will be minimized wherever possible, hovering and circling will be minimized, migratory bird staging areas and aggregations of wildlife will be avoided. The HTCs will be notified by means of an annual field plan of when field activities will be occurring.
Human presence	• Presence of humans in the Program area may cause temporary disturbance to wildlife. Mitigations include avoiding wildlife features (e.g., nests, dens) wherever possible, not walking offsite onto the tundra, and avoiding wildlife. A wildlife or environmental monitor will accompany Program crews during field activities and site visits when logistically feasible. • Wildlife may approach the Program site, potentially resulting in a wildlife encounter or incident. Mitigations include briefly surveying the Program area prior to landing, storing food and any generated waste in sealed containers, hauling out all waste, equipment and materials and contacting ENR if a bear is sighted within 1 km of the Program site to determine an appropriate course of action. The wildlife monitor will monitor the area for approaching wildlife and will assist in managing wildlife encounters. The crew will be equipped with bear deterrent measures and will follow the ENR Bear Encounter Response Guidelines (Appendix D), if required.

Helicopter accident or malfunction	• A helicopter accident or malfunction could lead to a spill or leak. Only small amounts of fuel will be on-site at any time and will be stored in an appropriate Canadian Standards Association (CSA) approved container. A drip tray will be used during refuelling of machinery and equipment. Spill clean-up materials will be on hand; leaks or spills will be contained immediately. The Program will employ the Spill Prevention Plan and Emergency Response Plan developed for the 2006-2008 Mallik Gas Hydrate Production Research Project, if necessary.

Table of Contents

1 Title 1
2 Contact Information 2
3 Regulatory Approvals 3
4 Location 4
5 Development Summary 7
5.1 Background 7
5.2 Purpose and Scope 7
5.2.1 Reporting 8
5.3 Mallik L-38 Site Sumps 8
5.3.1 1972 Imperial Oil Resources Ltd. Mallik L-38 Sump 8
5.3.2 1998 JAPEX/JNOC/GSC Mallik 2L-38 Sump 9
5.3.3 2002 JAPEX/JNOC/GSC *et al.* Mallik 3L/4L/5L-38 9
5.4 Previous Site Surveys 10
5.5 Sump Monitoring Program 13
5.5.1 Active Layer and Ground Temperature Monitoring 13
5.5.2 Geophysical Surveys and Soil Sampling 14
5.5.3 Surface Water Sampling 14
5.5.4 Sump Recontouring (Supplementary Activity) 14
5.5.5 Sump Revegetation (Supplementary Activity) 15
5.5.6 Storm Surge Monitoring (Supplementary Activity) 15
5.5.7 Snow cover Profiling (Supplementary Activity) 15
5.6 Transportation 15
5.7 Personnel 16
5.8 Equipment 17
5.9 Waste Disposal 18
5.10 Fuel 18
5.11 Water 18
5.12 Infrastructure 18
6 Development Timetable 19
7 Technology 21
8 Alternatives 22
9 Traditional and Other Uses 23
9.1 Harvesting Activities 23
10 Community Consultation 24
11 Environmental Overview 25
11.1 Introduction 25
11.2 Biophysical Resource Summary 25
11.2.1 Terrain 25
11.2.2 Vegetation 26
11.2.3 Wildlife 26
11.2.4 Fish 28
11.2.5 Historical Resources 29
12 Potential Environmental Impacts and Mitigation Measures 30
12.1 Wildlife Monitors 31
12.2 Effects of the Environment on the Program 32
12.3 Impact Assessment Summary 32

13 Cumulative Effects 33
13.1 Spatial and Temporal Overlaps with Other Projects 33
13.2 Assessment of Cumulative Effects 33
14 Emergency Response Plan 34
15 Clean-up, Disposal and Decommissioning Plan 35
16 Other Environmental Assessments 36
17 References 37
Appendix A ARI Response to NEB Information Request 39
Appendix B Inuvialuit Game Council 2002 Overflight Guidelines 52
Appendix C Record of Consultations 54
Appendix D ENR 2005 Bear Encounter Response Guidelines 68

List of Tables

Table 2-1 Contact Names and Addresses 2
Table 3-1 Approval Requested for the Program 3
Table 4-1 Approximate Distances from Mallik L-38 Site 4
Table 5-1 Summary of Mallik L-38 Site Surveys Conducted Since 2005 11
Table 5-2 List of Required Program Equipment 17
Table 6-1 Program Schedule 19
Table 10-1 Summary of Concerns Raised and Responses 24
Table 11-1 Wildlife Species with Special Conservation Status in the Program Area 27
Table 12-1 Potential Environmental Effects and Proposed Mitigation Strategies 30

List of Figures

Figure 4-1 Regional Overview 5
Figure 4-2 Mallik L-38 Site 6
Figure 5-1 Mallik 2L-38 Sump (August 2006) 9
Figure 5-2 Mallik 3L/4L/5L-38 Sump – Large Lobe (September 2006) 10

Abbreviations

ARI ..... Aurora Research Institute, Aurora College
COSEWIC ..... Committee on the Status of Endangered Wildlife in Canada
CSA ..... Canadian Standards Association
EISC ..... Environmental Impact Screening Committee
GNWT ..... Government of Northwest Territories
GSC ..... Geological Survey of Canada
EM ..... Electromagnetic
ENR ..... GNWT Environment and Natural Resources
HTC ..... Hunters and Trappers Committee
IGC ..... Inuvialuit Game Council
IORL ..... Imperial Oil Resources Ltd.
INAC ..... Indian and Northern Affairs Canada
ISR ..... Inuvialuit Settlement Region
JAPEX ..... JAPEX Canada Ltd.
JNOC ..... Japan National Oil Corporation
JOGMEC ..... Japan Oil, Gas and Metals National Corporation
KIBS ..... Kendall Island Bird Sanctuary
masl ..... metres above sea level
NEB ..... National Energy Board
NRCan ..... Natural Resources Canada
NWT ..... Northwest Territories
PVC ..... Polyvinyl chloride
SARA ..... *Species at Risk Act*
SDL ..... Significant Discovery Licence
TDS ..... total dissolved solids

1 Title

Aurora/JOGMEC/NRCan Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program.

2 Contact Information

The Aurora Research Institute, Aurora College (ARI), operator of the 2006-2008 Mallik Gas Hydrate Production Research Project, is proposing on behalf of the Japan Oil, Gas and Metals National Corporation (JOGMEC) and Natural Resources Canada (NRCan), to undertake the seven-year Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring Program (the Program). NRCan is providing scientific leadership, and ARI is providing implementation and scientific support. Contact information is provided in *Table 2-1*.

Table 2-1 Contact Names and Addresses

Main Program Contact	Alternate Program Contact
Andrew Applejohn, Director Aurora Research Institute, Aurora College 191 Mackenzie Road P.O. Box 1450 Inuvik, Northwest Territories X0E 0T0 Phone: (867) 777-3298 ext. 22 Fax: (867) 777-4264 Email: aapplejohn@auroracollege.nt.ca	**Pippa Seccombe-Hett** Aurora Research Institute, Aurora College 191 Mackenzie Road P.O. Box 1450 Inuvik, Northwest Territories X0E 0T0 Phone: (867) 777-3298 ext 26 Fax: (867) 777-4264 Email: pseccombe-hett@auroracollege.nt.ca

3 Regulatory Approvals

The Program will involve site visits throughout the year, for a total of 2-19 days per year, for the duration of the seven-year Program. Approvals required for the Program are listed in

Table *3-1*. Program activities do not trigger the *Territorial Lands Act* and thus do not require a Land Use Permit. The Program will also not require a Water Licence under the *Northwest Territories Waters Act*.

Required fill material will be transported to the Mallik L-38 site during winter 2007-08 for sump retrofitting (Section 5.5.4), this activity will be conducted under the terms and conditions of the existing Class A Land Use Permit issued for the 2006-2008 Mallik Gas Hydrate Production Research Project (No. N2006A034, expires December 8, 2008). The fill material will be transported to the site via the government ice road from Inuvik to Tuktoyaktuk as per the terms of the Temporary Highway Access Permit for which the Mallik Gas Hydrate Research Project will apply for the 2007-2008 drilling season.

Table 3-1 Approval Requested for the Program

Agency and Contact Person	Approval Requested
Barb Chalmers, Secretary Environmental Impact Screening Committee P.O. Box 2120 Inuvik, NT X0E 0T0	Project Description Approval *Inuvialuit Final Agreement*
Paulo Flieg Manager, Scientific Services Aurora Research Institute 191 Mackenzie Road P.O. Box 1450 Inuvik, NT X0E 0T0	Northwest Territories Scientific Permit *Scientists Act*

4 Location

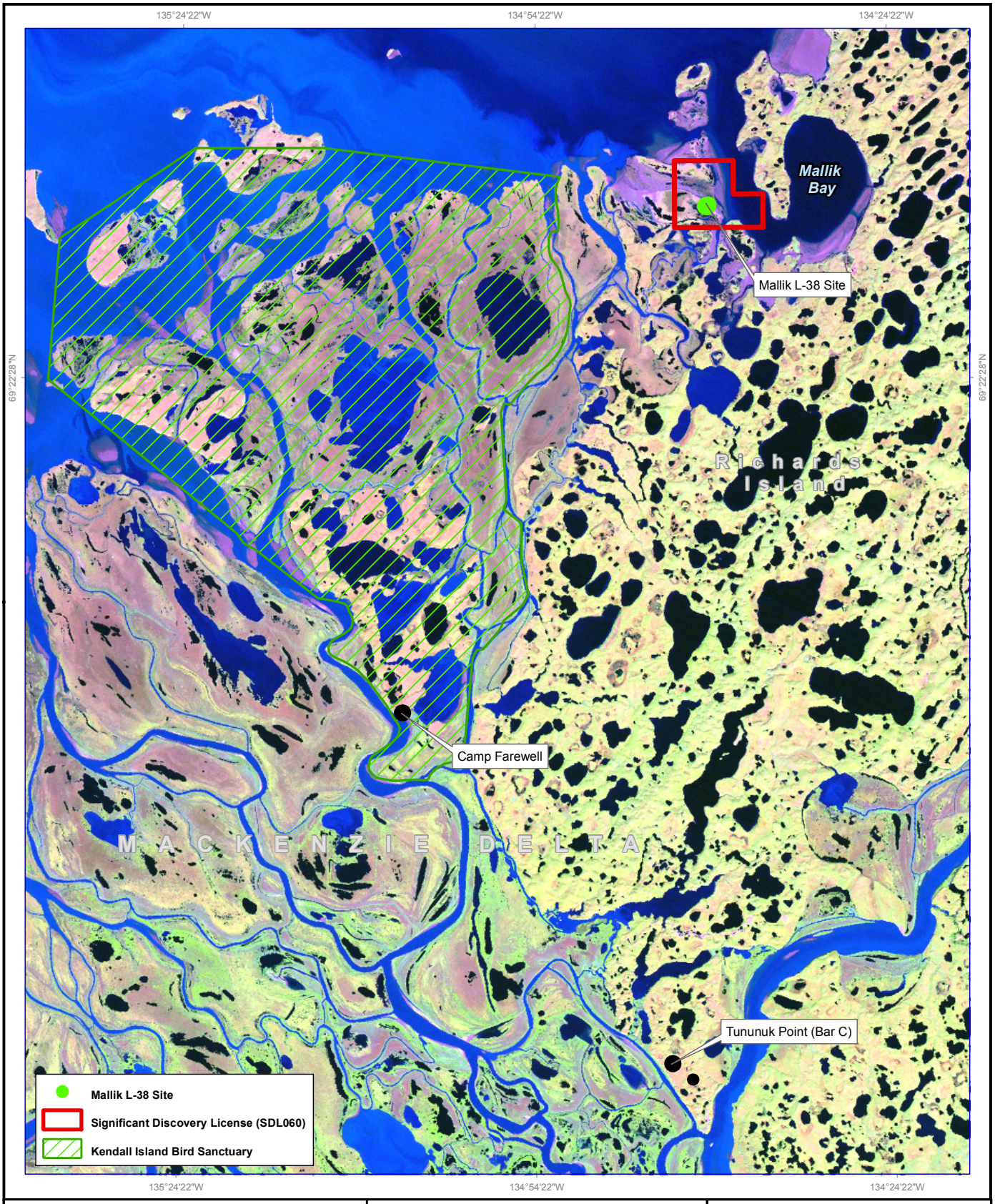
The proposed Program is located at the existing Mallik L-38 site on the western side of Richards Island in the Mackenzie Delta, Northwest Territories (NWT) (Figure 4-1). The Mallik L-38 site is located in the nearshore flood plain on the western side of Mallik Bay. The site coordinates are approximately 69°27'38"N, 134°39'42"W. The Program is located on Crown land in the Inuvialuit Settlement Region (ISR), within the Imperial Oil Resources Ltd. (IORL) Significant Discovery Licence (SDL) 060.

Straight line distances from the site to Inuvik, Aklavik and Tuktoyaktuk are provided in Table 4-1.

Table 4-1 Approximate Distances from Mallik L-38 Site

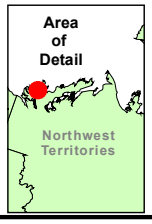
Project Site	**Distance to Inuvik** (km)	**Distance to Aklavik** (km)	**Distance to Tuktoyaktuk** (km)
Mallik L-38	130	140	65

In this document, the Mallik L-38 site, or *Program site*, refers to the area within the Mallik L-38 lease boundary (Figure 4-2). The *Program area* refers to the low-lying area of northwest Richards Island in the vicinity of the Project site, for the purposes of describing and assessing potential impacts to traditional use of the area (Section 9), and to the biophysical components that characterize the area (Sections 11, 12 and 13).



MALLIK 2L-38 AND 3L/4L/5L-38 SUMP MONITORING AND RETROFIT PROGRAM

Regional Overview



NORTH

3 0 3 6

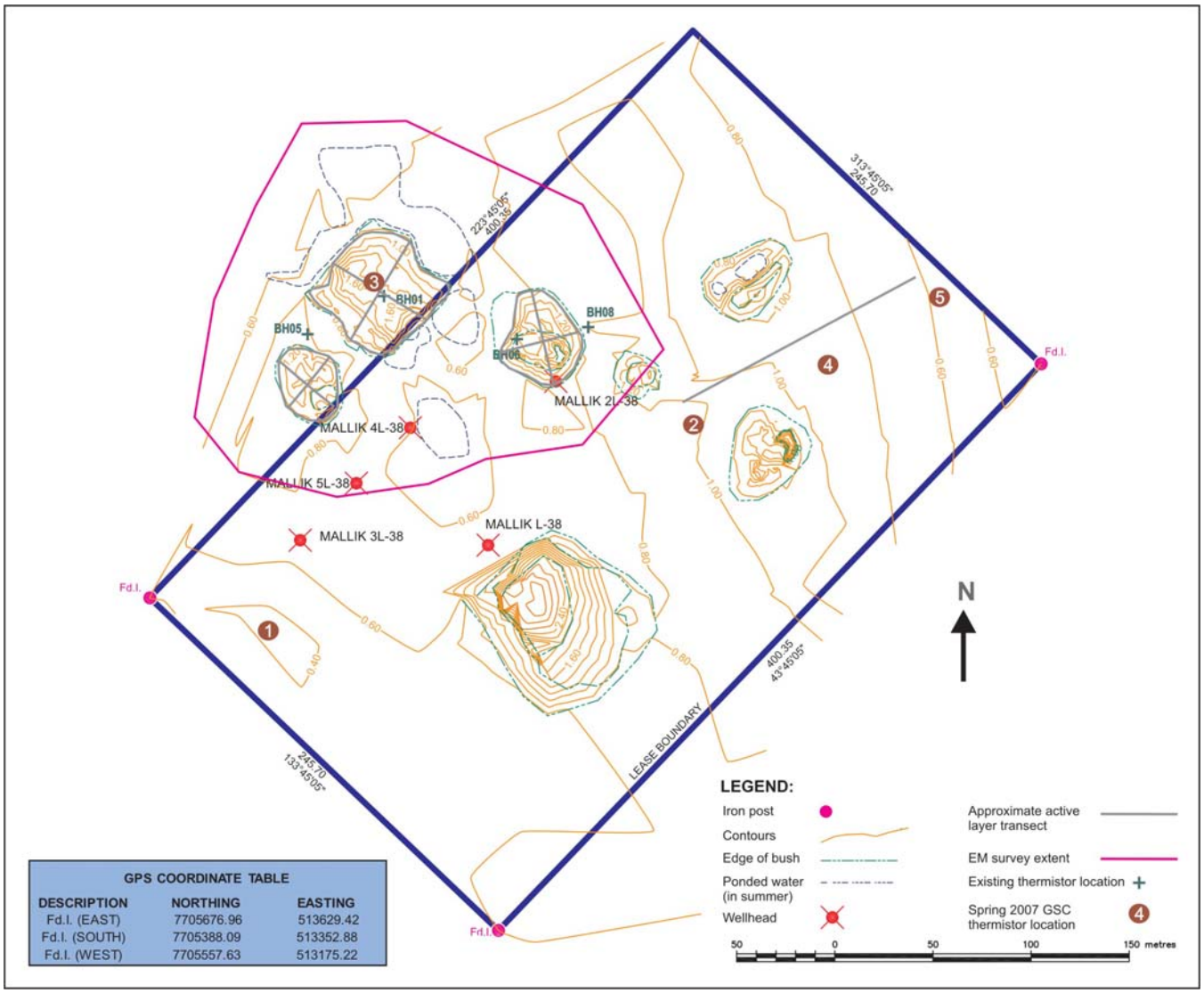
Kilometres

Acknowledgements:
Original Drawing by Kavik-AXYS Inc.
Landsat data provided by Natural Resources Canada; INAC, ICCP 2000

AURORA RESEARCH INSTITUTE
AURORA COLLEGE

PREPARED BY	KAVIK-AXYS Inc.				
DRAFT DATE 27/06/2007				SCALE 1:300,000	
REVISION DATE				PROJECT NDKA 9093	FIGURE NO. 4-1
DRAWN PM	CHECKED TB	APPROVED TB	VOL		

Figure 4-2 Mallik L-38 Site Detail



5 Development Summary

5.1 Background

The Mallik L-38 lease area has been the site of three historical drilling programs, during which a total of three conventional drilling sumps were constructed to dispose of drill cuttings and fluids. IORL drilled the original IORL Mallik L-38 discovery well during the winter of 1971-1972, and used a large drilling waste disposal sump (approximately 80 m x 95 m). In 1998, the Japan National Oil Corporation (JNOC) and the Geological Survey of Canada (GSC) collaborated to complete a gas hydrate research well program (Dallimore *et al*. 1999). With JAPEX Canada Ltd. (JAPEX) as the operator, JAPEX/JNOC/GSC drilled the Mallik 2L-38 well and constructed a drilling waste disposal sump (approximately 45 m x 50 m). In 2002, a seven-party consortia, again led again by JNOC and GSC with JAPEX as the operator (Dallimore and Collett 2005), drilled the JAPEX/JNOC/GSC *et al.* Mallik 3L-38, 4L-38 and 5L-38 wells. A sump with two excavated areas side by side (measuring approximately 30 m x 40 m, and 50 m x 55 m) was constructed to dispose of the drilling waste associated with the three wells. The locations of the sumps are identified in Figure 4-2.

ARI is proposing the Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring Program as a complimentary activity to the ongoing Aurora/JOGMEC/NRCan 2006-08 Gas Hydrate Research Well Program. The Sump Monitoring Program was initially proposed as part of a response to an Information Request from the National Energy Board (NEB) during the review of the 2006-2008 Mallik Gas Hydrate Production Research Project. The 2006-2008 Mallik Gas Hydrate Production Research Project is not using a sump for drilling waste disposal.

5.2 Purpose and Scope

ARI is proposing to conduct a seven-year monitoring program at the Mallik L-38 site to monitor the stability of the Mallik 2L-38 and 3L/4L/5L-38 drilling waste sumps. The Geological Survey of Canada (GSC) will provide permafrost and geological expertise to the program while ARI researchers will contribute expertise in vegetation studies. The Program has been designed to meet and exceed the criteria outlined in the *Protocol for the Monitoring of Drilling Waste Disposal Sumps, Inuvialuit Settlement Region, Northwest Territories* (NWT Water Board 2005), hereinafter referred to as the NWT Water Board Protocol. Field work will commence during summer 2008 and conclude in 2014. The Program will involve the following activities:

- Active layer and ground temperature monitoring of the sumps, sump perimeters, and adjacent undisturbed terrain (Section 5.5.1);
- Geophysical surveys of sumps and adjacent areas (Section 5.5.2);
- Soil sampling and analysis of undisturbed areas adjacent to the sumps (Section 5.5.2);
- Surface water sampling and analysis of any ponded water located on or near the sumps and in adjacent undisturbed terrain (Section 5.5.3);
- Sump recontouring (Section 5.5.4);
- Sump revegetation trials (Section 5.5.5);
- Storm surge monitoring (Section 5.5.6); and

- Snow cover profiling (Section 5.5.7).

The objectives of the Program are to:

- Further existing knowledge of long-term sump integrity and sump monitoring techniques;
- Present opportunities for Northerners to gain knowledge and skills related to sump monitoring;
- Provide training for ARI students interested in northern environmental science and engineering;
- Address the monitoring commitments of the 2006-2008 Mallik Gas Hydrate Production Research Project (ARI response to NEB Information Request No. 1; Environment Canada question 3 [Appendix A]);
- Address monitoring recommendations from previous site surveys; and
- Potentially contribute to related ongoing initiatives conducted by Indian and Northern Affairs Canada (INAC).

ARI commits to implementation of the Program as described in this document. Should changes that materially alter the scope of this Program as presented in this document become necessary, ARI will utilize the proper channels to ensure these changes are communicated and approved by the EISC, the appropriate regulatory authorities, and the Hunters and Trappers Committees (HTCs) in Inuvik, Aklavik and Tuktoyaktuk, as required.

5.2.1 Reporting

To meet the requirements of the NWT Water Board Protocol, information collected from the field activities will be provided to the Board by December 1 of every year for the duration of the Program. An annual report will be forwarded to the Aklavik, Inuvik and Tuktoyaktuk HTCs, as requested during consultations and to the EISC, if requested. All required sump monitoring information outlined in the NWT Water Board Protocol that does not require field activities (e.g., site identification, location and history) will be documented in the first report submitted to the NWT Water Board by December 1, 2008. Annual reports will also outline the workplan for the following year.

5.3 Mallik L-38 Site Sumps

This section provides an overview of the existing sumps at the Mallik L-38 site (Figure 4-2). ARI has established that there are three drilling waste sumps at the Mallik site. There are also several areas with disturbance of the natural soil conditions which seem to have resulted from past activities; the source of these disturbances is however unknown. While ARI is not proposing to monitor these disturbances it is proposing to undertake some local recontouring and placement of fill to even out the ground surface (Section 5.5.4).

5.3.1 1972 Imperial Oil Resources Ltd. Mallik L-38 Sump

The Mallik L-38 sump was constructed and used over 30 years ago by IORL. Maintenance and care of this sump is the responsibility of IORL, thus, the monitoring requirements for this sump are outside the scope of this Program.

5.3.2 1998 JAPEX/JNOC/GSC Mallik 2L-38 Sump

The Mallik 2L-38 sump was constructed for the 1998 drilling program. The surface of the sump is approximately 45 m by 50 m (2250 m^2), and is domed 40-60 cm above the surrounding terrain. The soil used to form the sump cap remains exposed and there is no evidence of vegetation re-colonization (Figure 5-1). A settlement area of approximately 3 m x 6 m x 1 m, periodically filled with ponded water was observed, and evidence of salt crystallization was observed on the perimeter of the sump (Figure 5-1).

Figure 5-1 Mallik 2L-38 Sump (August 2006)

5.3.3 2002 JAPEX/JNOC/GSC *et al.* Mallik 3L/4L/5L-38

The Mallik 3L/4L/5L-38 sumps were constructed and used during the 2002 drilling program. The smaller sump, measuring 30 m by 40 m (~1200 m^2) was constructed first. The larger sump, measuring 50 m by 55 m (~2750 m^2) was constructed adjacent to the first sump late in the program to accommodate unexpected volumes of drill cuttings. The larger sump is raised 60-80 cm above the surrounding elevation, while the smaller sump is domed 40-60 cm above the adjacent terrain. The surfaces of both sumps remain unvegetated and a settlement area of 2 m x 6 m x 1 m periodically containing ponded water was observed across both sumps. Evidence of salt crystallization was observed around the perimeter of the Mallik 3L/4L/5L-38 sumps (Figure 5-2).

Figure 5-2 Mallik 3L/4L/5L-38 Sump – Large Lobe (September 2006)

5.4 Previous Site Surveys

Table 5-1 presents a summary of the site surveys conducted at the Mallik L-38 site since 2005. These surveys provide baseline information to which data collected through the proposed monitoring Program can be compared.

Table 5-1 Summary of Mallik L-38 Site Surveys Conducted Since 2005

Surveyor (Year Conducted)	Survey Overview	Survey Findings	Recommendations
Kiggiak-EBA (August 2005)	• Conducted EM surveys of the 2L-38 and the 3L/4L/5L-38 sump • Drilled, logged and sampled 13 boreholes within and around the 2L-38 and 3L/4L/5L-38 sump • Conducted geotechnical testing on soil samples to characterize the soil and permafrost • Conducted chemical analysis of water from ponds on or adjacent to the sumps	• High apparent conductivity values within sump boundaries, confirming presence of saline drill cuttings. • Modestly elevated apparent conductivity values in some locations beyond the sump boundaries; likely the result of natural variation and/or drill site activity and are not necessarily indicative of sump seepage. • High apparent conductivity measurements associated with chloride concentrations from 1500 – 2200 mg/L, resulting from sump filling activities, or the evaporation of seawater from storm surges or seawater used in the construction of ice pads. • Pond water shows slightly elevated salinity levels; total dissolved solids (TDS) ranging from 850 mg/L to 875 mg/L. These values are within expected limits for sites subject to occasional storm surges and are likely not the result of sump seepage. • Essentially all saline-rich drill cuttings remain contained within the sump below the active layer, although it is possible that minimal migration of contaminated saline water from the sumps to the adjacent active later is occurring.	• Future EM surveys should be conducted to ascertain whether sump seepage is occurring and, if so, the extent to which it is occurring.
GSC/ARI (Summer 2005)	• Installed thermistor cables into previously drilled boreholes.	• Limited data collected demonstrated that winter ground temperature of sumps is lower than the surrounding tundra.	• Further ground temperature monitoring should be conducted.

Surveyor (Year Conducted)	Survey Overview	Survey Findings	Recommendations
GSC/ARI (Summer 2006)	• Conducted informal assessment of surface conditions of Mallik 2L-38 and 3L/4L/5L-38 sumps.	• Settlement of sumps has occurred	• Fill, similar to existing sump materials, should be trucked in for sump retrofit
KAVIK-AXYS (September 2006)	• Documented general characteristics of the sumps. • Surveyed contours of the sumps. • Conducted soil and surface water sampling on and around sumps.	• Salt crystallization was observed on the perimeter of the Mallik 2L-38 and 3L/4L/5L-38 sumps. • Settlement of the Mallik 2L-38 and 3L/4L/5L-38 sumps has occurred; some ponding has resulted on both. • No vegetation growth observed on the Mallik 2L-38 and 3L/4L/5L-38 sumps; however, no stressed vegetation was observed nearby. • Sump soil samples showed salinity levels above control concentrations. • Surface water samples indicate salinity levels far below sea water.	• Sumps should be recontoured to correct for settlement to date and to reduce the potential for settlement/ponding to occur. • Revegetation of the sumps should be undertaken, as required. • Monitoring of the sumps is proposed.
GSC (October 2006)	• Deployed two thermistor cables to monitor ground surface temperatures across the Mallik 2L-38 sump.	• Data not yet analyzed.	• Not applicable.
GSC (April 2007)	• Installed five thermistor cables in boreholes drilled to a depth of 12 m.	• Data not yet analyzed.	• Not applicable.
GSC (August 2007)	• Site visit to observe general condition and characteristics of sumps.	• Data not yet analyzed.	• Not applicable.
GSC (October 2007)	• Deployed two thermistor cables to monitor ground surface temperatures across the Mallik 2L-38 sump.	• Data not yet analyzed.	• Not applicable.

5.5 Sump Monitoring Program

This section outlines the proposed seven-year monitoring Program and its components. Monitoring activities will take place during early and late summer (June and August) and early and late winter (October and April) over the seven-year period. The Program crews will be mobilized out of Inuvik. During winter and early summer, monitoring activities will involve day-trips by helicopter to the Mallik site. In late summer, a remote field camp will be established at the Program site. Section 6 outlines the Program schedule.

Soil sampling and ground temperature measurements were previously conducted during the first winter of operations (2006-2007) of the Mallik Gas Hydrate Production Research Project in five boreholes drilled to 12 m. Four boreholes were drilled in undisturbed locations at the Mallik site, one to the southeast of the Mallik 3L-38 wellhead and three in a SW to NE transect on the eastern side of the lease to assess the influence of periodic flooding on ground thermal regimes. An additional borehole was drilled using a track-mounted shothole rig at the centre of the larger lobe of the Mallik 3L/4L/5L-38 sump. The planned borehole in the centre of the Mallik 2L-38 sump was not completed as planned because the sump was covered by drilling equipment at the time. Soil sampling at the borehole locations was conducted at the top of the mineral horizon and subsequently at every 1 m to the bottom of the borehole. Soil samples will be analysed by an approved environmental laboratory following the NWT Water Board Protocol. Thermistor cables were installed in all five of the boreholes to monitor ground temperature. In order to meet the requirements of the NWT Water Board Protocol, the thermistor cables were equipped with sensors at target depths of 0.25 m, 0.5 m, 0.75 m, 1.5 m, 3 m, 6 m, 9 m and 12 m. The cables were placed in a closed 2” PVC casing and a standard connector was used at the top of the cable for manual reading of the thermistors. Data loggers were attached to the cables for year-round temperature recording.

The planned Mallik 2L-38 borehole, along with one to five strategically placed additional boreholes, may be drilled in winter 2007-08 as part of the Mallik 2006-08 Gas Hydrate Production Research Project. Soil sampling will take place at each borehole and a thermistor cable and datalogger will be added. If winter installation is not possible, installation by water jet drilling as part of the late summer field work is proposed.

5.5.1 Active Layer and Ground Temperature Monitoring

Active layer depth will be measured annually to determine whether there are thaw penetration differences between the sumps and undisturbed areas. The active layer thickness will be measured using a graduated probe at a minimum of five points on the sump caps and at a minimum of eight points around the perimeter of Mallik 2L-38 and 3L/4L/5L-38 sumps. Active layer depths will be determined in the adjacent undisturbed terrain by probing along a 35 m transect at 5 m intervals. This design is consistent with the desired sampling scheme outlined in the NWT Water Board Protocol.

Ground temperature will be recorded year-round by the installed thermistor cables and data loggers. While the Program crew is on-site each summer, the data from the loggers will be downloaded, and the loggers will be re-launched.

5.5.2 Geophysical Surveys and Soil Sampling

Ground conductivity/resistivity surveys of the Mallik 2L-38 and 3L/4L/5L-38 sumps will be conducted each year using both shallow and deep ground penetrating equipment (e.g. EM31 and EM38). The conductivity data will be used to determine whether any lateral migration of saline drilling fluids has occurred.

In Year 1, soil grab samples from the surface, middle, and bottom of the active layer will be collected from an undisturbed area through shovel testing. Soil samples will be packaged according to standard soil sampling protocols and transported to an accredited laboratory for routine analysis (volumetric water content, moisture content, soil texture, organic matter content, pore-water conductivity and pH), and detailed salinity analysis. Hydrocarbon analysis of the samples will be conducted if hydrocarbon contamination is suspected.

If the geophysical surveys indicate elevated conductivity levels outside the sump areas, soil samples from the surface, middle, and bottom of the active-layer of the anomalous area(s) will be obtained and shipped to an accredited laboratory for analysis.

5.5.3 Surface Water Sampling

Surface water samples will be collected following standard water sampling protocols from any ponded water located on, or near the sumps, as well as in adjacent undisturbed terrain. Water samples will be shipped to an accredited laboratory for routine water chemistry testing (conductivity, pH, and major cations).

Concern was raised during consultations that the ponded water on or around the sumps may be contaminated. Analysis of the ponded water conducted during previous site surveys showed that the water was not contaminated (Section 5.4).

5.5.4 Sump Recontouring (Supplementary Activity)

The sump retrofit program was proposed by ARI in its response to NEB Information Request No. 1 (Environment Canada question 3, Appendix A) to fill in the depressions observed on both the Mallik 2L-38 and 3L/4L/5L-38 sumps. ARI is also proposing to recontour *unnamed sump* to address its eroded sump cap. The sump reclamation recommended practices provided in *Drilling Waste Management Recommended Best Practices for the Inuvialuit Settlement Region* (ESRF 2004) were incorporated into the design of the retrofit program. This work is beyond the scope of the requirements of the NWT Water Board Protocol.

Offsite fill material will be hauled in via existing ice roads during the winter 2007-2008 as a part of the Mallik Gas Hydrate Research Project. Concern about the composition of the fill material was raised during consultations. The fill material will be as close as possible to the fine sandy-silts that characterize the soils of the Program area. Recontouring, grading, and compression of the fill material using hand tools will be completed during summer 2008 by a crew of three to four personnel. The crew will use shovels to compress the material to the greatest extent possible to prevent settling. The depressions will be filled to ground-level and will not be crowned. Re-contouring and grading will take two days and the crew will be helicoptered in and out of Inuvik each day. During subsequent years of the Program, the sumps will be photographed and observed to assess the effectiveness of the recontouring. As requested during consultations, photographs of the sump caps, and especially the ponded areas, will be taken prior to recontouring.

5.5.5 Sump Revegetation (Supplementary Activity)

The surface of the Mallik 2L-38 and 3L/4L/5L-38 sumps consists of exposed sediment; no natural revegetation has taken place. ARI proposes to conduct seeding trials to investigate the potential for revegetation of the sump caps to prevent erosion. Under the leadership of ARI, vegetation specialist Pippa Seccombe-Hett is proposing experimental field trials of natural local seed mix. The seed mixes have been designed by ARI and a variety of seed mixes will be tested for effectiveness in reclamation at the Mallik site.

A crew of one to three vegetation specialists will manually spread seed over the sump caps and rake the seed into the sump cap soil in summer 2009. The sump caps will be inspected annually during Program site visits to evaluate revegetation success. This work is also beyond the scope of the requirements of the NWT Water Board Protocol.

5.5.6 Storm Surge Monitoring (Supplementary Activity)

The area around the Mallik site is periodically flooded during storm surge events. The frequency, magnitude, and duration of these events is of interest in the monitoring and assessment of sump stability. Dr S.V. Kokelj (Water Resources Division, Department of Indian Affairs and Northern Development) is currently testing storm surge monitoring instruments in the Outer Mackenzie Delta. If these trials are successful, a similar network of three to five storm surge monitoring devices will be deployed at the Mallik site. Each unit will consist of an YSI conductivity probe inserted into a PVC pipe. The PVC pipe is then driven into the streambed of a shallow (~2m) inactive cutbank. The instruments are deployed by small inflatable boat (zodiac) in early to mid-June and are retrieved before freeze-up in October.

5.5.7 Snow cover Profiling (Supplementary Activity)

Snow cover acts as an insulator and buffers the cold winter temperatures from penetrating into the ground. To maintain the integrity of the sump cap, the cap should be engineering so that snow does not accumulate on and around the sump. To assess the winter 2008 recontouring effort, snow surveys are proposed both prior to the recontouring and in winters of 2009-2012. Measurements will be made by with a "Standard Federal Snow Sampler" which consists of graduated aluminum tubes with a cutter bit affixed to the first section of the tubing. The tubes are driven through the snow to the ground and then carefully withdrawn, extracting a core of snow with them. A visual inspection of the snow core will be made to note thickness and snowpack properties. The snowpack will be sampled at a minimum of five points on the sump caps and at a minimum of eight points around the perimeter of Mallik 2L-38 and 3L/4L/5L-38 sumps. Snow properties will also be determined in the adjacent undisturbed terrain by sampling along a 35 m transect at 5 m intervals. Every attempt will be made to sample the snow and active layer at the same locations each year.

5.6 Transportation

Transportation will be by helicopter during the winter, except for the activities associated with the recontouring program planned for winter 2007-2008. These activities will be supported by truck accessing the site via the ice road constructed for the Mallik Gas Hydrate Production Research Project.

During early summer and early winter, transportation to the site will be by helicopter. A small zodiac-type boat will be used on-site to deploy and retrieve the storm-surge monitoring equipment.

During late-summer, Program activities will involve establishment of a remote field camp at the Program site. Program support and transportation to and from the site will be by helicopter. Once the camp has been established, a maximum of two round-trip flights per day will be required to support the activities. To minimize the potential for local impacts to the communities and wildlife, the aircraft charter company will be instructed to follow the flight altitudes as presented by the Inuvialuit Game Council (IGC) in their August 2, 2002 letter to aircraft operators working in the region (Appendix B). Additional on-site transportation will include a small zodiac-type boat for potential emergency evacuation to higher ground during a storm surge

5.7 Personnel

Each site visit associated with the Program will require up to six people. The Program team will consist of the following personnel:

- 1 Geologists and 1 field assistant (GSC-ARI)
- 1 Vegetation specialist and 1 student field assistant (ARI)
- 1 Inuvialuit wildlife monitor
- 1 Helicopter pilot (not remaining on-site)

The one-time recontouring personnel will be comprised of up to five workers:

- 1 Recontouring supervisor (ARI)
- 4 Recontouring crew

5.8 Equipment

A list of equipment required for the Program is provided in Table 5-2. All of the equipment for the program is helicopter transportable.

Table 5-2 List of Required Program Equipment

Equipment	Quantity
Thermistor Cable Installation	
12 m cables with 8 sensors (all contained in housing without free cable at surface)	1 to 5
XR-420 T8 Loggers with MHDG-9-BCR connectors or equivalent	1 to 5
70 m of 2” PVC casings, caps and joiners	1 to 5
Geophysical Surveys	
EM31 unit	1
EM38 unit	1
EM38 extender arm	1
DAS-70-CX field computer for use with EM31 and EM38	1
Soil and Water Sampling	
Sampling kits provided by Taiga Environmental Laboratory (includes sample bags, sample vials, preservative agents)	As required
Sump Retrofit	
Fill material (winter 2007-2008 only)	30-45 cubic m
Hand tools (shovels, etc.)	As required
Revegetation Program	
Natural seed mix (varying quantities in varying years)	As required
Vegetation monitoring equipment (e.g., collection bags, string, rulers)	As required
Hand tools (e.g., manual seed spreader, rakes, shovels)	As required
Additional Research Activities	
YSI conductivity probe for storm surge monitoring	As required
PVC casing for installation of probes	As required
	As required
General	
Hand-held Geographic Positioning System (GPS) units	2
Communications (satellite telephone, helicopter radio and cellular telephone)	As required
Safety and survival gear (e.g., meals, additional clothing, survival equipment, cameras, GPS units)	As required
Field camp equipment (e.g. field tent, sleeping tents, folding tables and chairs, portable waste containers, generator, fuel and containers)	As required

5.9 Waste Disposal

Little waste is expected to be generated by the Program. The Project team will haul all waste material back to Inuvik for disposal. Waste will be stored in heavy wildlife-proof bins to minimize odours and attractants.

The field camp will use portable camp toilettes, which will be hauled back to Inuvik upon completion of activities for disposal.

5.10 Fuel

The helicopter will refuel in Inuvik or at existing designated fuel caches (i.e., Swimming Point). No helicopter refuelling will be required at the Program site.

Some fuel will be on-site for the field camp generator. The fuel will be stored in Canadian Standards Association (CSA) approved containers. A drip-tray will be used when refuelling the generator.

5.11 Water

Water for camp use, including potable water, will be flown in via helicopter.

5.12 Infrastructure

No permanent infrastructure is required for the Program. The field camp will consist only of temporary structures, which will be removed yearly upon completion of Program activities. Thermistor cables and dataloggers will be left on-site from year to year to collect data. The PVC casings and standard connectors at the top of each thermistor cable, which allow for manual readings of the thermistors, protrude approximately 1 m from the ground. Following the completion of the Program in 2014, the PVC casing will be cut off below ground and all other equipment will be removed from the site.

6 Development Timetable

Table 6-1 outlines the Program schedule of activities to be conducted.

Table 6-1 Program Schedule

Program Year	Program Task	Estimated Timeframe
1 (2008) Winter	• Transportation of retrofit materials to site via Mallik ice road • Snow surveys	1 – 3 days
1 (2008) June	• Storm-surge equipment deployment	1 – 3 days
1 (2008) August	• Active layer and ground temperature monitoring • Geophysical surveys, soil and water sampling • Sump retrofit • Seed collection	7 – 10 days
1 (2008) October	• Storm-surge equipment retrieval	1 – 3 days
2 (2009) Winter	• Snow surveys	1 – 3 days
2 (2009) June	• Storm-surge equipment deployment	1 – 3 days
2 (2009) August	• Active layer and ground temperature monitoring • Geophysical surveys, soil and water sampling • Seed dispersal on sump caps • Retrofit monitoring	5 – 7 days
2 (2009) October	• Storm-surge equipment retrieval	1 – 3 days
3 (2010) Winter	• Snow surveys	1 – 3 days
3 (2010) June	• Storm-surge equipment deployment	1 – 3 days
3 (2010) August	• Active layer and ground temperature monitoring • Geophysical surveys, soil and water sampling • Retrofit and revegetation monitoring	5 – 7 days
3 (2008) October	• Storm-surge equipment retrieval	1 – 3 days
4 (2011) Winter	• Snow surveys	1 – 3 days
4 (2011) June	• Storm-surge equipment deployment	1 – 3 days
4 (2011) August	• Active layer and ground temperature monitoring • Geophysical surveys, soil and water sampling	5 – 7 days

4 (2011) June	• Retrofit and revegetation monitoring • Storm-surge equipment retrieval	1 – 3 days
5 (2012) Winter	• Snow surveys	1 – 3 days
5 (2012) June	• Storm-surge equipment deployment	1 – 3 days
5 (2012) August	• Active layer and ground temperature monitoring • Geophysical surveys, soil and water sampling • Retrofit and revegetation monitoring	5 – 7 days
5 (2012) October	• Storm-surge equipment retrieval	1 – 3 days
6 (2013)	• Active layer and ground temperature monitoring • Soil and water sampling • Retrofit and revegetation monitoring	1 – 2 days
7 (2014)	• Active layer and ground temperature monitoring • Soil and water sampling • Retrofit and revegetation monitoring • Final site clean-up	2 – 3 days

7 Technology

The Program will use proven technology to conduct the active layer and ground temperature monitoring, geophysical surveys, soil and water sampling, as well as the sump retrofit program. The sump revegetation program will utilize natural seed mix currently being developed at ARI for use in reclamation. Part of the intent of this Program is to evaluate the effectiveness of various natural seed mixes in reclamation.

8 Alternatives

The Mallik 2L-38 and 3L/4L/5L-38 sumps have been selected because the maintenance of the Mallik 2L-38 and 3L/4L/5L-38 sumps is the responsibility of the proponents (JOGMEC/JNOC, GSC/NRCan and JAPEX) who constructed them as a part of the ongoing gas hydrate research at the Mallik site. The histories of these sumps are known and documented and baseline information has been collected for them. In addition, during the first winter of the 2006-2008 Mallik Gas Hydrate Production Research Project, a portion of the Mallik 2L-38 sump was overlain with a thick (30 cm) ice pad. The ice pad was used for storage of steel mud tanks during operations. Monitoring of the thermal stability of the Mallik 2L-38 sump, therefore, is important for the Mallik Gas Hydrate Production Research Project and is also a requirement of project regulatory approvals (NEB Information Request No. 1, Appendix A). The IORL Mallik L-38 sump is not included in this Program because maintenance and care of this sump is the responsibility of IORL. No monitoring activities are proposed for *unnamed sump*, because it is not a drilling waste sump; however, ARI is proposing to recontour *unnamed sump* as part of this Program.

There are limited opportunities for use of alternative measures to effectively monitor the integrity of the Mallik 2L-38 and 3L/4L/5L-38 sumps. Furthermore, the methods proposed are consistent with those outlined in the NWT Water Board Protocol and required by Environment Canada (NEB Information Request No. 1, Appendix A).

9 Traditional and Other Uses

A review of the Community Conservation Plans (CCPs) for Tuktoyaktuk (TCCP 2000), Inuvik (ICCP 2000) and Aklavik (ACCP 2000) indicates that three Inuvialuit Special Management Areas overlap spatially and temporally with the proposed Program area (Table 9-1). The three Areas are identified as Category C lands, defined as lands and waters where cultural or renewable resources are of particular significance and sensitivity during specific times of the year. The CCPs recommend land use practices in these areas to reduce potential damages and disruption to the greatest extent possible.

Table 9-1 Inuvialuit Special Management Areas that have Spatial and Temporal Overlaps with the Program Area

Area	Site Name	Importance	CCP Noting Area as Important
312C	Fall Goose Harvesting Area	Key area for subsistence harvesting of geese during the fall	Tuktoyaktuk
712C	Beluga Management Zone 2	A major beluga travel corridor (encompasses all of the inshore coastal waters not covered by a 1a Zone); subsistence harvesting of beluga (June 15 to August 15)	Tuktoyaktuk, Aklavik and Inuvik
715C	Mackenzie River Delta Key Migratory Bird Habitat	Important nesting and breeding habitat for birds (May to September); subsistence harvesting of waterfowl (June to September)	Tuktoyaktuk, Aklavik and Inuvik

9.1 Harvesting Activities

The Tuktoyaktuk, Inuvik and Aklavik CCPs identify six traditional summer harvesting activities that overlap with the timing of the proposed Program (August). The summer harvesting of beluga, caribou, moose, grizzly bear, fish and birds are identified to occur during August. The majority of beluga hunting occurs in July. The CCPs recommend consulting the local HTCs to minimize effects on harvesting activities.

A review of the Inuvialuit Harvest Study Atlas (Fabijan *et al.* 1993) indicates that no traditional harvesting activities occurred in the Program area from 1987-1992.

ARI commits to avoiding all interference with traditional harvesting activities. The IGC and Aklavik, Tuktoyaktuk and Inuvik HTCs will be notified prior to crew deployment each summer and the crew will be accompanied by a wildlife monitor. Flight routes will be selected to mitigate adverse effects to wildlife and harvesting activities in accordance with the IGC Overflight Guidelines (Appendix B). Section 12 presents additional mitigations to avoid impacts to Inuvialuit harvesting and wildlife resources.

10 Community Consultation

This section summarizes the concerns raised during the consultation meetings conducted for the proposed Program (Table 10-1). Consultation meetings were held with the Inuvik, Tuktoyaktuk and Aklavik HTCs April 2 – 3, 2007. Additional program consultations were conducted on June 22, 2007 and July 3, 2007 as part of information and consultation sessions for the 2006-2008 Mallik Gas Hydrate Production Research Project. The complete consultation record is included in Appendix C.

Table 10-1 Summary of Concerns Raised and Responses

Concern/ Issue	Response
Sump construction – how far past the trench does the sump cap fill go?	The NWT Water Board has set a condition for sump design of 1 m of freeboard below the bottom of the active layer (ESRF 2004), so the sump cap depth is determined by the depth of the active layer.
Why is the Program only seven years long? We would like to see it extended beyond seven years. Many other sump monitoring programs are longer in duration.	This monitoring Program is a commitment of the ongoing 2006-2008 Mallik Gas Hydrate Research Project and is consistent with monitoring activities of other operators in the Mackenzie Delta. Longer-term monitoring has not been discussed.
Why are only two of the sumps at the Mallik site being monitored?	There are three drilling sumps at the Mallik L-38: one was constructed by IORL during their 1972 drilling program and is the responsibility of IORL. The other two were constructed to support the previous Mallik gas hydrate research projects in 1998 and 2002; these two sumps will be monitored as per the commitments of 2006-2008 Mallik Gas Hydrate Research Project.
There is ponding on the sumps. The ponded water may be contaminated. Heaving may result from filling those areas in without first pumping out the water.	The ponded water on and around the sumps will be tested as a part of the monitoring Program.
There is no vegetation growing on the sumps.	This may be due to the environmental conditions of the Program area – the area is low-lying and subject to storm surges and flooding. The sump caps have not been re-seeded; however, a revegetation study is being proposed as a part of the monitoring Program.
Noted that the area is used by migratory birds, including white-fronted geese and swans.	Mitigation measures, including adherence to the IGC Overflight Guidelines (Appendix B), have been identified in Section 12 to minimize the effects of helicopter use and human presence on waterfowl in the area.
The HTCs would like to receive copies of the annual reports submitted to the NWT Water Board.	ARI will forward copies of the annual reports to the Aklavik, Inuvik and Tuktoyaktuk HTCs.

11 Environmental Overview

11.1 Introduction

Sections 11 and 12 provide a summary of the environmental setting of the Program area and of the biophysical components which may potentially be affected by Program activities. Given the limited spatial and temporal scale of the proposed Program, the generally non-intrusive nature of the proposed activities and the low potential for adverse effects, a concise and adapted version of Sections 11 and 12 of the Project Description submission to the EISC for the 2006-2008 Mallik Gas Hydrate Research Project is included here.

11.2 Biophysical Resource Summary

11.2.1 Terrain

The Program is located on the west side of Richards Island in the east-central portion of the outer Mackenzie Delta (Figure 4-1). It is located in the Tuktoyaktuk Coastal Plain ecoregion. Most of this area lies at, or close to, sea level and is characterized by low-lying areas of recent sediments interspersed with numerous channels, lakes and coastal embayments. The area is subject to fluvial processes (flooding, deposition, erosion) associated with the Mackenzie River. It also experiences storm surges from the Beaufort Sea. Much of the Program area is inundated annually, has a permanently high water table, and exhibits wetland characteristics.

The Mallik L-38 site is composed of flat, low-lying deltaic silts, at an elevation of less than 2 metres above sea level (masl) (Figure 11-1). It is subject to sedimentation from the Mackenzie Delta. Because of its low-lying coastal position, the Mallik site is also subject to inundation during storm surge events and sea spray during periods of high winds. Permafrost at the Program site extends to a depth of more than 600 m (Collett and Dallimore 2002). North and east of the Mallik site are tidal mudflats. The Mallik L-38 site includes several anthropogenic features related to previous exploration and gas hydrate research projects, including six wellheads and two sumps.

Figure 11-1 Mallik L-38 Site Overview

11.2.2 Vegetation

Vegetation communities at the Program area reflect the brackish conditions and frequency of natural disturbance, and are common to low-lying coastal sites in much of the western Arctic. They are comprised primarily of graminoid species, such as grasses, rushes, and sedges. The Program site is characterized by a cover of vascular plants with small shallow ponds and bare mudflats scattered throughout. One rare plant species, roseroot (*Rhodiola integrifolia* Raf.), was found growing on the sparsely vegetated shoreline at the Program site in 2002 (Kemper 2005). There is some potential to find other rare species in the Program area. No uncommon plant communities are known to be associated with the vegetation conditions present at the Program site.

11.2.3 Wildlife

The habitat types in the Program area support a number of wildlife species including territorially- and federally-listed species of special conservation status (Table 11-1).

The Mackenzie Delta provides key migratory bird habitat for a variety of shorebird and waterfowl species, and supports Inuvialuit harvesting of waterfowl. The HTCs noted during consultations that the Program area is used by migratory birds, including the white-fronted goose and tundra swan.

Table 11-1 Wildlife Species with Special Conservation Status in the Program Area

Species	ENR[1]	COSEWIC[2]	SARA[3]
Marine Mammals			
Polar bear	Sensitive	Special Concern	Not Yet Listed[4]
Terrestrial Mammals			
Grizzly bear	Sensitive	Special Concern	Not Yet Listed[4]
Wolverine	Sensitive	Special Concern	Not Yet Listed[4]
Migratory Birds			
Eskimo curlew	At Risk	Endangered	Schedule 1
Peregrine falcon (tundrius subspecies)	May Be At Risk	Special Concern	Schedule 3
Short-eared owl	Sensitive	Special Concern	Schedule 3
Northern pintail	Sensitive	Not Listed	Not Listed
Dunlin	Sensitive	Not Listed	Not Listed
Lesser scaup	Sensitive	Not Listed	Not Listed
Common eider	Sensitive	Not Listed	Not Listed
King eider	Sensitive	Not Listed	Not Listed
Long-tailed duck	Sensitive	Not Listed	Not Listed
Harlequin duck	Sensitive	Not Listed	Not Listed
Black scoter	Sensitive	Not Listed	Not Listed
Surf scoter	Sensitive	Not Listed	Not Listed
White-winged scoter	Sensitive	Not Listed	Not Listed
Arctic tern	Sensitive	Not Listed	Not Listed
Least sandpiper	Sensitive	Not Listed	Not Listed
Semi-palmated sandpiper	Sensitive	Not Listed	Not Listed
Hudsonian godwit	Sensitive	Not Listed	Not Listed
Red phalarope	Sensitive	Not Listed	Not Listed
Whimbrel	Sensitive	Not Listed	Not Listed
Common snipe	Sensitive	Not Listed	Not Listed
American golden plover	Sensitive	Not Listed	Not Listed

NOTES:
1. Environment and Natural Resources, Government of the Northwest Territories (ENR 2007)
2. Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007)
3. *Species at Risk Act* (Government of Canada 2007)
4. Species currently being evaluated for inclusion under SARA Schedule 1.

The geographic range of many terrestrial mammal species extends into the Program area, including barren-ground grizzly bear, barren-ground caribou, moose, wolverine, muskrat, Arctic fox, wolf, marten, lynx, hare (Arctic and snowshoe), and a number of rodent species. However, frequent flooding of low-lying lands, including the Mallik L-38 site, results in relatively low habitat suitability for many of these species. It was noted during consultations that wolves have been hunted in the Program area in the past.

Caribou are more numerous east of the East Channel, where the high ground tundra provides calving grounds and over-wintering habitat for the Bluenose-West and Cape Bathurst caribou herds (Nagy *et al*. 1999). Wolves tend to follow a movement pattern similar to caribou. Caribou or reindeer tracks were noted at the site during a spring 2007 site visit.

The lack of topographic relief in the Program area, and particularly at the Mallik L-38 site and surrounding low-lying areas, limits the amount of denning habitat for grizzly bears. Grizzly bears have however, been known to use low-lying coastal areas in early spring (Pearson and Nagy 1976).

Marine mammals, including polar bear, beluga whale, ringed seals and bearded seals, have the potential to occur in the Program area while activities are ongoing. All four species are important for subsistence harvesting to the Inuvialuit. During the open water season, polar bear are generally found offshore, associated with the pack ice. Although polar bear do have the potential to occur in Mallik Bay and surrounding area, the area is not considered high-quality polar bear habitat. The Program area is however, a part of the Mainland Coastal Polar Bear Special Management Area (TCCP 2000).

Mallik Bay and surrounding coastal waters are in the Beluga Management Zone 2 as identified in the Beaufort Sea Beluga Management Plan (FJMC 2001). Beluga Management Zone 2 is a travel corridor for beluga although some feeding, calving and nursing might also occur in this zone. Beluga enter this area around late June and begin the return migration to the Bering Sea around late August (Harwood and Smith 2002).

Bowhead whales (*Balaena mysticetus*) occur in the Canadian Beaufort Sea, but are not expected to occur in the Program area due to the shallow water depths of the nearshore areas in and around Mallik Bay. Ringed and bearded seals might be present during the open water season.

11.2.4 Fish

The stream and lake systems of Richards Island, and the waters of Mallik Bay, support a variety of freshwater and marine species of fish. There are five coregonid (whitefish) species (broad and lake whitefish, least and Arctic cisco and inconnu) commonly found in the Program area and all are important species for subsistence harvesting. All five species use Mallik Bay, adjacent coastal areas and Mackenzie River channels as a migration corridor, and for feeding, rearing and overwintering (Percy 1975; Lawrence *et al*. 1984; Reist and Bond 1988). Broad and lake whitefish, and least cisco are known to use the stream and lake systems on Richards Island that are connected to the coast or outer channels (Lawrence *et al*. 1984). Inconnu are abundant in Mallik Bay during the summer (Evans *et al*. 2002). The Tuktoyaktuk Community Conservation Plan (2002) identifies Mallik Bay as being important habitat for both broad and lake whitefish.

There are no fish species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or the *Species at Risk Act* (SARA) in the Program area.

11.2.5 Historical Resources

There are few known archaeological sites in proximity to the Program area. A pre-contact period isolated find (NiTw 4) is situated on the highest point of Niglintgak Island, in the Kendall Island Bird Sanctuary (KIBS). A pre-contact period artifact scatter (NhTv 1) is located near Old Trout Lake in the southern part of KIBS. The Program area provides access to resources that are valuable for traditional harvesting, which likely resulted in historic or traditional settlement use in and around Mallik Bay. However, because the Program site is located in an active deposition and erosion floodplain, the potential for the identification of archaeological sites is low.

12 Potential Environmental Impacts and Mitigation Measures

Table 12-1 provides an overview of the potential effects of Program activities on the environment or traditional harvesting activities and corresponding mitigation measures.

Table 12-1 Potential Environmental Effects and Proposed Mitigation Strategies

Concern and or Anticipated Impact	Mitigation
Sensory disturbance to wildlife resulting from helicopter use	• A trained Inuvialuit wildlife monitor will accompany the field crew during each site visit; during the flight, the wildlife monitor will identify any aggregations of wildlife • The 2002 Inuvialuit Game Council (IGC) Overflight Guidelines (Appendix B) will be adhered to, whenever possible • Each year, the majority of Program activities will be conducted after the sensitive bird nesting period in May and June, and before the main staging period in late-August and early September • Pilots will maintain a 1.5 km horizontal distance from large concentrations of birds (e.g., breeding colonies, moulting areas) • The Program area will be accessed from the south to avoid flying over Mallik Bay or KIBS • Aggregations of marine mammals will be avoided • Hovering or circling will be avoided • The helicopter will fly at low altitudes only during take-off and landing • The number of flights will be minimized, whenever possible • The HTCs of Inuvik, Aklavik and Tuktoyaktuk and Environment and Natural Resources, Government of NWT (ENR) will be contacted prior to crew deployment each year to obtain information about wildlife in or near the Program area
Disruptions to Inuvialuit traditional harvesting activities resulting from helicopter use or human presence	• The HTCs and IGC will be notified prior to crew deployment each year • Active harvesting areas will be avoided
Disturbance to wildlife and/or wildlife habitat resulting from Program activities	• A trained Inuvialuit wildlife monitor will accompany the field crew during each site visit • Crew members will be instructed to avoid wildlife and report any sightings to the wildlife monitor • Crew members will not walk off the Program site onto the tundra at any time, unless there is a specific requirement (e.g., waste recovery) • Active nest sites will not be disturbed; their location will be communicated to the crew and the nest will be avoided • Any identified relic bear den will not be disturbed and the den location will be reported to ENR • Unnecessary noise will be avoided • All waste will be hauled out with the crew and properly disposed of in Inuvik • No material or equipment will be left on-site after yearly completion of activities • Following completion of Program activities each year, the crew will conduct a site clean-up

Concern and or Anticipated Impact	Mitigation
Wildlife may approach Program site while crew is present, potentially resulting in wildlife encounter/incident	• A trained Inuvialuit wildlife monitor will accompany field crew during field activities and will assist in managing wildlife encounters • The crew will conduct a brief aerial survey prior to landing and conducting Program activities to determine whether wildlife is present in the area • All waste will be contained in a sealed container and hauled out with the crew and properly disposed of in Inuvik • If a grizzly or polar bear is identified within 1 km of Program activities, ENR will be contacted to determine the appropriate course of action. The crew will be equipped with bear deterrents (e.g., bear spray, cracker shells). The Program crew will follow the ENR Bear Encounter Response Guidelines (Appendix D). If required, appropriate hazing techniques will be conducted in consultation with ENR. • Sightings of grizzly bear, polar bear or wolverine will be reported to CWS.
Impacts to terrain/vegetation resulting from ground-based Program activities	• Program activities will be confined to previously disturbed areas • Crew members will not walk off the Program site onto the tundra at any time, unless there is a specific requirement (e.g., waste recovery) • Helicopters will land on previously disturbed areas within the Program site
Potential impacts to wildlife and/or wildlife habitat resulting from helicopter fluid leak or fuel spill	• Only a small amount of fuel will be on-site at any one time; it will be properly contained and stored in CSA-approved containers • A drip tray will be used to refuel machinery or equipment • Spill clean-up materials will be on hand; in the event of a spill or leak, the fluid will be contained to avoid it being scavenged by wildlife • Leaks or spills of oil, fuel or other deleterious material will be reported immediately, as per immediately reportable spill requirements, to the NWT 24-hour Spill Report Line at (867) 920-8130 • Prior to site abandonment, all work areas will be inspected for contaminant residues and cleaned up as required to prevent contamination of soils and surface waters
Potential interactions with or impacts to wildlife resulting from remote field camp	• Food, waste and other highly scented materials will be stored in heavy animal-proof containers to minimize attractants • The camp will be inspected daily and kept tidy to ensure wildlife are not drawn to the area • All wastes will be removed from the site and transported to Inuvik following completion of activities • Cooking and sleeping tents will be established at least 100 m from each other to minimize possible human-wildlife interactions • A wildlife monitor will be employed for all field activities to manage human-wildlife interactions

12.1 Wildlife Monitors

The Program will employ, when logistics permit, a qualified local wildlife monitors to accompany the crew undertaking Program activities. The wildlife monitor will possess knowledge of the area and wildlife, and will have experience handling firearms. He or she will play a key role in the successful implementation of environmental mitigation measures. The responsibilities of the wildlife monitor will likely include:

- Identifying wildlife and key wildlife habitat features (e.g., dens and nests) in the Program area;
- Monitoring any wildlife detected in the Program area;
- Ensuring wildlife mitigation measures are being implemented adequately;
- Recommending further measures to protect wildlife, if applicable;
- Identifying any unforeseen situations that have the potential to result in adverse impacts on wildlife;
- Managing wildlife/human encounters and wildlife interactions with Program equipment;
- Employing proper herding or hazing techniques, if required;
- Documenting relevant information for regulatory authorities and co-management institutions, as required;
- Liaising with Program supervisors.

12.2 Effects of the Environment on the Program

Potential effects of the environment on the Program are extremely limited. Inclement weather may prevent the Program crew from conducting field work, resulting in temporary delays.

In cases where crew members are being mobilized to the site daily, they will be equipped with a survival kit adequate for the number of people in the helicopter, in case inclement weather prevents the helicopter from returning to Inuvik.

12.3 Impact Assessment Summary

If the mitigations presented in Table 12-1 are applied, the potential effects of Program activities on the environment will be short-term, infrequent, localized, and temporary, and will result in negligible residual environmental impacts.

13 Cumulative Effects

A cumulative effects assessment (CEA) is conducted to ensure the incremental effects resulting from the combined influences of various projects are assessed. These incremental effects may be significant even though the residual effects of each project, when independently assessed, are considered insignificant. It is difficult to predict the degree and intensity of industry and human activities that will take place in the outer Mackenzie Delta throughout the duration of the proposed Program (2008-2014), but it can be expected that activity will continue to increase.

13.1 Spatial and Temporal Overlaps with Other Projects

At this time, ARI is not aware of any projects – proposed or ongoing – that overlap spatially and temporally with the proposed Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring Program. There are, however, a number of projects projected for the near future which may overlap temporally with the Program. Program activities could overlap temporally with activities associated with the Mackenzie Gas Project (MGP), planned to begin construction as early as 2010 (pending regulatory approval). It is likely in the near future that the MGP anchor field proponents (Shell Canada Energy – Niglintgak; ConocoPhillips Canada (North) Ltd. – Parsons Lake; Imperial Oil Resources Ltd. – Taglu) will conduct helicopter-supported summer field programs, which will overlap temporally with the Program. MGM Energy Corp. is proposing a field program during the summers of 2008 and 2009 in support of its proposed winter drilling and seismic programs. These activities will not overlap spatially with the Program.

The Program may overlap temporally with site inspection activities associated with the 2006-2008 Mallik Gas Hydrate Research Project. Overlaps with winter drilling operations will be limited to transportation and storage of sump cap fill material on-site.

13.2 Assessment of Cumulative Effects

The proposed Program is limited in scope and duration, and avoids most sensitive periods for wildlife and Inuvialuit harvesting.

Section 12 concluded that there is negligible potential for residual Program effects after mitigation measures are applied. Therefore, the Program has very low potential to contribute to cumulative effects of industrial activity in the outer Mackenzie Delta.

14 Emergency Response Plan

To accomplish the science-based objectives of the Mallik sump monitoring program, the field party is planning to deploy a light camp (less than 500 lbs) to the Mallik site using Canadian Helicopters. The members of the field crew all have experience working and camping in the Arctic. The field party will include William Hurst a technician at Aurora Research Institute who has extensive experience working in the Mackenzie Delta. An Inuvialuit wildlife monitor will also accompany the field crew when logistically possible. Daily communications with the ARI by satellite phone will be scheduled. The field crew will have at least two qualified first aid attendants who hold current First Aid certificates and an expedition-type first aid kit will be carried.

The Program site is low-lying and is prone to flooding during storm surges. Normally, this flooding is progressive over many hours and not sudden. Therefore enough time should be available to pack-up the camp and call for a helicopter pick-up on the satellite phone. If a helicopter-based exit is not possible, the camp would be temporarily moved to the top of the 1972 IORL sump where the elevation is 3 m above sea level and has been observed to remain dry during extreme storm surge events. A small inflatable boat will also be available and could be used to move the camp to higher ground further inland if required.

15 Clean-up, Disposal and Decommissioning Plan

There is no permanent infrastructure associated with the Program. No significant impacts to terrain, permafrost, or vegetation are anticipated. Any leaks will be addressed as described in Sections 12 and 14. Clean-up will be minimal; all waste will be hauled out with the crew at the conclusion on Program activities.

16 Other Environmental Assessments

No other environmental assessment has been carried out in support of this Program.

17 References

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Appendix A ARI Response to NEB Information Request No. 1 for the 2006-2008 Mallik Gas Hydrate Research Project

AURORA COLLEGE
Aurora Research Institute

1 November 2006

Mr. Bharat Dixit, Chief Conservation Officer
National Energy Board
444 – 7th Avenue SW
Calgary, AB T2P 0X8

Dear Mr. Dixit:

Re: Aurora Research Institute – Mallik Gas Hydrate Production Research Project, National Energy Board Information Request No. 1 – Submission 2

Aurora Research Institute (ARI) is submitting the enclosed package in response to the remaining questions from Information Request No. 1 for the proposed 2006 to 2008 Mallik Gas Hydrate Production Research Project. These responses complete ARI's response to Information Request No. 1.

In addition, please find enclosed a letter to Fisheries and Oceans Canada addressing concerns and mitigation measures identified in the Letter of Advice, forwarded October 16, 2006.

I trust that you will find the enclosed information to be in order. Should have any additional concerns regarding any of the responses, please feel free to contact me at (867) 777-3298, extension 22.

Sincerely,

Andrew Applejohn
Aurora Research Institute
Aurora College

Encl.

c.c. Mr. Larry Peckford, Inuvialuit Environmental Impact Screening Committee
Ms. Lorraine Sawdon, Environment Canada
Ms. Tara Schweitzer, Fisheries and Oceans Canada
Mr. Andrew McAllister, Natural Resources Canada
Mr. Rob Walker, Indian and Northern Affairs Canada
Mr. Simon Toogood, Northwest Territories Water Board
Mr. Jim Morrell, Transport Canada

Box 1450
Inuvik, NT X0E 0T0
Tel: (867) 777-3298
Fax: (867) 777-4264

AURORA COLLEGE
Aurora Research Institute

1 November 2006

Ms. Tara Schweitzer, Habitat Biologist
Fisheries and Oceans Canada, Western Arctic Area
P.O. Box 1871
Inuvik, NWT X0E 0T0

Dear Ms. Schweitzer:

Re: Aurora Research Institute – Mallik Gas Hydrate Production Research Project, Letter of Advice

Thank you for your October 16, 2006, Letter of Advice regarding the Mallik Gas Hydrate Production Research Project (the Project). Aurora Research Institute (ARI) has reviewed and accepted the mitigation measures identified, with the following exceptions.

Regarding mitigation measure 1, that "all facilities, wastes, sewage containment, fuel tanks, etc. should be located several hundred metres from all waterbodies", please note that the Mallik site and proposed operations and facilities will be located within 200 m of Mallik Bay to the east, and within 100 m of an unnamed lake to the west. It is not possible to relocate the drilling operations to another site, as the Project relies on the existing infrastructure at the Mallik site. ARI has put forward many mitigation measures described in *Submission to the Environmental Impact Screening Committee – 2006-2008 Mallik Gas Hydrate Production Research Project* (KAVIK-AXYS Inc. 2006) which will protect fish and fish habitat including secondary containment for fuel and a spill response plan.

Regarding mitigation measure 8, that "the treated waste water should be discharged to land in a dispersed application rather than directly into the Mackenzie River", please note that the practice of distributing treated effluent on land was met with significant concerns during community consultation. ARI has selected distributing treated camp effluent on ice roads as this option was strongly preferred by communities. In this regard, ARI is seeking to comply with the requests of the communities, while operating within the requirements and conditions of the Project's Water Licence, as directed by the Northwest Territories Water Board. Effluent will be tested prior to dispersion. If it is found not to comply with the requirements of the Project Water Licence, it will be trucked to Inuvik for disposal.

Box 1450
Inuvik, NT X0E 0T0
Tel: (867) 777-3298
Fax: (867) 777-4264

If you have any questions regarding the details of this proposal, please do not hesitate to contact me. I can be reached at (867) 777-3298, extension 22.

Sincerely,

Andrew Applejohn
Aurora Research Institute
Aurora College

c.c. Ms. Anne-Marie Buchwald, National Energy Board
Ms. Lorraine Sawdon, Environment Canada
Mr. Larry Peckford, Environmental Impact Screening Committee
Mr. Andrew McAllister, Natural Resources Canada
Mr. Rob Walker, Indian and Northern Affairs Canada
Mr. Simon Toogood, Northwest Territories Water Board
Mr. Jim Morrell, Transport Canada

Aurora Research Institute (ARI), Aurora College
Mallik Gas Hydrate Production Research Project
National Energy Board Information Request No. 1 – Responses, Submission 2

National Energy Board

1. *Please identify how ARI proposes to address the recommended terms and conditions by the EISC. Include in your response justification for not implementing terms and conditions.*

    c) *That the proponent adhere to appropriate measures for grizzly bears in accordance with NWT ENR departmental guidelines (please see ENR letter attached), as well as contacting ENR to arrange for the carrying out of a bear and den survey prior to beginning the project. This would help minimize potential negative impacts on bears.*

    The grizzly bear denning survey was conducted in cooperation with the Government of the Northwest Territories Environment and Natural Resources (ENR) Division on Friday, October 20, 2006. Several grizzly bears were observed, though none within the vicinity of the Mallik site.

    e) *As indicated during the presentation by the proponent to the EISC, the proponent intends to monitor the existing sumps at the Mallik site. The proponent committed to provide the EISC with a letter outlining the intention to carry out long term monitoring, especially the sump which will be encroached upon by the ice pad constructed for this project*.

    The sump monitoring program is described in detail in the response to Environment Canada question 3 below and in the attached letter to the Environmental Impact Screening Committee (EISC).

Environment Canada

1. *In conversation with Douglas Ashford of Inuvialuit Oilfield Services (IOS) on September 1, 2006, IOS committed to providing Environment Canada with the detailed flare analysis for the production testing of well Mallik 2L-38. Environment Canada received* ***Mallik Gas Hydrate Research Project Thermal Radiation Effects on a Flare Stack Ice Pad RWDI project Number: W06-1292****, on September 6, 2006. Upon review, the document analyzes potential for ice melt, however it does not include an air quality analysis. Environment Canada requests that the proponents supply a flare management plan which would include composition of gas to be flared and modelling predictions of air quality impacts.*

    Potential air quality impacts resulting from emissions resulting from flaring at the Mallik 2L-38 well have been assessed. Emissions of nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), hydrogen sulphide (H_2S), sulphur dioxide (SO_2), and particulate matter (PM) are estimated. The

impact on air quality is predicted using a screening level regulatory dispersion model. Impacts on air quality are determined by comparing predicted ground-level concentration to applicable regulatory ambient air quality standards.

Flare emissions have been estimated using emission factors published in the Canadian Association of Petroleum Producers (CAPP) April 2003 Guide, *A Recommended Approach to the National Pollutant Release Inventory (NPRI) for the Upstream Oil and Gas Industry for Criteria Air Contaminants*. The CAPP Guide has been peer reviewed and is based upon a review of available emission factors in the upstream oil and gas industry. Emission rates and the gas composition (Wiersberg et al. 2005; previously submitted) of the flare gas are provided in Tables 1 and 2, respectively.

Table 1 Summary of Emission Data During Flaring

Emission Rates					
SO2 (g/s)	**H2S** (g/s)	**NOx** (g/s)	**CO** (g/s)	**VOC** (g/s)	**PM** (g/s)
0.00	0.00	0.44	2.40	0.34	0.86

Table 2 Estimated Gas Composition of the well Mallik 2L-38

Gas	Mole Fraction (%)
CH_4	92.5
CO_2	0.5
N_2	4.5
O_2	0.5
C_2	0.5
C_3	0.5
C_4	1
Total	100.0

A simple screening assessment has been completed using a dispersion model, which is a computer program that mathematically simulates atmospheric behaviour to estimate ambient air quality concentrations resulting from a proposed emission source. Ambient air quality associated with emissions from well testing was predicted using the U.S. Environmental Protection Agency SCREEN3 dispersion model. The SCREEN3 model is a Gaussian plume dispersion model that is suitable for screening level analysis of single emission sources. SCREEN3 uses a matrix of screening meteorological data to establish a conservative or 'worst-case' estimate of short-term air quality impacts. For purposes of the model, it was assumed that terrain surrounding the 2L-38 well is flat.

For purpose of emission estimates and dispersion modelling, it was assumed that the gas flow rate is 28,300 m^3/d and that the flare stack is 24 m (80 ft.) high. The

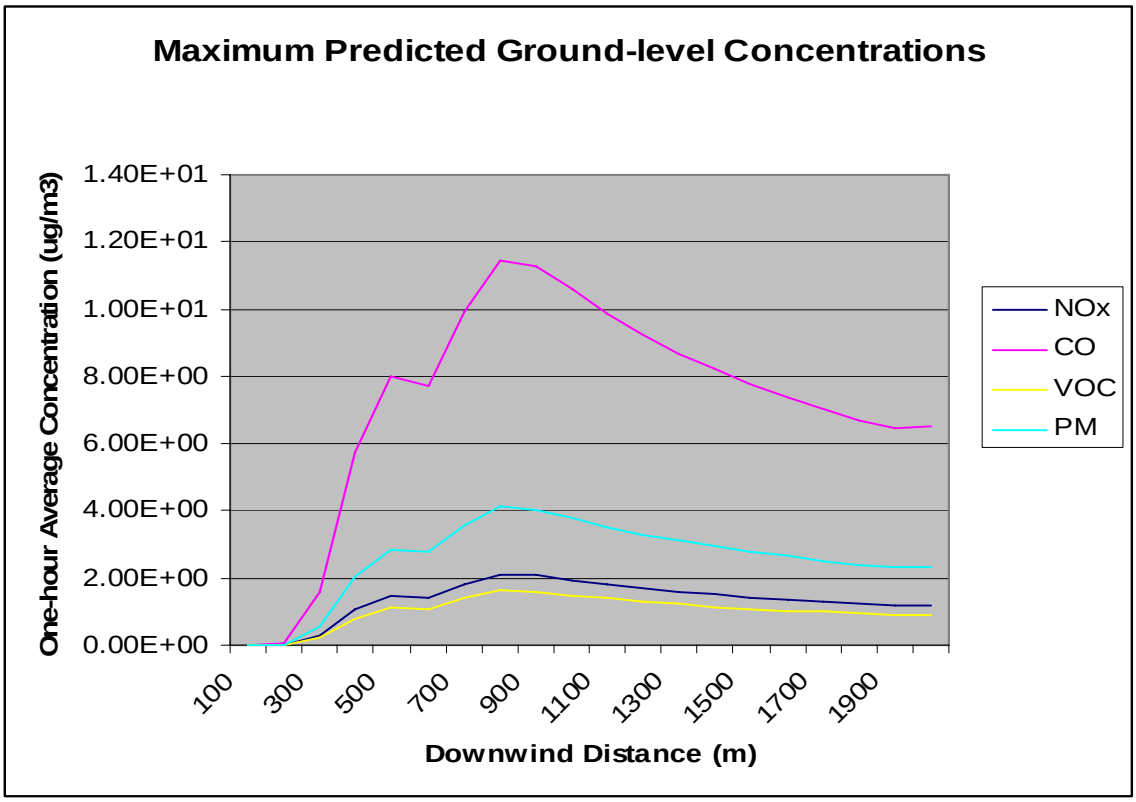
gas composition indicates that the gas is sweet, meaning that it is anticipated that there will be negligible amounts of H_2S present. As a result, it is expected that there will be no H_2S or SO_2 emissions associated with the flaring. Maximum predicted one-hour average concentrations of NO_x, CO, VOC and PM are predicted and compared to applicable ambient air quality criteria as presented in Table 3 for flaring at the Mallik 2L-38 well. Applicable Ambient Air Quality Standards (AAQS) and National Ambient Air Quality Objectives (NAAQO) are detailed in Table 3. The figure below presents the maximum predicted ground-level concentrations with downwind distance associated with flaring for NO_x, CO, VOC and PM.

The United States Environmental Protection Agency (US EPA) recommended averaging-period adjustment factors of 0.7, 0.4 and 0.08 are used to relate one-hour average maximum concentration predictions from the SCREEN3 model to longer averaging times of 8-hour, 24-hours and one-year, respectively. The ratio between a longer-term maximum concentration and a 1-hour maximum will depend upon the duration of the longer averaging time, source characteristics, local climatology and topography, and the meteorological conditions associated with the 1-hour maximum. These ratios are representative of typical ratios between concentrations measured over various averaging times by the US EPA. The results presented in Table 3 indicate that no air quality effects are expected as a result of flaring at the Mallik 2L-38 well. For all contaminants, maximum predicted one-hour average ground-level concentrations are at least one order of magnitude lower than applicable ambient air quality objectives or standards. The maximum predicted ground-level concentration is predicted to occur approximately 800 m downwind of the flare stack.

Table 3 Maximum Predicted One-Hour Ground-Level Concentrations Associated with Flaring of the Mallik 2L-38 Well

Contaminant	Averaging Period	Maximum Predicted Concentration	Ambient Air Quality Criteria
		($\mu g\ m^{-3}$)	($\mu g\ m^{-3}$)
NO_x	1-hour	2.11	400 [a]
	24-hour	0.84	200 [a]
	Annual	0.17	60 [a]
CO	1-hour	11.5	15,000 [a]
	8-hour	8.08	6,000 [a]
VOC	1-hour	1.63	N/A
	Annual	0.13	N/A
PM	1-hour	4.13	N/A
	24-hour	1.65	30 [b]
	Annual	0.33	N/A

[a] National Ambient Air Quality Objective
[b] NWT Ambient Air Quality Standard
N/A No Standard



3. *From a conversation with Douglas Ashford of IOFS on September 1, 2006, it is understood that the proponents are proposing to cover a portion of the sump located just north of well 2L-38, with an ice pad a minimum of 30 cm thick. Steel mud tanks will be located on the ice pad. Prior to establishing the ice pad cover, existing conditions and contours of the sump will be documented, and as part of the clean up, the proponents may improve the sump containment.*

   Environment Canada has concerns regarding the proposed sump encroachment and the potential impacts of the ice pad and site activities on the thermal and structural stability of the existing sump. Given that there already exists potential long-term stability and containment issues with the historical sump, the proponents are request to provide Environment Canada with justification for the sump encroachment. Further, if the sump encroachment is to proceed, Environment Canada requests that the proponents submit an impact analysis of the proposed encroachment on the sump's structural and thermal stability. The analysis should include waste and soil composition including the wastes freeze depression (core sampling if required), thermal regime (including background) deficiencies in sump performance (e.g. slumping, salt efflorescence, ponding, unfrozen wastes, etc.), existing drainage and vegetation in and around the sump area, in addition to the potential impacts to the sump from the placement of an ice pad. If the sump is to be encroached, the proponents should implement mitigative measures to ensure all site activities do not negatively impact sump performance.

In keeping with current regulatory and industry practice, this research project provides an excellent opportunity for the proponents to complete an audit of sump performance, document existing deficiencies, establish geo-thermal monitoring, and implement remedial measures to address deficiencies in sump performance. At a minimum, the Northwest Territories Water Board Guidelines for Sump Assessment should be followed, with cores, samples, and ground temperature monitoring to occur. Monitoring should include the drainage and vegetation on and around the sump, and any changes in those regimes that occur, as well as monitoring of the thermal and structural stability of the sump over time. This information should be made available to stakeholders and regulators.

ARI understands that concerns exist regarding sump encroachment during proposed 2006-2008 winter drilling activities, specifically how the thermal and structural stability of the 1998 2L-38 drilling sump will be affected as a result of this encroachment.

Justification for Sump Encroachment

ARI has consulted extensively with the drilling rig supplier, Akita Equtak Drilling Ltd., to determine the potential to reorganize the drilling rig layout so as not to require sump encroachment. As a result of the proximity of well 2L-38 to the 1998 2L-38 drilling sump, it is not possible to place the drilling rig at this location without some sump encroachment. A typical overhead view layout of drill rig 62E is attached for reference.

Impact Analysis

The sump contents and soil composition was determined through geotechnical testing conducted by Kiggiak – EBA Consulting Ltd. (2005, see attached) in August 2005. Borehole 05BH06 was drilled in the 1998 2L-38 drilling sump. The following conditions, described in Kiggiak – EBA (2005), were encountered:

- Grey clayey silt (silt and clay, to silt with some clay) were encountered in the sump cap
- Materials recognizable as drill cuttings were encountered at approximately 3.0 to 3.5 m
- Stratified grayish brown silt, some fine sand, and trace clay were encountered at a 4.3 m below the surface, indicating native soil below the sump
- The contents of the sump include potassium-chloride (KCl)-rich drill cuttings
- Permafrost conditions comprised of visible excess ice (random and stratified), with ice contents up to 30%
- Up to 80% excess ice in the base of the sump cap at a depth of approximately 2.1 m to 2.6 m (Kiggiak – EBA 2005).

The active layer in the vicinity of the 1998 2L-38 drilling sump was found to be between 0.4 and 1.3 m thick (Kiggiak – EBA 2005). The depths at which sump cap materials, sump contents, and base soils were encountered indicates the sump was constructed in accordance with recommendations presented in Kokelj and GeoNorth (2002), indicating a freeboard of 2 m, combined with a 1.5 m cap, for a total of 3.5 m of overburden.

Thermal data for the sump is limited as thermistors were only recently installed and are not equipped with continuous data loggers. A thermistor string was installed in 05BH06 in August 2005, as well as at 05BH08, located outside the sump as a control point. Data uploaded in November 2005 and August 2006 is presented in the table below. The data suggests that ground temperatures within the sump are lower than those of the surrounding soil.

Site	Depth (cm)	Temperature (°C)	
		November 2005	August 2006
05BH06 – 2L-38 Drilling Sump	10	-2.3	10.7
	210	-11.5	No data
05BH08 – Undisturbed tundra	80	-0.8	-0.0
	380	-5.0	-5.0

With respect to the evaluation of sump performance, in addition to the Kiggiak – EBA 2005 survey, a site survey was conducted in September 2006 by Inukshuk Geomatics Inc. (Inukshuk) and KAVIK-AXYS Inc. (KAVIK) to document sump contours and the general conditions of the sumps within the Mallik site. The results of this survey are presented in a letter from KAVIK to ARI (see attached). Electro-magnetic (EM) surveys described in Kiggiak – EBA (2005) indicate that "essentially all saline material from drill cuttings remains contained within the sump below the active layer". The results of the KAVIK/Inukshuk survey indicate elevated concentrations of potassium (K) and chloride (Cl) within the soil sample taken from the 1998 2L-38 drilling sump compared to background levels. This could indicate potential migration of underlying saline sump contents into the sump cap (KAVIK 2006). However, the reported salinity was also found to be less than that of sea water (KAVIK 2006), and is not anticipated to have a substantial effect on freezing point depression.

Inukshuk undertook a detailed survey of the sumps to establish elevation and depression contours of the sump cap. These contours are displayed in the attachments of the KAVIK submission to ARI (KAVIK 2006). Generally, there was pooled water observed at on the northwest margin of the 1998 2L-38 drilling sump. Some salt efflorescence and settlement of the sump cap was also noted during the survey (KAVIK 2006).

The KAVIK/Inukshuk survey also noted vegetation and drainage conditions in and around the sump. As identified previously, ponding was noted at the 1998 2L-38 drilling sump, and settlement of the sump cap has occurred. The sump was not vegetated, though no indication of stressed vegetation was noted adjacent to the 1998 2L-38 drilling sump (KAVIK 2006).

In terms of potential impacts to the 1998 2L-38 drilling sump as a result of drill rig placement and ice pad placement, ARI is proposing a rig layout that will result in the least possible disturbance to the 1998 2L-38 drilling sump. The proposed layout will be such that the components of the rig which will encroach on the sump will consist of the shaker container and tank, and the shale or davlin tank. The shaker tank is expected to be approximately 5°C, while the shale tank

will be between 2°C and -2°C. The encroachment will last for 12 days in Year 1 operations only, while the drilling rig is required at the 2L-38 wellsite. The ice pad under the rig will be at minimum 30 cm thick over the sump. Contour information from the Inukshuk site survey indicates a difference of 40 cm between the maximum height of the sump cap and adjacent terrain. To accommodate the change in elevation, the ice pad adjacent to the sump will be 70 cm, in order to provide an even work surface for the rig.

Complete freezing of the active layer will have been attained prior to construction of the ice pad as demonstrated by the ground temperature measurements in November 2005. The presence of the ice pad, which is cleared of snow, for a period of approximately 4 months is expected to have a cooling effect on the underlying permafrost, resulting in a lower near-surface ground temperatures within the soil than would normally occur over the course of the winter. The presence of the warm mud tanks for 12 days may result in some heat transfer to the ice pad. However, this is a short-term effect, with only slightly positive ground temperatures. Due to the expected cooling of the ground temperatures by placement of the ice pad, and the limited short-term heating of the pad, thermally-induced instability is not considered likely.

If, however, ground temperatures are prevented from reaching their normal winter lows, spring and summer warming may give rise to higher than normal peak subsurface temperatures, including a local increase in the depth of thawing. While unlikely, this effect would likely be limited to the first summer season and the ground thermal regime would eventually re-establish itself based on aggradation of the underlying permafrost, assisted by the lower temperatures of soils within the sump. During the first summer, a small degree of increased settlement may occur. However, the overall effects on sump stability and integrity are expected to be minor.

Mitigation Measures

Increase thawing and settlement, even minor, may increase the potential for ponding of surface water, which in turn can reduce subsequent frost penetration and in some cases lead to ongoing permafrost degradation. ARI intends to address this potential impact through application of the following remediation and monitoring program.

Further reduction in heat transfer will be achieved by insulation (rig matting) beneath the tanks. During winter 2006-2007 (Year 1) operations, snow will be cleared from the ice pad on the 1998 2L-38 drilling sump cap to minimize additional insulation of the sump and reduce remnant potential for ponding following thawing.

All of the 1998 2L-38 and 2002 3L/4L/5L-38 sump caps were observed to have settled, resulting in ponding at two of the sumps (2002 3L/4L/5L-38 drilling sump and 1998 2L-38 western drilling sump). Additionally, the cap at the 1998 2L-38 camp sump does not completely cover the exposed hole. ARI proposes to transport suitable fill material to the site in winter 2006-2007 operations, and stockpile it onsite. The fill will be similar in nature to that used for the existing sump caps (silt, clay and sand). During a summer 2007 site inspection, ARI proposed to conduct hand recontouring of the sump caps to result in sump caps of sufficient thickness to contain the active layer, and contoured to promote positive drainage and eliminate ponding.

Additionally, ARI, with 5-year funding from the Japan Oil, Gas & Metals National Corporation (JOGMEC), proposes a 7-year monitoring program at the site to monitor the stability of the 1998 2L-38 and 2002 3L/4L/5L-38 sumps. The monitoring program is proposed to consist of active layer and ground temperature monitoring for 7 years. The monitoring program will involve installation of four 9 m deep thermistor strings (two in sumps and 2 background), in addition to the 4 existing onsite. Temperature data will be logged with date loggers, and active layer depth measurements will be recorded on an annual site visit in August. An EM survey was previously conducted in 2005. Additional EM surveys are proposed to occur in 2007 (year 1 of the monitoring program), 2009 (year 3 of the monitoring program), and 2011 (year 5 of the monitoring program). Monitoring reporting will be completed as per the format defined in the Appendix of the *Protocol for the Monitoring of Drilling-Waste Disposal Sumps, Inuvialuit Settlement Region, Northwest Territories* (NWTWB 2005). The monitoring program will be used to further support research initiatives at ARI, Aurora College. In particular, ARI has consulted with experts in the Geological Survey of Canada (S. Dallimore) and Indian and Northern Affairs (S. Kokelj) about research opportunities that could be fulfilled with a multidisciplinary approach to the sump monitoring program. Topical research issues that could be advanced concurrently with a sump monitoring program include:

- assessment of naturally emplaced salts and clarification of background versus disturbed salinity;
- ground thermal studies and effects of elevation and snow cover;
- training opportunities on sump monitoring techniques; and
- use of natural plant species for sump re-vegetation.

References:

KAVIK-AXYS Inc. (KAVIK). 2006. *September 15, 2006 – Mallik Site Survey*. Submitted to Aurora Research Institute. Calgary, Alberta and Invuik, Northwest Territories.

Kiggiak – EBA Consulting Inc. 2005. *Geophysical and Subsurface Environmental Site Investigation 2005 Mallik 2L and 3L/4L/5L-38 Sump Sites*. Submitted to Canadian Petroleum Engineering Inc. Calgary, Alberta

Kokelj, S.V., and GeoNorth Ltd. 2002. *Drilling Mud Sumps in the Mackenzie Delta Region: Construction, Abandonment and Past Performance*. Submitted to Robert Jenkins, Oil and Gas Specialist, Department of Indian Affairs and Northern Development, Northwest Territories Region.

Northwest Territories Water Board (NWTWB). 2005. *Protocol for the Monitoring of Drilling-Waste Disposal Sumps, Inuvialuit Settlement Region, Northwest Territories.* Yellowknife, Northwest Territories.

Wiersberg, T., J. Erzinger, M. Zimmer, J. Schicks, and E. Dahms. 2005. *Real-time gas analysis at the JAPEX/JNOC/GSC et al. Mallik 5L-38 gas hydrate production research well*; in *Scientific Results from the Mallik 2002 Gas Hydrate Production Research Well Program,*

Mackenzie Delta, Northwest Territories, Canada, (ed.) S.R. Dallimore and T.S. Collett. Geological Survey of Canada, Bulletin 585, 15 p.

Appendix B Inuvialuit Game Council 2002 Overflight Guidelines

Summary of Advice Received by EISC from the Co-Management Groups for Recommended Environmentally Acceptable Minimum Flight Altitudes

Aircraft Type	Species/Situation	Recommended Altitude	Source
Not specified	Over areas likely to have birds	>650 m (2100 ft)	CWS [WMAC(NWT)]
Not specified	Over areas where birds are known to concentrate (sanctuaries, colonies, moulting areas)	>1100 m (3500 ft)	CWS [WMAC(NWT)]
Subsonic Aircraft	Over large mammals during ferry flights	>300 m (975 ft)	DRWED [WMAC(NWT)]
Subsonic Aircraft	During wildlife surveys	>100 m (325 ft)	DRWED [WMAC(NWT)]
Subsonic Aircraft	Aeromagnetic surveys in areas with large mammals	Timing should be restricted rather than altitude	DRWED [WMAC(NWT)]
Not specified	When flying point to point in vicinity of caribou and other wildlife species	>610 m (2000 ft)	Transport Canada [WMAC(NS)]
Not specified	Over parks, reserves, and refuges	>610 m (2000 ft)	Transport Canada
Not specified	Over areas where there are belugas and bowhead whales	>300 m (975 ft)	FJMC
Not specified	Zone 1	>760 m (2500 ft)	Tourism Guidelines Beluga Management Plan [FJMC]
Not specified	Zone 2	>610 m (2000 ft)	Tourism Guidelines Beluga Management Plan [FJMC]

General Advice

- Minimise the number of flights whenever possible
- Fly at times when few birds are present (e.g., early spring, late fall, winter)
- Avoid large concentrations of birds (e.g., migratory bird sanctuary, breeding colonies, moulting areas)
- Avoid especially sensitive areas such as seabird colonies and raptor nesting sites
- Plan routes that minimise flights over habitats likely to have birds
- Use small aircraft rather than large aircraft whenever possible
- Use fixed wing aircraft rather than helicopters whenever possible
- Inform pilots of these recommendations are areas known to have birds
- Hovering or circling may greatly increase disturbance and must be avoided
- Caribou calving grounds should be avoided whenever possible
- Aeromagnetic surveys should be controlled to prevent disturbance to large mammals by restricting the timing of the surveys rather than the elevation. These surveys should not take place near or on calving and post-calving areas during the period of May 25 to July 15. After July 15 they should avoid any areas known to have large aggregations of caribou
- Animals reactions will depend on a variety of situations including aircraft type, noise levels, speed of travel, overflight frequency, and animal activity (e.g., loafing, feeding, travelling) and its surroundings (water depth and clarity, substrate). The EISC may have to consider the circumstances of the activity on a case by case basis.
- DFO often recommends a minimum altitude of 400 m (1200 ft) for flights over marine mammal habitat in this region. Recommended or required minimum altitudes may be higher in areas of particularly intense aircraft activity, and in cases where flights are over marine mammal concentration areas, or at particularly sensitive times of their life cycle.
- Exceptions to these recommendations may be warranted for scientific studies (e.g., wildlife surveys) in which the benefits for conservation clearly outweigh the risks and should be evaluated on a case by case basis.

Appendix C Record of Consultations

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 1 of 6

Title/Topic:	**Mallik 2L-38 and 3L/4L-5L-38 Sump Monitoring Program**
Date:	**April 2, 2007**
Time:	**1700**
Location:	**Inuvik Hunters and Trappers Committee (HTC) Office, Inuvik**
Person(s) Involved:	**Inuvik HTC** • **Sam Lennie Jr.** • **Hank Rogers Sr.** • **Doug Esagok** • **Elizabeth Gordon** **Proponent** • **Michael Fabijan – KAVIK-AXYS**
Meeting Notes:	**NOTE:** **Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.**

Comment/Question	Response
1. Concern that the ponded water on and around the sumps contains contaminants and that the contaminated ponds will be filled in during recontouring.	ARI will be testing for salts; the purpose of the program is to determine whether the sumps have leaked/ are leaking.
2. Sump construction – how far past the trench does the sump cap fill go?	I think it is 2 m; will confirm for project description.

	3. Comment that vegetation should have been seen on the sumps during the last summer field visit.	These sumps are several years old and still have little vegetation on them. The area around the sumps does not have much vegetation either. The sumps have not had seed added to revegetate them.
	4. Noted that sump area is low and that silt settling may occur.	Acknowledged.
	5. Clarification – this is all summer work?	Yes.
	6. Clarification – there will be no camping crews? The crews will be making day trips only?	Yes.
	7. What kind of material will be used to recontour the sumps? Sand, gravel or dirt? It will not be any silt from around the area?	Unsure what the fill material will be. It will not be dug up from the sump area; the fill material will be trucked in. The material will be described in the project description.
	8. If you use gravel, it will not be a very good insulator after it is frozen.	Do you have any suggestions for fill material? There will be dirt on the topmost layer to allow vegetation to grow.
	9. Noted that the sumps around Big Lake have huge clumps of willows on top of them ~ 3 m high. It is higher ground there though, so it is not affected by storm surges.	The program area is low. The Imperial Oil Ltd. sump in the area has some vegetation growing on it, but not willows.
	10. Commented that pictures of the sumps and the area would be good to see. It would be good to have pictures from the same time of year as the work is proposed, as well.	Site photographs will be included in the project description. The crews will also be taking photos of the sumps and the area each year.
	11. The HTC would like to have copies of the annual study reports.	Acknowledged.
	12. Noted that site is low lying and floods each year. Noted the importance of monitoring the sumps because of uncertainty about what is coming out of the sumps with the flooding.	Yes, the sumps will be monitored each year. The EM survey will be used with the other tests to determine whether anything is leaking from the sumps.
	13. Why are they concentrating more on these sumps than other ones in low lying areas?	These sumps are the ones that the ongoing Mallik Gas Hydrate Production Research Project created and have committed to monitoring.
	14. Will they be leaving temperature probes in the sumps all year?	There are thermistors inserted into the sumps to measure the ground temperature and yes, they will be recording the temperature year-round.

	15. You will take pictures of the ponding around the perimeter before it is filled in?	Yes.
	16. Do you have some pictures from last summer?	Yes, I can produce these if you would like to see them.
	17. Why are they not doing anything on the L-38 sump?	That sump was created by Imperial Oil Ltd. and has nothing to do with the Mallik Gas Hydrate Production Research Project.
	18. Were the two Mallik (Gas Hydrate Production Research Project) sumps created this winter?	No, there is no sump program associated with the current Mallik Gas Hydrate Production Research Project. They trucked everything out this winter. The sumps are from the 1998 and 2002 programs.
	19. The area around the Mallik site is a staging area for white-fronted geese. They go there by the thousands from May through to the end of August. There may be birds in the surrounding area as well. We did swan surveys in the area up to about 4 years ago.	When we were up there last summer, there weren't any birds in the area.
	20. Appreciated the handout which provided a project summary. It would be great if everyone did that.	Thank you. I will continue to do this.
Recorded By:	Michael Fabijan	

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 2 of 6

Title/Topic:	**Mallik 2L-38 and 3L/4L-5L-38 Sump Monitoring Program**
Date:	**April 3, 2007**
Time:	**1300**
Location:	**Tuktoyaktuk Hunters and Trappers Committee (HTC) Office, Tuktoyaktuk**
Person(s) Involved:	**Tuktoyaktuk HTC** • **Paul Voudrach** • **Charles Gruben** • **David Nasogaluak** • **Lennie Emaghok** **Proponent** • **Michael Fabijan – KAVIK-AXYS**
Meeting Notes:	**NOTE:** **Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.**

Comment/Question	Response
1. Clarification that monitoring is to be conducted on two sumps.	Yes. The project will monitor the two sumps that the previous gas hydrate research projects constructed in 1998 and 2002. There is an old Imperial sump in the program area, but it is not the responsibility of the proponents.
2. Noted that the study area gets washed over by high tides and that this is a low-lying area. Noted that there is wood washed up. Used to hunt wolves in the area and so knows that the area is flat.	Acknowledged.

	3. Noted that birds will have moved out by late August. The birds move here and there in big flocks. The birds will be more in the water areas around the study area. The swans moult in July and the first part of August. Swans nest in the area.	Asked about the birds in the area.
	4. Where is the ponding around the sumps?	There will be pictures in the project description which will show this.
	5. What is the point of filling in the ponded areas around the sump if it is just going to wash out again?	The purpose of filling in the ponded areas in to maintain the integrity of the sump. The holes will be filled to ground level; the sump cap will be levelled off to ensure that there is no further ponding on the sump. The sump cap level will not be built up.
	6. Could the sump monitoring (specifically, the EM surveys) be continued through 2021? You have one year, three years, and five years – couldn't you add another 10 years? Would like to see the monitoring program extend beyond seven years. The monitoring work for DND sites has increased to 30 years. 7. Concerned that studying the sumps will lead to using the sumps again. Industry likes using the sumps again because it's the easiest way for them. Concerned that this will happen when they start getting gas hydrates out of there.	The ongoing Mallik Gas Hydrate Production Research Project has no plans to add another sump to their program. This is just a research program that runs only one more year. This is not the group that would be extracting the gas hydrates. This work is being done on an Imperial lease area. A sump monitoring program was committed to in the project description for the current drilling program.
	8. I know it is alright to have them test the sumps. Is this program getting direction from other oil and gas companies?	No. It was recommended to the Mallik Gas Hydrate Production Research Project and they committed to doing the monitoring for seven years when they submitted the project description for the current program. I don't know whether the monitoring activities will continue further than the seven years. ARI is planning to do long-term sump monitoring and this is one of the first programs they will be working on.
	9. Would like to see the program results and the annual reports.	Acknowledged. We will ensure you receive copies of the annual reports.
	10. Why is there nothing growing on top of the sumps? There is salt from the ocean when it gets flooded and it is flooded in the spring.	I think it is just a factor of where it is. If you look around the area, there is very little vegetation growing there. It gets flooded in the spring and the summer too.

	11. Anderson River area has salt added from flooding and the area has salt-resistant plants.	Yes, I have seen one of Jim Hines' presentations on the Anderson River area.
	12. Noted that there is a bird watching shack on the other side of the study area. CWS used the area.	Acknowledged. I have seen the shack.
Recorded By:	Michael Fabijan	

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 3 of 6

Title/Topic:	**Mallik 2L-38 and 3L/4L-5L-38 Sump Monitoring Program**
Date:	**April 3, 2007**
Time:	**1700**
Location:	**Aklavik Hunters and Trappers Committee (HTC) Office, Aklavik**
Person(s) Involved:	**Aklavik HTC** • **Billy Archie** • **Evelyn Storr** • **Danny C. Gordon** • **Clayton Gordon** **Proponent** • **Michael Fabijan – KAVIK-AXYS**
Meeting Notes:	**NOTE:** **Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.**

Comment/Question	Response
1. Who does the Mallik site belong to?	The site is an Imperial Oil Ltd. lease that JOGMEC, NRCan and ARI are working on for the Mallik Gas Hydrate Production Research Project this year and next. The sump monitoring program will continue after the drilling program is completed.

	2. Why would you wait until the EISC approves reclamation to fill in the ponded areas on the sump? The damage will only get worse. 3. *Response from HTC member*: There is a process that you gave to go through. There has to be a project description submitted to the EISC for screening. 4. *Additional comment from HTC director*: I feel that if the EISC has to approve the monitoring program, then work should not begin until the program is approved. The HTC should have time to consider and comment on the project description submitted to the EISC.	There is no existing permit to leave material on-site to fill in the ponded areas this summer. It was not written into the existing project description. This is a monitoring program that was committed to as a part of the current drilling program. The EISC is aware that this monitoring program will be submitted.
	5. These are old sumps you are talking about?	Yes, these are sumps that were created in 1998 and 2002 during the previous gas hydrate research projects.
	6. That is Imperial's lease and sump?	The work is on an Imperial lease area. There are three sumps: one belongs to Imperial and the other two were created during the previous gas hydrate research projects. The sump monitoring program will only look at only the two latter sumps. No work is being proposed for the Imperial sump.
	7. The DEW line sites have a 25 or 50-year monitoring program. Why just seven years for these sumps? Can we go for 25 years?	They have committed to seven years. I do not know about 25 years.
	8. Noted the sump failure at Parsons Lake and that EnCana had left the area. Do they have any responsibility after seven years?	I think if the sump fails, their responsibilities still exist.
	9. How many soil samples in all will be collected?	Unsure. This will be included in the project description.
	10. Are they going to pump out the water before filling in the ponding? If you do not pump the water out, there is a chance of heaving.	I have seen in other similar programs that the material is just put in without pumping any of the water out. I will confirm how this will be done and have the process described in the project description.
	11. There are no contaminants in the water?	The program will be checking for that. This year they will be testing the ponded areas.
	12. Are there liners in the sumps?	No.
	13. Would like to have seen pictures of the area.	Photos will be included in the project description.

	14. Is there a chance for erosion to occur in the sump area?	Unsure.
	15. Will the NWT Water Board receive a report after year one? The Aklavik HTC would like to receive a copy of the report as well.	There will be a report submitted each year and a copy will be sent to the HTCs as well. The other HTCs have requested the same.
	16. This is all paid for by the Japanese government? Or is ARI putting in funding?	Unsure. ARI may be providing personnel while JOGMEC is providing funding.
Recorded By:	Michael Fabijan	

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 4 of 6

Title/Topic:	**Mackenzie Delta Gas Hydrate Research and Development Project** **Mallik Update and Sump Monitoring Consultation**
Date:	**June 22, 2007**
Time:	**1100**
Location:	**Tuktoyaktuk, Hunters and Trappers Committee Office**
Person(s) Involved:	**Tuktoyaktuk HTC** • **Paul Voudrach (President)** • **Chalres Gruben (Vice President)** • **Lennie Emaghok (Director)** • **David Nasogaluak (Director)** • **Lila Voudrach (Secretary)** **Proponent** • **Michael Fabijan – KAVIK-AXYS**
Meeting Notes:	**NOTE:** **Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.**

Comment/Question	Response
1. How long will they be monitoring the sump?	I think this is a five year program.
2. The site is flooded with salt water. The salt water will kill the plants.	Yes the area is flooded. There is a bit of vegetation in the surrounding area. The sump will be re-contoured and local seed will be used to revegetate the sump.
3. They are starting now?	No, not until later in the summer.
4. Will they be flying out of Inuvik?	Yes. It is ARI in Inuvik that is doing this work.
5. We support sump monitoring. Would like to see a long monitoring process. 6. Five years is not a very long time for a sump monitoring program.	So far this is a five year science project.

	7. We are really happy with the sumpless drilling program.	The project is happy to be doing a sumpless program.
Recorded By:	Michael Fabijan	

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 5 of 6

<table>
<tr><td>Title/Topic:</td><td>Mackenzie Delta Gas Hydrate Research and Development Project
Mallik Update and Sump Monitoring Consultation</td></tr>
<tr><td>Date:</td><td>June 22, 2007</td></tr>
<tr><td>Time:</td><td>1730</td></tr>
<tr><td>Location:</td><td>Inuvik, Hunters and Trappers Committee Office</td></tr>
<tr><td>Person(s) Involved:</td><td><u>Inuvik HTC</u>
• Sam Lennie Jr. (President)
• Sam Lennie Sr. (Vice President)
• Kevin Allen (Director)

<u>Proponent</u>
• Michael Fabijan – KAVIK-AXYS</td></tr>
<tr><td>Meeting Notes:</td><td>NOTE:
Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.

<table><tr><th>Comment/Question</th><th>Response</th></tr><tr><td>1. How much equipment will be stored on-site?</td><td>Permanently, nothing.</td></tr></table></td></tr>
<tr><td>Recorded By:</td><td>Michael Fabijan</td></tr>
</table>

RECORD OF CONSULTATION

Project #: KA90930 **Client Name: ARI/NRCan**

Consultation Meeting No. 6 of 6 – To be submitted as an Addendum with the Project Description

<table>
<tr><td>Title/Topic:</td><td>Mackenzie Delta Gas Hydrate Research and Development Project
Mallik Update and Sump Monitoring Consultation</td></tr>
<tr><td>Date:</td><td>July 3, 2007</td></tr>
<tr><td>Time:</td><td>1700</td></tr>
<tr><td>Location:</td><td>Aklavik, Hunters and Trappers Committee Office</td></tr>
<tr><td>Person(s) Involved:</td><td><u>Aklavik HTC</u>
• Billy Archie(President)
• Evelyn Storr (Secretary / Treasurer)
• Clayton Gordon (Director)
• Danny C. Gordon (Director)
• Donald Aviugana (Director)

<u>Proponent</u>
• Michael Fabijan – KAVIK-AXYS</td></tr>
<tr><td>Meeting Notes:</td><td>NOTE:
Notes are not verbatim transcripts of the meeting, the questions and answers are summaries of what was said at the meeting and are intended to capture the intent of what was said.
<table>
<tr><th>Comment/Question</th><th>Response</th></tr>
<tr><td>1. Is Steve Kokelj going to be doing the work (re best practices report)?</td><td>No. ARI is doing the research. They are using what is in the best practices manual</td></tr>
<tr><td>2. How will they access the site?</td><td>They will fly in and out</td></tr>
<tr><td>3. The project is an ARI research application?</td><td>Yes. There will be an EISC submission for the program</td></tr>
<tr><td>4. Want to make sure that what is seeded on the sumps is what is found in the area. Do not want o have plants that bears dig up.</td><td>Plants will germinate from native seeds collected at the site.</td></tr>
<tr><td>5. The plants that the bears dig up are the ones with pink flowers. The bears go after the roots. Will take a picture of the plant and send it to Pippa at ARI.</td><td>Thank you.</td></tr>
</table></td></tr>
</table>

Recorded By:	Michael Fabijan

Appendix D Environment and Natural Resources 2005 Bear Encounter Response Guidelines – Oil and Gas Programs

Department of Environment and Natural Resources
Bag Service #1 Inuvik, NT X0E 0T0

Bear Encounter Response Guidelines
Oil and Gas Programs

I. PRINCIPLES:

1. Protection of Life and Property
2. Conservation

II. OPERATIONAL GUIDELINES:

A. Deterrence
B. Re-locate, if feasible
C. Destroy

III. OPERATIONAL PROCEDURES:

Contacts:

Initial contact:

Ian Ellsworth (867)-777-7230 (W), (867)-777-1185 (Cell)
777-7236 (Fax)

Response Personnel:

The following personnel can be available for responding to problem bear situations:

Owen Allen	Inuvik	777-7201	
Kevin Allen	Inuvik	777-7308	
Paul Voudrach	Tuktoyaktuk	977-2350	977-2335 (Fax)
Ian McLeod	Aklavik	978-2248	978-2756 (Fax)

Initial Contact:

1. The complainant should complete the attached checklist prior to calling DENR. It is critical that as much information as possible be provided at this point in order to determine the appropriate response.

IV. RESPONSE

Wildlife Monitors will be the initial responders to problem bears. It is imperative that they have a sufficient supply of approved deterrents at their disposal. All bear sightings and encounters shall be reported to the ENR office closest to the area of operation.

The potential responses will be considered in the following order:

a) Camps

1) Wildlife Monitors will employ conventional means of deterring problem bears which threaten public safety or property. This may involve chasing a bear out of the camp with a vehicle or snowmobile, or using noise makers and rubber bullets. If these methods prove ineffective, and where a helicopter is available or can be obtained in the area, the bear may be chased from camp. Pilots must be careful not to over stress the bear during this flight and must back off when the bear is a sufficient distance from the camp and keeps running in the desired location. If circumstances allow, a Renewable Resource Officer (RRO) should be contacted prior to using aircraft to deter bears. Undue harassment is illegal and must be avoided. **All incidents involving any means of deterrence should be reported to a Renewable Resource Officer as soon as possible.**

2) Should for some reason, the Wildlife Monitor be unable to deter a bear, and where the bear does not pose an immediate threat to public safety or property, the Department of Environment and Natural Resources (DENR) may send a deterrent or capture team to the site.

b) Denning bears

If a bear is located in, at or near a den site, work in the area must halt. All employees should safely retreat from the area and report the occurrence to the Site Supervisor, Wildlife Monitor, and the Renewable Resource Officer in your area as soon as possible. Staff from DENR will be required to assess the site and may implement measures to ensure bears are not unduly disturbed. This may include the establishment of an exclusion zone of 300 meters around the den in which no work will be permitted. Work inside the exclusion zone will remain stalled until after den emergence.

c) Free ranging bears

Prior to active deterrence of free ranging bears, and where public safety or property is not in immediate danger, the Wildlife monitor will assess the situation. The monitor should determine if the bear has been disturbed from a den or if it is denning in close proximity. Bears in the vicinity of a den should not be deterred and work should cease until DENR has assessed the site. If the Wildlife Monitor has determined that the bear is in fact free ranging, and not lingering around a den site, then active deterrence may commence.

d) Destruction of the bear

Instructions to destroy the bear will be given when deterrent actions have failed, when additional deterrent actions are not possible, and when it is determined that capture and relocation cannot be conducted or is unlikely to be successful.

The bear can be destroyed if human life or property is in immanent danger.

If a bear is killed, you will be required to:
1) Report the kill to DENR, as soon as possible.
2) Skin the bear, leaving the claws and penis (if applicable) attached, and preserve the hide by freezing or salting it and storing it in a cool place. Be generous with the salt.
3) Turn in the hide, the skull, and any other biological samples requested to a DENR Renewable Resource Officer.

As per the NWT Wildlife Act, no person may retain any part of a bear killed in defence of life or property.

V. FOLLOW-UP

After response measures are completed, the situation will be reviewed with the camp operator and corrective actions identified. These may include a wide array of actions aimed at avoiding future bear problems and ensuring that the operator is made aware of legal obligations. The need for conservation and the vulnerability of bear populations to over harvest is to be stressed.

APPENDIX G

Drilling Waste Sump Monitoring and Retrofit Program, ARI License

AURORA COLLEGE
Aurora Research Institute

FILE# 12 404 691

22-Apr-08

Ms. Pippa Seccombe-Hett
Aurora Research Institute
191 Mackenzie Road
PO Box 1450
Inuvik, NT X0E 0T0

Dear Ms. Seccombe-Hett:

Enclosed you will find your 2008 Scientific Research Licence No. 14330 as prepared under the Northwest Territories Scientists Act and approved by the Science Advisor, Andrew Applejohn. Should you require support from the Aurora Research Institute's Research Centre(s), please contact the applicable Research Centre Manager(s) to discuss your research needs.

According to the Scientists Act, researchers issued licences must provide a summary report for each year of their research. Accordingly, upon completion of your 2008 field work in the Northwest Territories, please ensure that you provide a 200-word (maximum) non-technical summary of your research findings to our office. **This summary is due no later than June 30, 2009, or with your 2009 application, whichever is earlier. In addition, we require a copy of your final report and copies of any papers that you publish that pertain to research conducted under this licence. Finally, if/as applicable, please provide to the communities copies of any reports that you have offered to them or that they have requested as a condition of their support for your project.** Such reports should be provided to the communities prior to submitting new applications. This is especially important on multi-year projects, for which it is to be expected that the communities would be particularly interested in inspecting the results of past work before approving future work.

Thank you for assisting in the promotion and development of a scientific research community and database within the Northwest Territories. The summary report and other information that you provide are utilized in our annual report compendium, which is distributed to communities and organizations in the N.W.T. as well as to researchers across Canada.

Best wishes for a successful study!

Sincerely,

Paulo Flieg
Manager, Scientific Services

Box 1450
Inuvik, NT X0E 0T0
Tel: (867) 777-3298
Fax: (867) 777-4264

SCIENTIFIC RESEARCH LICENCE

Licence # 14330N
File # 12 404 691

ISSUED BY: **Aurora Research Institute - Aurora College**
Inuvik, Northwest Territories

ISSUED TO: Ms. Pippa Seccombe-Hett
Aurora Research Institute
191 Mackenzie Road
PO Box 1450
Inuvik, NT X0E 0T0
Tel: (867) 777-3298 ext26

ON: 22-Apr-08

TEAM MEMBERS: Michelle Côté, Scott Dallimore, William Hurst, Larry Greenland

AFFILIATION: Aurora Research Institute

FUNDING: Government

TITLE: Aurora Research Institute Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program

OBJECTIVES OF RESEARCH:
The objectives of the sump monitoring activities are to gain further knowledge of long-term sump integrity and sump monitoring techniques while addressing both the commitments of the Mallik Gas Hydrate Project and the recommendations from site surveys.

DATA COLLECTION IN THE NWT:
DATE(S): April 22 to December 31, 2008
LOCATION: At the existing Mallik L-38 site on the western side of Richards Island in the Mackenzie Delta, NWT

Licence# 14330 expires on December 31, 2008
Issued at the Town of Inuvik on April 22, 2008

Andrew Applejohn
Director, Aurora Research Institute

Aurora Research Institute – Aurora College
P.O. Box 1450 Inuvik NT X0E 0T0
Phone 867-777-4029 Fax 867-777-4264 Email: licence@nwtresearch.com

12 404 691
Tuesday, April 22, 2008

NOTIFICATION OF RESEARCH
Scientific Research Licence No. 14330

I would like to inform you that Scientific Research Licence No. 14330 has been issued to:

Ms. Pippa Seccombe-Hett
Aurora Research Institute
191 Mackenzie Road
PO Box 1450
Inuvik, NT
X0E 0T0 Canada
Phone: (867) 777-3298 ext 26
Email: pseccombe-hett@auroracollege.nt.ca

to conduct the following study: "Aurora Research Institute Mallik 2L-38 and 3L/4L/5L-38 Sump Monitoring and Retrofit Program".

Please contact the researcher if you would like more information.

SUMMARY OF RESEARCH:
This licence has been issued for the scientific research licence application # 800.

The objectives of the sump monitoring activities are to gain further knowledge of long-term sump integrity and sump monitoring techniques while addressing both the commitments of the Mallik Gas Hydrate Project and the recommendations from site surveys.

Active layer depth will be measured to determine differences between sumps and undisturbed areas. Ground temperature will be recorded. Ground conductivity/resistivity surveys will be conducted using both shallow and deep ground penetrating equipment. Conductivity data will be used to determine lateral migration of saline fluids. Soil samples will be collected from an undisturbed area through shovel testing, and analyzed. Hydrocarbon analysis of samples will be conducted if contamination is suspected. If surveys indicate elevated conductivity levels outside the sump areas, soil samples from the anomalous area(s) will be obtained and analyzed. Water samples will be collected from ponded water on or near the sumps and in adjacent undisturbed terrain. Observed depressions in sumps will be filled. Offsite fill material (as close as possible to the soils of the area) will be hauled in via ice road during the winter and recontouring using hand tools will be completed during summer. Depressions will be filled to ground-level. Native seeds (5-10g/species/site) will be collected by hand from the site (targeting common, abundant, early colonizing species), and evaluated for seed viability and use for reclamation. Seed collections will be stored frozen at ARI. Storm surges will be monitored using 3 - 5 devices consisting of a conductivity probe inserted into a PVC pipe and driven into the streambed of a shallow, inactive cutbank. The instruments are deployed by boat in June and retrieved before freeze-up. Baseline snow data will be collected prior to recontouring by extracting cores of snow. Visual inspection of the core will note thickness and snowpack properties.

Aurora Research Institute – Aurora College
P.O. Box 1450 Inuvik NT X0E 0T0
Phone 867-777-4029 Fax 867-777-4264 Email: licence@nwtresearch.com

12 404 691
Tuesday, April 22, 2008

NOTIFICATION OF RESEARCH
Scientific Research Licence No. 14330

Transportation will be by helicopter to site and small boat on site. Wildlife monitors, students and contractors will be hired for short periods. Local supplies and services will be purchased. Local knowledge of conditions impacting the study will be sought. Any published results will be sent to communities, governing organizations, and local libraries.

Fieldwork will be conducted from April 22 to December 31, 2008 at the existing Mallik L-38 site on the western side of Richards Island in the Mackenzie Delta, NWT (69°27'38"N, 134°39'42"W), based from a camp at the Mallik site in August, and out of Inuvik by helicopter at other times.

Sincerely,

Paulo Flieg
Acting Manager, Scientific Services

DISTRIBUTION:
President, Inuvik Hunters and Trappers Committee, P.O. Box 1720, Inuvik NT X0E 0T0
President, Tuktoyaktuk Hunters and Trappers Committee, P.O. Box 286, Tuktoyaktuk NT X0E 1C0
RRC Coordinator, Nihtat Gwich'in Renewable Resource Council, P.O. Box 2570, Inuvik NT X0E 0T0
EA Coordinator, Environmental Impact Screening Committee - c/o Joint Secretariat, P.O. Box 2120, Inuvik NT X0E 0T0
Land Use Applications Manager, Inuvialuit Land Administration, P.O. Box 290, Tuktoyaktuk NT X0E 1C0