Environmental Monitoring Plan

Inuvik Soil Treatment Facility

Gwich'in Land and Water Board

G17L1-002 Type "B" Licence

Environmental Monitoring Plan

Prepared By:

KBL Environmental Ltd.

Environmental Monitoring Plan
Inuvik Soil Treatment Facility
V.1.1
May 2022

Table of Contents

LIST OF TABLES

Summary

This Environmental Monitoring Plan details the manner in which KBL Environmental Ltd. will monitor and manage groundwater, surface water, soil and permafrost at the Inuvik Soil Treatment Facility. The Facility includes a single bermed, lined cell for the treatment of petroleum hydrocarbon contaminated soil (bioremediation cell) in addition to an engineered water retention pond for the collection of runoff generated from precipitation; the retention pond also serves to hold contaminated snow during the winter season. The contaminated soil is treated using mechanical aeration with the purpose of stimulating microbial activity to promote bioremediation. Amendments including fertilizers of surfactants are sometimes added to the soil dependent on soil composition to enhance conditions to foster microbial activity/bioremediation.

Plan Revisions

The plan will be reviewed annually, and revised whenever there is an operational change at the Facility, changes to contact personnel, or as otherwise required by the Gwich'in Land and Water Board.

Date of Revision	Title, Section Number, or Page Number of Revised Sections	Summary of Changes
January 26, 2018	Section 5, 6 and 8	Update to wording
May 30, 2022	Sections 3.1 Section 9	Update wording to reflect construction of facility Addition of groundwater sampling results Addition of recommended action levels for groundwater

1.0 INTRODUCTION

KBL Environmental Ltd. (KBL) has developed this Environmental Monitoring Plan (EMP) in support of the activities at the Inuvik Soil Treatment Facility (STF).

The STF is an engineered facility designed to receive predominately hydrocarbon-contaminated soil and water from off-site sources including residential, commercial and industrial properties. The contaminants in the material entering the STF are primarily Benzene, Ethylbenzene, Toluene, Xylene (BTEX), heating oil and gasoline. The STF is active mostly during the summer months when temperatures allow for soil treatment activities. During the winter months, hydrocarbon contaminated snow may be received and stored in the engineered water retention pond, until thaw and subsequent treatment.

1.1. Company Name, Site Name and Site Location

KBL Environmental Ltd.

Inuvik Soil Treatment Facility

Town of Inuvik Solid Waste Disposal Facility
Inuvik, Northwest Territories

Coordinates: (N) 7582173.14; (E) 554308.00

1.2. Effective Date of the Plan

This Environmental Monitoring Plan and any subsequent revisions, will be effective for the duration of the KBL Inuvik STF. The effective date for the Petroleum Hydrocarbon Contaminated Soil Treatment Facility Environmental Monitoring Plan is upon approval of the plan from the Gwich'in Land and Water Board.

1.3. Purpose and Scope of the Plan

The purpose of this Plan is to identify and outline groundwater, surface water, soil and permafrost monitoring and management methods for the Facility.

The Site will manage operations responsibly and will comply with all licences, permits and applicable territorial and federal laws and regulations related to waste management specific to Facility operation.

1.4. Description, including rationale, of the site-specific monitoring activities required to identify impacts from Project-related activities

Monitoring activities at the STF were developed based on facility location, baseline testing, permafrost depth and engineering design. It is important to consider that the facility is located entirely within the boundaries of the Town of Inuvik's existing solid waste disposal facility. The geotechnical investigation has shown that much of the facility is constructed on areas previously used for the disposal (i.e., landfill) of a variety of waste materials. Initial analytical results obtained from areas in the vicinity of the STF indicated the pre-existence of petroleum hydrocarbon impacted soils. Baseline testing was completed in order to establish existing concentration ranges of potential contaminants of concern resulting from historical landfill operations. This will enable the ability to differentiate between existing subsurface impacts and any potential cumulative impact caused by the operations of the STF. The contaminants that were used to establish a baseline included: benzene; toluene; ethylbenzene; xylenes (BTEX); volatile organic compounds (VOC's); F1 to F4 hydrocarbon fractions; and, polycyclic aromatic hydrocarbons (PAHs).

Outside of the baseline testing, the proposed facility is designed to direct all surface water runoff into a storm water retention pond. This will enable regular sampling and reporting of any water collecting within the pond prior to applicable regulatory guideline comparison to determine management requirements.

Outside of monitoring the engineered surface water retention pond, it would appear that monitoring the site for surface water runoff down gradient of the facility would be of limited benefit. As reported in Earth Tech (Canada) Inc.'s report *"Town of Inuvik, NT – Operation and Maintenance Manual for Solid Waste Disposal Facilities"* issued in March 2006, the landfill is situated within a divide between two of Mount Baldy's small watersheds. Northern slopes tend to drain toward Boot Creek, to the west and north and the southern ones drain into a fenland and small ponds to the east and south. Flow from both of these areas is directed around, and not through, the landfill area.

"As a result, drainage leaving the main part of the landfill is limited to the rain and snow which fall directly on the rather small area of the landfill site itself, plus, possibly, a minor amount of permafrost meltwater from beneath the site. Owing to the very small quantities of water leaving this site, or passing its edges, there is little likelihood that any substantial quantity of contamination would be transported from the site to either of the adjacent watersheds."

The low risk of off-site migration of contaminants from the SWDF (and therefore the STF) via groundwater may be reinforced by a statement made in the same report that:

"the entire district is underlain by deep permafrost, and there are occasional large ice lenses… Inuvik is above the Arctic Circle, and well within the NWT's zone of continuous permafrost. Subsoils below the shallow active layer are frozen to considerable depth. In permafrost terrain, groundwater movement is confined to the seasonally-thawed active layer, and to the seasons of thaw. In the lands immediately surrounding the landfill site, little groundwater movement is expected at all, owing to the shallowness of the active layer (especially where the surface vegetation remains, as in the areas to the south and east) and to the generally low permeability of the area's soils. The compacted roadways running past the west side of the site, into the old Hospital Hill quarry and up to the newer Mt. Baldy one, also act as groundwater barriers. In conclusion, horizontal movement of groundwater out of the Mt. Baldy site is expected to be extremely slow if any at all;

and vertical movement is barred by deep permafrost.

It has occasionally been asked what effect a landfill has on permafrost, and vice-versa. In a landfill containing completely inert materials, it is likely that the permafrost table will gradually rise into the deposit, further improving encapsulation. A landfill that contains natural organic materials, on the other hand, will support bacteria and generate metabolic heat for a considerable number of years, and may actually drive the permafrost table down, forming a temporary basin in the frozen terrain mass. In a shallow permafrost setting, this would preclude reliance on permafrost as a liner, but in a deep permafrost setting, such as Inuvik's, it is not of practicable significance in terms of groundwater containment."

The paragraphs above combined with the low likelihood of off-site migration of contaminants from the STF via surface or groundwater, and the engineered design and construction of the soil treatment pad using clean fill, monitoring may be of limited value. However, the monitoring of surface water monitoring are detailed in Section 2 and soil monitoring program is detailed in Section 4 of this plan.

Please refer to Attachment C for a copy of the letter provided by Land Solutions regarding Environmental Monitoring and Permafrost Considerations at KBL Environmental's Inuvik Soil Treatment Facility (STF).

The geotechnical investigation confirmed the depth to permafrost beneath the site. Based on the information from the investigation a groundwater monitoring program has been outlined in Section 3 of this plan. Groundwater wells were installed with appropriate measures to protect permafrost.

The rationale regarding the monitoring and protection of permafrost are provided in Section 5 of this plan.

1.5. Results of the Geotechnical Investigation and Description of the underlaying and surrounding hydrogeology; as assessed by a Professional Engineer; Hydrologist; Hydrogeologist or equivalent professional

Regional Hydrogeology and Considerations with Permafrost

LandSolutions Environmental LP and Ashwell Consulting Inc. were retained by KBL to provide a description of the hydrogeology underlying and surrounding the STF. A copy of the information provided to KBL has been attached in Attachment A for reference and further information.

The site is located in the southeastern area of the Mackenzie Delta. Regional bedrock geology comprises a structurally complex sequence of Paleozoic and Proterozoic igneous, metamorphic and sedimentary rocks which are unconformably overlain by younger Cretaceous sedimentary rocks. Quaternary deposits comprising fluvial, fluvial fan, hummocky moraine and lacustrine deposits locally overly the bedrock throughout the area. Within the immediate vicinity of Inuvik, Quaternary deposits of the Mackenzie Delta, comprising fluvial and lacustrine clays, silts, sand and gravel topped with organic soils and are present beneath the western portion of the townsite (Canadian Geoscience Map 187). The Cretaceous Horton River Formation underlies the eastern portion of the town and comprises marine sandstone and siltstone (Canadian Geoscience Map 187). Inuvik is located within a zone of deep continuous permafrost which can extend to depths of greater than 700 meters below sea level (Mackay & Dyke, 1990).

Within permafrost regions, groundwater flow (vertical and lateral) will occur primarily within the active layer above the permafrost (i.e., the supra-permafrost aquifer) during the thawed season. The active layer is the soil above the permafrost that freezes and thaws annually and is variably saturated. The groundwater table is close to surface and shallow groundwater flow should generally mimic topography and drain toward the Mackenzie Delta. The thickness of the active layer within the region between Inuvik and Tuktoyaktuk to the north is typically 0.6 to 0.8 mbgs (Kiggiak, 2011) with a deeper active layer on elevated slopes and in areas of limited vegetation. Taliks represent areas of permanently unfrozen ground and typically occur beneath lakes and rivers where deep water does not freeze during the winter. Because of the extensive permafrost, groundwater from deep aquifers is not utilized and instead, drinking water for Inuvik is sourced from surface water.

It is generally accepted that permafrost is a barrier to groundwater flow which is confined to the active layer. However, much research is being undertaken within permafrost terrains across Canada and the world to improve understanding of the hydrogeological interactions within permafrost regions. This research is revealing complexity of the hydrogeology within permafrost regions and there is emerging evidence for increased water movement through permafrost zones due to preferential melting (Morse, 2017). The impact of lateral and vertical melting of permafrost is largely dependent on the host geology and how well water is transmitted under thawed conditions. For example, clay-rich glacial deposits do not allow efficient drainage of groundwater and the effect of permafrost thawing on groundwater flow is not readily noticeable (Morse 2017). The effect could be more pronounced in areas of fluvial deposits such as those underlying the western portion of Inuvik, although these deposits are generally considered to be of low permeability (Town of Inuvik, 2006). In addition, the influence of melting permafrost on groundwater movement is likely to be more pronounced in areas where the permafrost is discontinuous such as further to the south.

Site Conditions

The Site is located within the south west portion of the Mount Baldy Solid Water Community Landfill to the south east of the main Inuvik townsite. The Site is underlain by silt, clay, sand and organic soils consistent with quaternary deposits, to a maximum investigated depth of 7.5 meters below ground surface (mbgs). Garbage was noted at surface in 4 out of 10 field logs and extended to a maximum depth of 6.1 mbgs (KBL 2017). Permafrost was encountered at the site at depths ranging from 1.3 to 7.1 mbgs.

Based on the depth to permafrost, the active (seasonally thawed) layer at the Site is approximately 1.3 to 7 m thick (KBL 2017). The position of the Site on a south facing slope with minimal vegetation likely influences the thickness of the active layer. A total of four monitoring wells were installed at the Site in August 2017 but no groundwater level measurements were taken. Based on the field logs reviewed, saturated conditions were encountered at depths from 1.5 to 5.6 mbgs with the saturated thickness of the supra-permafrost aquifer ranging from approximately 0.2 m to 2.9 m. Groundwater flow is anticipated to follow topography and surface water drainage to the south-west but will be influenced by the geometry of the permafrost layer which appears to be variable at the Site. No measurements of hydraulic properties are available, so reference has been made to literature values. The hydraulic conductivity of silt/sandy silts/clayey sands are expected to be in the order of 1×10^{-8} m/s to 1×10^{-6} m/s (Fetter 2001). The hydraulic conductivity of lacustrine clays could be as low as 1×10^{-11} m/s (Fetter 2001).

The Mount Baldy Landfill is located on a ridge that extends from the base of Mount Baldy to the south west. The shoulder upon which the landfill is located is a divide between two of Mount Baldy’s small watersheds with Boot Creek as the drainage feature to the north and an area of fenland receiving water to the south

(Town of Inuvik 2006). Surface water drainage is directed around the active landfill and similar drainage controls would be in place at the soil treatment facility. Lateral groundwater movement into and out from the immediate vicinity of the Site is expected to be limited due to the thin active layer; the low permeability nature of the subsoils; the relatively small recharge area; and the presence of compacted roads (Town of Inuvik 2006). Vertical groundwater movement will be restricted by the presence of permafrost. However, the shallow groundwater table within the active layer makes groundwater immediately beneath the Site potentially vulnerable to contamination even if lateral and vertical migration is limited under the current conditions. It is understood that this potential vulnerability has been mitigated as part of the design of the soil treatment facility.

The thickness of the active layer and the depth to permafrost could potentially be impacted by heat generated from biological activity that would be expected from a soil treatment facility or within non-inert municipal waste (garbage). Evidence of this can potentially be seen in the depth to the permafrost measured during the 2017 summer site investigation. The depth to permafrost was greater in the locations that noted the presence of garbage. Melting of the permafrost could have implications on groundwater flow; however, this is of more concern in areas where the permafrost layer is thin and or discontinuous and could be penetrated, rather than areas such as Inuvik with deep permafrost. In contrast to this, compaction of the ground could lead to the permafrost rising and any changes in the morphology of the permafrost interface could influence groundwater flow direction such as a mounding of permafrost beneath the site and radial flow outward. Again, it is understood that mitigation measures to minimize impact on the active layer have been addressed as part of the design process of the STF.

Permafrost is or may be affected by the landfill therefore we are monitoring the groundwater (active layer) in four directions around the STF. Given the surface gradient, the most reasonable assumption would be that MW4 (SNP 0037-4) is the upstream well and wells MW1 (SNP 0037-5), MW2 (SNP 0037-6), MW3 (SNP 0037-7) are downstream. However, all wells will be monitored for impact and results will be shared with the inspector, GLWB, and the Town of Inuvik Solid Waste Disposal Facility.

2.0 SURFACE WATER MONITORING AND MANAGEMENT

2.1. A description of how leachate is monitored and managed at the STSF with appropriate maps or diagrams

The water retention pond (SNP 0037-1) was built to collect and store precipitation runoff from the soil treatment pad (leachate). It is a rectangular pond with the dimensions of approximately 18 m by 30 m with side slopes of 2.5 horizontal to 1 vertical. The overall pond capacity is 362 m^3 (no freeboard). A minimum of 0.9 m of freeboard will be maintained at all times in the pond. Working water level is 22.1 m (205 m^3 capacity). Please refer to Appendix A of the Operation and Maintenance Plan for water retention pond design and drawings.

The water retention pond volume is monitored regulatory during operations in the summer season by a KBL representative. Inspection results and measurements are recorded in a log kept on site. More frequent water level monitoring will occur when freeboard begins to decrease or in the event of heavier than normal precipitation events. During periods of precipitation when there is no work occurring at the STF, a KBL representative will be dispatched to ensure sufficient retention pond freeboard. If less than 1 m of freeboard is present or this condition is imminently present, a vacuum truck or pumps will be dispatched to remove water from the retention pond to ensure pond freeboard is maintained.

Retention pond water management may include pumping pond water into Water Holding Tanks (WHTs) to maintain sufficient freeboard in the pond. Water may be reapplied to the soil treatment pad as conditions dictate. The WHTs may be used to hold pond water prior to application on the treatment pad or until water treatment events have been conducted.

Drainage patterns from the soil treatment pad are assessed as part of the regular inspections to ensure that runoff water is diverted to the retention pond as per the design. Should it be determined that drainage is not occurring efficiently or that water is ponding on the soil treatment pad, equipment will be used to reconfigure soil piles to improve drainage.

Monthly Facility inspections during snow-free months include visual assessment for erosion, exposure of liner, leakage, and water retention pond volume measurements. Inspections are conducted by trained personnel (KBL staff, or an on-site operator/contractor). The inspector is prompted to inspect the above noted features through the use of a standardized inspection log (a copy is provided in the Operation and Maintenance Plan - Appendix C). The logs are maintained on site at all times.

Water held in the retention pond is analyzed and compared with the Effluent Quality Criteria (EQC) specified in the Facility Water Licence (Part E Section 24).

A record of all water removal, treatment, disposal or discharge will be stored electronically and summarized in the annual report.

Upon laboratory analysis and comparison against the EQC, the retention pond water may be discharged on-site. Prior to discharge, a copy of the water analysis result will be submitted to an inspector and the GLWB. The discharge location is identified in the Operation and Maintenance Plan - Appendix A. The volume of water discharged will not exceed 50 m^3 per discharge event and 300 liters per minute at SNP 0037-3, unless authorized by an inspector.

A map illustrating monitoring and sampling locations is provided in Attachment D.

2.2. An explanation of any actions to be taken in response to any exceedances of the effluent quality criteria specified in Part E of the Water Licence

Should the effluent exceed the effluent quality criteria specified in Part E of the Water Licence the following actions will be taken:

- May be utilized for application within the soil treatment pad for the provision of moisture to the soil. Moisture is an integral part of promoting microbial activity responsible for degradation of petroleum hydrocarbons. Water application for bioremediation is permissible provided the water is not hazardous as defined by the *"Guideline for the General Management of Hazardous Waste in the NWT (1998)"*;
- May be treated using KBL's portable water treatment plant (details provided in Section 6 of the Operations and Maintenance Plan) if analytical results determine that the water is suitable for treatment. The water will be treated, and water quality will be re-analyzed; and

- If the water exceeds EQC for contaminants and is beyond the treatment capacity of KBL's water treatment plant, the water will be transferred for transport and disposal to an approved receiving facility.

A record of the analytical results and a record of all water removal, treatment, disposal or discharge will be stored electronically and summarized in the annual report.

Please refer to the Operation and Maintenance Plan – Appendix A for facility drawings.

3.0 GROUNDWATER MONITORING

3.1. Baseline Groundwater Conditions

Baseline sampling to assess groundwater conditions were compelted in 2018, 2019, 2020, and 2021 prior to construction of the STF. Results will be tabulated and incorporated into the EMP and then submitted to the GLWB for approval. As per the Environmental Management Plan completed by KBL, the contaminants in the material entering the Site are primarily benzene, ethylbenzene, toluene, xylenes (BTEX), heating oil, and gasoline.

Baseline testing was completed in order to establish existing concentration ranges of potential contaminants of concern from the historical landfill operations.

Four monitoring wells were installed at the Site in 2017. One monitoring well was installed upstream of the soil treatment pad, and three were installed downstream (Figure 3). In accordance with Part C of Annex A: Surveillance Network Program (SNP) Annexed to Water License G17L1-002 Part B, Item 2 KBL Environmental the following monitoring is required:

SNP Station #	Description	Sampling Frequency	Parameters per EMP (page 11-13)
0037-4	MW4- northeast and upgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-5	MW1- southeast and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-6	MW2- south and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-7	MW3- southwest and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP

Metals- ICP-MS Metal Scan (Total)
Field Parameters (FP)
Petroleum Hydrocarbons (PHC) fractions 1 to 4 (F1-F4)
Benzene, toluene, ethylbenzene, and xylenes (BTEX)
Chemical Oxygen Demand (COD)
Extractable Petroleum Hydrocarbons (EPH)
Total Suspended Solids (TSS)
Oil and Grease (O&G)

However, per the Water License – Current to April 8, 2021 the environmental monitoring program was to include baseline data for: BTEX, volatile organic compounds (VOCs), PHC F1-F4, polycyclic aromatic hydrocarbons (PAHs), and total metals. Due to an oversight, analysis of VOCs and PAHs was missed and will be completed in 2022 and 2021 and the EMP updated upon review of the monitoring results.

The baseline groundwater conditions were evaluated by a third-party hydrogeologist, Beckingham Environmental Ltd and their report is included in Attachment B.

Baseline groundwater identified elevated levels over the Federal Interim Groundwater Quality Guidelines of metals (aluminum, arsenic, barium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc).

3.2. Map and attached table or detailed legend illustrating monitoring and sampling locations

The groundwater monitoring stations are identified on the map located in Attachment D.

3.3. Description of monitoring protocols, methodologies, parameters, and frequency

Four monitoring wells were installed at the STF in 2017. One monitoring well was installed upstream of the soil treatment pad, and three installed downstream. Please refer to Attachment D – Maps. The tables below describe the location, parameters, and frequency for the monitoring wells.

The parameters selected for groundwater monitoring are I accordance with Part C of Annex A: *Surveillance Network Program (SNP) Annexed to Water License G17L1-002 Part B, Item 2 KBL Environmental* and are presented in the table below along with the frequency and rationale.

Table 3.3-1: SNP Station Quick Reference Table

SNP Station #	Location	Description	Status
0037-1	Water Retention Pond	Monitors retention Waters in the Retention Pond prior to discharge	Active prior to proposed retention Water discharge
0037-2	Water Holding Tanks	Monitors Waters in the holding tanks prior to discharge	Active prior to proposed retention Water discharge
0037-3	Drainage Ditch	Monitors retention Waters in the Retention Pond prior to and during discharge	Active prior to proposed retention Water discharge
0037-8	Surface Water Monitoring	Downgradient of Water Retention Pond	Active
0037-4	Groundwater Well	MW4 – North-east, upgradient of the STF	Active
0037-5	Groundwater Well	MW1 – South-east, Downgradient of the STF	Active
0037-6	Groundwater Well	MW2 – South, Downgradient of the STF	Active
0037-7	Groundwater Well	MW3 – South-west, Downgradient of the STF	Active

Table 3.3-2: SNP 0037-4

Description	Groundwater monitoring well - MW4
Location	Northeastern corner of the site
Sampling Frequency	Twice annually (spring and fall)
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions)

	Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (EPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Upgradient monitoring well
Status	Active following spring freshet and before freeze-up

Table 3.3-3: SNP 0037-5

Description	Groundwater monitoring well - MW1
Location	Monitoring well southeast edge of STF
Sampling Frequency	Twice annually (spring and fall)
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions) Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (TPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Downgradient monitoring well
Status	Active following spring freshet and before freeze-up

Table 3.3-4: SNP 0037-6

Description	Groundwater monitoring well – MW2
Location	Monitoring well at southern edge of the STF
Sampling Frequency	Twice annually (spring and fall)
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions) Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (TPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Downgradient monitoring well
Status	Active following spring freshet and before freeze-up

Table 3.3-5: SNP 0037-7

Description	Groundwater monitoring well – MW3
Location	Monitoring well at southwestern edge of the STF
Sampling Frequency	Twice annually (spring and fall)
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions) Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (TPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Downgradient monitoring well
Status	Active following spring freshet and before freeze-up

Table 3.3-6: SNP 0037-1

Description	Monitoring retention waters in the Retention Pond prior to a proposed discharge
Location	Within the Retention Pond
Sampling Frequency	As required prior to and during discharge
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions) Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (TPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Point of compliance, prior to and during discharge
Status	Active prior to proposed retention water discharge

Table 3.3-7: SNP 0031-2

Description	Monitoring retention waters in the Water Holding Tanks prior to a proposed discharge
Location	Water Holding Tanks
Sampling Frequency	As required prior to and during discharge
Sampling Parameters	ICP-MS Metal Scan (Total) Field Parameters Total Petroleum Hydrocarbons (F1, F2, F3, F4 CCME Fractions) Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) Chemical Oxygen Demand (COD) Extractable Petroleum Hydrocarbons (TPH) Total Suspended Solids (TSS) Oil and Grease pH
Rationale	Point of compliance, prior to and during discharge
Status	Active upon discharge and weekly during discharge

Table 3.3-8: SNP 0037-3

Description	Monitoring retention waters in the drainage ditch
Location	Drainage Ditch
Sampling Frequency	During discharge of water from Retention Pond or Water Holding Tanks
Sampling Parameters	Total volume of water discharged Rate of flow
Rationale	Point of compliance during discharge
Status	Active upon discharge

3.4. Groundwater Monitoring and Sampling Methodology and QA/QC

During each groundwater sampling event, each monitoring well will be assessed to determine its overall state and condition. Any issues will be noted and if necessary repairs will be completed.

Monitoring wells will be measured for depth and the depth to groundwater from the top of the well casing using an interface probe. Measurements will be taken prior to any purging or sampling and the interface probe will be cleaned with a solution such as Alconox after measuring each well.

Prior to sample collection wells will be purged to remove stagnant water. This will be completed by removing three well volumes of water from the well to ensure that representative groundwater has entered the well casing. The volume of water purged will be recorded and reported in the annual report. Purging will be completed using dedicated equipment such as bailers, polyethylene tubing or low flow bladder pump with tubing.

Field parameters will be analyzed using a portable multimeter and recorded in the field so that they can be incorporated into the final report. Any visual observations (sediment, sheen, etc.) will also be noted and recorded.

Following purging and collection of field parameters, groundwater samples will be collected from the monitoring wells using dedicated sampling equipment and placed into laboratory supplied sample containers.

Effort will be taken to avoid collecting any suspended solids in each sample which could alter the analytical results. Specific sampling requirements including field filtering and preserving will be reviewed with the laboratory to ensure that all samples are collected correctly in the field.

Field personnel will take care to avoid cross contamination when switching between monitoring well locations and will ensure to wear new, clean disposable gloves prior to collecting each sample.

Samples will be placed on ice and packaged for transportation and delivery to the laboratory for analysis. While in transportation the samples will be under a Chain of Custody that will be signed and received upon arrival at the laboratory. Samples will be submitted to a laboratory accredited by the Canadian Association for Laboratory Accreditation (CALA) for the required analysis. The analyses will be performed in accordance with approved methods as recognized by CALA.

For quality assurance and quality control (QA/QC) additional samples will be collected and submitted to the laboratory. A blind field duplicate from one of the sample locations will be submitted under a different name and completed for the full suite of parameters to evaluate the precision of the laboratory. A field blank sample will be prepared in the field using distilled or deionized water and submitted for volatile organic parameters to evaluate the potential for ambient site conditions to introduce contaminants into the sample containers. A trip blank will be prepared by the laboratory using distilled or deionized water and will travel to the site with the empty sample containers and then be submitted along with all samples to the lab to evaluate the possibility of introduction of contaminants to the samples during transportation and handling.

A laboratory QA/QC program consisting of method blanks, spiked blanks and matrix spike shall also be checked to ensure that appropriate QA/QC results are obtained.

Results of the biannual Groundwater Monitoring will be submitted to the GLWB as part of the annual water license report.

4.0 SOIL MONITORING

The area of the lease contracted to KBL is above a historic landfill cell as reported by the Town's Director of Public Services. In 2016, KBL commissioned the excavation of three test pits within the boundary of the proposed STF (October 2016) and then completed additional boreholes in August of 2017. The Site is underlain by silt, clay, sand, and organic soils consistent with quaternary deposits, to a maximum investigative depth of 7.5 meters below ground surface (mbgs). Garbage was noted at surface in 4 out of 10 field logs from the August 2017 investigation and extended to a maximum depth of 6.1 mbgs.

Baseline soil monitoring was conducted in 2017 and the following exceedances were detected:

Sample ID		BH2-01	BH2-02	BH2-03	BH2-04	BH3-01	BH3-02	BH3-03	BH3-04	BH4-01	BH4-02	BH4-03	BH7-01	BH7-02	BH7-03
Sample Depth (mbgs)															
Analytical Parameter	Criteria (mg/kg)														
Arsenic, total	12	**38**	**26**	**24**	**32**	**39**	**18**	**59**	**36**	**43**	**32**	**18**	**96**	**67**	**31**
Copper, total	91									**230**					
Nickel, total	50	**53**	**51**							**240**	**77**		**51**	**53**	
Zinc, Total										**22,000**					

*Government of the Northwest Territories, Environmental Guideline for Contaminated Site Remediation, November 2003, assumes coarse-grain soil

The complete analytical baseline analysis is attached in Attachment E.

With the low likelihood of off-site migration of contaminants from the STF via surface or groundwater, the construction of the soil treatment pad using clean fill will lend itself to monitoring of the soil if there is any release of material outside of containment for potential contaminants of concern (specifically, BTEX and F1 to F4 petroleum hydrocarbon fractions). Monthly facility and liner inspections will occur during the operation of the STF, please refer to the Operations and Maintenance Plan for more details regarding facility inspections. At the time of facility decommissioning, soil sampling will be required to examine soil quality beneath the former STF for comparison against pre-construction data.

5.0 PERMAFROST MONITORING AND PROTECTION

KBL completed a drilling program to confirm the depth to permafrost beneath the site. Based on the borehole program completed in the summer of 2017 the measured permafrost depths in the area of the of the STF varied between 3.5 to 7.1 mbgs, with an *apparent* active layer (indicated as moist/wet soils) averaging approximately 2 meters above the permafrost layer. After a review of the borehole data, and the determination that both the apparent active layer and permafrost was at an sufficient depth, it was decided that the engineered design of the STF did not require additional mitigation in order to account for the possibility of permafrost impacts. In other words, the permafrost layers were at sufficient depth and the STF design was robust enough, to negate the need for permafrost protection measures.

The STF is sited entirely within the footprint of the Inuvik Solid Waste Landfill, which has been in operation for decades without monitoring of permafrost depths or impacts due to operations. It appears that the former landfill cell that the STF will be sited on has already influenced the depth of permafrost (with offsite controls showing permafrost at shallower depths of 1.5 m) and has caused variability in the measured depth to permafrost across the site. This is a previously disturbed footprint, and should not be considered as natural or back ground conditions. There is not yet enough data to determine a defensible baseline (starting point) permafrost depth in order to monitor potential changes caused by the STF over time, or to determine whether changes in depth are attributable to the existing landfill, the STF's operation, or climate change. KBL has engineered the facility to mitigate its impact to the permafrost (i.e. using a light-coloured liner for the water pond), which is outlined in the Water Licence application.

The importance of maintaining a shallow permafrost depth, although vistal for maintaining landscape and infrastructure stability across much of the arctic, is negated at the STF site due to pre-existing impacts and influences from the landfill. As previously noted, there is little risk to the integrity of the STF due to changes in permafrost depths.

Groundwater levels in the piezometers may provide an indication of changes in the active layer over time, since the landfill would be considered an unconfined aquifer (and therefore the water level in the piezometer is the level of the water table, which is in turn likely associated with the active layer – if the permafrost and active layer were driven deeper, the water level in the piezometer should also drop, all other factors negated). However, this assumption is a bit premature at this time.

6.0 ACTION LEVELS

6.1. Definitions, with rationale, for Action Levels for parameters of concern that will be monitored under the Environmental Monitoring Program.

The action levels that are described in the following section are established to trigger Corrective Actions. Results from groundwater monitoring and sampling will be evaluated against the Action Levels and if a contaminant of concern has an exceedance, corrective action planning will be initiate. The determined action levels and definitions are presented in tables in Attachment F.

Action levels have been developed using two separate methods in relation to the STF operations:

- If baseline concentrations were below the most stringent guideline, then the most stringent guideline is used as the Action Level; and
- If a parameter baseline concentration was above or approaching (less than 25% difference) the guideline value, then the maximum baseline concentration plus 25% is used as the Action Level.

Action Level development is presented in the tables found in Attachment F, showing guideline values along with minimum and maximum concentrations that are detected during baseline monitoring and sampling as per the recommendations from Beckingham.

6.2. For each Action Level, a description of actions taken in response to any Action Level exceedances under the Groundwater Monitoring Program

Corrective Actions shall be evaluated and/or implanted if the following occurs:

- Groundwater concentrations of one or more of the monitored parameters exceed Action Level.

Step 1

During Step 1 of Corrective Actions, the action level exceedance will be evaluated to determine the likelihood that it occurred from operations of the STF. If the exceedance occurs from a contaminant that is present at the facility, then the parameters that are exceeded will be monitored during the next groundwater monitoring cycle (2 sampling events) to determine the trend of the exceedance. In the event that an unplanned or accidental release of waste material occurs, samples will be collected to determine if any impacts have been caused to groundwater. Based on the nature of the unplanned release, sample quantity and follow up needs will be determined and provided to the GLWB and the Inspector.

If an Action Level exceedance is deemed to be anomalous based on subsequent sampling, then no further remedial action will be taken, and monitoring will continue biannually as outlined in this plan. If subsequent sampling indicates a stable or increasing trend, then Step 2 of Corrective Actions will be implemented.

As part of Step 1 Corrective Actions, operations and maintenance practices will be reviewed to determine conditions that triggered the exceedance and to assess the probability that the exceedance is directly related to operation of the STF and not due to other factors which may have the ability to affect the general groundwater in the area. The outcome of this assessment will be discussed with GLWB in the event that it is believed an action level was triggered for a reason other than the day to day operations of the STF.

Step 2

If it is believed that exceedances occur from operations of the STF and subsequent sampling during Step 1 indicate that concentrations are stable or increasing, then KBL will prepare a Remedial Action Plan (RAP) to further investigate the impacts or LNAPL detection. The RAP will be submitted to the GLWB for review, comment and approval. KBL will implement the RAP once it is approved. If necessary, KBL will implement immediate actions to help mitigate impacts while awaiting a formal RAP.

7.0 SAMPLE MANAGEMENT

7.1. Quality Assurance/Quality Control Plan for Sample Management

During each groundwater sampling event, each monitoring well will be assessed to determine its overall state and condition. Any issues will be noted and if necessary repairs will be completed.

Monitoring wells will be measured for depth LNAPL (if present) and the depth to groundwater from the top of the well casing using an interface probe. Measurements will be taken prior to any purging or sampling and the interface probe will be cleaned with a solution such as Alconox after measuring each well.

Prior to sample collection wells will be purged to remove stagnant water. This will be completed by removing three well volumes of water from the well to ensure that representative groundwater has entered the well casing. The volume of water purged will be recorded and reported in the annual report. Purging will be completed using dedicated equipment such as bailers, polyethylene tubing or low flow bladder pump with tubing. The purge water will be monitored for field parameters. Water levels in the well will be recorded at the beginning and end of the purging process, and then be allowed to recover prior to sampling. It should be recognized that the stable field measurements (conductivity, temperature, turbidity, and pH) are likely to be indicative of a quasi-equilibrium condition.

Field parameters will be analyzed using a portable multimeter and recorded in the field so that they can be incorporated into the final report. Any visual observations (sediment, sheen, etc.) will also be noted and recorded.

Following purging and collection of field parameters, groundwater samples will be collected from the monitoring wells using dedicated sampling equipment and placed into laboratory supplied sample containers.

Effort shall be taken to avoid collecting any suspended solids in each sample which could alter the analytical results. Specific sampling requirements including field filtering and preserving will be reviewed with the laboratory to ensure that all samples are collected correctly in the field.

Field personnel will take care to avoid cross contamination when switching between monitoring well locations and will ensure to wear new, clean disposable gloves prior to collecting each sample.

Samples will be placed on ice and packaged for transportation and delivery to the laboratory for analysis. While in transportation the samples will be under a Chain of Custody that will be signed and received upon arrival at the laboratory. Samples will be submitted to a laboratory accredited by the Canadian Association for Laboratory Accreditation (CALA) for the required analysis. The analyses will be performed in accordance with approved methods as recognized by CALA.

For quality assurance and quality control (QA/QC) the following additional samples will be collected and submitted to the laboratory.

Blind Field Duplicate – For the entire laboratory suite of parameters at one chosen sampling location.

Field Blank – A sample prepared in the field with distilled or deionized water, completed for volatile organic parameters BTEX, F1.

Trip Blank – A sample prepared in the laboratory with deionized water and shipped and kept with the sampling containers during the entire sampling program. Completed for volatile parameters BTEX, F1.

In addition to the above noted field collected QA/QC samples, the laboratory will also complete an internal QA/QC check consisting of Method Blanks, Spiked Blanks and Matrix Spikes to ensure the appropriate QA/QC results are obtained prior to confirming the groundwater sampling programs results.

Results of the biannual Groundwater Monitoring Program will be submitted to the MVLWB as part of the annual water license report.

8.0 REPORTING

8.1. Reporting of Action Level exceedances and actions taken during the year in the Annual Water Licence Report as per Part B of the Water Licence

As identified in Schedule 1 of the Water Licence, all Action Level exceedances and actions taken during the year will be included in the Annual Water Licence Report as required by the Water Licence.

ATTACHMENT A

ASHWELL / LAND SOLUTIONS LETTER

LANDSOLUTIONS
by the experts

Ashwell
CONSULTING INC

November 6, 2017

KBL Environmental Ltd.
PO Box 1895
17 Cameron Road
Yellowknife, NT
X1A 2P4

Attention: Renee White, EP, *Licensing and Compliance Manager*

Dear Renee,

As requested, this letter provides a commentary on the likely hydrogeological conditions to be expected at the site of the KBL Soil Treatment Facility in Inuvik.

Data Sources

In providing this commentary reference has been made to the following documents and resources:

- Canadian Geoscience Map 187. Geology. Inuvik, Northwest Territories. ess.nrcan.gc.ca.
- Operation and Maintenance Manual for the Solid Waste Disposal Facilities, Town of Inuvik, NT, 2006.
- Report on the Permafrost and Hydrogeology Interactions Meeting, 14 November 2016, Yellowknife, Northwest Territories.
- Environmental Impact Statement for Inuvik to Tuktoyaktuk Highway.
- Scientific Services Program. Science Institute of the Northwest Territories.
- Field logs from 3 test pits and 7 boreholes from intrusive investigations conducted on behalf of KBL in October 2016 and August 2017 respectively.

Regional Hydrogeology and Considerations with Permafrost

Inuvik is located in the southeastern area of the Mackenzie Delta. Regional bedrock geology comprises a structurally complex sequence of Paleozoic and Proterozoic igneous, metamorphic and sedimentary rocks which are unconformably overlain by younger Cretaceous sedimentary rocks. Quaternary deposits comprising fluvial, fluvial fan, hummocky moraine and lacustrine deposits locally overly the bedrock throughout the area. Within the immediate vicinity of Inuvik, Quaternary deposits of the Mackenzie Delta, comprising fluvial and lacustrine clays, silts, sand and gravel topped with organic soils are present beneath the western portion of the townsite (Canadian Geoscience Map 187). The Cretaceous Horton River Formation underlies the eastern portion of the town and comprises marine sandstone and siltstone (Canadian Geoscience Map 187). Inuvik is located within a zone of deep continuous permafrost which can extend to depths of greater than 700 metres below sea level (Mackay & Dyke, 1990).

Within permafrost regions, groundwater flow (vertical and lateral) will occur primarily within the active layer above the permafrost (i.e., the supra-permafrost aquifer) during the thawed season. The active layer is the soil above the permafrost that freezes and thaws annually and is variably saturated. The groundwater table is close to surface and shallow groundwater flow should generally mimic topography and drain toward the Mackenzie Delta. The thickness of the active layer within the region between Inuvik and Tuktoyaktuk to the north is typically 0.6 to 0.8 mbgs (Kiggiak, 2011) with a deeper active layer on elevated slopes and in areas of limited vegetation. Taliks represent areas of permanently unfrozen ground and typically occur beneath lakes and rivers where deep water does not freeze during the winter. Because of the extensive permafrost, groundwater from deep aquifers is not utilized and instead, drinking water for Inuvik is sourced from surface water.

It is generally accepted that permafrost is a barrier to groundwater flow which is confined to the active layer. However, much research is being undertaken within permafrost terrains across Canada and the world to improve understanding of the hydrogeological interactions within permafrost regions. This research is revealing complexity of the hydrogeology within permafrost regions and there is emerging evidence for increased water movement through permafrost zones due to preferential melting [Morse, 2017]. The impact of lateral and vertical melting of permafrost is largely dependent on the host geology and how well water is transmitted under thawed conditions. For example, clay-rich glacial deposits do not allow efficient drainage of groundwater and the effect of permafrost thawing on groundwater flow is not readily noticeable (Morse, 2017). The effect could be more pronounced in areas of fluvial deposits such as those underlying the western portion of Inuvik, although these deposits are generally considered to be of low permeability (Town of Inuvik, 2006). In addition, the influence of melting permafrost on groundwater movement is likely to be more pronounced in areas where the permafrost is discontinuous such as further to the south.

Site Conditions

The study site (the Site) is located within the south west portion of the Mount Baldy Solid Waste Community Landfill to the south east of the main Inuvik townsite. The Site is underlain by silt, clay, sand and organic soils consistent with quaternary deposits, to a maximum investigated depth of 7.5 metres below ground surface (mbgs). Garbage was noted at surface in 4 out of 10 field logs and extended to a maximum depth of 6.1 mbgs (KBL, 2017). Permafrost was encountered at the site at depths ranging from 1.3 to 7.1 mbgs.

Based on the depth to permafrost, the active (seasonally thawed) layer at the Site is approximately 1.3 to 7m thick (KBL 2017). The position of the Site on a south facing slope with minimal vegetation likely influences the thickness of the active layer. A total of 4 monitoring wells were installed at the Site in August 2017 but no groundwater level measurements were taken. Based on the field logs reviewed, saturated conditions were encountered at depths from 1.5 to 5.6 mbgs with the saturated thickness of the supra-permafrost aquifer ranging from approximately 0.2 m to 2.9 m. Groundwater flow is anticipated to follow topography and surface water drainage to the south-west but will be influenced by the geometry of the permafrost layer which appears to be variable at the Site. No measurements of hydraulic properties are available so reference has been made to literature values. The hydraulic conductivity of silt/sandy silts/clayey sands are expected to be in the order of $1x10^{-8}$ m/s to $1x10^{-6}$m/s (Fetter, 2001). The hydraulic conductivity of lacustrine clays could be as low as $1x10^{-11}$ m/s (Fetter 2001).

The Mount Baldy Landfill is located on a ridge that extends from the Base of Mount Baldy to the south west. The shoulder upon which the landfill is located is a divide between two of Mount Baldy's small watersheds with Boot Creek as the drainage feature to the north and an area of fenland receiving water to the south (Town of Inuvik, 2006). Surface water drainage is directed around the active landfill and similar drainage controls would be in place at the soil treatment facility. Lateral groundwater movement into and out from the immediate vicinity of the Site is expected to be limited due to the thin active layer; the low permeability nature of the subsoils; the relatively small recharge area; and the presence of compacted roads (Town of Inuvik, 2006). Vertical groundwater movement will be restricted by the presence of permafrost. However, the shallow groundwater table within the active layer makes groundwater immediately beneath the Site potentially vulnerable to contamination even if lateral and vertical migration is limited under the current conditions. It is understood that this potential vulnerability has been mitigated as part of the design of the soil treatment facility.

The thickness of the active layer and the depth to permafrost could potentially be impacted by heat generated from biological activity such as that to be expected at a soil treatment facility or within non-inert municipal waste (garbage). Evidence of this can potentially be seen in the depth to the permafrost measured during the 2017 summer site investigation. The depth to permafrost was greater in the locations that noted the presence of garbage. Melting of the permafrost could have implications on groundwater flow; however, this is of more concern in areas where the permafrost layer is thin and or discontinuous and could be penetrated, rather than areas such as Inuvik with deep permafrost. In contrast to this, compaction of the ground could lead to the permafrost rising and any changes in the morphology of the permafrost interface could influence groundwater flow direction such as a mounding of permafrost beneath the site and radial flow outward. Again, it is understood that mitigation measures to minimize impact on the active layer have been addressed as part of the design process of the soil treatment facility.

PROFESSIONAL GEOLOGIST ALBERTA
LOUISE BURDEN
LICENSED TO PRACTICE

10th NOV 2017

Louise Burden M.Sc., P.Geol
Principal Hydrogeologist
Ashwell Consulting Inc.

Scott Dionne, M.Eng., P.Ag.
Vice President, Environmental Services
LandSolutions Environmental LP

Permit to Practice APEGA: P13986

Terms of Reference

Louise Burden of Ashwell Consulting Inc. was engaged as a Professional Hydrogeologist (P.Geol) in Alberta by LandSolutions of Calgary, Alberta to provide commentary on the hydrogeology of a site located in Inuvik, Northwest Territories. The study area is located within a former cell of the Mount Baldy Solid Waste Community Landfill within the Town of Inuvik, Northwest Territories and is the site of a proposed soil treatment facility.

This commentary has been prepared by Ashwell Consulting Inc. for the exclusive use of Land Solutions Environmental GP Inc. and its client. Ashwell Consulting accepts no liability or responsibility with respect to the property described in this letter or for any business or design decisions relating to the property or the construction of the soil treatment facility. Nothing in this letter report is intended to constitute or provide a legal opinion. The commentary provided reflects the best judgment of Ashwell Consulting based on the information available at the time of preparation of this letter report. Ashwell Consulting has exercised reasonable skill, care, and diligence in assessing the information acquired during the preparation of this letter report, but makes no guarantees or warranties as to the accuracy or completeness of this information. Any use, reliance on, or decision made, by a third party based on this letter report is the sole responsibility of said third party.

References

Canadian Geoscience Map 187. Geology. Inuvik, Northwest Territories. ess.nrcan.gc.ca.

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KBL, 2017. Field logs from intrusive investigations conducted in October 2016 and August 2017.

Kiggiak-EBA Consulting, 2011. Environmental Impact Statement for Construction of Tuktoyaktuk to Inuvik Highway NWT. Hamlet of Tuktoyaktuk, Town on Inuvik and Government of Northwest Territories.

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Morse, P.D. (comp.), 2017. Report on the Permafrost and Hydrogeology Interactions meeting, 14 November 2016, Yellowknife, NWT; Geological Survey of Canada, Open File 8192, 60 p. (also Northwest Territories Geological Survey, NWT Open Report 2017-010). doi:10.4095/299674

Town of Inuvik, 2006. Operation and Maintenance Manual for the Solid Waste Disposal Facilities.

ATTACHMENT B

BECKINGHAM REPORT

Environmental Monitoring Report

Inuvik Soil Treatment Facility

Gwich'in Land and Water Board
Inuvik

Submitted To:
KBL Environmental Ltd.

On
March 30, 2022

Prepared By:

Beckingham Environmental
info@beckinghamenviro.com

Beckingham Project No.: BE22015

Letter of Transmittal

March 30, 2022
KBL Environmental Ltd.
3601 – 75 Avenue
Leduc, AB T9E 0Z5

Attention: Ms. Katie Oliver

Re: Groundwater Monitoring – Inuvik Soil Treatment Facility

Beckingham Project No.: BE22015

Beckingham Environmental Ltd. is pleased to submit this Environmental Monitoring Report on the above referenced property.

We have enjoyed working with you on this project and look forward to working with you in the future.

Prepared by:

Nicole Shelton, H.B.Sc, EP, P.Ag
Senior Environmental Scientist

Date: March 30, 2022

Reviewed by:
Caroline Martel, P.Eng.
Senior Environmental Engineer

REGISTERED PROFESSIONAL ENGINEER
C.M.L. MARTEL
LICENSEE
NT/NU

PERMIT TO PRACTICE
BECKINGHAM ENVIRONMENTAL LTD.
Signature ____________
Date 2022-03-30
PERMIT NUMBER: P 1417
NT/NU Association of Professional Engineers and Geoscientists

1.0 Introduction

Beckingham Environmental Ltd. (Beckingham) was retained by KBL Environmental (KBL) to report on the findings of environmental monitoring conducted to assess the environmental impacts, if any, at the Inuvik Soil Treatment Facility (STF) (the Site). The location of the Site is illustrated on Figure 1 and Figure 2.

As part of the Environmental Monitoring Plan (EMP), KBL monitors and manages groundwater, surface water, soil, and permafrost at the Site. The Facility includes a single bermed, lined cell for the treatment of petroleum hydrocarbon (PHC) contaminated soil within a bioremediation cell in addition to an engineered water retention pond to collect the runoff generated from precipitation. The retention pond also holds contaminated snow during the winter season. The contaminated soil is treated utilizing mechanical aeration to stimulate microbial activity to promote bioremediation. Fertilizers and surfactants are to be added to the soil as needed to enhance conditions to foster microbial activity. The construction of the facility was completed on September 27, 2021. Soil has been accepted at the facility since October 2021.

1.1 Scope of Work

The scope of work comprised the following:

- Review the groundwater monitoring data that was gathered from 2018 to 2021;
- Analyze and interpret field and laboratory analytical data; and
- Prepare a report that includes:
  - a summary of results;
  - recommendations and rationale for future monitoring/sampling (frequency and parameters), if needed; and
  - provide rationale for recommendations if no additional sampling is recommended.

2.0 Background Information

As per Ashwell Consulting Inc. report dated November 6, 2017, Inuvik is located within a zone of deep continuous permafrost which can extend to depths of greater than 700 metres (m) below sea level. Within permafrost regions, groundwater flow (vertical and lateral) occurs within the active layer above the permafrost during the thawed season. This layer freezes and thaws annually and is variably saturated. The groundwater table is close to the surface and shallow groundwater flow generally mimics the topography. Permafrost was encountered at the Site from 1.3 to 7.1 m below ground surface (bgs); saturated conditions occurred at depths of 1.5 to 5.6 mbgs.

2.1.1 Groundwater Monitoring Well Network

As per the Environmental Management Plan completed by KBL, the contaminants in the material entering the Site are primarily benzene, ethylbenzene, toluene, xylenes (BTEX), heating oil, and gasoline.

Baseline testing was completed in order to establish existing concentration ranges of potential contaminants of concern from the historical landfill operations.

Four monitoring wells were installed at the Site in 2017. One monitoring well was installed upstream of the soil treatment pad, and three were installed downstream (Figure 3). In accordance with Part C of Annex A: Surveillance Network Program (SNP) Annexed to Water License G17L1-002 Part B, Item 2 KBL Environmental, the following monitoring is required:

SNP Station #	Description	Sampling Frequency	Parameters per EMP (page 11-13)
0037-4	MW4- northeast and upgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-5	MW1- southeast and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-6	MW2- south and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP
0037-7	MW3- southwest and downgradient of the STF	Twice annually (spring and fall)	Metals, PHC F1-F4, BTEX, COD, EPH, TSS, O&G, pH, FP

Metals- ICP-MS Metal Scan (Total)
Field Parameters (FP)
Petroleum Hydrocarbons (PHC) fractions 1 to 4 (F1-F4)
Benzene, toluene, ethylbenzene, and xylenes (BTEX)
Chemical Oxygen Demand (COD)
Extractable Petroleum Hydrocarbons (EPH)
Total Suspended Solids (TSS)
Oil and Grease (O&G)

Beckingham notes, however, that per the Water License – Current to April 8, 2021, the environmental monitoring program was to include baseline data for: BTEX, volatile organic compounds (VOCs), PHC F1-F4, polycyclic aromatic hydrocarbons (PAHs), and total metals.

2.2 Regulatory Framework

KBL provided generated tables to Beckingham for review and utilized the Federal Contaminated Sites Action Plan (FCSAP) Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites for the Most Stringent Pathway, including coarse- and fine-grained soils (FCSAP; Government of Canada, 2012).

3.0 Environmental Monitoring and Sampling Program

3.1 Summary of Field Activities

3.1.1 Sampling Events

Sampling of the groundwater monitoring wells was attempted twice a year at all locations from 2018 to 2021.

The following limitations occurred during the sampling events:

- June 2018
  - Sampling was unable to be completed at locations: SNP0037-5 (MW-1); SNP0037-6 (MW-2); and SNP0037-4 (MW-4), as they were dry.
- October 2018
  - Sampling was unable to be completed at SNP0037-4 (MW-4), as it was dry.
- August 2019
  - Sampling was unable to be completed at SNP0037-4 (MW-4), as it was dry.
- June 2020
  - Sampling was unable to be completed at locations: SNP0037-5 (MW-1); SNP0037-6 (MW-2); SNP0037-7 (MW-3), and SNP0037-4 (MW-4), as they were dry/frozen.
- August 2020
  - Sampling was unable to be completed at locations: SNP0037-6 (MW-2) and SNP0037-4 (MW-4), as they were dry/frozen.
- July 2021
  - Sampling was unable to be completed at locations: SNP0037-5 (MW-1); SNP0037-6 (MW-2); and SNP0037-4 (MW-4), as they were dry.
- September 2021
  - Sampling was unable to be completed at locations: SNP0037-6 (MW-2) and SNP0037-4 (MW-4), as they were dry.

3.1.2 Groundwater Sampling Methodology

Prior to purging, groundwater level and well depths were measured using an electronic interface water level meter prior to purging well water so that the volume of water in the casing and annuls could be calculated. Following these measurements, at least three well volumes were purged according to industry recognized low flow protocols using a Geotech Geopump™ peristaltic pump and polyethylene tubing. The peristaltic pump was connected to a handheld In-Situ smarTROLL™ multi-parameter meter to monitor field parameters (pH, temperature, electrical conductivity, dissolved oxygen, etc.) as purging continued. Purging was conducted until water quality parameters stabilized and then samples were collected. For each well, the handheld multi-parameter meter was rinsed, and new polyethylene tubing was used to prevent cross-contamination.

Groundwater samples were collected in clean laboratory supplied sample bottles/vials. All water samples were stored for transport in ice-packed coolers and kept at a temperature of 4°C or less. After sampling was completed, samples were immediately transported to an accredited laboratory under chain-of-custody.

3.2 Quality Assurance/ Quality Control

3.2.1 Duplicate Samples

During each sampling event, a duplicate sample was collected and submitted for analysis. The results from the duplicate samples were compared for quality assurance and are reported in the data tables next to the results from the samples they are duplicates of.

4.0 Results and Discussion

4.1 Groundwater Analytical Results

Routine and total metal analysis is summarized on Table 1. Beckingham completed the maximum baseline level + 25% for future comparison at the facility. This takes into consideration the levels observed onsite prior to the addition of the facility.

4.1.1 Aluminum

Total aluminum was found over the most stringent (pH <6.5) Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, August 2020, and September 2021 sampling events (all events).
- MW-2 on the October 2018 and August 2019 events (all events).
- MW-3 on June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021.

Discussion: MW-1 had concentrations ranging from 17.5 to 6,830 ug/L. This well showed moderate concentrations of total aluminum in October 2018 and September 2021 and low concentrations in August 2020. The one elevated event showed an increase in total suspended solids (TSS). Based on this, it is expected that the elevation was due to the increase in sediments in the sample. Beckingham notes that pH of the groundwater was not provided; as such, the lowest/most stringent standard was utilized.

MW-2 had concentrations ranging from 3,870 to 6,930 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed. During the two events that groundwater was sampled, TSS were over 1,000 mg/L.

MW-3 had concentrations ranging from 158 to 3,780 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 8,538 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.2 Arsenic

Total arsenic was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018 and August 2019 sampling events.
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations of total arsenic ranging from 0.7 to 15.8 ug/L. This well showed low concentrations in August 2020 and September 2021.

MW-2 had concentrations of total arsenic ranging from 22.5 to 28.6 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed. Arsenic was relatively stable in the two events; however, further testing is required to determine if there is any trending within this well.

MW-3 had concentrations of total arsenic ranging from 6.61 to 27 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 36 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.3 Barium

Total barium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-3 in the June 2018, October 2018, August 2019, August 2020, and July 2021.

Discussion: MW-3 had concentrations of total barium ranging from 499 to 750 ug/L. No trending was apparent from the results. The September 2021 results were below the guidelines.

In review of the baseline levels, the maximum baseline level plus 25% equals 938 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.4 Boron

Total boron was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, August 2020, and September 2021 sampling events (all sampling events in this well).

- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from 1,600 to 2,680 ug/L.

MW-3 had concentrations ranging from 2,650 to 4,240 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 5,300 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.5 Cadmium

Total cadmium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, August 2020, and September 2021 sampling events (all events).
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from 0.226 to 0.37 ug/L.

MW-2 had concentrations ranging from 0.346 to 0.437 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from <0.025 to 0.218 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 0.55 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.6 Chromium

Total chromium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the August 2019 sampling event.
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the August 2019, August 2020, and July 2021 events.

Discussion: MW-1 had concentrations ranging from 1.25 to 13.6 ug/L. The levels of total chromium were below the guideline in 2020 and 2021.

MW-2 had concentrations from 8.99 to 15.6 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 3.59 to 12.1 ug/L. This well was found below guidelines in the September 2021 sampling event.

In review of the baseline levels, the maximum baseline level plus 25% equals 20 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.7 Copper

Total copper was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, August 2020, and September 2021 sampling events (all events).
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the October 2018, August 2019, August 2020, July 2021, and September 2021 events.

Discussion: MW-1 had concentrations ranging from 2.29 to 7.6 ug/L.

MW-2 had concentrations ranging from 12.2 to 22.7 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 0.68 to 19.8 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 28 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.8 Iron

Total cadmium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, and September 2021 sampling events (all events).
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from 33 to 19,700 ug/L.

MW-2 had concentrations ranging from 22,400 to 33,700 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 33,300 to 108,000 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 135,000 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.9 Lead

Total lead was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018 and August 2019 sampling events.
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from <0.2 to 11.5 ug/L.

MW-2 had concentrations ranging from 15.1 to 21.1ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations of ranging from <0.025 to 0.218 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 36 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.10 Manganese

Total manganese was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, August 2020, and September 2021 sampling events (all events).
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from 664 to 1,410 ug/L.

MW-2 had concentrations ranging from 5,660 to 5,810 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 2,300 to 3,450 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 7,263 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.11 Mercury

Total mercury was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the August 2019 sampling event.
- MW-2 on the October 2018 and August 2019 events.

Discussion: MW-1 had concentrations ranging from <0.0050 to 0.0684 ug/L.

MW-2 had concentrations ranging from 0.0685 to 0.305 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

In review of the baseline levels, the maximum baseline level plus 25% equals 0.38 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.12 Nickel

Total nickel was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the August 2019 sampling event.
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the August 2019 and August 2020 events.

Discussion: MW-1 had concentrations ranging from 10.9 to 29.8 ug/L.

MW-2 had concentrations ranging from 27.8 to 37.6 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 12.5 to 36.5 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 47 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.13 Selenium

Total selenium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the August 2019 sampling event.
- MW-2 on the August 2019 event.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, and July 2021 events.

Discussion: MW-1 had concentrations ranging from <0.50 to 1.36 ug/L.

MW-2 had concentrations ranging from 0.941 to 1.18 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 0.71 to 6.3 ug/L. This well met guidelines in the final event of 2021.

In review of the baseline levels, the maximum baseline level plus 25% equals 8 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.14 Silver

Total silver was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-2 on the October 2018 and August 2019 events.

MW-2 had concentrations ranging from 0.291 to 0.311 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

In review of the baseline levels, the maximum baseline level plus 25% equals 0.39 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.15 Thallium

Total thallium was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-2 on the October 2018 and August 2019 events.

MW-2 had concentrations ranging from 0.868 to 1.06 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

In review of the baseline levels, the maximum baseline level plus 25% equals 1.33 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.16 Zinc

Total zinc was found over the Federal Interim Groundwater Quality Guidelines in:

- MW-1 on the October 2018, August 2019, and September 2021 sampling events.
- MW-2 on the October 2018 and August 2019 events.
- MW-3 on the June 2018, October 2018, August 2019, August 2020, July 2021, and September 2021 events (all events).

Discussion: MW-1 had concentrations ranging from 7.8 to 76.9 ug/L.

MW-2 had concentrations ranging from 49.5 to 88 ug/L. This well was dry during all other events; as such, a trending for this well was unable to be completed.

MW-3 had concentrations ranging from 68 to 184 ug/L.

In review of the baseline levels, the maximum baseline level plus 25% equals 230 ug/L. This value should be utilized as a reference for any impacts of the newly constructed facility.

4.1.17 Petroleum Hydrocarbons

All petroleum hydrocarbon parameters were found to be below the Federal Interim Groundwater Quality Guidelines. All results are summarized on Table 2.

5.0 Conclusions and Recommendations

5.1 Groundwater Results

Routine and Metal Parameters

Upon review of the groundwater monitoring results which were available for MW1 to MW-4, a maximum baseline level +25% was created. Beckingham notes that no groundwater was found in MW-4 which is up-gradient of the facility. If analytical results change significantly over time, further up-gradient locations may be warranted to ensure that offsite impacts are not causing changes in the areas being monitored.

The maximum baseline level + 25% was created to assist in the future analytical review of the results compared to background conditions and for analytical with no standards. Beckingham notes that several metals were found over the most stringent levels, at the Site. However, as this work was completed prior to the construction and bioremediation at the facility, these levels are considered to be baseline levels.

Petroleum Hydrocarbons

Upon review of the groundwater monitoring results which were available for MW1 to MW-4, a maximum baseline level +25% was created. Beckingham notes that no groundwater was found in MW-4 which is up-gradient of the facility. If analytical results change significantly over time, further up-gradient locations may be warranted to ensure that offsite impacts are not causing changes in the areas being monitored.

The maximum baseline level + 25% was created to assist in the future analytical review of the results with no comparable standards.

VOCs

VOCs were not addressed in the baseline data.

PAHs

PAHs were not addressed in the baseline data.

5.2 Recommendations

Future groundwater monitoring should be compared to the maximum baseline level + 25% in all analytical which have been tested for during the baseline work. Beckingham further recommends that VOCs and PAHs be tested for in 2022 and 2023 to gain some detail and ensure that these chemicals are not leading to an increase in trending over time. During the June events, many of the monitoring wells were dry; Beckingham recommends that the Summer event occur near August as it appears that groundwater amounts were sufficient in most cases in August. Given that there have been changes to the environment by the addition of the facility, continued monitoring twice a year is recommended to document any changes to the amount and quality of the groundwater in the area.

6.0 Closure

This report was prepared for:

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Prepared by:
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1206 - 20 Avenue SE
Calgary, Alberta
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Nicole Shelton, H.B.Sc, EP, P.Ag
Senior Environmental Scientist
Assessment & Remediation
Reporting and Report Editing

7.0 Assessor Qualifications

Nicole Shelton, H.B.Sc, EP, P.Ag. ,
Data Review / Analysis and Report Writing

Nicole has an Honours Bachelor of Science degree in Environmental Science from the University of Toronto. She has a strong background in soil science, geology, hydrology, and contaminated sites. She has worked throughout Canada and the United States of America as a consultant on a wide range of projects including: Phase I II and III ESAs, remediation, risk mitigation, and reclamation work, on oil and gas, residential, commercial, and industrial properties. Work has also included mould, hazardous materials assessments, and occupational health and safety concerns. Nicole has worked on many large scale programs on facilities such as nuclear power plants, shooting ranges, gas stations, dry cleaning facilities, and large industrial chemical operations.

8.0 Disclaimer and Limitation of Liability

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- the property specified in the document;
- the information known to the Consultant at the time of the work;
- the regulatory standards in place at the time of the work;
- the data yielded by any sampling or other testing program conducted under the Scope of Work; and
- the accuracy of the information provided by third parties, including, without limitation, data generated by the sampling or other testing program, information from government agencies and anecdotal information regarding the property provided to the Consultant.

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a. *Claims brought within a period of 1 year from the date of the termination or completion of the Project by the Consultant; and*
b. *Not more than the total amount paid by the Client to the Consultant for its services under this agreement (excluding disbursements) to a maximum of $10,000.00.*

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The Consultant is not responsible for any project delays caused as a result of event(s) beyond its control.

9.0 References

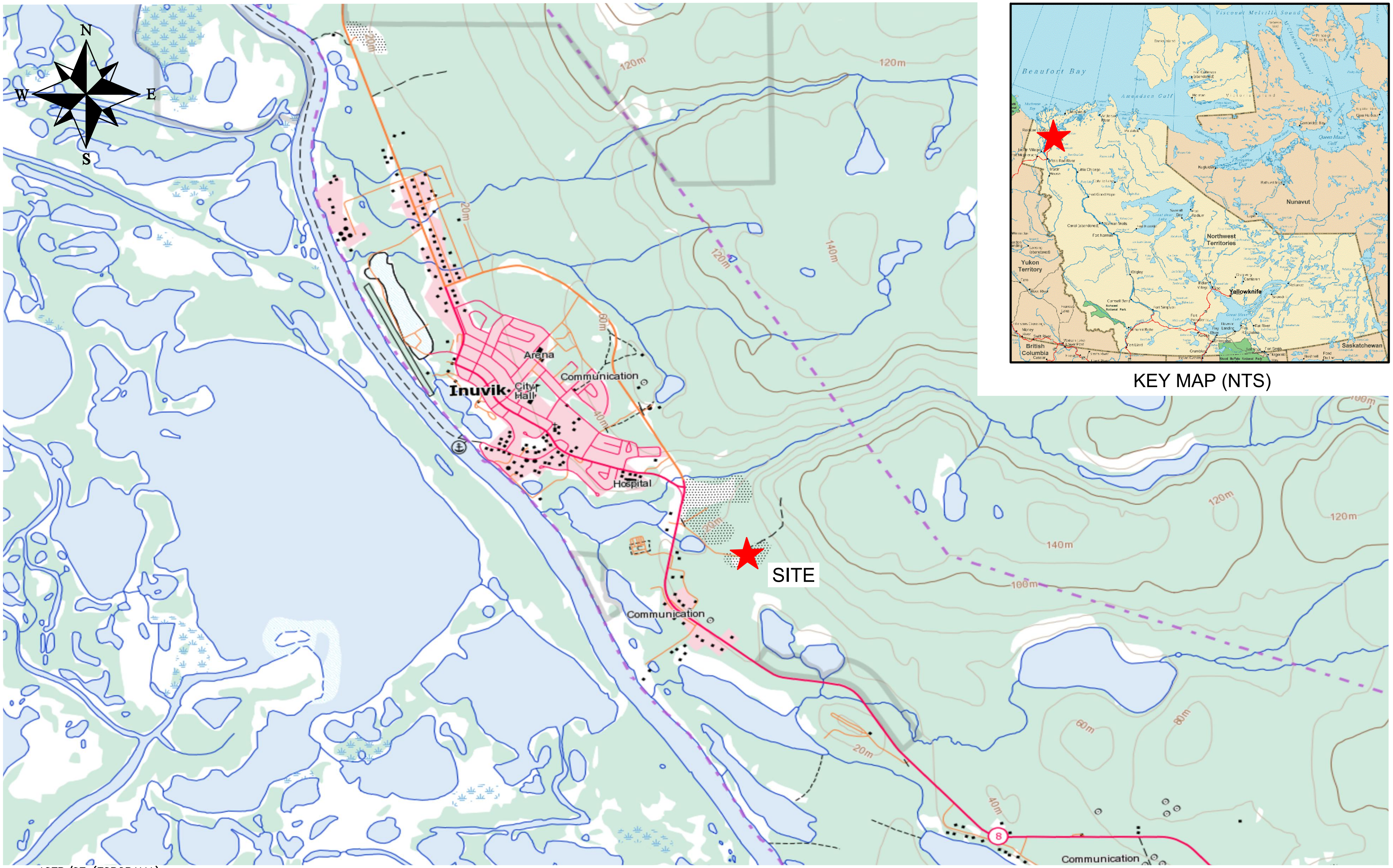
Environment Canada. 2016. "*Federal Contaminated Sites Action Plan (FCSAP) Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites*" Government of Canada, Ottawa, ON. 2016.

Gwich'in Land and Water Board. 2021. Re: Inuvik Soil Treatment Facility – Issuance of Amended of Type "B" Water License, dated April 8, 2021

KBL Environmental Ltd. (KBL), 2018. "*Environmental Monitoring Plan*" KBL, dated January 2018.

Figures

File: DEPT4200_SLM.dwg Date: September-26-19 3:25:52 PM



107B/07 (TOPORAMA)

0 500 1000 2000m

Scale 1 : 50 000

SITE LOCATION MAP

KBL

Date: 26-SEP-2019	Drawn: CD	GOVERNMENT OF THE NORTHWEST TERRITORIES HIGH ROAD, INUVIK, NT	Figure: 1
File name: DEPT4200_SLM–A.dwg	Approved: CL		

File: DEPT4200_19GWMP.dwg Date: September-30-19 11:14:14 AM

SATELLITE AERIAL PHOTO SOURCE: DIGITALGLOBE, CNES, DISTRIBUTION AIRBUS DS (BING)

LEGEND

SITE LOCATION

NOTES:

LOCATIONS ARE APPROXIMATE.

0 25 50 100m

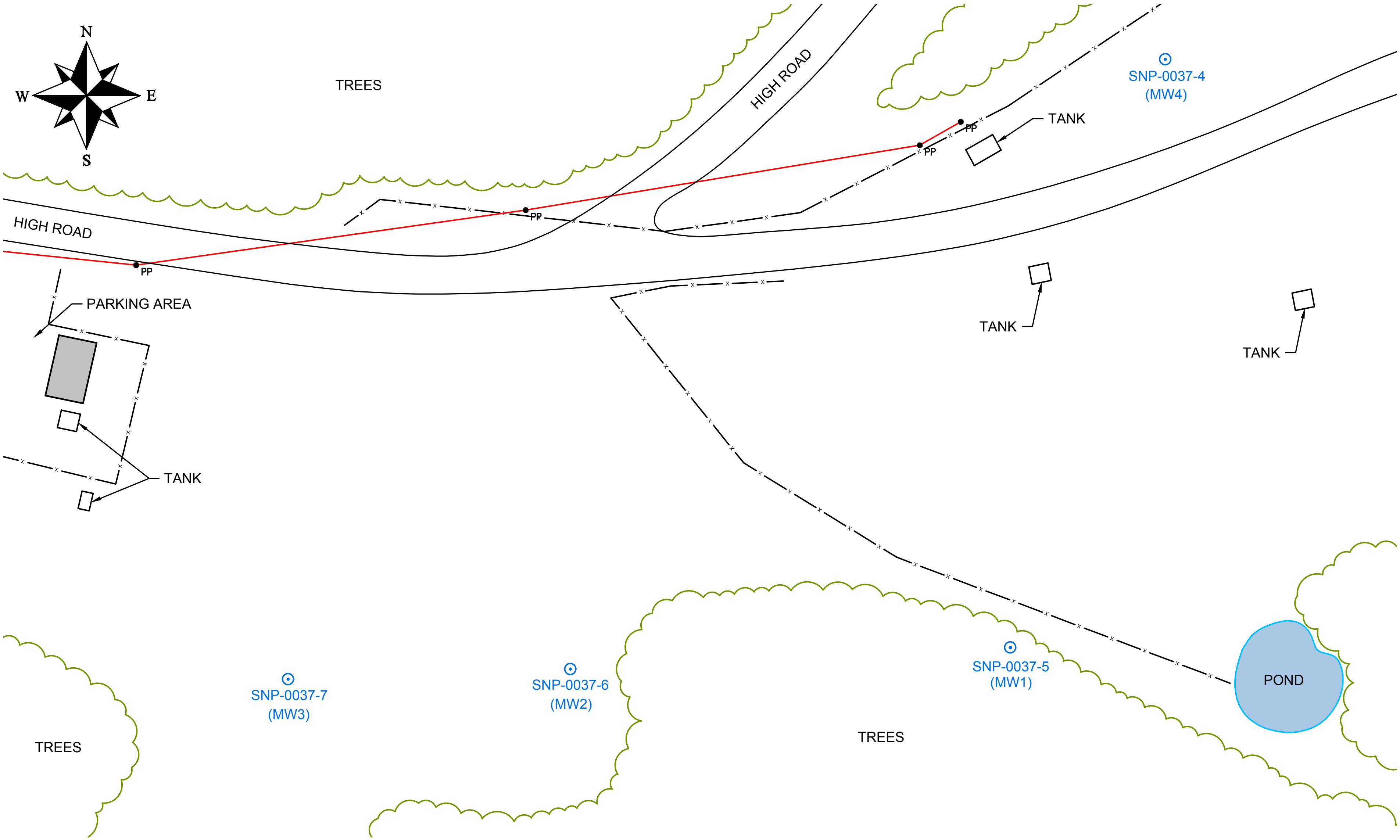
Scale 1 : 2500

AERIAL OVERVIEW

KBL

Date: 26-SEP-2019	Drawn: CD	GOVERNMENT OF THE NORTHWEST TERRITORIES HIGH ROAD, INUVIK, NT	Figure: 2
File name: DEPT4200_19GWMP-A.dwg	Approved: CL		

File: DEPT4200_19GWMP.dwg Date: September-30-19 11:14:14 AM



LEGEND

- MONITORING WELL
- BUILDING
- POWER LINE / POLE
- FENCE

NOTES:

LOCATIONS ARE APPROXIMATE.

0 10 20 40m

Scale 1 : 1000

SITE DIAGRAM

KBL

Date: 30-SEP-2019	Drawn: CD	GOVERNMENT OF THE NORTHWEST TERRITORIES HIGH ROAD, INUVIK, NT	Figure: 3
File name: DEPT4200_19GWMP-C.dwg	Approved: CL		

Tables

Table 1: Groundwater Characterization Data – Total Metals and Routine Parameters
Client: GNWT
Project: Groundwater Monitoring Program
KBL File #: Inuvik STF GW Monitoring

Monitoring Location	Sample ID	Lab ID	Date	Total Suspended Solids	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Bismuth (Bi)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Cesium (Cs)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Magnesium (Mg)
Sampling Information				Physical Tests	Total Metals																
-	-	-	dd-mmm-yy	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
FCSAP - Most stringent of commercial/industrial, with fine or co				3,000	5	2,000	5	500	5.3	-	500	0.017	-	-	8.9	50	2	300	1	-	-
Maximum Baseline Level + 25% or existing standard				3,000	8,538	2,000	36	938	5.3	0.23	5,300	0.55	633,750	1.8125	20	50	28	135,000	36	93	1,023,750
Groundwater Monitoring Locations																					
SNP0037-5 (MW-1)	Dry	-	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SNP0037-5-100518	L2177196-1	5-Oct-18	138	2,130	0.4	5.05	86.5	0.15	0.06	1,600	0.298	464,000	0.423	4.17	4.25	7.24	5,500	2.89	29	260,000
	SNP-0037-5 (MW-1)	L2340180-1	30-Aug-19	449	6,830	0.74	15.8	214	0.55	0.18	2,390	0.282	433,000	1.37	13.6	8.28	21.2	19,700	11.5	73.7	276,000
	Dry / Frozen	-	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SNP-0037-5 MW-1	0090055-01	27-Aug-20	254	17.5	0.3	0.7	14.1	<0.10	<0.10	2,680	0.226	507,000	-	1.25	1.89	2.29	33	<0.2	39.2	294,000
	Dry	-	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	MW1-210908	L2638080-1	8-Sep-21	320	1,140	<0.2	2.9	34.4	<0.20	-	1,850	0.37	490,000	-	3.48	3.51	7.6	3,020	2.51	60.3	269,000
SNP0037-6 (MW-2)	Dry	-	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SNP0037-6-100518	L2177196-2	5-Oct-18	1,280	3,870	0.79	22.5	194	0.22	0.07	397	0.346	434,000	0.893	8.99	10.3	12.2	22,400	15.1	228	819,000
	SNP-0037-6 (MW-2)	L2340180-2	30-Aug-19	1,610	6,930	0.92	28.6	268	<0.50	<0.25	395	0.437	475,000	1.45	15.6	15.1	22.7	33,700	21.1	173	428,000
	Dry / Frozen	-	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	27-Aug-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	8-Sep-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SNP0037-7 (MW-3)	SMP0037-7	L2112859-1	14-Jun-18	-	164	0.66	10.1	695	<0.10	<0.050	3,510	0.027	343,000	0.028	4.89	1.04	0.68	63,600	4.65	43.8	248,000
	MWA	L2112859-2	14-Jun-18	-	158	0.66	10.1	656	<0.10	<0.050	3,570	0.031	346,000	0.027	4.95	1.02	0.77	63,100	4.73	44	238,000
	Quality Assurance RPD				3.7%	0.0%	0.0%	5.8%	-	--	1.7%	13.8%	0.9%	3.6%	1.2%	1.9%	12.4%	0.8%	1.7%	0.5%	4.1%
	SNP0037-7-100518	L2177196-3	5-Oct-18	184	646	1.06	11.9	549	<0.10	<0.050	3,980	0.0772	316,000	0.091	5.32	1.86	3.36	33,500	8.6	57.2	241,000
	SNP0037-A-100518	L2177196-4	5-Oct-18	201	622	1.03	11.8	558	<0.10	<0.050	3,930	0.0709	316,000	0.088	5.39	1.75	3.72	34,200	8.47	54.2	241,000
	Quality Assurance RPD			-	3.8%	2.9%	0.8%	1.6%	-	--	1.3%	8.5%	0.0%	3.4%	1.3%	6.1%	10.2%	2.1%	1.5%	5.4%	0.0%
	(MW-3)	L2340180-3	30-Aug-19	444	2,260	1.09	19.2	745	<0.20	<0.10	2,690	0.151	337,000	0.312	9.13	5.27	10.9	97,700	19.0	40.5	237,000
	DUP-1	L2340180-4	30-Aug-19	431	3,780	1.37	27.0	750	0.23	<0.10	2,650	0.218	332,000	0.486	12.1	8.01	19.5	108,000	29.10	42.2	240,000
	Quality Assurance RPD				50.3%	22.8%	33.8%	0.7%	14.0%	--	1.5%	36.3%	1.5%	43.6%	28.0%	41.3%	56.6%	10.0%	42.0%	4.1%	1.3%
	Dry / Frozen	-	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SNP-0037-7 MW-3	0090055-02	27-Aug-20	132	2,190	1.18	19.9	737	0.15	<0.10	3,940	0.127	347,000	-	9.82	6.45	8.88	97,700	17.9	52.9	263,000
	MW3 (SNP-0037-7)	2767695	15-Jul-21	74	1,230	1.0	17.0	750	<1.0	-	3,880	0.1	-	-	9.0	5.0	7.0	50,400	19.4	74.0	-
	MW3-210908	L2638080-2	8-Sep-21	33	212	0.51	6.61	499	<0.50	-	4,240	<0.025	286,000	-	3.59	1.51	<2.5	33,300	5.97	42.4	233,000
SNP0037-4 (MW-4)	Dry	-	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	5-Oct-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	30-Aug-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry / Frozen	-	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	27-Aug-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dry	-	8-Sep-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sample ID	Date	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)	Rubidium (Rb)	Selenium (Se)	Silicon (Si)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulphur (S)	Tellurium (Te)	Thallium (Tl)	Thorium (Th)	Tin (Sn)	Titanium (Ti)	Tungsten (W)	Uranium (U)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
-	dd-mmm-yy	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
FCSAP - Most stringent of commercial/industrial, with fine or co		200	0.026	73	25	-	-	-	1	-	0.25	-	-	-	-	0.8	-	-	100	-	10	100	10	-
Maximum Baseline Level + 25% or existing standard		7,263	0.38	73	47	1,750	50,625	20	8	20,625	0.39	677,500	3,450	1,837,500	0.81	1.33	7	5	100	0.26	10	100	230	5
Groundwater Monitoring Locations																								
Dry	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SNP0037-5-100518	5-Oct-18	1,410	<0.0050	0.501	15.8	270	8,200	5.72	0.397	6,840	0.049	103,000	2,280	779,000	0.52	0.1	2.08	0.42	21.5	<0.10	1.71	8.93	24	1.85
SNP-0037-5 (MW-1)	30-Aug-19	664	0.0684	1.3	29.8	970	15,300	15.1	1.36	15,600	0.186	101,000	2,760	780,000	0.45	0.153	5.81	0.64	47.2	<0.20	2.13	30.6	76.9	2.22
Dry / Frozen	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SNP-0037-5 MW-1	27-Aug-20	690	<0.040	0.24	10.9	<50	9,890	-	<0.50	4,600	<0.050	105	2,570	787,000	<0.50	0.047	<0.10	<0.20	<5.0	<1	1.85	<1.0	7.8	0.29
Dry	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW1-210908	8-Sep-21	1,270	<0.0050	0.15	11.3	-	8,010	-	0.28	-	0.027	87,300	-	-	-	0.064	-	<0.20	18.3	-	3.47	7.2	23.8	-
Dry	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SNP0037-6-100518	5-Oct-18	5,660	0.0685	1.71	27.8	755	10,900	13.6	0.941	9,150	0.291	161,000	2,410	1,470,000	0.65	0.868	1.91	0.31	47.3	<0.1	7.36	18.3	49.5	1.71
SNP-0037-6 (MW-2)	30-Aug-19	5,810	0.305	2.71	37.6	1,250	12,200	16.1	1.18	13,300	0.311	163,000	2,590	953,000	<1.0	1.06	3.42	<0.50	60.6	<0.50	5.15	33.9	88	1.5
Dry / Frozen	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	27-Aug-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	8-Sep-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SMP0037-7	14-Jun-18	3,450		0.414	12.8	1,080	40,500	11.9	1.1	12,900	0.037	528,000	1,750	7,730	<0.2	<0.010	<0.1	2	6.32	0.21	0.079	11.4	69.1	3.28
MWA	14-Jun-18	3,250		0.421	12.5	1,050	39,800	11.9	1.11	12,700	0.028	530,000	1,710	8,850	<0.2	<0.010	<0.1	2.08	7.95	0.2	0.076	11.9	70.2	3.34
Quality Assurance RPD		6.0%	--	1.7%	2.4%	2.8%	1.7%	0.0%	0.9%	1.6%	27.7%	0.4%	2.3%	13.5%	--	-	-	3.9%	22.8%	0.0%	3.9%	4.3%	1.6%	1.8%
SNP0037-7-100518	5-Oct-18	2,350	<0.0050	0.655	15.6	987	38,500	13.5	1.24	11,600	0.03	517,000	1,630	23,600	0.4	0.015	0.15	3.24	10.5	0.18	0.212	20.2	102	2.98
SNP0037-A-100518	5-Oct-18	2,380	<0.0050	0.614	15.4	1,060	38,300	13.7	1.17	11,500	0.036	526,000	1,590	24,200	0.3	0.012	0.16	3.83	10.2	0.18	0.186	20.9	105	3.79
Quality Assurance RPD		1.3%	--	6.5%	1.3%	7.1%	0.5%	1.5%	5.8%	0.9%	18.2%	1.7%	2.5%	2.5%	--	-	-	16.7%	2.9%	10.5%	13.1%	3.4%	2.9%	23.9%
(MW-3)	30-Aug-19	3,100	<0.0050	3.03	27.5	1,110	33,200	11.6	1.02	14,100	0.095	471,000	1,760	5,200	<0.40	0.059	0.58	2.31	24.7	<0.20	0.351	18.5	133	1.81
DUP-1	30-Aug-19	3,160	<0.0050	4.91	36.5	1,400	33,100	12.8	1.11	16,500	0.111	470,000	1,760	6,400	<0.40	0.090	0.87	3.41	60.6	0.21	0.554	27.8	184	2.69
Quality Assurance RPD		1.9%	--	47.4%	28.1%	23.1%	0.3%	9.8%	8.5%	15.7%	15.5%	0.2%	0.0%	20.7%	--	41.6%	40.0%	38.5%	84.2%	4.9%	44.9%	40.2%	32.2%	39.1%
Dry / Frozen	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SNP-0037-7 MW-3	27-Aug-20	2,960	<0.040	2.18	28.6	1,310	37,100	-	1.01	14,800	0.059	542,000	1,970	7,000	<0.50	0.05	0.62	3.22	39.6	<1.0	0.346	21	142	3.28
MW3 (SNP-0037-7)	15-Jul-21	3,130	0.009	2.0	23.0	-	-	-	6.3	9,970	0.10	1,780	1,780	-	-	<0.5	-	3.0	20.0	-	-	21.0	150	-
MW3-210908	8-Sep-21	2,300	<0.0050	0.71	13.7	-	31,700	-	0.71	-	<0.050	452,000	-	-	-	<0.050	-	1.58	6.6	-	0.099	5.9	68	-
Dry	14-Jun-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	5-Oct-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	30-Aug-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry / Frozen	23-Jun-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	27-Aug-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	15-Jul-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry	8-Sep-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Legend

µg/L micrograms per litre
mg/L milligrams per litre

Applicable Guidelines

- Federal Contaminated Sites Action Plan (FCSAP) Guidance Document on Federal Interim Groundwater Quality Guidelines for

Notes

- Parameters not measured and absence of applicable guideline indicated by "-"
- Analytical data reported by ALS Environmental (Work Order #: L2340180), CARO Analytical (WO#0090055) AGAT (WO# 21E778093)
- Exceedance of applicable guidelines or background conditions indicated by
shading; where multiple guidelines apply, the most stringent guideline was used

Table 2: Groundwater Characterization Data – Petroleum Hydrocarbon and Volatile Parameters
Client: GNWT
Project: Groundwater Monitoring Program
KBL File #: Inuvik STF GW Monitoring

Sampling Information				Volatile Organic Compounds and MTBE							Extractable Petroleum Hydrocarbons						Aggregate Organics	
Monitoring Location	Sample ID	Lab ID	Date	Benzene	Toluene	Ethylbenzene	Xylenes (Total)	Styrene	Methyl t-butyl ether (MTBE)	F1 (C6-C10)	EPH10-19	EPH19-32	F1-BTEX	F2 (C10-C16)	F3 (C15-C34)	F4 (C34-C50)	COD	Oil and Grease
-	-	-	dd-mmm-yy	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
FCSAP - Most stringent of commercial/industrial, with fine or coarse grained soils				88	83	3,200	3,900	72	340	810	-	-	810	1300	-	-	-	-
Maximum Baseline Level + 25% or existing standard				88	83	3,200	3,900	72	340	810	5,313	1,638	810	1,300	675	775	547,500	13,250
Groundwater Monitoring Locations																		
MW-1 (SNP0037-5)	SNP0037-5-100518	L2177196-1	5-Oct-18	<0.5	<0.5	<0.5	<0.71	<0.5	-	<100	-	-	<100	<100	<250	<250	54,000	<2000
	SNP-0037-5 (MW-1)	L2340180-1	30-Aug-19	<0.5	<0.45	<0.5	<0.75	<0.50	<0.50	<100	<250	<250	<100	<300	<300	620	55,000	<5000
	SNP-0037-5 MW-1	0090055-01	27-Aug-20	<0.5	<1.0	<1.0	<2.0	<1.0	<1.0	<100	<250	<250	<104	<400	<400	<400	39,000	2,400
	MW-1-210908	L2638070-1	8-Sep-21	<0.5	<0.5	<0.5	<0.71	-	-	<100	4,250	1,310	<100	<100	<250	<250	42,000	<1000
MW-2 (SNP0037-6)	SNP0037-6-100518	L2177196-2	5-Oct-18	<0.5	<0.5	<0.5	<0.71	<0.5	-	<100	-	-	<100	<100	430	<250	26,000	<2000
	SNP-0037-6 (MW-2)	L2340180-2	30-Aug-19	<0.50	<0.45	<0.5	<0.75	<0.50	<0.50	<100	<250	<250	<100	<300	<300	<300	53,000	<5000
MW-3 (SNP0037-7)	SMP0037-7	L2112859-1	14-Jun-18	8.7	8	7.0	140	<1.0	-	180	870	<250	140	560	290	<250	-	1,600
	MWA	L2112859-2	14-Jun-18	7.40	6.90	6.3	11.90	<1.0	-	130	810	<250	130	540	<250	<250	-	2,400
	SNP0037-7-100518	L2177196-3	5-Oct-18	12.8	11.1	9.0	15.1	1.00	-	<100	-	-	<100	820	420	<250	433,000	<2000
	SNP0037-A-100518	L2177196-4	5-Oct-18	12.1	10.5	10.2	15.1	0.96	-	<100	-	-	<100	760	320	<250	-	<5000
	Quality Assurance RPD			5.6%	5.6%	12.4%	0.0%	--	--	-	-	--	-	7.6%	27.0%	--	-	-
	SNP-0037-7 (MW-3)	L2340180-3	30-Aug-19	7.20	8.7	9.2	19.5	<0.50	<0.50	<200	690	<250	<200	440	360	<300	395,000	10,600
	DUP-1	L2340180-4	30-Aug-19	7.4	8.5	9.1	20	<0.50	<0.50	220	690	<250	170	440	360	<300	438,000	<5000
	Quality Assurance RPD			2.7%	2.3%	1.0%	1.5%	--	--	9.5%	0.0%	--	16.2%	0.0%	0.0%	--	10.3%	71.8%
	SNP-0037-7 MW-3	0090055-02	27/Aug/20	<8.0	8.0	11.3	22.4	<1.0	<1.0	<100	594	<250	<112	480	<400	<400	393,000	5,600
	MW3 (SNP-0037-7)	2767695	15-Jul-21	8.3	6.2	9.8	18.1	-	-	<100	0.8	0.2	<100	500	500	<100	268,000	900
	MW-3-210908	L2638070-2	8-Sep-21	9.20	5.1	7.7	11.3	-	-	<100	1,100	340	<100	820	540	<250	342,000	1,100

Legend
µg/L micrograms per litre
RPD relative percent difference (-- indicates incalculable as below detection limits)

Applicable Guidelines
- Federal Contaminated Sites Action Plan (FCSAP) Guidance Document on Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites for the Most Stringent Pathway, including coarse and fine grained soils (FCSAP; Government of Canada, 2012)

Notes
- Parameters not measured and absence of applicable guideline indicated by "--"
- Analytical data reported by ALS Environmental (Work Order #: L2340180), CARO Analytical (WO#0090055) AGAT (WO# 21E778093)
- Exceedance of applicable guidelines or background conditions indicated by shading; where multiple guidelines apply, the most stringent guideline was used

KBL

ATTACHMENT C

LAND SOLUTIONS LETTER - PERMAFROST

May 10, 2017

KBL Environmental
3601 - 75 Avenue
Leduc, AB
T9E 0Z5

Attention: Renee White, Licensing & Compliance Manager

Dear Renee:

Re: Environmental Monitoring and Permafrost Considerations at KBL Environmental's Proposed Inuvik Soil Treatment Facility (STF)

LandSolutions Environmental LP (LSELP) is pleased to provide the following in support of a response to both regulatory and public consultation concerns expressed regarding the operation and maintenance of KBL Environmental's (KBL) proposed petroleum hydrocarbon-impacted soil treatment facility (STF) in Inuvik, NT.

LSELP understands that during the regulatory application review and public consultation process, questions were raised regarding KBL's plans for longer term environmental monitoring at their proposed facility that is to be co-located with the boundaries of the Town of Inuvik's Sanitary Solid Waste Landfill Facility (SWDF). More specifically, the questions were with regards to:

1. How KBL plans to complete monitoring (e.g. soil, surface water and/or groundwater) to ensure that the activities taking place upon the STF do not result in an off-site environmental impact (i.e., risk of contamination creating an adverse effect to human and/or environmental health); and,
2. Whether or not KBL has considered the potential impact of their STF facility and operations on permafrost underlying the proposed location and what, if any, mitigative measures or monitoring should be implemented.

For the above questions, it is important to consider that KBL's proposed facility is to be entirely situated within the boundaries of the Town of Inuvik's SWDF. In fact, preliminary test-pitting results have shown that much of the facility is to be constructed upon areas previously used for the disposal (i.e., burial) of a variety of waste materials. Also, initial analytical results obtained beneath the proposed development have identified the presence of localized petroleum hydrocarbon-impacted soils. Both of these conditions make monitoring for potential future impacts from the proposed STF challenging.

On the outset, monitoring surface water runoff down gradient of the STF may also be of limited benefit. As reported in Earth Tech (Canada) Inc.'s report "Town of Inuvik, NT - Operation and Maintenance Manual for Solid Waste Disposal Facilities" issued in March 2006, the landfill is situated within a divide between two of Mt. Baldy's small watersheds. Northern slopes tend to drain toward Boot Creek, to the west and north and the southern ones drain into a fenland and small ponds to the east and south. Flow from both areas is directed around, and not through, the SWDF.

> *"As a result, drainage leaving the main part of the landfill is limited to the rain and snow which fall directly on the rather small area of the landfill site itself, plus, possibly, a minor amount of permafrost meltwater from beneath the site. Owing to the very small quantities of water leaving this site, or passing its edges, there is little likelihood that any substantial quantity of contamination would be transported from the site to either of the adjacent watersheds."*

The low risk for off-site migration of contaminants from the SWDF (and therefore the STF) may be reinforced by a statement made in the same report that:

> *"the entire district is underlain by deep permafrost, and there are occasional large ice lenses . . . Inuvik is above the Arctic Circle, and well within the NWT's zone of continuous permafrost. Subsoils below the shallow active layer are frozen to considerable depth. In permafrost terrain, groundwater movement is confined to the seasonally-thawed active layer, and to the seasons of thaw. In the lands immediately surrounding the landfill site, little groundwater movement is expected at all, owing to the shallowness of the active layer (especially where the surface vegetation remains, as in the areas to the south and east) and to the generally low permeability of the area's soils. The compacted roadways running past the west side of the site, into the old Hospital Hill quarry and up to the newer Mt. Baldy one, also act as groundwater barriers. In conclusion, horizontal movement of groundwater out of the Mt. Baldy site is expected to be extremely slow if any at all; and vertical movement is barred by deep permafrost.*
>
> *It has occasionally been asked what effect a landfill has on permafrost, and vice-versa. In a landfill containing completely inert materials, it is likely that the permafrost table will gradually rise into the deposit, further improving encapsulation. A landfill that contains natural organic materials, on the other hand, will support bacteria and generate metabolic heat for a considerable number of years, and may actually drive the permafrost table down, forming a temporary basin in the frozen terrain mass. In a shallow permafrost setting this would preclude reliance on permafrost as a liner, but in a deep permafrost setting, such as Inuvik's, it is not of practical significance in terms of groundwater containment."*

It would appear that the above sourced information was the reasoning for not monitoring groundwater from the Town of Inuvik's SWDF for the potential off-site migration of landfill leachate or potential permafrost impacts.

STF Baseline Assessment and Monitoring Program

Regardless of the information presented by AECOM in 2006, KBL will be completing a baseline soil sampling program within the footprint of their proposed facility to characterize and delineate any pre-existing impacts resulting from historical SWDF operations. This assessment will facilitate being able to differentiate between pre-existing impacts and any possible future impacts created by the operation of the STF, if necessary. Existing contaminants to establish a baseline should, at a minimum, include: benzene, toluene, ethylbenzene, xylenes (BTEX), volatile organic compounds (VOCs), F1 to F4 hydrocarbon fractions and polycyclic aromatic hydrocarbons (PAHs).

As part of the baseline sampling program, geotechnical drilling will be completed to confirm the depth to permafrost beneath the proposed site, its type and any active layer considerations. This will assist in confirming the statements made by AECOM in 2006, enable decisions to be made regarding the need to design and implement a permafrost protection strategy, and explore the potential for completing a groundwater monitoring program. The need to implement permafrost protection measures will be explored should any aspect of the proposed STF operations be expected to impact permafrost over and above that attributed to the current SWDF. Examples of permafrost protection designs may include, but not be limited to:

- A granular separation beneath the STF to provide insulation to permafrost; or,
- Rigid board insulation to provide protection to permafrost; or
- Raising the base of the STF to provide a sufficient buffer.

Upon completion of the geotechnical drilling, the STF will be redesigned to accommodate any necessary permafrost protection measures and, if a monitoring system is required, thermistors can be installed to monitor for changes in subsurface temperature resulting from the STF. If a significant active layer is identified above the permafrost table or a groundwater-bearing zone is encountered, KBL will install a network of groundwater monitoring wells (as indicated on supporting design drawings) to monitor groundwater for potential contaminants of concern during the life of the STF. Regular groundwater monitoring will be completed unless conditions indicate that a groundwater gradient and meaningful direction of flow cannot be determined (and thus provides no reliable means of distinguishing impacts from KBL operations from that of the SWDF). If groundwater wells are installed, appropriate measures will be undertaken to protect permafrost, as necessary (e.g. down-hole packers).

KBL is also designing its proposed facility to direct all surface water runoff into a storm water collection pond. This will enable regular sampling and reporting of any water collecting within the pond prior to applicable regulatory guideline comparison to determine pump-off or off-site disposal requirements. Any excess retention pond water is to be discharged at a designated location (proposed on the STF design drawings) where erosion can be controlled and the water will be unable to reach the nearby Boot Creek.

With the low likelihood of off-site migration of contaminants from the STF via surface or groundwater, the construction of the STF using clean fill will lend itself to periodic monitoring of the soil for potential contaminants of concern accepted by the STF; specifically, BTEX and F1 to F4 petroleum hydrocarbon fractions.

So, as part of on-going operations, KBL's will complete a soil monitoring program to consist of sampling soil around the perimeter of the STF in a horizontal 10 metre grid pattern to an initial depth of 30 centimetres below grade. All samples are to be pre-screened for volatile organic compound (VOC) concentrations using a calibrated photoionization (PID) or volatile organic analyzer (VOA). In addition, samples will be tested for total petroleum hydrocarbon content above 500 mg/kg using Cheiron Oil-in-Soil test kits. Twenty-five percent (25%) of the samples with the highest field-screened readings will be submitted to an accredited laboratory for analysis.

The results of any soil, surface water, groundwater or permafrost monitoring program(s) are to be provided to the appropriate regulatory authorities for review and comment.

LSELP appreciates the opportunity to provide KBL with assistance on this matter. Please feel free to contact the undersigned if you have any additional questions or concerns.

Sincerely,

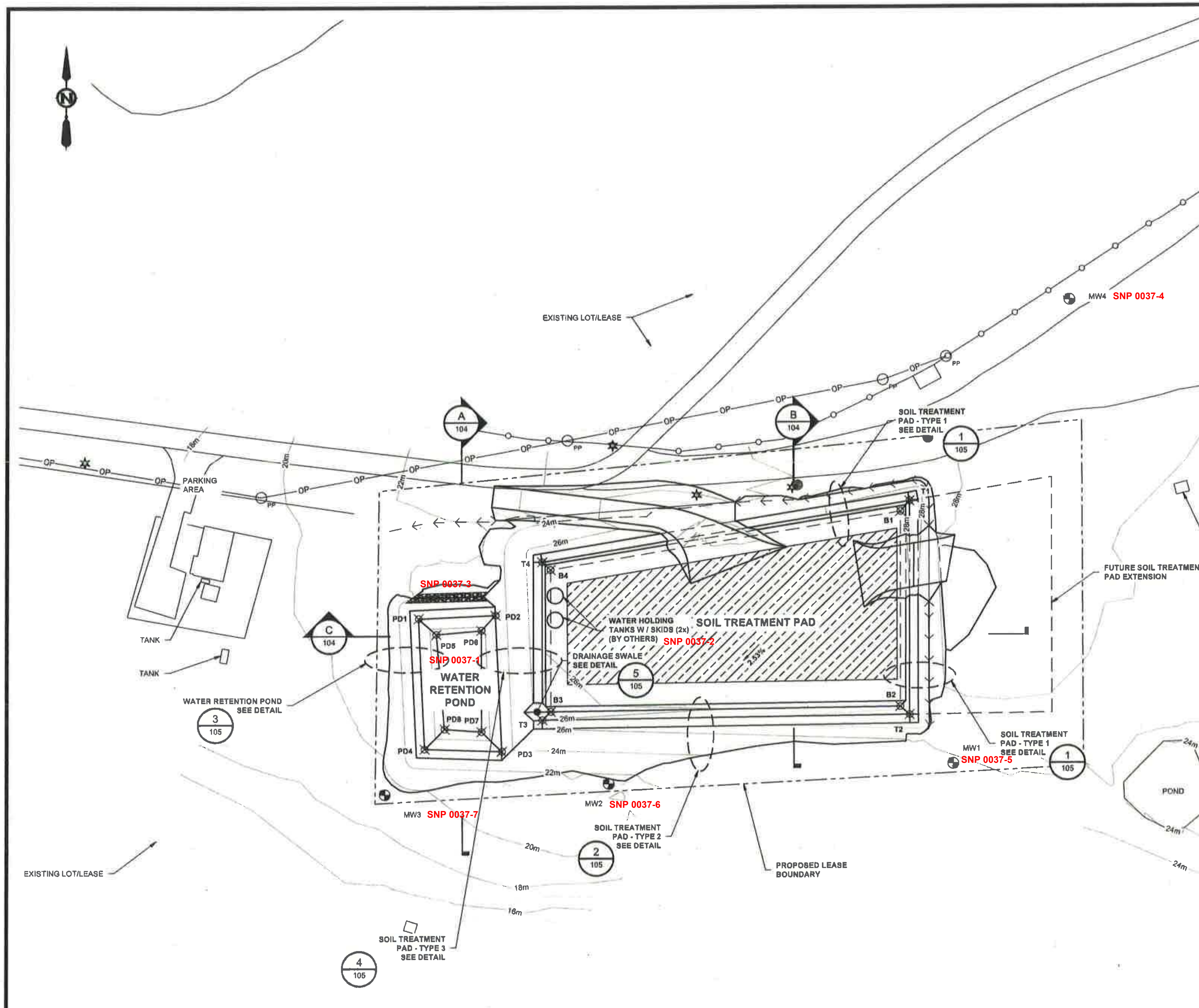
LandSolutions Environmental LP

T. Chidlaw

Timothy Chidlaw, P.Ag.

ATTACHMENT D

MAP



DESIGN COORDINATE AND ELEVATION TABLE

POINT	NORTHING	EASTING	ELEVATION
B1	7582202.140	554348.601	27.508
B2	7582158.810	554348.544	26.714
B3	7582156.608	554268.400	25.293
B4	7582188.791	554268.400	25.871
T1	7582204.592	554350.698	28.387
T2	7582154.919	554350.676	27.518
T3	7582153.867	554266.484	26.028
T4	7582190.575	554266.484	26.668

POND COORDINATE AND ELEVATION TABLE

POINT	NORTHING	EASTING	ELEVATION
PD1	7582177.458	554238.268	23.000
PD2	7582176.228	554265.853	23.000
PD3	7582146.599	554257.238	23.000
PD4	7582147.160	554239.584	23.000
PD5	7582173.758	554242.297	21.451
PD6	7582174.704	554252.624	21.648
PD7	7582151.158	554252.624	21.238
PD8	7582151.772	554244.141	21.098

LEGEND

- 28m — TOPOGRAPHIC MAJOR CONTOUR, CONTOUR INTERVAL = 2.0m
- TOPOGRAPHIC MINOR CONTOUR
- TREES
- EXISTING FENCE
- OP — EXISTING OVERHEAD POWER
- PP — EXISTING POWER POLE
- EXISTING LIGHT
- EXISTING TANK
- WASTE COVERAGE AREA
- DRAINAGE DIRECTION
- PROPOSED CULVERT
- PROPOSED LEASE BOUNDARY
- MW4 — EXISTING MONITORING WELL
- T1 — DESIGN COORDINATE POINT
- RIP RAP

NOTES:

1. DATUM: UTM NAD83 ZONE 8.
2. CONTOURS PROVIDED BY KBL.
3. BOLD LINES & TEXT REFERS TO NEW CONSTRUCTION.
4. MONITORING WELLS EXACT LOCATION TO BE DETERMINED ON SITE.
5. PRESERVE AND PROTECT EXISTING MONITORING WELLS.

No.	DATE	REVISION	BY	APP
0	2017SEP08	ISSUED FOR CONSTRUCTION	NAR	BJ

		INITIALS
PROJECT No.	20173924-00	
DRAWN BY	J HUBERT	
DESIGNED BY	S BARTSCH / B JARDINE	
SCALE	1:1000	

PERMIT TO PRACTICE
ASSOCIATED ENGINEERING (B.C.) LTD.
Signature
Date 11 Sept 2017
PERMIT NUMBER: P 554
The Association of Professional Engineers, Geologists and Geophysicists of NWT/NU

REGISTERED PROFESSIONAL ENGINEER
S.M. BARTSCH
LICENSEE
Sept 8/17
NT/NU

NLR/AE CONSULTANTS

CLIENT
KBL

PROJECT
INUVIK
SOIL TREATMENT FACILITY

TITLE
DEVELOPMENT PLAN

DRAWING NUMBER	REV. NO.
3924-00-103	0

ATTACHMENT E

SOIL BASELINE ANALYTICAL RESULTS

	Sample ID	BH2-01	BH2-02	BH2-03	BH2-04	BH3-01	BH3-02	BH3-03	BH3-04	BH3-05	BH4-01	BH4-02	BH4-03	BH4-04	BH7-01	BH7-02	BH7-03
	Sample Depth (mbgs)																
Analytical Parameter	*Criteria (mg/kg)																
AT1 BTEX AND F1 - F4 IN SOIL																	
Moisture	**-**	20	32	20	19	17	23	21	30	30	14	17	35	62	14	17	38
Benzene	**5**	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0095	<0.0050	0.012	0.010	0.15	0.51	<0.0050	<0.010	0.0075	0.024	0.035
Toluene	**0.8**	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	0.036	<0.020	0.032	0.63	<0.020	<0.040	<0.020	0.045	0.088
Ethylbenzene	**20**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.019	<0.010	0.17	0.18	<0.010	<0.020	0.035	0.024	0.035
Xylenes (Total)	**20**	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.47	<0.040	<0.080	<0.040	0.072	0.040
F1 (C6 – C10) - BTEX	**-**	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<20	<10	<10	<10
F1 (C6 – C10)	**230**	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	11	<10	<20	<10	<10	<10
F2 (C10 – C16)	**150**	14	<10	<10	<10	13	12	11	29	28	41	150	<10	<26	61	29	16
F3 (C16 – C34)	**-**	89	120	53	52	71	58	<50	140	140	330	580	79	360	1100	420	150
F4 (C34 – C50)	**-**	<50	<50	<50	<50	<50	<50	<50	<50	<50	93	70	<50	<130	230	230	51
CCME REGULATED METALS - SOIL																	
Antimony (Sb), Total	**40**	0.62	0.61	0.65	0.87	1.1	0.57	1.3	1.2	-	1.8	1.4	0.56	-	2.6	2.1	0.86
Arsenic (As), Total**	**12**	**38**	**26**	**24**	**32**	**39**	**18**	**59**	**36**	-	**43**	**32**	**18**	-	**96**	**67**	**31**
Barium (Ba), Total	**2,000**	220	230	220	170	250	210	130	170	-	180	240	240	-	230	180	240
Beryllium (Be), Total	**8**	0.73	0.94	0.60	0.60	0.70	0.52	0.50	0.63	-	0.64	0.85	0.54	-	0.84	0.77	0.71
Boron (B), Soluble (hot water)	**-**	3.9	8.9	1.3	1.1	0.27	0.83	0.57	1.4	-	1.7	4.0	2.0	-	1.8	0.97	0.95
Cadmium (Cd), Total	**22**	0.19	0.12	0.21	0.40	0.64	0.30	0.27	0.54	-	1.1	0.42	0.27	-	0.75	0.44	0.24
Chromium (Cr), Total	**87**	52	41	25	22	23	24	25	21	-	25	35	16	-	25	28	29
Chromium Hex. (Cr 6+)	**1.4**	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080	-	<0.080	<0.080	<0.080	-	<0.080	<0.080	<0.080
Cobalt (Co), Total	**300**	17	16	14	14	18	15	18	17	-	17	20	9.0	-	18	20	15
Copper (Cu), Total	**91**	43	33	34	34	35	43	31	38	-	**230**	45	18	-	32	37	31
Lead (Pb), Total	**600**	14	13	14	16	18	14	21	16	-	38	40	14	-	39	44	17
Mercury (Hg), Total	**50**	0.082	0.071	0.094	0.12	0.14	0.092	0.28	0.13	-	0.23	0.16	0.067	-	0.35	0.26	0.11
Molybdenum (Mo), Total	**40**	1.3	0.92	1.7	2.8	4.3	1.1	4.7	4.6	-	4.2	3.7	1.2	-	5.8	5.4	2.1
Nickel (Ni), Total	**50**	**53**	**51**	39	40	47	44	**52**	44	-	**240**	**77**	26	-	**51**	**53**	43
Selenium (Se), Total	**2.9**	1.5	1.3	1.3	1.7	1.8	1.1	1.9	2.3	-	2.1	2.4	1.1	-	3.6	3.1	1.4
Silver (Ag), Total	**40**	<0.20	<0.20	<0.20	0.22	0.25	<0.20	0.34	0.26	-	0.30	0.21	<0.20	-	0.26	0.26	<0.20
Thallium (Tl), Total	**1**	<0.10	0.12	0.14	0.19	0.26	0.12	0.54	0.23	-	0.27	0.24	<0.10	-	0.47	0.31	0.15
Tin (Sn), Total	**300**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-	12	<1.0	<1.0	-	<1.0	2.7	<1.0
Uranium (U), Total	**-**	1.2	1.8	1.0	1.2	1.6	0.85	1.2	1.6	-	1.4	1.8	1.6	-	1.5	1.4	1.1
Vanadium (V), Total	**130**	110	86	48	48	58	44	37	54	-	58	100	38	-	70	66	61
Zinc (Zn), Total	**360**	130	91	120	130	180	160	120	310	-	**22,000**	150	83	-	160	150	200
SEMIVOLATILE OGRANICS BY GC-MS (SOIL)																	
Acenaphthene	**-**	0.012	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.029	0.029	0.0082	0.035	<0.0050	<0.013	0.028	0.0054	0.018
Benzo[a]pyrene equivalency	**-**	0.028	0.012	0.016	0.018	0.026	0.022	0.014	0.026	0.026	0.02	0.019	<0.0071	<0.019	0.035	0.052	0.023
Acenaphtyhlene	**-**	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.013	<0.0050	<0.13	<0.0050	<0.0050	<0.0050
Acridne	**-**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.08	<0.010	<0.026	0.038	0.013	<0.010
Anthracene	**-**	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	0.013	<0.0040	<0.0040	0.0016	0.0082	<0.0040
Benzo(a)anthracene	**10**	<0.0050	<0.0050	<0.0050	0.0062	0.0082	0.0085	0.0055	0.0091	0.0095	0.0088	0.011	<0.0050	<0.013	0.025	0.044	0.0085
Benzo(b&j)fluoranthene	**10**	0.032	0.019	0.0	0.032	0.036	0.032	0.022	0.034	0.034	0.029	0.026	<0.0050	<0.013	0.042	0.047	0.033
Benzo(k)fluoranthene	**10**	<0.0050	<0.0050	<0.0050	<0.0050	0.0052	<0.0050	<0.0050	<0.0050	0.0063	<0.0050	<0.0050	<0.0050	<0.013	0.0081	0.011	<0.0050
Benzo(g,h,i)perylene	**-**	0.05	0.021	0.0	0.042	0.052	0.05	0.025	0.057	0.06	0.037	0.036	<0.0050	<0.013	0.046	0.041	0.04
Benzo(c)phenanthrene	**-**	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.013	<0.0050	<0.0050	<0.0050
Benzo(a)pyrene	**0.7**	0.017	0.0061	0.0	0.0094	0.013	0.013	0.0071	0.016	0.016	0.011	0.011	<0.0050	<0.013	0.02	0.032	0.015
Benzo(e)pyrene	**-**	0.036	0.016	0.035	0.035	0.041	0.037	0.025	0.039	0.039	0.026	0.025	<0.0050	<0.013	0.04	0.045	0.028
Chrysene	**-**	<0.0050	<0.0050	<0.0050	0.011	0.014	0.013	0.011	0.016	0.015	0.013	0.015	<0.0050	<0.013	0.03	0.046	0.011
Dibenz(a,h)anthracene	**10**	0.0054	<0.0050	<0.0050	<0.0050	0.0051	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.013	0.0054	0.0072	<0.0050
Fluoranthene	**-**	0.013	<0.0050	0.0	0.0078	0.0087	0.016	0.011	0.022	0.022	0.016	0.025	<0.0050	<0.013	0.056	0.034	0.02
Fluorene	**-**	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.019	0.017	0.0092	0.094	<0.0050	<0.013	0.032	0.008	0.0064
Indeno(1,2,3-cd)pyrene	**10**	0.014	0.0076	0.0	0.013	0.016	0.014	0.0071	0.017	0.016	0.011	0.012	<0.0050	<0.013	0.017	0.015	0.012
2-Methylnaphthalene	**-**	0.0051	<0.0050	0.011	0.014	0.022	0.043	0.035	0.058	0.051	0.043	0.56	<0.0050	<0.013	0.24	0.042	0.013
Naphthalene	**22**	<0.0050	<0.0050	0.0	0.009	0.019	0.03	0.03	0.041	0.035	0.028	0.15	<0.0050	<0.013	0.2	0.024	0.012
Phenanthrene	**50**	0.007	0.007	0.02	0.02	0.028	0.041	0.046	0.046	0.042	0.035	0.24	0.0052	0.015	0.1	0.041	0.024
Perylene	**-**	0.32	0.095	0.1	0.11	0.15	0.18	0.066	0.3	0.31	0.16	0.14	<0.0050	0.0	0.15	0.089	0.24
Pyrene	**100**	0.023	0.0086	0.011	0.012	0.016	0.027	0.015	0.035	0.037	0.025	0.04	<0.0050	<0.013	0.068	0.06	0.031
Quinoline	**-**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.026	<0.010	<0.010	<0.010

*Government of the Northwest Territories, *Environmental Guildeline for Contaminated Site Remediation,* November 2003, assumes coarse-grain soil

ATTACHMENT F

ACTION LEVELS

GROUNDWATER ACTION LEVELS – ORGANICS AND GENERAL CHEMISTRY

		Groundwater Guidelines	Action Level				
Constituent	Units	FIGQG[1]	Min. Baseline Concentration	Max. Baseline Concentration	Max. Baseline Concentration + 25%	Action Level	Action Level Basis
Volatiles							
Benzene	ug/L	88	<0.5	12.8	16.0	88	FCSAP
Toluene	ug/L	83	<0.5	11.1	13.9	83	FCSAP
Ethylbenzene	ug/L	3,200	<0.5	11.3	14.1	3,200	FCSAP
Xylene (Total)	ug/L	3,900	<0.71	140.0	175.0	3,900	FCSAP
Hydrocarbon							
F1 - BTEX (C6-C10)	ug/L	810	<100	220	275	810	FCSAP
F2 (C10-C16 Hydrocarbons)	ug/L	1300	<100	820	1,025	1,300	FCSAP
F3 (C16-C34 Hydrocarbons)	ug/L	-	<250	430	538	538	Baseline +25%
F4 (C34-C50 Hydrocarbons)	ug/L	-	<250	620	775	775	Baseline +25%
Extractable Petroleum Hydrocarbons (10-19)	ug/L	-	<250	4,250	5,313	5,313	Baseline +25%
Extractable Petroleum Hydrocarbons (19-32)	ug/L	-	<250	1,310	1,638	1,638	Baseline +25%
Oil and Grease	ug/L	-	<1000	10,600	13,250	13,250	Baseline +25%
Free Product 0 LNAPL							
LNAPL Thickness	mm	-	None	None	None	None	
General Chemistry							
Total Suspended Solids	ug/L	3,000	33	1,610	2,013	3,000	FCSAP
Chemical Oxygen Demand	ug/L	-	0.10	438,000	547,500	547,500	Baseline +25%
pH	pH	6.5 - 9	5.42	8.25	4.0 – 10.3	4.0 – 10.3	Baseline +25%

Notes
[1] FCSAP – Federal Interim Groundwater Quality Guidelines (FIGQG) for Federal Contaminated Sites, June 2016
Table 3 FIGQG For Commercial and Industrial Land Uses – Tier 1 Lowest Guideline

GROUNDWATER ACTION LEVELS – TOTAL METALS

		Groundwater Guidelines	Action Level				
Constituent (ICP-MS Metals)	Units	FIGQG[1]	Min. Baseline Concentration	Max. Baseline Concentration	Max. Baseline Concentration + 25%	Action Level	Action Level Basis
Aluminum (Al)	ug/L	5 (10)[2]	18	6,930	8,663	8,663	Baseline +25%
Antimony	ug/L	2000	0.30	1.37	1.71	2,000	FIGQG
Arsenic (As)	ug/L	5	0.70	29	36	36	Baseline +25%
Barium	ug/L	500	14	750	938	938	Baseline +25%
Beryllium (Be)	ug/L	5.3	0.15	0.55	0.69	5.30	FIGQG
Boron (B)	ug/L	500	395	4,240	5,300	5,300	Baseline +25%
Cadmium (Cd)	ug/L	0.017	0.03	0.44	0.55	0.55	Baseline +25%
Chromium (Cr)	ug/L	8.9	1	16	20	20	Baseline +25%
Cobalt (Co)	ug/L	50	33	15	19	50	FIGQG
Copper (Cu)	ug/L	2 (4)[2]	1	23	28	28	Baseline +25%
Iron (Fe)	ug/L	300	33	108,000	135,000	135,000	Baseline +25%
Lead (Pb)	ug/L	1 (7)[2]	3	29	36	36	Baseline +25%
Lithium (Li)	ug/L	-	29	228	285	285	Baseline +25%
Magnesium (Mg)	ug/L	-	233,000	819,000	1,023,750	1,023,750	Baseline +25%
Manganese (Mn)	ug/L	200	664	5,810	7,263	7,263	Baseline +25%
Mercury (Hg)	ug/L	0.026	0.01	0.31	0.38	0.38	Baseline +25%
Molybdenum (Mo)	ug/L	73	0.15	5	6	73	FIGQG
Nickel (Ni)	ug/L	25 (150)[2]	11	38	47	47	Baseline +25%
Phosphorous (P)	ug/L	-	270	1,400	1,750	1,750	Baseline +25%
Potassium	ug/L	-	8,010	40,500	2,013	2,013	Baseline +25%
Selenium (Se)	ug/L	1	0.28	6.30	7.88	8	Baseline +25%
Silicon (Si)	ug/L	-	4,600	16,500	2,013	2,013	Baseline +25%
Silver (Ag)	ug/L	0.25	0.03	0.31	0.39	0.39	Baseline +25%
Sodium (Na)	ug/L	-	105	542,000	677,500	677,500	Baseline +25%
Strontium (Sr)	ug/L	-	1,590	2,760	3,450	3,450	Baseline +25%
Sulphur (S)	ug/L	-	5,200	1,470,000	1,837,500	1,837,500	Baseline +25%
Thallium (Tl)	ug/L	0.8	0.01	1.06	1.33	1.33	Baseline +25%
Tin (Sn)	ug/L	-	0.31	3.83	4.79	4.79	Baseline +25%
Titanium (Ti)	ug/L	100	6	61	76	100	FIGQG
Uranium (U)	ug/L	10	0.08	7.36	9.20	10.00	FIGQG
Vanadium (V)	ug/L	100	6	34	42	100	FIGQG
Zinc (Zn)	ug/L	10	8	184	230	230	Baseline +25%

Notes

[1] FCSAP – Federal Interim Groundwater Quality Guidelines (FIGQG) for Federal Contaminated Sites, June 2016
Table 3 FIGQG For Commercial and Industrial Land Uses – Tier 1 Lowest Guideline

[2] Guideline depends on water quality parameter (e.g. hardness), first value shown is lowest acceptable concentration, value in brackets is highest acceptable concentration

[3] Hardness dependent guideline; if hardness of receiving surface water is available can be calculated as $10^{\{0.83(\log[\text{hardness}])-2.46\}}$