Defence Construction Canada on behalf of the Department of National Defence

Water Use Licence Amendment
FOX-4, Cape Hooper Landfill Monitoring

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1.0 Post Construction Monitoring Program

1.1 Introduction

The former FOX-4 DEW Line Site is located at Cape Hooper, Nunavut, on the east coast of Baffin Island, at 68º 26' N, 66º 44' W, approximately midway between the communities of Clyde River and Qikiqtarjuaq. The former station was located at the Upper Site, situated on a peninsula, 2.5 km long and 1 km wide, which slopes steeply up from sea level on the southwest side to an elevation of 386 m on the northeast side. An active NSWO station sits where the former station used to be. The airstrip and Lower Site facilities were located along the base of the valley at the southwestern edge of the peninsula.

1.2 Background

FOX-4 was the first DEW Line site within Nunavut to be cleaned up as part of the DLCU Project. The remediation of FOX-4 was conducted as a demonstration project while the negotiations between DND and Nunavut Tunngavik Incorporated (NTI) regarding the economic and environmental agreements for the DLCU Project were underway. FOX-4 was remediated between 1996 and 1998 according to a site-specific agreement, with minor work elements and demobilization occurring in 1999. The DLCU Protocol was modified as part of the DND/NTI Cooperation Agreement to include confirmatory testing and delineation protocols for contaminated soil remediation, address hydrocarbon contamination and provide an expanded evaluation process for landfills.

The long-term monitoring program at FOX-4 began in 1999. After reviewing results from the FOX-4 Phase 1 monitoring program, the Environmental Working Group (EWG) recommended that the frequency of the Phase 2 monitoring events be increased during the initial years, with monitoring completed yearly between 2008 and 2010. In 2010, a maintenance assessment (MA) program was initiated to assess the status of all landfills and other areas of potential concern at FOX-4. The results of the landfill assessments resulted in additional remediation of the FOX-4 landfills between 2011 and 2013. The original monitoring program consisted of the Tier II Disposal Facility and Lower Site Landfill, Tanner Bay Landfill, Station Landfill, Helipad Landfill – East and West Lobes, Barrel Dump Landfill, and Airstrip Landfill. As a result of the maintenance and remediation work carried out between 2011 and 2013, the Helipad Landfill – East and the Airstrip Landfill were excavated and therefore no longer require long term monitoring.

There are six landfill areas at the FOX-4 site that are included in the landfill monitoring program:

- Tier II Soil Disposal Facility
- Non-Hazardous Waste Landfill
- Pallet Line Landfill
- Tanner Bay Landfill
- Station Landfill
- Helipad Landfill West

1.3 Objective

The objective of the landfill monitoring program is to collect sufficient information to assess the performance of the landfills from a geotechnical and environmental perspective. The landfill monitoring plan specifies the requirements for visual inspection, and chemical and thermal monitoring of landfills at the DEW Line sites under DND's jurisdiction.

2.0 Program Components

The post-construction landfill monitoring program consists of four main components to measure the performance of the landfills, depending on the remediation plan for each landfill. These components are visual, soil, groundwater and thermal monitoring. Details on each of the monitoring components are provided below.

2.1 Visual Monitoring

The physical integrity of the landfill is inspected and reported using hand-drawn sketches. The documented observations include:

- settlement
- erosion
- frost action
- animal burrows
- vegetation reestablishment on surface
- staining
- vegetation stress
- seepage points or ponded water
- debris exposure

2.2 Soil and Groundwater Monitoring

The soil and groundwater program consists of baseline/background assessment and contaminant evaluation. Background conditions represent soil and water quality from an area not impacted by the landfill. Background (naturally occurring) values are obtained from samples collected from areas that were not directly influenced by activities at the DEW Line site, but are indicative of the prevailing geochemistry. These samples are taken hydraulically up-gradient and at some distance from the landfill.

Soil and groundwater samples (where required) are collected prior to construction/closure of a landfill, to represent background as well as baseline conditions. The results of subsequent landfill monitoring events are compared to these baseline and background values to evaluate any potential changes in environmental conditions.

In general, at least one monitoring well is installed up-gradient and two to three wells are installed down-gradient of the landfill during the construction phase. Using water elevation

data from a minimum of three wells allows assessment of the hydraulic gradient and flow velocities. Review of analytical data from water samples collected from wells up and down-gradient allows evaluation of potential impacts associated with the landfill. Soil samples are collected from the toe of the landfill, generally from the same locations as the monitoring wells. Contamination in soil samples at the toe of the landfill reflects chronic input from water that may have infiltrated the landfill, and is an important factor of contaminated leachate.

2.2.1 Soil Sampling

The soil monitoring program has the following requirements:

- Soil samples are to be collected from 0 to 15 cm depth and at 40 to 50 cm depth, at the locations as indicated on the Drawings. If the specified sampling depth cannot be achieved, a sample shall be collected at or near the zone of refusal.
- When collecting soil samples at monitoring well locations, the soil samples are to be collected within a 2-4 metre radius of the monitoring well. Samples are not to be collected immediately adjacent to the well.
- Soil samples are to be collected with contaminant free utensils and stored in contaminant free containers that are appropriate for subsequent analytical use. Sampling utensils are to be thoroughly cleaned between each sampling episode and rinsed with distilled water. Alternatively, single use sampling utensils may be used.
- Soil samples are to be analyzed for the following constituents:
  - PCBs (polychlorinated biphenyls – Total Aroclor analysis);
  - Total Petroleum Hydrocarbons (TPH), as represented as the total of F1 (nC6 to C10), F2 (nC10 to nC16) and F3 (nC16 to C34) as defined by CCME Tier I Method – Rev. 5 Analysis of Petroleum Hydrocarbons in Soil; and
  - Inorganic elements: arsenic, cadmium, chromium, cobalt, copper, lead, nickel, zinc, and mercury.

2.2.2 Groundwater Sampling

The groundwater monitoring program has the following requirements:

- Monitoring wells are to be purged prior to sampling, maintaining a purge rate at 100 mL/min or less.
- Conductivity, pH, and temperature are to be monitored during purging. Groundwater samples are to be collected when values for these parameters have stabilized and at least one well volume has been purged.
- Final conductivity, pH, temperature and turbidity are to be recorded prior to collection of the groundwater sample.
- Sample bottles are to be filled during a single collection event.
- Groundwater samples are to be collected at the well locations as indicated on the Figures.
- The following groundwater analyses are required. It should be noted that where well volumes do not meet minimum requirements for sample volumes, the sampling is prioritized in the following order:

- Inorganic elements – total concentrations: arsenic, cadmium, chromium, cobalt, copper, lead, nickel, zinc and mercury. Samples are not to be filtered.
- PCBs (polychlorinated Biphenyls – Total Aroclor analysis).
- Total Petroleum Hydrocarbons (TPH) Carbon Range C6 to C34.

2.3 Thermal Monitoring

Geothermal analysis are carried out as part of the design to predict the length of time required for permafrost aggradation through landfills requiring leachate containment, including the Tier II Soil Disposal Facility. These analyses also provided information on the long and short term thermal regime in the ground, and the depth of the active layer in the cover material.

A thermal monitoring system provides measurement of subsurface ground temperatures, which allows comparison to and verification of the predicted ground temperatures. The thermal monitoring system consists of installation of thermistor strings, with thermistor beads at selected intervals to provide ground temperature profiles at various locations within the landfill. The thermistor strings are attached to automated dataloggers that allow for remote data collection. In general, a minimum of three thermistors are installed at each landfill where permafrost aggradation through the landfill contents is an integral part of the design.

The following are the requirements of the thermal monitoring program:

- The data is to be retrieved from the ground temperature data using a personal computer equipped with the appropriate software and the programming file from the specific datalogger. The programming file will be supplied by DND.
- The data is to be translated and view in the field to ensure completeness.
- Manual readings of the thermistor using a digital readout that is compatible with the thermistors or a multimeter and a switch box are to be collected.
- For the first monitoring event completed by the Consultant, the distance of the thermistor cable above ground is to be measured.
- A sketch to indicate the location of each cable is to be prepared.
- The datalogger memory will be reset memory to zero and restart readings. The system will be monitored using the personal computer to verify that thermistors are being measured.

2.4 Frequency

The landfill monitoring program consists of three phases, as described in detail below.

2.4.1 Phase I

Phase I involves monitoring of conditions to confirm that equilibrium is achieved. The frequency of monitoring events during Phase I monitoring is dependent on the closure or remediation design at specific landfills. The five year term was selected on the basis that ground temperature thermal regimes at specific landfills will require three to five years to reach equilibrium. Typically, the remaining landfills are not required to be monitored every year in the first five years; however, because the Tier II Disposal Facility requires yearly monitoring, it is only prudent to complete the monitoring of the other landfills while on site.

An evaluation of all Phase I data is carried out at the end of five years to confirm that thermal and chemical equilibrium is achieved, and that no stability issues are identified. The Phase I monitoring program may be extended, if required, to provide sufficient data to establish equilibrium conditions.

The first year of the Phase I post construction monitoring is completed by the Environmental Sciences Group (ESG) of the Royal Military College of Canada, who are part of the DEW Line Clean-Up Project Team. Subsequent landfill monitoring events are carried out by independent contractors, who successfully win the competitive tender.

2.4.2 Phase II

Phase II monitoring is the verification of equilibrium conditions established in Phase I. The monitoring frequency in Phase II is downgraded from Phase I and will be carried out according to the following schedule: year 7, 10, 15 and 25. Year 25 marks the end of Phase II monitoring.

2.4.3 Phase III

Phase III involves the monitoring for longterm issues such as liner integrity, permafrost stability and significant storm events. At the end of the Phase II program, 25 years after construction, a re-evaluation of the landfill monitoring program will be carried out prior to initiating any Phase III program. The scope of the Phase III monitoring program is not included here, but is anticipated to be based on a 10 year monitoring interval.

2.5 Review and Evaluation Process

An Environmental Working Group (EWG) was established to provide a technical report and to support the DLCU Steering Committee. This working group is comprised of qualified engineering and environmental scientists with expertise in environmental remediation and clean-up in northern climates. The EWG has four designated representatives, two from each of the Owner (DND) and the Inuit (through the NTI), respectively.

During the monitoring program, the EWG reviews the results of the monitoring program in accordance with the methodology as described previously. The results of the review and any recommendations regarding changes to the monitoring plan and/or remediation requirements are reported to the DND/NTI Steering Committee.

The requirement for further monitoring after 25 years is evaluated. Monitoring may be terminated if the performance of the landfill was satisfactory over the period of monitoring from an environmental, geotechnical and thermal perspective, as appropriate. The assessment of satisfactory performance is carried out jointly by the NTI and DND.

3.0 Detailed Landfill Monitoring Requirements

The following sections provide a summary and the detailed monitoring requirements for each landfill at FOX-4.

3.1 Tier II Disposal Facility

The Tier II Disposal Facility was constructed for the disposal of Tier II soil excavated from the FOX-4 site. Long term monitoring of the Tier II soil disposal facility will consist of visual monitoring for evidence of settlement, erosion, differential movement, collection of soil and groundwater samples from around the facility to monitor the effectiveness of the containment system, and monitoring of sub-surface ground temperatures in the berms and in the main body of the disposal facility. The long term monitoring plan for the Tier II Disposal Facility consists of visual monitoring, and the periodic collection of soil and groundwater samples. Approximate locations for the collection of monitoring samples are identified in Table 1.

3.2 Non-Hazardous Waste Landfill

The Non-Hazardous Waste Landfill (NHWL) and Tier II Disposal Facility are located near the west end and north of the airstrip, in relatively close proximity to one another. The NHWL was constructed for the disposal of non-hazardous demolition and site wastes, and Tier I soil. The long term monitoring requirements for the NHWL include visual inspection of evidence of settlement, or erosion, and groundwater and soil sampling and analyses. Approximate locations for the collection of monitoring samples are identified in Table 1.

Table 1: Approximate location for the collection of monitoring samples for the Non-Hazardous Waste Landfill and the Tier II Disposal Facility

	Coordinates[1]		Elevation
Landfill Designation/Monitoring Locations	**North (m)**	**East (m)**	**(masl)**
Non-Hazardous Waste Landfill and Tier II Disposal Facility			
MW11-01 (soil and groundwater)	7596130.8	588468.4	21.0
MW11-02 (soil and groundwater)	7596046.4	588459.4	19.5
MW11-03 (soil and groundwater)	7596025.9	588524.3	20.3
MW11-04 (soil and groundwater)	7595961.2	588536.5	19.2
MW11-05 (soil and groundwater)	7595911.0	588352.6	18.6
MW11-06 (soil and groundwater)	7595926.0	588352.6	18.0
MW12-07 (soil and groundwater)	7595977.9	588334.9	16.4
MW12-08 (soil and groundwater)	7596055.8	588361.3	18.7
VT-1 (temperature)	7596005.7	588474.2	23.1
VT-2 (temperature)	7595989.1	588481.2	22.6

VT-3 (temperature)	7596033.0	588457.8	22.7
VT-4 (temperature)	7596002.9	588436.3	22.5
VT-5 (temperature)	7596019.9	588428.6	22.3
VT-6 (temperature)	7596007.5	588406.4	21.9
VT-7 (temperature)	7595949.9	588398.2	22.4
VT-8 (temperature)	7595975.5	588405.7	23.2
VT-9 (temperature)	7595947.7	588454.0	23.5
VT-10 (temperature)	7595956.9	588479.7	23.9

3.3 Pallet Line Landfill

The Pallet Line Landfill is located at the Lower site, at the location of the former Pallet Line. The area of the landfill is 1,342 m2. Landfill remediation consisted of excavation of two areas of Tier II contaminated soil and one area of Tier II contaminated soil, and covered with 0.4 m of Type 1 granular fill over 0.4 m of Type 2 granular fill. The long term monitoring plan consists of visual monitoring, and the periodic collection of soil samples. Approximate locations for the collection of monitoring samples are identified in Table 2.

Table 2: Approximate location for the collection of monitoring samples for the Pallet Line Landfill

	Coordinates[1]		Elevation
Landfill Designation/Monitoring Locations	**North (m)**	**East (m)**	**(masl)**
Pallet Line Landfill			
F4-25 (soil)	7596110.9	588613.0	
F4-26 (soil)	7596053.7	588664.6	
F4-27 (soil)	7596000.6	588615.9	
F4-28 (soil)	7596020.1	588584.1	
F4-29 (soil)	7596050.8	588530.2	

3.4 Tanner Bay Landfill

The Tanner Bay landfill is located at the original beach landing area for the site, along Tanner Bay. Access to the area is gained from an abandoned road to the former water supply lake. The long term monitoring plan for this landfill includes visual inspection to monitor for evidence of settlement and/or erosion, and periodic collection of soil samples to monitor for the presence of leachate. Approximate locations for the collection of monitoring samples are identified in Table 3.

Table 3: Approximate location for the collection of monitoring samples for the Tanner Bay Landfill

	Coordinates[1]		Elevation
Landfill Designation/Monitoring Locations	**North (m)**	**East (m)**	**(masl)**
Tanner Bay Landfill			
F4-11 (soil)	7592944.5	589652.9	
F4-12 (soil)	7592915.4	589568.1	
F4-13 (soil)	7592970.2	589593.5	

3.5 Station Landfill

The Station Area Landfill is a new landfill constructed for the disposal of demolition and site wastes generated during the clean-up. It is located at the Upper site, east of the SRR facilities. The long term monitoring plan consists of visual monitoring and collection of soil and groundwater samples. Approximate locations for the collection of monitoring samples are identified in Table 4.

Table 4: Approximate location for the collection of monitoring samples for the Station Landfill

	Coordinates[1]		Elevation
Landfill Designation/Monitoring Locations	**North (m)**	**East (m)**	**(masl)**
Station Area Landfill			
MW98-07 (soil and groundwater)	7597050.2	590466.8	379.4
MW98-08 (soil and groundwater)	7597092.0	590380.4	373.2
MW98-09 (soil and groundwater)	7597080.0	590340.5	372.4
MW-8 (soil and groundwater)	9877.3	15490.4	303.5

3.6 Helipad Landfill West

The Helipad Landfill – West is located at the Upper site to the west of the SRR facilities. The long term monitoring plan consists of visual monitoring and the collection of soil and groundwater samples. Approximate locations for the collection of monitoring samples are identified in Table 5.

Table 5: Approximate location for the collection of monitoring samples for the Helipad Landfill West

	Coordinates[1]		Elevation
Landfill Designation/Monitoring Locations	**North (m)**	**East (m)**	**(masl)**
Helipad Landfill-West			-
MW98-01 (soil and groundwater)	7597182.2	590039.4	372.6
MW98-02 (soil and groundwater)	7597244.0	590014.5	369.5

MW98-03 (soil and groundwater)			
MW98-06 (soil and groundwater)	7597260.5	590044.7	382.1

Table 6: Monitoring Frequency and Parameters as it pertains to Sample Type

Sample Type	Frequency	Parameters
Visual	Once per year in years 5, 7, 10, 15, 25 postconstruction	N/A
Groundwater	Once per year in years 5, 7, 10, 15, 25 postconstruction	Total Arsenic
		Total Cadmium
		Total Chromium
		Total Cobalt
		Total Copper
		Total Lead
		Total Nickel
		Total Zinc
		Total Mercury
		PCB's
		Total Petroleum Hydrocarbons(TPH)(C_6-C_{32})
Soil	Once per year in years 5, 7, 10, 15, 25 postconstruction	PCB's
		TPH as F1(C_6-C_{10})
		TPH as F2(C_{10}-C_{16})
		TPH as F3(C_{16}-C_{34})
		Arsenic
		Cadmium
		Chromium
		Cobalt
		Copper
		Lead
		Nickel
		Zinc
		Mercury

Table 7: Monitoring Schedule – FOX-4 Cape Hooper

Monitoring Schedule – FOX-4 Cape Hooper		
No. of Years After Construction	**Monitoring Event Number**	**Year**
Prior to/During:	Baseline	1996-1999
1	1	1999
2	2	2000
3	3	2001
4	4	2002
5	5	2003
7	6	2005
8	7	2006
9	8	2007
10	9	2008
12	10	2010
16	11	2014
18	12	2016
20	13	2018
25	14	2023

Table 8 : FOX-4 Landfill Monitoring Requirements

Landfill Designation	Visual Inspection	Groundwater Sampling	Soil Sampling	Thermal Monitoring
Tier II Soil Disposal Facility	✓	✓	✓	✓
Non-Hazardous Waste Landfill	✓	✓	✓	
Pallet Line Landfill	✓		✓	
Tanner Bay Landfill	✓		✓	
Station Landfill	✓		✓	
Helipad Landfill West	✓		✓	