Imperial Oil

Renewal Application for Water Licence S03L1-001
Socio-Economic and Environmental Setting
(Section 4 of 20)

Submitted to the Sahtu Land and Water Board by Imperial Oil Resources N.W.T. Limited

August 2013

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4.0 Socio-Economic and Environmental Setting

4.1 Introduction

This section provides an overview of the communities and the biophysical environment in the region. Imperial Oil Resources N.W.T. Limited (IOR) visited each of the communities in the Sahtu Settlement Area as part of its Renewal Application.

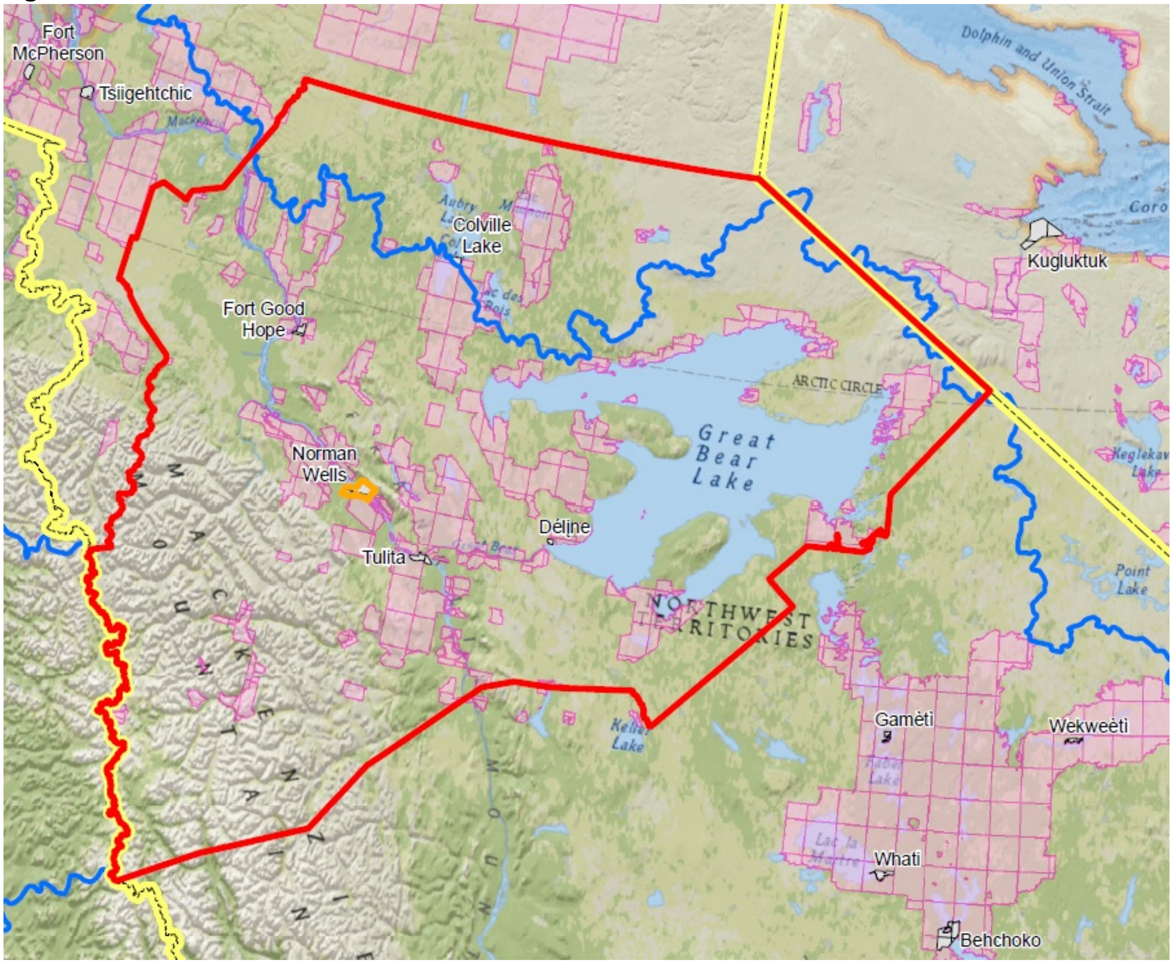
Open houses were held at each of the communities in the Sahtu Settlement Area from May 6th to the 10th 2013. Details regarding the open houses are presented in the Engagement Record Section of the Renewal Application (Section 10).

Traditional knowledge (TK) workshops were held in Fort Good Hope and Norman Wells on April 24th and 26th, 2013. Information that was gathered as part of the TK study, including maps with updated TK information, is available in the Traditional Knowledge Section of the Renewal Application (Section 19).

4.2 Overview

IOR's Norman Wells Operations (NWO) are located at Latitude +65^{o}17' and Longitude -126^{o}51'. NWO is within the boundaries of the Town of Norman Wells which is located within the Tulita district of the Sahtu Settlement Area. The Tulita district is one of three districts in Sahtu Settlement Area. The remaining two districts are the Deline and K'asho Gotine. Figure A presents the location of Norman Wells within the Sahtu Settlement Area.

Figure A: Sahtu Settlement Area



Section 9 (Maps and Figures) presents additional maps showing the location of Norman Wells and IOR's NWO.

4.3 Sahtu Settlement Area

An estimated 2,680 people or 6% of the total population of the Northwest Territories (NWT) live in the Sahtu Settlement Area (GNWT 2013). The Sahtu Settlement Area covers approximately 283,000 km^2 or one quarter of Canada's NWT.

4.4 Local Communities

There are five communities in the Sahtu Settlement Area (SLUPB 2009). These are:

- Colville Lake;
- Déline;
- Fort Good Hope;

A brief description of each community is provided below. Further information is available from the Government of the Northwest Territories Bureau of Statistics (GNWT 2013) and the Sahtu Land Use Planning Board (SLUPB 2009).

4.4.1 Colville Lake

Colville Lake is located at 67°02’N, 126°07’W. The population of Colville Lake in 2011 was 149. Settlement of the community occurred cira 1962, when the Roman Catholic Mission was established. Colville Lake is considered to be a very traditional community whose economy is primarily based on hunting, fishing and trapping (GNWT 2013).

4.4.2 Déline

The community of Déline is situated on Great Bear Lake at +65°10'N and -123°25'W. In 2011, the population of Déline was 472. Deline became a Charter Community on April 1, 1993, and officially changed its name from Fort Franklin on June 1, 1993 (GNWT 2013).

4.4.3 Fort Good Hope

Fort Good Hope is located along the east bank of the Mackenzie River at 66°15’N and 128°37’W. The population of Fort Good Hope in 2011 was 515. Established in 1805, Fort Good Hope is the oldest settlement in the lower Mackenzie Valley. (GNWT 2013). The Church of Our Lady of Good Hope was built between 1865 and 1885 and designated a National Historic Site of Canada on June 6, 1977 (Parks Canada 2013).

4.4.4 Norman Wells

Noman Wells is located on the east bank of Mackenzie River at +65°17'N and -126°50'W. The population of Norman Wells in 2011 was 727. Petroleum was first recorded in the area when Alexander Mackenzie found traces of oil on the River during expeditions in 1789 and 1793 (Hume and Link 1945). Establishment and growth of the Town closely followed the exploration and development of hydrocarbons in the area (GNWT 2013).

4.4.5 Tulita

Tulita is a located at the confluence of the Great Bear and Mackenzie Rivers, at 64°54'N and 125°35'W. In 2011, the population of Tulita was 478.The community was established circa 1805 by the Northwest Company. The Anglican Church was built in 1860 (GNWT 2013).

4.5 Heritage

IOR has been active in the Norman Wells area since the 1920s. Details of the changes to NWO since this time are presented in Section 6 (Norman Wells Operations) of the Renewal Application. The geographical footprint of NWO is stable. There are no plans at the current time for expansion.

A search request was submitted to the Prince of Wales Northern Heritage Centre (Prince of Wales 2013) to check for heritage sites located within a 500 m buffer of the Norman Wells town boundaries. The Prince of Wales advised of one site at an undisclosed location.

Three gravesite areas were identified during the Traditional Knowledge workshops as follows: Town of Norman Wells Cemetery on the upper bank of the Mackenzie River south of E-25X, and two single grave sites (one along the west side of Bosworth Creek and east of the historic Tanks 53 and 401, and the second located south of D-36X on the bank of the Mackenzie River). The location of these gravesites was marked on the Traditional Knowledge map to help ensure future avoidance of these areas.

4.6 IOR’s Community Involvement

IOR is an active member of communities in which it operates and is committed to engaging communities in an honest, transparent, accurate, and timely manner. IOR’s NWO is committed to a number of community building initiatives. These initiatives include efforts focused on: community relations, workforce development, business development, and other local investments through scholarships and charitable giving. Details of these initiatives are presented below.

4.6.1 Training Programs

IOR has a Northern Development Program (NDP) to increase the number of Sahtu Aboriginal employees at the NWO. This program was implemented by IOR in 1990. Since the program’s creation, a total of 33 candidates have participated in the program. Highlights of the 2012 NDP include:

- 11 NDP graduates employed at IOR’s NWO;
- 1 graduate of the program employed as a contractor for IOR;
- 1 NDP trainee completed their term and was offered fulltime employment; and
- 1 NDP trainee was hired.

4.6.2 Employment

IOR is a major employer in the Sahtu Settlement Area. In 2012, just over 300 people worked on IOR’s NWO either directly or through one of IOR’s contractors or subcontractors. Of the total number of people who worked on the NWO:

- 14% were Sahtu beneficiaries;
- 5% were Northern Aboriginal;
- 29% were Northern; and
- 53% were Southern.

4.6.3 Local Contractors

As noted in Section 4.6.2, IOR is a major employer in the Sahtu Settlement Area. As part of its commitment to local communities, IOR works with local businesses to encourage local economic activity. IOR contracts with local companies were worth 32.8 million dollars in 2012. This included:

- Aboriginal Owned Companies $2.9M
- Aboriginal 3rd Party $7.2M
- Northern Companies $17.5M
- Southern Companies $5.2M
- **Total business spend $32.8M**

Services provided by Sahtu Aboriginal companies covered a diverse array of services including:

- Aviation,
- Marine,
- Transportation,
- Heavy Equipment / Construction,
- Communication,

- Well Services,
- Emergency Services, and
- Building Services.

4.6.4 Norman Wells Aboriginal Council

In 1990, the Norman Wells Native Network was created. The group was re-formed in 2011 as the Norman Wells Aboriginal Council. The mandate of the Norman Wells Aboriginal Council is to improve and advance Aboriginal involvement, employment and training. Twenty employees from IOR's NWO are currently participating in the Council with 11 of those being graduates of IOR's NDP program.

Recently the Council identified the following two opportunities to further enhance Aboriginal involvement and employment:

- Workplace Development and Promotion; and
- Community Relations.

4.6.5 IOR Educational Investments

As part of its commitment to education in the Sahtu Settlement Area, IOR continues to sponsor academic awards in each of the five Sahtu schools. Awards presented by IOR include:

- Grade 9 to 12 achievement awards for best overall academic achievement; and
- Grade 10 to 12 math and science award.

In addition to these ongoing awards, IOR also provided scholarships to six Sahtu aboriginal students in 2012. A summary of IOR's educational investments in 2012 include:

Program	Investment
• Education and Development o Achievement Awards Grade 9 to 12 o Math and Science Achievement Award o Sahtu Aboriginal Scholarship	$237,550

- Summer Student Program (6 students)
  - Northern Development Program (1 trainee)
  - Sahtu Graduation Events

- Donations $64,200
  - IOR Sahtu Cup - Minor Hockey Tournament
  - Aboriginal Day Venue
  - Community Initiatives
  - Imperial Oil Foundation Sponsorships

Total $301,750

4.7 Ecosystem Classification

The NWT has an ecological landscape classification system based on the 1996 National Ecological Framework for Canada (ENR 2013). The system recognizes four regions within the NWT. These are the:

- Taiga Plains;
- Taiga Shield;
- Tiaga/Boreal Cordillera; and
- Southern Arctic.

Within these four regions there are nine level II ecoregions, eighteen level III ecoregions and approximately 150 level IV ecoregions (ENR 2013). This hierarchical classification allows increasingly small ecoregions (e.g. level IV) to be described.

4.8 Sahtu Settlement Area Ecoregions

All four of the principle ecoregions within the NWT are present within the Sahtu Settlement Area. However, the predominant ecoregions within the Sahtu region are the Tiaga Plains and the Taiga Cordillera. The Tiaga Plains ecoregion runs north south and is principally located east of the Mackenzie River. The Taiga Cordillera ecoregion extends west of the Mackenzie River to the Yukon border.

4.8.1 Taiga Plains

The Taiga Plains is located mainly within the NWT and northern Alberta. Small extensions of the Plains are also present in northern British Columbia and western portions of the Yukon. The topography of the Taiga Plains is characterized by subdued relief with a few significant hill systems. In the NWT, the Taiga Plains cover 480,493 km^2. Much of the Taiga Plains drains to the Arctic Ocean via the Mackenzie River, and its main tributaries, the Liard, Root, Peel, Keele, Carcajou, Mountain, Great Bear, and Arctic Red Rivers. Two of Canada's largest freshwater bodies, Great Slave Lake and Great Bear Lake, are also present within the Taiga Plains, along with numerous smaller lakes and ponds averaging less than 10 ha in size. Approximately 18 percent or 88,000 km^2 of the Taiga Plains in the NWT is covered by water. A major portion of the Mackenzie River Delta is located within the Taiga Plains (ENR 2009).

4.8.2 Cordillera

Approximately 14 percent or 164,351 km^2 of the NWT mainland is covered by the Cordillera. The Cordillera includes the plateaus, foothills, and mountains. In the far north, the Cordillera extends east in a narrow strip from the Yukon to the Mackenzie Delta. Further south it forms a crescent-shaped massif between the NWT Yukon border and the Taiga Plains (ENR 2009).

4.9 Permafrost

Permafrost is defined as ground that remains below 0° Celsius continuously for several years (NRC 1988). The Norman Wells area lies in a zone of discontinuous permafrost (GSC 1969), where typical maximum permafrost thickness ranges from 50 to 65 m. Permafrost in the Norman Wells area is not uncommon and is regularly encountered at IOR's NWO beneath roads and other locations. Significant differences in permafrost depth and thickness are evident, based on both non-intrusive (geophysical survey) and intrusive (borehole) investigations. In some areas, extensive unfrozen zones within the permafrost (taliks) have developed, separating the permafrost into ice lenses.

4.10 Hydrology of the Mackenzie River Basin

The Mackenzie River drainage basin is the largest river basin in Canada and the tenth largest river basin in the world. The Mackenzie River system flows roughly 4,200 km from the headwaters of the Athabasca River in the Columbia ice-field in Jasper National

Park, Alberta, and the snowfields of the upper Peace River headlands in northeastern British Columbia to its final destination at the Beaufort Sea of the NWT (MRBB 2003).

The Mackenzie River empties a volume of almost 10,000 cubic metres per second into the Beaufort Sea of the Arctic Ocean at the Mackenzie River delta, accounting for 60% of the freshwater that flows into the Arctic Ocean from Canada and about 9% of the freshwater discharged to all the oceans by all Canadian watersheds (MRBB 2003).

4.11 Wildlife Species at Risk

IOR's activities at its NWO must comply with the Canadian Species at Risk Act (SARA), Species at Risk (NWT) Act, the Migratory Bird Convention Act, and province / territory-specific species at risk legislation. In 2012, the Government of the NWT published a species at risk guide for the NWT. Table A summarizes those species at risk in the Sahtu Region as assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The status of the species listed in Table A is taken from the latest COSEWIC assessment.

Table A: Species at Risk in the Northwest Territories

Taxon	Common Name	Status
Mammals	Grizzly Bear (Northwestern population)	Special Concern
	Wolverine (Western population)	Special Concern
	Woodland Caribou (Boreal population)	Threatened
	Woodland Caribou (Northern Mountain Population)	Threatened

Taxon	Common Name	Status
Birds	Barn Swallow	Threatened
	Common Nighthawk	Threatened
	Horned Grebe (Western Population)	Special Concern
	Olive-sided Flycatcher	Threatened
	Peregrine Falcon (anatum subspecies)	Threatened
	Peregrine Falcon (anatum-tundrius subspecies)	Special Concern
	Rusty Blackbird	Special Concern
	Short-eared Owl	Special Concern
Fish	Dolly Varden (Western Arctic population)	Special Concern
	Shortjaw Cisco	Threatened

4.12 Background Soil and Groundwater Conditions

The assessment of background environmental conditions at Norman Wells has been an important part of Abandonment and Reclamation (A&R) activities since 1997. As it was not the practice to collect baseline data in the early 1920s when the operation started, efforts have been made to establish appropriate background sample locations. A summary of these background soil and groundwater conditions are provided in Appendices A and B respectively. These background concentrations tables have been previously submitted to the SLWB in 2011 annual A&R report that is publicly available on the SLWB registry (www.slwb.com).

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Appendix 1 Determination of Soil Geochemical Background and Glossary of Soil Quality Parameters

DETERMINATION OF SOIL GEOCHEMICAL BACKGROUND CONDITIONS

Soil and bedrock analytical results from several Phase 2 Environmental Site Assessments within the Norman Wells Field have indicated that there are concentrations of hydrocarbons, salts and metals in certain stratigraphic units that are naturally elevated above generic federal environmental quality guidelines (CCME 1999 and updates, CCME 2008). Understanding background (pre-industrial disturbance) soil quality is required to determine appropriate site remediation criteria for the Norman Wells Field. This section reviews available data with the objective of determining background soil and bedrock geochemical conditions for the different near surface (i.e., <10 mbgs) stratigraphic units present within the Norman Wells Field.

Shale material from the Town of Norman Wells quarry has been crushed to varying degrees and used as fill material across the Norman Wells Field, to allow construction on the unstable muskeg areas. Further, the underlying siltstone bedrock is at or very close to surface along the lower terrace of the Mackenzie River on the Mainland portion of the Norman Wells Site. Given the potential for the shale and siltstone bedrock to be influencing soil chemistry at this site, bedrock (siltstone and shale) chemical conditions are also summarized herein.

The available data for background soil and bedrock chemistry collected between 1998 and 2012 have been compiled and assessed to confirm maximum reported values, as well as 95th percentile values where sufficient data existed within a specific stratigraphic unit. For the purposes of the Norman Wells environmental assessment programs, soil and bedrock data were summarized into the following general categories / stratigraphic units:

- surface organic soil (generally upper 0.5 m of soil profile);
- surface mineral soil (generally upper 0.5 m of soil profile);
    - mainland; and
    - islands.
- subsurface mineral soil (> 0.5 m below ground surface [bgs] to bedrock contact);
    - mainland; and
    - islands.
- bedrock;
    - mainland (Siltstone); and
    - shale (Fill Material from Quarry).

Available Background Soils Data

The majority of the background soils/bedrock data was collected in 1998, 2003, 2010 and 2012. Data were collected for a range of environmental projects and it is possible that a location considered suitable for background purposes for a groundwater or subsurface soils investigation may not necessarily provide suitable background surface soils data due to disturbance of surface soils, or due to the presence of shale fill material. Only data from those background locations considered to have minimal or no potential industrial impact were included in the attached summary table. Selected background locations are provided in attached tables. In addition to the reduced number of locations, not all stratigraphic units were sampled or analyzed at each location. As a result, there is a reduced amount of background data that can be utilized for the specific objectives of this project.

As indicated in attached tables, the suitable data set (i.e. number of analyzed samples) for each stratigraphic unit comprised the following:

Stratigraphic Unit	No. of Sampling Locations	No. of Analyzed Samples
Mainland Surface Organic Soil	10	10
Mainland Surface Mineral Soil	5	10
Mainland Subsurface Mineral Soil	20	43
Mainland Siltstone Bedrock	4	8
Mainland Shale Bedrock	4	4
Islands Surface Mineral Soil	5	5
Islands Subsurface Mineral Soil	9	30

There were insufficient samples to characterize Islands Surface Organic Soil, and no bedrock was encountered or sampled during intrusive investigations on the Islands.

The data summarized in attached tables (provided in this appendix) have been screened against generic contaminated sites guidelines for fine-grained soils that were selected to be a conservative screening tool for the likely post-industrial use of the Norman Wells Field. Maximum parameter concentrations as well as 95th percentile concentrations have been provided for each stratigraphic unit when sufficient data were available for statistical analysis. This land use assumes Imperial Oil will maintain ownership of the land but will not prevent occasional access by people or wildlife and as such is modified from CCME Industrial and Residential/Parkland land use conceptual models. In general terms, the Industrial land use guidelines were applied to Mainland areas, whereas Residential/Parkland guidelines were applied to the Natural Islands (Bear, Frenchy's and Goose). The majority of the soils assessed at the Norman Wells Site were determined to be fine-grained, especially on the Mainland and Bear Island. On Goose Island, both coarse and fine-grained alluvial deposits have been identified.

Background Soil Chemistry

As noted above, the background data compiled to date for the Norman Wells Field have been compiled by geographic area (Mainland versus Islands) and by general stratigraphic unit as follows: surface organic soil, surface mineral soil, subsurface mineral soil, and bedrock. The first bedrock interval encountered in the subsurface is siltstone, although layers of shale are present deeper in the profile.

MAINLAND

Surface Organic Soil

Between 1998 and 2012, surface organic soil or peat was sampled at the ten locations noted in attached tables. Ten samples were subject to laboratory analysis for some or all of the following general characterization parameters:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G); and
- benzene, toluene, ethylbenzene and xylenes (BTEX).

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	Range of Values	95th Percentile Value
EC	0.25 to 2.7 dS/m	2.35 dS/m
As	2.6 to 17.1 mg/kg	16.6 mg/kg
Cr	6.7 to 65 mg/kg	48.5 mg/kg
Cu	5.0 to 98.1 mg/kg	76.2 mg/kg
Mo	1.0 to 46.8 mg/kg	45.4 mg/kg
Ni	11 to 239 mg/kg	231 mg/kg
Se	0.53 to 81.6 mg/kg	68.6 mg/kg
Tl	0.15 to 2.5 mg/kg	Not Calculated (NC)
Zn	30 to 435 mg/kg	357 mg/kg

It is also noteworthy that concentrations of one or more BTEX and PHC parameters below the applicable CCME guidelines were present in all of the samples analyzed.

In general, it is not uncommon to find elevated hydrocarbon and metals concentrations in association with peat/organic material at the Site. Metals tend to bond strongly to organic matter, and the lower pH of the peat may also increase metals concentrations in pore water. The elevated EC values are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.

Surface Mineral Soil

The natural soil profile on the Site (excluding muskeg areas) generally consists of a thin organic layer underlain by varying combinations of silts and clays, which are underlain by siltstone bedrock.

Between 1998 and 2012, surface mineral soil was sampled at the five locations noted in attached tables. Ten samples were subject to laboratory analysis for some or all of the following general characterization parameters:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G);
- benzene, toluene, ethylbenzene and xylenes (BTEX); and
- polycyclic aromatic hydrocarbons (PAHs).

Analytical data are summarized in attached tables. None of the analyzed parameters were measured at concentrations/levels exceeding the generic CCME soil quality guidelines for unrestricted land use.

Very low concentrations of PHC F2, F3 and F4 were present in the three samples analyzed for petroleum hydrocarbons. BTEX and PHC F1 concentrations were below the analytical method detection limits.

Although there is a limited background data set for the Mainland Surface Mineral Soil interval, based on the available data, the analyzed parameters and concentrations meet CCME guidelines for unrestricted land use.

Subsurface Mineral Soil

The natural soil profile on the Site (excluding muskeg areas) generally consists of a thin organic layer underlain by varying combinations of silts and clays, which are underlain by siltstone bedrock. The mineral subsurface soil texture ranges from silty clay to loam, and is consistently fine-grained. Permafrost was encountered within the upper 3 m of the soil profile at the majority of background locations, and where a thick organic layer is present, permafrost may be less than 1 m below ground surface.

Between 1998 and 2012, subsurface mineral soil was sampled at the 20 locations noted in attached tables. Forty-three (43) samples were subject to laboratory analysis for some or all of the following general characterization parameters:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G);
- benzene, toluene, ethylbenzene and xylenes (BTEX); and
- polycyclic aromatic hydrocarbons (PAHs).

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	Range of Values	95th Percentile Value
pH	6.11 to 8.1	8.1
EC	0.26 to 2.4 dS/m	1.82 dS/m
SAR	0.17 to 22	2.26
As	4 to 49 mg/kg	27.1 mg/kg
Mo	0.2 to 11.0 mg/kg	6.1 mg/kg
Ni	16 to 127 mg/kg	63 mg/kg
Se	0.25 to 2.7 mg/kg	1.3 mg/kg
Zn	31 to 350 mg/kg	156 mg/kg

In addition to the above noted guideline exceedances at background locations, concentrations of one or more BTEX and PHC parameters below the applicable CCME guidelines were present in all of the samples analyzed. Maximum reported values for Mainland Subsurface Soil included: Benzene (0.019 mg/kg), Toluene (0.18 mg/kg), Ethylbenzene (0.059 mg/kg), Xylenes (0.34 mg/kg), PHC F1 (21 mg/kg), PHC F2 (72 mg/kg), PHC F3 (530 mg/kg) and PHC F4 (220 mg/kg). The naturally occurring levels of PHC F3, in particular, should be considered when determining appropriate soil remediation objectives relative to background conditions.

In general, it is not uncommon to find elevated select hydrocarbon and metals concentrations in association with mineral subsurface soil at the Mainland portion of the Site. The few locations with EC values above CCME Parkland guidelines are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.

ISLANDS

Surface Mineral Soil

Due to the relatively small background soil chemistry data set for the Islands, and the relative similarity between samples collected on Bear and Goose Islands, the data were pooled for a resulting five surface mineral soil sampling points. Only five samples from these locations were analyzed for chemical characterization. As the natural islands comprise alluvial deposits, there is significant variability in the soil texture. The majority of the background soils sampled to date have been fine-grained, with intermittent lenses/layers of coarser sands at depth.

The Island surface soils, particularly on Goose Island, are influenced by ice scouring of the surface soils during spring breakup on the Mackenzie River. Although an organic rich ‘A’ horizon may be present in some non-scoured locations, profile development is relatively limited within these alluvial deposits.

Island mineral surface soil samples were analyzed for some or all of the following general characterization parameters:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G);
- benzene, toluene, ethylbenzene and xylenes (BTEX); and
- polycyclic aromatic hydrocarbons (PAHs).

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	**Range of Values**	**95th Percentile Value**
EC	0.49 to 2.9 dS/m	2.7 dS/m

Reported metals concentrations for Island mineral surface soils were within generic guidelines.

In addition to the above noted guideline exceedances at background locations, concentrations of one or more BTEX and PHC parameters below the applicable CCME guidelines were present in all of the samples analyzed. Maximum reported values for Island Surface Soil included: Benzene (0.0025 mg/kg), Toluene (0.01 mg/kg), Ethylbenzene (0.019 mg/kg), Xylenes (0.087 mg/kg), PHC F1 (14 mg/kg), PHC F2 (72 mg/kg), PHC F3 (370 mg/kg) and PHC F4 (140 mg/kg). The naturally occurring levels of PHC F3, in particular, should be considered when determining appropriate soil remediation objectives relative to background conditions.

The few locations with EC values above CCME Parkland guidelines are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.

Subsurface Mineral Soil

Due to the relatively small background soil chemistry data set for the Islands, and the relative similarity between samples collected on Bear and Goose Islands, the data were pooled for a resulting nine subsurface mineral soil sampling points. Thirty samples from these locations were analyzed for chemical characterization. As the natural islands comprise alluvial deposits, there is significant variability in the soil texture. The majority of the background soils sampled to date have been fine-grained, with intermittent lenses/layers of coarser sands at depth.

Whereas permafrost is often reached within 3 m of ground surface on the mainland locations, permafrost was only reported at one of the island background sampling locations, at 4.3 m below ground surface. Island subsurface mineral soil samples were analyzed for some or all of the following general characterization parameters:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G);
- benzene, toluene, ethylbenzene and xylenes (BTEX); and
- polycyclic aromatic hydrocarbons (PAHs).

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	Range of Values	95^{th} Percentile Value
EC	0.35 to 2.7 dS/m	2.3 dS/m
As	4.0 to 15 mg/kg	9 mg/kg
Mo	1.2 to 45 mg/kg	9.9 mg/kg
Se	0.25 to 3.0 mg/kg	0.93 mg/kg
Tl	0.15 to 2.6 mg/kg	NC

In addition to the above noted guideline exceedances at background locations, concentrations of one or more BTEX and PHC parameters below the applicable CCME guidelines were present in all of the samples analyzed. Maximum reported values for Island Subsurface Soil included: Benzene (0.0025 mg/kg), Toluene (0.01 mg/kg), Ethylbenzene (0.02 mg/kg), Xylenes (0.02 mg/kg), PHC F1 (31 mg/kg), PHC F2 (220 mg/kg), PHC F3 (410 mg/kg) and PHC F4 (130 mg/kg). The naturally occurring levels of PHC F3, in particular, should be considered when determining appropriate soil remediation objectives relative to background conditions. The reported maximum PHC F2 concentration exceeds the CCME Parkland use guideline (150 mg/kg) for fine-grained surface soil. This hydrocarbon exceedance was at one location only (BIBG-10-3 @ 0.3-0.6 mbgs).

None of the PAH analytical results for background locations exceeded the applicable CCME Parkland use guidelines for fine-grained surface soil.

The few (three) locations with EC values above CCME Parkland guidelines are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.

BACKGROUND BEDROCK CHEMISTRY

Siltstone

Samples of the weathered siltstone bedrock encountered in the majority of sampling locations on the Mainland were collected from four background locations. A total of eight samples have been analyzed to date for chemical analyses, including:

- detailed salinity (pH, electrical conductivity [EC], major soluble ions [calcium, sodium, magnesium, potassium, sulphate and chloride], and sodium adsorption ratio [SAR];
- trace elements and metals (antimony [Sb], arsenic [As], barium [Ba], beryllium [Be], boron [B], cadmium [Cd], chromium [Cr], cobalt [Co], copper [Cu], lead [Pb], mercury [Hg], molybdenum [Mo], nickel [Ni], selenium [Se], thallium [Tl], uranium [U], vanadium [V], and zinc [Zn];
- petroleum hydrocarbon fractions 1 through 4G (PHC F1 through F4G);
- benzene, toluene, ethylbenzene and xylenes (BTEX); and
- polycyclic aromatic hydrocarbons (PAHs).

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	Range of Values	95^{th} Percentile Value
SAR	0.28 to 26	17.9
As	7.6 to 24 mg/kg	23 mg/kg
Ni	22 to 64 mg/kg	63 mg/kg
PHC F2	5 to 1200 mg/kg	899 mg/kg
PHC F3	58 to 2900 mg/kg	2144 mg/kg

In addition to the above noted guideline exceedances at background locations, concentrations of PHC F1 and F4 parameters below the applicable CCME guidelines were present in all of the samples analyzed. Maximum reported values for siltstone bedrock included: PHC F1 (80 mg/kg) and PHC F4 (1100 mg/kg). The naturally occurring levels of PHC F3, in particular, should be considered when determining appropriate soil remediation objectives relative to background conditions.

The elevated hydrocarbon concentrations that are intermittently reported in the Mainland siltstone bedrock are interpreted to be associated with the presence of natural hydrocarbon seeps that have been documented throughout the Site, particularly on the lower terrace of the Mackenzie River where bedrock may be present at or near surface. The seeps generally occur at the mineral soil / bedrock interface. This interface is found at greater depths with distance from the river.

None of the PAH analytical results for background location bedrock samples exceeded the applicable CCME land use guidelines for fine-grained surface soil.

The few (three) locations with EC values above CCME Parkland guidelines are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.

Shale

As noted above, shale bedrock from the Town of Norman Wells quarry located to the northeast of the IOL Site has been extracted for use as fill material both on the Site and throughout the developed Town site.

To date, a limited number of shale samples have been collected for laboratory analysis for the purpose of characterizing background conditions. These samples were obtained from the Town of Norman Wells quarry rather than the Site, to minimize the potential for industrial effects. Additional investigations are on-going into the potential for this shale fill to affect underlying and adjacent soil and/or water chemistry.

Analytical results for four shale samples have been included in this background characterization section. The analysis was limited to pH, and trace elements/metals.

Analytical data are summarized in attached tables. The analyzed parameters which were measured at concentrations/levels exceeding the generic CCME soil quality guidelines included:

Parameter	Range of Values	95^{th} Percentile Value
As	7.19 to 42.9 mg/kg	39.6 mg/kg
Mo	29.8 to 66.4 mg/kg	64.7 mg/kg
Se	4.38 to 7.9 mg/kg	7.56 mg/kg
Tl	0.88 to 2.33 mg/kg	2.29 mg/kg

Summary

From the review of the available background data, some general trends are apparent.

- concentrations of one or more metals/trace elements (As, Mo, Ni, Se, Tl and Zn) exceeding CCME guidelines have been confirmed in background organic surface soil, mineral subsurface soil, and underlying siltstone bedrock on the Mainland.
- concentrations of As, Mo, Se and Tl exceeding CCME guidelines have also been confirmed in shale bedrock samples collected from the Town of Norman Wells quarry. This shale material is used as fill throughout the Site and the adjacent Town.
- above guideline SAR values have been measured/calculated for a limited number of mineral subsurface soil samples on the Mainland, as well as the siltstone bedrock.
- in the Island soils, background metals concentrations in surface mineral soil are typically below CCME Parkland use guidelines. However, several metals (As, Mo, Se, Tl) may be present at concentrations above guidelines in the subsurface soil.
- EC levels above CCME Parkland guidelines (2 dS/m) may be present in both organic and mineral soil on both the Islands and the Mainland. The EC is typically

associated with concentrations of sulphate, calcium and magnesium ions rather than chloride – an indicator of industrial activities.

- one or more BTEX and PHC F1 through F4 parameter concentrations above detection limits but generally below CCME guidelines have been reported in all strata and may be associated with organic matter and / or hydrocarbon seeps at the bedrock / soil interface, particularly in the vicinity of the Mackenzie River.
- background data sets for the organic and mineral surface soil on the Islands, as well as the underlying bedrock are very limited and should be interpreted/referenced with caution.

GLOSSARY OF SOIL QUALITY PARAMETERS

GENERAL SOIL PARAMETERS

pH

Soil pH provides a measurement of the relative acidity/alkalinity of a soil/water solution, and is strongly dependent on the salt concentration in the solution. Soil pH could be affected by both natural processes (vegetation cover and geology), and industrial activities (accidental release of acids, or caustic substances). Soil pH <4.5 will result in reduced crop yield, and pH >8.5 will limit fertilizer and micronutrient uptake from the soil by plants. The optimum soil pH range for growth of most plant species is typically 6.0 to 8.0. However, local geological and biological conditions can result in natural soil pH outside this range. For example, soil developed under coniferous forest cover (spruce or pine) or muskeg (sphagnum peat) is naturally acidic with pH below 6.

Electrical Conductivity (EC)

Soil EC is a measure of a dissolved salts in a soil/water solution, prepared at a specified ratio. The accumulation of soluble salts (e.g. sodium (Na) and chloride (Cl)) may affect plant growth by limiting moisture availability, creating nutrient imbalances, or producing ion-specific toxicity. Plants such as rye grass, wheat grass, alfalfa and sweet clover are able to grow in soil with higher EC (>8 deci Siemens per metre (dS/m)), whereas plants such as potatoes, peas, timothy and red clover have quite low tolerance for higher salt concentrations in the soil (prefer EC <4 dS/m). Plant responses to EC, measured in dS/m, include:

EC (dS/m)	Plant Response
0 - 2	No salinity problems
2 - 4	Restricts growth of salt sensitive plants, delays seed germination
4 – 8	Restricts growth of most plants
8 – 14	Restricts growth of all except salt tolerant plants, seed germination reduced or prevented
>14	Prevents growth of almost all plants

Note that naturally saline (e.g. marine) environments have a different (higher) baseline salinity, and vegetation may have already adapted to naturally higher salt levels in the soil.

Sodium Adsorption Ratio (SAR)

Soil sodicity is expressed as SAR, which is a ratio of sodium to calcium and magnesium concentrations present in the soil solution. High SAR can have an adverse effect on soil structure by creating “hard pan” layers in the profile, which in turn restrict plant root development and infiltration of precipitation. Soil structure is not usually affected at an SAR value less than 7 or 8. The SAR guidelines in the NT have been set at 5 for Parkland use, and 12 for Industrial land use.

MAJOR IONS

Calcium (Ca) and Magnesium (Mg) Calcium and magnesium naturally present in soil result from the weathering of Ca and Mg-rich rocks. These parameters are not usually indicators of contamination in soil. There are no current regulatory guidelines for Ca or Mg in soil. Soluble salt levels are measured and monitored indirectly through the EC parameter noted above.

Sodium (Na) Sodium is a naturally occurring element; however, if present in large concentrations, soil structure can be adversely affected. There is no current regulatory guideline for sodium levels in soil – this parameter is usually measured indirectly through the SAR ratio noted above.

Potassium (K) Potassium is an essential nutritional element for humans, animals and plants, and is naturally occurring in soils. However, at high concentrations (>100 milligrams per litre (mg/L)) this constituent may be an indicator of spills of specific materials such as drilling muds/fluids. There is no current regulatory guideline for potassium in soil. Soluble salt levels are measured and monitored indirectly through the EC parameter noted above. Optimum available potassium levels for good plant growth should be around 200 parts per million (ppm).

Chloride (Cl) Higher chloride levels in soil (i.e. >500 mg/L) can be an indicator of industry related impact; as this constituent is not usually present at high concentrations in a natural non-marine, non-saline environment. However, in marine or naturally saline environments, high concentrations (>1,000 mg/L) of chloride may be common in soils. There is no current regulatory guideline for chloride in soil. Soluble salt levels are measured and monitored indirectly through the EC parameter noted above.

Sulphate (SO_4) High concentrations of soluble sulphate in soils (i.e. >1,000 mg/L) are usually an indicator of naturally occurring salinity. There is no current regulatory guideline for sulphate in soil. Soluble salt levels are measured and monitored indirectly through the EC parameter noted above. Optimum levels of sulphate for good plant growth are around 10 ppm available sulphate.

Nitrate and Nitrite (NO_3 and NO_2) Nitrate and nitrite occur in natural and contaminated soil. Common sources include food preservatives, commercial fertilizers, sewage and manure. Nitrate presence in soil is essential for plant growth; optimum levels are plant-specific, but should generally be around 40 ppm available nitrate.

SECONDARY CONSTITUENTS

Metals

Metals in soil naturally result from the weathering of mineral and rock fragments present in the subsurface. Industry related sources may include commercial fertilizers, sewage, drilling fluids/muds, process waters, industrial combustion and smelting activities. When present at high concentrations, some metals can be toxic to plants and soil micro-organisms. At northern sites, metals are of particular importance as certain constituents (e.g. arsenic, molybdenum, nickel, selenium) occur naturally at high concentrations due to the bedrock geochemistry. There are a number of metals that are currently regulated by NT and CCME as listed below, along with the respective CCME (1999 and updates) Parkland and Industrial guideline concentrations, and interpreted background levels in milligrams per kilogram (mg/kg).

Metal	Parkland Guideline (mg/kg)	Industrial Guideline (mg/kg)	Interpreted Background Level (mg/kg)
Arsenic (As)	12	12	See attached tables
Barium (Ba)	500	2,000	
Cadmium (Cd)	10	22	
Chromium (Cr)	64	87	
Hexavalent Chromium (Cr^{6+})	0.4	1.4	
Cobalt (Co)	50	300	
Copper (Cu)	63	91	
Lead (Pb)	140	600	
Mercury (Hg)	6.6	50	
Molybdenum (Mo)	10	40	
Nickel (Ni)	50	50	
Selenium (Se)	1	3.9	
Thallium (Tl)	1	1	
Zinc (Zn)	200	360	

SOIL - VOLATILE ORGANICS

BTEX

BTEX is comprised of four different constituents - benzene, toluene, ethylbenzene, and xylenes. Benzene is a common constituent of gasoline, but may also be associated with unrefined petroleum products. This compound is the most soluble of the BTEX constituents, and is a known cancer causing agent in humans. Therefore, guidelines of 0.5 mg/kg and 5 mg/kg have been set for NT soils under Parkland and Industrial use respectively. Under CCME, the most conservative recent benzene guideline for Parkland and Industrial use, fine-grained soil, drinking water protection pathway, is 0.0068 mg/kg.

Toluene, ethylbenzene and xylenes primarily originate from the petroleum industry, but are also present in various solvents, gasoline additives, and manufactured chemicals. Unlike benzene, these compounds are not classified on the basis of potential health effects. This is a function of their differing physical and chemical properties. The current NT soil guidelines for toluene, ethylbenzene and xylenes under Industrial land use, fine-grained soil, groundwater protection pathway, are 0.8 mg/kg 20 mg/kg and 20 mg/kg, respectively. However, the most recent CCME soil guidelines for these same parameters are 0.08 mg/kg, 0.018 mg/kg, and 2.4 mg/kg, respectively.

SOIL - HYDROCARBONS

Petroleum Hydrocarbon Fractions 1 (PHC F1), 2 (PHC F2), 3 (PHC F3) and 4 (PHC F4)

Petroleum products such as crude oil, jet fuel, and heating oil contain numerous compounds in varying proportions. For the purpose of regulating these compounds, CCME (2008) and NT have classified the hydrocarbons on the basis of specified ranges of carbon present. For soils, petroleum hydrocarbon fractions (PHC) include F1 (C6 to C10 excluding BTEX), F2 (>C10 - C16), F3 (>C16 - C34), and F4 (>C34 - C50+). Due to the more complex molecular structure, these compounds tend to be less soluble than the lighter hydrocarbons, such as the BTEX components. As soil texture is one of the primary factors governing hydrocarbon migration through soil, regulatory guidelines have been recommended for both fine- and coarse-grained soil as defined by having a median grain size <75 µm (fine) or >75 µm (coarse).

The CCME PHC guidelines for soil are currently set as follows for Parkland and Industrial land uses (based on eco soil contact pathway).

Land Use	Soil Texture	PHC F1 (mg/kg)	PHC F2 (mg/kg)	PHC F3 (mg/kg)	PHC F4 (mg/kg)
Parkland	Fine	210	150	1,300	5,600
	Coarse	30	150	300	2,800
Industrial	Fine	320	260	2,500	6,600
	Coarse	320	260	1,700	3,300

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, from the burning of tobacco, and are present in charbroiled foods. PAHs are also present in crude oil, bitumen, coal, tar pitch, creosote, and roofing tar. These organic compounds generally occur as complex mixtures (for example, as part of combustion products such as soot), and not as single compounds.

PAHs enter the environment mostly as releases to the air from volcanoes, forest fires, residential wood burning, exhaust from automobiles and trucks and discharges from industrial facilities. These compounds tend to adsorb to organic matter in the subsurface, and are therefore not that mobile. Exposure of animals to high concentrations of some PAHs has been linked to the development of cancer.

NT and CCME regulatory soil guidelines for some of the more common PAHs include.

PAH	Parkland Guideline (mg/kg)	Industrial Guideline (mg/kg)
Benzo(a)pyrene	0.7	0.7
Naphthalene	0.6	22
Phenanthrene	5	50
Pyrene	10	100

REFERENCES

CCME (Canadian Council of Ministers of the Environment), 1999 and updates. Canadian Environmental Quality Guidelines. Updated September 2007.

CCME (Canadian Council of Ministers of the Environment), 2008. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil. Canadian Council of Ministers of the Environment, Winnipeg. January 2008.

Background Soil/Bedrock Locations

AREA	LOCATIONS							
	Organic Surface Soil		***Mineral Surface Soil***		***Mineral Subsurface Soil***		***Bedrock***	
	Borehole ID	No. of Samples	Borehole ID	No. of Samples	Borehole ID	No. of Samples	Borehole ID	No. of Samples
Mainland	PEAT 03-01	1	MCBG-12-1	1	CLAY PIT#1	1	SILTSTONE	
	PEAT 03-02	1	MLS-09-22	1	CLAY PIT#2	1	MEBG-12-2	1
	S98-35A	1	S12-6	6	A45X OVERBURDEN 1	1	MWBG-10-01	1
	MCBG-10-02	1	MWBG-10-03	1	A45X OVERBURDEN 2	1	MEBG-10-3	4
	MEBG-10-01	1	MWBG-12-2	1	B38X98-1	2	MWBG-12-2	2
	MEBG-12-1	1			WBIO 08-1	2		
	MEBG-12-2	1			WBIO 08-2	2		
	MWBG-10-01	1			WBIO 08-3	2		
	MWBG-10-02	1			MCBG-10-02	3	SHALE	
	MWBG-12-1	1			MCBG-12-1	3	S12-Quarry 1	1
					MEBG-10-01	3	S12-Quarry 2	1
					MEBG-10-2	4	S12-Quarry 3	1
					MEBG-12-1	2	SHALE-1	1
					MEBG-12-2	2		
					MWBG-10-01	2		
					MWBG-10-02	3		
					MLS-09-22	1		
					MWBG-12-1	2		
					MWBG-10-03	4		
					MWBG-12-2	2		
Bear / Frenchy's/Goose Is	BI 08-01	1	BIBG-10-3	1	BI 08-01	2	--	0
			BIBG-10-2	1	BIBG-10-3	4		
			FIBG-10-1	1	BIBG-10-2	4		
			GIBG-10-1	1	BIBG-10-1	2		
			GIBG-10-2	1	BIBG-12-1	5		
					BIBG-12-2	3		
					FIBG-10-1	3		
					GIBG-10-1	3		
					GIBG-10-2	4		

Background Geochemical Statistics for Soil and Bedrock: Salinity Parameters

Imperial Oil - Norman Wells	pH (pH units)	EC (dS/m)	SAR (ratio)
CCME Residential/Parkland Fine Surface	6 - 8	2	5
CCME Industrial Fine Surface	6 - 8	4	12
95th Percentile Background - Organic Surface Soil (Mainland)	7.54	2.35	0.45
Maximum Background - Organic Surface Soil (Mainland)	7.57	2.7	0.5
95th Percentile Background - Mineral Surface Soil (Mainland)	7.53	0.76	1.8
Maximum Background - Mineral Surface Soil (Mainland)	7.72	0.78	2
95th Percentile Background - Mineral Surface Soil (Islands)	7.76	2.7	0.72
Maximum Background - Mineral Surface Soil (Islands)	7.77	2.9	0.8
95th Percentile Background - Mineral Subsurface Soil (Mainland)	8.1	1.82	2.26
Maximum Background - Mineral Subsurface Soil (Mainland)	8.1	2.4	22
95th Percentile Background - Mineral Subsurface Soil (Islands)	7.78	2.3	0.46
Maximum Background - Mineral Subsurface Soil (Islands)	7.81	2.7	0.54
95th Percentile Background - Bedrock (Mainland Siltstone)	7.76	0.95	17.9
Maximum Background - Bedrock (Mainland Siltstone)	7.78	0.97	26

Background Geochemical Statistics for Soil and Bedrock: Metals and Trace Elements

Imperial Oil - Norman Wells	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Boron (Hot Water Soluble) (mg/kg)	Cadmium (mg/kg)	Chromium (6+) (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Molybdenum (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Thallium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)	Zinc (mg/kg)
CCME Residential/Parkland Fine Surface	20	12	500	4	---	10	0.4	64	50	63	140	6.6	10	50	1	1	23	130	200
CCME Industrial Fine Surface	40	12	2000	8	---	22	1.4	87	300	91	600	50	40	50	2.9	1	300	130	360
95th Percentile Background - Organic Surface Soil (Mainland)	NC	16.6	424	1.2	3.55	3.85	NC	48.5	25.9	76.2	17.6	NC	45.4	231	68.6	NC	6	51.5	357
Maximum Background - Organic Surface Soil (Mainland)	2	17.1	430	1.4	4.1	5.6	0.15	65	26	98.1	18.1	0.14	46.8	239	81.6	2.5	7	56	435
95th Percentile Background - Mineral Surface Soil (Mainland)	NC	9.5	399	0.81	0.85	0.94	NC	21.9	10.2	21.6	11	NC	1.86	31	0.65	0.15	1.1	43.8	133.8
Maximum Background - Mineral Surface Soil (Mainland)	0.5	11	402	0.87	0.89	1.09	0.075	22	11	23	11	0.09	2	33	0.67	0.15	1.2	45.1	150
95th Percentile Background - Mineral Surface Soil (Islands)	NC	7.8	346	NC	NC	0.6	NC	26.6	7.8	16.4	11.4	NC	3.84	30	0.6	NC	NC	24.6	84.6
Maximum Background - Mineral Surface Soil (Islands)	0.5	8	360	0.2	0.3	0.6	0.075	30	8	17	12	0.07	4.1	32	0.6	0.15	1	25	85
95th Percentile Background - Mineral Subsurface Soil (Mainland)	NC	27.1	360	0.9	4.01	0.92	NC	37	25	38	16	NC	6.1	63	1.3	NC	NC	50	156
Maximum Background - Mineral Subsurface Soil (Mainland)	1	49	390	1.4	10	2	0.18	39	19	45	26	0.33	11	127	2.7	0.8	2.3	66	350
95th Percentile Background - Mineral Subsurface Soil (Islands)	NC	9	337	NC	0.41	0.68	NC	17	8.8	23	11.7	NC	9.9	30	0.93	NC	NC	34	96
Maximum Background - Mineral Subsurface Soil (Islands)	2	15	400	0.55	0.58	0.7	0.075	20	9.4	25	12	0.07	45	35	3	2.6	3	61	120
95th Percentile Background - Bedrock (Mainland Siltstone)	NC	23	257	0.83	2.4	NC	NC	42	22	45	13.6	NC	NC	63	NC	NC	NC	84	140
Maximum Background - Bedrock (Mainland Siltstone)	0.5	24	260	0.95	3.1	0.37	0.075	42	22	53	15	0.12	1.5	64	0.25	0.15	0.5	94	150
95th Percentile Background - Bedrock (Mainland Shale)	2.12	39.6	354	0.65	NC	0.74	NC	51.2	6.97	42.5	10.8	0.284	64.7	49.2	7.56	2.29	NC	125.7	106.2
Maximum Background - Bedrock (Mainland Shale)	2.13	42.9	370	0.66	NC	0.82	NC	53.6	7.16	43.6	11	0.312	66.4	49.6	7.9	2.33	NC	129	108

Background Geochemical Statistics for Soil and Bedrock: Petroleum Hydrocarbon Parameters

Imperial Oil - Norman Wells	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (Total) (mg/kg)	PHC-F1 (-BTEX) (mg/kg)	PHC-F2 (mg/kg)	PHC-F3 (mg/kg)	PHC-F4 (mg/kg)
CCME Residential/Parkland Fine Surface*	2.1	110	120	65	210	150	1300	5600
CCME Industrial Fine Surface*	2.8	330	430	230	320	260	2500	6600
95th Percentile Background - Organic Surface Soil (Mainland)	NC	NC	NC	NC	NC	NC	442	231
Maximum Background - Organic Surface Soil (Mainland)	0.17	0.24	0.29	0.6	29	150	460	240
95th Percentile Background - Mineral Surface Soil (Mainland)	NC	NC	NC	NC	NC	NC	93	54
Maximum Background - Mineral Surface Soil (Mainland)	0.0025	0.01	0.005	0.02	NC	19	97	57
95th Percentile Background - Mineral Surface Soil (Islands)	NC	NC	NC	NC	NC	61.6	322	122
Maximum Background - Mineral Surface Soil (Islands)	0.0025	0.01	0.019	0.087	14	72	370	140
95th Percentile Background - Mineral Subsurface Soil (Mainland)	NC	NC	NC	NC	NC	NC	401	141
Maximum Background - Mineral Subsurface Soil (Mainland)	0.019	0.18	0.059	0.34	21	72	530	220
95th Percentile Background - Mineral Subsurface Soil (Islands)	NC	NC	NC	NC	NC	NC	304	NC
Maximum Background - Mineral Subsurface Soil (Islands)	0.0025	0.01	0.02	0.02	31	220	410	130
95th Percentile Background - Bedrock (Mainland)	NC	NC	NC	NC	67.4	899	2144	859
Maximum Background - Bedrock (Mainland)	0.0025	0.01	0.005	0.02	80	1200	2900	1100

* denotes criteria with drinking water protection guideline eliminated

Shading indicates parameters above most restrictive guidelines selected

Appendix 2 Determination of Groundwater Geochemical Background and Glossary of Groundwater Quality Parameters

DETERMINATION OF GROUNDWATER GEOCHEMICAL BACKGROUND

In order to effectively evaluate the origin of groundwater parameters which may exceed regulatory guidelines (in this case, CCME FWAL criteria), it is important to defensibly determine naturally occurring background concentrations for the parameters of interest. Background monitoring wells would ideally be installed in an undisturbed, up-gradient area, isolated from any potential sources of anthropogenic impact. However, these locations tend to be heavily influenced by permafrost in the vicinity of Norman Wells. Previous attempts to install background wells in up-gradient areas of the lease, removed from the IOL facilities and in areas of natural vegetation, have resulted in rapidly frozen groundwater monitoring wells that consistently remain frozen. As such, the use of the term “background” in this report does not necessarily mean the groundwater monitoring well is installed in an undisturbed, up-gradient area. Rather, the term is used for locations inferred to be removed from site facilities and free of facility-related impacts.

In an effort to improve characterization of background soil and groundwater conditions, the 2010 and 2012 Phase 2 ESA programs focused on installation of new potential background wells in surficial sediments. This included 6 new wells on the Natural Islands and 5 wells distributed throughout Mainland East, Central, and West areas over the past three years. As a result of these new wells, supplemented by annual groundwater sampling from 1997 to 2012, a sufficient database has now been compiled to determine a statistical background for key geochemical parameters from a range of hydrogeological units of interest. As summarized in attached tables, twenty-four wells within the monitoring network have been identified as background locations. These wells are separated into four groups, based on the hydrogeological zone where the well screen is completed, as follows:

- surficial sediments on Mainland (10 wells, 9 producing water, total 28 samples);
- surficial sediments on Natural Islands (7 wells, all producing water, total 20 samples);
- shallow bedrock on Mainland (3 wells, all producing water, total 21 samples); and
- deeper bedrock on Mainland (4 wells).

Data from the first three hydrogeological is of primary interest for analysis of the environmental monitoring results collected to date. As such the statistical background analyses concentrated on these categories. The deep bedrock category is not characterized to the same extent, and considering that groundwater quality in the deeper bedrock is less important for comparison to the environmental monitoring program, deeper bedrock data will not be considered further in this discussion.

A geometric mean, minimum, maximum, and 95th percentile value for each parameter listed below was determined for each of the three hydrogeological units of interest.

Indicator Parameters		
pH	Iron	Nitrite as N
Chloride	Sulphate	Nitrate as N
DOC	TDS	Phenols
Fluoride		
Hardness		

Dissolved Metals and Trace Elements			
Aluminum	Boron	Mercury	Thallium
Antimony	Cadmium	Molybdenum	Titanium
Arsenic	Chromium	Nickel	Uranium
Barium	Copper	Selenium	Zinc
Beryllium	Lead	Silver	

One of the key aspects of the statistical calculations is the method of dealing with results reported below the laboratory method detection limit (MDL), which is a frequent occurrence with some of the dissolved trace metals in particular. In order to calculate the 95th percentile value, a real number is required rather than a “less than” result. The approach used was as follows. In cases where the MDL is the normal precision reported for that particular parameter, then a real number value of ½ the MDL is used in the calculation. For example, if the dissolved copper result was reported as <0.001 mg/L, then a real number value of 0.0005 mg/L is assumed for the statistical calculations. In cases where matrix interferences increase the MDL, this method cannot be used and the data point is typically discarded for the purpose of the 95th percentile calculation. Note that although this method is acceptable for 95th percentile calculations, it is much more problematic in the calculation of geometric means (U.S. EPA Unified Guidance, 2009).

Results of the statisitical analyses are provided in attached tables. The following results are of particular note in the interpretation of data in the attached report:

1. The CCME FWAL water quality guidelines for a number of trace metals vary depending on the pH and total hardness of the water. For the purpose of selecting appropriate guidelines for comparison to Norman Wells water samples, the pH value is considered greater than 6.5, and the total hardness as CaCO3 is greater than 180 mg/L (very hard water). The 95th percentile value for groundwater samples from background locations was as follows

- surficial sediments on mainland, pH of 7.1 and hardness of 1345 mg/L;
- surficial sediments on islands, pH of 7.2 and hardness of 1681 mg/L; and

2. shallow bedrock, pH of 7.8 and hardness of 254 mg/L.

3. The attached analysis of background geochemistry in local groundwater has intentionally avoided using chloride values derived from a background well which is located within a historically documented natural seepage zone on the Mackenzie River shore, directly south of the Former Refinery. Well NWR 03-38-3 represents a natural crude oil and saline formation water seepage zone, where shallow bedrock subcrops within a few metres of ground surface under sediments along the shoreline. Chloride readings from this well, on the order of 250 mg/L, have been discounted in the determination of the 95th percentile chloride value for surficial sediments on the Mainland.

4. The 95th percentile analyses indicate that the following parameters may naturally exceed the applied CCME FWAL criteria in groundwater at this site:

- groundwater from surficial sediments on Mainland sites - iron, phenols, arsenic, cadmium, copper, selenium, uranium, and zinc. Chloride and petroleum hydrocarbons can also occur above the applied guideline in natural seepage zones;
- groundwater from surficial sediments on Natural Islands sites - iron, phenols, cadmium, copper, selenium, uranium, and zinc; and
- groundwater from shallow bedrock – chloride, iron, phenols, aluminum, arsenic, copper, and selenium. As noted previously, petroleum hydrocarbons would also be expected within areas of natural seepage in the upper bedrock.

GLOSSARY OF GROUNDWATER TERMS

GENERAL WATER PARAMETERS

pH One of the main objectives in controlling the pH is to minimize corrosion and encrustation in the household water distribution system. This can result from the complex relationships between pH and other constituents, such as carbon dioxide, hardness, alkalinity and temperature. The Canadian Council of Ministers of the Environment (CCME 2007) guideline for protection of Freshwater Aquatic Life (FWAL) is 6.5 to 9.0.

Alkalinity Alkalinity is caused by the presence of carbonates, bicarbonates and hydroxides of various minerals. Not considered to be detrimental to humans, alkalinity is generally associated with pH values, hardness, and the presence of excessive amounts of dissolved solids. There is no set limit for alkalinity in the current CCME FWAL guidelines.

Electrical Conductivity (EC) EC is a measure of the water’s capacity to carry electrical current. This is in turn, directly related to the concentration of ionised inorganic compounds in the water. Values of EC can vary considerably from well to well, and depend on the well location, depth of completion, and type of aquifer sediments completed in. Values in excess of 2,000 μS/cm would be considered elevated for fresher waters. There is no set limit for EC in the current CCME FWAL guidelines.

Hardness (as $CaCO_3$)

Public acceptability of the degree of hardness may vary considerably from one community to another. The hardness of water is caused by dissolved, polyvalent ions (principally calcium and to a lesser extent magnesium). Depending on the interaction of other factors, such as pH and alkalinity, water with a hardness above 200 mg/L may cause the build-up of scale deposits in water delivery systems. There is no set limit for hardness in the current CCME FWAL guidelines.

MAJOR IONS

Calcium (Ca)

Calcium in groundwater results from the weathering of Ca-rich rocks and soils. It is important as a constituent or hardness (see hardness). Excess calcium may be detrimental for domestic uses such as washing, bathing, and laundering because of its tendency to neutralise soap and cause encrustations plumbing fixtures. There is no set limit in the current CCME FWAL guidelines.

Magnesium (Mg)

Magnesium is also a constituent of hardness, and an essential element in human metabolism. At high concentrations, magnesium may have a laxative effect, particularly upon new users. Nevertheless, the body can develop a tolerance over time. There is no direct evidence of adverse health effects associated with magnesium; therefore no limit has been set for Canadian drinking water. There is no set limit in the current CCME FWAL guidelines.

Sodium (Na)

Sodium is not considered to be acutely toxic to humans, and up to 5 grams/day are consumed by the average person without apparent adverse effects. The average intake of sodium from water is only a small fraction of that consumed in a normal diet. There is no set limit in the current CCME FWAL guidelines.

Potassium (K)

Potassium is an essential nutritional element in human metabolism. However, at high concentrations (>1,000 mg/L) this constituent may have laxative effects. Concentrations rarely exceed this value (in most potable aquifers). There is no set limit in the current CCME FWAL guidelines.

Chloride (Cl)

Concentrations of chloride are generally quite low in most shallow groundwater systems. However, due to the presence of natural shallow seeps containing hydrocarbon and associated produced water at the Norman Wells site, significant measurable chloride can be locally present. The current CCME FWAL guidelines is 120 mg/L chloride.

Sulphate (SO_4)

No serious health effects are associated with high sulphate levels. At concentrations above 500 mg/L, sulphate may impart a noticeable taste to the water and cause a laxative effect in occasional users. There is no set limit in the current CCME FWAL guidelines.

Bicarbonate (HCO_3)

Bicarbonate is formed by the weathering of organic matter and carbonate-bearing minerals (e.g. limestone) present in the subsurface. The concentration of this anion in natural and contaminated waters is related to such factors as temperature, pH, concentrations of other dissolved solids, and biological activity. This parameter is not considered a health hazard. There is no set limit in the current CCME FWAL guidelines.

SECONDARY CONSTITUENTS

Nitrate and Nitrite (NO_2 and NO_3)

Nitrite-nitrogen (NO2) and nitrate-nitrogen (NO3) occur in natural and contaminated waters. The current CCME FWAL guidelines are 0.06 mg/L and 2.9 mg/L for nitrite and nitrate as N, respectively.

Iron and Manganese (Fe and Mn)

Although iron and manganese are essential elements in humans and animals, drinking water is not considered to be an important source. At high enough levels these metals can stain laundry and plumbing fixtures, and causes an undesirable taste in beverages. The precipitation of excess iron gives an objectionable reddish-brown colour to drinking water. There is no set limit in the current CCME FWAL guidelines for manganese. The CCME FWAL guideline for dissolved iron is 0.3 mg/L.

Trace Metals

Metals are a common occurrence in groundwater, and result from the weathering of mineral and rock fragments present in the subsurface. There are a number of dissolved metals, other than iron and manganese, which are currently regulated for protection of Freshwater Aquatic Life under the Canadian Council of Ministers of the Environment guidelines (CCME 2007).

ORGANIC INDICATORS

Dissolved Organic Carbon (DOC)

DOC provides a measure of the total amount of dissolved organic matter in water. This parameter is not capable of distinguishing between the various compounds making up the organic loading of a sample; therefore it is only used as an indicator of organic loading.

High DOC readings can be related to soluble compounds originating from the breakdown of natural organic matter in the subsurface, or soluble hydrocarbon components originating from an industrial source. DOC concentrations in most natural waters generally fall within the range of 10 mg/L or less (Hem 1989). Higher concentrations (up to 60 mg/L) can sometimes occur in pore waters associated with organic-rich soils, such as lake and swamp sediments and muskeg deposits (Thurman 1985). There is no current CCME FWAL guideline for DOC.

Phenols (total)

Phenols are a common occurrence in groundwater. This class of compounds is derived from the degradation of natural organic matter, the distillation of wood and coal, and the refining of oil. Phenols are also associated with heavy oil. Phenols are quite soluble in water, and easily degraded by subsurface bacteria. At present the CCME FWAL guideline for phenols is 0.004 mg/L.

Concentrations of total phenols are generally quite low in most natural groundwater systems. However, due to the presence of shallow natural hydrocarbon seeps at the Norman Wells site, measurable phenols are also present.

Phenols analyzes are performed at Maxxam Analytics (Maxxam) using the 4-AAP colorimetric method. This method yields a single phenols value. However, there are limitations to the colorimetric method, including interference with other compounds in a sample. Plastics, phenols-decomposing bacteria, oxidizing and reducing substances and alkaline pH can interfere with the natural amount of phenols in a sample. These interferences could result in false-positive results and/or poor precision. However, while limitations are present, the colorimetric method is considered to be a useful screening tool for phenols.

VOLATILE ORGANICS

BTEX

BTEX is comprised of four different constituents - benzene, toluene, ethylbenzene, and three isomers of xylene (o-, m-, and p-). BTEX compounds are associated with both refined petroleum products and crude oil, and represent some of the more soluble components of petroleum hydrocarbon mixtures.

The CCME FWAL guidelines for benzene, toluene, and ethylbenzene are 0.37, 0.002, and 0.09 mg/L respectively. There is no current CCME FWAL guideline set for xylenes.

HYDROCARBONS

Total Purgeable Hydrocarbons (TPH)

Due to the more complex molecular structure, these compounds tend to be less soluble than the lighter hydrocarbons, such as the BTEX components.

Total Extractable Hydrocarbons (TEH)

These parameters can only be used to indicate the presence of higher molecular weight hydrocarbons, as the method of analysis is incapable of distinguishing between the different compounds present. However, the results can be used to more fully characterize areas identified by key indicator parameters such as DOC and phenols. Therefore these analyses are useful as an indicator parameter of higher order hydrocarbons.

Petroleum Hydrocarbon Fractions 1 and 2 (PHC F1, PHC F2)	The former TPH and TEH scans have been recently replaced with the newer AENV (2001) petroleum hydrocarbon fractions, which include PHC F1 (C_6 through C_{10}, excluding BTEX) and PHC F2 ($C_{>10}$ through C_{16}). No CCME FWAL guidelines are defined for PHC F1 and F2.

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Background Wells and Hydrogeologic Unit

Monitoring Station	Depth Interval of Sandpack *(m bgs)*	Dominant Hydrogeologic Unit for Well screen	Lithology Within Screened Interval	Comments
Background Locators With Groundwater from Surficial Sediment				
Mainland Locations				
NWR 03-38-3	0.50 - 3.00	Surficial sediment	Sand and clay	Former refinery area, known seepage zone, shale fill present
B38 93-2-4	less than 4 m	Surficial sediment	no borehole log	Mainland east area, shale fill present
MEBG-10-1-3	1.00 - 3.00	Surficial sediment	Silty Sand / Clayey Silt	Mainland east area, shale wellpad 3 m away
MLS 09-6-2	0.80 - 2.20	Surficial sediment	Silty clay and bedrock	Mainland sumps area, shale roadbed 3 m away
BT3 97-2-5	1.10 - 4.60	Surficial sediment	Silt	Mainland central area, shale roadbed 3 m away
MCBG-10-1-3	0.80 - 2.50	Surficial sediment	Clayey Silt / Peat / Silty Clay	Mainland central area, shale helipad 10 m away
MCBG-12-1-2	0.50 - 3.00	Surficial sediment		Mainland central area, shale roadbed 3 m away
MWBG-10-1-3	0.80 - 2.70	Surficial sediment	Silt / Clay	Mainland west area, shale roadbed 3 m away
MWBG-12-1-3	1.20 - 3.00	Surficial sediment		Mainland west area, shale roadbed 3 m away
WBIO-08-1-2	0.60 - 2.40	Surficial sediment	Sandy clay / Silty sand	Mainland west area, shale roadbed 20 m away
Island Locations				
BI 08-1-4	0.60 - 2.40	Surficial sediment	Silty clay	Bear Island
BIBG-10-1-4	0.78 - 4.10	Surficial sediment	Silty Clay / Sand	Bear Island, shale fill present
BIBG-10-2-4	0.50 - 3.77	Surficial sediment	Sand	Bear Island
BIBG-12-2-4	0.70 - 4.20	Surficial sediment		Bear Island
FIBG-10-1-4	0.69 - 3.97	Surficial sediment	Silty Clay / Sand	Frenchies Island
GIBG-10-1-5	1.20 - 4.50	Surficial sediment	Sandy Silt	Goose Island
GIBG-10-2-3	1.30 - 3.00	Surficial sediment	Sand	Goose Island
Background Locators With Groundwater from Shallow Bedrock				
NWR 98-18-15	11.00 - 14.70	Shallow bedrock	Siltstone	Upgradient of former refinery area
NWR 99-16-17	12.60 - 17.00	Shallow bedrock	Siltstone	Upgradient of former refinery area
RB 02-3-2	0.60 - 3.30	Shallow bedrock	Siltstone / Shale	Former refinery area, known seepage zone, screen intercepts shale
Background Locators Not Used in Statistics (all deeper bedrock)				
B38 00-32-44	37.30 - 43.40	Deep bedrock	Sandstone and shale	delete from list - too deep for our study
BT3 00-28-44	39.50 - 43.30	Deep bedrock	Shale	delete from list - too deep for our study
NWR 00-25-36	30.90 - 36.30	Deep bedrock	Siltstone and shale	delete from list - too deep for our study
NWR 00-26-40	33.30 - 39.60	Deep bedrock	Siltstone	delete from list - too deep for our study

Background Geochemical Statistics for Groundwater: Indicators and Phenols

	Field pH (ph units)	Chloride (mg/L)	Dissolved Organic Carbon (DOC) (mg/L)	Fluoride (mg/L)	Hardness (as CaCO3) (mg/L)	Iron (mg/L)	Sulphate (mg/L)	Total Dissolved Solids (TDS) (mg/L)	Nitrite as N (mg/L)	Nitrate as N (mg/L)	Phenols (mg/L)
CCME Freshwater Aquatic Life, 2011	(6.5 - 9)	120	---	---	---	0.3	---	---	0.06	2.9	0.004
Federal Interim Groundwater Quality Guidelines, Res/Parkland, 2010 [1]	(6.5 - 9)	230	---	0.12	---	0.3	100	---	0.06	2.9	0.004
95th Percentile Background - Surficial Sediments - Mainland	7.1	15	44	0.4	1345	1.7	720	1945	0.031	0.17	0.021
95th Percentile Background - Surficial Sediments - Islands	7.2	13	no data	no data	1681	3.2	1125	2490	0.025	0.42	0.006
95th Percentile Background - Shallow Bedrock	7.8	332	33	0.3	254	0.8	65	1936	<0.005	<0.02	0.022

Background Geochemical Statistics for Groundwater: Dissolved Metals and Trace Elements

	Aluminum (mg/L)	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Boron (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)
CCME Freshwater Aquatic Life, 2011	0.1	---	0.005	---	---	1.5	0.00031	0.0089	0.004	0.007
Federal Interim Groundwater Quality Guidelines, Res/Parkland, 2010 [1]	0.1	1.6	0.005	2.3	0.0053	---	0.00031	0.0089	0.004	0.007
95th Percentile Background - Surficial Sediments - Mainland	0.048	0.0160	0.0090	0.79	< 0.001	0.708	0.00046	0.0040	0.014	0.0029
95th Percentile Background - Surficial Sediments - Islands	0.011	0.0005	0.0020	0.22	< 0.001	0.040	0.00042	<0.001	0.012	<0.0002
95th Percentile Background - Shallow Bedrock	0.176	0.006	0.054	6.15	< 0.001	1.36	<0.0001	<0.002	0.016	0.0023

	Mercury (mg/L)	Molybdenum (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Silver (mg/L)	Thallium (mg/L)	Titanium (mg/L)	Uranium (mg/L)	Zinc (mg/L)
CCME Freshwater Aquatic Life, 2011	0.000026	0.073	0.15	0.001	0.0001	0.0008	---	0.015	0.03
Federal Interim Groundwater Quality Guidelines, Res/Parkland, 2010 [1]	0.000026	0.073	0.15	0.001	0.0001	0.0008	0.1	0.3	0.03
95th Percentile Background - Surficial Sediments - Mainland	< 0.00005	0.0030	0.028	0.0020	< 0.0001	< 0.0002	< 0.001	0.025	0.036
95th Percentile Background - Surficial Sediments - Islands	< 0.00005	0.0025	0.025	0.0009	< 0.0001	< 0.0002	< 0.001	0.024	0.030
95th Percentile Background - Shallow Bedrock	< 0.00005	<0.005	<0.008	0.0032	<0.0001	<0.0001	< 0.003	0.0019	0.018

Superscript 1 - Guidelines shown for Federal Interim Groundwater Quality Guidelines for Residential/Parkland Land Use are Tier 2, with the Marine Life pathway eliminated.