Appendix F

Report: “Development of Clean-Up Criteria for Petroleum Hydrocarbons for Silver Bear, Contact Lake and El Bonanza Sites”

Final Report:

DEVELOPMENT OF CLEANUP CRITERIA FOR PETROLEUM HYDROCARBONS FOR SILVER BEAR, CONTACT LAKE AND EL BONANZA SITES

Prepared For:

Indian and Northern Affairs Canada

Prepared By:

SENES Consultants Limited

October 2008

FINAL REPORT

DEVELOPMENT OF CLEANUP CRITERIA FOR PETROLEUM HYDROCARBONS FOR SILVER BEAR, CONTACT LAKE AND EL BONANZA AND SAWMILL BAY SITES

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October 2008

Printed on Recycled Paper Containing Post-Consumer Fibre

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1.0 INTRODUCTION

Indian and Northern requested that SENES Consultants Limited prepare a report that outlined the development of petroleum hydrocarbon criteria for the Silver Bear sites (five sites including Terra, Northrim, Norex, Graham Vein, and Smallwood) on the Camsell River, as well as the Contact Lake and El Bonanza mine sites near Echo Bay at the eastern shore of Great Bear Lake. Given that these sites are in the same geographic area (the Great Bear Lake watershed) and that the geology and site use patterns are not very different, separate calculations were deemed to be unnecessary for the these (eight) sites.

The petroleum hydrocarbon contamination at these sites is mainly associated with fuel storage, and maintenance activities at the site which resulted in spills, leakage or improper disposal of hydrocarbons. Thus, diesel and lubricating/motor oils are the main source of contamination at these sites. Diesel generally comprises petroleum hydrocarbons in the range of C10 to C25 and is generally assumed to be approximately 50% of the F2 and F3 hydrocarbon fractions where as lubricating oils are generally made up of F3 and F4 fractions.

The Canada Wide Standard for Petroleum Hydrocarbons provides soil quality guidelines for each of the four fractions (F1 to F4). These generic guidelines have been derived using common assumptions that involve access to the sites. These sites are in remote locations (generally 200km away from the nearest community) and thus access to the sites is extremely limited. Therefore the use of the generic CWS criteria for the protection of human health is not applicable to this site. Furthermore, the amount of snow cover and number of days per year with frozen ground is greater at these sites relative to other locations in Canada and also there is very little soil cover at these sites. In general, there is a thin veneer of soil that covers waste rock. Thus, this thin soil cover does not provide an adequate matrix for soil invertebrates.

Criteria have been developed based on the protection of human health as well as the protection of ecological health. The final criteria values are based on the most protective (i.e. the lowest) values between human health and ecological protection. It should be noted that the criteria derived in this document can also be used at other sites such as Sawmill Bay.

1.1 CONCEPTS, ASSUMPTIONS, CONSIDERATIONS

In the development of the proposed clean-up criteria, several documents were reviewed in order to determine the most appropriate approach. The documents that were reviewed included:

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

- Golder Associates Limited 2008. *Protocol for the Evaluation of Hydrocarbon Impacted Areas at INAC DEW Line Sites.* Draft. January.
- Risk Assessment Documents for Silver Bear, Contact Lake and EL Bonanza that were carried out by SENES.

After reviewing the documentation, the first step in the process was to develop the appropriate standards based on human health. In this regard, the calculations assumed that the F1 fraction consisted of 91% aliphatic compounds and 9% aromatic compounds and for the other fractions (F2 to F4) it was assumed that they contained 80% aliphatic and 20% aromatic compounds. The breakdown of the fractions is the same as the CCME used in their development of their petroleum hydrocarbon criteria.

This document provides clean-up criteria for the individual fractions described above as well as for total petroleum hydrocarbons (Total PHC) as these criteria are more relevant to field measurements. In addition, Indian and Northern Affairs Canada (INAC) has also requested criteria values for Type A (F3 and F4) and Type B (F1 and F2) hydrocarbons in order to be comparable to the values derived by Golder (2008).

2.0 DEVELOPMENT OF CRITERIA BASED ON HUMAN HEALTH

2.1 BACKGROUND

In general, people can receive exposure to contamination via several different pathways such as air, water, soil and food. The development of the criteria for petroleum hydrocarbons (PHC) considers a multimedia approach to ensure that human health will be protected. The multimedia approach takes into account background and also makes allowances for uncharacterized exposures from other media. This approach is identical to the approach that has been adopted by the CCME (2008).

The pathways considered in the human health exposure were soil ingestion, dermal contact and inhalation of vapours (for the F1 and F2 fractions). At these remote sites, groundwater pathways are incomplete and not considered as a drinking water resource; therefore, the drinking water pathway is not included in the exposure pathways calculations. Since petroleum hydrocarbons have not been found to accumulate in plants and move up the food-chain it was not necessary to include other indirect pathways. Thus for petroleum hydrocarbons, the allocation factor for soil pathways applied is based on consideration of the potential pathways of exposure from all sources. The development of the site-specific human health values were based on the application of a soil allocation factor as prescribed by the CCME (2008). The soil allocation factors used in this evaluation are provided in Table 2.1-1.

TABLE 2.1-1
SOIL ALLOCATION FACTORS USED IN DERIVATION OF HUMAN HEALTH CLEAN-UP CRITERIA

Petroleum Hydrocarbon Fraction	Soil Allocation Fraction	Rationale
F1	0.5	Physical and chemical properties indicate a co-residency in air and water. Not likely to occur in significant quantities in food due to poor contact with primary sources and volatility. Little or no information on background exposures.
F2	0.5	Physical and chemical properties indicate a co-residency in air and water but at lower concentrations than F1. No background exposure identified. Greater probability of occurrence in food than F1.
F3	0.6	Sparingly soluble in water and has a very low volatility. Known to occur in consumer products such as lubricants, etc. Some exposure in food likely from barbecued and grilled foods. Exposure from soil likely to occur mainly from soil ingestion and dermal contact.
F4	0.8	Physical and chemical properties indicate that carbon compounds of C > 34 cannot dissolve in water or volatilize significantly. Any non-soil exposure likely to come from consumer products such as heavy lubricants, greases and waxes. Exposure from soil likely to occur mainly from soil ingestion and dermal contact.

Note: Adapted from CCME (2008).

2.2 HUMAN HEALTH CRITERIA DEVELOPMENT FOR SURFACE SOILS

Site-specific risk assessments were carried out for the Terra, Contact Lake and El Bonanza sites. These risk assessments were carried out using Health Canada protocols and receptor characteristics and were peer reviewed by the expert agencies and the assumptions and results of these assessments were the basis of the derivation of the petroleum hydrocarbon criteria that were considered to be protective of human health. In the human health assessment at the sites, it was assumed that the sites were remote enough that people would be present on the site for approximately 200 hours per year. While at the site, humans were assumed to be exposed to petroleum hydrocarbons through soil, berries and game as well as through inhalation. Even though these sites were remote, it was assumed that a child may visit these sites with an adult for hunting and trapping purposes. Therefore a child was considered to be the most sensitive receptor and resulted in the highest calculated hazard quotients at the site. Hazard quotient values calculated for a child exposed to petroleum hydrocarbons at these sites were <0.01 for exposure to F4, 0.02 for exposure to F3, and 0.4 for exposure to F2. This indicates that the presence of hydrocarbon contamination at these sites does not represent a risk from a human health perspective. The child was selected to be representative of the most sensitive receptor present at the site.

Human health criteria were developed based on a back calculation of these hazard quotient values for the child to the appropriate soil allocation factor as provided in Table 2.1-1. In other words, the calculated hazard quotient was adjusted to the soil allocation factor and the soil concentration corresponding to this soil allocation factor (essentially a target hazard quotient) became the site-specific human health clean-up criteria. For example, at Contact Lake, the F3 aliphatic fraction measured at the site (16,200 mg/kg) resulted in a HQ value of 0.02. Adjusting the F3 aliphatic fraction concentration to correspond to the soil allocation factor of 0.6 (as provided by the CCME) results in a theoretical soil clean-up value of 38,611,000 mg/kg (i.e. the HQ value is adjusted from 0.02 to 0.6 and the corresponding PHC concentration in soil is around 38×10^6 mg/kg - this is theoretical value only, it is not possible to exceed 1×10^6 mg/kg). The clean-up values that were calculated for aliphatic and aromatic compounds contained within each fraction were used to calculate the concentration in the overall fraction using the relative proportions of aliphatic and aromatic compounds in the F1 (91% aliphatic; 9% aromatic) and F2 to F4 (80% aliphatic; 20% aromatic) fractions. So the clean-up value of 38,611,000 that was calculated above for the F3 aliphatic fraction becomes 48,263,750 (weighted value) for total F3 after it is divided by a fraction of 0.80 (i.e. 38,611,000/0.8 = . 48,263,750).

Adjustments of the site-derived hazard quotients were done for the Silver Bear and Contact Lake sites and the results were essentially the same. Since Contact Lake had measured values for more petroleum hydrocarbon fractions, back calculations based on this site were used to derive the human health values. No F1 concentrations were measured on site, however back calculations were done using the same approach as used for other petroleum hydrocarbons and the appropriate soil allocation factor to determine F1 clean-up concentrations.

Table 2.2-1 provides the human health clean-up criteria for surface soils for a 200hr/yr stay at the sites along with the soil allocation factors that were obtained from the CCME. As can be seen by this table, human health clean-up values for the F1 fraction are low due to the volatility of this fraction. For F2, the values are at least an order of magnitude higher due to the lower volatility of this fraction as compared to the F1 fraction and for F3 and F4 hydrocarbon fractions, the values are very large, and in some cases above the physical limit. Therefore, it is apparent that for F3 and F4 hydrocarbon fractions, human health exposure is not the driver for the clean-up criteria.

TABLE 2.2-1
DERIVED HUMAN HEALTH CLEAN-UP CRITERIA FOR SURFACE SOILS FOR 200hr/yr

PHC FRACTION		Soil Allocation Factor[1]	Human Health Clean-up Value (mg/kg)	
			Calculated Value	Weighted Value [3]
F1 (C_6 to C_{10})	aliphatic	0.5	852	936
	aromatic	0.5	293	3,256
F2 (>C_{10} to C_{16})	aliphatic	0.5	10,294	12,868
	aromatic	0.5	6,069	30,345
F3 (>C_{16} to C_{34}) [2]	aliphatic	0.6	38,611,000	48,263,750
	aromatic	0.6	579,170	2,895,850
F4 (>C_{34}) [2]	aliphatic	0.8	51,481,500	64,351,875
	aromatic	0.8	772,225	3,861,125

Note:
[1] Soil Allocation Factor from CCME (2008) equivalent to a hazard quotient.
[2] Calculated F3 and F4 concentrations are above the physical limit (one million parts per million (>1,000,000 mg/kg)).
[3] Weighted values for the total concentration of each fraction is calculated to account for the relative proportions of aliphatic and aromatic compounds contained in F1 (91% aliphatic; 9% aromatic) and F2 to F4 (80% aliphatic; 20% aromatic) PHC fractions.

Sawmill Bay was added to the site list, and since there was the potential to stay a longer period at the site due to the presence of a lodge, human health criteria were derived for a three month stay at the site. Table 2.2-2 provides the criteria for human health that can be applied to Sawmill Bay.

TABLE 2.2-2
DERIVED HUMAN HEALTH CLEAN-UP CRITERIA FOR SURFACE SOILS FOR 3 MONTHS/YR

PHC FRACTION		Soil Allocation Factor[1]	Human Health Clean-up Value (mg/kg)	
			Calculated Value	Weighted Value [3]
F1 (C_6 to C_{10})	aliphatic	0.5	85	94
	aromatic	0.5	29	32
F2 (>C_{10} to C_{16})	aliphatic	0.5	1,000	1,287
	aromatic	0.5	600	3,000
F3 (>C_{16} to C_{34}) [2]	aliphatic	0.6	3,861,100	4,826,375
	aromatic	0.6	58,000	290,000
F4 (>C_{34}) [2]	aliphatic	0.8	5,150,000	6,440,000
	aromatic	0.8	77,000	386,000

Note:
[1] Soil Allocation Factor from CCME (2008) – equivalent to a hazard quotient.
[2] Calculated F3 and F4 concentrations are above the physical limit (one million parts per million (>1,000,000 mg/kg)).
[3] Weighted values for the total concentration of each fraction is calculated to account for the relative proportions of aliphatic and aromatic compounds contained in F1 (91% aliphatic; 9% aromatic) and F2 to F4 (80% aliphatic; 20% aromatic) PHC fractions.

2.3 HUMAN HEALTH CRITERIA DEVELOPMENT FOR SUB-SURFACE SOILS

The Canadian Council of Ministers of the Environment defines sub-soils as earthy materials below 1.5m. Thus, at these northern sites, samples taken at depth need to be confirmed that they are indeed earthy materials and not waste rock or other material. In defining the human health values for sub-surface soils at these sites, the same protocol as was applied by the CCME was used.

The pathways considered by the CCME were:

- Soil Ingestion – this is an incomplete pathway under undisturbed conditions; however, workers may be exposed to hydrocarbons at depth under occasional conditions. The CCME determined that workers under this exposure scenario would result in a value that exceeds the physical limit of the hydrocarbons or one million parts per million (i.e. > 1,000,000 mg/kg).
- Soil Dermal Contact - this is an incomplete pathway under undisturbed conditions; however, workers may be exposed to hydrocarbons at depth under occasional conditions; however the CCME determined that a value of one million parts per million applies.
- Vapour Inhalation – In an outdoor situation this is an incomplete pathway.

- Protection of Potable Groundwater – This is an incomplete pathway since groundwater is not used in a potable situation at these mine sites.

Table 2.3-1 provides the human health criteria that are applicable to petroleum hydrocarbons at depth in sub-surface soils at these northern sites.

TABLE 2.3-1
DERIVED HUMAN HEALTH CLEAN-UP CRITERIA FOR SUB-SURFACE SOILS

PHC FRACTION	Human Health Clean-up Value (mg/kg)
F1 (C_6 to C_{10})	1,000,000
F2 ($>C_{10}$ to C_{16})	1,000,000
F3 ($>C_{16}$ to C_{34})	1,000,000
F4 ($>C_{34}$)	1,000,000

3.0 DEVELOPMENT OF CRITERIA BASED ON ECOLOGICAL HEALTH

The ecological criteria development was based on the protection of soil invertebrates and vegetation, consistent with the CCME (2008). Individual criteria are provided in the following sections for soil invertebrates and plants because at a number of the sites the organic content of the soil material is not enough to support soil invertebrates. Weathering of petroleum hydrocarbons, which has occurred at these sites, occurs through biodegradation and volatilazation and results in the differential loss of more easily degraded constituents. The partial breakdown of the petroleum hydrocarbons can result in metabolic intermediates that are less toxic than the parent but in some cases, they may be similar or more toxic than the parent compound.

3.1 CRITERIA FOR WEATHERED PETROLEUM HYDROCARBONS IN SURFACE SOIL

There are a few studies that have been provided in the CCME (2008) Supporting Technical document (Appendix G) that provide information for weathered petroleum hydrocarbons. Visser and her colleagues are currently undertaking studies to determine the effects of aging on the toxicity of Federated Crude to soil invertebrates and plants in three different soil types. The soil types are sandy soil, loam and clay. The experiments were run for three months using earthworms, lettuce and barley and the preliminary results were provided in CCME (2008). Based on an original total petroleum hydrocarbon concentration of 24,000 mg/kg, a no observable effects concentration (NOEC) was determined for soil invertebrates and plants in sandy soils. In the loam and clay soils, the original concentrations were 96,000 and 48,000 mg/kg, respectively. The NOEC values were the same for plants and soil invertebrates in sand and loam but not for clay. The NOEC values are provided in Table 3.1-1. F1 values are not provided since the majority of that fraction had volatilized.

TABLE 3.1-1
NO OBSERVABLE EFFECTS LEVEL CONCENTRATIONS FOR SOIL INVERTEBRATES AND PLANTS FOR WEATHERED PETROLEUM HYDROCARBON FRACTIONS IN SURFACE SOIL

PHC FRACTION	No Observable Effects Level Concentrations (mg/kg)					
	Soil Invertebrates			Plants		
	Sand	Loam	Clay	Sand	Loam	Clay
F2 (>C_{10} to C_{16})	240	780	1,942	240	780	6,049
F3 (>C_{16} to C_{34})	2,711	10,253	13,717	2,711	10,253	32,430
F4 (>C_{34})	4,481	18,567	12,882	4,481	18,567	23,926
Original PHC Concentration (mg/kg)	24,000	96,000	48,000	24,000	96,000	48,000

Note: From Visser *et al*. study provided in Appendix G of CCME (2008).

Results from studies carried out by Saterbak *et al.* (1999) were also provided in the CCME (2008) Appendix G. These studies were related to the effects of weathering and bioremediation on toxicity to soil invertebrates using methods similar to Visser *et al.* discussed above. The results of the study indicated that inhibition of plant growth and germination as well as mortality in earthworms may occur at concentrations of the F2 fraction ranging from 2 to 540 mg/kg and for concentrations of the F3 fraction ranging from 54 to 8000 mg/kg. Although, the soil types were not specified in the experiments, the results of the experiments indicated that there were variations in toxicity associated with soil type as has been demonstrated in Table 3.1-1. The range of these concentrations overlap with the F2 and F3 values provided in Table 3.1-1 which are specific for different soil types.

For the F1 fraction, the data on fresh petroleum hydrocarbons were used since there is very little information on weathered soils since this fraction is readily volatilized. The information provided in Appendix E of the CCME (2008) Technical Support document was used to derive the clean-up values for the F1 fraction. There are three values provided in Section E 3.2 of the Technical Support document related to soil invertebrates. It should be noted that for the F1 fraction, the soil type is not provided and thus the derived values are assumed to be applicable to all soil types. The measured effects concentrations resulting in 20% mortality or a 20% change in reproduction are 230 mg/kg, 220 mg/kg and 510 mg/kg. An average of the effects relating to soil invertebrates is 320 mg/kg. For plants, there are data available for alfalfa, barley, corn and red fescue with average effects concentrations related to a 20% change in shoot or root length or shoot or root weight of 232.5 mg/kg, 552.5 mg/kg, 527.5 mg/kg and 296.7 mg/kg, respectively. This results in an overall average value of 402 mg/kg.

Table 3.1-2 provides the ecological clean-up criteria based on un-weathered material for the F1 fraction and on weathered material for F2 to F4. The weathered values are based on the studies by Visser *et al.* which was provided in Appendix G of CCME (2008). The data by Visser *et al.* are supported by studies from Saterbak *et al.* (1999) and thus were deemed appropriate.

TABLE 3.1-2
ECOLOGICAL CLEAN-UP CRITERIA FOR SOIL INVERTEBRATES AND PLANTS IN SURFACE SOIL

PHC FRACTION	No Observable Effects Level Concentrations (mg/kg)					
	Soil Invertebrates			Plants		
	Sand	Loam	Clay	Sand	Loam	Clay
F1 (C_6 to C_{10})	320	320	320	402	402	402
F2 (>C_{10} to C_{16})	240	780	1,942	240	780	6,049
F3 (>C_{16} to C_{34})	2,711	10,253	13,717	2,711	10,253	32,430
F4 (>C_{34})	4,481	18,567	12,882	4,481	18,567	23,926
Total PHC Concentration (mg/kg)	7,752	29,920	28,861	7,834	30,002	62,807

3.2 PHC CRITERIA PROTECTIVE OF FRESHWATER AQUATIC LIFE

The CCME Technical Support document and the Golder (2008) document for DEW Line sites provide information on the derivation of values in soil that are protective of aquatic life in nearby waterbodies. The criteria for the protection of aquatic life are only relevant to the lighter-weight, mobile petroleum hydrocarbon fractions, i.e. the F1 and F2 fractions. The values provided in the CCME document are applicable to southern sites whereas Golder (2008) adjusted the values to be more applicable to northern sites. In reviewing the Golder (2008) methodology and the modelling carried out, it was our opinion that this methodology was applicable to the Silver Bear, Contact Lake and El Bonanza sites and thus the values derived by Golder (2008) were adopted in this report. A discussion of the methodology is provided below.

Golder Associates Limited (2008) derived clean-up criteria for the INAC DEW Line sites, which are located within the Arctic Circle and continuous permafrost zone. Much of the hydrocarbon contamination at the DEW Line sites is diesel fuel based, with lesser volumes of soil impacted by lubricating/motor oils and other heavier end products. As part of their development of criteria for the DEW Line sites, Golder (2008) examined soil concentrations of petroleum hydrocarbons that would be protective of freshwater aquatic life, which considers mobile petroleum hydrocarbon contamination (i.e. F1 and F2 fractions) that is in close proximity to a waterbody.

While the CCME provides generic guidelines for the protection of freshwater aquatic life, the parameters and assumptions used in the groundwater transport model used to derive these criteria differ significantly from conditions at northern sites and may thus have limited applicability to northern environments. In developing these criteria for the DEW Line sites, Golder (2008) utilized more appropriate Arctic specific input parameters derived from data collected at DEW Line sites or from the literature. The primary parameters that were modified from the CCME default values, which were also found to have a significant influence on calculated guideline values, included organic carbon fraction, Darcy's velocity and half-life (degradation rate) of hydrocarbon constituents. Sensitivity analyses were then carried out varying these parameters to select appropriate F1 and F2 fraction guideline values, which are shown on Table 3.2-1. In addition, Golder (2008) also conducted a sensitivity analysis to determine an appropriate set-back distance (i.e. distance between contaminated soil and waterbody supporting aquatic life) for the application of the recommended guidelines for the protection of freshwater aquatic life at INAC DEW Line sites.

The following discussion provides the assumptions used by Golder (2008) in their derivation of the aquatic life guidelines.

Organic Carbon Fraction: Golder (2008) found the fraction of organic carbon present in the subsurface to have a considerable effect on the calculated guideline value. Using site-specific data determined from the analyses of 69 soil samples that were collected from across the DEW Line sites, Golder (2008) calculated a geometric mean of 0.0045 for organic carbon fraction, which was used to develop the aquatic life value. However, it should be noted that this value is very similar to the CCME default value of 0.005.

Darcy's Velocity: Darcy's velocity (V = Ki) is a measure of the flow velocity, which is calculated from the hydraulic conductivity of the soil (K) and the hydraulic gradient (i). Values of hydraulic conductivity were estimated by reviewing grain size distributions in soils occurring at the DEW Line sites and comparing them to relationships between grain size and hydraulic conductivity in the literature. Soils typically encountered at these sites consisted of well-graded gravel and sand with varying amounts of silt. Based on these data, the hydraulic conductivities were estimated to range from 32 to 1600 m/year. The CCME default value for coarse grained soils is 320 m/year. Values of hydraulic gradient were determined by reviewing the topography in hydrocarbon impacted areas at DEW Line sites as well as the varying depth to the permafrost table. Based on these considerations, hydraulic gradients were typically about 0.03, which is similar to the CCME default value of 0.028. To account for the fact that groundwater flow is effectively eliminated at these sites for a major portion of the year due to permafrost conditions, a factor of 0.33 was applied to Darcy's velocity to reflect flow through the active layer only over a four month period (June to September). However, based on field observations of groundwater/soil contamination plumes at other DEW Line sites, this latter assumption proved to be conservative resulting in higher velocities than those estimated from the field observations. Based on the field observations, Darcy's velocity values were estimated to be in the range of 1 to 4 m/year for gravel and sand materials typical of the INAC DEW Line sites and Golder (2008) adopted the most conservative value of 4 m/year. In our opinion, this value is also applicable to the Silver Bear, Contact Lake and EL Bonanza sites and other northern sites.

Hydrocarbon Degradation Rates: Golder (2008) noted that there is a paucity of data on hydrocarbon degradation under Arctic conditions, and an insufficient amount of available information to set boundary values. Golder (2008) thus adopted the half-life values that were used by the CCME. The values used by the CCME were found to be significantly conservative and thus the values were not adjusted for temperature effects. However, the values were modified to reflect degradation during the thaw season only (four month period). Values of 5.85 and 14.4 years were used for the F1 and F2 constituents, respectively, and are considered to be applicable to the conditions at the Silver Bear, Contact Lake and EL Bonanza sites and other northern sites.

Set-Back Distance: To determine an appropriate set-back distance, Golder (2008) conducted a sensitivity analysis where the distance (10, 20 or 30 m) and Darcy's velocity (2.0, 3.0 or 4.0 m/year) were varied while the organic carbon fraction was set to 0.0045. The analysis showed that at distances greater than 30 m, the guideline values for both the F1 and F2 fractions using any of the velocities shown above were typically greater than or close to 2,500 mg/kg. At these soil concentrations (>2,500 mg/kg), exposure pathways other than aquatic life will likely drive the remediation process. At 20 m, based on the most conservative velocity value (4.0 m/year), the guideline values for the F1 and F2 fractions were determined to be 1,290 and 330 mg/kg, respectively. The 20 m distance between source and receptor determined through this analysis was deemed more appropriate than the 10 m distance that is applied by the CCME, because bulk fuel storage areas at most sites were typically located 20 to 30 m inland from waterbodies. Golder recommended an overall set-back distance of 30 m and this setback has been adopted in this evaluation. This means that any soil within 30m of an aquatic body needs to meet the criterion that is set out in Table 3.2-1. This setback distance is similar to the distance used by the Ontario Ministry of the Environment in the development of their generic criteria for protection of aquatic life.

TABLE 3.2-1
PHC CLEAN-UP CRITERIA PROTECTIVE OF AQUATIC LIFE

PHC FRACTION	Soil Concentration Protective of Freshwater Aquatic Life (mg/kg)
F1 (C_6 to C_{10})	1,290
F2 (>C_{10} to C_{16})	330

Note:
Values are appropriate within 30 m of a waterbody.
Derived by Golder Associates Limited for INAC DEW Line sites (Golder 2008).

3.3 ECOLOGICAL CRITERIA FOR PETROLEUM HYDROCARBONS IN SUB-SURFACE SOIL

The CCME adopted a similar protocol for evaluating the appropriate ecological criteria in subsoils as they did for human health. Thus, they considered the various applicable pathways to determine which were appropriate for sub-soils. The pathways that the CCME considered were:

- Direct Soil Contact – The CCME considered that very deep rooted species may have roots that are exposed to hydrocarbon at depths greater than 1.5m. In these northern sites, roots do not generally extend to these depths and thus this is an incomplete pathway. The CCME also considered that some earthworms may migrate to avoid moisture stress on a periodic basis. However, the CCME determined that there is a very small proportion of earthworm species that migrate to depth and that the time that earthworms that do migrate spend at depth is minimal. Therefore the protection of earthworms has not been considered in the criteria development for subsurface soils. Thus an upper limit of 30,000 mg/kg is selected as indicated by the CCME.

- Protection of aquatic life – The criteria that were developed in Section 3.2 above are also applicable at depth.
- Off-site migration – This is an incomplete pathway.

Based on the above discussion, Table 3.3-1 provides the ecological criteria for sub-surface soils that are close to a waterbody and further away from a waterbody.

TABLE 3.3-1
DERIVED ECOLOGICAL CLEAN-UP CRITERIA FOR SUB-SURFACE SOILS

PHC FRACTION	Ecological Clean-up Value (mg/kg) for PHC < 30m to a Waterbody	Ecological Clean-up Value (mg/kg) > 30m from a Waterbody
F1 (C_6 to C_{10})	1,290	30,000
F2 (>C_{10} to C_{16})	330	30,000
F3 (>C_{16} to C_{34})	30,000	30,000
F4 (>C_{34})	30,000	30,000

4.0 DEVELOPMENT OF CRITERIA FOR NORTHERN SITES

The previous sections have provided petroleum hydrocarbon clean-up values that are protective of human health (Section 2) and of soil invertebrates and vegetation (Section 3) and protective of aquatic life in near-by waterbodies (Section 3). In addition to these criteria, INAC has also requested criteria for Total PHC (for Type A (F3 and F4) and Type B (F1 and F2)) as these criteria are more relevant to field measurements. In this regard, a summary table has been generated which provides total PHC value and a summary of all the relevant criteria developed for these sites (Table 4.1-1). For the human health criteria, the most conservative of the aliphatic or aromatic compounds has been selected as the overall human health value for each fraction.

As seen from Table 4.1-1, the protection of ecological life (plants and earthworms) is the driver for the clean-up criteria for sites not close to waterbodies. For sites close to waterbodies the protection of aquatic life is the driver for the mobile F1 and F2 fractions. Table 4.1-1 also provides an Upper Limit which represents the theoretical limit at which free-phase hydrocarbons can form in the soil. These criteria are applicable up to a depth of 1.5 m which the CCME considers to be the transition from soil to subsoil. These criteria are also applicable to other sites such as Sawmill Bay where the matrix is sand rather than loam or clay.

TABLE 4.1-1
RELEVANT PHC CLEAN-UP CRITERIA FOR USE AT NORTHERN SITES

		SURFICIAL SOILS (mg/kg)								
PHC FRACTION [1]		**Human Health** [2]	**Ecological** [3] **(direct soil contact)**						**Aquatic Life** [4]	**Upper Limit**
		Includes: Soil Ingestion, Vapour Inhalation, & Dermal Contact	**Soil Invertebrates**			**Plants**				
			Sand	Loam	Clay	Sand	Loam	Clay		
F1 (C_6 to C_{10})		950	350	350	350	400	400	400	1300	30,000
F2 (>C_{10} to C_{16})		13,000	250	800	2000	250	800	2000	330	30,000
F3 (>C_{16} to C_{34})		>1,000,000	2700	10,300	13,800	2700	10,300	32,400	-	30,000
F4 (>C_{34})		>1,000,000	4,500	18,500	13,000	4,500	18,500	24,000	-	30,000
Total PHC	F1 to F4	>1,000,000	7,800	30,000	29,000	8,000	30,000	30,000	-	30,000
Type A	F3 to F4	>1,000,000	7,200	29,000	27,000	7,200	29,000	30,000	-	30,000
Type B	F1 to F3	>1,000,000	3,300	11,400	16,000	3,400	11,400	30,000	-	30,000

Note:
[1] PHC - Petroleum Hydrocarbon.
F1 - motor gas.
F2 and light F3 (typically to C_{19}, potentially to C_{25}) - diesel fuel.
F3 and F4 - lubricating oils.
F1 - 91% aliphatic; 9% aromatic.
F2, F3 and F4 - 80% aliphatic; 20% aromatic.
Total PHC - sum of all fractions, F1 to F4.
Type A - sum of F3 to F4; heavy end PHC products such as lubricating oils; when all fractions are present, F3+F4 must be >70% of TPH and F2<F4 to define Type A.
Type B - sum of F1 to F3; lighter end or more volatile PHC products such as motor gas, jet and diesel fuels.
[2] Based on a 200 h exposure duration (using calculations from Contact Lake HHERA).
[3] F1 to F4: F1 based on fresh crude and F2 to F4 based on weathered petroleum hydrocarbons (CCME 2008).
[4] Derived by Golder Associates Limited for INAC DEW Line sites (Golder 2008).

In order to use these criteria at the various sites, consideration needs to be made as to:

- Whether the petroleum hydrocarbon contamination is present in soil;
- Whether pathways exist that result in exposure and pose a risk to aquatic life, ecological health and human health (for example, does waste rock contaminated with petroleum hydrocarbons pose a risk);
- The soil type (sand, loam, clay);
- Whether earthworms are present at these sites; and,
- Whether the Upper Limit, which is not based on weathered petroleum hydrocarbons is applicable.

Table 4.1-2 provides a matrix of PHC concentrations that can be applied to the Terra, Silver Bear, Contact Lake and El Bonanza sites. It must be kept in mind that in some of these sites there is a thin veneer of soil over the mine rock and this veneer will not support earthworms and may not be able to support vegetation. In these cases it may be more appropriate to apply the mine rock criteria. Mine rock consists of material with less than 0.2% by weight of organic carbon.

TABLE 4.1-2
PHC CLEAN-UP CRITERIA MATRIX FOR USE AT SILVER BEAR, CONTACT LAKE AND EL BONANZA SITES FOR SURFICIAL SOILS

PHC FRACTION	SURFICIAL SOILS (mg/kg)		
	Soil < 30m to Waterbody	Soil > 30m from a Waterbody	Mine Rock – Only Dermal Contact No Ecological Pathways
F1 (C_6 to C_{10})	400	400	940
F2 (>C_{10} to C_{16})	300	800	13,000
F3 (>C_{16} to C_{34})	10,300	10,300	30,000
F4 (>C_{34})	18,500	18,500	30,000
Total PHC	30,000	30,000	30,000
Type A	29,000	29,000	30,000
Type B	11,000	11,000	30,000

Note:
PHC concentrations in table have been rounded for field analyses and are based on the assumption that the soil matrix is loam.
Total PHC concentrations for waste rock valid if F1 fraction is believed to not be significant (i.e. presence unlikely due to weathering).

For sub-surface soils at depths greater than 1.5m, the clean-up criteria are based on the Upper Limit as there are no operable exposure pathways. Table 4.1-3 provide a summary of these values.

TABLE 4.1-3
DERIVED CLEAN-UP CRITERIA FOR SUB-SURFACE SOILS FOR USE AT SILVER BEAR, CONTACT LAKE AND EL BONANZA SITES

PHC FRACTION	Clean-up Value (mg/kg) for PHC < 30m to a Waterbody	Clean-up Value (mg/kg) > 30m from a Waterbody
F1 (C_6 to C_{10})	1,290	30,000
F2 (>C_{10} to C_{16})	330	30,000
F3 (>C_{16} to C_{34})	30,000	30,000
F4 (>C_{34})	30,000	30,000

Table 4.1-4 provides a matrix of PHC concentrations that can be applied to surficial soils at the SawMill Bay site. As indicated above, in some cases it may be more appropriate to apply mine rock criteria which are also provided.

TABLE 4.1-4
PHC CLEAN-UP CRITERIA MATRIX FOR USE AT SAWMILL BAY FOR SURFICIAL SOILS

PHC FRACTION	SURFICIAL SOILS (mg/kg)	
	Soil < 30m to Waterbody	Soil > 30m from a Waterbody
F1 (C_6 to C_{10})	30	30
F2 (>C_{10} to C_{16})	250	250
F3 (>C_{16} to C_{34})	2,700	2,700
F4 (>C_{34})	4,500	4,500
Total PHC	7,500	7,500
Type A	7,200	7,200
Type B	330	300

Note:
PHC concentrations in table have been rounded for field analyses and are based on the assumption that the soil matrix is loam.
Total PHC concentrations for waste rock valid if F1 fraction is believed to not be significant (i.e. presence unlikely due to weathering).

For sub-surface soils (Table 4.1-5) at depths greater than 1.5m, the clean-up criteria are based on the Upper Limit as discussed above since there are no operable exposure pathways.

TABLE 4.1-5
DERIVED CLEAN-UP CRITERIA FOR SUB-SURFACE SOILS FOR USE AT SAWMILL BAY

PHC FRACTION	Clean-up Value (mg/kg) for PHC < 30m to a Waterbody	Clean-up Value (mg/kg) > 30m from a Waterbody
F1 (C_6 to C_{10})	30	30,000
F2 (>C_{10} to C_{16})	300	30,000
F3 (>C_{16} to C_{34})	30,000	30,000
F4 (>C_{34})	30,000	30,000

Uncertainty

Many areas of uncertainty are involved in the development of the clean-up criteria. This is due to the fact that assumptions have to be made throughout the assessment either due to data gaps, environmental fate complexities or in the generalization of receptor characteristics. To be able to place a level of confidence in the results, an accounting of the uncertainty, the magnitude and type of which are important in determining the significance of the results should be presented. In recognition of these uncertainties, cautious assumptions are used throughout the development of the criteria to ensure that the potential for an adverse effect would not be underestimated. Some of the major assumptions are outlined below.

For example, in the development of the criteria for the protection of human health, the receptors and their characteristics are, in general, selected in order to over-estimate potential exposures. It was assumed that the human receptors would be present for all their time at the site on the area with the highest petroleum hydrocarbon concentrations. In reality, if individuals were present at the site, they would not be stationary.

Another area of uncertainty in the development of toxicity is the use of a single value for toxicity for the petroleum hydrocarbons. The toxicity values used are selected to be very protective. No adjustments are made for bioavailability of the chemicals of concern from the soil into the body, which can result in an over-estimation of exposure and thus leads to uncertainty in the risk assessment. The toxicity assays used to generate these toxicity values are not generally conducted for humans, thus toxicological data from laboratory species, generally rats or mice were used in the assessment. Based on the current state of toxicology, these are the best values available and tend to over-estimate risks.

In terms of the criteria that are protective of ecological health, there is uncertainty in parameters such as dilution factors in soil and groundwater, transport and degradation factors in soil, fraction of organic carbon used to derive the values that are protective of aquatic life. In general, the values of the parameters that are selected tend to be conservative in nature. For example, there is a great variability in the fraction of organic carbon at sites in the north, and the use of a single value (0.005) is a geometric mean of the data available and is thought to be conservative. In developing the Darcy's velocity, many conservative assumptions have been made, for example it has been assumed that there is groundwater flow for 4 months of the year which may not be the case. In addition, a Darcy's velocity of 4 m/y was selected as the most appropriate value due to the permafrost conditions since only a four month flow is expected and the exclusion of dissolved contaminants during the freezing process results in the dissolved phase contaminants being trapped near the interface with the permafrost table resulting in limited transport of the dissolved phase early in the thaw season. The degradation rates selected were also conservative since there is limited data on hydrocarbon degradation in northern climates. The use of the Canada Wide Standard degradation rates over a four month thaw period represents a conservative estimate of the rate of petroleum hydrocarbon degradation.

In developing the terrestrial ecological criteria, there is uncertainty surrounding the bioavailability to soil organisms (invertebrates and plants). In addition, the toxicity data is based on laboratory studies in barley, oats, corn and other species that are not found in northern climates. The effect of multiple effects by the various hydrocarbon fractions has not been accounted for since this information is not available in the literature.

Given these uncertainties and the conservative nature of the assumptions used in the derivation of the cleanup criteria, it is not anticipated that the values would change substantively.

5.0 APPLICATION OF CRITERIA TO NORTHERN SITES

The criteria for loam soils for distances greater than 30m were applied to measured concentrations of petroleum hydrocarbons at the Silver Bear (including the Terra, Norex, Northrim and Smallwood sites), Contact Lake and El Bonanza sites in order to provide an example how the criteria can be applied at the sites. Tables 5.1-1 to 5.1-4 provide a summary of the data. As seen from the data, there are a number of samples that exceed the loam criteria. For the Terra Mine site (Table 5.1-1), a number of the samples are located in rocky outcrops or mine (waste) rock and also do not represent a large spatial area. For the Contact Lake and El Bonanza sites (Tables 5.1-3 and 5.1-4), many of these samples are small in spatial area and are located in areas that are designated for clean-up and thus will be addressed as part of that program. In many of these cases, a clean cover of 0.5 m would be adequate to remove the exposure pathways and may be the most appropriate remedial action. The application of the criteria and the appropriate remedial actions at a given site were discussed by a Petroleum Hydrocarbon Working Group which comprised of representatives of INAC, PWGSC, Environment Canada and two consultants.

In addition, it is our opinion that cleanup criteria for BTEX are not needed since these compounds should have volatilized due to the length of time that has elapsed since the sites were active and thus it is our opinion that the CCME soil criteria are applicable. There is a marginal exceedence of xylene (2.3 mg/kg vs. 1.2 mg/kg) in TP-12 at the Terra (Silver Bear) site. This location also has elevated PHC values, thus any action to mitigate this contamination will result in the xylene exceedence being mitigated.

TABLE 5.1-1
SUMMARY OF SAMPLES AT TERRA SITE THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

No.	Terra Sample	Hydrocarbon Fractions (mg/kg)				Exceed?
		F1	F2	F3	F4	
		(C6-C10)-BTEX	(>C10-C16)	(>C16-C34)	(>C34-C50)	
97	TP-01	<5	<5	18	<5	
43	TP-02	<5	13	22	<5	
84	TP-03	44	4900	1300	<5	Y
85	TP-04	<5	140	58	<5	
1	TP-05	<5	<5	<5	<5	
98	TP-06	<5	<5	44	<5	
86	TP-07	<5	<5	<5	<5	
99	TP-08	<5	<5	<5	<5	
89	TP-10	620	18000	3700	28	Y
37	TP-100	<5	<5	86	44	
80	TP-101	<5	<5	160	29	
102	TP-103	<5	67	110	26	
109	TP-104	<5	<5	12	9	
110	TP-105	22	3800	1400	43	Y
63	TP-106	<5	79	190	22	
81	TP-107	<5	19	290	54	
58	TP-108	<5	<5	98	26	
22	TP-109	<5	37	840	390	
87	TP-11	<5	8	9	<5	
15	TP-110	<5	7	2500	740	
16	TP-111	<5	12	330	120	
64	TP-112	<5	6	99	35	
23	TP-113	<5	610	5600	1000	
96	TP-114	<5	1000	2100	220	Y
24	TP-115	<5	6	70	24	
48	TP-119	<5	<5	7	<5	
112	TP-12	1100	18000	4600	130	Y
49	TP-121	11	830	230	<5	Y
42	TP-122	<5	7	<5	<5	
38	TP-123	<5	<5	27	15	
25	TP-124	<5	<5	110	11	
59	TP-125	<5	<5	<5	<5	
39	TP-126	<5	<5	<5	<5	
82	TP-128	<5	<5	69	40	
65	TP-13	67	4800	1400	<5	Y
19	TP-131	25	320	840	100	
51	TP-132	<5	12	130	65	
83	TP-133	<5	830	950	43	Y

TABLE 5.1-1 (Cont'd)
SUMMARY OF SAMPLES AT TERRA SITE THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

50	TP-134	<5	<5	100	16	
40	TP-136	<5	250	370	26	
100	TP-14	33	5200	2000	41	Y
106	TP-15	<5	6	67	33	
90	TP-16	25	2600	730	<5	Y
2	TP-17	<5	48	13000	3000	Y
104	TP-19	<5	<5	41	26	
111	TP-20	<5	<5	84	30	
113	TP-22	<5	<5	140	<5	
21	TP-23	<5	<5	85	14	
91	TP-24	<5	81	140	<5	
3	TP-26	<5	23	540	110	
66	TP-27	<5	<5	290	92	
107	TP-29	<5	<5	83	38	
52	TP-30	<5	<5	94	<5	
4	TP-31	<5	32	500	140	
67	TP-32	<5	<5	430	80	
26	TP-33	<5	100	500	24	
60	TP-34	<5	600	610	15	
61	TP-36	<5	59	2500	300	
53	TP-37	<5	10	990	120	
5	TP-38	<5	<5	100	38	
62	TP-39	<5	<5	63	14	
27	TP-40	<5	<5	230	33	
68	TP-41	<5	<5	520	92	
92	TP-42	<5	86	2300	260	
93	TP-43	<5	52	1400	170	
28	TP-44	<5	<5	61	24	
29	TP-45	<5	80	910	120	
44	TP-46	<5	<5	11	<5	
45	TP-49	<5	15	6900	680	
6	TP-50	<5	200	8700	940	
30	TP-51	38	3300	14000	1900	Y
31	TP-52	<5	18	920	300	
7	TP-53	<5	<5	<5	<5	
17	TP-54	<5	12	960	190	
101	TP-55	<5	<5	53	7	
8	TP-56	<5	<5	21	16	
9	TP-57	<5	17	120	42	
20	TP-57	<5	17	120	42	
69	TP-58	97	9400	3600	290	Y
46	TP-60	12	24	610	140	

TABLE 5.1-1 (Cont'd)

SUMMARY OF SAMPLES AT TERRA SITE THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

32	TP-61	33	4500	2400	?	Y
10	TP-62	26	6100	7600	?	Y
33	TP-63	84	1700	490	<5	Y
70	TP-64	<5	9	50	6	
34	TP-66	27	4400	2500	25	Y
54	TP-67	<5	<5	<5	<5	
71	TP-69	<5	7	26	14	
72	TP-70	<5	410	650	<5	
55	TP-71	<5	280	830	<5	
35	TP-72	<5	<5	55	37	
73	TP-73	<5	<5	13	5	
74	TP-74	<5	12	290	180	
94	TP-75	<5	<5	32	<5	
75	TP-76	<5	<5	63	10	
103	TP-78	<5	33	1700	380	
105	TP-80	<5	100	200	7	
36	TP-81	<5	240	6600	450	
108	TP-82	<5	520	270	20	
76	TP-83	<5	38	430	67	
41	TP-84	<5	740	17000	3900	Y
11	TP-85	<5	410	280	<5	
95	TP-86	<5	<5	29	6	
88	TP-87	<5	10	1100	160	
12	TP-88	<5	150	2500	910	
77	TP-89	<5	<5	620	190	
56	TP-90	<5	19	11000	900	Y
57	TP-93	<5	110	1400	310	
13	TP-94	<5	490	760	66	
14	TP-95	9	250	280	75	
47	TP-96	<5	35	5600	1400	
18	TP-97	<5	<5	<5	<5	
78	TP-97	19	3400	1200	79	Y
79	TP-98	49	9000	820	50	Y
	Criteria	**402**	**780**	**10200**	**19000**	
					N>Criteria	**21**

TABLE 5.1-2
SUMMARY OF SAMPLES AT NOREX, NORTHRIM AND SMALLWOOD SITES THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

Depth (m)	Sample ID	Hydrocarbon Fractions (mg/kg)				Exceed?
		F1	F2	F3	F4	
		(C6-C10)-BTEX	(>C10-C16)	(>C16-C34)	(>C34-C50)	
0.45	Norex TP-01	<5	530	390	<5	
0.60	Norex TP-03	<5	140	4200	650	
	Norex TP-04	<5	<5	21	<5	
0.60	Norex TP-05	<5	14	1600	370	
0.50	Norex TP-07	<5	<5	140	22	
0.70	Norex TP-08	<5	270	690	54	
0.75	Norex TP-10	<5	16	79	25	
0.75	Norex TP-11	<5	7	350	28	
0.80	Norex TP-12	<5	<5	30	<5	
0.75	Norex TP-15	<5	13	47	21	
0.60	Norex TP-16	52	2100	830	33	Y
0.60	Norex TP-17	<5	6	170	33	
0.50	Norex TP-18	<5	48	3700	600	
0.50	Norex TP-19	<5	21	120	25	
0.30	Norex TP-20	<5	8	44	42	
0.20	Norex TP-21	<8	30	460	370	
0.50	Norex TP-21	<5	15	21	<5	
0.50	Norex TP-25	23	480	570	110	
0.45	Norex TP-27	<5	<5	29	<5	
0.60	Norex TP-28	<5	<5	<5	<5	
0.10	Northrim TP-01	<5	<5	<5	<5	
0.60	Northrim TP-02	18	870	120	<5	Y
0.75	Northrim TP-03	20	770	100	<5	
0.40	Northrim TP-04	<5	35	60	13	
	Northrim TP-06	<5	<5	960	470	
Surface	Northrim TP-07	<5	360	1400	620	
0.30	Northrim TP-08	<5	150	76	<5	
Surface	Northrim TP-09	<5	<5	730	280	
0.65	Northrim TP-10	<5	16	830	360	
Surface	Northrim TP-11	<5	18	660	370	
0.40	Northrim TP-12	<5	79	950	420	
0.20	Northrim TP-13	<5	<5	400	190	
0.42	Northrim TP-14	<5	37	2600	1400	
	Northrim TP-15	<5	<5	<5	<5	
0.20	Northrim TP-16	<5	<5	<5	9	
Surface	Northrim TP-17	<5	<5	<5	<5	
0.75-1.10	Northrim TP-18	<5	190	510	190	
1.50-2.00	Northrim TP-19	<5	890	730	160	Y
1.20	Northrim TP-20	7	670	1000	330	

TABLE 5.1-2 (Cont'd)
SUMMARY OF SAMPLES AT NOREX, NORTHRIM AND SMALLWOOD SITES THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

Depth (m)	Sample ID	Hydrocarbon Fractions (mg/kg)				Exceed?
		F1	F2	F3	F4	
		(C6-C10)-BTEX	(>C10-C16)	(>C16-C34)	(>C34-C50)	
1.20	Northrim TP-24	9	630	440	160	
	Northrim TP-25	<5	16	160	49	
1.20	Northrim TP-27	47	650	51	6	
0.30	Northrim TP-27	90	3200	2000	210	Y
0.45	Northrim TP-28	<20	<5	830	490	
0.60	Northrim TP-28	21	1300	280	22	Y
0.90	Northrim TP-29	<5	23	150	54	
0.90	Northrim TP-30	<5	1300	930	18	Y
0.30	Northrim TP-30	<5	8	53	39	
0.90	Northrim TP-31	<5	500	340	43	
0.30	Northrim TP-31	<6	<5	410	270	
0.30	Northrim TP-32	<5	15	50	24	
0.6-0.9	Northrim TP-32	<5	23	75	53	
0.30	Northrim TP-33	73	330	330	100	
0.35	Northrim TP-34	<5	<5	40	29	
0.35	Northrim TP-35	<5	<5	7	11	
0.60	Smallwood TP-01	<5	16	150	41	
0.80	Smallwood TP-02	<5	8	140	42	
0.30	Smallwood TP-03	<5	880	5200	800	Y
0.23	Smallwood TP-04	<5	1900	2200	300	Y
	Smallwood TP-05	<5	<5	190	37	
0.50	Smallwood TP-06	<5	340	1700	450	
0.60	Smallwood TP-07	<5	8	540	130	
0.75	Smallwood TP-08	<5	200	720	45	
0.20	Smallwood TP-11	<10	100	7900	1100	
0.30	Smallwood TP-12	<6	28	1100	910	
0.60	Smallwood TP-14	86	6100	1900	100	Y
0.45	Smallwood TP-16	<5	76	2300	530	
1.00	Smallwood TP-20	<5	<5	270	70	
	Criteria	**402**	**780**	**10200**	**19000**	
					N>Criteria	**9**

Note: 1 sample at Norex exceeds the criteria; 5 samples at Northrim exceed the criteria and 3 samples at Smallwood exceed the criteria.

TABLE 5.1-3
SUMMARY OF SAMPLES AT CONTACT LAKE SITE THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

Sample Location	F1 (C6-C10)	F1 (C6-C10) - BTEX	F2 (C10-C16 Hydrocarbons)	F3 (C16-C34 Hydrocarbons)	F4 (C34-C50 Hydrocarbons)	Exceed?
Unit	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	
CL-DUMP1-A	<10	<10	<10	310	1300	
CL-DUMP1-B	<10	<10	<10	300	37000	Y
CL-DUMP2	<10	<10	<10	67	12	
CL-DUMP3	<10	<10	11	250	1400	
CL-DUMP3A	<10	<10	<10	120	700	
CL-DUMP3B	<10	<10	<10	61	23	
CL-SHOP-SOIL	<10	<10	250	30000	15000	Y
CL-OFFICE-SOIL	<10	<10	1400	110000	160000	Y
CL-OFFICE-SOIL2	<10	<10	19	510	260	
CL-OFFICE-SOIL3	<10	<10	250	6900	6900	
CL-CORESHACK	<10	<10	<10	170	1000	
CL-FOUNDATION	<10	<10	1200	29000	16000	Y
CL-SHOP-DUP	<10	<10	190	28000	15000	Y
CL-HOIST-1	<20	<20	<20	790	2400	
CL-TANK-1	<10	<10	<10	49	<10	
CL-TANK-2	<10	<10	250000	97000	<1,000	Y
CL-TANK-3	<10	<10	<10	52	<10	
CL-TANK-4	<10	<10	<10	150	<10	
CL-TANK-5	53	51	<20	910	5500	
CL-TANK-6	<10	<10	<10	18	<10	
CL-TANK-7	<10	<10	<10	11	<10	
CL-SHOP-SOIL2	<10	<10	<10	66	<10	
CL-SHOP-SOIL3	<10	<10	16	2100	350	
CL-TANK-DUP	<10	<10	76000	33000	200	Y
CL-CABIN4-SOIL	<10	<10	13	280	240	
CL-CABIN4-SOIL DUP	<10	<10	24	340	300	
	Criteria	**402**	**780**	**10200**	**19000**	
					N>Criteria	**7**

TABLE 5.1-4
SUMMARY OF SAMPLES AT EL BONANZA SITE THAT EXCEED SOIL PHC CRITERIA FOR DISTANCES GREATER THAN 30m

Sample Location	F1 (C6-C10)	F1-BTEX	F2 (C10-C16)	F3 C16-C34)	F4 (C34-C50)	Exceed?
Unit	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	
Fuel Tanks 1	2.5	2.5	2.5	9	2.5	
Fuel Tanks 2	2.5	2.5	2.5	2.5	2.5	
Fuel Tanks 3	2.5	2.5	2.5	2.5	2.5	
Air Strip Tank Farm	2.5	2.5	1700	4700	2.5	Y
Air Strip 400's	2.5	2.5	2.5	2.5	2.5	
EB-BLDG-2a	5	5	980	47000	20000	Y
EB-BLDG-6	5	5	50	15000	10000	Y
EB-BLDG-7	5	5	5	210	220	
EB-BLDG-9	5	5	5	200	5	
EB-BLDG-13	5	5	430	3300	23000	Y
EB-BLDG-14	35	35	5700	8000	960	Y
EB-DUP-1	5	5	50	12000	8500	Y
EB-DUP-2	36	36	5300	7000	750	Y
EB-DUMP-2a	20	20	20	710	210	
EB-DUMP - 2b	15	15	3500	3300	180	Y
EB-DUMP - 2c	5	5	13	230	120	
EB-DUMP-3a	5	5	100	20000	3700	Y
EB-DUMP-3b	5	5	5	12	5	
EB-BD-A	5	5	5	5	5	
EB-BD-B	5	5	360	210	5	
EB-BD-C	5	5	5	5	5	
EB-BD-D	5	5	16	2800	660	
EB-BD-E	5	5	28	6800	4800	
EB-BD-F	5	5	5	5	5	
EB-BD-G	5	5	5	5	5	
EB-BD-H	5	5	5	5	5	
EB-BD-DUP	5	5	5	5	5	
EB-DRUM-L1	18	18	790	41000	340000	Y
EB-AIR-16	5	5	2100	3600	10	Y
EB-AIR-16a	5	5	5	5	5	
EB-AIR-17	5	5	140	580	30	
EB-AIR-17a	5	5	17	340	5	
EB-AIR-18	5	5	5	5	5	
EEB-AIR-19	5	5	500	430	5	
EB-AIR-20	5	5	5	5	5	
EB-AIR-21	5	5	5	75	70	
EB-AIR-22	5	5	5	5	5	
EB-AIR-23	5	5	1200	360	5	Y
EB-AIR-24	5	5	14	130	5	
	Criteria	**402**	**780**	**10200**	**19000**	
					N>Criteria	**12**

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